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: 10/1/13 through 12/31/13
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/LTTP 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

Guidebook for Selecting Highway Project Delivery Methods and Alternative Contracting Strategies Pooled Fund, TPF-5(260)
Study No: 3.60

<u>Background</u>

Numerous project delivery methods and contracting strategies are available to highway agencies. A one-size-fits-all approach to design and construction does not facilitate the acceleration of project delivery or equitable allocation of project risk. However, the selection of an effective alternative approach is often difficult to make and to justify. Just as construction projects are unique, the delivery method, procurement procedure, and contract payment provisions should be unique to maximize the process for each individual project.

At issue are the terms surrounding project delivery methods. These terms can be confusing and even experienced professionals often misuse them. An additional goal of this project is to help solidify a common language for project delivery methods and alternate contracting strategies. This project will take a three-tier approach to providing this common language as follows:

- Project delivery method: the comprehensive process by which designers, constructors, and various consultants provide services for design and construction to deliver a complete project for the owner. The three most common delivery methods are design-bid-build, construction manager general contractor, and design-build.
- Procurement procedure: the process of purchasing and obtaining the necessary property, design, contracts, labor, materials, and equipment to build a project. Four common procurement procedures are low-bid, best-value, qualifications-based, and sole-source procurement.
- Contract payment provision: the contract language that defines how design and construction professionals receive payments for their services. Four common contract payment provisions are fixed price lump sum, guaranteed maximum price, cost plus fee, and cost reimbursable.

These three aspects of the delivery process have a great deal of influence on risk and potential project acceleration. Understanding how delivery methods, procurement procedures, contracting payment provisions interact will allow for more appropriate and justifiable project selection

<u>Project Goal</u>

The objective of this project is to develop a guidebook that discusses highway project delivery methods and alternative contracting strategies. The guidebook will discuss methodologies, both tested and experimental, for strategies and contract provisions that allow for project acceleration and risk minimization. The overarching objective is to:

- Develop a Guidebook to aid in the selection of project delivery methods, procurement procedures, and contract payment provisions based on their benefits and risks for each project.

Reporting Period: 10/1/2013 through 12/31/2013
Type:

Principal Investigator(s):
Keith Molenaar, University of Colorado at Boulder, 303-735-4276

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

Study Panel Members:
Jerry Yakowenko, FHWA
Bryan Cawley, FHWA
Richard Duval, FHWA
David Unkefer, FHWA
Randy Jensen, FHWA
Nabil Haddad, CDOT
John Vetterling, CDOT
Marc Mastronardi, GDOT
Greg Mulder, IaDOT
Jake Goettle, MtDOT
John Obr, TxDOT
Imad Aleithawe, MsDOT
John Kulka, HRI (ARTBA)
Les Fukuda, HDR (ACEC)

Project Scope

The research team generated seven work tasks for the completion of the Guidebook. The tasks generated are:

1. Define the State-of-Practice
    a. Collect and review relevant literature, research findings, and other appropriate material, inside and outside of the transit and highway industry.
2. Select delivery methods, procurement procedures, and contract payment provisions
    a. Create a list of applicable delivery methods, procurement procedures, and payment provisions based on the findings in task 1. Provide definitions of the different methods.
    b. Determine and select appropriate delivery methods, procurement procedures, payment procedures, or a combination of the three that are useful for highway projects. Determining the appropriate set will involve using task 1 information as well as validating the collected data with a survey and interviews with key personnel in the highway construction industry.
3. Develop selection methodology
    a. Develop specific information around each selected contracting methodology from task 2 by describing and analyzing pertinent issues related to each project delivery method and alternative contracting strategy in terms of its application to transit in the United States.
    b. Develop benefits and drawbacks for each contracting methodology through the development of a framework and methodology for analyzing the advantages and disadvantages of the project delivery methods, procurement procedures, and contract payment provisions for use by highway agencies in evaluating and selecting options. The research team will examine relevant case studies to determine possible pertinent issues as well as how to handle them properly.
    c. Develop benefits and drawbacks for common combinations of delivery, procurement, and contracting methods. This analysis will document, evaluate, and compare the merits of each respective type of project delivery method and alternative contracting strategy, discussing the advantages and disadvantages of each. The use of case studies and associated lessons learned will assist in developing proper benefits and drawbacks.
4. Prepare interim report
    a. Prepare an interim report documenting the results of Tasks 1 through 3. The interim report shall also contain a detailed annotated outline of the Guidebook expanding upon the current annotated outline.
5. Develop decision support tool
    a. Based on the results of tasks 1 through 4 and feedback from the Pool Fund Committee, develop a decision matrix at the macro level to guide decision makers on selecting the most appropriate project delivery method, procurement procedure and contract payment provision.
6. Validate and calibrate the decision support tool
    a. Vet with current Pooled Fund Committee members, CDOT employees and industry members to verify, validate, and calibrate a preliminary version of the Guidebook through workshops and interviews to verify Guidebook

effectiveness. 7. Prepare final guidebook a. Prepare the guidebook, a stand-alone executive summary, and a final report documenting the entire research effort	

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
07/31/12	100%	07/31/12	Define state of practice
09/30/12	100%	10/25/12	Select contracting methodologies
09/30/12	100%	09/30/12	Tech memo
01/31/13	100%	02/01/13	Develop information around each contracting methodology
03/31/13	100%	06/01/13	Develop benefits and drawbacks for combinations of project delivery and alternative contracting methods
05/31/13	100%	06/30/13	Examine framework in regards to traditional project delivery
06/30/13	90%	Ongoing	Develop draft and pilot test electronic version of the delivery methods and procurement procedures selection matrix tool
07/31/13	95%	Ongoing	Interim report / draft of guidebook
12/31/13	95%	Ongoing	Develop complete draft of decision support tool
03/31/14	10%	Ongoing	Validate and calibrate
06/01/14	10%	Ongoing	Final guidebook, executive summary, and research report

SIGNIFICANT EVENTS

- 10/01/2013 - General PDSM tool available on the website in MS Word format (http://www.colorado.edu/ceae/TCM/) for download and use.

- Oct 2013 – Finalized payment provision selection matrix tool. All three tools, project delivery, procurement, and payment are now ready for full testing or individual testing.

- Nov 2013 – Working on developing how to incorporate supplementary procurement procedures and payment provisions into the selection tools. A matrix of different delivery methods and procurement procedures will show the appropriate conditions for using a supplementary procurement procedure. A second matrix of different procurement procedures and payment provisions will show the appropriate conditions for using a supplementary payment procedure.

- Dec 2013 – The supplementary procurement procedures and payment provisions are about 90% complete. Each document contains the what, why, how, when and who uses the method. Also an example and references accompany each method. At the present time, there are 11 of 13 payment provisions are complete in draft form and 11 of 16 procurement procedures are complete in draft form. All supplementary documents will be complete and ready for review in February for the TCM workshop.

- 12/19/2013 – Quarterly advisory committee meeting took place via conference call/webinar. The meeting included introductions of advisory committee members, review of project progress, and discussion on project 1 (Selection Guidebook), project 2 (Community outreach), and project 3 (CEI services). Guidebook discussions included project update and a detailed discussion on the procurement procedures selection tool. The procurement procedures pilot tests were discussed and summarized to the committee.

Further, we discussed the supplementary procurement and payment methods to include in the guidebook. A list of procurement procedures and payment provisions was provided to each committee member. Each member was tasked to review the list and provide feedback on the importance and relevancy of including the methods in the final guidebook. Also, we requested more projects for testing each of the selection tools.

- 12/31/2013 – Completed Q4 quarterly reports for CDOT and Transportation Pooled-Fund. Quarterly reports provide updates and progress of the TCM pooled-fund project.

ANTICIPATED EVENTS FOR Q1 2014

- The next advisory committee meeting/conference call will take place in Feb/Mar 2014. We will discuss the developed supplementary procurement and payment methods that are to be included in the final guidebook. Also projects 2 and 3 have kicked off and we will discuss details about starting these projects.

- A one-day workshop will be held on February 7th, 2014 in Boulder, CO on the University of Colorado campus. The workshop will be used to gather the technical advisory committee members in one location to review, test, calibrate, and vet the three selection tools and supplementary procurement and payment methods. Workshop will be interactive and will be available via conference call/webinar for those who cannot attend in person. This is one of the final critical tasks that was presented in the scope of work proposal.

- Guidebook draft is 90% complete. Further development and refinement will take place after the workshop on February 7th. Guidebook will be a complete draft by April for review by the TCM advisory committee.

- Research report is 80% complete. Final details and refinement will occur after the workshop takes place on February 7th. Research report outlines the work performed to create, develop, and draft the guidebook.

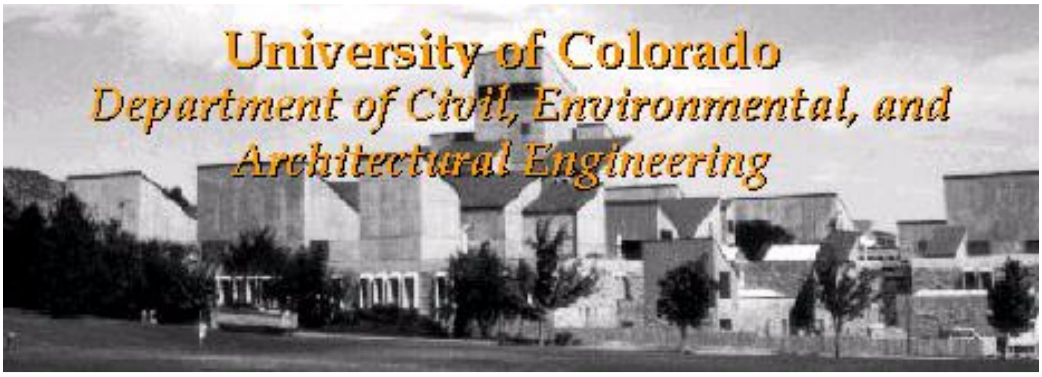
- Testing to continue with the three tools beyond the workshop. Project delivery selection matrix has been used by many and is in a useable form. Procurement procedures selection matrix needs further testing. Payment provisions selection matrix needs pilot testing.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period 10/1/13 through 12/31/13 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 QUARTERLY COLORADO LTAP REPORT



COLORADO LTAP

LTAP Quarterly Report

Report Period
October 1, 2013 – December 31, 2013

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

Submitted by:
Colorado LTAP
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Table of Contents

Colorado LTAP

2nd Quarter

October 1 – December 31, 2013

Program Snapshot:

Total number of training sessions*:	29
Total number of participants*:	575
Total number of participant hours*:	4025
Total Newsletter circulation:	1,498 (hard-copy), 211 (electronic)
Total Class Brochure circulation:	1,046 (hard-copy), 180 (electronic)
Total number of LTAP FTEs:	2.25

*(*Only for classes held between October 1 and December 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

- October 1 - December 31, 2013, Colorado LTAP had two full-time staff persons working for the center – Program Director, Renée Railsback and Training Coordinator, Cassandra Guild.
- The graduate student, Musiket (Noom) Kamtornkiat, continued working part time for the center this quarter. Noom handles the library loan program and training resources.
- Office Assistant, Marty Butcher, worked a few days this quarter. A majority of her time is worked when both the director and training coordinator are out of the office.

B. Training

B.1 Total Training Program

Colorado LTAP continued offering courses in its three training programs – *Roads Scholar I*, *Roads Scholar II* and *Supervisory Skills and Development Program.* The list of 2nd Quarter courses offered in each training program is shown in the table below. The list also shows the distribution

of attendance between local (City/County), State, Federal, Tribal and Other (Contractors, Private, etc.).

- There were 29 days of training events offered this quarter - 17 of the classes were Roads Scholar I, 9 Roads Scholar II, and 3 Supervisory Skills and Development Program class.
- Class evaluations received an average greater than 97.34% for classes held this quarter.
- There were 7 Roadway Safety, 4 Worker Safety, 11 Infrastructure Management, and 7 Workforce Development courses offered this quarter.
- Details on any training course are available upon request; additional course descriptions and comments are provided below, under the Focus Area in which the class occurs. A complete list of classes by location, attendance, evaluation, etc. held between October 1 – December 31, 2013 is included in Appendix A.

2nd Quarter Training Classes

Class Name	Hrs. per Class	# Sessions	# Contact Hours						# Paritipcants	Total Participant Hours
				Local	State	Federa	Tribal	Other		Hrs/class x #Part
ROAD SCHOLAR I PROGRAM										
Drainage	7	4	28	94	25	0	0	3	122	854
Safety on the Job	7	4	28	87	23	0	0	1	111	777
Introduction to Surveying	7	3	21	52	1	0	0	2	55	385
Winter Maintenance	7	2	21	69	5	0	0	4	78	546
Basic Math	7	2	14	39	1	1	0	0	41	287
Math Applications for Roadway Workers	7	2	14	21	1	1	0	0	23	161
TOTAL Road Scholar I:	**42**	**17**	**126**	**362**	**56**	**2**	**0**	**10**	**430**	**3010**
ROAD SCHOLAR II PROGRAM										
Navigating the Environmental Maze	7	3	21	16	0	0	0	3	19	133
Devloping Local Road Safety Plans	7	3	21	27	0	0	0	0	27	189
Preparing for Winter by Planning for Winter	7	3	21	29	0	0	0	0	29	203
TOTAL Road Scholar II:	**21**	**9**	**63**	**72**	**0**	**0**	**0**	**3**	**75**	**525**
SUPERVISORY SKILLS & DEVELOPMENT PROGRAM										
So You're a Supervisory Now	7	1	7	28	0	0	0	3	31	217
Successful Employees Make Successful Supe	7	1	7	28	0	0	0	2	30	210
Do's and Don'ts: Legal and Liability Issues	7	1	7	9	0	0	0	0	9	63
TOTAL Supervisory Skills:	**21**	**3**	**21**	**65**	**0**	**0**	**0**	**5**	**70**	**490**
TOTALS:	**84**	**29**	**210**	**499**	**56**	**2**	**0**	**18**	**575**	**4025**

B1.1a Roads Scholar Program

- There were 27 Roads Scholar I graduates presented with their plaques this quarter. The following are number of graduates in each course: Winter Maintenance (6); Surveying (6); Drainage (6); Safety on the Job (3); and Math (6).
- Colorado LTAP's instructor for the RS I Core class *Roadway Safety & Work Zone Traffic Control* passed away unexpectedly in October. LTAP will need to find a new instructor for this course to be offered in the Spring.
- The new Roads Scholar II program received its FIRST graduate this fall. Rob McArthur of the Town of Green Mountain Falls was the first to complete the program requirements by attending every RS II class offered since the beginning of the program in 2012. Rob completed the program with the *Preparing for Winter* course, and was recognized at the

LTAP Advisory Board meeting in December. Rob will receive a specialized plaque for his accomplishment.

- In the Fall, it seemed as if we were experiencing low attendance for classes because we had to cancel and reschedule some due to low registration and many people were cancelling their registrations at the last minute. However, after comparing 2013 attendance data to 2012, it appears that our total 2013 Attendance was UP 2.5% and Participant Hours was UP 3.5%. The greatest impact on this was from our Roads Scholar I program which had an increase of 20% in attendance & participant hours. Attendance/Participant hours in our Roads Scholar II program, however, decreased by 38.5% in 2013.
  - One reason the RS II program had lower attendance is that 2012 was the first year of the program and we did NOT hold participants responsible for completing the programs prerequisites (hence higher registrations). In 2013, however, we required attendees to have completed the program's prerequisites in order to participate in the RS II classes, and attendance was affected accordingly. This quarter, RS II classes averaged about 10 people per class; but the attendee reviews for those classes were all extremely positive.

B1.1b Supervisory Skills and Development Program

- The first two Supervisory Skills classes had to be canceled and rescheduled due to Colorado's flood event. The majority of registered participants were from Longmont, Boulder, and Weld County. Those two classes were re-offered in November with good attendance.
- The *Whole New World: Nuts & Bolts of Local Government* class scheduled in Grand Junction in November was canceled due to low registration. We will try to reschedule it in the spring.
- There were 3 Supervisory Skills graduates presented with their plaques this quarter. The following are number of graduates in each course: Legal and Liability Issues (2) and So You're a Supervisor Now (1).

B1.1c Training Scholarships

- APWA and CARSE (Colorado's NACE affiliate) provide training scholarship for local agencies to attend LTAP classes. We will receive this funding at the beginning of the calendar year. A list of scholarship recipients is provided to APWA and CARSE at the end of the year and is available upon request.

B1.1d Special Training Programs

Special Training includes multi-day Heavy Equipment Training programs, Certification Training (Flagger, TCS, etc), Workshops and Roadshows, and Training Enhancement Materials.

B1.1d.5 Training Enhancement Materials

- This quarter, training enhancement materials were purchased; 100 Winter Maintenance Manuals ($385) and 200 Drainage Manuals ($968). The Drainage manuals were updatedfor 2013 info before printing.

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.

- The Fall issue was delayed and distributed this quarter. There were 1501 recipients on the hard copy mailing list, and 205 people on the electronic mail list.
- The main cover story of the Fall newsletter addressed the significant changes to federal requirements on providing ADA curb ramps when streets, roads, or highways are altered through resurfacing.
- Other topics included lessons on how buses can better share the streets with bicyclists; CDOT's debris eating Gator Getter; the LoTrans Virtual Transportation Conference; using pig poop as a binder in asphalt pavements; and Colorado flood recovery resources. The "Ideas that Work" project that was highlighted was City of Cañon City's *Pipe Puller*, Colorado's 2013 You Show Us Contest winner.
- The Fall newsletter issue was printed through an online printing company and so far LTAP has cut the total cost of Newsletter production nearly in half from the 2013-2014 average cost.

C0.2 Library Materials Distribution

- Continued to manage our in-house lending library consisting of over 2600 items - instructional videos, publications, and resources focusing on transportation design, maintenance, safety, and workforce related topics.
- In the second quarter, 27 items were *loaned* free to local transportation agencies. The table below shows the distribution by type and focus area. The most frequently loaned topics addressed managing snow, on the job safety, and geotextiles. Separate from the lending library, 214 free publications, guidebooks and videos were distributed.
- Two new DVDs were added to the library in the 2nd Quarter on roadway safety.
- Between October1 – December 31, $114 was spent on postage for mailing loaned materials, $132 was spent on purchasing free publications for distribution, and $422 was spent on new materials for the lending library.

Pub Type	Highway Safety	Infrastructure Management	Worker/Workplace Safety	Workforce Development
Book	0	0	1	0
Bulk Material	0	0	0	0
CD	0	0	0	0
Disk	0	0	0	0
DVD	2	5	6	1
Free Publication	113	55	31	13
Software	0	0	0	0
Video	2	1	7	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

- LTAP center staff spent about 25% time providing technical assistance to local agencies. Examples of technical assistance provided this quarter included requests on School bus and defensive driver training; hazardous materials resources; ADA Road & Bridge Requirements; routing concrete pavements; culvert management software; and needs for Sign related conferences and workshops.

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 Colorado LTAP Director currently serves as *President* of the National LTAP Association, presides over the Executive Committee, and participated in meetings and monthly conference calls related to Association business.
  - In October each year, NLTAPA holds a 1-day Officer's Retreat and 2-day Executive Committee meeting at the FHWA TPP headquarters in Arlington, VA. As President, Renée organized the two events which included meetings with managers from FHWA TPP; Office of Safety-Rosemarie Anderson and Gabe Rousseau; Brian Roberts-NACE, and ARTBA throughout the 3-days. Travel to these meetings is paid for by NLTAPA.
  - Topics discussed with Association partners included: FHWA Office of Safety's projects on "Assessment of Local Road Safety Funding, Training, and Technical Assistance" and "Local Road Safety Toolkit"; NACE's funding support for LTAP in next reauthorization; NLTAPA's support of NACE's Toward Zero Deaths initiatives; Promotion of local participation on State Strategic Highway Safety Plan (SHSP) updates; commitment to improving local data collection; NLTAPA's participation on ATSIP– the Professional Association of Transportation Safety Data Professionals; and NLTAPA's participation as a Charter Partner in the LoTrans Virtual Conference.
  - Association Business topics discussed covered: Officer Reports, Treasury Update, Work Group Committee Discussions, Communications WG Changes, Association Management document development, New Website Management & Design, Annual Workplan and Budget Development, 2014 LTAP-TTAP Conference, 2015 Conference Proposals, Joint FHWA/NLTAPA Work Group Updates, and FHWA's Strategic Planning Committee. The Officer's Retreat early in the fall is an essential opportunity for new Officers and Executive Committee members to get familiar with responsibilities and define direction for the Program in the coming year. The discussion and interaction amongst participating members and partners is heightened when meeting face-to-face.

- The FHWA Division office requested LTAP Director, Renée, to attend two additional out-of-state meetings in October; the FHWA Safety Plan Peer Exchange and the CO-MN Safety Scan. Both meetings were held in Minneapolis, MN in October, and travel was paid for by FHWA.
  - FHWA, LTAP, and CDOT Traffic Safety and Data staff attended the Safety Scan tour to review recent safety improvement success programs in MN; their online data access web portal; and their County Safety Plans.
  - Renée for Colorado LTAP, Scott Wiggs of Arapahoe County, and Doyle Villers of La Plata County attended the Regional Local Safety Plans Peer Exchange. This peer exchange incorporated attendees from several mid-west states - LTAPs, DOTs, and County reps. The program covered status of state programs with local safety plans; how to start County road safety plans; developing plans; data analysis; desirable safety plan content; implementing the road safety plans; and a Moving Forward roundtable discussion with Minnesota Counties. Everyone felt the peer exchange was very beneficial; and within one week of returning, Arapahoe County had already budgeted to develop a county safety plan in 2014. Arapahoe County is also eager to participate on Colorado's update of SHSP. Only detriment was Colorado did not have any DOT or FHWA representatives attend this peer exchange.

C0.4b Region 7 Local Roads Conference

- Colorado LTAP was not able to participate in the annual Local Roads Conference in Rapid City, SD in October due to added responsibilities related to helping locals with flood recovery and other FHWA travel requests.
- This budgeted funding will roll over and be used for half of the hotel cost at the NACE Conference in April. As NLTAPA President, NACE has provided Renée with a free conference registration. NLTAPA will be covering the airfare, hotel and per diem for the first two days in order to attend the Executive Committee meeting. Colorado LTAP will need to cover the remaining hotel and per diem for the last two days.

C0.4d Region 7 LTAP Meeting

- Budgeted Out-of-State Travel this quarter included the 2014 Region 7 LTAP meeting; December 11-12, 2013 in St. Louis, MO. The Region meeting is normally held in May, however, the group met early this year because Region 7 is hosting the 2014 LTAP-TTAP Conference in St. Louis in July. The Region centers met at the conference hotel to go over planning logistics. Both the Colorado LTAP director and training coordinator participated in this meeting. This was Cassandra's first time meeting staff from the other Centers in our Region. Renée provided an NLTAPA Update presentation; and other meeting highlights included: What the Center is doing in Worker Safety and Roadway Safety; Center Operations, Changes and Challenges; and Partnerships – How we work with our partners. Colorado's only responsibility in preparation for the 2014 conference was to develop the list of Transportation Options & Discounts for the conference website; which has been completed and provided.

C.1 Safety Programs

Colorado LTAP has a long history of providing safety related training, technology transfer and technical assistance through its traditional services and Roads Scholar I and II training programs.

There were 11 training classes offered on Roadway, Worker, and Work Zone Safety topics this quarter. Programs and training completed between October 1 and December 31 in this focus area include:

- SAFETY TRAINING
  - *Roadway and Roadside Drainage* – This course addresses the maintenance of drainage features for safety and is one of the four safety CORE classes in the Road Scholar I program. This course was designed to help local road agency maintenance workers understand the importance of maintaining and upgrading drainage features and the effect it has on the safety of their road system. It covered why drainage is important, maintenance aspects, different drainage types, evolution of drainage materials used, integrity and strength of subgrade, effects of moisture, basics of predicting cover, runoff, pulling ditches, erosion control, and new stormwater drainage regulations. This was a 1-day class offered in 4 locations. It was very popular this year. We initially only scheduled 3 classes in Brighton, Grand Junction, and Durango, but then had to set up a fourth class in Castle Rock due to the large number of people on the waiting list. Even the Durango class was very well attended with 27 participants – a majority of which were CDOT Alamosa and Durango employees. There were 6 Roads Scholar I graduates completing the program requirements with this course and were presented with their plaques.

  - *Safety on the Job* – Safety must be a priority for every employee. Accidents can be reduced by learning the risks and how to mitigate them. The instructor, Tim Longbrook, used humor, real life examples, and his expertise to help attendees learn how to create a safety culture in their workplace. This Roads Scholar I CORE class covered: Developing a Safety Culture in Your Workplace; Preventing Slips, Trips, and Falls; Personal Protective Equipment; Lockout-Tagout; Machine Guarding; Safety Around Heavy Equipment; and Trenching and Excavation Safety. This course was offered in 4 locations around the state. This was another Roads Scholar class that had a lot of CDOT employees attend the Durango location class. There were 3 Roads Scholar I graduates completing the program requirements with this course and were presented with their plaques.

  - *Developing Local Road Safety Plans* – Local road practitioners play a critical role in addressing crash risks at the local level and can help to identify the specific conditions that contribute to crashes in their jurisdictions. The Local Road Safety Plan (LRSP) defines key emphasis areas and strategies that impact local roads and provides a framework to accomplish safety enhancements at the local level. The LRSP helps communities take a proactive stance in reducing and preventing local road fatalities and injuries. A number of tools have been developed to help local communities work toward a LRSP. This class was taught by Hillary Isebrands of the FHWA Resource Center, and provided an overview of key components and stakeholders in developing a local roads safety plan, and detail some of the information, training and technical assistance resources available in Colorado. We received good feedback from these classes; and agencies were positive about developing plans. This Roads Scholar II class was held in 3 locations, and provided 7 credit hours in the *Safety* focus area.

C1.1 Public Safety Awareness Programs

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. Safety related activities included:

- LTAP was invited to be a participant on the Colorado's Steering Committee for the Strategic Highway Safety Plan (SHSP) Update. Colorado is doing a strong push to incorporate local agency needs in this update and to include local participation in development and implementation of the new SHSP. Colorado's first SHSP Committee meeting was held on October 31. LTAP's training coordinator, Cassandra, attended the meeting. The group discussed the Toward Zero Deaths nationally goal and how it relates to Colorado; designing a mission and vision addressing a safety culture combining driver behavior as well as roadway safety; review of the initial SPIRS 18 focus areas; local agency participation; and which areas to spend safety funding. Future regional meetings will encourage local agency participation to get input on regional traffic safety concerns so that they can be incorporated into Colorado's SHSP which will guide traffic safety funding in Colorado.
- Cassandra also attended the *Denver Emergency Management Summit* in Denver in October. Cassie attended because Renée was at the FHWA Safety Plans Peer Exchange in MN. The initial agenda of topics looked like it could provide some useful information moving forward in flood recovery efforts; however, ultimately speakers were very vague & there was not too much useful information gleamed from the event.
- LTAP promoted several Local Agency Resources in Safety including – FHWA Office of Safety's research project & report on *Assessment of Local Road Safety Funding, Training, and Technical Assistance;* the new *Guide for Maintaining Pedestrian Facilities for Enhanced Safety;* the *Research Report for Maintaining Pedestrian Facilities for Enhanced Safety*; and the webinar on *ADA Resurfacing Technical Assistance*.
- Center staff responded to Safety related technical assistance requests addressing: School bus and defensive driver training; hazardous materials resources; and ADA Road & Bridge Requirements.
- The quarterly newsletter provided two articles addressing topics regarding safety aspects – federal requirements on providing ADA curb ramps and lessons on how buses can better share the streets with bicyclists.
- Colorado LTAP used the electronic mail list to promote available Safety related webinars and other distance learning opportunities offered through organizations such as the national LTAP Clearinghouse; FHWA; APWA; and NACE.

C1.2 Sign Retroreflectometer Loan Program

The only expenses posted to *Safety Programs* this quarter were for the Sign Retroreflectivity Loan Program. Several agencies continued to participate in the retroreflectometer loan program.

- Agencies that have recently loaned the meter include: Yuma County; Otero County; Montezuma County; Town of Milliken, and City of Fort Lupton.
- Renée provided Retroreflectometer and sign inspection training for the Police Chief and Street Superintendent for the Town of Milliken. Police staff is helping the Street department by doing the sign inspections while they're out on the road.
- Renée has also been asked by the USDA Forest Service, Road Operations and Maintenance Division, to do training on Sign Retroreflectivity as part of a 2-day training event they are holding in Fort Collins in April.

- Status of the Other "Broken" Retroreflectometer – The older retroreflectometer was sent back to the manufacturer for repairs, supposedly "fixed", returned and sent back out to staff of the Air Force Academy. Although Reneé did a thorough review of the machine when it returned; we've heard from their staff that the machine is still not working properly. The machine will do readings, but it is not holding the data in its internal memory. The Air Force Academy is still using the machine for their inspections, but they are hand writing down all the readings. Cassie has been in contact again with the manufacturer over what to do next. This is the first/oldest machine the Center purchased and may need to be replaced. We still have the money that was saved for the pavement marking retro-meter, and a new sign meter will probably need to be purchased first because - 1) the loan program is still in demand (we currently have a wait list); and 2) the sign retro regulations are in effect – the pavement markings requirements have been put on hold indefinitely.

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 11 training classes offered on Infrastructure Management topics this quarter. Programs and training completed between October 1 and December 31 in this focus area include:

- INFRASTRUCTURE MANAGEMENT TRAINING
  - *Winter Maintenance and Snow Removal* – This course was part of the winter maintenance training program that CDOT offers to its employees. This course has been frequently requested by local agencies, and LTAP worked with Ross Hamilton of CDOT to offer it in 3 locations (one of these classes was offered last quarter). The course objectives were to increase the safety of winter employees and customers; prevent unnecessary damage to equipment; and provide better customer service. The class covered Costs and budgets; Storm preparedness; Equipment maintenance, cleaning, and inspecting; Materials, types, usage, and storage; Snow removal techniques; Avalanche awareness; and Accidents and accident prevention. This course was offered as a Roads Scholar I Elective, and there were 6 RS I graduates completing the program requirements with this course and were presented with their plaques. The course received great reviews, and we'd like to offer it again in the future if possible.

  - *Introduction to Surveying, Grade Checking & Staking* – Roger Johnson returned to teach this Roads Scholar I Elective course that covered use of transits; eye levels; standard and metric rods; math as it relates to surveying & staking; laying out a project; making grade stakes; measurements to a specific set of plans; distinguishing between back slope and foreslope; and hands on demonstrations. Attendees were asked to bring an eye level and grade rod to the class and had the opportunity in the afternoon to practice what they learned. This class was offered in 3 locations across the state. There were 6 Roads Scholar I graduates completing the program requirements with this course and were presented with their plaques.

- *Navigating the Environmental Maze: Practical Strategies for Success* – The first Roads Scholar II class this fall was a new program titled *Navigating the Environmental Maze.* We partnered Jeff Berna, an Environmental Specialist with FHWA's Resource Center, to offer this class. The class provided participants with an overview of the environmental review process, FEMA requirements, and how environmental requirements can be efficiently addressed. The program was comprised of short instructional sessions, followed by group exercises and facilitated discussion on the following topics: Key environmental requirements; Roles and responsibilities; Common challenges; Strategies to expedite delivery; Achieving success; Planning for the unexpected; and Resource material. It was tailored for local Colorado agencies and relied heavily upon the shared experiences of the audience. Due to the topic's significance following Colorado's flooding event, Colorado LTAP opened this particular RS II class to ALL participants and did not require agencies to meet the program's pre-requisites to attend. We promoted and encouraged participants from all departments to attend; but attendance was still low for this course – especially on the West Slope. It was offered in 3 locations around the state. There ended up only being 4 participants in the Montrose class because we received several cancelations and no shows.

- *Preparing for Winter by Planning for Winter* – This was the second Roads Scholar II class offered this fall, and it was off to a rocky start. Due to another job opportunity, the original instructor for this class canceled on us *after* the registration brochures went out in the mail. Many people wanted to register for the program as we scrambled to find a new instructor and reschedule the class dates. Bruce Drewes, former Idaho LTAP Director, came to teach the class in November; and new brochures had to be printed and mailed. The objective of the class was to provide a solid understanding of the preparation and implementation of a sound snow and ice control program. This program took participants through the necessary planning that goes into a successful approach to winter weather on our local roads and addressed the details that go into proper planning and execution of best practices for winter maintenance - Budget preparation; Employee training and scheduling; Communicating with upper management and the public; Equipment preparation; Materials: needs and on-going inventory; Measuring effectiveness (costs, employee performance, equipment status, etc.); Snow plan creation and implementation; and How to plan for winter emergencies. The class was offered in 3 locations and Bruce received an average of 99%-100% on all of the course evaluations. The Colorado Springs class was hit by the same snow storm that affected the CARMA Winter Workshop, and only 5 people attended. The course was in the *Transportation Management* Focus Area, and worth 7 Credit Hours. There was 1 Roads Scholar II graduate completing the program requirements with this course.
  - Rob McArthur of the Town of Green Mountain Falls became the FIRST to complete the requirements of the Roads Scholar II program with this class. Rob attended every class offered since the RS II program began in 2012. Rob was recognized at the LTAP Advisory Board meeting in December; and will receive a specialized plaque for his accomplishment.

Other than training, there were no direct expenses posted to the Infrastructure Management category this quarter. However, additional Infrastructure Management related activities included:

- Colorado LTAP helped local transportation agencies with their 2013 flood recovery efforts. The LTAP office in Boulder was closed for 5 days during flooding as it is on the University of Colorado Boulder's East Campus, along the Boulder Creek. A couple of LTAP classes were canceled during the height of the flood event and rescheduled. Some agencies still needed to cancel their course registrations several months after the September flooding. LTAP staff worked with Steve Markovetz of CDOT's Local Programs to develop a flood resource list; designed an LTAP webpage with Flood Recovery Resources; attended CDOT's Flood recovery resources were included in the Fall Newsletter.
  - Renée also developed a presentation for the NLTAPA Winter Business Meeting in Arlington, VA. Renée did research and discussed recovery efforts with other LTAP Centers that have recently experienced other natural disasters such as Katrina and Sandy. The presentation covered Colorado's Flood Recovery efforts from the DOT's perspective as well as the first responder's (Renée's husband is a firefighter that did swift water rescues in Lyons) and provided best practices on how LTAP/TTAP Centers and Local Agencies can be better prepared for future devastating events.
- Renée attended an interesting workshop provided by APWA and ACEC (American Council of Engineering Companies) on *Challenges Facing Public Works Departments*. Presentations were made by the Town of Superior on Flood Recovery; Arapahoe County on Funding, Partnerships, and Contracting; and the City of Golden on Integration of Multiple Utilities.
  - Renée also had a meeting with Marilyn Reimer, ACEC Executive Director, on coordinating resources for local agencies. Renée has been asked to serve on a panel with FHWA and the City of Centennial on working with local agencies at their training for Colorado Transportation Professionals in February.
- LTAP promoted several Local Agency Resources on Infrastructure Management including – the Minnesota Local Roads Research Board's new document *Dust Control of Aggregate Roads: A Brief Synthesis of Current Practices*; a webinar on *Maintaining Pedestrian Facilities*; a webinar on *Accommodating Large Trucks and Oversize Loads at Roundabouts*; a webinar on Pavement Preservation; Ohio's webinar on *Evaluation of the Epoke Bulk Spreader for Winter Maintenance*; and the Minnesota DOT's Video on *Anatomy of a Winter Storm*.
- The LTAP program director serves as the Colorado Association for Roadway Maintenance (CARMA) Board of Directors secretary and newsletter editor. One CARMA Newsletter was designed and distributed this fall. The board met twice between October and December to develop agendas and speakers for both the November Winter Workshop and Spring Street Conference. LTAP helps coordinate needed infrastructure related presentations included on these agendas. Colorado LTAP also handles pre-registration processes for the Spring Street Conference, and is reimbursed by APWA for its services.
- Colorado LTAP staff served on CARMA's committee for *Winter Workshop* development. LTAP staff participated in two planning meetings and helped coordinate the agenda. The workshop was held at the Town of Castle Rock. Registration for this event is normally ~100 people; however, there were only 65 registrants this year. Then, only about 15 people were able to make it due to snow event. The program ended early after lunch. There is no cost to LTAP for helping with this workshop.

- Center staff responded to Infrastructure Management related technical assistance requests on routing concrete pavements; culvert management software; and needs for Sign related conferences and workshops.
- The quarterly newsletter provided three articles addressing topics regarding infrastructure management aspects – CDOT's debris eating Gator Getter; using pig poop as a binder in asphalt pavements; and Colorado flood recovery resources.
- Colorado LTAP used the electronic mail list to promote available infrastructure management related webinars and other distance learning opportunities offered through organizations such as the national LTAP Clearinghouse; FHWA; and APWA.

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. The following additional initiatives specific to work force development were offered between October and December:

- LōTrans Virtual Conference – Renée worked with the FHWA-LTAP Clearinghouse to develop sessions for Centers and locals for the LōTrans Conference in November. NLTAPA is a Charter Partner of the LōTrans event. The Clearinghouse filmed a welcome video of Renée for the NLTAPA virtual booth.
- 2014 Spring Street Conference – LTAP staff participated in two CARMA meetings in development of the 2014 Street Conference. The CARMA board is responsible for getting the majority of speakers for the conference, LTAP helps if it has related contacts. LTAP designs, prints and mails the registration brochures.
- The quarterly newsletter provided one article addressing workforce development, and highlighted our "Ideas that Work" project – the City of Cañon City's Pipe Puller. This was Colorado's 2013 You Show Us Contest winner.

- WORKFORCE DEVELOPMENT TRAINING

  There were 7 additional training classes specific to Workforce Development topics offered this quarter. Training programs for the spring 2014 schedules were under development and course registration brochures for January classes were designed and distributed in December.

- *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 3 graduates this quarter in the Supervisory Skills program.

  - *So You're a Supervisory Now: Roles & Responsibilities of New Supervisors* - This class familiarized participants on techniques for transitioning into a new supervisory role, and explored the changes in relationships and personal challenges that may occur when one is promoted to supervision. This was an engaging seminar in which participants focus primarily on the differences between subordinate and supervisory roles. It was offered once in Westminster. The class was presented by Kathy Stewart, with Lundy Professional Development Resources, Inc. It had one SSDP graduate that received their plaque.

- *Successful Employees Make Successful Supervisors* – This course addressed dealing with employees and managing for success. It presented characteristics of effective supervisors as project leaders, motivators, coaches, and team-builders. It was offered once in Westminster. This class was offered back-to-back with SYSN and also presented by Kathy Stewart. The City of Westminster provided a free location at their Recreation Center for these two days of training.

- *The Do's & Don'ts: Legal & Liability Issues* – The third Supervisory course this quarter covered legal & liability issues of local governments and was presented by Tom Lyons, an attorney with Hall & Evans. The class addressed Guarantees, promises, representation; When to act? When to ask? Nobody ever told me about that; Supervisor conferences and records; Performance evaluations; Sexual harassment; and local issues and questions. This class was offered once on the Western Slope in Glenwood Springs. There were 2 Supervisory Skills graduates completing the program requirements with this course and were presented with their plaques.

- *A Whole New World: Nuts & Bolts of Local Government* – This class was originally scheduled to be in Grand Junction in November; however, we were forced to cancel it due to low pre-registrations and last minute cancellations. We are hoping to reschedule it in the spring in Glenwood Springs in the hopes of drawing some attendees from both the Western Slope and Front Range agencies.

❖ The majority of our Workforce Development type courses are offered under our Supervisory Skills and Development program. This quarter, we also provided two additional Workforce Development topics as Roads Scholar I Electives.
- *Basic Math* and *Math Applications for Roadway Workers* – Math is a subject that is quickly lost if not constantly used. Without regular use, it's not long before it's hard to remember common formulas like volume or how to simplify a fraction. Math is an important tool in the roadway industry and is used in a variety of scenarios. These classes are designed and taught by the LTAP Director, Renée, to be a stress-free way to review and learn some new applications. The two Math classes were offered back-to-back in Aurora and Grand Junction. Attendees did not have to attend both days, but the Basic Math class is required at some point *before* taking the advanced applications class. Renée updated the two training programs and included math related videos, and new transportation related examples. There were 6 Roads Scholar I graduates completing the program requirements with the Math classes and were presented with their plaques.
  - The *Basic Math* class covered a review on topics such as Algebra terms, symbols, formulas; fractions; percentages; ratios; converting units; areas and volumes; and understanding equations. The Basic Math class includes a pre- and post-test as a Kirkpatrick Level II evaluation method. 62% of the participants in the Basic Math class increased their score on the pre- to post-test by more than 10%.
  - The *Math Applications for Roadway Workers* class built on material from the basic class and focused on using math principles in transportation applications. It covered geometry and trigonometry; road gradient and slope; estimating material quantities; surveying applications; and more.

C3.1 You Show Us Contest & Local Agency Sponsor

In its 18th year, the concept for the "You Show Us" Contest began in 1994 with FHWA's "Show Us How". LTAP encourages local agencies to enter as a profitable way to share their innovative ideas with others that may benefit from their cost saving concepts. It is a good way for road crews to get some well earned recognition for solving problems requiring efficient use of existing funds and materials, along with the application of cost-reducing and innovative techniques.

- Colorado LTAP administered the Colorado state and Region 7 "You Show Us" Contests this fall. Brochures promoting the contest were designed and distributed to government agencies in Colorado. Six entries were received and presented to the LTAP Advisory Board in September – 5 projects from the City of Cañon City and 1 from Yuma County. The City of Cañon City's *Pipe Puller* was selected as the State winning project.
- To encourage local agencies to share their successful programs and ideas, Colorado LTAP sponsored two participants from Cañon City to represent their project at the Local Road Coordinators' Conference in Rapid City in October. It cost $847 to have the two Cañon City participants in attendance to receive their state award; and they brought a display to present their winning project.
- El Paso County's 2012 State and Regional winning *Asphalt Spray Bar* project recently won 2nd Place in the 2013 National "Build a Better Mousetrap" Competition provided by the FHWA-LTAP Clearinghouse. The Clearinghouse sent Colorado LTAP a plaque for their 2nd Place award and El Paso County requested that LTAP staff come present it to the project developers at their all-hands meeting in October. Additional funding was for Renée to attend the meeting and make the presentation.
- Finally, other expenses under the *You Show Us Contest* category were for shipping the Regional Awards to South Dakota DOT because Renée did not attend the conference this year.

C3.2 Local Road Coordinators' Conference Support

As one of the 5 sponsor centers, Colorado LTAP helped organize the annual LTAP Region 7 *Local Road Coordinators Conference* in Rapid City, South Dakota. This year, Colorado did not have to split any of the conference related expenses; and we did not sponsor a Colorado speaker for the agenda. Expenses in this category included the design and distributed of the brochures promoting the conference to local agencies throughout Colorado.

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. Work on the conference program began this quarter, but the majority of the work for this conference is completed after the first of the year. As board members, Colorado LTAP staff have a significant influence on session topics presented at this conference. Expenses in this category, so far, cover the printing and mailing of the conference save-the-date postcards.

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.

- Throughout this quarter, Colorado LTAP prepared material needed to submit the annual Program Assessment Report (PAR) and Center Assessment Report (CAR) due to FHWA by January 31, 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.
- Complete program expenses for July 1 – December 31, 2013 are included in Appendix B.

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. Expenses for ITS averaged $57/month.

- Our toll-free number continued to be available for any LTAP customer to reach us for direct technical assistance. $10 was spent on phone service this quarter.
- 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. A flood recovery resources section was added to the website, along with new fall class and conference registrations. $163 was spent on website maintenance this quarter.
- 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 has increased to 211 recipients of Newsletters and 180 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 brochure and newsletter lists are still maintained (1,498 for Newsletters and 1,046 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 only expense in this category this quarter was related to the monthly lease and meter readings of the Konica Minolta copy machine, which averaged $122/month.

C4.3 Office Supplies

- A majority of office supply costs are now included in the copier lease program. However, additional expenses in this category included paper for any printed products – brochures, certificates, name badges, flyers, envelopes, notebook binders for SSDP classes, and toner for the other HP printer, etc. There was $384 spent on office supplies this quarter.

C4.4 Staff Training

- The new LTAP Training Coordinator, Cassie, attended the 2-day Microsoft Access, Level I training in order to learn how to manage the Center's training database.

C4.5 Monthly & Quarterly Advisory Meetings

- October 1 – December 31, Colorado LTAP staff and project sponsors held 2 monthly conference calls in October and November to review project status and other program initiatives. An additional Advisory Board meeting was held in December.

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 currently 11 *voting* members on the advisory board representing cities and counties across the state. There are also 5 *non-voting* members representing the program and sponsoring agencies. The LTAP advisory board is now represented by 3 City, 7 County, and 1 CDOT representatives. Board members are not paid for their participation, but are reimbursed for direct expenses incurred due to attending LTAP meetings. This quarter, $390 was spent on the advisory board meeting.
- The advisory board met on December 2nd in Colorado Springs. Topics discussed included: National Transportation Update; Local Agency Resources and Upcoming Free Transportation Webinars; CDOT Local Programs; LTAP's Flood Recovery Efforts; FHWA Safety Scan and Safety Plans Peer Exchange; CDOT SHSP Meeting; Safety Conferences; fall & spring classes – successes and challenges; CDOT University; and Winter Newsletter topics.

C4.6 Program Needs Survey

- The Needs Survey is done electronically and the survey software is paid annually in January.

C4.7 NLTAPA Dues

- Colorado LTAP paid $500 in annual National LTAP Association dues to support the Executive Committee's work benefiting the advancement and resource development of all Centers.

C4.8 Program Parking

- Two parking cards were purchased for program sponsors, staff, instructors and local agencies to attend meetings at the LTAP Office as there is no free parking available. A total of $150 parking funds were purchased for $75.

Financial Report

Total program expenses for July 1, 2013 – December 31, 2013 are included in Appendix B. The attached itemized categories list shows a balance of ($5,103.03) for the first *half* of the fiscal year. The total expenses for the whole first half of the year were included so as to review status of each category in reference to the total proposed budget. Training program expenses are right on budget so far; library services is under budget – additional new materials will be purchased; and website maintenance, equipment and office supplies are running under budget. Part of the reason for the negative balance is that the LTAP program has not yet received any of its cash match from the CEAE Graduate School.

Appendix A: Profile Training Hours October 1, 2013 – December 31, 2013

Class Name	Location	Date	Hrs/class	# Part.	NS	WL	CAN	Tot. Part. Hours
ROADS SCHOLAR CORE COURSES								
RS CORE: Drainage								
97.84%	Castle Rock	10/22/13	7	40	3	0	1	280
100.00%	Brighton	10/24/13	7	33	8	2	4	231
97.62%	Grand Junction	10/28/13	7	22	1	0	0	154
96.64%	Durango	10/31/13	7	27	11			189
RS CORE: Safety on the Job								
91.18%	Durango	10/8/13	7	31	2			217
100.00%	Rifle	10/10/13	7	20	1			140
-	Brighton	11/7/13	7	37	6		3	259
96.21%	Colorado Springs	11/20/13	7	23	1			161
ROADS SCHOLAR I ELECTIVE COURSES								
RS ELECTIVE: Winter Maintenance and Snow Removal								
97.11%	Grand Junction	10/3/13	7	29	1	0		203
98.28%	Northglenn	10/7/13	7	49	8	16	1	343
RS ELECTIVE: Intro to Surveying, Grade Checking & Staking								
94.81%	Loveland	10/7/13	7	23	4	12		161
98.72%	Colorado Springs	10/8/13	7	26		9		182
100.00%	Montrose	10/17/13	7	6	3	**0**		42
RS ELECTIVE: Basic Math								
97.62%	Grand Junction	11/13/13	7	8	1		1	56
93.06%	Aurora	11/18/13	7	33	3		2	231
RS ELECTIVE: Math Applications for Roadway Workers								
100.00%	Grand Junction	11/14/13	7	6	1			42
98.89%	Aurora	11/19/13	7	17	2		4	119
ROADS SCHOLAR II COURSES								
RS II: Evironmental Focus Area								
Navigating the Environmental Maze								
97.92%	Lakewood	10/16/13	7	10	1			70
100.00%	Pueblo	10/22/13	7	5				35
100.00%	Montrose	10/24/13	7	4	2			28
RS II: Transportation Management Focus Area								
Preparing for Winter by Planning for Winter								
98.56%	Glenwod Springs	11/18/13	7	12	1			84
100.00%	Loveland	11/20/13	7	12			3	84
100.00%	Colorado Springs	11/21/13	7	5			4	35
RS II: Safety Focus Area								
Developing Local Road Safety Plans								
98.48%	Silverthorne	11/4/13	7	13			1	91
87.80%	Colorado Springs	12/3/13	7	9	2		3	63
100.00%	Grand Junction	11/17/13	7	5	5		2	35

SUPERVISORY SKILLS & DEVELOPMENT PROGRAM								
SSDP: So You're a Supervisor Now								
92.11%	Westminster (rescheduled)	11/12/13	7	31			2	217
SSDP: Successful Employees Make Successful Supervisors								
96.20%	Westminster (rescheduled)	11/13/13	7	30			2	210
SSDP: The Do's and Don'ts: Legal and Liability Issues								
96.55%	Glenwood Springs	11/21/13	7	9	2			63
SSDP: A Whole New World: Nuts & Bolts of Local Government								
	Grand Junction - CANCELLED	11/5/13	7	-				-

97.34%	**Total 2nd Quarter Participants:**	**575**	
Evaluations	Total **RS I** Participants:	430	3010
	Total **RS II** Participants	75	525
	Total **SSDP** Participants:	70	490
	Total **Workshop** Participants:	0	0
		Total Participant Hours:	**4025**

Appendix B: Total Program Expenses, July 1, 2013 – December 31, 2013

Itemized Categories
7/1/2013 through 12/31/2013

INCOME	**152,180.13**
1. SPONSOR REIMBURSEMENTS	**152,180.13**
a. CDOT Reimbursement	105,000.00
b. CU Matching	18,333.00
c. Class Registration Fees	28,847.13
c1. Deposits	29,165.00
c2. Credit Card Charges	-317.87
d. Partner Reimbursement	0.00
EXPENSES	**-157,287.16**
A. PROGRAM ADMINISTRATION	**-103,322.37**
A1. Administration Costs	-85,062.43
A2. Program Administration Fee	-18,259.94
B. TRAINING PROGRAM	**-42,474.57**
B1.1 Training	
a. Roads Scholar	-30,911.91
b. Supervisory Skills	-7,401.86
d. Special Training Programs	
d5. Training Enhancement Mat'ls	-1,352.80
Other B. TRAINING PROGRAM:B1.1 Training	-2,808.00
C.0 GENERAL	**-5,867.43**
C0.1 Newsletter & Information Exchange	-1,316.48
C0.2 Library Services	-848.04
C0.3 Prog Marketing Outreach Research	-1,465.35
C0.4 Out-of-State Travel	-2,237.56
2.Region 7 LTAP Meeting	-1,002.08
3.National LTAP Meeting	-1,235.48
C.1 SAFETY PROGRAMS	**-29.58**
C1.1 Safety Awareness Programs	0.00
C1.2 Retroreflectivity Prog	-29.58
C.3 WORKFORCE DEVELOPMENT	**-1,989.00**
C3.1 You Show Us Contest	-1,002.37
C3.2 Local Roads Conference	-578.88
C3.3 APWA Conf Admin & Library Matls	-407.75
C.4 OPERATIONAL EXCELLENCE	**-3,604.21**
C4.1 Information Technology Services	-351.34
C4.2 Equipment	-1,161.78
C4.3 Office Supplies	-626.35
C4.4 Staff Training	-500.00
C4.5 Advisory Meetings	-389.74
C4.7 NLTAPA Dues	-500.00
C4.8 Program Parking	-75.00
OVERALL TOTAL	**-5,107.03**

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Durable Wearing Surfaces for HMA
Study No: 10.37

Background	Reporting Period: 10/1/13 through 12/31/13 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 Pooled Fund, 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 : 10/1/13 through 12/31/13
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	Reporting Period: 10/1/13 through 12/31/13 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
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.	

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: 10/1/13 through 12/31/13
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	70	12/31/2013	Task 2 – 2013 Reflection Crack Performance
9/30/14	0		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

12/31/2013: The I-70 test section locations have been obtained and condition surveys were conducted in November. Reflection cracking has begun and a summary of the results for the far right lanes of I-70 are included below. Condition survey data was also collected for the center and median lanes and will be reported next quarter.

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

9/30/13: The I-70 test section locations have been obtained and condition surveys are scheduled for Oct 4, 2013. Test sections on US-85 in Region 4 are being 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 A bump, and often transverse cracks, occurs in an overlay of hot mix asphalt when placed over crack sealant in the underlying substrate pavement. The cause of this phenomenon is largely unknown. However, recent research by the author for CDOT and Jefferson County, CO suggests some factors which may relate to the formation of bumps and some which do not appear to relate. The factors which seem to exacerbate the formation of bumps include: 1) the temperature of the overlay mixture, 2) the pavement grade, 3) 'overbanded' crack sealant, 4) vibratory breakdown compaction, and 5) number of passes of the breakdown roller. Factors which do not appear to contribute to bump formation or are less significant include: 1) crack sealant type, 2) crack sealant application geometry, 3) substrate pavement temperature, 4) pneumatic breakdown compaction, and 5) age of crack sealant. One factor which seemed to be significant, but was not evaluated in a controlled manner during the research for Jefferson County, CO, was the size of the 'bow wave' which occurs immediately ahead of the drum during breakdown rolling. The size of this 'bow wave' is affected by the temperature of the mixture, pavement grade and vibration.	Reporting Period: 10/1/13 through 12/31/13 Type: SP&R Start: 07/16/13 End: 07/16/16 Principal Investigator: Scott Shuler, CSU: PO 211019397 Study Manager: Skip Outcalt, Research Branch, 303-757-9984 Study Panel Members: (Tentative) Bill Schiebel Michael Stanford Donna Harmelink, CO. Div. of FHWA

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
9/30/13	100	12/31/2013	Task 1 – Literature Review
07/31/14	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	35	12/31/2013	Task 4 – Progress Reports
05/31/16	0		Task 5 – Presentation
05/31/16	0		Task 6 – Draft Final Report
07/31/16	0		Task 7 – Final Report

SIGNIFICANT EVENTS

12/31/13: No activity

9/30/13: The literature review continued and found several articles referencing the phenomenon of bumps caused by crack sealant. However, no research has been discovered, to date, that uses other than anecdotal evidence for the cause or causes.

Two projects were studied where bumps were occurring in a new overlay placed over crack sealant.

The first project was on SH194 northwest of La Junta in Region 2. The 2-inch warm mix asphalt overlay was being placed by A & S Construction when bumps began appearing over the crack sealant in the old asphalt pavement. However, the contractor took steps to mitigate the bumps and by the time the Principal Investigator arrived at the project the bumps were no longer appearing in the overlay. This could have been due to two reasons; 1) the mitigation process solved the problem or 2) the areas of the pavement observed by the PI did not present a condition favorable to bump creation, and therefore, no bumps were observed.

The mitigation process used by the contractor to alleviate the bumps was to increase the tack coat rate to 0.10 gallons per square yard of diluted emulsion. Since this seemed like a plausible method to alleviate bumps an experiment was devised to determine if, indeed, it was the reason for elimination of the bumps on this project. The experiment was to place the original 0.05 gallons per square yard of diluted tack coat to see if the bumps returned.

Unfortunately, for the experiment, the remaining overlay to be constructed was not being placed over cracks with crack sealant overbanding. In fact, most of the crack sealant was below the pavement surface. However, the experiment proceeded by placing a short section of overlay with the lower tack coat rate. This was done in the eastbound lane from milepost 3 to milepost 0. No bumps were observed.

It seemed reasonable that an increase in adhesion between the overlay and the substrate pavement created by additional tack coat emulsion could reduce the potential for bumps. Therefore, a second experiment was designed to test this hypothesis. This experiment was on SH14 in the Poudre River canyon west of Rustic between milepost 87.4 and 88. Region 4 Maintenance placed the hot mix asphalt overlay. The substrate pavement contained many transverse cracks which had been crack sealed with overbanding. Five pavement sections were identified for testing. These sections consisted of Control Sections 1 and 2 at 0.05 gallons per square yard of undiluted CSS-1h, Section 3 at 0.025 gallons per square yard of undiluted CSS-1h and Sections 4 and 5 with 0 gallons per square yard of undiluted CSS-1h.

Construction occurred on August 5, 2013 beginning in the morning at 8:00 AM. The pavement temperatures were 80F while paving the westbound lane and 90F while paving the eastbound lane. The hot mix asphalt was 290F at the paver screed and 250F during the first pass of the breakdown roller. The paver was a Caterpillar and the only roller was a Hypac. Crack sealants were all ASTM D6690 Type II placed in the summer of 2012. Transverse cracks were marked with pavement marking paint prior to the overlay placement so that after the overlay was placed the locations could be observed to determine if bump formation was occurring after rolling.

Results

No bumps were observed in the overlay placed in Control Sections 1 or 2 (0.05 gsy) or Section 3 (0.025 gsy). However, transverse bumps did occur in Test Sections 4 and 5 where no tack coat was applied to the substrate pavement. These cracks did not manifest themselves until after four or five passes of the relatively lightweight breakdown roller.

Conclusions

It appears that the bond between the substrate and a new asphalt overlay has an effect on whether bumps occur in the new overlay when placed over crack sealant. This experiment will be repeated to verify this first observation on SH14.

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: 10/1/2013 through 12/31/2013 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 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: 10/1/13 through 12/31/13 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 were 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: 10/1/13 through 12/31/13 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: Skip Outcalt, 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	25	12/31/2013	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

12/31/13: The two inch cores were cut from the SH13 and I-70 6 inch cores in preparation for direct tension bond strength tests. Bond strength tests were completed and preparations to cut 4 inch cores for shipment to the LTRC and shipment of 6 inch cores to NCAT are underway.

9/30/13: The literature review continued this quarter and two field sites were located where core samples were obtained for laboratory testing. These sites are on SH13 north of Rifle and I-25 near Fountain. Six inch diameter

cores were obtained from Region 3 from the Rifle site and from Region 2 from the I-25 site. Cores were taken in areas of the pavement that appeared to demonstrate both good performance and potentially poor performance resulting from delamination of the upper asphalt layer.

The cores were taken to the CSU laboratories in preparation for delamination testing. This preparation consists of removing three 2 inch diameter cores from the six inch cores for testing at CSU, removing one 4 inch core from each six inch core for testing at Louisiana Transportation Research Center (LTRC) and shipping six inch cores to the National Center for Asphalt Technology (NCAT). The process of cutting the 2 inch cores at CSU is in progress and work is underway to procure a 4 inch core barrel and fabrication of a jig to cut the 4 inch cores.

More cores are needed from additional sites to complete the laboratory program and further assistance from CDOT will be required to identify these locations.

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: 10/1/13 through 12/31/13 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

Mileage Based User Fee Study
Study No: 30.51

Background

The Colorado Transportation Finance and Infrastructure Panel (CTFIP) identified a gap between infrastructure investment and use of the system compounded by the funding gap between revenue and needs over the long term. In short, Colorado's current system and extent of transportation finance is insufficient to maintain the state's highway and transit network, let alone grow the system to adequately address anticipated population, employment, and visitor growth. There are many options available to the state for resolving this finance gap. One strategy proposed by the CTFIP, and the subject of this study, is Mileage Based User Fees (MBUF). MBUF involves the collection of a user fee that is directly scalar with the use of designated roadways. At its simplest, an MBUF implementation may involve simply a per-mile fee; however, the specific rate of pay may include various deviations from a flat fee, in order to provide for incentives and mitigation (be it traffic, environmental, or geographic equity purposes). In order to properly assess the efficacy of MBUF towards these objectives, this study has been designed to:

1. evaluate the policy parameters surrounding a potential pilot program,
2. create a preliminary concept of operations for the conduct of MBUF, and
3. develop a framework for testing this program in Colorado.

Project Goal

In 2008, the CTFIP recommended that the Colorado Department of Transportation (CDOT) conduct a MBUF pilot project. Through the current effort, CDOT intends to develop a scope of work for the pilot program and produce a competitive proposal for Federal grant funding.

Project Scope

To achieve the objectives identified above, the study scope of work provides not only the technical parameters for the pilot program, but also sufficient research into the policy parameters that inform the technical procedures.
Whereas the objectives of the study are directly responsive to the goal of developing a successful proposed demonstration program of MBUF, these objectives are informed by the overall goals of a potential MBUF pilot program. The goals of the MBUF pilot program are to:

1. demonstrate the potential effectiveness of MBUF as a strategy for resolving the financial gap identified by the Panel, and
2. engage public, stakeholders, and institutions towards a potential full-scale MBUF implementation in Colorado.

Reporting Period: 10/1/13 through 12/31/13
Type: SP&R Start: 04/26/11

Principal Investigator(s):
David Ungemah; Parsons Brinckerhoff, 720-837-1522

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

Study Panel Members:
Kurtis Morrison, CDOT Legislative Liaison
Sandy Kohrs, CDOT DTD Intermodal Planning
Charles Meyer, CDOT Chief Engineer's Office
Ben Stein, CDOT CFO
Michael Cheroutes, HPTE Director
Herman Stockinger, CDOT Office of Policy & Govt Relations

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
10/19/10	100	10/19/10	Advertise RFP
11/22/10	100	11/22/10	Receive Proposals
1/24/11	100	1/24/11	Selection
4/26/11	100	4/26/11	Notice to Proceed
8/15/11	100	1/10/12	State of the Practice Assessment
9/15/11	100	3/28/13	Policy Outreach
9/15/11	100	5/18/12	Performance Measures
10/21/11	100	10/30/12	Preliminary Concept of Operations
11/18/11	90		Pilot Scope of Work / Final Report

SIGNIFICANT EVENTS

- 4/26/11 – Project commencement
- 6/24/11 – Meeting with CDOT policy guidance team
- 12/5/11 – Restart project
- 12/8/11 – Submission of MBUF Options Technical Memorandum (serves towards defining program goals and objectives)
- 12/8/11 – Submission of MBUF Focus Group protocol
- 12/8/11 – Submission of MBUF Stakeholder Interview protocol
- 1/10/12 – Submission of State of the Practice Technical Memorandum
- 2/13/12 – Presentation to CDOT DTD.
    - Outcome from presentation and technical memoranda: rescope project to incorporate an expanded array of public opinion assessment prior to development of MBUF policy, concept of operations, and pilot program design.
- 5/1/12 – Presentation to MBUF Symposium
- 5/18/12 – Reallocation of scope and budget to emphasize more public opinion data collection
- 6/25/12 – Initiation of Stakeholder Interviews and data collection
- 7/5/12 – Preparation of Project Update Presentation for CDOT policy / legislative outreach
- 8/27/12 – Presentation of Stakeholder interview findings to CDOT Research Division
- 9/28/12 – Completion of Stakeholder Interviews and Preparation of Stakeholder Assessment
- 10/4/12 – Conduct of MBUF Workshop with state stakeholders at Colorado DOT HQ
- 10/30/12 – Completion of concept of operations based upon stakeholder feedback
- 03/28/13 – Completed focus groups of citizens in Brush and Denver regarding MBUF strategies
- 08/26/13 – Draft Report sent to CDOT for review and met with study panel to review it.
- 09/27/13 – Met with study panel to walk them through draft report.

ANTICIPATED EVENTS FOR Q1 2014

- Submittal of final report documentation

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 10/1/13 through 12/31/13 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
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.	

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: 10/1/13 through 12/31/13 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	75%		Monitoring – 17 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	25%		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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background

CDOT has used rubber in hot mix asphalt (HMA) for over 25 years. Since the early 80s, 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.

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 research 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. Also, the research project aims to develop guidelines and best management practices for the construction of rubberized asphalt pavements.

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: 10/1/13 through 12/31/13
Type: SP&R Start: 12/1/09

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

Research Study Manager:
Temporary: Skip Outcalt, CDOT Research
303-757-9984

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		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

12/31/13: No activity

9/30/13: Condition surveys were completed this quarter and a draft of the final report was submitted to the panel and a report to the Materials Advisory Committee was given.

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: 10/1/13 through 12/31/13
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 CDOT 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:** 10/1/13 through 12/31/13 **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

ANTICIPATED WORK NEXT PERIOD

- Finalizing the data analysis in January
- Producing the report and ingesting the Thermal mapping data into Navigator early February

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

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:** 10/1/13 through 12/30/13 **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
			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

ANTICIPATED WORK NEXT PERIOD

- February 201- Continued superhydrophobic coating development
- March 2014- Perform scaled aerodynamic analysis of traffic signal in windtunnel
- March 201 - Begin testing of top candidates from lab results in outdoor testbed

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 10/1/2013through 12/31/2013 Start: 5/21/13 Contract Amount: $135,992.50 Principal Investigator: Arthur Hirsch Terralogic, LLC, 303-786-9111 Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Mike Banovich, CDOT Environmental Programs Branch (303) 757-9542 Study Panel Members: Jennifer Klaetsch, CDOT EPB Landscape 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
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.	

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	10	11/19/2013	Initiate field work (fall); Field QC Visited one of 5 sites Colorado Springs; scheduled first visit in Sterling and trying to coordinate site visit at I-225
05/1/2014			Initiate field work (spring)
09/14/14			Draft Report (75 days prior to report publication)
12/1/14			Final Report publication

SIGNIFICANT EVENTS

- Developed and submitted Final Research Methodology Plan to CDOT for review and comment; obtained CDOT approval of Final Research Methodology Plan
- Visited the I-25 Monument to Colorado Springs construction site as part of a RECAT assessment; limited revegetation information gained; visit summary developed and submitted to CDOT

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Assessment and Placement of Living Snow Fences to Reduce Highway Maintenance Costs and Improve Safety
Study No: 47.10

Background Living snow fences are designed plantings of trees and/or shrubs and native grasses along highways, roads and ditches that create a vegetative buffer that traps and controls blowing and drifting snow. These strategically placed fences have been shown to be cost effective in reducing highway maintenance associated with blowing and drifting snow conditions. The objective of the study is to equip CDOT with the tools and knowledge to expand the use of living snow fences. These tools should provide a roadmap for local CDOT maintenance staff which includes: 1) Identifying the best locations 2) Identifying land owners and securing their cooperation 3) Engaging resource agency support of the design and establishment 4) Insuring initial maintenance 5) Tracking these assets over time and documenting the benefits	Reporting Period: 10/1/13 through 12/31/13 Start: 11/29/12 Contract Amount: $ 70,000 Principal Investigator: Greg Sundstrom, Colorado State Forest Service, CSU Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Mike Banovich, CDOT Environmental Programs Branch (303) 757-9542 Study Panel Members: Jen Klaetsch, CDOT Environmental Programs Branch Mark Harrington, CDOT Environmental Programs Branch David Vialpando, CDOT, R-5, Maintenance Jeff Peterson, CDOT Environmental Programs Branch

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/30/12		11/29/12	PO 211017905 issued to CSU to start project
12/14/12	100	12/14/12	Kick Off meeting
12/31/12	100	1/22/13	Kick Off meeting minutes submitted
12/31/12	100	1/22/13	Quarterly project report
3/31/13	100	4/5/13	Inventory of existing LSFs on state highways 2/1913 – Received CDOT maintenance section LSF data from David Vialpando. 2/21/13 - Met with USDA Natural Resources Conservation Service and State Conservation Agency staff to discuss project and information needs for the inventory. Found that old Interagency LSF Program files had been pretty much disposed of. 2/22/13 – Sent CDOT maintenance section LSF data to CSFS District Foresters for review and additions to inventory. 2/22/13 through 4/5/13 – Received LSF inventory information from districts
3/31/13	100	4/5/13	Summary report of inventory information found along with copies of documents located 4/5/13 – Consolidated inventory information into summary report to be submitted with quarterly report.
3/31/13	100	4/8/13	Quarterly project report Inventory summary report and copies of documents/emails attached to email submitting

			report..
6/30/13	100	7/11/13	Quarterly project report Submitted as attachment to email
9/15/13	25% 100	6/28/13 9/15/13	Drafts of guidelines and research report Reviewing reference material and conducting interviews for most current and relevant LSF information. Have most current estimate of cost per mile of trees. Met with Wyoming State Forestry staff to learn more about the successful LSF program and relationship with WDOT. Developing outline for Guidelines and training session's agenda. 6/13/13 Received Living Snow Fence Procedure for WY and WDOT LSF program contact information. Drafts of guidelines and research report prepared for Research Team review at upcoming 10/17/13 meeting
9/19/13	0% 100	Postponed 10/17/13	Status meeting – Postponed due to potential schedule issues caused by flooding and extreme damages to Hwys.– Rescheduled for October 17th. Status meeting was held on 10/17/13, 9:30 AM, CDOT Headquarters –
9/30/13	0% 100	Postponed 11/1/13 11/19/13 12/16/13	Status meeting minutes submitted – To be submitted after meeting which was postponed is held Status meeting minutes were submitted on 11/1/13 Dates and locations for 5 short courses have been set – workshops scheduled to start in February Notebook reviews were received and comments incorporated into course.
9/30/13	100	10/14/13	Quarterly project report Submitted as attachment to email
12/31/13	100	1/6/14	Quarterly project report Submitted as attachment to email
3/31/14			Quarterly project report
4/7-8/2014			First workshop
4/9-10/2014			Second workshop
4/15-16/2014			Third workshop
4/16-17/2014			Fourth workshop
6/30/14			Completion of Workshops and end of study

SIGNIFICANT EVENTS

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

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: 10/1/13 through 12/31/13
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%		Task 2 - Field Observations
4-8/2014	100%		Task 3 - Interview Operators and Maintenance Staff
5-12/2014	100%		Task 4 – Performance Evaluation
1-6/2015	0		Task 5 – Outline Recommendations

7/2015	0		Task 6 – Final Report
			Project Complete

SIGNIFICANT EVENTS

- The interviews have been completed and results tallied.

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:** 10/1/13 through 12/31/13 **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	% done	Achieved	Description, Discussion, and Related Issues
07/01/12	100	07/02/12	Notice to Proceed
03/31/13	95		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	85		Task 2 – Methodology & critical decision-making metrics
09/30/13	100	12/06/13	Meeting with CDOT Study Panel
01/31/14	35		Task 3 – Propose a general CDOT policy in applying concept of risk- and consequent-based analysis
06/20/14	75		Task 4 – quarterly reports (8 total)
05/31/14	10		Task 5 – Final Report
06/20/14	0		Task 6 – CDOT Review Draft Report; presentation of results to CDOT

SIGNIFICANT EVENTS

Objective 1

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 (see **Error! Reference source not found.** below). Our presentation shortly after the quarter ended presented results and requested feedback for the development of a specific methodology for CDOT. Some comments are provided below. For more information on the developed framework, please refer to the slide deck provided from the presentation on 1/16/2013.

In addition to the work from the previous quarter based mostly on risk management in the project setting, the work this quarter focused on applying risk management to broader applications. Two influential documents include recommendations from the Committee of Sponsoring Organizations of the Treadway Commission (COSO) and the International Organization for Standardization (ISO). COSO provides guidance for the risk management of an entire organization through internal controls (COSO, 2004. *Enterprise Risk Management — Integrated Framework*). Additionally, the International Organization of Standardization (ISO) in 2009 published a standard for the use of risk management in organizations (ISO 31000:2009). Both emphasize the critical nature of integrating a risk-aware mindset throughout the organization, and the necessity of fostering such a mindset through appropriate training, communication, and accountability. A general methodology (see Figure 1), integrating key concepts from these broader documents and from state specific methodologies, was developed with the objective of maintaining enough flexibility such that it could be applied at any level within an organization such as 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. Some comments are provided below.

Risk based decision methodology has been adopted as a framework for decision making by several states' Department of Transportations. California (Caltrans, 2012. *Project Risk Management Handbook: A Scalable Approach*) and Washington state (WsDOT, 2010. *Project Risk Management Guidance for WSDOT Projects*) have developed detailed reports of how to best implement risk-based decision-making on a project scale and have both developed tools for qualitative and quantitation evaluation of potential uncertainties in the life of the project. Both states emphasize the importance of communication between team members and with stakeholders; to promote this, they provide templates for a "risk register" where risks items, their qualitative or quantitative impact, associated action task, and monitoring updates can be collected and viewed by members of the team. The risk register also clearly preserves who is in charge of maintaining which individual risk, making ownership and accountability more transparent and tangible. Many states, including Florida, Utah, and Minnesota, have adopted these tools or general framework for their own project process guidelines. A number of other states, including Texas, Virginia, and Colorado, have also adapted risk-based methodology for specific issues within various selection processes. Additionally, the Federal Highway Administration is supporting pilot risk-based assessments in a few states on the potential impacts of climate change on their respective transportation infrastructures. Selected states, including states of diverse climate and settings such as Hawaii and New Jersey, follow a provided generic decision making model to assess the vulnerability of their state transportation assets.

Objective 2

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.

The structural analysis studies of the mast arms was conducted during this period. Mast arm risk observations have been developed from these runs. Some notable findings include determining that there is an insignificant structural impact due to rust (from 0 to 40 percent) and missing bolts; a structural risk does arise due to formation of sharp edges from incidents such as a car impact.

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. The bridge was designed using AASHTO LFRD, 6th Edition, with current interims as of December 7, 2012. According to the design data available from the bridge drawings, the bridge was not designed with seismic provisions. The team has chosen to use Computer and Structures, Inc.'s CSiBridge software (CSiBridge 2014, v. 16.0.0). This software was chosen for its modeling capabilities specific to bridges, in conjunction to its ability to perform nonlinear analysis. Additionally, a review of the AASHTO 4th edition revisions from 2008 and 2009 was conducted to identify changes in seismic requirements for areas of low to moderate seismic activity.

The design standard for mast arms was obtained from CDOT and reviewed, and the finite element input data prepared for the structural analysis of mast arms with and without defects.

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.

For the bridge study the summary of bridge characteristics was determined and shared with CDOT for guidance in the selection of the "typical" bridge that will be analyzed for seismic risk.

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

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

The following quarter will be the last full work period for this project. The anticipated work is listed below.

Objective 1
We will continue to refine a specific methodology recommended for CDOT in order to meet needs related to budgeting, MAP-21, and other risk-related concerns regarding built facilities.

Objective 2
Using the findings and data from the mast arm finite element analysis and input from CDOT regarding analysis interests, the mast arm illustrative example will be furthered to show how the risk-based framework can be used with reference to mast arm budgeting and risk-based inspections.
For the second illustrative example, we will continue the analysis of the identified, representative bridge in order to examine the effectiveness of the updated AASHTO seismic bridge requirements in the framework of the developed risk-based methodology as stated above through the use of CSiBridge. We will then repeat the analysis with a modified, seismic-designed bridge, and compare the results.

Objective 3
The work and findings from Objectives 1 and 2 will be synthesized in a report to CDOT in order to provide

operational guidelines for incorporating the risk-based framework.

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: 10/1/13 through 12/31/13
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 if this study is to develop a new methodology for in-situ, near real-time forecasting of the stability of highway embankments. Snow-melt and rainfall induced landslides occur every year along the highways of Colorado. These failures of natural and engineered slopes potentially threaten human lives and private property and severely disrupt transportation. An active landslide on I-70 west of the Eisenhower Tunnel (Mileposts 212.0 to 212.1) was identified. In the past forty years, the hillslope in this area has episodically moved causing settlement of the pavement. Based on the current asphalt thickness, the settlement on this area is in the order of 2 feet in two decades. Currently, CDOT utilizes survey and geotechnical staff to record periodic measurements of monuments and below grade instruments, which provides for two to three data sets per year. However, at present there is not an installed system that can provide year round and continuous data on the slide movement. The improved monitoring and forecasting processes can reduce the uncertainty associated with planning improvements to the slide as well as providing an action level or early warning for the period of greater than expected movement.

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.

The development of the new methodology will be accomplished by: a) performing a thorough literature review that includes information from other state DOTs and CDOT current methodologies, b) testing the new methodology, and c) analyzing all data collected. Testing of the new methodology consists of four steps: 1) characterization of the site geomorphology and groundwater, 2) material sampling and lab characterization, 3) instrumentation of the field and site monitoring, and 4) modeling synthesis, validation, and landslide prediction. The technology can then be deployed at any similar geomorphologic environment around the country and the world.

Reporting Period: 10/1/13 through12/31/13
Type: SP&R Start: 12/07/10 Ver:
Contract: 11HAA25597

Completion/End Date: 09/30/2013

CDOT SAP # 27100300

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

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

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

Study Panel Members:
Laura Conroy, Materials & Geotechnical Branch
(Panel Leader)
Grant Anderson, R-1 Resident Engineer
Russel Cox, R-1 Resident Engineer
David Thomas, Materials and Geotechnical Branch
Amanullah Mommandi, CDOT Staff Hydraulics
Trever Wang, Bridge Design and Management Branch
H-C., Liu, Yeh and Associates, Inc.
Mark Vessely, Shannon and Wilson, Inc.
Tonya Hart, US Bureau of Reclamation

Mathew Greer, FHWA-Colorado

RESEARCH TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
4/30/11	100%	Y	Task 1: Literature Review
7/30/11	100%	Y	Task 2: National DOT Survey
4/30/11	100%	Y	Task 3: Detailed review of CDOT/Consultants methodologies

11/07/12	80%		Task 4: Testing of new proposed methodology
11/07/12	80%		Task 5: Analysis of data
12/07/12	0%		Task 6: Draft and final report

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
08/11/10	100	Y	Proposal presented
09/01/10	100	Y	Kick-Off Meeting with CSM and USGS Landslide Hazard Team
12/07/10	100	Y	Notice to Proceed (NTP) to CSM
12/22/11	100	Y	Interim Progress report presented
08/2012	100	Y	Progress report: Observations from the field
10/07/12	100	Y	Installation of all sensors in the scope of work agreed in last meeting was completed

Project completion

PI/CSM requested a no cost extension which was granted until September 30, 2013. A draft report is being prepared to be submitted to CDOT.

SIGNIFICANT EVENTS

Note 1: A third piezometer was installed in the East bound of I-70 and was hooked up to the automated data acquisition system.

Note 2: Based on new information obtained from field work (horizontal drains, boring log on I-70 shoulder, and topographic survey) a new cross-section profile was developed. Data on flow rates from horizontal drains 1 & 5 is recorded every site visit

Note 3: A report on findings of the field work was submitted to Dr. Khan in August, 2012.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of CDOT Materials and Construction Specifications for Bridge Deck Sealers
Study No: 80.11

Background	Reporting Period: 10/1/13 through12/31/31
Chemical sealers, applied on the top concrete surface, are employed by CDOT for waterproofing bare new and existing bridge decks that do not have asphalt overlay. The type of sealers includes silane, siloxane, epoxy, and methacrylate. These and other commercially available sealers products have been developed to reduce the penetration of chloride ions from deicing salts and thereby preventing the corrosion of the reinforcing steel. Unfortunately CDOT material specifications allows for only limited types of sealers, silane for the "penetration sealers" and methacrylate for the "crack sealers." This research should develop generic type of performance-based material and construction specification for penetration and crack sealers that would allow for acceptance of other type of sealers materials based on the results of performance tests. The study should present all the details for the types of these tests (laboratory and field) and for interpretation of the test results. Some of the tests that should be considered for the penetration sealers include the chloride ponding test, elongation test, skid test, UV stability test, freeze-thaw tests, and tests for quality assurance of the placed sealers during construction. Some of the tests that should be considered for crack sealers include skid test, UV stability test, freeze-thaw tests, depth of penetration into the typical size of cracks developed in bridge decks, and tests for quality assurance of the placed sealers during construction. The crack sizes for application of the crack sealers should be established. The construction requirements should include information on the surface preparation before application of the sealers.	Type: SP&R Principal Investigator(s): Yunping Xi, 303-492-8991 Study Manager: Aziz Khan, Research Branch 303-757-9522 Panel Leader: Ali Harajli, Bridge Design & Management, 303-512-4078 Study Panel Members: Gary DeWitt, Region 4 Materials 970-350-2379 Eric Prieve, Staff Materials 303-398-6542 Scott Roalofs, Staff Materials 303-398-6509 Mathew Greer, CO Div. of FHWA 720-963-3008

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
10/1/06	100	10/26/06	Hold first panel meeting to discuss scope of work and domain of PI. This meeting is scheduled for October 26, 2006
11/1/06	100	12/29/06	Finalize scope of work (SOW) and RFP
3/5/07	100	3/5/07	SOW sent to purchase office for finalizing RFP
7/30/07	100	10/15/07	Finalize the selection of the Principal Investigator (PI)
2/15/08	100	5/20/08	Notice to Proceed

RESEARCH TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/31/08	100%	09/30/08	Task 1 Literature review on sealers and sensors Literature review completed.
	100%	07//09/09	Task 2: Field evaluation of monitoring system
	100%	04/01/10	Task 3: Interim report and testing plan
	100%	06/02/10	Task 4: Field evaluation of sealers
	95%	06/31/11	Task 5: Analysis of field evaluation results
	95%	12/31/11	Task 6: Draft report and final report

	99%	12/31/13	Final report submitted and reviewed by CDOT. Revision almost done.

SIGNIFICANT EVENTS

1/07: RIC Approved additional funding

12/06: It was determined that additional funds were needed to for traffic control. The study has been put on hold until the additional funds could be secured through the Research and Implementation Council (RIC).

11/06/08: The CU research team and CDOT program managers had a field trip to bridge structure F-17-KJ, which was selected as the bridge to install the sealers and sensors for performance monitoring. During the field trip, it was found that de-icing salts will not be applied on the bridge decks of F-17-KJ in the winter of 2008. As a result, another bridge will be selected by CDOT study panel.

04/03/2009: Four bridges were recommended by CDOT study panel for the application of selected sealers. They are E-17-NX, E-17-QM, E-16-PJ, and E-17-PD. One of the four bridges will be selected for actual application. Field trips will be arranged.

05/27/09: Two field trips for bridge selection on May 21 and May 27, 2009. Bridge structure E-17-QM is the final candidate bridge for the project. A meeting to coordinate the effort for setting up power supply on E-17-QM is scheduled on 07/13/09.

10/15/09: CU Boulder research team completed confined space training needed for the box girder instrumentation installation and data collection.

10/15/09: CU Boulder research team filed a no-cost extension for the project. The ending date will be Nov. 30, 2010.

05/26/10: 18 moisture/temperature sensors were installed and concrete cores from four testing sections were taken.

06/02/10: Four types of sealers were applied on the bridge.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Evaluation of Thin-Bonded Overlays as Cost-Effective Bridge Deck Barriers and Reducing Bridge Construction Costs
Study No: 80.15

<u>Background</u>

In order to improve long-term performance of concrete bridge decks, asphalt and waterproofing membranes (AWM) and chemical sealers are often applied on the top concrete surface for protecting concrete bridge decks. In general, AWM and sealers are developed to reduce the penetrations of moisture and chloride ions from deicing salts and thereby preventing the corrosion of the reinforcing steel embedded in bridge decks. Under different service conditions, the performances of AWM and chemical sealers are different. All of these protection methods have a common feature that is the requirement of routine maintenance activities to insure proper performance.

A recent development in the area of bridge deck protection is to use thin bonded polymer overlays on concrete decks, which have been used in other states and have shown some advantages such as better protection for concrete decks, lighter load than conventional overlays, and better durability than AWM and chemical sealers. So far, there has been no systematic research conducted in Colorado for the performance evaluation of the thin bonded overlays. The main goal of this project is to evaluate the behavior and cost effectiveness of the thin bonded overlays applied on reinforced concrete decks under service load including traffic, freeze-thaw, and wet/dry exposure. This research project has two specific objectives:

- To determine the ability of various thin bonded overlays to stop the intrusion of chloride from deicers into concrete bridge decks.
- To determine the cost effectiveness of the thin bonded overlays.

Reporting Period: 10/1/13 through 12/31/13

Principal Investigator(s):
Yunping Xi, 303-492-8991

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

Panel Leader:
Ali Harajli, Bridge Design & Management, 303-512-4078

Study Panel Members:
Gary DeWitt, Region 4 Materials
970-350-2379
Eric Prieve, Staff Materials
303-398-6542
Scott Roalofs, Staff Materials
303-398-6509
Mathew Greer, CO Div. of FHWA
720-963-3008

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
4/9/12	100	4/9/12	Kick-Off Meeting
5/30/12	100	6/11/12	Invite Vendors to participate
6/1/12	100	7/31/12	Literature Review
6/1/12	100	6/2/12	Material Collected for Casting of Test specimen
6/1/12	100	6/5/12	Experimental Plan
6/7/12	100	6/7/12	Meeting at CDOT Region 6 to discuss test dates, closures, coring location
6/8/12	100	6/12/12	Test Specimens Casted, set for curing
6/21/12	100	6/21/12	Vendor and Material selection finalized
6/30/12	100	6/30/12	All Testing Material and Equipment Ordered/Finalized
7/14/12	100	7/14/12	All testing materials installed on the bridge decks
3/27/13	100	3/27/13	The second trip: take concrete cores and conduct skid resistance tests
9/04/13	100	9/04/13	The third trip: take concrete cores and conduct skid resistance tests
12/31/13	100	12/31/13	Prepare the final report

SIGNIFICANT EVENTS

5/16: Meeting with Dr. Yunping Xi to finalize test selection and details
5/24: Receive possible vendor information
5/25: v1 Experimental Plan completed
5/30: Initial Invitations sent out to vendors
6/05: vF Experimental Plan
6/07: Meeting at CDOT Region 6. Initial single closure data of 7/15 replace with 2 closures back to back on 7/13 and 7/14. Traffic will be reopened between closures. Apply for closure time extension on 7/14 to provide adequate installation time. Attendance: Skip Outcalt, Ben Gallaher, Aziz Khan, Tesfaye Alazar.
6/11: Two vendors back out, begin sending out more invitations
6/14: Two other vendors agree to participate
6/15: Coring Locations picked based on structural drawings of E-17-QM
6/21: Vendor and Material selection finalized

- Sika Corperation – Sikadur 21/22 Lo-Mod Binder
- Euclid Chemical Company – Flexolith
- Plexi-Coat America – Plexideck
- DOW/Poly-Carb – Mark 163 Flexogrid

6/30: Testing Material and Equipment Finalized
7/14: Testing materials installed on decks of E-17-QM.
Skid resistance tests performed and thin-bonded overlay samples collected.
3/27/13: The second field trip was completed: take concrete cores and conduct skid resistance tests
9/04/13: The third field trip was completed: take concrete cores and conduct skid resistance tests

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Hybrid A-Frame Micropile/MSE Wall with Impact Barrier, Unique Design and Construction Approach
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:
10/1/13 through 12/31/13
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 ~~T meth~~odologies and experience relevant to design of hybrid Micro-pile/MSE walls with impact barriers.
12/1/12	80%		Task 3a: Construct comput<u>er mode</u>ls and perform parametric study using finite element code LS DYNA for a MSE w<u>all subje</u>ct to gravity load with a A-frame micropile system to resist lateral loads 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	30%		Task 4: Develop design methodology, and construction worksheets for hybrid micropile-MSE walls for CDOT consideration.
2/15/14	20%		Task 5: Draft and submit final report and recommendations

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Thin-Bonded Overlays on Asphalt and Concrete Surfaces
Study No: 84.14

Background

The CDOT and other state DOTs are faced with a continuous problem of maintaining and replacing the wearing surfaces on bridge decks. Wearing surfaces are utilized on many bridge decks in an effort to maximize the life of the bridge deck, prevent the infiltration of water and aggressive chemicals such as chlorides from deteriorating the concrete surface and corroding the steel reinforcement.

There are a number of wearing surface materials available; however, the service life of many of these materials is less than ten years and requires extensive time and equipment to remove and replace such surfaces. In addition, care is need when removing these types of surfaces as to no damage the impermeable membrane placed atop the concrete bridge deck surface.

Recently, advancements in thin-bonded overlays have produced materials that promote an improved wearing surface and anti-icing properties. These innovative materials can replace more traditional overlays such as asphalt, portland cement concrete, non-reinforced polymer cement concrete.

If the products examined in this study prove successful in providing a durable skid resistant wearing surface that prevents the formation of bonded snow or ice to the bridge surface, the CDOT will be able to recommend these products for future bridge construction and rehabilitation projects. Ultimately this could be a cost savings to the CDOT as it would potentially reduce maintenance costs on bridge structures. In addition, the anti-icing component of these materials may improve driver safety during winter conditions thereby reducing weather related accidents.

Reporting Period: 10/1/13 through12/31/13
Type: SP&R Start: 05/09 Ver:
Contract:

Principal Investigator
Dr. Rui Liu

Study Manager:
Aziz Khan, Research Branch

Study Panel Members:
Glenn Frieler
Ali Harajli
Eric Prieve
Roberto de Dios
Ryan Sorensen
Mark Mueller
Skip Outcalt
Patrick Kropp
Mickey Madeliro
Matt Becker
Telecia McCline

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/20/09	100	5/20/09	PI Selected
7/22/09	100	7/22/09	Notice to Proceed Issued
8/24/09	100	8/24/09	Project “Kick-Off” Meeting
10/05/09	100	5/01/10	Traffic Control, Instrumentation, Testing, and Const. Plans
10/15/09	100	6/09/10	Field Implementation of SafeLane Overlay
10/22/09	100	10/31/09	Literature Review Completed
10/22/09	100	10/31/09	DOT Survey Findings Report Completed

RESEARCH TASKS (Thin-Bonded Overlays on Asphalt Surfaces)
I-76/Weld County Road 53

Planned	% done	Achieved	Description, Discussion, and Related Issues
10/22/09	100%	10/31/09	Task 1a: Literature review
10/22/09	100%	10/31/09	Task 1b: Conduct a national survey of state DOTs

10/05/09	100%	5/01/10	Task 2: Develop a traffic, instrumentation, and data collection plan
10/05/09	100%	6/09/10	Task 3: Install the approved products on I-76 and Weld County Road 53 east bound bridge at MP 36.54. Document installation process.
08/22/10	100%	6/24/11	Task 4: Collect and analyze data to determine the effectiveness of the anti-wearing/anti-icing products. The examination will included, but not limited to: anti-icing, skid resistance, chloride penetration, permeability and snow melting.
02/28/12	95%		Task 5: Prepare and submit a Draft and Final Report to the CDOT.

*UCD is still planning to continue gather overlay performance data on this bridge structure as the Phase II contract continues through 12/31/13.

RESEARCH TASKS (Thin-Bonded Overlays on Concrete Surfaces)
Parker Road/I-225, and I-25/I-225 Structures

Planned	% done	Achieved	Description, Discussion, and Related Issues
6/14/2011	100%	6/30/2011	Task 1: Literature review
12/15/2011	100%	12/31/2011	Task 2: Conduct a detailed investigation of bridge deck overlay construction and performance
10/14/2013	100%		Task 3: Data collection and analysis of thin-bonded overlays on structures F-17KK and F-17-OD
10/14/2013	90%		Task 4: Laboratory/field testing
12/31/2013	90%		Task 5: Prepare and submit a draft and final report to CDOT

SIGNIFICANT EVENTS

08/09	Project "Kick-off" meeting
08/09	Preliminary Literature Review Submitted
09/09	DOT Survey Findings Report Completed
09/09	Progress Report Submitted
09/09	DOT Survey Findings Report Submitted (to be submitted by 09/30/09)
10/09	Field Cores Taken from Bridge Deck (to be used for chloride and permeability testing.
12/09	Chloride Testing of Bridge Cores Performed
12/09	RCIP Permeability Testing Performed on Bridge Cores
04/10	Testing Plan Complete (meeting between CDOT and UCD on April 8, 2010)
04/10	Instrumentation Plan Complete (meeting between CDOT and UCD on April 8, 2010)
04/10	Traffic Control and Construction Plans Meeting Scheduled (April 21, 2010)
06/10	Construction of SafeLane Product on I-76 and WCR 53 by Region 4 Personnel
09/10	Meeting to Discuss Maintenance, Testing, and Data Collection for winter
01/11	Project Update at CDOT Materials Laboratory (Holly Branch)
03/11	Additional Physical Testing of Overlays on I-76/Parker Rd./I-25
06/11	Permeability and Chloride Results Complete
12/11	Project Update at UCD
01/12	PI Transition
03/12	Meeting held at CDOT to discuss next phase of testing and rad sensor installation on I-225/Parker
05/12	Field inspection of the I-76/WCR 53 structure (076-035 D-18-BK)
09/12	Meeting to Discuss Data Collection at I225/Parker and I25/I225 structures
10/12	Sampling at I225/Parker and I25/I225
12/12	Permeability and Chloride Results Complete
01/13	Project update at CDOT Headquarter

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: 10/1/13 through 12/31/13 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: 10/01/13 - 12/31/13
Type: SP&R Start: 06/09 Ver:
Completion/End Date: 7/22/2014

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
Sept. 2013	30		Physical Testing in the Lab
Feb 2014			Complete Analysis of physical test and calibration of FE models
April 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	45		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.

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: 10/1/13 through 12/31/13 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	80		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	50		It is planned to submit the draft final report by 5/15/2014, if not sooner, for CDOT to review. The final report will be submitted by 07/31/2014. The report is currently under preparation/revision.

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	80		Task 6: Illustrative examples
~~1/31/2014~~ 5/15/2014	50		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.

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:** 10/1/13 through 12/31/13 **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	80		Task4 – Decision Criteria Development
5/15/13	5		Task 5 – Arterial Analysis
5/15/13	5		Task 6 – Freeway Analysis
6/15/13	10		Task 7 – Develop Decision Tool
6/30/13	10		Task 8 – Documentation

SIGNIFICANT EVENTS

- Minimal work progress occurred during the 4th Quarter of 2013 due to notice to proceed timing and the holidays. Notice to proceed was provided November 20, 2013.

ANTICIPATED WORK NEXT PERIOD

- Meeting to refresh study, progress toward completion of final report

ISSUES

- Minimal work progress occurred during the 4th Quarter of 2013 due to notice to proceed timing and the holidays. Notice to proceed was provided November 20, 2013.

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:** 10/1/13 through 12/31/13 **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

Safety Performance Functions (SPF) for Freeway Merge Zones
Study No: 90.75

Background Road safety management activities include screening the network for sites with a potential for safety improvement (Network Screening), diagnosing safety problems at specific sites and evaluating the safety effectiveness of implemented countermeasures. The state-of-the-art methodologies for conducting these activities make use of statistical models to predict expected accident frequencies and severity using traffic volumes and other site characteristics as the input to the models. These models are known as Safety Performance Functions (SPFs). Currently, SPFs are not available for all roadway facility types in Colorado. The aim of the proposed research is to fill one of these gaps by developing SPFs for merge lanes using data from Colorado freeways. The mitigation of collisions at on-ramp merge lanes can be accomplished by safety treatments such as ramp metering or design modifications. Thus it is desirable to develop SPFs for these types of facilities.	Reporting Period: 10/1/2013 through 12/31/2013 Type: SP&R Start: 05/14/12 PO: 211015884 PO Expiry: 12/31/2013 Principal Investigator(s): Mr. David Hattan; Felsburg Holt & Ullevig Denver, 303-721-1440 Mr. Craig Lyon; 613-422-2542 Study Manager: David Reeves, CDOT Division of Transportation Development, 303-757-9518 Study Panel Members: ~~Jake Kononov, DTD Research (Retired 7/1/12)~~ Charles Meyer, Traffic & Safety David Swenka, Traffic & Safety ~~Bryan Allery, Traffic & Safety (Retired 7/1/12)~~

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	05/14/12	Notice to Proceed
	100	05/23/12	Kick-Off Meeting
	100	09/30/212	Task 1 – Data Collection
05/01/13	100	05/01/2013	Task 2 – Develop Merge Zone SPF's
07/01/13	100		Task 3 – Draft Report
08/01/13	100		Task 3 – CDOT Review Draft Report
12/15/13	100	12/15/2013	Task 3 – Final Report

SIGNIFICANT EVENTS

- Craig Lyon provided online training for David Swenka and David Reeves to walk them through some examples.
- Final report is complete and published. This will be the last status report

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Tension Cable Guardrail
Study No: 91.06

Background

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

This study will monitor the performance of tensioned cable guardrail systems installed in Colorado. Important factors include: Severity of injuries and damage to vehicles; cost for repairs including time and materials; availability of materials and product support; ease of repair and maintenance.
Accident, maintenance and repair data will be evaluated to establish criteria to help in selection of the best system and best configuration for a particular situation.

Implementation

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

Reporting Period: 10/1/13 through 12/31/13
Type: Experimental Feature

Principal Investigator:
Skip Outcalt, CDOT Research, 303.757.9984

Study Manager:
Skip Outcalt CDOT Research 303.757.9984

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

MILESTONES

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

07/07		07/07	Install approximately 1 mile of each of the 5 certified manufacturers' systems in the median of C-470 from mp 14 to 19
12/13	90		Evaluate accident and MMS system data. Write and distribute the final report.

SIGNIFICANT EVENTS

12/13 – No activity.

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

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

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

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

1/12: Data collection and analysis in progress

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

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

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

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

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

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

12/07: An Excel spreadsheet database with extensive information about each of the high tension cable barrier (HTCB) sites constructed through 12/07 is available. Also available is a "Things to Watch" list that explains many of the problems encountered by CDOT and their solutions.

A five-mile long site has been constructed using about one mile from each of the five manufacturers who currently have HTCB that has received NCHRP 350 certification – Trinity, IA Safence, GSI Nucor, Gibraltar and Brifen. The systems will be evaluated for performance and “maintainability”.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

LED Lighting to Replace Overhead Lighting
Study No: 92.20

Background

State law requires lighting methods to minimize light pollution caused by overhead lighting at highway interchanges. Light pollution or trespass can be a significant problem, especially when overhead lighting is employed on elevated structures.

During reconstruction of a pair of structures on I-25 in Trinidad, the overhead luminaire lighting will be replaced by Light Emitting Diode (LED) lights mounted on the barriers adjacent to the highway rather than on poles above the structures.

The LED lighting will be evaluated for effectiveness in delineating the highway and interchanges associated with the structures, and for costs and ease of installation and maintenance, and durability of the LED lighting components

The study will continue for 5 years to provide time for evaluating the durability and life of lighting components. Accident data will be gathered during the study and compared with a like time period before construction.

Visibility testing was added to the scope of this study. Ron Gibbons, Virginia Polytechnical Institute and State University was hired to perform it.

Implementation

Findings of this study regarding the durability and cost effectiveness of barrier mounted LED lighting in lieu of overhead lighting can be used to justify the practice at future locations.

Reporting Period: 10/1/13 through 12/31/13
Type: Experimental Feature

Principal Investigator(s):
Dr. Ron Gibbons, VA Tech U. 540-231-1581
Nancy Clanton, Clanton & Assoc 303.530.7229

Study Manager:
Skip Outcalt, CDOT research 303.757.9984
Dave Reeves, CDOT research 303.757.9518

Study Panel Members:
Gregg Adams, Clanton & Assoc 303.530.7229
Joe Garcia, Reg 2 Design 719.546.5727
Darrell Dingus, Stds & Design 303.757.9083
Doug Lollar, R 2 Eng 719.546.5439
Dwayne Wilkinson, Safety 303.512.5134

FHWA CO Div 720.963.3007

TASKS AND MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
04/04		04/04	Establish study panel
05/04		04/15/04	First study panel meeting to determine the methods of research and evaluation.
07/04		07/04	Initial evaluation of the light levels associated with the overhead luminaire lighting on the two structures on I-25 in Trinidad. Levels on the deck and on the ground below the structure will be measured to compare with levels after the LED installation.
7/08	100		Begin construction of the structures including the installation of the LED lights to replace overhead luminaires.
9/09	100		Light levels of the of the LED lights at Trinidad initial post construction evaluation.
01/10			Evaluation of the measured post-construction light levels by Clanton & Assoc.
06/11			Safety evaluation of the LEDs
			"Evaluation of Guardrail Embedded Lighting" to be done as a continuation of this study.
11/8/12		11/8/12	Virginia Polytechnical Institute has been hired to conduct a visibility evaluation of the lighting system
2/1/13	100	09/13	Schedule visibility evaluation line up panel of observers to participate in the test
4/30/13	100	09/13	Virginia Tech and panel of observers conduct visibility evaluation

8/31/13	100	11/13	Virginia Tech field testing report
7/31/13	100	11/13	Draft Final Report for study
11/31/13	100	01/14	Publish Final Report.

SIGNIFICANT EVENTS

12/31/13 – The final report is completed. This is the last Quarterly Report for this study.

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: 10/1/13 through 12/31/13 Type: SP&R Start: 03/06/12 PO: 271001635 Expires: 12/31/2013 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: 10/1/13 through 12/31/13
Start: 3/1/09
Complete: TBD

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

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

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

Study Panel Members:
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
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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.

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: 10/1/2013-12/31/2013
Start: 10/5/12
Complete: TBD

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

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

Panel Leader:
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Study Panel Members:
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Saeed Farahmandi, City and County of Denver

FHWA Washington Contact:
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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

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.

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:

Introduction of new parameters to pipe size selection guidelines to accommodate debris flows.

Development of criteria by debris-basin material types and ranges of basin slopes.

Reporting Period:10/1/2013 through12/31/2013
Start: 10/5/12 Complete: TBD

Principal Investigator(s):
CSU/Dr. ChristopherThornton,
970-491-8394
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Study Manager:
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Study Panel Members:
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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
3/31/2014	20	9/30/2013	Development of numerical tools for debris flow modeling

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

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:

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).

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.

Development of pier and abutment equations for mountain streams.

Reporting Period: 10/1/2013through 12/31/2013
Start: 10/5/12 Complete: TBD

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

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

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

Study Panel Members:

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Mike Banovich, CDOT Environmental 303-757-9542
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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 25 sites.
3/31/14	40	9/30/13	Development of bridge scour equations using excess velocity approach

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background Extended detention and full-spectrum detention basins improve the quality of stormwater runoff through settling of sediment. This is achieved by detaining and slowly releasing the stormwater over a prescribed time duration of generally 40-72 hours. An alternative outlet that is less susceptible to clogging and therefore requires less frequent maintenance would be of great benefit to CDOT and others. The primary objective is to study a new type of outlet metering device which is referred to as an elliptical slot weir, its name derived from the elliptical curvature of the weir. Ken MacKenzie with the Denver Metropolitan Area Urban Drainage and Flood Control District will be undertaking a research study in partnership with Colorado State University to investigate an elliptical slot weir for metering water from settling ponds.	Reporting Period: 10/1/2013 through 12/31/2013 Start: 09/21/12 Contract Amount: $70,000 Principal Investigator: Ken A. MacKenzie, P.E., CFM Master Planning Program Manager Urban Drainage and Flood Control District Study Manager: Bryan Roeder, CDOT ARIB, 303-512-4420 Study Panel Leader: Mommandi, Amanullah, CDOT PDB Hydraulics Program Manager Study Panel Members: Kenneth Quintana, CDOT R2 Maintenance Al Roys, CDOT R4 Maintenance Aziz Khan, CDOT ARIB

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

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).

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

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

9/30/2013 – UDFCD investigated retrofitting the Grant Ranch Orchard Pond extended detention basin with an elliptical slot weir and found that, due to a relatively small storage volume and large storage depth. This information will help bracket the limits of applicability for this type of outlet control plate. Two other sites have been identified for retrofitting 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 The accuracy of flood-frequency estimates can be greatly improved when historical flood information is used in conjunction with systematic flood data. The recent completion of the Colorado Flood Database (http://cwscpublic2.cr.usgs.gov/projects/coflood/COFloodMap.html) provides a unique opportunity to improve at-site and regional flood-frequency equations with easier access to flood data. Having an easy-to-use Web-based database of flood and paleoflood information allows engineers and water-resource managers to fully use these data to help improve flood-frequency estimates of large floods in Colorado. Maintaining this database will ensure continued access to these data and regular updates will keep the database current, further enhancing its value and use. The objective of this study is to maintain and enhance the Colorado Flood Database (http://cwscpublic2.cr.usgs.gov/projects/coflood/COFloodMap.html) annually by updating the database with new flood data, and performing routine Website maintenance as needed. The data sources of historical flood information include: high outliers at gages used in the latest Colorado flood frequency report published by the USGS; unpublished USGS indirect and paleoflood measurements; and the peak flood of record at all USGS gages. The updated Web-based interface containing links to systematic data and historic flood information is the ultimate product of this project. A short USGS Open-File Report (http://pubs.usgs.gov/of/2012/1225/) has been published to describe the contents of the database, its features, and how to use them.	Reporting Period: 10/1/13through12/31/13 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

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: 10/1/13 through 12/31/13

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

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: June 2014	Collect, document, and archive paleoflood data at each site
6/30/14	5	Expected: June 2014	Determine the peak discharge, age, and uncertainty of each paleoflood
6/30/14	0	Expected: June 2014	Perform site specific flood-frequency analysis using PeakFQ/EMA
12/31/14	0	Expected: December 2014	Develop regional flood-frequency equations
3/31/15	0	Expected: March 2015	Determine the uncertainty of the new flood-frequency equations
9/30/15	0	Expected: September 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 Spring of 2014, weather permitting.

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

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: 10/1/13 through 12/31/13 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

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: 10/1/13 through 12/31/13 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

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Survey, Evaluation and Long-Term Monitoring of the EDC GRS Abutment Performance for Multiple Spans CDOT Bridges Replacement Project
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:10/1/13 through 12/31/13 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 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

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 Spans CDOT Bridges Replacement Project
Study No. 214.055

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: 10/1/13 through 12/31/13 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

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 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.
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 Wall
9/12/14			Install instruments in Phase II Wall
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

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: 10/1/13 through 12/31/13 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

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: 10/1/13 through 12/31/13
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.