COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Guidebook for Selecting Highway Project Delivery Methods and Alternative Contracting Strategies TPF-5(260)
Study No: 3.06

Background

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

Project Goal

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.

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

Reporting Period: 7/1/13 - 9/30/13
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
Marc Mastronardi, GaDOT
Greg Mulder, IaDOT
Jake Goettle, MtDOT
Rodger Rochelle, NCDOT
Teresa Bruton, NCDOT
John Obr, TxDOT
Imad Aleithawe, MsDOT
John Kulka, HRI (ARTBA)
Les Fukuda, HDR (ACEC)

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	80%	Ongoing	Interim report / draft of guidebook
12/31/13	80%	Ongoing	Develop complete draft of decision support tool
03/31/14			Validate and calibrate
06/01/14			Final guidebook, executive summary, and research report

SIGNIFICANT EVENTS

- 07/01/2013- General PDSM tool available on the website in MS Word format (http://www.colorado.edu/ceae/TCM/ICACtool.html) for download and use.

- 08/13/2013 – Quarterly advisory committee meeting took place in person at the AASHTO Subcommittee on Construction meeting in Detroit, MI. The meeting included introductions of advisory committee members, review of project progress, and discussion on guidebook. 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.

- Sep 2013 – The payment provisions selection matrix is in a draft form. Areas of concern are the checklists, which are not populated, and defining each of the eight evaluation factors in terms of payment provisions. This draft will be shared with the advisory committee with a request of two to four members providing a detailed review and comments.

- Sep 2013 – CU has been developing the supplementary procurement and payment methods for the guidebook. Each method includes the what, why, how, when and who uses the method. Also an example and references accompany each method. At the present time, we have completed five of the supplementary method write-ups, which will be discussed with the advisory committee at the next quarterly meeting/conference call.

- Aug/Sep 2013 – CU has been preparing the interim report for review by the advisory committee. It includes details on the tasks completed, discusses completing the remaining tasks, and outlines the final guidebook.

- 09/30/2013 – Completed Q3 quarterly reports for CDOT and Transportation Pooled-Fund. Quarterly reports provide updates and progress of the TCM pooled-fund project.

ANTICIPATED EVENTS FOR Q4 2013

- The next advisory committee meeting/conference call will take place in November 2013. 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.

- Continue testing of project delivery, procurement procedures, and payment provisions selection matrix tools. Volunteer projects that have a selected delivery method but not a procurement procedure are ideal.

- Complete Interim Report and draft payment provisions selection guide. Payment provisions selection tool will be more of guidelines in what payment provision to use, either unit price or lump sum.

- Further work on developing all of the supplementary procurement and payment methods. As these are completed, they will be distributed to the advisory committee for review.

- Anticipate that the project delivery selection matrix, the procurement procedures selection matrix, and the payment provision guidelines will all be in a usable draft form for further calibration and validation to take place in Q4 and 2014 Q1.

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: 7/1/13 - 9/30/13
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.
			Future visits and other activities will depend on FHWA decisions

SIGNIFICANT EVENTS

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

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

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

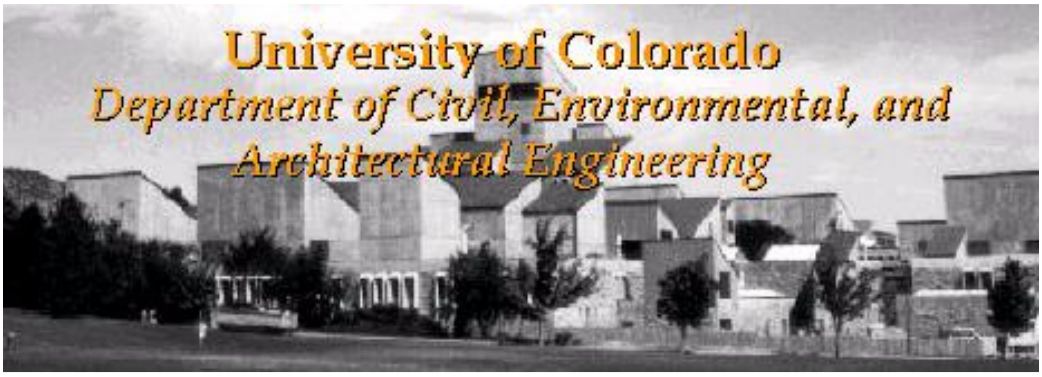
12/01/10 FHWA and Nichols Consulting Engineers (NCE) conducted the Long-Term Pavement Performance (LTPP) seminar at the Turnpike Conference Room in Materials Lab building.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period 7/1/13 - 9/30/13 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 REPORT COLORADO LTAP REPORT



COLORADO LTAP

LTAP Quarterly Report

Report Period
July 1, 2013 – September 30, 2013

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

Submitted by:
Colorado LTAP
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Colorado LTAP

1st Quarter

July 1 – September 30, 2013

Program Dashboard:

Total number of training sessions*: 1
Total number of participants*: 14
Total number of participant hours*: 98
Total newsletter circulation: 1,501 (hard-copy), 205 (electronic)
Total number of LTAP FTEs: 2.25
(Only for classes held between July 1 and September 30. Five sourses scheduled in the first quarter were cancelled & rescheduled due to the flooding event.)

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

- July 1 - September 30, 2013, Colorado LTAP had two full-time staff persons working for the center – Program Director and Training Coordinator. As of August 1, 2013, Cassandra Guild replaced Lindsay Marshall as the Training Coordinator.
- A graduate student continued working part time for the center this quarter. The student mainly handles the library loan program and training prep assistant. Wang Xingang was replaced by Musiket (NOOM) as the part-time graduate student worker.
- Due to Temporary Aid restrictions, Office Assistant-Marty Butcher is unable to return to LTAP until October.
- A lot of office time this quarter was spent training the new staff people.

B. Training

- The start of the fall training schedule was delayed both by the flooding events, and loss of an instructor. 5 classes previously scheduled for September were rescheduled in November.
- This quarter, there was only 1 Roads Scholar I class offered. The course evaluation received an average of 96.15% for classes held this quarter.
- The one class offered was an Infrastructure Management focus course - *Winter Maintenance and Snow Removal*. CDOT Alamosa's Russ Hamilton was the instructor for the course. This course is part of the winter maintenance training that CDOT offers to its employees. The course objectives for this class were to increase the safety of employees and customers; prevent unnecessary damage to equipment; provide better customer service; conserve resources; and develop the professionalism of the employee.
- Three Roads Scholar I plaques were distributed to participants that had previously completed the program requirements but had not yet received their plaques.
- Details on any training course are available upon request; additional detail is also provided in the annual Work Plan.
- A complete list of classes held in the first quarter, July 1 – September 30, 2013 is included in Appendix A.

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

Two tools utilized for technology transfer and information exchange include our quarterly newsletter publication and free lending library. Due to training new staff and added responsibilities due to flooding recovery efforts, the Fall issue will be delayed and distributed in October. It is intended for both the Fall and Winter issues to be produced in the 2nd Quarter report.

C0.2 Library Materials Distribution

- Continued to manage our in-house lending library consisting of over 2500 items - instructional videos, publications, and resources focusing on transportation design, maintenance, safety, and workforce related topics.
- Between July 1 – September 30, 23 items were loaned free to local transportation agencies. The table below shows the distribution by type and focus area. The most frequently loaned titles were related to Highway Work Zone Safety.
- Separate from the lending library, we also distributed 89 free publications, guidebooks and videos.
- 50 different titles of new or additional materials were added to the library in the 1st quarter – 9 books, 0 CDs, 6 DVDs, and 35 Free Publications. Topics addressed in the new materials included Excavation and Trenching, ADA in Work Zones, Berming, and Snow and Ice Control.

- About $118 was spent on ordering new materials, and $48 was spent on postage for mailing loaned materials.

Pub Type	Highway Safety	Infrastructure Management	Worker/Workplace Safety	Workforce Development
Book	0	0	0	0
Bulk Material	0	0	0	0
CD	0	0	0	0
Disk	0	0	0	0
DVD	3	1	9	2
Free Publication	29	35	10	9
Software	0	0	0	0
Video	3	1	3	0

C0.3 Program Marketing, Outreach & Research

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

Marketing

- 15 dozen Safety work gloves were purchased to promote on the job safety. The items were designed to include LTAP logo, contact information, and website. The gloves will be distributed with each training program graduate plaque; and at conferences.

Outreach

- Colorado LTAP provides a booth of educational, promotional and free library materials at a select few transportation meetings and conferences that benefit the scope of the program. These opportunities also help to advance staff knowledge base on the latest transportation technologies, processes, and resources.
  - Program Director, Renée Railsback and new Training Coordinator Cassie Guild attended and presented at the West Slope APWA Snow & Ice Conference in Gunnison. Colorado LTAP had a free booth at this conference. The Quarterly LTAP Advisory Board meeting was scheduled to be held in conjunction with this meeting; however was cancelled due to lack of committee member attendance.
  - Colorado LTAP usually has a free booth at the Western Regional APWA Snow & Ice Conference in Estes Park. However, that conference was cancelled due to Colorado flooding events.
  - LTAP staff also attended the CARMA Winter Workshop planning meeting.

- $1,054.53 was spent on Program Marketing and Promotion this quarter.

Technical Assistance

- LTAP center staff spent about 25% time providing technical assistance to local agencies. A majority of technical assistance this quarter was related to flood recovery efforts and resources. Other examples of technical assistance provided this quarter included requests on local agency working project development.

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.

- As 2013 National Conference Chairperson, Renée attended the National LTAP-TTAP Conference in Boise, ID in July. This conference offers many peer learning opportunities, and has sessions geared specifically to different levels of LTAP staff. Renée designed a Pecha Kucha session on "The Future of Training", which was the hit of the conference receiving endless accolades.
- Renée participated in the LTAP Region 7 meeting while at the conference in Boise.
- Renée also attended a Road Safety Scan in Minnesota, sponsored by FHWA. Representatives from CDOT Safety & Data, FHWA Division Office, and LTAP participated in this Safety Scan hosted by the Minnesota DOT.
- At this National LTAP conference, Renée was voted in as the new NLTAPA *President* for 2013-2014. As President of the Association, Renée coordinated the NLTAPA Officer's Retreat and Fall Executive Committee Meeting held at FHWA TPP headquarters in Arlington. Travel began on September 30 but the Oct 1-3 meeting will be reported on in the next Quarter report. Travel for this meeting was reimbursed by NLTAPA.

C.1 Safety 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. One of the significant meetings Colorado LTAP participated in this quarter was the FHWA Road Safety Scan in Minnesota along with CDOT and FHWA.

C.2 Infrastructure Management

- In September, most of the work in this focus area was related to flood recovery efforts and resource development. A webpage of flood related resources was developed and also emailed out to local agencies on the LTAP mailing list. The resources were much appreciated.
- Renée also attended CDOT's Flood Recovery meeting in Boulder County.
- Renée is developing a Flood Recovery presentation to be presented at the National LTAP meeting during TRB in January.
- LTAP staff participated in FHWA's Sign Inventory Management webinar.
- The one LTAP training offered this quarter, *Winter Maintenance and Snow Removal*, was in this focus area.

C.3 Workforce Development

- Agency best practice projects were collected for the "You Show Us" contest entries were collected from local agencies. The 5 submissions received this year were provided to the LTAP Advisory Board for selection of the state winner. The *Pipe Puller* submitted by City of Cañon City was selected as the State winner and their project was submitted to compete in the Regional "You Show Us" contest. The regional winner and state awards will be announced at the Local Roads Conference in South Dakota in October. Colorado LTAP will sponsor a representative from Cañon City to attend the conference and receive their Award.
- Registration brochures were designed, printed and distributed for the LTAP Region 7 *Local Road Coordinators Conference* in Rapid City, SD.
- 5 training courses previously scheduled for this quarter had to be rescheduled due to flooding events, and loss of an instructor. Additional training programs for the fall Roads Scholar II program were also under development.
- LTAP staff participated in the agenda planning meeting for the CARMA Winter Workshop.

C.4 Operational Excellence

- The Colorado LTAP Advisory Board scheduled for September had to be cancelled due to lack of attending members. The next meeting will be in December.
- Colorado LTAP staff held one monthly meeting this quarter with FHWA, CDOT and CU managers in August. The group discussed National LTAP conference, Region 7 Meeting, status of upcoming classes, MN Road Safety Scan, CDOT SHSP planning, Safety Circuit Rider program, CDOT MAP-21 Asset Management plan update, and ADA Curb cut requirements.
- Renée participated in FHWA's LTAP *Strategic Planning Committee* meeting in July. It was a 2-day virtual meeting.
- A total of $1,718.49 was spent in the *Operational Excellence* category.
  - Information Technology Services expenses covered phone service and web design.
  - Equipment expenses this quarter included the lease and meter readings of the office copier/printer, and updated computer software programs.
  - Additional expenses in this category were for Office Supplies and annual NLTAPA dues.

Financial Report

- Total program expenses for July 1, 2013 – September 30, 2013 are included in Appendix B. The attached itemized categories list shows a balance of ($4,113.88). Class registration fees have not yet started to come in, and CU has not deposited their matching funds.

Appendix A: Profile Training Hours July 1, 2013 – September 30, 2013

Class Name	Location	Date	Hrs/class	# Part.	NS	WL	CAN	Tot. Part. Hours
ROADS SCHOLAR CORE COURSES								
RS CORE: Drainage								
	Castle Rock	10/22/13	7					0
	Brighton	10/24/13	7					0
	Grand Junction	10/28/13	7					0
	Durango	10/31/13	7					0
RS CORE: Safety on the Job								
	Durango	10/8/13	7					0
	Rifle	10/10/13	7					0
	Brighton	11/7/13	7					0
	Coloraod Springs	11/20/13	7					0
ROADS SCHOLAR I ELECTIVE COURSES								
RS ELECTIVE: Winter Maintenance nd Snow Removal								
96.15%	Durango	9/18/13	7	14	2			98
	Grand Junction	10/3/13	7					0
	Northglenn	10/7/13	7					0
RS ELECTIVE: Intro to Surveying, Grade Checking, & Staking								
	Loveland	10/7/13	7					0
	Colorado Springs	10/8/13	7					0
	Montrose	10/17/13	7					0
RS ELECTIVE: Basic Math								
	Grand Junction	11/13/13	7					0
	Aurora	11/18/13	7					0
RS ELECTIVE: Advanced Math								
	Grand Junction	11/14/13	7					0
	Aurora	11/19/13	7					0
ROADS SCHOLAR II COURSES								
RS II: Evironmental Focus Area								
	Lakewood	10/16/13	7					0
	Pueblo	10/22/13	7					0
	Montrose	10/24/13	7					0
RS II: Transportation Management Focus Area								
	Preparing for Winter by Planning for Winter							
	Glenwod Springs (rescheduled)	11/18/13	7					0
	Loveland (rescheduled)	11/20/13	7					0
	Colorado Springs (rescheduled)	11/21/13	7					0
RS II: Safety Focus Area								
	Developing Local Road Safety Plans							
	Silverthorne	11/4/13	7					0
	Colorado Springs	12/3/13	7					0
	Grand Junction	11/17/13	7					0
RS II: Technical Skills Focus Area								
	Advanced Equipment Maintenance and Inspection							
	Grand Junction	12/9/13	7					0
	Denver	12/11/13	7					0
SUPERVISORY SKILLS & DEVELOPMENT PROGRAM								
SSDP: Ethics for Supervisors								
	Grand Junction	12/5/13	7					0
SSDP: So You're a Supervisor Now								
	Westminster (rescheduled)	11/12/13	7					0
SSDP: Successful Employees Make Successful Supervisors								
	Westminster (rescheduled)	11/13/13	7					0
SSDP: The Do's and Don'ts: Legal and Liability Issues								
	Glenwood Springs	11/21/13	7					0
SSDP: A Whole New World: Nuts & Bolts of Local Government								
	Grand Junction	11/5/13	7					0
96.15%	**Total Spring 2013 Participants:**			**14**				
Evaluations	Total **RS I** Participants:			14				98
	Total **RS II** Participants			0				0
	Total **SSDP** Participants:			0				0
	Total **Workshop** Participants:			0				0
				Total Participant Hours:				**98**

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

Itemized Categories - Last quarter
7/1/2013 through 9/30/2013

	Memo	Tag	Amount
INCOME			**58,857.97**
1. SPONSOR REIMBURSEMENTS			**58,857.97**
a. CDOT Reimbursement			**52,500.00**
July 13			17,500.00
August 13			17,500.00
September 13			17,500.00
c. Class Registration Fees			**6,357.97**
c1. Deposits			**6,475.00**
Credit Cards (6) (49624)			1,550.00
Checks (20) (49624)			4,925.00
c2. Credit Card Charges			**-117.03**
June'13 ($1910) (49624)			-63.07
July'13 ($0) Fees Charged (49624)			-16.12
August'13 ($1550) (49624)			-37.84
EXPENSES			**-62,971.85**
A. PROGRAM ADMINISTRATION			**-52,851.50**
A1. Administration Costs			**-43,057.65**
A2. Program Administration Fee			**-9,793.85**
B. TRAINING PROGRAM			**-5,367.65**
B1.1 Training			**-5,367.65**
a. Roads Scholar			**-3,582.33**
b. Supervisory Skills			**-1,445.09**
Other B. TRAINING PROGRAM:B1.1 Training			**-340.23**
C.0 GENERAL			**-2,455.33**
C0.2 Library Services			**-165.32**
C0.3 Prog Marketing Outreach Research			**-1,054.53**
C0.4 Out-of-State Travel			**-1,235.48**
3.National LTAP Meeting			**-1,235.48**
C.3 WORKFORCE DEVELOPMENT			**-578.88**
C3.2 Local Roads Conference			**-578.88**
C.4 OPERATIONAL EXCELLENCE			**-1,718.49**
C4.1 Information Technology Services			**-179.37**
C4.2 Equipment			**-796.58**
C4.3 Office Supplies			**-242.54**
C4.7 NLTAPA Dues			**-500.00**
		OVERALL TOTAL	**-4,113.88**

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of Estimation Methodology for Bicycle and Pedestrian Volumes Based on Existing Counts
Study No: 8.41

Background

In 2009, the Colorado Department of Transportation adopted the Bicycle and Pedestrian Policy directive stating that "...the needs of bicyclists and pedestrians shall be included in the planning, design, and operation of transportation facilities, as a matter of routine..." (CDOT 2009). However, without sufficiently accurate estimates of bicycle and pedestrian volume on CDOT facilities, whether or not these road users are being adequately accommodated remains unknown. Consequently, this research project will help establish methods that will facilitate improved use of existing bicycle and pedestrian data through the development of Colorado-specific methodologies for estimating bicycle and pedestrian volumes using a limited sample of existing counts. More specifically, the research proposed herein will:

- Survey the state-of-the-practice literature for bicycle and pedestrian volume estimation;
- Contact local, state, and national agencies working with bicycle and pedestrian count data;
- Collect and evaluate existing bicycle and pedestrian count data from around the state of Colorado;
- Overlay and compare variations in bicycle and pedestrian volumes to variations for motorized traffic volumes;
- Develop and validate bicycle and pedestrian volume models based upon direction of travel, hourly peaking, seasonality, weather, and special events;
- Document standard bicycle and pedestrian statistical estimation methods in a procedures report for CDOT facilities; and
- Nationally disseminate findings in peer-reviewed journal papers and presentations at key conferences.

This work will enable CDOT to better understand the needs of bicyclists and pedestrians and best allocate limited resources in order to properly meet those needs. Local and regional agencies will also benefit from this research via data usage as well as access to the procedures and methodologies. An ancillary benefit from the dissemination of this research is national recognition and highlighting CDOT as a leader in managing and estimating annual bicycle and pedestrian work using statistically-based methods. The primary deliverables from this research to CDOT will be a final report and presentations that cover all study findings and recommendations.

Reporting Period: 7/1/13 - 9/30/13
Type: SP&R Start: 11/16/11

Principal Investigator(s):
Wesley E. Marshall; University of Colorado Denver, 303-352-3741

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

Study Panel Members:
Jake Kononov, CDOT DTD Research
Betsy Jacobsen, Bicycle Pedestrian Unit
Mehdi Baziar, Mobility Analysis Manager
Steven Abeyta, Traffic Analysis Unit
Leo Livecchi, Traffic Analysis Unit

SIGNIFICANT EVENTS

Final report has been published:
http://www.coloradodot.info/programs/research/pdfs/2013/bikecounts.pdf/view
This will be the last quarterly report for this project

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Optimum Use of CDOT French and Hamburg Data
Study No: 10.15

Background

The Euro Lab has been used by CDOT for asphalt performance testing on asphalt projects for over ten years now. The Materials Lab produces reliable and valuable test results that are indicative of the expected pavement performance over the life of the pavement. A number of transportation departments and organizations are using results from the Hamburg and French pavement performance testing machines for project acceptance testing, as well as for incentive/disincentive payments. The CDOT European Test Lab is a robust lab, with experienced testers, and valuable equipment. The potential inclusion of the European test results into the acceptance criteria for projects could provide CDOT with improved pavement performance prediction capabilities, increased pavement performance, and improved system quality/reliability.

The objective of this study is to analyze data collected over the years and develop a proposed roadmap for inclusion of the French and Hamburg test results in QA/QC on asphalt projects. This roadmap would be used to assist CDOT in determining the viability and cost-effectiveness on using such tests as part of performance-based specifications for asphalt paving acceptance and payment.

Reporting Period: 7/1/13 - 09/30/2013
Type: SP&R Start: 4/18/13 End: 10/17/13

Principal Investigators: Kim Gilbert, JilBehr Engineering Services

Study Manager: TBD

Study Panel Leader:
Mike Stanford, Materials and Geotechnical Br.
303-398-6576

Study Panel Members:

Stephen Henry, Materials and Geotechnical Br.
Shamshad Hussain, Region 1 Materials
Donna Harmelink, FHWA-Colorado Division
720-963-3021

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
04/30/13	100	4/18/13	Start project: A purchase order was issued based on proposal receive from Kim Gilbert.
04/30/13	100	4/26/13	Kickoff Meeting: The PI met with Mike Sanford and Bill Schiebel to discuss available data and study approach.
08/31/13	100	8/15/13	Analyze data form Region 2 project. HQ lab did not run the tests needed for the analyzation to be done. Drop the hours.
07/31/13	100	8/15/13	Survey and interview Engineers from various states
09/14/13	100	8/23/13	Submit draft final report
09/30//13	99?	7/31/13	Conduct presentation of completed work to CDOT: Presented all information except two interviews to Mike Stanford and Ed Trujillo.
10/15/13	99?	9/27/13	Submit final report. Awaiting direction to add, or not, to scope.

SIGNIFICANT EVENTS

9/15/13 The end date of the PO was changed to 12/31/13 to allow more time for panel to review the reports.

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

4/26/13 At meeting with Bill Schiebel and Mike Stanford, the project was altered to better

reflect CDOT's current needs.

7/31/13 Presented all information except two interviews to Mike Stanford and Ed Trujillo of CDOT.

8/23/13 Submitted draft report.

9/27/13 Submitted what may be the final report. Awaiting information from CDOT about whether to include some Fed comments in final report.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Durable Wearing Surfaces for HMA
Study No: 10.37

Background The Colorado Department of Transportation spends a large sum of money each year on the design and placement of new asphalt pavements. Inevitably, these pavements will need rehabilitation. Wearing surfaces provide an alternative to CDOT's current rehabilitation strategies. A pavement design system incorporating wearing surfaces will both protect the existing pavement structure and provide a quality overlay system for all pavements. A durable wearing surface is essential for preserving CDOT's investment in its paving program. The wearing surfaces will be evaluated on an annual basis at eleven sites: Five SMA sites, three Nova chip sites and three SHRP SuperPave SX sites. The test sites will have their ruts measured, cracks mapped, general condition visually evaluated and the skid number and texture depth measured using the CDOT Pavement Friction Test System (skid truck and trailer).	Reporting Period: 7/1/13 - 9/30/13 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

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

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Participation in Southeastern Superpave Center (Pooled Fund)
Study No. 10.40

Background

Pooled fund study TPF-5(228)
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 : 7/1/13 - 9/30/13
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.

SIGNIFICANT EVENTS

01/31/13 The Study Manager, Roberto DeDios, retired from CDOT in January 2013

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13 Type: SP&R Start: 11/1/12 End: 12/01/13 Principal Investigator: David Peshkin, Applied Pavement Technology, Inc. Study Manager: TBD Study Panel Members: Phillip Anderle, R-4 Maintenance Donna Harmelink, CO Div. FHWA Frank McCoy, R-6 Maintenance Mark Mueller, 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	?	?	Task 2 Draft guidelines; originally scheduled for 7/15/13; propose changing to 8/31/13
8/31/13	?	?	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
10/15/13			Task 2 Final guidelines
10/15/13			Task 3 Final procedures
10/31/13			Presentation

SIGNIFICANT EVENTS

11/4/13 As of this date, the PI has not provided a progress report for the quarter ending 9/30/13.
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.
7/1/12 Funds for this project became available.

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: 7/1/13 - 9/30/13
Type: SP&R Start: 10/5/12 End: 12/31/15

Principal Investigator:
Scott Shuler, CSU, PO: 211017352

Study Manager:
Temporarily Rich Griffin, Research Branch, 303-757-9975

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	75		Task 1 – Initial Crack Locations: Initial and followup crack maps for the Alamosa site has been obtained from Region 5. The I-70 and US-85crack maps have yet to be obtained from CDOT Regions.
9/30/13			Task 2 – 2013 Reflection Crack Performance, data collection was scheduled on I-70 but had to be postponed due to a snowstorm.
9/30/14			Task 2 – 2014 Reflection Crack Performance
9/30/15			Task 2 – 2015 Reflection Crack Performance
10/31/15			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

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	Reporting Period: 7/1/13 - 9/30/13 Type: SP&R Start: 07/16/13 End: 07/16/16 Principal Investigator: Scott Shuler, CSU: PO 211019397 Study Manager: Aziz Khan, Research Branch, 303-757- Study Panel Members: (Tentative) Bill Schiebel Michael Stanford Donna Harmelink, CO. Div. of FHWA
A bump, and often transverse cracks, occurs in an overlay of hot mix asphalt when placed over crack sealant in the underlying substrate pavement. The cause of this phenomenon is largely unknown. However, recent research by the author for CDOT and Jefferson County, CO suggests some factors which may relate to the formation of bumps and some which do not appear to relate. The factors which seem to exacerbate the formation of bumps include: 1) the temperature of the overlay mixture, 2) the pavement grade, 3) 'overbanded' crack sealant, 4) vibratory breakdown compaction, and 5) number of passes of the breakdown roller. Factors which do not appear to contribute to bump formation or are less significant include: 1) crack sealant type, 2) crack sealant application geometry, 3) substrate pavement temperature, 4) pneumatic breakdown compaction, and 5) age of crack sealant. One factor which seemed to be significant, but was not evaluated in a controlled manner during the research for Jefferson County, CO, was the size of the 'bow wave' which occurs immediately ahead of the drum during breakdown rolling. The size of this 'bow wave' is affected by the temperature of the mixture, pavement grade and vibration.	

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
9/30/13	85		Task 1 – Literature Review
07/31/14	30		Task 2 – Identify Test Site(s)
07/31/15	30		Task 3 – Install Test Sections
07/31/16	20		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

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.

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: 7/1/13 - 9/30/13 Start: TBD Contract Amount: $ 70,000 Principal Investigator: Ken A. MacKenzie, P.E., CFM Master Planning Program Manager Urban Drainage and Flood Control District Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Mommandi, Amanullah, CDOT Hydraulics Program Manager Study Panel Members: Bob McDade, CDOT EPB Mike Banovich, CDOT EPB Bob Mero, R6 Materials Bill Schiebel, Staff Materials and Geotech Branch

MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
7/15/12	100%	7/18/12	Select study panel
7/31/12	100%	8/27/12	Finalize scope of work that will be attached to the IGA.
11/1/12	100%	12/11/12	Establish Location of Test Sections: CDOT and UDFCD agreed to place two test sections in the Maintenance Yard at 5701 Federal Blvd.
1/31/13	100%	1/31/13	Execute an intergovernmental agreement (IGA) with the Urban Drainage and Flood Control District: A work agreement was sent to the purchasing staff responsible for intergovernmental agreements.
2/25/13	100%	2/25/13	Reject Maintenance Yard at 5701 Federal Blvd. due to site problems; establish new location at CDOT maintenance shed located at 6050 Wadsworth Blvd.
2/28/13	90%		Design Test Sections
6/30/13			Build Test Sections
7/15/13			Begin Monitoring test sections
7/31/13			Initial Falling Weight Deflectometer (FWD) test
7/15/15			Monitoring concludes
7/31/15			Final FWD test

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Investigation of the Benefits from Utilizing Small Aggregates for Seals on Hot Mix Asphalt (HMA) Roadways
Study No: 12.72

Background

Many existing highways in Colorado are far from ideal HMA aggregate sources. Often due to the high cost of aggregate transportation to these areas, highway pavements are not timely preserved. An additional maintenance or rehabilitation treatment for HMA pavements is needed to help preserve deteriorating roadway structures until funding is secured for traditional resurfacing projects. Several river basins in Colorado exist that may provide aggregates that with minimal processing may extend the serviceable roadway life in a value-added analysis.

The Nebraska Department of Roads (NDOR) has developed specifications for an aggregate application referred to in NDOR context as "**Armor Coat**." The application is a generic term which generally refers to an emulsion-aggregate combination with aggregate derived from river sources such as the North or South Platte River. It is commonly applied by NDOR maintenance personnel utilizing standard "chip seal" equipment. The aggregate size is generally 3/8 inch.

Reporting Period: 7/1/13 - 9/30/13
Type: SP&R Start: 03/30/09

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

Technical Panel Leader:
Gary DeWitt, CDOT R-4 Materials
970-350-2379

Study Panel Members:
Masoud Ghaeli, CDOT R-6 Materials
Rex Goodrich, CDOT R-3 Materials
Donna Harmelink, FHWA Colorado Division
Stephen Henry, CDOT Materials and Geotechnical Branch
Gary Strome, CDOT R-4 Materials

Research Study Manager:
Temporary: Rich Griffin, CDOT-DTD Research
303-757 9975 richard.griffin@state.co.us

SIGNIFICANT EVENTS

Final report has been published: http://www.coloradodot.info/programs/research/pdfs/2013/aggregates.pdf/view
This will be the last progress report for this study.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Asphalt Emulsion Full Depth Reclamation Best Practices
Study No: 12.75

Background	Reporting Period: 7/1/13 - 9/30/13 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: TBD 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 and Presentation

SIGNIFICANT EVENTS

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

In-Place Void Follow-up
Study No. 12.92

Background

With a perfect mix design methodology, the in-place voids should match the design voids after a certain length of time. Data from a recently completed study indicated that pavements in Colorado achieve final densification under traffic within the first three years. However, the in-place voids at three years average 1.2% higher than one would expect based on the design voids. This indicates that these projects were designed at too high of compactive effort and resulted in stiffer mixes.

This study recommended two options for adjusting mix designs for Colorado. The first option was to lower the compactive effort during the mix design process. The second was to adjust the target mix design air void content. The first option was undesirable as the required change in compaction effort to achieve the difference in voids would be quite large.

Implementation of the second option has already begun, and will change constructed air voids while maintaining historic design void requirements and ensure that additional asphalt cement is used to fill mix voids. Recommendations to change the air voids target on the Job Mix Formula (Form 43) at 0.6% lower voids will decrease field voids by 0.6%, half the difference shown by the study. The change will result in more asphalt in the field-produced hot-mix asphalt.

Even though this change is felt to be a step in the right direction additional research is needed to track these changes to ensure the desired outcome is achieved.

Reporting Period: 7/1/13 - 9/30/13
Type: SP&R Start:7/03 Ver:

Principal Investigator(s):
Research Branch Personnel

Dave Weld, Field Coordinator/Support
CDOT Research Branch
303-512-4052

Study Manager: TBD

Study Panel Members:
Mike Stanford, Mat. & Geotech Branch
303-398-6576
Bill Schiebel, Mat. & Geotech Branch
303-398-6504
Donna Harmelink, FHWA Colorado Division
720-963-3021

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/03	100	7/03	Identify the projects for evaluation. 17 sites were selected for evaluation in 2003. The remaining sites to complete the environmental and temperature matrix will be established next year during construction.
9/03	100	10/03	Monitor 2003 construction
5/04	100	7/04	Additional sites to complete the environmental and temperature matrix were identified: SH385 near Holyoke and SH135 at Almont.
9/04	100	8/31/04	Monitor 2004 construction projects: Holyoke done in June and Almont done in August.
9/04	100	3/31/05	Collect cores for first year evaluation.
11/04	100	11/24/05	Laboratory testing of Cores
9/05	100	10/1/05	Collect cores for second year evaluation, complete void testing in laboratory
11/05	100	05/06	Laboratory testing of Cores
9/06	100	11/06	Collect cores for final evaluation, 15 of 19 sites have been cored and evaluated

7/31/07	100	6/30/07	Complete testing of Cores
7/31/13	70		Determine how to move forward on this study: A meeting was held to determine how to move forward on this study. It was decided to first assemble the project data and then determine who can analyze it and produce a report. Core test results for all projects have been found. Form 43s (Final job mix) for all but one project have been found.
8/31/13		9/30/13	Get mix designs: Region Materials Engineers have been asked for mix designs: About half of the mix designs were obtained and it was decided that they probably wouldn't after so many years.
8/31/13	70		Region Materials offices were ask for roadway condition data for each of the test sections. Four of the six regions provide the information
10/18/13		10/18/13	Met with Kim Gilbert regarding interpretation of the data. It was decide that when the design voids were not available, 4% would be assumed because it is the goal of all mix designs. In-place voids reaching 3 to 5 % within the first few years should be regarded as a good mix as far as voids are concerned. She suggested making the report an update of Donna Harmelink's 2007 report.
10/31/13	30		In-place void graphs versus time have been prepared for each paving project and a table of other relevant data was pasted below each graph.
11/30/13			Publish final report

SIGNIFICANT EVENTS

3/31/13 The two principals of this study are no longer available either as consultant or employees to write a final report for this study. ARIB will meet with the Materials and Geotechnical Branch to determine how to proceed.

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

5/31/12 Research staff met with FHWA to decide what to do with this inactive project. FHWA personnel suggested bringing this issue to the Materials Advisory Committee for final disposition. Some test results are missing and need to be recovered or reconstructed. It was decided that a final report will be prepared for this research project. A consultant will be hired to analyze data and prepare the final report.

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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: 7/1/13 - 9/30/13 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: Richard Griffin, Research Branch, 303-757-9975 Study Panel Members: (Tentative) Gary DeWitt, R-4 Materials, 970-350-2379 Shamshad Hussain, R1Materials, 303-398-6802 Steven Henry, Mat. and Geotech Branch, 303-398-6579 Mike Stanford, Mat. and Geotech Branch, 303-398-6576 Donna Harmelink, CO. Div. of FHWA

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
8/31/12	100	9/5/12	Hold initial study panel meeting.
9/15/12	100	9/7/12	Develop scope of work
9/30/12	100	9/7/12	Issue RFP: issued to Colorado public universities, proposals are due 10/8/12
11/07/12	100	11/5/12	Select researcher: Scott Shuler with CSU was selected to perform the research
12/7/12	100	11/28/12	Notice to Proceed
4/1/13	75		Task 1-Reviews
9/1/13	20		Task 2-Field Survey
12/7/14	25		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

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

Internal Curing of HPC Using Techniques Other Than Light-Weight Aggregate
(Internal Curing of HPC)
Study No: 22.60

Background

Through extensive laboratory testing, this research effort is expected to produce information that can be useful in the potential use of internal curing (IC) for the CDOT's high performance concrete (HPC). Improvements expected include resistance to shrinkage and premature cracking, and low permeability.

Traditionally, concrete cures by using water already free in the mixture or by drawing water from the surface. For traditional concrete adequate curing can be achieved by maintaining moisture on the surface. However HPC, with its low water-cement ratio, has little excess water. In addition the low permeability of HSC quickly blocks surface water from permeating into the concrete for curing. The primary manifestations of inadequate water for curing are impeded hydration, shrinkage, and premature cracking.

Internal curing (IC) is the process of placing water throughout the structure fo the concrete, so it is available later for curing without altering the pore structure of the paste. Special admixtures, super adsorbent polymers (SAP), natural fibers, and light weight aggregate (LWA) all have the ability to retain water and release it as the curing process demands it.

The use of LWA has been the primary approach for IC. However concerns regarding LWA impacting performance and problems with displacing LWA uniformly through the mix, have limited its use.

Project Goal

It is anticipated that at the completion of the project the Colorado Department of Transportation will have: 1) mixture proportions for a high performance concrete that is internally cured that is ready for use in a field application, 2) data indicating the differences in freeze-thaw performance that may be expected from concrete where fine and coarse aggregate is replaced with lightweight aggregate, and 3) resources that can be used to share these findings with contractors, other department of transportation personnel or the executive staff.

Project Scope

This scope of this study is to investigate, through extensive laboratory testing, the freeze-thaw performance of internally cured high performance concrete for use by the Colorado Department of Transportation. In particular, this study will evaluate a series of internally cured high performance concrete mixtures for the Colorado Department of Transportation that meet the specifications of a Class H concrete. The goal of this study is to address concerns regarding the use of lightweight aggregate for internal curing and the impact of this lightweight aggregate on the freeze-thaw performance. Specifically this study will be divided into two portions. The first portion of the work will investigate the freeze-thaw response of a typical class H concrete mixture and a typical class H mixture where a portion of the fine aggregate and coarse aggregate are replaced with lightweight aggregate. The second portion of the work will investigate the freeze-thaw behavior of a typical class H concrete mixture using the other two aggregates (those not

Reporting Period: 07/01/13 through 09/30/13
Type: SP&R Start: 11/8/12 End: 12/31/13

Principal Investigators:
Jason Weiss, Purdue University
PO: 211017650
765-494-2215

Study Manager:
Aziz Khan
Research Branch
(303) 757-9522

Study Panel Members: (Tentative)
Gary Dewitt
Region 4 Materials
970-506-0359

Eric Prieve
Mat. And Geotech Branch
303-398-6542

Matt Greer,
CO div. of FHWA
720-963-3008

Patrick Kropp
Mat. And Geotech Branch,
303-398-6541

Mike Mohseni
CDOT Bridge
303-512-4300

used in the first portion) that are available in Colorado. In addition, the second phase of the research will also work on developing/evaluating an internally cured concrete that meets the class D specification. In addition to simply performing the experimental evaluation the research team will work closely with the Colorado Department of Transportation to describe the principles that make these mixtures resistant to freezing and thawing so that specifications can be developed for durable, long-lasting internally cured concrete.implementation of additional systems on other State Highways.	

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/31/12	100	7/31/12	Hold initial study panel meeting.
8/15/12	100	8/29/12	Develop scope of work
8/30/12	100	8/29/12	Issue RFP to selected researchers from public univerisities: proposals are due 10/1/12
10/23/12	100	10/23/12	Select researcher: The panel reviewed 4 proposal and selected Dr. Jason Weiss of Purdue University to conduct the research.
11/30/12	100	11/8/12	Start Project
12/08/12	100	2/14/13	Task 1 Mixture Proportioning
12/30/12	100	6/25/13	Task 2 Material Collection and Shipping
4/1/13	100	9/25/13	Task 3 Evaluation of Preliminary Mixtures
8/15/13	95		Task 4 Evaluation of Optimized Internally Cured Mixtures
8/31/13	95		Task 5 Draft Final Report
11/1/13	50		Final Report

SIGNIFICANT EVENTS

7/02/12 Funds are now available for this project
11/8/12 Begin Project with CDOT providing a contract to Purdue University
12/5/12 Project SAC Meeting – This meeting was held Go to Meeting (slides and minues in dropbox account)
2/19/13 Casting for freeze-thaw and scaling mixtures completed from the preliminary mixtures
3/22/13 Cast remaining samples from preliminary mixtures complete
5/7/13 Project SAC Meeting - This meeting was held Go to Meeting (slides and minues in dropbox account)
5/14/13 Casting for freeze-thaw and scaling mixtures completed from the optimized mixtures
6/28/13 Received final shipment of project material
7/31/13 Fresh, mechanical , and freeze-thaw related testing completed for all mixtures
8/17/13 All mixtures completed 91 day curing and began conditioning for transport and sorption testing
9/25/13 Completeion of shrinkage testing on preliminary mixtures

ANTICIPATED EVENTS FOR Q4 2013 (Project Q5)

- Completion of remaining dual ring (2) and autogenous shrinkage (2) optimized mixtures
- Analysis of ionic transport properties for all mixtures
- Completion of sorption testing
- Delivery of draft final report and final report
- Discuss final presentation of research

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Recycled Tires as Coarse Aggregate in Concrete Pavement Mixtures
Study No: 22.65

<u>Background</u>

Colorado has about 45 million tires stored, roughly one-third of the stockpiled tires in the country. In addition, the number of tires stockpiled in Colorado is rising every year. In the early 1990s, recycled waste tire particles' usage expanded into a relatively new product called rubberized. Rubberized concrete uses portland cement as its binder. Research has shown that rubberized concrete has a very positive outlook for inception into selected markets such as pavement applications. With waste tires having a specific gravity of approximately 1.1, compared to 2.6 or greater for virgin aggregates, a legal 80,000-pound gross weight tractor-trailer delivering recycled "tire chips" (0.2 in-1.5 in) would provide 2 to 2-1/2 times the volume of virgin coarse aggregate for concrete pavement per delivery. The results are cost savings and reduction in carbon footprint.

A recent research study conducted by the University of Colorado at Denver (UCD) for the Colorado Department of Public Health and Environment indicated the feasibility of using commercially processed crumb rubber as a partial replacement for the fine aggregate in CDOT Class P paving concrete mixes. Volumetric portions ranging from 10 to 50% replacements of sand were tested for fresh and hardened concrete properties. From the five replacement values, the 20 and 30% replacement mixtures performed adequately to fulfill CDOT Class P concrete requirements. The recycled waste tire particles did not exhibit any type of unusual rate of strength gain behaviors with the different replacement quantities. The leaching tests (TCLP) were performed to examine the environmental sustainability of the rubberized concrete mixtures. According to these tests performed, this material would pose no threat to human health.

The price of one ton well-processed crumb rubber is $300~$400. It seems it is very expensive to replace fine virgin aggregates that are readily available in Eastern Colorado. A more economical alternative exists if recycled tire chips are used to supplement/replace the coarse aggregate. Costs associated with crushing, shredding and screening materials, including tires, to ever smaller sizes progressively increase. The less effort required to create a product, the less its associated costs will be.

This proposed research will examine the reuse potential of tire chips as coarse aggregate in paving concrete mixes. The proposed use of recycled tires would replace the more expensive virgin coarse aggregate on the eastern plain of Colorado.

Reporting Period: 7/1/13 - 9/30/13
Type: SP&R Start: 10/11/12

Principal Investigator(s): Dr. Rui Liu
University of Colorado-Denver
303-556-5270
Research Study Manager:
Aziz Khan CDOT-DTD Research
303-757-9522
Technical Panel Leader:
Eric Prieve, CDOT Materials and Geotechnical
Branch 303-398-6542

Study Panel Members:
Patrick Kropp, CDOT Materials and Geotechnical Branch
Bob Mero, CDOT Region 6

Final report has been published:
http://www.coloradodot.info/programs/research/pdfs/2013/rubberconcrete.pdf/view
This will be the last quarterly report for this study

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Evaluation of Soil Resources for Sustained Vegetative Cover of Cut and Fill Slopes along I-70 near Straight Creek
Study No: 30.02

Background	Reporting Period: 7/1/13 - 9/30/13 Start: 9/13/07 Complete: 7/31/13 Principal Investigator(s): Vic Claassen, University of California Davis Study Manager: Bryan Roeder, CDOT-DTD Research 303-512-4420 Study Panel Leader: Mike Banovich, CDOT-DTD EPB 303-757-9542 Study Panel Members: Jennifer Klaetsch, CDOT-DTD EPB 303-757-9481 Allan Hotchkiss, CDOT Materials and Geotechnical Branch 303-398-6587 Amanullah Mommandi, CDOT Staff Hydraulics 303-757-9044
Severe weather and erosion on steep slopes can destroy revegetation plots testing tackifiers, fertilizers and mulches along any highways. Several reapplications of seed and fertilizer may be needed before vegetation is reestablished using standard CDOT methods and materials. The longevity of these amendments and the sustainability of the vegetative cover are not known. Adequate plant cover is critical for erosion control on these steep and sandy sites. The objectives of this research initiative are: to evaluate the moisture and nutrient characteristics of revegetated soils along wall embankments, fill slopes and cut slopes along I-70 near Straight Creek; and to compare these values with those of native, undisturbed sites (topsoil retained) and barren slopes with inadequate plant growth. This data will verify the current ability of the sites to support vegetation and it will help evaluate the ability of the soils to continue to support adequate vegetative cover in the long term. The anticipated product will include construction and maintenance specifications that promote long-term sustainability of the vegetative cover and provide guidelines to modify specifications as needed to encourage growth of sustainable vegetative cover for steep and sandy sites. The developed specifications should be applicable to control erosion on steep and sandy sites anywhere in the nation.	

SIGNIFICANT EVENTS

Final report has been published:
http://www.coloradodot.info/programs/research/pdfs/2013/cutslopes.pdf/view
This will be the last quarterly report for this project

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: 7/1/13 - 9/30/13
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 Q3 2013

- 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 The highway right-of-way provides the opportunity for the development of solar power systems across the state. However, this is only feasible if it can be done in a manner that does not interfere with the operation and maintenance of the highway system and does not create an unacceptable risk to transportation system users. Two reports will be produced, addressing general (not necessarily site specific), potential impacts from solar array installation and operation. The first report should identify visual and other potential impacts to highway user safety, evaluate the probability for these impacts to occur and recommended criteria for minimization or control of any impacts that have a high probability of occurring, or carry very high risk even if probability appears low. The second report will focus on the potential for solar arrays to affect on-going maintenance and operation activities.	Reporting Period: 7/1/13 - 9/30/13 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 Members: Sasan Delshad, CDOT Region 2 Traffic and Safety Mike Delong, CDOT Region 1 Maintenance and Operations Jim Eussen, CDOT Region 1 Environmental Sarah Mitchell, CDOT Environmental Programs Branch Dave Ruble, CDOT Region 1 Utility Engineer Rick Santos, Colorado Div. of FHWA

MILESTONES/TASKS

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
11/1/12	done	11/1/12	Notice to Proceed
11/6/12	done	11/16/12	Kick Off Meeting
3/1/2013	90%	09/30/2013	**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
2/30/2013	90%	09/30/2013	**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

12/30/2012	60%	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	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
9/01/2013	20%		**Task 4-Report Development: Draft Report** **Report on snow drifting**
10/30/2013			Report outline and referencing style are set Study Panel Meetings and comments
11/30/2013			CDOT Draft Reports Review (Presentation)
12/30/2013			Final User Impact Report Development/CDOT Transmittal
12/30/2013	25%	12/31/2012	**Task 5- PI Project Management (Communication)**
12/30/2013			Project Close Out
		   09/04/2013	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

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: 7/1/13 - 9/30/13
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	60%		Monitoring – 14 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 34.24

Background

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

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

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

The goal of this 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. 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: 7/1/13 - 9/30/13
Type: SP&R Start: 12/1/09

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

Research Study Manager:
Temporary: Rich Griffin, CDOT-DTD Research
303-757-9975
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	90		Task 4 – Project Status Reporting
6/30/14	100		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

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

Innovative Noise Mitigation Design Solutions for Mountain Corridors
Study No: 34.28

Background Noise impacts from high-volume roads in mountain corridors have increased significantly as truck and car volumes and residential development increase. Compounding the problem because of the terrain, mitigation of noise impacts is particularly challenging. The I-70 Mountain Corridor Programmatic Environmental Impact Statement (PEIS) (Final published March 2011) has identified highway segments in need of safety and capacity improvements and has delineated general areas of traffic noise concern. Traffic noise has alienated local communities and has resulted in significant project delays and associated costs for CDOT. This study will research and identify noise mitigation technologies from high-volume traffic areas of difficult terrain within sensitive noise environments. The researchers will develop recommended abatement measures and identify innovative materials, acoustical designs or retrofits. The final report will include theoretical noise abatement designs and modeling documentation for required mitigation solutions that reduce community noise levels measurably over conventional barriers. The recommended designs and construction materials shall include a discussion of context sensitive abatement measure installation where terrain is difficult and social costs are high.	Reporting Period: 7/1/13 - 9/30/13 Start:8/8/12 Contract Amount: $57,040 End: 7/31/13 Principal Investigator: Dale Tischmak, Felsburg Holt & Ullevig Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Jill Schlaefer, CDOT Environmental Programs Branch (303) 757-9016 Study Panel Members: Jordan Rudel, CDOT Region 1 Environmental Robert Mero, CDOT Region 1 Materials Unit Paula Durkin, CDOT Region 3 Environmental Stephanie Gibson, FHWA Colorado Chuck Attardo, CDOT Region 1 Environmental

SIGNIFICANT EVENTS

Final report has been published:
http://www.coloradodot.info/programs/research/pdfs/2013/mountain.pdf/view
7/22/13: Final presentation to CDOT
This will be the last quarterly report for this project

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: 7/1/13 - 9/30/13
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	100		Transfer $25,000 for FY13 commitment: entered commitment on web site and sent transferred request to DTD Business office.

SIGNIFICANT EVENTS

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

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

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

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

CDOT committed the following funds in support of this project:

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Snow on LED Traffic Signals
Study No: 40.06

Background

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

The research effort encompasses the following topics:

- Literature review
- Application and testing of various superhydrophobic coatings
- Perform scaled aerodynamic testing of traffic signal in wind tunnel
- Development of laboratory cold chamber for simulated testing
- Laboratory cold chamber testing of candidate coatings
- Initial field testing of coatings
- Optimize heat transfer pathway from LED housing to lens
- Final coating selection and design modification evaluation.

It is anticipated that a final design, which minimizes snow and ice build-up, will incorporate all three proposed mitigation techniques and design elements.

Reporting Period: 7/1/13 - 9/30/13
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	09/30/13	Task 1 - Literature Review
11/15/13			Task 2 - Modification of laboratory cold chamber to simulate field conditions
11/30/13			Task 3 - Testing and analysis of superhydrophobic coatings
12/01/13			Task 4 - Initial field testing of superhydrophobic coatings
12/15/13			Task 5 - Scaled model testing of current traffic light aerodynamics
01/15/14			Task 6 - Proposed aerodynamic modifications
02/15/14			Task 7 - Proposed heat transfer pathway design concepts
02/15/14			Task 8 - Wind tunnel testing of proposed aerodynamic modifications
03/15/14			Task 9 - Heat transfer pathway design construction
03/15/14			Task 10 - Construction and testing of modified traffic light
04/30/15			CDOT Review Draft Report
06/30/15			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
- 09/30/13 - Completed literature review

ANTICIPATED WORK NEXT PERIOD

- October 2013
  - Modify laboratory cold chamber for simulated snow and ice production
  - Begin testing of various superhydrophobic coatings under laboratory conditions
- November 2013 - Perform scaled aerodynamic analysis of traffic signal in wind tunnel
- December 2013 - Begin testing of top candidates from lab results in outdoor testbed

ISSUES

- No issues

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13 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
9/10/2013	100	10/10/2013	Draft Study Plan Submitted to CDOT for Review

10/17/2013			Draft Study Plan forecasted
10/18/2013			Initiate field work (fall)
05/1/2014			Initiate field work (spring)
9/14/14			Draft Report (75 days prior to report publication)
12/1/14			Final Report publication

SIGNIFICANT EVENTS

- Continued and completed Tasks 1 and 2 literature research
- Presentation to Study Panel on Task 1 and 2 Tables of potential-short listed test variables and recommendations (7/29/2013)
- Consolidated list of R&D test variable (3 tables) into one main table
- Reviewed CDOT Study Panel Top 5 R&D test variables
- Developed table matrix of the top 12 R&D test variables
- Identified TerraLogic's top 5 R&D test variables on table matrix
- TerraLogic Team meeting discussed the top test variables for CDOT to consider and costs for the Study Panel Meeting
- Submitted Task 2 Technical Memorandum to Study Panel/CDOT Project Manager; technical memorandum summarized Tasks 1 and 2, provide implementation recommendations and critique on CDOT revegetation specifications
- Conduct two Study Panel Meetings to identify test variables for study
- CDOT identified the top three R&D studies; Salvaged Top Soil Management, Construction Revegetation QC and Forensic Revegetation Studies
- Developed and submitted Draft Research Methodology Plan to CDOT for review and comment

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Benefit-Cost Analysis of CDOT Fixed Automated Spray Technology (FAST) Systems
Study No: 42.50

Background The primary goal of the study is to determine the cost effectiveness of each of the existing FAST systems in Colorado's bridges. At the same time, the research effort aims to develop a best management and performance practices guidance document for planning, designing, constructing, operating and maintaining a cost-effective FAST system specific for Colorado's highway and bridge networks.	Reporting Period: 7/1/13 through 9/30/13 Type: SP&R Start: 11/20/12 End: 10/18/14 Principal Investigator: Xianming Shi, Ph.D., P.E.; Montana State University. Study Manager: TBD Study Panel Leader: Phillip Anderle, R-4 Maintenance Study Panel Members: Masoud Ghaeli, CDOT Region 6 Materials Stephen Henry, CDOT Staff Materials and Geotechnical Branch Aziz Khan, CDOT-DTD Research Branch Mark Mueller, CDOT Staff Maintenance and Operations Branch Skip Outcalt, CDOT-DTD Research Branch Steve Pineiro, CDOT Region 6 Maintenance Andrew Pott, CDOT Staff Bridge Design and Management Branch David Reeves, CDOT-DTD Research Branch David Wieder, CDOT Staff Maintenance and Operations Branch David Swenka, CDOT Staff Traffic and Safety Branch Matt Rickard, CDOT Intelligent Transportation System Matt Greer, FHWA, Colorado Division

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/20/12	NA	11/20/12	Contract 27000179 issued to MSU to begin study
10/18/14	30%		Task 1 Project Management and Planning of Research Activities
6/30/13	80%		Task 2: Literature review and practitioner Surveys
8/30/13	5%		Task 3: Preparation of Field Survey
4/30/14			Task 4: Data Collection
4/30/14			Task 4: Operational Testing
7/30/14			Task 4: Benefit Cost Analysis

8/18/14			Task 5: Best Management and Performance Guide/Final report & Presentation, Draft Final Report
10/18/14			Final report and presentation

SIGNIFICANT EVENTS

9/30/13 The research team continued to work on Tasks 1 and 2 (30% and 80% done by 9/30/13, respectively). The literature review is 95% complete. Two survey instruments were designed and distributed. The national survey has got excellent responses, but the CDOT survey has not yet got sufficient responses (partially due to the flooding occurred in Colorado). A field trip to Colorado was planned to occur in July and cancelled due to the flooding. We expect to wrap up the survey in Oct. and likely conduct field site visits in Nov. or Dec. 2013.

5/9/13 A kickoff meeting is scheduled for the PI to discuss the scope with the CDOT Technical Advisory Board Members, via a teleconference.

1/1/13 The research team started to work on Tasks 1 and 2

1/31/13 Roberto DeDios, the original study manager has retired from 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: 7/1/13 - 9/30/13 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%	Postponed	Status meeting – Postponed due to potential schedule issues caused by flooding and extreme damages to Hwys.– Rescheduled for October 17th.
9/30/13	0%	Postponed	Status meeting minutes submitted – To be submitted after meeting which was postponed is held
9/30/13	100	10/14/13	Quarterly project report submitted as attachment to email
12/31/13			Quarterly project report
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: 7/1/13 - 9/30/13
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	75%		Task 2 - Field Observations
4-8/2014	25%		Task 3 - Interview Operators and Maintenance Staff
5-12/2014	50%		Task 4 – Performance Evaluation
1-6/2015	0		Task 5 – Outline Recommendations

7/2015	0		Task 6 – Final Report
			Project Complete

SIGNIFICANT EVENTS

- The majority of field observations have been completed and initial operator and maintenance staff input has been collected.
- Interviews have been completed with Ohio DOT, Missouri DOT, and Gator Getter staff to gather input on experiences at other transportation agencies
- Basic performance evaluation data has been collected.

ANTICIPATED WORK NEXT PERIOD

- October and November 2013-Research team will conduct operator interviews
- December 2013 –First draft of outline recommendations will be drafted
- October- December 2013- Additional field observations and site observation by Walter Hopkins as directed by CDOT

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:** 7/1/13 - 9/30/13 **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 Date	**% done**	**Achieved Date**	**Description, Discussion, and Related Issues**
07/01/12	100	07/02/12	Notice to Proceed
03/31/13	90		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	75		Task 2 – Methodology & critical decision-making metrics
09/30/13	0		Meeting with CDOT Study Panel
01/31/14	15		Task 3 – Propose a general CDOT policy in applying concept of risk- and consequent-based analysis
06/20/14	62.5		Task 4 – quarterly reports (8 total)
05/31/14	0		Task 5 – Final Report
06/20/14	0		Task 6 – CDOT Review Draft Report; presentation of results to CDOT

SIGNIFICANT EVENTS

It is noted that the students found paid summer 2013 engineering internships, and therefore, with CDOT approval, they were not supported or involved in the project during the first two months of the current reporting period (July and August 2013). This results in a deferral of some accomplishments, but does not put the project

behind schedule for on time completion.

Objective 1

9/30/13

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

6/30/13

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

3/31/13

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

12/31/12

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

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, 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

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 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.

ANTICIPATED WORK NEXT PERIOD

Objective 1
We will continue to develop a specific methodology recommended for CDOT. The team would like to meet during this next period with the CDOT group working on the MAP-21 issues to discuss how this research can facilitate those efforts. Depending on the outcome of that meeting, it is anticipated that the methodology will be largely completed in the next period, and then refined in the period after that.

Objective 2
The structural analysis studies of the mast arms will be conducted in this next period, along with the mast arm risk guidelines that will be developed from these runs.

For the second illustrative example, we 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.

The following two graphics were presented in the last quarterly report. They provided an overview of the current milestones for the project (first graphic) and the future work (second graphic). It was thought these might be a helpful way of conveying the status and planned work for the project. These are still valid, except that with the students off the project for most of the summer, the status in the Future Work graph at the end of this past quarter (September 30, 2013) was about what the graph indicated for the end of August.

ISSUES

- No issues and project is on track. The anticipated meeting with the CDOT MAP-21 team did not occur at the end of September, and would be desirable during the coming quarter.

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: 7/1/13 - 9/30/13
Type: SP&R Start: 12/07/10 Ver:
Contract: 11HAA25597

Completion/End Date: 9/30/2013

CDOT SAP # 27100300

Principal Investigator(s):
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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: 7/1/13 - 9/30/13
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.	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.
07//09/09	100%	07//09/09	Task 2: Field evaluation of monitoring system
04/01/11	100%	04/01/11	Task 3: Interim report and testing plan
06/02/11	100%	06/02/11	Task 4: Field evaluation of sealers
09/31/12	100%	06/30/2013	Task 5: Analysis of field evaluation results
10/31/12	95%		Task 6: Draft report and final report

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

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

Background	Reporting Period: 7/1/13 - 9/30/13 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
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 them. In addition, care is needed when removing these types of surfaces as to not 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, 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.	

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	75%		Task 3: Data collection and analysis of thin-bonded overlays on structures F-17KK and F-17-OD
10/14/2013	75%		Task 4: Laboratory/field testing
12/31/2013	65%		Task 5: Prepare and submit a draft and final report to CDOT

SIGNIFICANT EVENTS

07/09 Project officially begins
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
01/10 Progress Report Submitted
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
07/11 Progress Report Submitted
10/11 Progress Report Submitted
12/11 Project Update at UCD
01/12 PI Transition
02/12 Progress Report Submitted

03/12	Meeting held at CDOT to discuss next phase of testing and rad sensor installation on I-225/Parker Rd.
05/12	Field inspection of the I-76/WCR 53 structure (076-035 D-18-BK)
06/12	Progress Report Submitted
09/12	Meeting to Discuss Data Collection at I225/Parker and I25/I225 structures
10/12	Sampling at I225/Parker and I25/I225
11/12	Progress Report Submitted
12/12	Permeability and Chloride Results Complete
01/13	Project update at CDOT Headquarter
02/13	Progress Report Submitted
04/13	Progress Report Submitted

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

Background

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: 7/1/13 - 9/30/13
Type: SP&R

Principal Investigator(s):
Yunping Xi, University of Colorado at Boulder
(303)492-8991

Study Manager:
Aziz Khan, Research Branch

Panel Leader:
Ali Harajli, Bridge Design & Management

Study Panel Member:
Eric Prieve, Materials and Geotechnical Branch
Bob Mero, R-6 Materials
Steve Pinero, R-6 Maintenance
Mike Stanford, Materials and Geotechnical Branch
Tyler Weldon, CDOT- Maintenance
Skip Outcalt, DTD-Research
Mathew Greer, FHWA-Colorado

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

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 Micro-pile/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: 7/1/13 - 9/30/13
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 methodologies and experience relevant to design of hybrid Micro-pile/MSE walls with impact barriers.
12/1/12	80%		Task 3a: Construct computer models and perform parametric study using finite element code LS DYNA for a MSE wall subject 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

Evaluation of Seismic Testing for Quality Assurance of Lime-Stabilized Soil
Study No: 80.30

Background

In the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) procedure, the critical design parameter required for subgrade, subbase, base and stabilized layers is modulus. In CDOT design practice, the resilient modulus (M_R) of the material is estimated via correlation to unconfined compressive strength (UCS). During quality assurance (QA) process, the M_R is also estimated from correlation to UCS. For stabilized soils, the correlation to M_R is based upon UCS of samples that have undergone accelerated curing (100 ^oF) for 5 to7 days. There are a number of limitations to this QA approach:

- This lab-based assessment is not a true evaluation of the field-constructed product. While the soil does come from the construction site, specimens are prepared in the lab using standard Proctor energy (and not actual field compaction energy). This creates a structure that is different from the field-compacted soil. It has been demonstrated that field compaction and lab compaction can be significantly different.

- The estimation of field-constructed M_R comes from a correlation to UCS that may not be representative for all soils. The test does not directly measure M_R.

- The M_R - UCS correlation equation is based on 28-day normally cured samples; however, the M_R is determined via correlation by using UCS results from accelerated cure (e.g., 5 days at 105 ^oF) samples to expedite construction. This introduces additional uncertainty because 5-day accelerated curing is only an approximation of 28-day normal temperature curing. Tthere is no unique 105 ^oF curing duration that mimics 28-day normal curing for all soils. Therefore, 5-day 105 ^oF curing will overestimate or underestimate strength and stiffness, depending on soil type.

Ideally, a QA approach should directly measure the design parameter (i.e., modulus) of the field-constructed material. The technique should allow for testing after 3, 4 or 5 days to expedite construction. The seismic technique enables the direct measurement of modulus in the lab and in the field. Seismic waves propagate through the soil at a speed that is proportional to Young's modulus E and shear modulus G. The design modulus may be determined in the laboratory for the given stabilized soil using a free-free resonant (FFR) test, and can be verified directly in the field with a seismic method. The main objective is to determine the technical and economic feasibility of using seismic techniques to measure the laboratory and field modulus of lime-stabilized soils (LSS) used in a CDOT construction project.

Reporting Period: 7/1/13 - 9/30/13
Type: SP&R Start: 06/29/10 end: 12/31/12
PO: 211010111

Principal Investigators:
Colorado School of Mines, Dr. Mike Mooney,
(303) 384-2498
Dr. Judith Wang
(303) 273-3836

Study Manager: TBD

Study Panel Members:
C.K. Su, Mat. & Geotech Branch (303) 398-6586
Gary Dewitt, Region 4 Materials
(970) 506-0359
Alan Hotchkiss, Mat. & Geotech Branch
(303) 398-6587
Aziz Khan, Research Branch (303) 757-9522
Shamshad Hussain, Region 1 Materials
(303) 398-6582
Mathew McMechen, Region 6 Materials
(303) 398-6706
Scott Roalofs, Mat. & Geotech Branch
(303) 398-6509
Michael Stanford, Mat. & Geotech Branch
(303) 398-6544
Jim Noll, Kumar and Associates,
(303)882-1954

Final report has been published: http://www.coloradodot.info/programs/research/pdfs/2013/lss.pdf/view
This will be the last quarterly report for this study.

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: 7/1/13 - 9/30/13
Type: SP&R Start: 10/10/13 PO: 211020425

Principal Investigator(s): Yunping Xi, CU Boulder

Study Manager: Vacant

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		10/10/13	Issue PO and notice to proceed: PI provide revised proposal based on using a new bridge being constructed on Arapahoe Road over Cherry Creek.
12/1/13			Kickoff Meeting
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

9/12/13 SEMA Construction identified as the lowest bidder.

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;
(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.

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 (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: 7/1/13 - 9/30/13
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	35		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: 7/1/13 - 9/1/13
Type: SP&R Start: 02/12 Ver:

Completion/End Date: 2/01/2014

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	80		Investigation of design detailing has started. It seems that more time is needed to finish than we originally planned. It is expected that the overall project finish time will not be affected.

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	~~*~~	~~* See below~~	Task 4: Calibration with nonlinear FEM software
~~10/01/2013~~ ~~07/01/2013~~ 09/01/2013	80		Task 5: Investigation of design detailing
1/01/2014			Task 6: Illustrative examples
1/31/2014			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.

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.

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:** 7/1/13 - 9/30/13 **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

- No work progress occurred during the 3rd Quarter of 2013 due to contractual issues. The project will be completed upon approval of a new task order to cover the project.

ANTICIPATED WORK NEXT PERIOD

- Approval of new task order to complete work

ISSUES

- No work progress occurred during the 3rd Quarter of 2013 due to contractual issues. The project will be completed upon approval of a new task order to cover the project.

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:** 7/1/13 - 9/30/13 **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 (720) 540-6812 **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		5/3/2013	Revised Project Schedule
8/23/13	100	8/23/13	Work Element 2 – Data Gathering
10/18/13	90		Work Element 3 – Screenline Analysis
11/8/13	50		Work Element 4 – Literature Review
1/10/14	75		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	10		Work Element 8 – Project Management

SIGNIFICANT EVENTS

- 12/11/12 – Notice to proceed issued to SEH.
- Revised project schedule completed
- Data collection is underway with CDOT and DRCOG.
- **11/01/13 Updates:**
  - **Work Performed to date**: We have received all of the data that we believe is readily available for us to use. We have performed quite a bit of analysis comparing crash history patterns and volume patterns of the arterial intersections within the study area to the crash history and volume history of C-470. We have also performed some analysis of volume/crash history across screenlines and compared the results between the arterials and C-470 as well. We have researched the literature to investigate driver behavior and diversion tendencies and have found 6 articles so far. We are just getting into this phase of the project and will continue to research more articles.
  - **Task 3: Screenline Analysis** (90% Complete) Screenline Analysis was intended to develop approximately 6 screenlines to develop growth charts and see what patterns emerge. We have developed 7 screenlines thus far and have not definitively identified a conclusive pattern. We have identified additional analyses we will perform as a result. Therefore, though we met the parameters of this task by October 18, we will still be performing work under this task to see if we can identify patterns in the data. Upon completion of this work, we will develop a brief memorandum summarizing the results for review by CDOT research staff. We would be happy to sit down with you to discuss our preliminary findings.
  - **Task 4:** Literature Review (50% complete) This task is not along the critical path of the project and can run concurrent with Tasks 1-5 for this project. There is still some work to do before we can complete the Literature review write-up and memorandum and plan the completion of this task prior to the Task 5 deadline of January 10, 2014.
  - **Task 5:** Accident Patterns (75% complete) We performed this work along with the volume pattern analysis and are ahead of schedule for this task.

ANTICIPATED WORK NEXT PERIOD

- We will work next week to catch up on this task and finish up with the screenline analysis. We will invite CDOT to meet with us to discuss our findings to date..
- Complete literature review (Work Element 4)

ISSUES

- Project completion date will need to be extended from 9/8/13 to reflect project schedule.

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: 7/1/13 - 9/30/13 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: Charles Meyer, Traffic & Safety David Swenka, Traffic & Safety

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			Task 3 – Final Report

SIGNIFICANT EVENTS

- Documented the work for the final report.

ANTICIPATED WORK NEXT PERIOD

- Finalization of final report
- CDOT's Review of Draft Report
- Completion of study

ISSUES

- No issues and project is on track.

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: 7/1/13 - 9/30/13
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

FHWA Contact:

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
06/02		09/02	Monitor and document the installation of Brifen guardrail on US 285 at MP 141 – Windy Point.
04/03		04/03	A study panel meeting will be held to discuss the work plan for the study, what information will be kept in the databases, and to establish the length of the study and the number of sites that will be accepted for evaluation under this study.
08/03		08/03	Monitor construction of the site on I-25 near MP 250
12/03	90		Evaluate the systems based on repair costs and time needed to repair hits and the effectiveness of the system in reducing the severity of accidents.
05/04		06/04	Write and distribute interim report with recommendations for suitable situations and specific items that should be addressed on each project
12/04		05/05	Construction of median WRSF systems has begun on I-25 mp 229 – 269. CASS is being installed along the frontage road at mp 252. Very little accident data has been received in Research for inclusion in the accident database.
04/05		04/05	Study panel meeting to evaluate the progress of the study and discuss accident reports.
10/05		12/05	Installation of Trinity CASS systems in the median on I-25 ≈mp 174 – 181 and SH-86 near Castle Rock.
07/07		07/07	Install approximately 1 mile of each of the 5 certified manufacturers' systems in the median of C-470 from mp 14 to 19
06/11	90		Evaluate accident and MMS system data. Write and distribute the final report.

SIGNIFICANT EVENTS

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”.

08/07: The Research Branch (Skip Outcalt & Rich Sarchet) will set up and maintain a database with information

concerning tensioned cable barrier systems installed by CDOT.

07/07: Rich Sarchet attended a seminar sponsored by TRB to discuss TCGR with manufacturers and representatives of several DOTs.

09/06: Several anchor blocks have been seen to be pulled out of the ground and the tension is low in some of the systems installed on I-25 north of Denver. Brifen has recommended a fix for the anchors and sent representatives to Colorado to conduct training system maintenance methods seminars for personnel who have cable guardrails.

06/06: Accident data for all sites before the TCGR installation is being reviewed and tabulated. Maintenance data for the sites built before mid 2005 is being reviewed and tabulated. The first draft of the report will be sent to the panel for review by the end of July 06.

01/06 No new sites will be added to this study. The accident and maintenance data will be evaluated and the final report written by the end of the fiscal year.

12/05: The FHWA will approve no more project specific FIPIs to justify the use of proprietary TCGRs As of December 2005 there are five TCGR systems that have FHWA approval at NCHRP TL-3. Of the five, CDOT has installed and is evaluating two for this study: Brifen's WRSF and Trinity's CASS. Because there are five systems with similar capabilities (according to the NCHRP 350 testing), and only two of them have been installed up to this time, this study will be concluded. The accumulated data will be evaluated and a report written based on the WRSF and CASS systems.
A five-mile project, STU 4701-107, will be constructed on C-470 in 2006 to include about one mile of each of the Trinity, Nucor, Blue Systems and Gibraltar systems. The new site is contiguous to an existing Brifen WRSF median site; however, a section of the newly approved three-cable Brifen system may be built as part of the new study.

7/05: New systems installed: Brifen – on I-70 and SH-9 near Frisco, US-287 near Ted's Place.
Proposed systems: Trinity on I-25 and SH-86 near Castle Rock, and the newly approved Brifen TL-4 system on I-70 east of the Eisenhower Tunnel.

8/05: End anchor blocks in Brifen systems on I-25 ≈mp 243 and on US-287 near Ted's Place, were pulled out of the ground by hits near the end of the guardrail systems. Initial evaluations indicate that the blocks may be tapered from top to bottom forming a cone shape rather than the designed 4' diameter cylinder.

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: 7/1/13 - 9/30/13
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:
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Darrell Dingus, Stds & Design 303.757.9083
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FHWA :
Marcee Allen, 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		Schedule visibility evaluation line up panel of observers to participate in the test
4/30/13	100		Virginia Tech and panel of observers conduct visibility evaluation

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

SIGNIFICANT EVENTS

10/01/13 – The final report draft is written and is being edited. It should be ready for publication by the end of November.

8/13 – Dr. Gibbons' staff returned to the site in Trinidad to confirm evaluations and gather more information.

5/27/13 – Dr. Ron Gibbons, Virginia Polytechnical Institute performed visual evaluations of the LEDs.

11/8/12 – Dr. Ron Gibbons, Virginia Polytechnical Institute has been hired to conduct the visibility testing.

06/11 – As an extension of this study, the Research Implementation Council approved funding for a study "Evaluation of Guardrail Embedded Lighting" for FY 2012.

09/10 – Further evaluation by VTTI depends on the decision of the FY11 RIC in January 2012.

03/10 – Dr. Ronald Gibbons at the Virginia Tech Transportation Institute (VTTI) has been contacted and asked to prepare a proposal for a safety evaluation of the LEDs. The proposal will be presented to the RIC in FY11.

9/09 – Construction complete. Light levels were taken on the deck with only the LED lights on. Clanton & Associates will evaluate the light levels and prepare an interim report. Due to time constraints and construction scheduling, the evaluation of the light levels was done before the lane stripes were painted on the deck. Start of construction of the southbound lanes requires two way traffic on the northbound structure which will be in effect until the completion of the new southbound structure. Further evaluations will be made when the southbound structure is complete and ready for traffic.

12/08 – About 25 % of the bridge rail is done; 90% is expected to be done by March. LED installation will begin late April or May, 2009

07/08 – Girders are being set. Deck and barrier work should begin around January, 09.

07/07 – Demolition of the structures has begun. The power to the northbound bridges was cut so some of the light standards could be removed, so it was not possible to gather pre-construction light data in the northbound lanes. The data previously collected on the southbound bridge will be used.

12/06 – Demolition of the existing structures is scheduled for April of 2007, construction of the new structures is scheduled to begin July 2008 and completion is planned for June of 2009.

09/30/06 – The project has yet to be awarded.

06/19/06 – The scheduled Ad date is July 20, bid openings on Aug 31 for the new project. Since the plan now is to construct northbound first, the baseline readings will have to be re-taken. Dates for the Milestones will be established after the project has been awarded and the schedule established.

01/06 – Region to re-advertise the NB project on June 15, 2006

11/05 – Region is waiting for decision if additional money will be given to the project to AD as whole project or half a project. AD date postponed until sometime in 06.

11/05 – Referendum C passed, D failed.

5/05 – The project will be re-advertised in January 06. Depending on the passing of Referendums C and D it may be done as either a single project or two separate projects.

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: 7/1/13 - 9/30/13
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 Q4 2013

- 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.

Reporting Period: 7/1/13 through 9/30/13
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
Al Gross, CDOT R-1 Hydraulics 303-757-9342
Mohan Sagar, CDOT Specifications 303-757-9649
Fred Schultz, CDOT Maintenance 303-757-9103
C.K. Su, Materials and Geotechnical 303-757-9750
Dave Wieder, CDOT-Maintenance 303-357-8973

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

MILESTONES

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

6/05/09 PI met with Research Panel Leader to select additional culvert test sites.

6/09/09 Culvert Testing along I 70 between MP280 and MP370 with CDOT participation

6/15/09 Culvert testing along I-70 between MP370 and MP 425 and along HW40

6/19/09 Culvert testing along I-76 with CDOT participation

6/24/09 Meeting with CSU Soils Testing laboratory to analyze the water and soil samples from the first batch of 40 sites.

7/28/09 Met with Research Panel to update them on the status of the project and to get their approval on the sites that will be included in the study. Phase 2A will include the Eastern half of Colorado.

12/31/09 Completed Phase 2A

04/01/10 Started Phase 2B of the study to compile data from the Western Colorado

06/19/10 Conducted a 4-day trip along State Highway 160 covering the area between I-25 and Cortez, Colorado. Collected water and soils data and soil resistivity data from 34 sites along HW 160 and connecting highways.

07/16/10 Conducted a 3-day trip along Interstate State Highway 70 from Denver to Utah border. Included sites along HW 13, HW 131 and HW 139. Collected water and soils data and soil resistivity data from 30 sites along I-70 and connecting highways.

09/17/10 Conducted a 3-day trip along HW 40 from Walden to Craig. Included sites along HW 13, HW14, and HW 131. Collected water and soils data and soil resistivity data from 15 sites along HW 40 and connecting highways.

10/1/10	Conducted a 3-day trip along I-70 and HW 50 and collected data from Grand Junction to Gunnison. Inspectedculvert sites along HW 6, HW 340, and HW 141. Collected water and soils data and soil resistivity data from 29 sites along HW 50 and connecting highways.
9/30/12	Results of soil testing have been tabulated for final analysis.
3/5/12	Completing additional testing on missing laboratory data.
6/30/12	Re-tabulation of soil testing results for final analysis.
9/30/13	Additional literature review for new research on the topic completed.

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: 7/1/13 - 9/30/13
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:
Roberto DeDios, CDOT Research Branch 303-757-9975
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT R-1 Hydraulics 303-757-9342
Scott Leiker, CDOT R-6 Hydraulics 719-2485493
C.K. Su, Materials and Geotechnical 303-757-9750
Dave Wieder, CDOT-Maintenance 303-357-8973
Carl Valdez, CDOT R-2 Maintenance

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

Saeed Farahmandi, City and County of Denver

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

MILESTONES

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

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

Reporting Period: 7/1/13 - 9/30/13
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:
Roberto DeDios, CDOT Research Branch 303-757-9975
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT R-1 Hydraulics 303-757-9342
Dennis Cress, CDOT R-2 Hydraulics 719-2485493
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

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.

MILESTONES

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

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

Reporting Period: 7/1/13 - 9/30/13
Start: 10/5/12 Complete: TBD

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

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

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

Study Panel Members:

Lynn Croswell, CDOT Staff Bridge 303-757-9188
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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

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.

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.
3/31/13	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.

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 Q4 2013

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13 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: ~~Rik Gay~~, CDOT EPB Kenneth Quintana, CDOT R2 Maintenance Al Roys, CDOT R4 Maintenance Aziz Khan, CDOT ARIB
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.	

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	33		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	33		Creation of design charts and/or an Excel spreadsheet computer model for water quality detention elliptical slot weir outlet designs.
4/30/2013	20		Installation of a prototype elliptical slot weir at a UDFCD-monitored water quality

			detention basin (monitoring hydraulics and debris handling characteristics will continue for two years at this test site)
9/30/2013	0		Determination of clogging potential and consideration of clogging mitigation strategies (e.g., well screen or trash rack) for this new outlet compared to the current standard.
9/30/2013	0		Coordination with CDOT, who will install and monitor the prototype device at a rural water quality detention pond, to insure the device is installed and monitored correctly.
9/30/2014	0		Comparison of maintenance requirements for this new outlet vs. the current standard.
8/18/2015	0		Submission of draft final report no later than 75 days before end of contract
8/18/2015	0		Presentation of findings to study panel and other invitees with electronic copy of associated PowerPoint presentation.
8/18/2015	0		Submission of guidance document on best practices in producing, installing and maintaining an alternative outlet water quality structure.
10/2/2015	0		Address the comments of the study panel.
10/2/2015	0		Submission of a final report per CDOT manuals and specifications (re: CDOT Research website, http://www.dot.state.co.us/Research/)
10/2/2015	0		Creation and delivery of CD(s) containing reports, all electronic files, photographs, and data generated for the project at the close of the study.

SIGNIFICANT EVENTS

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

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

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

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

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

(having a low front edge, two sloping sides, and a high back edge). We hope through the work at USBR to better calculate these flows.

3/31/2013 – The debris modeling has been completed. CSU has submitted a final report on the testing setup and process titled "CSU Elliptical Weir Hydraulic Testing Final Report 2013-03-29." Work is progressing on derivation of an equation-based sizing methodology for field installations. A 3-dimensional CFD model of three different elliptical slot weirs was completed by ARCADIS and a report titled "ARCADIS Calculation of Rating Curves for Three Elliptical Slot Weirs 2011-08-15" has been submitted. Testing of overflow structure hydraulics at the USBR hydraulics lab also continues. To date, an overflow structure with a 3:1 sloping top weir and a 4:1 sloping top weir have been modeled and the results have been compared to the classical and modified 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. This equation takes the form of:

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

where

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

and

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

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

Work completed to date at the USBR hydraulics lab includes overflow rectangular weir modeling for overflow 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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13
The accuracy of flood-frequency estimates can be greatly improved when historical flood information is used with systematic flood data. At the present, much of the historical flood information for Colorado is stored in numerous published and unpublished reports, files, and photographs in local, state, and federal agency offices as well as consulting engineering offices. Having an easy-to-use Web-based database of historical flood and paleoflood information with links to sources of systematic flood data will allow engineers and water-resource managers to fully use this data to provide accurate flood recurrence estimates of the largest floods in Colorado. Engineers and scientists then will be able to incorporate these estimates for proper floodplain regulation, dam-safety design, and other uses. The objective of this study is to develop a Web-based geodatabase accessible using an ARCGIS map or similar interface for historical flood information that will facilitate easier access to this information for the compilation of flood data and result in improved flood frequency estimates in Colorado. 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. A Web-based interface that contains links or data on systematic and historic flood information will be the ultimate product of this project. In addition, a short fact sheet will be published to describe the contents of the database and how to use it.	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	50	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.

Currently, the database only contains data up to water year 2011. Data from water year 2012 (October 1, 2011 to September 30, 2012) will not be published until the spring of 2012. After which time, the database will be updated to include data through water year 2012. Due to the September 2013 flooding, the 2012 data update has been delayed but it should be finished by the end of 2013. Data from the 2013 water year will be added to the database during the summer of 2014 since it will not be published until the spring of 2014.

Project completion

The initial project completion/end date is 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 funding agreement was signed with CDOT 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: 214.02

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: 7/1/13 - 9/30/13

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. As of October 2013, collection of new paleoflood data has begun.

Project completion

The project completion/end date is 09/30/2015 per the CDOT/USGS Funding Contract signed in September 2013.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13 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: ~~Rik Gay~~, CDOT EPB Kenneth Quintana, CDOT R2 Maintenance Al Roys, CDOT R4 Maintenance Aziz Khan, CDOT ARIB
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.	

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	33		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	33		Creation of design charts and/or an Excel spreadsheet computer model for water quality detention elliptical slot weir outlet designs.
4/30/2013	20		Installation of a prototype elliptical slot weir at a UDFCD-monitored water quality

			detention basin (monitoring hydraulics and debris handling characteristics will continue for two years at this test site)
9/30/2013	0		Determination of clogging potential and consideration of clogging mitigation strategies (e.g., well screen or trash rack) for this new outlet compared to the current standard.
9/30/2013	0		Coordination with CDOT, who will install and monitor the prototype device at a rural water quality detention pond, to insure the device is installed and monitored correctly.
9/30/2014	0		Comparison of maintenance requirements for this new outlet vs. the current standard.
8/18/2015	0		Submission of draft final report no later than 75 days before end of contract
8/18/2015	0		Presentation of findings to study panel and other invitees with electronic copy of associated PowerPoint presentation.
8/18/2015	0		Submission of guidance document on best practices in producing, installing and maintaining an alternative outlet water quality structure.
10/2/2015	0		Address the comments of the study panel.
10/2/2015	0		Submission of a final report per CDOT manuals and specifications (re: CDOT Research website, http://www.dot.state.co.us/Research/)
10/2/2015	0		Creation and delivery of CD(s) containing reports, all electronic files, photographs, and data generated for the project at the close of the study.

SIGNIFICANT EVENTS

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

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

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

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

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

(having a low front edge, two sloping sides, and a high back edge). We hope through the work at USBR to better calculate these flows.

3/31/2013 – The debris modeling has been completed. CSU has submitted a final report on the testing setup and process titled "CSU Elliptical Weir Hydraulic Testing Final Report 2013-03-29." Work is progressing on derivation of an equation-based sizing methodology for field installations. A 3-dimensional CFD model of three different elliptical slot weirs was completed by ARCADIS and a report titled "ARCADIS Calculation of Rating Curves for Three Elliptical Slot Weirs 2011-08-15" has been submitted. Testing of overflow structure hydraulics at the USBR hydraulics lab also continues. To date, an overflow structure with a 3:1 sloping top weir and a 4:1 sloping top weir have been modeled and the results have been compared to the classical and modified 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. This equation takes the form of:

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

where

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

and

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

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

Work completed to date at the USBR hydraulics lab includes overflow rectangular weir modeling for overflow 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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 7/1/13 - 9/30/13
The accuracy of flood-frequency estimates can be greatly improved when historical flood information is used with systematic flood data. At the present, much of the historical flood information for Colorado is stored in numerous published and unpublished reports, files, and photographs in local, state, and federal agency offices as well as consulting engineering offices. Having an easy-to-use Web-based database of historical flood and paleoflood information with links to sources of systematic flood data will allow engineers and water-resource managers to fully use this data to provide accurate flood recurrence estimates of the largest floods in Colorado. Engineers and scientists then will be able to incorporate these estimates for proper floodplain regulation, dam-safety design, and other uses. The objective of this study is to develop a Web-based geodatabase accessible using an ARCGIS map or similar interface for historical flood information that will facilitate easier access to this information for the compilation of flood data and result in improved flood frequency estimates in Colorado. 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. A Web-based interface that contains links or data on systematic and historic flood information will be the ultimate product of this project. In addition, a short fact sheet will be published to describe the contents of the database and how to use it.	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	50	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.

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: 7/1/13 - 9/30/13
Type: SP&R Start: 9/6/13 PO: 211019963

Principal Investigator(s): Chengyu Li, Atkins Global

Study Manager: Aziz Khan, ARIB

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		7/4/13	Issue bid invitation: purchase requisition was entered on 7/4/13, the first day FY14 funding codes could be used. Bid invitation had to be issued a second time because of no bids on the first round.
8/31/13		8/31/13	Select PI from bidders. Only one Bidder
9/15/13		10/1/13	1. Issue PO and NTP
10/7/13		10/7/13	2. Kick Off meeting
11/4/13			3. Literature Review
12/10/13			4. Survey of other state:
4/4/14			5. Determine type and scale of structures
1/14/14			6. Progress Meeting
5/16/14			7. Estimate Cost
5/16/14			8. Estimate number of bridges
6/13/14			9. Provide estimate of direct cost savings
4/15/14			10. Progress Meeting
7/16/13			11. Identify procedures
7/17/14			12. Interim Status Meeting: Consider revising PO end date from 9/30/13
8/15/14			13. Investigate computer tools
8/15/14			14. Identify SOW to fully develop standard plans
9/5/14			15. Determine impact on as-built plan generation

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.

Currently, the database only contains data up to water year 2011. Data from water year 2012 (October 1, 2011 to September 30, 2012) will not be published until the spring of 2012. After which time, the database will be updated to include data through water year 2012. Due to the September 2013 flooding, the 2012 data update has been delayed but it should be finished by the end of 2013. Data from the 2013 water year will be added to the database during the summer of 2014 since it will not be published until the spring of 2014.

Project completion

The initial project completion/end date is 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 funding agreement was signed with CDOT 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: 214.02

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: 7/1/13 - 9/30/13

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:
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Project Development Branch
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Study Panel Members:
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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. As of October 2013, collection of new paleoflood data has begun.

Project completion

The project completion/end date is 09/30/2015 per the CDOT/USGS Funding Contract signed in September 2013.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background The CDOT Region 1 project to replace the twin bridges over the Union Pacific Railroad and Smith Road incorporates innovations that implement the CDOT/FHWA mandate − EDC GRS (Geosynthetic Reinforced Soil) abutment technology. These twin bridges carry I-70 east and westbound traffic on three-span, (107'+ 158' + 155') horizontally-curved steel welded-plate girder structures. The mid-span piers are founded on deep foundation; however, the GRS abutments are supported by spread footings and founded on embankments. This unique feature of a GRS transition zone, to a GRS abutment founded on an embankment (shallow foundation), to pier (deep foundation) is a new design methodology to eliminating bridge "bumps". Such "bumps" are typically caused by differential settlement between the bridge founded on deep foundations and the roadway founded on embankment (shallow foundation) and can result in roadway maintenance problems. The objective of the study is to validate the performance of GRS abutment for multi-span bridges, and the use of geofabric without positive connections to the fascia blocks for GRS retaining walls.	Reporting Period: 7/1/13 - 9/30/13 Type: SP&R Start: 10/8/13 Performance Monitoring: Shannon & Wilson TO#1: 14HA161608, PO: 231004424 Principal Investigator(s): TBD Study Manager: Aziz Khan, ARIB Study Panel Members: Panel Chair: ShingChun (Trever) Wang, Bridge Design and Management Ilyess Ksouri, Materials and Geotechnical Branch Steve Yip, Bridge Design and Management Branch Teddy Meshesha, Bridge Design and Management Matt Greer, CO Division of FHWA Daniel Alzamora, Resource Center, FHWA Larry Quirk, Region 1 Project Engineer Ty Ortiz, Materials and Geotechnical Branch Dave Thomas, Materials and Geotechnical Branch Roman Jauregui, R1 Resident Engineer

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/31/13		10/18/13	Establish Study panel and develop scope of work: in order to expedite the instrumentation of the GRS systems, it was decided to break out the research into three parts: instrumentation, GRS Wall data analysis and reporting, and 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		10/8/13	Issue task order for instrumentation and monitoring: Cost for the monitoring was determined to be way over what was budgeted. The need to securing additional funding delayed this task order.
8/15/13		10/18/13	Issue bid invitation for Abutment research
11/15/13			Secure additional research funds and issue RFP for GRS Block-faced wall research
10/30/13			Instrumentation consultant finalizes instrumentation design
11/15/13			Select PI for abutment research from bidders.
11/18/13			Issue PO and notice to proceed to Abutment researcher
11/30/13			Shannon & Wilson orders and take delivery of instrumentation equipment
12/19/13			Install instruments in Phase I Wall and abutment
3/1/13			Initial Phase I data to Researcher
9/12/14			Install instruments in Phase II Wall and 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

SIGNIFICANT EVENTS

9/20/13 An additional $200,000 of project funds has been made available for the monitoring
7/1/13 Research funding becomes available
6/27/13 Construction Project was advertise for bidding
6/15/13 $200,000 of project funds have been made available for instrumentation and monitoring

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: 7/1/13 - 9/30/13 Type: SP&R Start: 11/1/13: PO: 211019964 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 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		10/8/13	Kick Off meeting
1/31/14			Literature Review
1/31/14			Sampling Matrix and Locations
1/31/16			Field Sampling
4/30/16			Laboratory Testing
4/30/16			Analysis of Test Results
4/30/16			Draft final report
6/30/16			Publish final report

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: 7/1/13 - 9/30/13
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

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.