# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## SHRP2 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. CDOT has also shifted gear and is focusing on product implementation, especially those products that are applicable to CDOT. Over the last few years we have moved some of the LTPP products from concept to full implementation. Among them are the narrower concrete joint design (1/8" wide), the Wider slabs (14-ft. wide) and other innovative technologies such as spray injection patcher for potholes, Georgia-fault-meter for measuring faults at concrete joints, Iowa-vacuum tester to identify leaks and a new distress identification manual (DIM).

As part of the SHRP product implementation, AASHTO enacted the Lead States Program in 1996. The centerpiece of the program is seven Lead State teams responsible for the implementation of a specific SHRP technology at the national level. The teams include states, FHWA, academia, industry representatives, as well as one AASHTO member. The primary objective of the AASHTO lead state program is to provide an avenue for timely implementation of proven SHRP technologies by those states that are in the forefront of a specific technology. CDOT has selected two lead-state teams: Innovative Pavement Maintenance Technologies and Anti-Icing, and Road Weather Information System (RWIS).

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 1/1/89

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

Study Manager:
Roberto DeDios, Research Branch, 303-757-9975

Study Panel Member:

Skip Outcalt, CDOT 303-757-9984

FHWA Washington Contact:
P. Teng, HNR-40

## 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. |
| 01/13/08 | 100 | 01/13/08 | Roberto de Dios attended the LTPP Coordinators sessions at the TRB annual meeting. |
| 12/31/10 | 100 | 12/01/10 | Conducted FHWA LTPP Visit |

# SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**09/30/12** Field inspection of SHRP sites will be rescheduled sometime in the future (year 2013) because of traffic control issue.

**06/30/12** It was learned that the transportation reauthorization bill "Moving Ahead for Progress in the 21st Century," also known as MAP-21 is anticipated to be signed by the President sometime in July 2012. The bill will authorize the funding for the implementation of SHRP 2 products using SP&R money.

**01/22-26/12** The LTPP State Coordinators' meeting and the LTPP Technical Session were held as part of the annual TRB meeting. Several presentations were made pertaining to LTPP program.

**12/31/11** No reported activity during this quarter.

**09/19-30/11** LTPP data collection activities for Specific Pavement Studies (SPS) sites were performed by the consultant personnel (Nichols Consulting Engineers, Inc.) during this quarter.

**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.

**01/11** FHWA held LTPP Coordinators' meeting and had LTPP sessions on leveraging the LTPP experience to collect quality weigh-in-motion (WIM) data.

**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.

**09/30/10** Nichols Consulting Engineers (NCE) in coordination with FHWA and CDOT sent a draft of the agenda for the FHWA LTPP seminar/meeting between CDOT and FHWA/Consultant scheduled on December 1, 2010.

**06/30/10** Nichols Consulting Engineers initiated coordination of FHWA visit to promote LTPP program

**03/31/10** No activity this quarter.

**12/31/09** No activity this quarter.

**9/30/09** The budgeted amount for this project under the WBS 90050 needs to be rolled forward to a new WBS number. The 90050 account needs to be closed. The new WBS account will be used for SHRP2 project activities. No significant activity was reported by the consultant for this quarter.

**6/30/09** No activity by the consultant was reported for this year.

**03/31/08** The assessment, calibration and performance evaluation of LTPP SPS Weigh-In-Motion (WIM) Site ID 080200 is scheduled on April 29, 2008. Barbara K. Ostrom, Principal Investigator of MACTEC Engineering and Consulting, Inc., 12104 Indian Creek Court, Suite A, Beltsville, Maryland 20705, Phone:301-210-5105 scheduled the site visit and evaluation meeting.

**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.

**9/21/07** Nichols Consulting Engineers performed the required coring and data collection for the Long-Term Pavement Performance (LTPP program). CDOT sent check to FHWA in the approximate amount of $32k to cover the cost of coring job.

**6/30/07** It was confirmed that approximately $75k is left unspent in FY07. This money has to be rolled forward and must be approved by the Transportation Commission before it becomes available again to be spent. Kevin Senn of Nichols Consulting Engineers indicated that his company cannot do the coring as this is not part of the scope of work that is stipulated in their contract with FHWA. CDOT has no manpower/equipment to do the coring in-house specially the 12-inch cores AND needs to contract out this work using the unspent SHRP program money. CDOT requested Nichols Consulting Engineers to submit an estimate of the coring work. The estimated cost of coring is $34k.

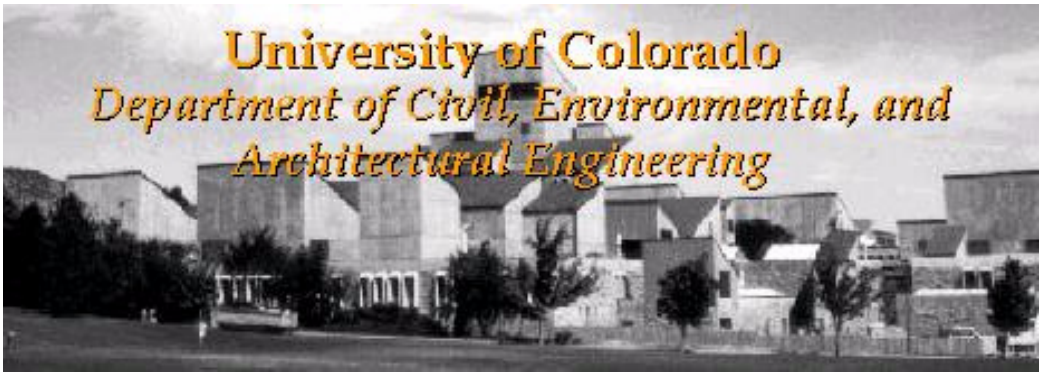
**3/12/07** Kevin Senn of Nichols Consulting Engineers estimated that 16 days of traffic control will be required for 11 locations in 2007 and 7 days of traffic control will be needed in 2008. Latest information from DTD indicates that approximately $75k appears to be remaining in the budget. In the revised Materials Action Plans for both SPS-2 and SPS-8 projects, a total of sixty one (61) 4-inch cores and eighteen (18) 12-inch cores will be required to complete this round of testing.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| Background | Reporting Period 10/1/12 through 12/31/12<br>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.<br><br>Providing training for rural and urban transportation communities is the number one priority of Colorado LTAP.<br><br>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):<br>Yunping Xi, University of Colorado/Boulder<br>(303)-492-8991<br><br>Study Manager:<br>Joan Pinamont (303) 757-9972<br><br>Study Panel Members:<br>Joan Pinamont, CDOT (303) 757-9972<br>Rick Santos, FHWA |

SEE LTAP CENTER REPORT ON NEXT PAGE




# COLORADO LTAP

# LTAP Quarterly Report

Report Period
October 1, 2012 – December 31, 2012

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

Submitted by:
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# Colorado LTAP

## 2nd Quarter

October 1 – December 31, 2012

## Program Dashboard:

| | |
|---|---|
| Total number of training sessions*: | 22 |
| Total number of participants*: | 445 |
| Total number of participant hours*: | 3115 |
| Total newsletter circulation: | 1,514 (hard-copy), 175 (electronic) |
| Total number of LTAP FTEs: | 2.25 |

*(*Only for classes held between October 1 and December 31.)*

## Four Strategic Focus Areas

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

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

Colorado LTAP's FY2012-2013 work plan reflects this outline and completed activities emphasize these four focus areas.

## A. Program Administration

- October 1 - December 31, 2012, Colorado LTAP had two full-time staff persons working for the center – Program Director, Renée Railsback and Training Coordinator, Lindsay Marshall.
- The graduate student, Wang Xingang, continued working part time for the center this quarter. Wang handles the library loan program and training resources.
- Due to Temporary Aid restrictions, Office Assistant-Marty Butcher only worked a few days this quarter. A majority of her time worked was over the holiday season when both the director and training coordinator were out of town.
- Due to a death in the family, Renée was out of town and working remotely a considerable amount during this quarter. Family Leave was also used for this absence.

## B. Training

- Colorado LTAP continued offering courses in its three training programs – *Roads Scholar I*, *Roads Scholar II* and *Supervisory Skills and Development Program.* This quarter, there were 21 days of training events offered - 17 of the classes were Roads Scholar I, 7 Roads Scholar II, and 3 Supervisory Skills and Development Program class. Class evaluations received an average greater than 95%* for classes held this quarter. (The Preventive Pavement Maintenance evaluations have not yet been entered, but the class was very well received, so the average is expected to increase.)
- There were 0 Roadway Safety, 9 Worker Safety, 7 Infrastructure Management, and 5 Workforce Development courses offered this quarter. A full list of the courses offered in each focus area is shown in the table below. The list also shows the distribution of attendance between local (City/County), Tribal, State, Federal, and Other (Contractors, etc.).
- There were 13 Roads Scholar I graduates this quarter representing Eagle County, City of Longmont, Lockheed Martin, Town of Breckenridge, City of Arvada, Delta County, Garfield County, City of Westminster, El Paso County and Town of Snowmass Village.
- There were 3 Supervisory Skills graduates this quarter representing City of Longmont and Teller County.
- The Roads Scholar II: Road Master classes that were offered this quarter were Water Quality for Roadway Maintenance, Preventive Pavement Maintenance, and Powerful Presentation Skills.
- Colorado LTAP continued to print its class brochures through an online printing company to save money and provide a more professional quality.
- 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 second quarter, October 1 – December 31, 2012 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


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

- The Fall issue was delayed and distributed this quarter. There were 1517 recipients on the hard copy mailing list, and 160 people on the electronic mail list.
- The main cover story of the Fall newsletter covered FHWA's series of videos - *Federal-aid Essentials for Local Public Agencies* - a transportation resource designed to help local agency professionals navigate the Federal Aid Highway Program. Other

topics included articles on El Paso County's winning You Show Us Contest project – the Asphalt Spray Bar; LTAP's Forklift Certification training; Forklift Operation Safety; Online Gravel Roads Maintenance Training; and CDOT's new Flagger Certification training materials.

- The Fall newsletter issue was printed through an online printing company and so far LTAP has cut the total cost of Newsletter production nearly in half from the 2012-2013 average cost.

## C0.2 Library Materials Distribution

- Continued to manage our in-house lending library consisting of over 2500 items - instructional videos, publications, and resources focusing on transportation design, maintenance, safety, and workforce related topics.
- In the second quarter, 30 items were loaned free to local transportation agencies. The table below shows the distribution by type and focus area. The most frequently loaned topics addressed winter maintenance and plowing; work zones; and on job safety.
- Separate from the lending library, 88 free publications, guidebooks and videos were distributed.
- 42 titles of new or updated materials were added to the library in the 2nd Quarter – 2 books, 0 CDs, 18 DVDs, and 16 Free Publications. Topics addressed in the new materials included accident prevention, pavement repairs, heat stress, heavy equipment safety, and work zones.
- Between October1 – December 31, $297.72 was spent on postage for mailing loaned materials, and $7.50 was spent on travel reimbursement since all packages over 13 oz. have to be brought to the USPS office and mailed in person.

| Pub Type | Highway Safety | Infrastructure Management | Worker/Workplace Safety | Workforce Development |
|---|---|---|---|---|
| Book | 0 | 5 | 0 | 0 |
| Bulk Material | 0 | 0 | 0 | 0 |
| CD | 0 | 2 | 2 | 0 |
| Disk | 0 | 0 | 0 | 0 |
| DVD | 4 | 1 | 5 | 2 |
| Free Publication | 10 | 16 | 58 | 4 |
| Software | 0 | 0 | 0 | 0 |
| Video | 2 | 3 | 8 | 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*** & ***Outreach***

- Colorado LTAP provided a booth of educational, promotional and free library materials at a select few transportation meetings and conferences that benefit the scope of the program. These opportunities also help to advance staff knowledge base on the latest transportation technologies, processes, and resources.

- A total of $768.85 was spent on Program Marketing and Outreach for staff travel to provide a booth at the APWA Snow & Ice Conference; and printing and mailing of the Street Conference Save-the-Date Postcards.

***Technical Assistance***

- ❖ LTAP center staff spent about 25% time providing technical assistance to local agencies. Examples of technical assistance provided this quarter included requests on safety and design of median barriers; Roads Scholar program development for other LTAP centers; National You Show Us Contest information and best practices from other local agencies; MUTCD field applications, nuclear gauge training; and mobile apps.

## C0.4 Out-of-State Travel

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

- ❖ The Colorado LTAP Director currently serves on the National LTAP Association Executive Committee as the *President-Elect*, and *2013 LTAP-TTAP Conference Chairperson*; and participated in monthly conference calls related to Association and Conference Planning business.
- ❖ The Program Director attended the LTAP Region 7 Local Road Coordinator's Conference in Rapid City, SD in October. The director coordinated the state and regional You Show Us Contest, and presented a conference session recognizing each state's winning project, and distributed the state and regional awards to recipients at this conference.
- ❖ Second quarter expenses of $1339.26 in this category were for the Local Roads Conference travel AND upcoming airfare to the National LTAP meeting in DC in January.

# C.1 Safety Programs

- ❖ Colorado LTAP has a long history of providing infrastructure related training, technology transfer and technical assistance through its traditional services and Roads Scholar I and II training programs. There were 9 training classes offered on Worker Safety topics this quarter. Programs and training completed between October 1 and December 31 in this focus area include:
    - *Safety on the Job* – Safety must be a priority for every employee. Accidents can be reduced by learning the risks and how to mitigate them. The instructor, Tim Longbrook, used humor, real life examples, and his expertise to help attendees learn how to create a safety culture in their workplace. This Roads Scholar I CORE class covered: Developing a Safety Culture in Your Workplace; Preventing Slips, Trips, and Falls; Personal Protective Equipment; Lockout-Tagout; Machine Guarding; Safety Around Heavy Equipment; and Trenching and Excavation Safety. This course was offered in 3 locations around the state. There were 9 Roads Scholar I graduates completing the program requirements with this course and were presented with their plaques.

- *Winter Survival* – This one-day Roads Scholar I Elective course is divided into modules covering each aspect of winter survival. This is an important class for anyone exposed to extreme elements, especially snow plow operators & other public workers. This class covered Carbon Monoxide; Hypothermia; Shelter-Clothing; Survival Methodology; The Will to Survive & the Way to Survive; Survival Equipment & How to Make Your Own; and In Class Demonstrations. Participants felt the instructor, Steve Jenkins from MT LTAP, "provided a practical and entertaining training that keeps your interest the entire class. The information provided applies not only to conditions you might encounter while working, but also during personal activities; highly recommend attending this class to anyone who works or plays outdoors"; and "thought it was a great class and really enjoyable. A lot of good information was given. One of the best classes ever." This course was offered in 3 locations around the state.

- *Forklift Certification* – The documented daily inspection and safe operation of a forklift is the operator's responsibility. This full-day RS I Elective class provided attendees the opportunity to earn a certificate of training and an operator competency wallet card at the successful conclusion of the class. Whether you were a novice or an experienced operator, this class was educational. The morning consisted of a classroom portion that covered operational considerations. Safety inspections, operator safety, lifting, moving, and setting down loads were presented in an easy to understand format using short videos, handouts, and workbooks. The afternoon session provided operators with hands-on forklift operation. The training meets OSHA Standards and OCPO Training Units Standards, and there was a proficiency test for attendees to receive their operator competency card. This course was offered in 3 locations around the state. Chip Buttrick, Town of Breckenridge was the only Roads Scholar I graduate completing the program requirements with this course and was presented with his plaques.

Center staff worked on several initiatives to bring national and local attention to the importance of improving safety on our local and rural road system. There were no direct expenses posted to Safety programs this quarter. Additional Safety related activities included:

- Colorado LTAP participated in the Walk to School Day event with an area elementary school. LTAP was able to get free materials, posters, and giveaways from CDOT and the National Safe Routes to School Network.
- Agencies continued to participate in the retroreflectometer loan program while it was still warm; but then the meters get held at the LTAP office during the winter months due to freezing temperatures.
- Center staff responded to Safety related technical assistance requests addressing: safety and design of different type median barriers, and options for accessing the MUTCD regulations while in-field.
- The quarterly newsletter provided two articles addressing topics regarding safety aspects – Forklift Operation Safety and Flagger Certification.
- Colorado LTAP used the electronic mail list to promote available Safety related webinars and other distance learning opportunities offered through organizations such as the national LTAP Clearinghouse; FHWA; and APWA.

## C.2 Infrastructure Management

- Colorado LTAP has a long history of providing infrastructure related training, technology transfer and technical assistance through its traditional services and Roads Scholar I and II training programs. There were 7 training classes offered on Infrastructure Management topics this quarter. Programs and training completed between October 1 and December 31 in this focus area include:
    - *Drainage, Drainage, Drainage* – Our Drainage course is designed to provide basic drainage information to people who maintain and construct drainage systems along our streets and roads. It is a CORE Roads Scholar I course that covered: why drainage is important, maintenance aspects, different drainage types, evolution of drainage materials used, integrity and strength of subgrade, effects of moisture, basics of predicting cover, runoff, pulling ditches, erosion control, and new stormwater drainage regulations. This was a 1-day class offered in 4 locations – 2 of the classes occurred in the first quarter, and the last two classes occurred in the second quarter. There were 3 Roads Scholar I graduates completing the program requirements with this course and were presented with their plaques.

    - *Water Quality in Roadway Maintenance* – This was the first Roads Scholar II course offered this fall. This training was designed to help Phase II government agencies meet Minimum Control Measures 5 & 6 of the General Statewide Permit for Water Quality that was issued by the Colorado Department of Health and Environment in 1999. MCM 5 pertains to permanent stormwater runoff control devices and their maintenance. MCM 6 pertains to public works facilities housekeeping and maintenance activities of infrastructure in the field. The training also helped government entities not under Phase II oversight meet regulation for the Clean Water Act while conducting maintenance on their infrastructure. This course was originally scheduled in 4 locations around the state; however, after the first two presentations it was determined that the material was not at a high enough level for Roads Scholar II credit. The remaining two classes were postponed until spring, and the course content will be re-designed. The instructor was Dick McKee, formerly with the City of Longmont, now working in the private sector. The course was in the *Environment* Focus Area, and worth 7 Credit Hours.

    - *Preventive Pavement Maintenance* - This was the second Roads Scholar II course offered this fall and covered types of pavement preservation and when to use; materials and equipment; training, adapting, and scheduling crew; working with a budget: performance based budgeting and job-cost analysis; problems encountered: weather, utility cuts, lack of budget dollars, lack of a strong pavement preservation policy; and local questions and discussion topics. The instructor was Dave Van Wagoner, formerly with the City of Grand Junction, now working in the private sector. This class was offered in 3 locations around the state. The course was in the *Transportation Management* Focus Area, and worth 7 Credit Hours.

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

- The LTAP program director serves as the Colorado Association for Roadway Maintenance (CARMA) Board of Directors secretary and newsletter editor. One CARMA Newsletter was designed and distributed this fall. The board met twice between October and December to develop agendas and speakers for both the November Winter Workshop and Spring Street Conference. LTAP helps coordinate needed infrastructure related presentations included on these agendas. Colorado LTAP also handles pre-registration processes for the Spring Street Conference, and is reimbursed by APWA for its services.
- Colorado LTAP staff served on CARMA's committee for *Winter Workshop* development. The training coordinator attended the workshop held for free at El Paso County DOT. There were 70 people in attendance, and topics covered Sun Safety; Panel on How Agencies are Using Contractors and Contracts for Winter Maintenance; New CDOT Winter Maintenance Applications; Panel on New Cutting Edge Technologies and Blade Options; and Winter Chain Use and Demo. A facilities tour was also scheduled with the El Paso County Sign Shop.
- Colorado LTAP joined 4 other select LTAP Centers to participate in a feedback meeting on Permeable Pavement Training Deployment. It was organized by FHWA Pavement & Materials Specialists; Office of Technical Services, and FHWA Resource Center. A rep from the Interlocking Concrete Pavement Institute discussed technology transfer of permeable pavements to state and local DOTs; addressing the importance of satisfying the mandate in MAP-21 for technology transfer of permeable/pervious/porous pavements. They are looking to work with LTAP in designing a ½-day or full-day course on permeable interlocking concrete pavements covering 1) permeable interlocking concrete pavement, 2) pervious concrete and 3) porous asphalt. Renée will continue to work with this group to develop a national conference session on the topic.
- The Colorado LTAP Director attended CDOT's Traffic Data Committee Meeting. Topics covered included MAP-21 and National Highway System changes; AVID Phase II; Bike & Ped Updates; National Committee Updates; and Data Sharing. Colorado LTAP has also set up an additional meeting with CDOT's Traffic Analysis Unit to discuss possible future project partnerships.
- Center staff responded to Safety related technical assistance requests for projects highlighting best practices from local agencies.
- The quarterly newsletter provided one article addressing topics regarding infrastructure management aspects – Asphalt Spray Bar project design.
- Colorado LTAP used the electronic mail list to promote available infrastructure management related webinars and other distance learning opportunities offered through organizations such as the national LTAP Clearinghouse; FHWA; and APWA.

## C.3 Workforce Development

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

- Training programs for the spring 2013 schedules were under development and course registration brochures for January & February classes were designed and distributed in December.
- The quarterly newsletter provided two articles addressing topics regarding workforce development aspects – online training for Federal-Aid Essentials for Local Public Agencies and Gravel Road Maintenance.

- *Supervisory Skills & Development (SSDP) Training* – This program is specifically designed to address workforce development issues. The courses offered in this program each year are intended to provide a fundamental understanding of the roles and responsibilities of a new supervisor and to develop tools for succeeding in management. There were 3 graduates this quarter in the Supervisory Skills program.

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

    - *Successful Employees Make Successful Supervisors* – This course addressed dealing with employees and managing for success. It presented characteristics of effective supervisors as project leaders, motivators, coaches, and team-builders. It was offered once in Grand Junction. This class was offered back-to-back with SYSN and also presented by Stefani Conley. The CDOT office in Grand Junction provided a free location for these two days of training.

    - *The Do's & Don'ts: Cover Your Assets or You Could Get Burned* – The third Supervisory course this quarter covered legal & liability issues of local governments and was presented by Tom Lyons, an attorney with Hall & Evans. The class addressed Guarantees, promises, representation; When to act? When to ask? Nobody ever told me about that; Supervisor conferences and records; Performance evaluations; Sexual harassment; and local issues and questions. This class was offered once on the Front Range at a free location provided by the City of Westminster. There were 3 Supervisory Skills graduates completing the program requirements with this course and were presented with their plaques.

- *Powerful Presentation Skills* – As an employee of a government agency, you may be asked to give a presentation about something related to your Department, division, or team. Your job may require you to make presentations to Council, Commissioners, community groups, or the public. This was a Roads Scholar II presentation skills course designed to provide a safe and relaxed environment in which to develop confidence and effectiveness in communicating with an audience. The class was designed to help participants: Develop ways to overcome and let go of stage fright and to portray confidence; Incorporate tips for creating and using visuals, including PowerPoint; Practice preparing and delivering a presentation in a sequential

framework that includes an opening & specific talking point; Be able to lead a Question and Answer session at the conclusion of a presentation. The instructor was Dave Van Wagoner, formerly with the City of Grand Junction, now working in the private sector. This class was offered in 2 locations – one on the Front Range and one on the Western Slope. The course was in the *Technical Skills* Focus Area, and worth 7 Credit Hours.

### C3.1 You Show Us Contest Support

In its 17th year, the concept for the "You Show Us" Contest began in 1994 with FHWA's "Show Us How". LTAP encouraged local agencies to enter as a profitable way to share their innovative ideas with others that may benefit from their cost saving concepts. It is a good way for road crews to get some well earned recognition for solving problems requiring efficient use of existing funds and materials, along with the application of cost-reducing and innovative techniques. Colorado LTAP administered the Colorado state and Region 7 "You Show Us" Contests this fall. Brochures promoting the contest were designed and distributed to government agencies in Colorado. Three entries were presented to the LTAP Advisory Board in September and the Asphalt Spray Bar project submitted by El Paso County was selected as the State winner. To encourage local agencies to share their successful programs and ideas, Colorado LTAP sponsored two participants from El Paso County to represent their project at the Local Road Coordinators' Conference in Rapid City in October, and they were in attendance to receive their state and regional awards. El Paso County's project also took 1st Place in the Regional contest, and their project is now submitted to compete nationally in the "Build a Better Mousetrap" Competition.

### C3.2 Local Road Coordinators' Conference Support

As one of the 5 sponsor centers, Colorado LTAP helped organize the annual LTAP Region 7 *Local Road Coordinators Conference* in Rapid City, South Dakota. Brochures promoting the conference were designed and distributed to local agencies throughout Colorado. To promote local participation, Colorado LTAP sponsored one speaker from the City of Golden to speak on Asset Management.

### C3.3 APWA Street Conference Administration & Library Materials

Colorado LTAP helps CARMA & APWA administer pre-conference planning, brochure design and distribution, registration, and agenda development for the Spring Street Conference held in Grand Junction each year. Colorado LTAP is reimbursed for all direct costs and an additional $2000; $1500 administration and $500 library training materials to benefit local agencies. Work on the conference program began this quarter, but the majority of the work for this conference is completed after the first of the year. As board members, Colorado LTAP staff have a significant influence on session topics presented at this conference.

## C.4 Operational Excellence

Colorado LTAP seeks to provide high quality services to meet the needs of its customers. Several activities were conducted to help ensure that LTAP is meeting this goal - including obtaining more feedback on emerging needs of Colorado's customers as well as their perception of the program. Operational Excellence is a continuous service management improvement program,

and efforts to improve our operational efficiency are continually implemented. Specific internal and external initiatives this fall included below.

- Throughout this quarter, Colorado LTAP prepared material needed to submit the annual Program Assessment Report (PAR) and Center Assessment Report (CAR) to FHWA in January 2013, as part of the evaluation effort for the National LTAP program.
- Colorado LTAP provided CDOT and FHWA quarterly and mid-year reports highlighting progress of Center operations including a budget/expense report.
- Complete program expenses for July 1 – December 31, 2012 are included in Appendix B.

## C4.1 Information Technology Services

- Colorado LTAP managed their Information Technology Services (ITS) to provide communication services to state agencies, local governments, and partners across Colorado and the United States. ITS incorporated the study, design, development, implementation, support and management of Colorado LTAP's telecommunication and computer-based information systems this quarter. It included maintaining network and video services, telephone, emailing, program websites and operational databases.
  - The website is a useful tool to communicate upcoming training courses and online registration, conferences, online training & webinars, needs survey, and to highlight resources specific to local agency needs, and is updated regularly. The web designer has been making continuous updates and suggesting new ideas for a fresh new design.
  - Our toll-free number continues to be available for any LTAP customer to reach us for direct technical assistance.
  - Expenses for ITS include web design and phone service and averaged $181/month.

- Colorado LTAP regularly updates the contact information of local transportation agency contacts for the efficient dissemination of training announcements, newsletter publications, library resources, outreach efforts, and technology transfer. LTAP staff work with transportation industry associations to identify potential customers, meet needs, and disseminate technology. The electronic mail list has increased to 175 recipients of Newsletters and 160 recipients of event Brochures. This service expedites facilitates communication, and provides more efficient service and improved coordination and delivery of technical assistance and technology services. It is extremely helpful to regularly update locals on upcoming free online or webinar based training opportunities. The mailed brochure and newsletter lists are still maintained (1514 for Newsletters and 1057 for Brochures) until the recipient chooses to switch to electronic mailings.

## C4.2 Equipment

This budget category covers purchasing office equipment and supplies necessary for production of training materials, office tasks, and to keep up with technology that will help the program efficiently deliver technology deployment. The majority of expense in this category this quarter was related to the monthly lease and meter readings of the Konica Minolta copy machine, which averaged $145/month.

## C4.3 Office Supplies

A majority of office supply costs are now included in the copier lease program. However, additional expenses in this category included paper for any printed products – brochures,

certificates, name badges, flyers, etc –envelopes, certificate paper, notebook binders for SSDP classes, and toner for the other HP printer, etc. There was $1,143 was spent on office supplies this quarter.

### C4.4 Staff Training

Due to limited funds, the Staff Training budget had to be removed from this year's work plan.

### C4.5 Monthly & Quarterly Advisory Meetings

- October 1 – December 31, Colorado LTAP staff and project sponsors held one meetings/conference call in October to review project status and other program initiatives. Additional Advisory Board meetings were held in September and November.

- *LTAP Advisory Board* - Quarterly Advisory Board meetings are organized to solicit input for program content, provide feedback on needed services, and evaluate the effectiveness of the program. There are nine *voting* members on the advisory board representing cities and counties across the state. There are also four non-voting members representing the program and sponsoring agencies. The LTAP advisory board is now represented by 2 City representatives and 7 County representatives. Board members are not paid for their participation, but are reimbursed for direct expenses incurred due to attending LTAP meetings. This quarter, $666 was spent on the advisory board meeting.
- The advisory board met on November 26th in Colorado Springs. Topics discussed included: National transportation issues, Snow & Ice Conference, Walk to School Day efforts, NCHRP Research, CARMA Winter Workshop, developing LTAP training, local roads conference, and LTAP projects and technical assistance.

### C4.7 NLTAPA Dues

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

## Financial Report

Total program expenses for October 1, 2012 – December 31, 2012 are included in Appendix B. The attached itemized categories list shows a balance of ($14,986.75) for the first half of the year. The total expenses for the whole first half of the year were included so as to review status of each category in reference to the proposed budget. The training program is currently under budget; the conference sponsored You Show Us contest winners have not yet billed for reimbursement; all out-of state travel so far is considerably under budget; and office supplies and the Library program are currently at their budgeted amount so they will need to borrow money from another category to complete the spring. Part of the reason for the negative balance is that the LTAP program has not yet received its $27,500 match from the CEAE Graduate School.

# Appendix A: Profile Training Hours October 1, 2012 – December 31, 2012

| Class Name | Location | Date | Hrs/class | # Part. | NS | WL | CAN | Tot. Part. Hours |
|---|---|---|---|---|---|---|---|---|
| **ROADS SCHOLAR CORE COURSES** | | | | | | | | |
| | | | | | | | | |
| **RS CORE: Drainage** | | | | | | | | |
| 96.85% | Pueblo | 10/1/12 | 7 | 22 | | | 6 | 154 |
| 94.33% | Dillon | 10/2/12 | 7 | 27 | 1 | | 1 | 189 |
| 97.62% | Montrose | 10/4/12 | 7 | 15 | 2 | | 1 | 105 |
| | | | | | | | | |
| **RS CORE: Safety on the Job** | | | | | | | | |
| 99.60% | Colorado Springs | 11/7/12 | 7 | 45 | 8 | | 4 | 315 |
| 97.78% | Loveland | 11/13/12 | 7 | 38 | 2 | | 2 | 266 |
| | Grand Junction | 11/27/12 | 7 | 19 | 4 | | 1 | 133 |
| | | | | | | | | |
| **ROADS SCHOLAR I ELECTIVE COURSES** | | | | | | | | |
| | | | | | | | | |
| **RS ELECTIVE: Forklift Competency Certification** | | | | | | | | |
| 98.15% | Fort Morgan | 10/16/12 | 7 | 9 | | | 3 | 63 |
| 100.00% | Colorado Springs | 10/18/12 | 7 | 16 | | | 1 | 112 |
| 90.74% | Montrose | 10/30/12 | 7 | 9 | 3 | | | 63 |
| | | | | | | | | |
| **RS ELECTIVE: Winter Survival** | | | | | | | | |
| 97.44% | Gypsum | 10/22/12 | 7 | 13 | | | | 91 |
| 97.59% | Aurora | 10/23/12 | 7 | 31 | 1 | | 5 | 217 |
| 100.00% | Aurora | 10/24/12 | 7 | 27 | 1 | | 1 | 189 |
| | | | | | | | | |
| **ROADS SCHOLAR II COURSES** | | | | | | | | |
| | | | | | | | | |
| **RS II: Technical Skills Focus Area** | | | | | | | | |
| | **Powerful Presentation Skills** | | | | | | | |
| 97.06% | Centennial | 11/5/12 | 7 | 18 | 1 | | | 126 |
| 100.00% | Grand Junction | 11/11/812 | 7 | 9 | 2 | | | 63 |
| | | | | | | | | |
| **RS II: Environment Focus Area** | | | | | | | | |
| | **Water Quality** | | | | | | | |
| 47.22% | Montrose | 11/16/12 | 7 | 12 | | | | 84 |
| | Pueblo | 11/26/12 | 7 | 10 | 1 | | 1 | 70 |
| - | Denver - Rescheduled | 12/4/12 | 7 | | | | | 0 |
| | | | | | | | | |
| **RS II: Transportation Management Focus Area** | | | | | | | | |
| | **Preventive Pavement Maintenance** | | | | | | | |
| working on | Grand Junction | 11/30/12 | 7 | 33 | 3 | | | 231 |
| working on | Durango | 12/5/12 | 7 | 14 | | | | 98 |
| working on | Westminster | 12/17/12 | 7 | 34 | | | 2 | 238 |
| | | | | | | | | |
| **SUPERVISORY SKILLS & DEVELOPMENT PROGRAM** | | | | | | | | |
| | | | | | | | | |
| **SSDP: So You're A Supervisor Now** | | | | | | | | |
| 96.30% | Grand Junction | 10/15/12 | 7 | 10 | | | 1 | 70 |
| **SSDP: Successful Employees Make S.S.** | | | | | | | | |
| 100.00% | Grand Junction | 10/16/12 | 7 | 8 | | | 1 | 56 |
| **SSDP: Do's & Don'ts: Legal & Liability** | | | | | | | | |
| 97.59% | Westminster | 11/25/12 | 7 | 26 | 8 | | 2 | 182 |
| | | | | | | | | |
| **94.60%** | | **Total Fall 2012 Participants:** | | **445** | | | | |
| **Evaluations** | | Total **RS** I Participants: | | 271 | | | | 1897 |
| | | Total RS II Participants | | 130 | | | | 910 |
| | | Total **SSDP** Participants: | | 44 | | | | 308 |
| | | | | **Total Participant Hours:** | | | | **3115** |

# Appendix B: Total Program Expenses, July 1, 2012 – December 31, 2012

Itemized Categories
7/1/2012 through 12/31/2012

| | | |
|---|---|---|
| **INCOME** | | **160,385.91** |
| 1. SPONSOR REIMBURSEMENTS | | |
| a. CDOT Reimbursement | 118,125.00 | |
| b. CU Matching | 18,333.00 | |
| c. Class Registration Fees | 23,927.91 | |
| c1. Deposits | 24,105.00 | |
| c2. Credit Card Charges | -177.09 | |
| d. Partner Reimbursement | 0.00 | |
| **EXPENSES** | | **-175,372.66** |
| A. PROGRAM ADMINISTRATION | | -105,909.85 |
| A1. Administration Costs | -80,670.64 | |
| A2. Program Administration Fee | -25.239.21 | |
| B. TRAINING PROGRAM | | -52,147.67 |
| B1.1 Training | | |
| a. Roads Scholar | -34,572.08 | |
| b. Supervisory Skills | -7,780.60 | |
| d. Special Training Programs | | |
| d1. Heavy Equipment Training, Fall | -7,668.54 | |
| Other B. TRAINING PROGRAM:B1.1 Training | -2,126.45 | |
| C.0 GENERAL | | -9,522.36 |
| C0.1 Newsletter & Information Exchange | -1,424.82 | |
| C0.2 Library Services | -2,188.88 | |
| C0.3 Prog Marketing Outreach Research | -2,508.06 | |
| C0.4 Out-of-State Travel | -3,400.60 | |
| 1.TRB | -376.49 | |
| 3.National LTAP Meeting | -2,131.34 | |
| 4.Local Roads Conference | -892.77 | |
| C.1 SAFETY PROGRAMS | | -156.67 |
| C1.1 Safety Awareness Programs | -43.50 | |
| C1.2 Retroreflectivity Prog | -113.17 | |
| C.3 WORKFORCE DEVELOPMENT | | -1,956.45 |
| C3.1 You Show Us Contest | 0.00 | |
| C3.2 Local Roads Conference | -1,626.56 | |
| C3.3 APWA Conf Admin & Library Matls | -329.89 | |
| C.4 OPERATIONAL EXCELLENCE | | -5,679.66 |
| C4.1 Information Technology Services | -1,080.41 | |
| C4.2 Equipment | -1,356.61 | |
| C4.3 Office Supplies | -1,483.79 | |
| C4.5 Advisory Meetings | -1,258.85 | |
| a. Quarterly Meetings | -1,252.62 | |
| b. Monthly Meetings | -6.23 | |
| C4.7 NLTAPA Dues | -500.00 | |
| **Balance Forward** | | **0.00** |
| | **OVERALL TOTAL** | **-14,986.75** |

# 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: 10/1/12 through 12/31/12
Type: SP&R Start: 11/16/11
PO: 271001543
PO Ends: 11/15/2014

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

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 10/19/10 | 100 | 10/19/10 | Advertise RFP |
| 9/9/11 | 100 | 9/9/11 | Receive Proposals |

| | | | |
|---|---|---|---|
| 9/20/11 | 100 | 9/20/11 | Selection |
| 11/16/11 | 100 | 11/16/11 | Notice to Proceed |
| 1/17/12 | 100 | 1/17/12 | Kick-Off Meeting |
| 2/1/12 | 100 | 2/1/12 | Literature Review |
| 3/1/12 | 100 | 3/1/12 | State of the Practice |
| 3/1/12 | 100 | 3/1/12 | Data Collection and Evaluation |
| 11/15/12 | 95 | | Data Analysis |
| 11/30/12 | 60 | | Bike/Pedestrian Models and Estimation Factors |
| 12/30/12 | 40 | | Final Report |

## SIGNIFICANT EVENTS

- Data analysis near completion (data from 17 more locations received in late July that required additional formatting and analysis)
- Made progress toward statistically selecting best method for factor creation (Denver data investigated but need to include data from other locations before final selection)
- Continue documenting work in final report

## ANTICIPATED EVENTS FOR Q4 2012

- Completion of data analysis
- Completion of bike/ped models and estimation factors
- Complete final report

# 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 development of a proposed roadmap for inclusion of the French and Hamburg Test results in QA/QC for pay on asphalt projects would assist the CDOT Staff Materials and Geotechnical Branch Asphalt Program in facilitating the discussion with CDOT Regions and industry on the potential options, costs, and other opportunities for associated inclusion. CDOT currently performs testing on asphalt project materials in the Euro Lab for information only. The Euro Lab has a considerable investment in equipment (~$600,000) and personnel (2- FTEs). The operating costs are considerable and the continued use of information only testing may be of limited value. Other DOTs (i.e. Utah, Texas, Illinois Tollway Authority) have advanced the use of their European labs to be included in acceptance and possibly for incentive/disincentive payments for quality. The Asphalt Program anticipates that industry and possibly CDOT Regions would be resistant to incorporating the results from the Euro Lab, as it would require substantial capital expenditure to set up a statewide program. There may be opportunities to eliminate some existing testing requirements with the inclusion of Euro Lab results in the QA/QC acceptance items, and the test results from the European test results may be better indicators of the expected performance of in-place asphalt pavements.

Reporting Period: 10/1/12 through 12/31/2012
Type: SP&R Start: End:

Principal Investigators: TBD

Study Manager: TBD

Study Panel Leader:
Mike Stanford, Materials and Geotechnical Br.
303-398-6544

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 |
|---|---|---|---|
| 8/20/12 | 100 | | Hold initial study panel meeting |
| 12/19/12 | | | Develop scope of work |
| 12/26/12 | | | Select researcher |
| 01/02/12 | | | Start project |
| 07/26/13 | | | Submit draft final report |
| 09/12/13 | | | Conduct presentation of completed work to CDOT |

| | | | |
|---|---|---|---|
| 10/17/13 | | | Submit final report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Durable Wearing Surfaces for HMA
## Study No: 10.37

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: 09/01/02 Ver: 12/31/02<br><br>Principal Investigator(s):<br>Skip Outcalt, Research 303-757-9984<br>Dave Weld, Research 303.512.4052<br><br>Study Manager:<br>Skip Outcalt (303)-757-9984<br><br>Study Panel Members:<br>Bill Schiebel, Region 1 Materials<br>Dave Eller, Region 3 Eng<br>Jay Goldbaum, Materials and Geotechnical |
|---|---|
| The Colorado Department of Transportation spends a large sum of money each year on the design and placement of new asphalt pavements. Inevitably, these pavements will need rehabilitation. Wearing surfaces provide an alternative to CDOT's current rehabilitation strategies. A pavement design system incorporating wearing surfaces will both protect the existing pavement structure and provide a quality overlay system for all pavements. A durable wearing surface is essential for preserving CDOT's investment in its paving program.<br>The wearing surfaces will be evaluated on an annual basis at eleven sites: Five SMA sites, three Nova chip sites and three SHRP SuperPave SX sites. The test sites will have their ruts measured, cracks mapped, general condition visually evaluated and the skid number and texture depth measured using the CDOT Pavement Friction Test System (skid truck and trailer). | |

## MILESTONES

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

## SIGNIFICANT EVENTS

**6/12:** Data collection and analysis in progress

**3/12:** Data collection and analysis in progress

**1/12:** Data collection and analysis in progress

**06/11:** Site evaluations for 2011 in progress

**09/10:** Site evaluations for 2010 continue

**06/10:** Site evaluations for 2010 in progress

**12/09:** Site evaluations completed for 2009

**10/09:** Site evaluations are in progress.

**12/08:** Site evaluations have been completed.

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

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

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

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

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

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

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

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

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Participation in Southeastern Superpave Center
## Study No. 10.40

Background

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.

The products of this research may include the development of specifications, practices, and equipment to help build and extend the service life of a hot mix asphalt pavement.

Reporting Period : 10/1/12 through 12/31/12
Type: SP&R Start:7/03 Ver:

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

Technical Panel Leader:
Bill Schiebel, Region 1 Materials
(303) 398-6801

Study Panel Members:
Jim Zufall, Materials and Geotechnical Br.
Steve Olson, Materials and Geotechnical Br.
Jay Goldbaum, Materials and Geotech. Br.
Richard Zamora, Region 2 Materials
Rex Goodrich, Region 3 Materials
Gary Dewitt, Region 4 Materials
Michael Coggins, 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 | Tim Aschenbrener, Jay Goldbaum, Bob Laforce, Bob Mero and Donna Harmelink met to discuss the possibility of developing a study to conduct noise evaluation on pavements in Colorado. It was decided that the evaluation this fall would be conducted by NCAT with their Close-Proximity 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 will measure noise levels using the close proximity method on 21 sites. |
| 12/31/04 | 100 | 4/08/05 | NCAT will provide a report regarding noise levels measured and compare measurement from the 17 sites the previous year. |
| 06/30/05 | 100 | 07/05 | Draft final report was accepted and loaded into CDOT Research Branch website. |

| | | | |
|---|---|---|---|
| 10/12/05 | 100 | 10/18/05 | NCAT performed (Close Proximity Testing) 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 plans to complete another round of noise measurements and may perform other types of research services or projects for CDOT. |
| 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. |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

09/30/12 The Materials and Geotechnical Branch Asphalt Program Manager Mike Stanford had arranged an NCAT Short Course in Asphalt Technology to be conducted at Colorado Asphalt Pavement Association (CAPA) office in Denver from December 10 to December 13, 2012. A total of CDOT 14 employees will be attending the course including two from Research Branch. Meanwhile, the setting up of the next phase of pooled-fund program (next 3 years) for Southeast Superpave Center led by Alabama DOT is underway. The set-up is necessary to commit fund to this pooled-fund effort.

06/30/12 No activity was reported during this quarter.

12/31/11The final report is kept in our experimental features published materials.

09/30/11 Comments to the draft report were provided by Region 1 Materials Engineer, Bill Schiebel.

06/30/11 No activity was reported during this quarter.

03/02/11 Dr. Randy West of NCAT gave an electronic copy of the draft report on WMA research to Roberto DeDios. Region 1 Materials Engineer, Bill Schiebel will review and provide comments.

10/15/10 The National Center for Asphalt Technology (NCAT) and CDOT performed the final distress survey of the warm mix asphalt (WMA) test sections in I-70 from Mileposts 208 to 211.

09/30/10 Region 1 Materials Engineer Bill Schiebel scheduled a pavement distress survey of WMA test sections on I-70, west of Eisenhower Tunnel on October 15, 2010.

06/30/10 No work was reported for this quarter.

03/31/10 No work was reported for this quarter.

11/17/09 Performed pavement distress survey on WMA test sites on I-70.

09/30/09 No work was performed for this quarter. A new pooled-fund study for this effort is being set up for the

next three years with the Alabama DOT as the lead agency. The pooled-fund transfer process is currently being done by the Office of Financial Management and Budget (OFMB). NCAT is currently involved in evaluating Region 1 warm mix asphalt (WMA) experimental project built on I-70 west of Eisenhower Tunnel.

06/30/09 No work was performed this quarter.

12/31/08 No work was performed this quarter.

09/30/08 The draft report is still being reviewed by the Study Manager for final editing by the CDOT Librarian before uploading into the branch web site.

06/30/08 The draft report is still being reviewed by the appropriate Research Branch staff before uploading into the branch website.

02/11/08 The Research Implementation Council (RIC) approved the continued annual funding in the amount of $20k for Southeast Superpave Center/NCAT research activities.

10/02/07 NCAT submitted the draft final report for the CPX noise measurements project involving 30 test sites. The review of the draft report by the technical panel is still under process.

9/30/07 NCAT completed the CPX noise measurements for 30 sites that Transtec Group is also doing.

7/07 to 8/07 NCAT personnel participated in monitoring the Warm Mix Asphalt (WMAs) installations carried out by Region 1 on I-70 west of the Eisenhower Tunnel.

6/30/07 NCAT is in the process of conducting the noise study using the close-proximity trailer test that was planned for calendar year 2006. Also, NCAT is currently doing the Warm Mix Asphalt (WMA) experimental research project on I-70 in Region 1. NCAT will have the responsibility of monitoring, collecting data, documenting the placement of WMA additives consisting of Aspha-min, Sasobit, and Evotherm.

3/20/07 Communication with Don Watson of Auburn University indicated that the $20k approved by the RIC for participation in Southeastern Superpave Center should be contributed to the pooled-fund no. TPF 5-037. As soon as the contribution is made to this fund, NCAT should be able to proceed with the noise testing as well as other asphalt/pavement-related research needed by CDOT.

3/02/07 The DTD Director and Chief Engineer approved the entire Research Branch Program which included the $20k pooled-fund money for participation in Southeastern Superpave Center.

1/29/07 The Research Implementation Council (RIC) approved $20k funding for participation of CDOT in the pooled-fund research effort of the Southeastern Superpave Center/National Center for Asphalt Technology.

11/06 The final report for the tire-pavement noise data collected by NCAT for the year 2005 was completed and loaded into CDOT Research Branch website.

6/06 NCAT was reminded to submit the final report that incorporates the recommended changes from the research study panel but NCAT never responded.

5/06 NCAT submitted the draft final report for review and comment. The draft report was reviewed by the research panel members and comments were transmitted back to NCAT for incorporation into the final report.

The revised final report has not been received until the end of this quarter's reporting period.

2/06 NCAT promised to deliver the draft final report. The draft final report has not been received by the end of the first quarter of 2006.

12/15/05 NCAT indicated that it will send the preliminary noise data in 01/06. The analysis is almost complete. CDOT requested NCAT to deliver one updated report that included all the data collected in the past and the year 2005.

10/03/05 Research Coordination Engineer Rich Griffin notified NCAT to go ahead with another round of noise measurements for Colorado Noise Study this year.

6/16/05 The revised draft final report was submitted by NCAT. The draft final report is being reviewed and processed for final publication, distribution, and uploading into the CDOT Research Branch website.

3/22/05 The draft final report was submitted by NCAT for review and comment.

10/22/04 A meeting was held with both members of the Pavement and Environmental Oversight Teams to hear presentations from Doug Hanson of NCAT and Mike Hankard of Hankard Environmental, Inc. on the status of pavement and environmental noise studies in Colorado. Also, the meeting was held to evaluate the needs for future noise research studies.

7/31/04 The study manager, Donna Harmelink, has retired. Robert DeDios is serving as manager for now.

7/30/04 Based on two meetings in July, the study panel decided to request NCAT to conduct CPX noise testing on 21 sites in Colorado. Seventeen of these sites were tested in the fall of 2003, while four additional sites were added. This will help establish a trend in noise emissions as pavements age.

7/30/04 The panel also decided to submit a problem statement for the Research and Implementation Council to consider for funding July 1, 2005. The problem statement will outline a long-term study on pavement noise to determine how pavement/tire noise varies as the pavement ages. SBPI roadside noise testing will also be incorporated into this proposed study to determine how pavement/tire noise affect neighborhood noise levels.

3/31/04 With the FY 04 money from the Southeast Superpave Center, NCAT brought their specially developed noise trailer to Colorado to evaluate 17 projects with various surface treatments. The seventeen projects included different textured concrete, including the evaluation of the Minnesota drag, carpet drag, longitudinal tining, transverse tining, and ground surface. In addition several different asphalt mixtures were included. The asphalt surface treatments evaluated were SMA, OGFC, Nova Chip and Superpave S and SX. The data was collected in fall 2003 and NCAT analyzed the data and provided the department with a written report. The conclusion of their evaluation indicated that the OGFC surface was the quietest and that the age of an HMA pavement can have a major effect on the noise level of the pavement. This was a limited study and further research was recommended. The report no. is CDOT-DTD-R-2004-5.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Evaluation of Longitudinal Joint Density
## Study No. 10.155

Background

The longitudinal joint between asphalt mats is a major area of pavement distress. During the placement of asphalt pavement it is difficult to compact the unconfined edge, which typically results in lower densities than in the remainder of the asphalt mat.

The inconsistent quality of the longitudinal joints in hot mix asphalt pavements was a concern with both the asphalt industry and CDOT and eventually was identified by the Chief Engineer to be addressed. A task force effort was identified and the direction of the task force was to develop an end result specification based on density at the longitudinal joint.

In 2000, the longitudinal joint construction on 7 projects was monitored to determine the state of the practice for the construction of the longitudinal joints. The construction method and density at the joint and adjacent mat was documented. A minimum of seven projects constructed under the new longitudinal joint density specification will also be monitored for comparison to the joints in the projects from 2000. In 2005 7-12 new sites will be added, at least one for each regions. SMAs are also included in the study.

Reporting Period: 10/1/12 through 12/31/2012
Type: SP&R Start:7/03 Ver:

Principal Investigator(s):
DTD Research Branch
Dave Weld, Research 303.517.4052

Study Manager: TBD

Study Panel Members:
Bill Schiebel, R1 Materials 303.398.6801
Donna Harmelink, FHWA 720.963.3021

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 6/05 | | 9/15/05 | Approximately, two sites from each region will be identified for incorporation into this study, one of which may be an SMA. |
| 9/05 | | 10/15/05 | Establish 10 test sections. Acquire 10 cores at 5 locations in a 1000 foot test section, one on the center of the joint and one on the hot side. Deliver the cores to staff materials for density. Review and document any distresses at the site. Only 8 test sections established. |
| 06/06 | 100 | 12/31/06 | Materials Lab testing of cores |
| 9/06 | 100 | 6/30/07 | Review and document any distresses at the site. |
| 9/11 | | | Review and document any distresses at the site. |
| 12/12 | | | Project to be closed out. Letter will be sent to inform FHWA of the Research Branch and Materials Advisory Committee's decision to officially close this project. |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**09/30/12** No activity was reported during this quarter.

**05/31/12** Research staff met with FHWA personnel to discuss the final disposition for this project which had been inactive for a while. Construction specifications had already been developed and implemented in the field. FHWA suggested soliciting the opinion of the Materials Advisory Committee (MAC) on what direction to take since construction specifications were already in place and working well which was the ultimate goal of the study in the first place. It was decided that this project will be closed out and a letter will be drafted to inform FHWA of this decision.

**5/07/12** Dave Weld conducted field inspections and noted that the longitudinal joints are performing very well.

**09/30/10** Dave Weld conducted a field inspection and took photos of the various test sites during this quarter to document any observed distresses in the pavements.

**6/30/07** The visual survey of the remaining sites to be evaluated is underway.

**3/31/07** Powers Blvd. was dropped from the 8 test sections being monitored because it was milled. Four sites had been visually inspected and no distresses related to longitudinal joint failure were observed. No cracking and rutting were noted. Photos for these four sites are shared in Dave Weld's PC. The visual survey or evaluation of the other three sites is planned to be completed sometime in June of this year.

**1/01/07:** Roberto de Dios took over as Study Manager for this project.

**06/30/06:** The principal investigator, Ahmad Ardani, retired June 1, 2006.

**03/31/05:** The scope of work was revised and Research is now soliciting two sites from each region to incorporate into this study. These sites may include SMAs.

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

**12/31/04:** The Materials Engineer and the Materials Advisory Committee discussed the lack of projects available for evaluation in 2004 and set a target of seven projects in 2005.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: 11/1/12 End: 12/01/14<br><br>Principal Investigator:<br>David Peshkin, Applied Pavement Technology, Inc.<br><br>Study Manager: TBD<br><br>Study Panel Members:<br>Phillip Anderle, R-4 Maintenance<br>Donna Harmelink, CO Div. FHWA<br>Frank McCoy, R-6 Maintenance<br>Mark Mueller, Staff M&O<br>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.<br><br>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 | 50 | | Task 1 literature review |
| 2/14/13 | | | Kick-off meeting |
| 6/30/13 | | | Status update |
| 7/15/13 | | | Task 2 Draft guidelines |
| 7/15/13 | | | Task 3 Draft procedures |
| 9/15/13 | | | CDOT completes review of guidelines and procedures |
| 10/15/13 | | | Task 2 Final guidelines |
| 10/15/13 | | | Task 3 Final procedures |
| 10/31/13 | | | Presentation |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

12/15/12 Literature search completed.
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

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

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: End: |
|---|---|
| Crack sealants are often placed in transverse cracks to extend pavement life. However, when a hot mix asphalt overlay is placed on top, a pavement bump and additional transverse cracks often occur in the new overlay asphalt above the sealant.<br><br>Previous research and observations indicate that much of the problem may result from the overlay slipping on the sealant during rolling. Suggestion to mitigate this age-old problem include: 1) overlay mixtures with high frictional properties 2) variations of the compaction equipment and rolling scheme, and 3) the use of stiffer tack coats and sealant materials.<br><br>This research will seek to identify the primary reasons for these bumps and determine the best approach to mitigation. | Principal Investigators:<br>Tentatively, Scott Shuler, CSU<br><br>Study Manager: TBD<br><br>Study Panel Members:<br>Donna Harmelink, CO div. of FHWA<br>Michael Stanford, Materials and Geotech Branch<br>Bill Schiebel, Materials and Geotech Branch |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 8/31/12 | | 9/10/12 | Hold initial study panel meeting. |
| 9/15/12 | | 9/14/12 | Develop scope of work |
| 9/30/12 | | 9/14/12 | Issue RFP: Scott Shuler of CSU was asked to provide proposal by 10/8/12 |
| 10/31/12 | | 10/16/12 | Select researcher: The final proposal was received from Dr. Shuler. |
| 11/20/12 | | | Find Paving Project for test sections: We are having a problem finding an appropriate paving project for this research. CDOT only has two projects statewide that include warm mix: on near Cortez and one on Berthoud Pass. The Cortez site is a problem because of its distance from Ft. Collins and Berthoud Pass is a problem because of grade and curves complicating traffic control. |
| 11/31/12 | | | Notice to Proceed. Can't move forward until resolve the test section issues. |
| 9/15/13 | | | Draft Final Report |
| 11/31/13 | | | Final Report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

# 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<br><br>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.<br><br>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.<br><br>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.<br><br>CDOT will build the test section per UDFCD design at a maintenance yard and UDFCD will conduct the monitoring and reporting. | Reporting Period: 10/1/12 through.12/31/12<br>Start: TBD Contract Amount: $ 70,000<br><br>Principal Investigator:<br>Ken A. MacKenzie, P.E., CFM<br>Master Planning Program Manager<br>Urban Drainage and Flood Control District<br><br>Study Manager:<br>Bryan Roeder, CDOT, 303-512-4420<br><br>Study Panel Leader:<br>Mommandi, Amanullah, CDOT Hydraulics Program Manager<br><br>Study Panel Members:<br>Rik Gay, CDOT EPB<br>Mike Banovich, CDOT EPB<br>Bob Mero, R6 Materials<br>Bill Schiebel, Staff Materials and Geotech Branch |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 7/15/12 | | 7/18/12 | Select study panel |
| 7/31/12 | | 8/27/12 | Finalize scope of work that will be attached to the IGA. |
| 11/1/12 | | 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 | 50% | | 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. |

| | | | |
|---|---|---|---|
| 2/28/13 | | | Design Test Sections |
| 6/30/13 | | | Build Test Sections |
| 7/15/13 | | | Begin Monitoring test sections |
| 7/31/13 | | | Initial Falling Weight Deflectometer (FWD) test |
| 7/15/15 | | | Monitoring concludes |
| 7/31/15 | | | Final FWD test |
| 10/15/15 | | | Draft report |
| 12/31/15 | | | Final Report publication |

## SIGNIFICANT EVENTS

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

9/30/12: An extensive process requirement for Local Government agreements when construction is involved has prevented moving forward. It is necessary to first establish the location of the test sections before continuing.

# 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: 10/1/12 through 12/31/12
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
Roy Guevara, CDOT Materials and Geotechnical Branch
Donna Harmelink, FHWA Colorado Division
Stephen Henry, CDOT Materials and Geotechnical Branch
Gary Strome, CDOT R-4 Materials

Research Study Manager: TBD

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 3/31/09 | 100 | 3/31/09 | Notice to proceed |
| 7/31/09 | 100 | 3/31/10 | Task 1 – Literature Review |
| 8/31/09 | 100 | 6/30/09 | Task 2 – Activity Plan and Schedule |
| 3/31/13 | 100 | 6/30/10 | Task 3 - Execute Activity Plan |
| 3/31/13 | 0 | | Task 4 – Final Presentation |
| 3/31/13 | 100 | 12/31/12 | Task 5 – Quarterly Progress Reports |
| 3/31/13 | 0 | | Task 8 – Final Report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

A draft of the specifications for design and construction of chip seals using local alluvial aggregate sources for chip seals on low volume roadways was continued this quarter. The intent is to complete the recommendations for the specification during the next quarter after a final condition survey is done to document performance during the past year.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Asphalt Emulsion Full Depth Reclamation Best Practices
## Study No: 12.75

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: End:<br><br>Principal Investigators: TBD<br><br>Study Manager: TBD<br><br>Study Panel Members: (Tentative)<br>Gary DeWitt, R-4 Materials, 970-350-2379<br>Shamshad Hussain, R1Materials, 303-398-6802<br>Steven Henry, Mat. and Geotech Branch, 303-398-6579<br>Mike Stanford, Mat. and Geotech Branch, 303-398-6576<br>Donna Harmelink, CO. Div. of FHWA |
|---|---|
| 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.<br><br>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. | |

## 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 | | 11/5/12 | Select researcher. Scott Shuler with CSU was selected to perform the research |
| 12/7/12 | | 11/28/12 | Notice to Proceed |
| 9/20/13 | | | Draft Final Report |
| 12/7/13 | | | Final Report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

# 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: 10/1/12 through 12/31/12
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:
Bill Schiebel, R1 Materials 303.398.6801
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 |
| 02/28/12 | | | Draft final report |
| 04/30/13 | | | Publish final report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**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.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: End: |
|---|---|
| Poor bonding with underlying HMA layers can greatly influence the long term performance of HMA in the form of premature cracking and fatigue. The primary method to achieve bonding between layers is through the use of an emulsified tack coat, which is typically diluted at 50/50 with water before application. The tack coat is often tracked by HMA delivery vehicles during the paving process. 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, we assume responsibility for any pavement failures related to poor bonding. CDOT should consider 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.<br><br>This research will first determine if bond failure is a significant problem and then if it is, the research will develop a bond strength test and test it on several overlay projects with varying tack coats to determine an acceptable range for the specification. | Principal Investigators: TBD<br><br>Study Manager: TBD<br><br>Study Panel Members:<br>Richard Zamora, Program Development 303-757-9040<br>Gary Dewitt, R-4 Materials , (970) 506-0359<br>Shamshad Hussain, R-1 Materials, 303- 398-6582<br>Michael Stanford, Mat. & Geotech Branch, 303-398-6544<br>Craig Wieden, R-2 Materials, (719)546-5438<br>Donna Harmelink, CO div. of FHWA 720-963-7021 |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 7/25/12 | | 7/25/12 | Hold initial study panel meeting. |
| 8/15/12 | | 8/15/12 | Develop scope of work |
| 8/30/12 | | 9/18/12 | Issued Invitation for Bid (Due 10/14/12) |
| 9/30/12 | | | Select researcher |
| 10/31/12 | | | Start Project |
| 10/31/15 | | | Draft Final Report |
| 12/31/15 | | | Final Report |

## SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| | |
|---|---|
| Background<br><br>Despite recent advancements in the design of asphalt mixtures containing Reclaimed Asphalt Pavement (RAP), many states are still cautious in their regulations to avoid durability problems related to the recycling process. In many states, RAP is currently not allowed in highest-class asphalt mixtures and in polymer-modified asphalt products. In addition, high percentages of RAP exceeding 25% are not commonly used in practice. On the other hand, many state agencies are taking a more aggressive approach by considering increasing the allowable percentages of RAP in hot-mix asphalt (HMA) to take full advantage of this promising technology. For instance, up to 50% RAP has been used in some asphalt mixtures, which produced an acceptable level of performance.<br><br>To ensure successful use of RAP, confidences in the mixture design procedure require addressing many concerns related to the interaction between virgin and recycled materials and durability of the produced mixture. Current AASHTO recommendations make it difficult to design asphalt mixtures with high-RAP contents. Modifications to the current specifications are needed to assure agencies that satisfactory performance will result from the use of high-RAP content HMA mixes. | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: End:<br><br>Principal Investigators: TBD<br><br>Study Manager: TBD<br><br>Study Panel Members:<br>Masoud Ghaeli, Region 6 Materials, 303-398-6701<br>Bill Schiebel, Region 1 Materials, 303-398-6801<br>Mike Stanford, Materials and Geotechnical Br. |

## MILESTONES

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

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

## SIGNIFICANT EVENTS

**The CDOT Study Manager, Roberto DeDios, retired from CDOT in January 2013**

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

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Assessment of Alternate PCCP Texturing Methodologies in Colorado
## Study No: 21.80

Background

CDOT, as part of a multi-state, FHWA-sponsored study conducted in 1995, adopted a new texturing specification for its concrete pavements. The new specification, which was adopted in 1977, called for uniformly spaced longitudinal tining at 3/4 of an inch intervals with the depth and width of 1/8 of an inch. The results of this study indicated that longitudinal tining, in addition to possessing adequate frictional properties, were easier to install and produced a lower noise level than CDOT's traditional transverse tining (1"uniformly spaced). However, CDOT has received complaints concerning the handling of vehicles on newly constructed Portland cement concrete pavements textured with longitudinal tining.

An effort is under way to address the handling problems associated with longitudinal tining. The goal of this study is to identify a texturing method that is safe and durable, provides adequate surface friction and lowers the noise levels.

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 06/30/01

Principal Investigator(s):
The Transtec Group, Inc.
Robert Otto Rasmussen, Ph.D., INCE, P.E.(TX)
512-451-6233

Technical Field Support:
Skip Outcalt, CDOT Research, 303.757.9984

Technical Panel Leader:
Jay Goldbaum. Mat'l. & Geotech 303-398.6561

Study Manager: TBD

Study Panel Members:
Jim Zufall , Materials & Geotech 303-757-9249
Eric Prieve, Materials & Geotech 303-398.6541
Donna Harmelink, FHWA, CO Div. 720-963-3021
Richard Zamora, R-2 Materials 719.546.5778

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 07/30/01 | 100 | 07/30/01 | Meet with the ACPA/CDOT task force members to discuss the issues related to longitudinal tining and to develop strategies for conducting a study. |
| **09/31/01** | 100 | 03/30/01 | Assemble a study panel and identify locations with vehicle handling problems. Conduct preliminary investigations and report the results |
| 09/31/01 | 100 | 10/30/01 | Identify test sections on upcoming new concrete paving projects and examine the use of astro-turf as a method to texture concrete. |
| 07/30/02 | 100 | 08/30/02 | Conduct noise and skid tests on the existing nine experimental test sections on I-70 near Deer Trail and SH 40 near Wild horse. |
| 11/30/02 | 100 | 0915/02 | Analyze all the acquired data from the Deer Trail test sections, new astro-turf test sections, and document the results. Work with region IV, Gary DeWitt in establishing the second site for this study. |
| 9/30/04 | 100 | 9/30/04 | Establish new sites: 1- Proposed PCCP on US 287 at Berthoud Bypass in Region IV scheduled for construction in 2003. 2- Proposed PCCP on Powers Blvd in Colorado Springs in Region II in 2004. 3-Recently built PCCP on SH 83 near the Town of Parker and the control sections near Arapahoe Rd. 4-PCC Pavement on SH 85 south of c-470. Acquire skid, sand patch test, on all the new test sections on a yearly basis. Conduct other methods of texture measurement using FHWA's ROSAN van (if available). |

| | | | |
|---|---|---|---|
| 06/30/08 | 100 | | Acquire skid and texture depth on several older sites including: US 160 at South Fork, I-76 at Nebraska state-line, I-70 at Rifle, I-76 at Brush-Atwood, I-225 at Iliff, SH 287 at Campo, and SH 270 at Vasquez Blvd to I-70. Acquire skid texture depth on the new sites. The Skid trailer is up and running and Skip Outcalt will complete the first round of data by the end of June, 2008. Problem with delivery of new skid truck and licensing of the trailer has delayed data collection till Spring of 06. Breakdown of new Skid truck further delayed data collection. |
| 04/30/12 | 100 | | Perform sand patch testing. |
| 9/30/12 | 100 | | Publish and distribute the final report. Hold a slide presentation to show results to the Materials Engineers. |

# SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**09/11/12** Dr. Rob Rasmussen presented the results of the study to the MAC members and the industry. CDOT Research Branch will publish report in October 2012.

**06/19/12** A teleconference meeting between the study panel and Transtec Inc. was held to discuss test results and details of draft report/presentation. It was agreed that a final presentation will be made in September for CDOT and the industry.

**03/31/12** Skip and Dave performed more sand patch testing this quarter. They planned to complete the testing by the end of 4/12.

**12/31/11** Sand patch testing was carried out by Skip Outcalt and Dave Weld of Research Branch to gather surface texture data for selected state highway Portland cement concrete pavements.

**11/02/11** A purchase order to procure professional service to complete the research was issued by the CDOT Purchasing Agent to Transtec Group Inc.

**09/30/11** Planned to hire a private consultant to complete this project.

**06/30/11** No activity during this quarter. The skid truck broke down and was under repair.

**09/30/10** Skid data collected are being compiled.

**06/30/10** Skip Outcalt collected skid data during this quarter for some of the test sites.

**09/30/08** Field data collection is ongoing.

**06/30/08** Data collection was resumed and gathered information is being analyzed for inclusion into the final report in the future.

**12/31/07** The projected data collection to be performed was not successfully achieved during this reporting period because of weather-related conditions and malfunctioning of skid truck. This task is re-scheduled to be completed by June 2008.

**9/30/07** The data collection is under way.

**6/30/07** The data collection is still in progress. The malfunctioning of the skid truck hampered the data collection process.

**3/20/07:** Skip Outcalt planned to complete the data collection within the next four (months).

**11/06:** Ahmad Ardani, the original PI has retired. Roberto DeDios will take over. Breakdown of new skid truck delayed skid testing.

**09/04:** Acquisition of skid numbers and texture measurement has been delayed until early 05. The Research Branch will be acquiring a brand new skid testing machine equipped with a texture measuring device toward the end of 04.

**12/03:** Due to problems associated with the Research Branch skid testing machine, this project is now on hold until a new skid testing machine is purchased.

**09/03:** Skid testing machine was calibrated during this quarter. The study was delayed somewhat due to unavailability of ROSAN equipment. Nevertheless, field work will commence on this study in the first week of October 03.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Developing Criteria for Performance-Based Concrete Specifications
## Study No: 22.50

Background

Many of CDOT's mix design requirements are based on results of studies in the 1940's and 1950's on durability. For more than 50 years now, concrete technology has advanced, but CDOT specifications for durability have remained mostly unchanged. The minimum cement content for a given strength is derived from mix design guidelines that were developed before water reducing admixtures were widely used and accepted. These minimum cement contents generally control the mix design process with many mix designs exceeding the minimum strength requirements by 500 to 1,000 psi. Ready-mix suppliers that supply to non-CDOT projects have developed mix designs that use less cement and more fly-ash than CDOT mix designs and exceeded their strengths. They are able to accomplish this improvement through gradation optimization and admixture combinations.

The proposed study will test current CDOT standard mix designs to determine minimum required performance criteria that will be used to develop performance-based concrete mix design criteria.

After performance criteria are defined, the ready mixed concrete producers will be asked to submit mix designs they would like to use on CDOT projects. These mix designs will be tested and evaluated based on the performance criteria established. CDOT will use the developed performance criteria to prepare a project special provision to allow the use of performance-based criteria for mix design approval on pilot projects. The ultimate goal is to develop and adopt a performance-based concrete standard special provision for use in applicable projects.

The product of this research will provide CDOT Materials and Geotechnical Branch with criteria that can be used in the development of a performance-based concrete mix design specification. The use of performance-based specifications would allow ready mixed concrete suppliers to optimize the materials used in creating mix designs. This materials optimization can lower cement contents and increase fly-ash content that would lead to reduction of costs and concrete carbon footprint in CDOT construction projects.

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 09/23/10

Principal Investigator(s): Dr. Rui Liu/
(Dr. Stephan Durham) University of Colorado-Denver, 303-556-5270
Research Study Manager: TBD
Technical Panel Leader:
Eric Prieve, CDOT Materials and Geotechnical Branch 303-398-6542

Study Panel Members:
Gary DeWitt, CDOT R-4 Materials
Donna Harmelink, FHWA Colorado Division
Aziz Khan, CDOT-DTD Research Branch
Patrick Kropp, CDOT Materials and Geotechnical Branch
Michael Stanford, CDOT Materials and Geotechnical Branch

FHWA Washington Contact:
Ahmad Ardani, Turner-Fairbank Highway Research Center 202-493-3422

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 9/23/10 | 100 | 9/23/10 | Issue Notice-to-Proceed letter |
| 10/13/10 | 100 | 10/13/10 | CDOT Panel/Principal Investigator (PI) kick-off meeting |
| 12/31/10 | 100 | 7/14/11 | Comprehensive literature review |
| 12/31/10 | 100 | 9/01/11 | Obtain needed materials for testing |
| 12/31/10 | 100 | 12/31/10 | First progress report |
| 1/31/11 | 100 | 5/10/11 | Complete selection of concrete mixture designs |
| 3/31/11 | 100 | 4/31/11 | Second progress report |
| 6/30/11 | 100 | 7/14/11 | Summarize past research activities/Third progress report |

| | | | |
|---|---|---|---|
| 8/31/11 | 100 | 2/15/12 | Create concrete mix in lab, test, and develop performance criteria |
| 9/30/11 | 100 | 1/16/12 | Summarize past research activities/Fifth progress report |
| 9/30/11 | 100 | 2/15/12 | Solicit and batch non-standard mixture designs |
| 12/31/11 | 100 | | Test supplier-provided concrete |
| 12/31/11 | 100 | 4/16/12 | Summarize past research activities/Sixth progress report |
| 12/31/11 | 100 | | Analyze and summarize test results |
| 7/01/12 | 100 | 7/01/12 | Draft project report |
| 7/11/12 | 100 | 7/11/12 | Conduct PowerPoint presentation to CDOT Panel/MAC |
| 12/31/12 | 100 | | Submit final project report to CDOT/Publish final report |

# SIGNIFICANT EVENTS

**The CDOT Study Manager, Roberto DeDios, retired from CDOT in January 2013**

| | |
|---|---|
| 7/01/12 | Submitted draft final report to CDOT |
| 2/15/12 | Completed laboratory batching of non-standard concrete mixtures |
| 1/16/12 | Fifth progress report |
| 12/31/11 | Principal Investigator Stephen Durham left the University of Colorado-Denver |
| | Completed laboratory batching of concrete mixtures. |
| 10/10/11 | Fourth progress report |
| 9/01/11 | Obtained all of needed materials from around the state for batching mixtures |
| 7/14/11 | Complete literature review/third progress report |
| 4/31/11 | Second progress report |
| 12/31/10 | Literature review progress report |
| 12/20/10 | UCD Laboratory Inspection |
| 10/13/10 | Project “Kick-off” meeting |
| 9/23/10 | Project officially begins |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Internal Curing of HPC Using Techniques Other Than Lightweight Aggregate
## Study No: 22.60

Background

Through extensive laboratory testing, this research effort is expected to produce a recommended approach for internal curing (IC) of CDOT's high performance concrete (HPC). Improvements expected include resistance to shrinkage and premature cracking, lower permeability, and higher tensile, shear, and compressive strengths.

Traditionally, concrete cures by using water already free in the mix or 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 and its low permeability quickly blocks surface water from permeating back into the structure for curing. The primary manifestation of inadequate water for curing is shrinkage and premature cracking.

Internal curing (IC) is the process of encumbering water throughout the structure, so it is available later for curing. Special admixtures, highly adsorptive polymers (HAP), 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.

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.

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.

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 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 CDOT 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.

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 11/8/12 End: 12/31/13

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

Study Manager: TBD

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

# 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 universities: 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 | 95 | | Task 1 Mixture Proportioning |
| 12/30/12 | 75 | | Task 2 Material Collection and Shipping |
| 12/15/12 | 0 | | Task 3 Evaluation of Preliminary Mixtures |
| 4/1/13 | ~ | | Task 4 Evaluation of Optimized Internally Cured Mixtures |
| 8/15/13 | ~ | | Task 5 Draft Final Report |
| 11/1/13 | ~ | | Final Report |

# SIGNIFICANT EVENTS

**The CDOT Study Manager, Roberto DeDios, retired from CDOT in January 2013**

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 minutes in dropbox account)

# ANTICIPATED EVENTS FOR Q1 2013 (Project Q2)

- Materials for preparation of laboratory samples are currently being collected in Colorado and will be shipped to Purdue. This has been slightly delayed due to the holiday however the aggregate producer, cement producer, lightweight aggregate producer, shipping container, and shipper have all been contacted.
- Once received, the constituent materials will be prepared and be readied for testing
- In Early February a second meeting will be held with the SAC committee to discuss the preliminary observations from some mixture proportions.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

The State of Colorado has an estimated inventory of more than 70 million used tires, the highest number of scrap tires stockpiled in any state. It generates about 4.83 million waste tires annually while recycling about 4.49 million tires mostly as a source of tire derived fuel, leaving a balance of about 340,000 tires that are destined for "mono-fills" which are landfills exclusively for waste tires. The Colorado Senate Bill 09-289 requires elimination of all Colorado waste tire mono-fills by year 2019.

A recent research study conducted by the University of Colorado at Denver 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. Up to 50% by volume of fine aggregates was replaced. Although, the stated cost of $300-$400 per ton seemed to be high for a well-processed crumb rubber to replace fine virgin aggregates that are readily available in eastern Colorado, the processed crumb rubber materials would be much less expensive than using scarce virgin coarse aggregates suggesting that a more economical alternative exists if tire chips are used to supplement 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. In this case, it is suggested that rather than investing in higher expenditure to create finer crumb rubber particles, create a coarse fraction that facilitates an end product that meets the intent of the design performance needs, and costs less than finer crumb rubber materials. The proposed use of recycled tires would replace the more expensive virgin coarse aggregate, and not the fine aggregates found abundantly on the eastern plains of Colorado. Research is needed to determine if recycled tires can be used as a coarse aggregate in concrete pavements and to determine if it creates the overall anticipated value.

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: End:

Principal Investigators:
Dr. Rui Liu, University of Colorado-Denver

Study Manager: TBD

Study Panel Leader:
Eric Prieve, Materials and Geotechnical Branch, 303-398-6542

Study Panel Members:

Patrick Kropp, Materials and Geotechnical Branch 303-398-6541
Bob Mero, Region 6 Materials, 303-398-6703

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 7/31/12 | 100 | | Hold initial study panel meeting. |
| 9/19/12 | 100 | | Develop scope of work |
| 9/26/12 | 100 | | Select researcher (UCD was selected) |
| 10/01/12 | | | Start project |
| 03/29/13 | | | Draft final report |
| 05/31/13 | | | Submit final report |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Application of Roller Compacted Concrete in Colorado's Roadways
## Study No: 25.00

Background

The goal of the research work is to develop guidelines, procedure, and specifications for the design, placement and maintenance of roller compacted concrete (R CC) in Colorado's roadways. RCC is relatively less expensive than the traditional Portland cement concrete that is used in high volume roads. Currently, RCC is used in a few industrial lots and roads in Colorado and has been found to be performing successfully for these low volume road applications. RCC can be placed and used as a wearing surface, although its pavement smoothness is not as good as conventional concrete. To harness the potential of RCC and identify its appropriate applications in Colorado's roadways, the following issues and information must be researched using highway pavement pilot test sections:

- Minimum strength needed for durability;
- Minimum thickness needed to hold different volumes of traffic;
- Minimum cement contents needed;
- New design procedure for designers to use;
- Minimum equipment requirements for placing RCC; and
- Other factors that may impact its performance.

RCC takes its name from the construction method used to build it. It is placed with conventional or high-density asphalt paving equipment and then is compacted with rollers. RCC has the same basic ingredients as conventional concrete which include cement, water, and aggregates. However, unlike conventional concrete, RCC is a drier mix, meaning it is stiff enough to be compacted by vibratory rollers. Typically, RCC is constructed without joints. It needs neither forms nor finishing, nor does it contain dowels or reinforcing steel. RCC has been historically used for dam construction and heavy duty industrial pavements such as rail yards (Denver Burlington Northern Yard, 22 years old), paper mills, and port facilities. State highway agencies (SHAs) like Georgia have also used RCC for shoulders along interstate highways. RCC is reputed to have the strength and performance of conventional concrete with the economy and simplicity of asphalt. Because of these qualities and low initial cost, it would be beneficial for CDOT to investigate and determine its various applications to highway construction projects.

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 06/2009

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

Study Manager: TBD

Study Panel Members:
Gary DeWitt, Region 4 Materials
Jay Goldbaum, Materials & Geotechnical Br.
Rex Goodrich, Region 4 Materials
Matt Greer, FHWA-Colorado Division
Shamshad Hussain, Region 1 Materials
Jamie Johnson, PCA RMCC
Steve Olson, Materials & Geotechnical Branch
Eric Prieve, Materials & Geotechnical Branch
Scott Rees, Project Development
Bill Schiebel, Region 1 Materials

The final report has been published and is available on the CDOT website:
http://www.coloradodot.info/programs/research/pdfs/2012/rcc.pdf/view

This will be the final progress 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<br><br>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.<br><br>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.<br><br>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. | Reporting Period: 10/1/12 through 12/31/12<br>Start: 9/13/07 Complete: 6/30/12<br><br>Principal Investigator(s):<br>Vic Claassen, University of California Davis<br><br>Study Manager:<br>Bryan Roeder, CDOT-DTD Research<br>303-512-4420<br>Study Panel Leader:<br>Mike Banovich, CDOT-DTD EPB<br>303-757-9542<br><br>Study Panel Members:<br>John Bordoni, CDOT R-1 Maintenance<br>303-512-5765<br>Allan Hotchkiss, CDOT Materials and Geotechnical Branch 303-398-6587<br>Amanullah Mommandi, CDOT Staff Hydraulics<br>303-757-9044<br>Vacant, CDOT R-1 Resident Engineer<br>303-512-5751 |

## MILESTONES

| Planned | % Done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| | | | **2007** |
| 3/31/06 | 100 | 4/07 | Assemble the CDOT Study Panel. Develop the scope of work (SOW). |
| 4/30/07 | 100 | 6/07 | Complete the SOW and request for proposal (RFP) process (if applicable). |
| 6/30/07 | 100 | 9/07 | Select the Principal Investigator (PI). Initiate task order/purchase order/agreement/contract. |
| 9/13/07 | 100 | 9/07 | Award the contract. (Purchase Order signed) |
| 11/15/07 | 100 | 09/07 | Conduct the CDOT Study Panel/PI kick-off meeting. (field meeting with CDOT group, now need to present preliminary work to committee) |
| 12/31/07 | 100 | 09/07 | Establish control and experimental sites. |
| 9/15/07 | 100 | 09/07 | Prepare experimental set-up. |
| 10/15/07 | 100 | 09/07 | Monitor, gather and analyze plant cover data. |
| | | | **2008** |
| | 100 | due 05/08 | Gather, prepare and analyze soil data |
| 11/30/07 | 100 | July 20 08 | Prepare and submit interim report to CDOT study panel for review. |
| 08/20/08 | 100 | | Research oversight committee Aug 26, 2008 |
| 09/30/08 | 100 | 10/02/08 | Design and install nutrient release experiment using common soil amendment materials |
| 10/01/08 | 100 | spring 09 | Analyze Time 0 samples (fresh amendment mixed with Straight Creek substrate) to determine initial nutrient content |

| | | | |
|---|---|---|---|
| | | | **2009** |
| winter 09 | 75 | spring 09 | Analyze nutrient release from T0, develop fractionation scheme for organics and nutrients |
| meltoff 09 | 100 | spring 09 | First field sampling of nutrient release experiment (Time 1 treatment). |
| summer 09 | 100 | fall 09 | Soil and vegetation sampling on existing plots (Insert additional nutrient sampling time??) |
| fall 09 | 100 | spring 09 | Second field sampling of nutrient release experiment (Time 2 treatment). |
| 11/30/09 | 100 | fall 09 | Submit draft interim report for review by CDOT study panel. |
| 12/31/09 | 100 | fall 09 | Respond to study committee review on the timing of nutrient release and field sampling. |
| | | | **2010** |
| meltoff 10 | 100 | June 2010 | Nutrient release experiment sampling |
| sum/fall 10 | 100 | September 2010 | Nutrient release experiment sampling |
| winter 2011 | 85 | Dec 2010 | Sample prep, N extraction |
| spring 2011 | 30 | | N release report |
| melt 2011 | 100 | | Field sampling |
| Fall 2011 | 100 | Feb 2012 | Final field sampling |
| spr 2012 | | | Prepare and submit draft final report to CDOT study panel for review. |
| June15 '12 | | | Complete review of draft final report by CDOT study panel with comments to be addressed. |
| June 30 '12 | | | Prepare and submit draft final project report. Project extended until Dec 2012. |
| Sept 30 '12 | 100 | 9/27/12 | Complete field vegetation cover surveys. Review project in field with research comm. |
| Oct 31 '12 | | | Complete review of draft final report by CDOT study panel with comments to be addressed. |
| Nov 15 '12 | | | Schedule presentation with CDOT staff. |
| Dec 31 '12 | | | Project completion |

## SIGNIFICANT EVENTS

December, 2012: Draft Final Report has been submitted. Project Extended to 2/28/13.

September, 2012: Final vegetation cover sampling completed for all plot locations at original transects. Review field plots and slope conditions with research committee members and view related issues on Berthoud Pass and Straight Creek sediment basins; discuss final report objectives.

August, 2012: Draft report narrative and data processing finished.

June 21, 2012: Project extended through 12/31/2012

March 2012: Final field sampling was made, soils were dried and nitrogen loading and nitrogen leaching horizons were separated. Final data analysis was started and materials gathered for final report.

December 2011: A request for extension was submitted and received , setting the current end-of-project deadline to June 30, 2012. Since most of the nitrogen fertility being released from the soil amendments will be in the nitrate form, and since this is a very water soluble form, supplemental work was done to be able to estimate the flow of nitrate through the porous sand during snow melt and summer rains. This additional information will be integrated with the main purpose of the project, which was nutrient loading and release from soil amendments added to the cut slopes along Straight Creek section of I-70.

September 2011: No activity reported this quarter.

May, June 2011: Found problems with limits of detection on N analysis, start re-work on sensitivity and look for

alternate forms of N in remaining samples. Completed improved method to evaluate soil water retention in soils using tension infiltrometer for general evaluation of field growth conditions.

May 2011: Study Manager Vanessa Henderson was promoted to a position in the Division of Transportation Development Environmental and Planning Branch and was temporarily replaced by Roberto De Dios.

March 2011: Extractable nitrogen evaluation mostly completed, including ammonium and nitrate by amended horizon and leached horizon. Samples prepared to run total nitrogen and carbon. Preliminary data set up for modeling leaching losses from amendments in sandy granite substrates during snowmelt or summer rain events.

December 2010: Project extended to fourth and final year. Sample fractionation by horizons and nitrogen extraction starting.

July - Sept 2010: Sampled fall fertilizer release trial tubes September 30 (T4). Preparation in progress for bulk analysis of all samples. Three sample points remaining in the field tube sets, so the next sampling will be scheduled based on data results this winter.

Apr - Jun 2010: Worked up incubation equipment (no charge, but necessary for project) and sampled Spring 2010 samples from field sites. Start work with drying, fractionating samples. Nutrient analysis ongoing through summer.

Jan - Mar 2010: Soil sample analysis continued on the fertilizer incubation chambers collected from the I-70 Straight Creek field site. Several instruments were evaluated to determine if the fertilizer materials could be "read" instrumentally rather than relying on chemical extracts or lengthy incubations. Spring 2010 samples are to be taken when the snow pack comes off and precipitation predominantly switches to rainfall. Data are to be compiled for a research committee interim report.

Oct - Dec 2009: The samples were collected before snow cover in Fall 2009. No other activity occurred on this project, but analysis is starting Jan 1, 2010.

July - Sept 2009: The field incubation chambers survived the first winter, so now are experiencing the first summer growing season. The next time point will be collected in Fall 2009. The lab work involves learning the hydrological modeling software and preparing instruments for analysis of the Time 0, 1 and 2 samples in late Fall 2009 and Winter 2010.

March - June 2009: First winter nutrient release soil columns were collected right at snow melt and prepared for analysis. Lab methods were prepared (non-dispersed particle size analysis, water release curves from organics and substrates, respiration curves) and will be run uniformly on a set of the first year's samples (T0, T1, T2) in Fall of 2009.

January - March, 2009: Field work for the project was inactive during this winter period due to snow cover at the I-70 Straight Creek site. Weather is being monitored (MM209 I-70 truck ramp; I-70 Eisenhower web cams) and the winter 2009 soil amendment leaching columns will be harvested and monitored at final snow melt. Meanwhile, in the lab, work is being done to more effectively evaluate field soils for soluble nitrogen release, either from soil organic matter or soil amendments. This involves fractionation of soil N-containing compounds for N analysis and interpretation of soil respiration.

September 27 - Oct 2, 2008: Return to site and install groups of leaching tubes in time for measuring first season nutrient release. Time 0 samples were returned to the lab Fall 2008. Time 1 samples will be collected at melt off

in Spring 2009 before growth begins. Time 2 samples will be collected just before snow fall in Fall 2009. This spring and fall sampling (twice per season) is incorporated into the experimental construction for three additional sampling times, but can be accelerated if initial nutrient release rates turn out to occur quickly, or the sampling times can be delayed if release appears to be slow.

September, 2008: Plan and design and construct nutrient release experiment to test release from soil amendments. The rate and chemistry of the release will be measured from PVC leaching tubes installed at the Straight Creek site. Replicate tubes of fungal biomass amendment, humate, a blend of these two, and a nitrified organic amendment were loaded into experimental columns.

August 26, 2008: Field site meeting with CDOT study panel. Gather second year of field survey data. Study panel recommends modifying work plan to include nutrient release tests from common soil amendments used along the Straight Creek Corridor.

July 20, 2008: Provide initial project findings to CDOT study panel, arrange for review by meeting or conf call.

May, June 2008: Statistically analyze non-N nutrient content and vegetation cover for plot comparisons. A general tentative finding is that as slope conditions become more harsh, grasses tend to decline relative to forbs, which maintain their cover area. This suggests that grasses are more directly affected by declining soil conditions than forbs. This helps focus the search for growth limiting conditions to differences between these vegetation types. Alternatively, the change in forb species may indicate differences in survival ability as stress conditions increase. A field monitoring approach to surface horizon hydrology and availability of selected nutrients is being developed for presentation to the CDOT study panel.

April 2008: Finish soil testing and data summary

Jan - Mar 2008: Soil sample preparation.

12/20/07: Summarize initial plot locations, cover and soil information.

9/21/07: Meet with CDOT field crews, review site selection, select plot locations, collect soils and evaluate late season plant cover using point intercept transects.

9/15/07: PI met with CDOT staff at site to set up test plot locations and inventories

9/13/07: Purchase Order issued to PI.

6/30/07: Documented Quotes received and reviewed. PI selected.

3/31/07: Statement of Work completed. Contract process to begin this month.

2/26/07: Task panel met and revised Statement of Work. Comments due back March 16, then Pat will finalize and begin contracting process.

9/30/06: The SOW and RFP is still being finalized by Mike Banovich and Roberto de Dios. The RFP is anticipated to be completed sometime in November 2006.

8/15/06: A major change in the time of completion of the Scope of Work (SOW) was proposed by the champion of the research project. The two-year time for completion is being planned to be changed to four years

to gather more information without increase in cost.

6/27/06: The study panel kick-off meeting was held to refine the problem statement and start developing the Scope of Work (SOW) and Request for Proposal (RFP) document.

6/5/06: The research study panel was assembled and established.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Mileage Based User Fee Study
## Study No: 30.51

Background

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

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

Project Goal

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

Project Scope

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

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

Reporting Period: 10/1/12 through 12/31/12
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:
Jake Kononov, CDOT DTD Research
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 | 70 | | Policy Outreach |
| 9/15/11 | 100 | 5/18/12 | Performance Measures |
| 10/21/11 | 40 | | Preliminary Concept of Operations |
| 11/18/11 | 10 | | 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

## ANTICIPATED EVENTS FOR Q4 2012

- Conduct first MBUF workshop at CDOT HQ (10 / 4 / 2012)
- Identify next steps in project development by CDOT management
- Preparation of final report documentation

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Helicopter Avalanche Control
## Study No: 30.70

| | |
|---|---|
| Background<br><br>Avalanche danger presents many hazards to the transportation infrastructure in Colorado. In hazardous areas, near roads too arterial to close, these hazards must be mitigated by forcing slides during temporary road closures. Often the avalanches are triggered via high explosive charges dropped from helicopters. Many factors such as weather, explosive duds, or charges rolling away from trigger zones can prolong or even scrap a mission. When traffic is stopped, loaders are staged for snow removal, ground control is in operation, and the helicopter crew is working, costs drastically increase with mission time. Also, increasing the amount of time in flight increases the probability of an in flight accident.<br><br>This research project is designed in two phases. The first is focused on a global survey designed to identify current methods in avalanche control. The goal of phase one is to determine what differences, if any, exist in the methods of helicopter avalanche control performed by CDOT in comparison to other agencies.<br><br>The second phase is designed to field test any differences found in phase one, as well as test any promising technology not identified in phase one. One potential avenue of investigation in phase two is the DaisyBell system. The DaisyBell generates a compressed gas explosion, while tethered to a helicopter, and can therefore be fired many times. This increase in firings can potentially increase the number of avalanches triggered per flight. The DaisyBell apparatus itself, however, may cause more mission scraps due to wind and the increased aircraft cross-section. Phase two intends to field test such cost to benefit ratios with real world technologies.<br><br>Upon analyzing the results of phases one and two, suggestions can be made, and training implemented, to help reduce the cost and safety hazards associated with CDOT's helicopter avalanche operations. | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R Start: 5/1/11<br>PO: 271001410<br>PO Expiry: 05/22/13<br><br>Principal Investigator(s):<br>Dr. Vilem Petr, Colorado School of Mines 303.273.3222<br>Dr. Ethan Greene, Colorado Avalanche Information Center 303.499.9650<br><br>Study Manager:<br>David Reeves, DTD Research, 303-757-9518<br><br>Study Panel Members:<br>Mark Mueller, Staff Maintenance Engineer (HQ)<br>James Walker, Maintenance & Operations (HQ)<br>Dr. Aziz Khan, CDOT Research Engineer (HQ-DTD) |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| | | | **Phase 1** |
| 5/11 | 50 | 5/11 | Task 1.1: Review of current practices in helicopter avalanche control at CDOT and by other agencies performing the same kind of work. |
| 5/11 | 100 | 5/11 | Task 1.2.0 thru 1.2.2: Perform national and international survey of current helicopter safety and use in avalanche control. Survey will include types of explosives used, their delivery methods, and respective initiation systems. Special focus on delivery methods of "turkey bombs" will be reviewed. |
| 5/11 | 100 | 5/11 | Task 1.2.3: Industry survey of available initiation systems for explosives used in helicopter avalanche control. |
| 5/11 | 100 | 5/11 | Task 1.3: Perform national and international survey for alternative methods to explosives within avalanche control such as DaisyBell and Gas-Ex avalanche control systems. |
| 5/11 | 25 | 6/11 | Task 1.4: Contingent on availability of equipment and coordination with CDOT |

| | | | |
|---|---|---|---|
| | | | maintenance operation, the research team will conduct a preliminary field experiment to help guide phase 2. The experiment will collect data and compare effectiveness of two types of ANFO charges, emulsions/heavy ANFO and the DaisyBell. The field data would include, but not be limited to, measuring crater dimensions, atmospheric overpressure, high-speed images, and initial and final snow structure. The data would be used to evaluate the different explosive methods and help to validate and benchmark the new numerical simulation of other blasting scenarios. |
| 9/11 | 100 | 1/12 | Task 1.5: Submit written report summarizing findings from tasks 1 through 3 as per CDOT research report format within six months from start of project. This report will compare effectiveness of current CDOT helicopter avalanche control efforts to other agencies in terms of number of successful efforts per mission, how often the efforts fail, and by what mechanism (snow failed to slide despite apparently good charge placement and initiation, dud, charge rolled/bounced down slope, weather caused scrub after takeoff, etc.) failure occurred. |
| **Phase 2** | | | |
| 12/11 | 0 | | Task 2.1: Dependent upon evaluation of data obtained in phase 1, the research team will propose improved strategies in terms of new explosive types, delivery methods, and/or initiation methods which are intended to improve crew safety, mission effectiveness and cost effectiveness. The strategy should consider not only explosive characteristics but also avalanche/snow mechanics and how the process could be optimized for different conditions. |
| 4/12 | 0 | | Task 2.2: Design and build a test matrix for comparison of actual explosives, and their alternative systems, studied in phase 1. The research team will perform and analyze these comparisons with different initiation systems, delivery methods, and explosive types in relation to snow mechanics, environmental effects using high speed imaging and other technologies. Numerical modeling will also be performed using results from these comparison tests. Test locations will be pre-selected be CDOT personnel, such as Independence Pass in early spring, to afford realistic snow conditions. |
| 4/12 | 0 | | Task 2.3: The research team will design and implement training courses and materials in the proposed strategy based on the test results of Task 2.2 in order to minimize cost and help improve the effectiveness of CDOT's helicopter avalanche control program. |
| 4/12 | 0 | | Task 2.4: Continue annual CDOT training while documenting the effectiveness of the newly implemented strategies described in tasks 2.2 and 2.3. |
| 5/12 | 0 | | Task 2.5: The research team will submit a final written report on the new helicopter avalanche control strategies, implemented training, and effectiveness of new strategies in the field. This report will also highlight the comparison between current explosive methods to alternative methods such as the Daisy Bell avalanche control systems and will comply with CDOT Research Branch requirements. |

# SIGNIFICANT EVENTS

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

following results

- **1/5/12** Final survey report was sent to CDOT and other necessary personnel for revision.
- **2/12** Working on setting up testing with Loveland Ski area and finalizing test matrix with CDOT for 1 or 2 days of testing, according to availability of Loveland Ski Area, CDOT personnel, and CAIC personnel.
- **2nd Quarter 2012** – No significant events reported.
- **3rd Quarter 2012** – No significant events reported.
- **November 2012** – We have meeting with CDOT research team at CSM research team at CSM and we suggested and proposed a new schedule for the experiments which should be done by February 2013 in Loveland. This is dependent on snow conditions.
  We also agreed on 4 tests using different charges as well as initiation systems.

# COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

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|---|---|
| Background<br><br>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.<br>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.<br>The second report will focus on the potential for solar arrays to affect on-going maintenance and operation activities. | Reporting Period: 10/01/12 through 12/31/12<br>Start: 10/29/12 Contract Amount: $74,970<br>End: 12/31/14<br><br>Principal Investigator:<br>Dr. Ananda Paudel, Assistant Professor Engineering Department, Colorado State University-Pueblo<br><br>Study Manager:<br>Bryan Roeder, CDOT, 303-512-4420<br><br>Study Panel Leader:<br>Yates Oppermann, CDOT Environmental Programs Branch<br><br>Study Panel Members:<br>Sasan Delshad, CDOT Region 2 Traffic and Safety<br>Mike Delong, CDOT Region 1 Maintenance and Operations<br>Jim Eussen, CDOT Region 1 Environmental<br>Sarah Mitchell, CDOT Environmental Programs Branch<br>Dave Ruble, CDOT Region 1 Utility Engineer<br>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 | 20% | | **Task 1. Literature study done:**<br>ODOT, Volpe Institute, snow drifting |
| 2/30/2013 | 10% | 11/20/2012 | **Task 2. Frame work development done via** Tele conference and in person meeting:<br>Action items generation on literature review, field visit and interviews and work assignment |
| 12/30/2012 | 10% | 12/31/2012 | **Task 3. Potential CDOT Reference Site Search/ study /Interview** |
| 2/15/2013 | | | Reference Site Identification |
| 9/01/2013 | | 12/12/2012 | Reference Site Observations Performed:<br>CSUP, NW Parkway<br>State Highway 93 (City of Arvada), Federal Center (Golden, Colorado) and US 36 near University Research Park |
| 9/01/2013 | 2% | | **Task 4-Report Development: Draft Report on snow drifting** |
| 10/30/2013 | | | 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 | 5% | 12/31/2012 | **Task 5- PI Project Management (Communication)** |
| 12/30/2013 | | | Project Close Out |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Mule Deer and Elk Right-of-Way Escape Ramp Design Monitoring
## Study No: 32.47

| Background | Reporting Period: 10/1/12 through 12//31/12<br>Start: 05/09/12 Contract Amount: $ 71,994<br><br>Principal Investigator:<br>Kenneth Wilson, Ph.D. (dept. head) &<br>Jeremy Siemers, M.S. (research associate)<br>Department of Fish, Wildlife, and Conservation Biology at Colorado State University (CSU)<br><br>Study Manager:<br>Bryan Roeder, CDOT, 303-512-4420<br><br>Study Panel Leader:<br>Tony Cady, Region 5 Environmental<br><br>Study Panel Members:<br>Jeff Peterson, CDOT Environmental Programs Branch<br>Alison Michael, US Fish & Wildlife Service<br>Jim Eussen, CDOT Region 1 Environmental<br>Rob Frei, CDOT Region 2 Environmental<br>David Valentinelli, CDOT Region 5 Engineering |
|---|---|
| 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.<br>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. | |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 05/09/12 | | 05/09/12 | Notice to Proceed |
| 05/31/12 | | 5/31/12 | Kickoff Meeting |
| 06/20/12 | | 06/20/12 | Field Meeting with CSU, CDOT, and CPW personnel |
| 07/31/12 | | 07/31/12 | Camera testing and deployment evaluation – test data evaluated and final deployment scheme decided upon |
| 07/31/12 | | 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 | 10% | | Monitoring – 2 months of monitoring data collected to date |
| 01/14/15 | | | Cost-benefit analysis |
| 01/14/15 | | | Ramp use and design analysis |
| 01/14/15 | | | Draft report (75 days prior to report publication) |
| 03/30/15 | | | Final Report publication |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Recycled Materials Resource Center, TPF-5(270)
## Study No: 33.20

| | |
|---|---|
| Background<br><br>Over the past 10 years, State DOTs have made significant progress incorporating recycled materials and industrial byproducts in transportation applications. As a whole, recycled materials can add value to DOT projects, yet many of these materials still remain under-utilized due to technical and institutional barriers. The Recycled Materials Resource Center (RMRC) was created to assist State DOTs and FHWA in breaking down these barriers by providing the research and outreach activities needed to further the appropriate use of recycled materials.<br><br>The Center was started in 1998 at the University of New Hampshire (UNH) through an agreement with FHWA based on language in TEA-21. Under the original agreement, the RMRC sponsored 39 research projects in 14 states. The RMRC was renewed in 2007 by FHWA for an additional 4 years.<br><br>The University of Wisconsin at Madison has joined the RMRC as a major partner to provide additional expertise as well as providing a more national perspective to the Center. As part of the new agreement, FHWA mandated that the RMRC seek funds through a pooled fund study to provide support for research and outreach activities. Now a pooled-funded study, Wisconsin became the lead state in 2012 (TPF-5(270). | Reporting Period: 10/1/12 through 12/31/12<br>Start: 8/15/09 Complete: 6/1/13<br><br>Principal Investigator:<br>Jacqueline Kamin, Wisconsin DOT<br><br>Federal Highway Administration Liaison<br>Steve Mueller<br><br>Study Manager:<br>Bryan Roeder, CDOT Research<br><br>Study Panel Members:<br>David Wieder, Operations & Maintenance<br>Jim Zufall, Materials & Geotechnical |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 7/30/10 | 100 | 7/30/10 | Funding request to Business Office for transfer of $30,000 to Lead Agency |
| 10/12/10 | 100 | 10/12/10 | Business Office signs transfer request and sends to Lead Agency. |
| 10/26/10 | 100 | 10/26/11 | Lead Agency processes transfer. |
| 12/1/12 | | 12/1/12 | $30,000 transferred for CDOT's FY12 commitment. |
| 11/5/12 | | 11/5/12 | Committed $25,000 for FY2013 |
| 12/31/12 | 50% | | Completed fund transfer: FHWA 1575 submitted to DTD Business Office for processing on 12/20/12 |

## SIGNIFICANT EVENTS

October 2010: CDOT officially became part of RMRC Pooled Fund Study.

CDOT has committed the following funds to this study:

FY2011 $30,000
FY2012 $30,000
FY2013 $30,000

Refer to www.pooledfund.org for more details on this study and progress.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## FHWA Traffic Noise Model: Version 3.0 Software Development, TPF-5(158)
## Study No: 34.22

| | |
|---|---|
| Background<br><br>The FHWA Traffic Noise Model (FHWA TNM) was originally released in 1998 and has undergone several upgrades. On May 2, 2005 the FHWA TNM, Version 2.5 became the required traffic noise prediction model to be used on Federal-aid highway projects.<br><br>FHWA TNM Version 3.0 Software Development:<br>FHWA is currently funding the development of the FHWA TNM Version 3.0. The main objective of Version 3.0 is to contemporize the software, making sure that the FHWA TNM does not become obsolete as computers/operating systems advance. Contemporizing FHWA TNM will allow for more efficient upgrades and future maintenance. The FHWA is also funding a limited number of enhancements which will be included in Version 3.0.<br><br>Objectives for the FHWA TNM Version 3.0 Software Development include:<br>1) Enhance the graphical user interface (GUI).<br>2) Correct known software bugs.<br>3) Enhance functionality. | Reporting Period: 10/1/12 through 12/31/12<br>Start: 6/16/10 Complete: 9/30/13<br><br>Principal Investigator:<br>Federal Highway Administration<br>Mark Ferroni<br><br>Study Manager:<br>Bryan Roeder, CDOT Research<br><br>Study Panel Members:<br>Jill Schlaefer, CDOT Environmental Programs Branch<br>Bob Mero, CDOT Region 6 |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 11/24/09 | 100 | 11/24/09 | Funding request to Business Office for transfer of $30,000 to Lead Agency |
| 1/4/10 | 100 | 6/8/10 | Business Office signs transfer request and sends to Lead Agency. |
| 2/1/10 | 100 | 6/16/10 | Transfer completed to Lead Agency for first year of participation. |
| 7/22/10 | 100 | 7/22/10 | Annual TRB Transportation Related Noise committee meeting. |
| 7/26/11 | 100 | 7/26/11 | Annual TRB Transportation Related Noise committee meeting. |
| 1/20/12 | 100 | 1/20/12 | Transferred $10,000 for FY12 commitment |
| 12/26/12 | | 12/1/12 | Project extended. |
| 1/20/13 | | 11/1/12 | Committed $10,000 for FY13 |
| 12/20/12 | | 12/20/12 | Transfer funds for FY13: sent FHWA 1576 to CDOT Business Office |

## SIGNIFICANT EVENTS

Details of this study and progress reports are available at:
http://www.pooledfund.org/Details/Study/384

CDOT has committed the following funds in support of this project:

FY2010 $10,000
FY2013 $10,000

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

The goal of this research is to evaluate the performance of crumb rubber test sections and develop construction specifications, guidelines, best management practices and Colorado-specific materials for rubberized asphalt pavement. 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 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.

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 Colorado Department of Public Health and Environment (CDPHE) provided the grant money to construct the two pilot test sections.

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

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

Research Study Manager: TBD

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
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 Materials Branch
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 | 75 | 12/31/12 | Task 3 - Data Collection |
| Quarterly | 80 | 9/30/12 | Task 4 – Project Status Reporting |
| 6/30/14 | 0 | | Task 5 – Draft and Final Report Presentation and Submittal |

# SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

Condition surveys were completed on the test sections this quarter. A summary of the performance of the two test sections and control section are shown below in Figures 1 through 3 for transverse, longitudinal and alligator cracking. A summary of the performance of the driving lane and passing lane shoulders which contain control PG64-28 are shown in Figures 4 and 5.

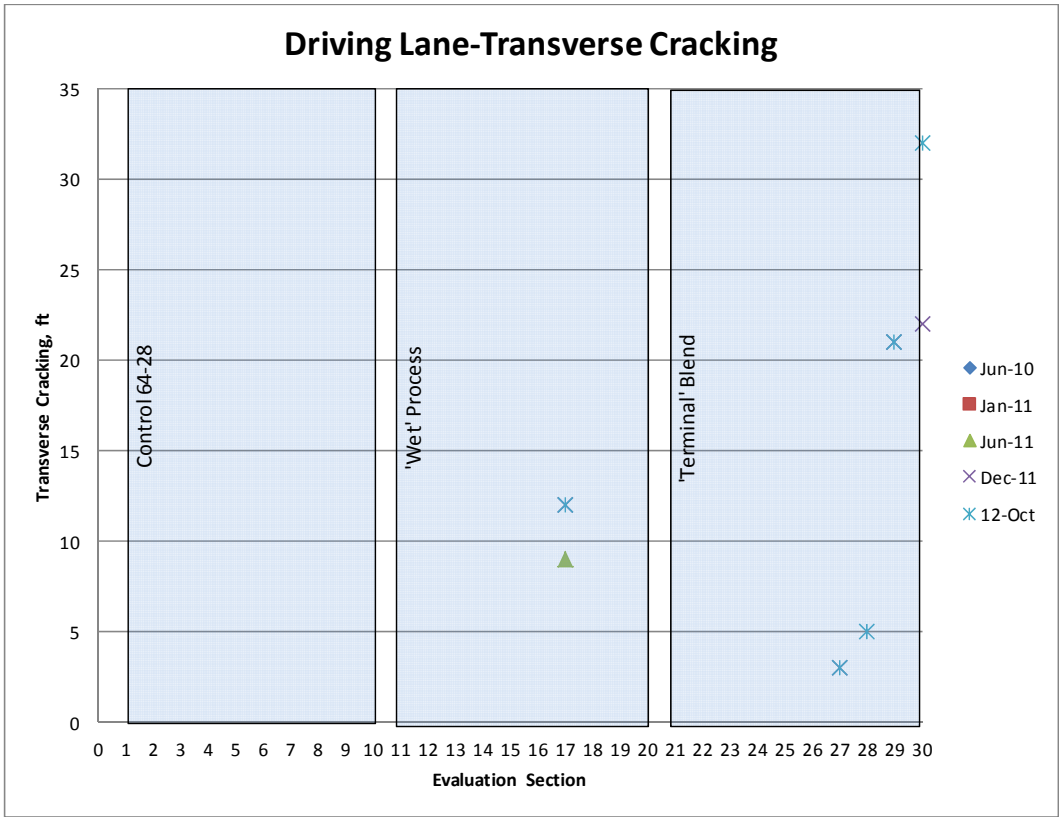


**Figure 1 – Transverse Cracking in Driving Lane**

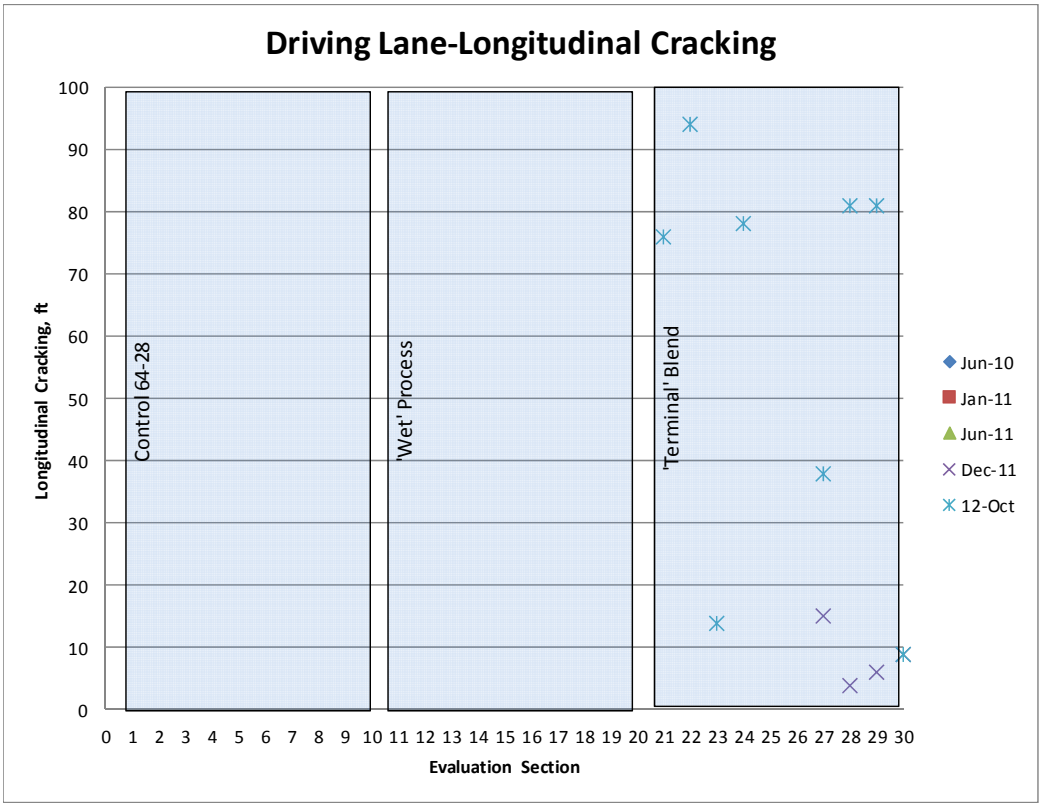


**Figure 2 – Longitudinal Cracking in Driving Lane**

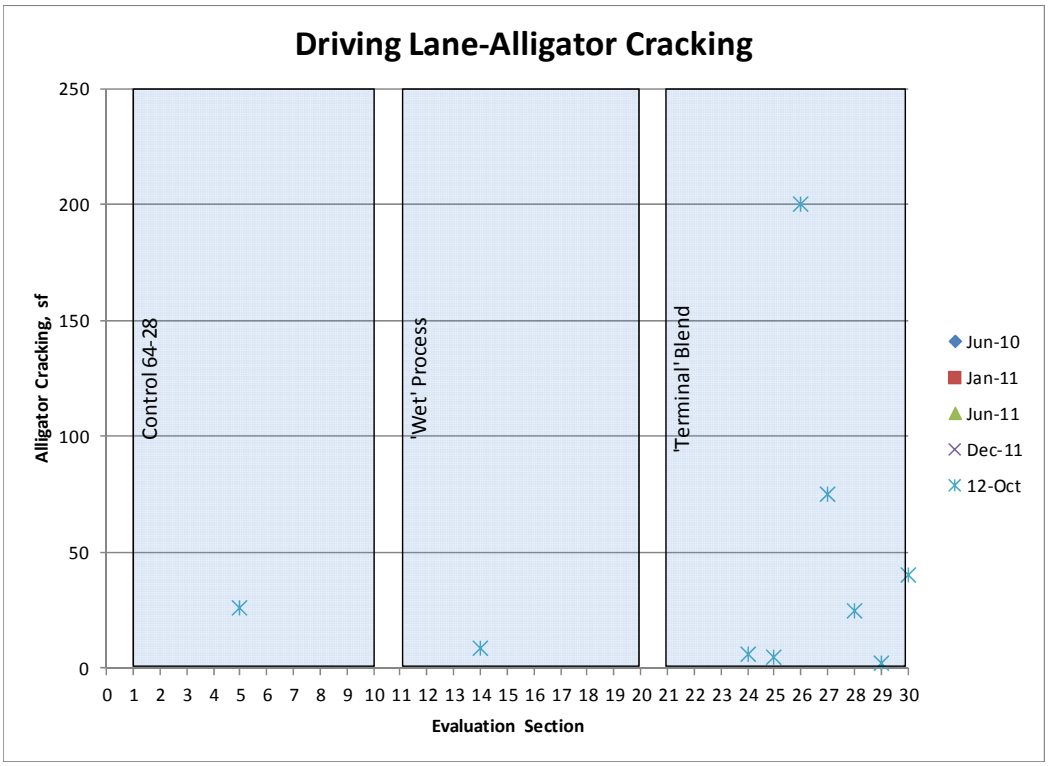


**Figure 3 – Alligator Cracking in Driving Lane**

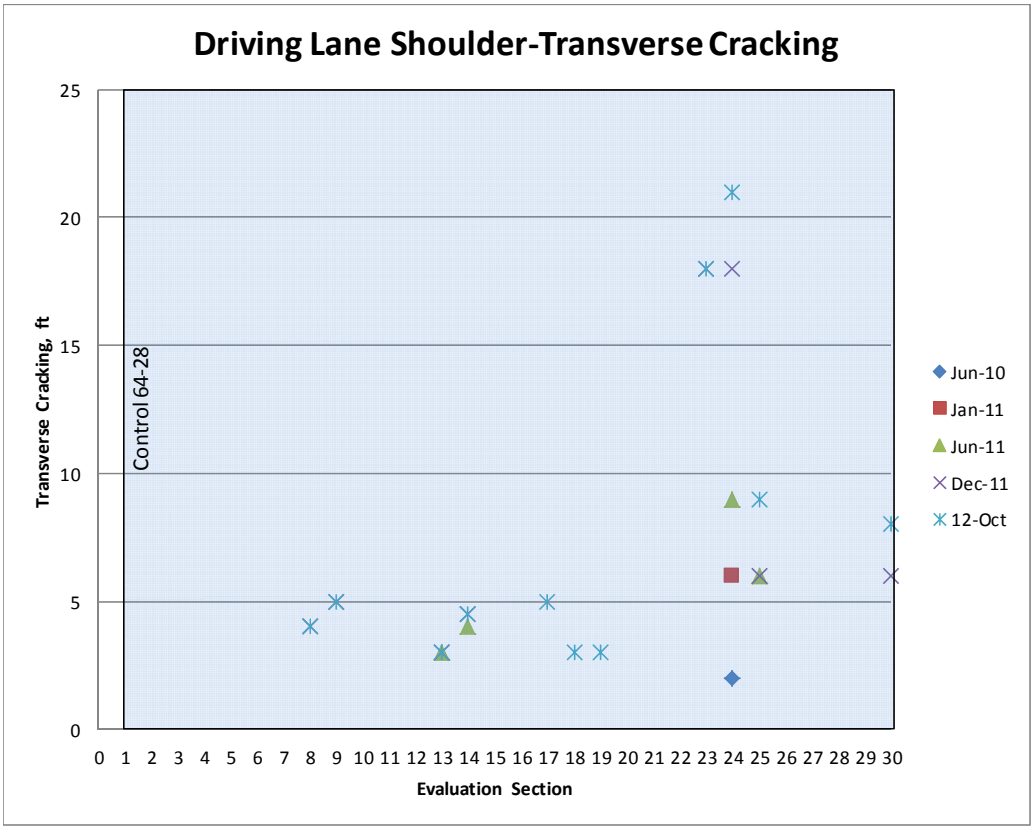


**Figure 4 – Transverse Cracking in Driving Lane Shoulder**

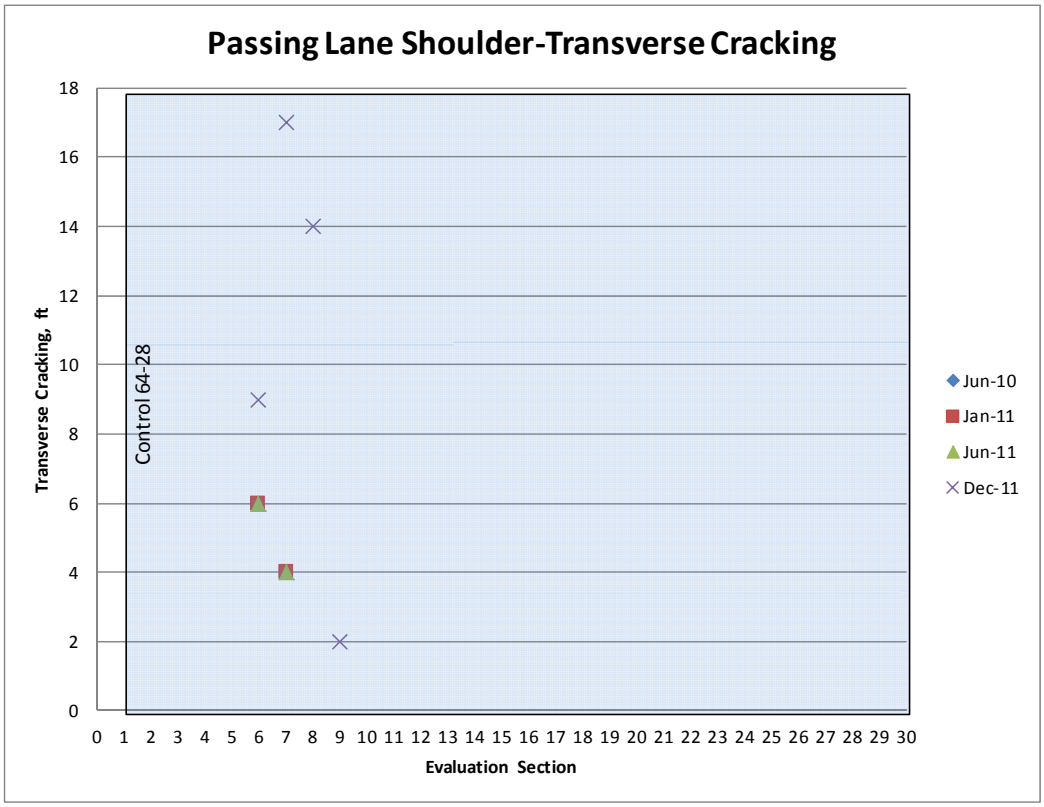


**Figure 5 – Transverse Cracking in Passing Lane Shoulder**

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| Background | Reporting Period: 10/1/12 through 12/31/12<br>Start:8/8/12 Contract Amount: $57,040<br><br>Principal Investigator:<br>Dale Tischmak, Felsburg Holt & Ullevig<br><br>Study Manager:<br>Bryan Roeder, CDOT, 303-512-4420<br><br>Study Panel Leader:<br>Jill Schlaefer, CDOT Environmental Programs Branch<br>(303) 757-9016<br><br>Study Panel Members:<br>Jordan Rudel, CDOT Region 6 Environmental<br>Robert Mero, CDOT Region 6 Materials Unit<br>Paula Durkin, CDOT Region 3 Environmental<br>Stephanie Gibson, FHWA Colorado<br>Roberto DeDios, CDOT Research Branch<br>Chuck Attardo, CDOT Region 1 Environmental<br><br>FHWA Washington Contact: |
|---|---|
| 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.<br><br>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. | |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 09/01/2012 | 100 | 08/08/2012 | Purchase Order issued to Felsburg Holt and Ullevig |
| 08/20/2012 | 100 | 08/20/2012 | Project Kick Off Meeting: met with research panel to discuss research project goals, scope, deliverables and schedule |
| 11/2012 | 99 | 12/31/2012 | Literature search of potential abatement actions |
| 11/2012 | 100 | 11/29/2012 | 2nd Committee meeting |
| 12/2012 | 100 | 10/26/2012 | Research Technical Memo |
| 01/2013 | 0 | | 3rd Committee meeting |
| 03/2013 | 50 | 12/31/2012 | Abatement concepts and computer modeling tasks |
| 04/2013 | 5 | 12/31/2012 | Conceptual designs & Design Report |
| 04/2013 | 0 | | 4th Committee meeting |
| 06/05/2013 | 0 | | Draft report (75 days prior to final report publication) |
| 07/31/2013 | 0 | | Final presentation |
| 08/19/2013 | 0 | | Final Report publication |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

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

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

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

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

## MILESTONES

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

# SIGNIFICANT EVENTS

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

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

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

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

Background

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

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

The study will provide a fresh and scientifically based review of the effectiveness or shortcomings of proposed and current CDOT specifications, guidelines, processes, and contractor compliance for construction site revegetation. The research project will review revegetation strategies used in other arid states and agencies. The research will survey CDOT contractors on techniques and equipment use and survey CDOT engineers on successful and unsuccessful measures attempted or implemented.

This study will provide species surveys conducted on existing highway areas and adjacent areas for use in ecologically relevant planting suggestions and seed mixes. The emphasis will be to identify ways in which site stabilization can be accelerated, improved and/or optimized using innovative techniques that take into account site specific habitat conditions and the difficulties present in transportation construction and planning.

Reporting Period: 10/1/12 through 12/31/12
Start: TBD  Contract Amount: $ TBD

Principal Investigator:
TBD

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

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 7/15/12 | | 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 | | 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 | | 11/2/12 | The Procurement Office issued request for proposals |
| 2/15/13 | 50% | | Select researcher: Several proposals were received on 12/12/12 and are being reviewed by the selection committee. |
| 4/15/13 | | | Notice to Proceed, begin study |
| 5/15/15 | | | Final Report publication |

# 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<br><br>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.<br>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:<br>1) Identifying the best locations<br>2) Identifying land owners and securing their cooperation<br>3) Engaging resource agency support of the design and establishment<br>4) Insuring initial maintenance<br>5) Tracking these assets over time and documenting the benefits | Reporting Period: 10/01/12 through 12/31/12<br>Start: 11/29/12 Contract Amount: $ 70,000<br><br>Principal Investigator:<br>Greg Sundstrom, Colorado State Forest Service, CSU<br><br>Study Manager:<br>Bryan Roeder, CDOT, 303-512-4420<br><br>Study Panel Leader:<br>Mike Banovich, CDOT Environmental Programs Branch (303) 757-9542<br><br>Study Panel Members:<br>Jen Klaetsch, CDOT Environmental Programs Branch<br>Mark Harrington, CDOT Environmental Programs Branch<br>David Vialpando, CDOT, R-5, Maintenance<br>Jeff Peterson, CDOT Environmental Programs Branch |

## TASKS, MILESTONES, AND DELIVERABLES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 11/30/12 | | 11/29/12 | PO 211017905 issued to CSU to start project. |
| 12/14/12 | 100 | 12/14/12 | Kick Off meeting |
| 12/31/12 | 100 | 1/22/13 | Kick Off meeting minutes submitted |
| 12/31/12 | 100 | 1/22/13 | Quarterly project report |
| 3/31/13 | | | Inventory of existing LSFs on state highways |
| 3/31/13 | | | Summary report of inventory information found along with copies of documents located |
| 3/31/13 | | | Quarterly project report |
| 6/30/13 | | | Quarterly project report |
| 9/15/13 | | | Drafts of guidelines and research report |
| 9/19/13 | | | Status meeting |
| 9/30/13 | | | Status meeting minutes submitted |
| 9/30/13 | | | Quarterly project report |
| 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 |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Cost Construction Index Forecasting Model
## Study No: 61.12

| | |
|---|---|
| Background<br><br>The Colorado Department of Transportation (CDOT) estimates a composite index of the costs of highway construction in Colorado, the Colorado's Construction Cost Index (CCCI). The historical time series of CCCI estimates is used by the U.S. Federal Highway Administration (FHWA), the general construction industry, the local governments and municipal planning organizations (MPOs) of Colorado as well as several divisions within CDOT: the Office of Financial Management and Budget (OFMB), the Office of the Chief Engineer and the Division of Transportation Development.<br><br>The primary objective of this research study is to build a model that CDOT staff can use on an ongoing basis to estimate and forecast a cost index for highway construction in Colorado ("Colorado Construction Cost Index" or "CCCI"). The secondary objective of this research study is to forecast of the CCCI over the period from 2012 to 2040. | **Reporting Period:** 10/1/12 through 12/31/12<br>**Type:** SP&R<br>**PO: CONTRACT AMENDMENT ROUTING NUMBER HAA 46402**<br>**Start:** 07/23/12<br>**End:** 05/31/13<br><br>**Principal Investigator(s):**<br>**Peter Mills, Dye Management Group Inc.**<br><br>**Study Manager:**<br>David Reeves, CDOT Division of Transportation Development, 303-757-9518<br><br>**Study Panel Members:**<br>Scott Richrath, CDOT DTD Performance Measures Branch Manager |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| | 100% | 07/23/12 | Notice to Proceed |
| | 100% | 07/27/12 | Kick-Off Meeting |
| 06/30/13 | 60% | | Task 1 – Project initiation and project management. |
| 09/30/12 | 95% | 11/28/12 | Task 2 – Cost item data. |
| 10/31/12 | 40% | 11/28/12 | Task 3 – Input weighting into cost items |
| 01/31/13 | 0% | | Task 4 – Input and cost item regressions. |
| 02/15/13 | 0% | | Task 5 – Construct model |
| 02/28/13 | 0% | | Task 6 – Estimate future construction costs. |

## SIGNIFICANT EVENTS

- September and October 2012 – Task 2 Cost Item Data
    - Settled the data collection plan with CDOT staff on 25 September 2012.
    - Historical data for all 2,549 unit cost items, with the exception of the oil price adjustment force accounts, have been transcribed from CDOT pdf data files into our regression models for the periods 2005-2008 and 2010-2011.

- 364 unit cost items were selected from these 2,549 unit cost items, representing over 80% of the total value of prior CDOT contracts, for further analyses and forecasting.

- September and October 2012 – Task 3 Input Weighting into Cost Items
  - 86 of the 364 unit cost items have been analyzed for their composition of labor, heavy equipment, oil, steel and concrete.
  - Historical data series for two of the five independent variables – labor and oil – have been compiled.

## ANTICIPATED WORK NEXT PERIOD

- November and December 2012 – Task 2 Cost Item Data
  - Load 2009 data.
- November and December 2012 – Task 3 Input Weighting into Cost Items
  - Assign input compositions to the remaining 278 unit cost items selected for forecasting.
  - Complete compilation of historical data for independent variables.
- November and December 2012 – Task 4 Input and Cost Item Regression
  - Preliminary regressions of unit cost items against independent variables.

## ISSUES

- Availability of data on the costs of oil price adjustments to asphalt costs, “plan force account” 700-70019

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| | |
|---|---|
| Background<br><br>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:<br>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.<br>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.<br>3. Provide operational guidelines for further development of consequent-consistent risk-based approaches for performance design of other types of CDOT facilities. | **Reporting Period:** 10/1/12 through 12/31/12<br>**Type:** SP&R<br>**PO:** 271001703<br>**Start:** 07/02/12<br>**End:** 06/20/14<br><br>**Principal Investigator(s):**<br>Dr. Ross Corotis, CU Boulder, 303.735.0539, Corotis@colorado.edu<br>Dr. Abbie Liel, CU Boulder, abbie.liel@colorao.du<br>**Yolanda Lin, CU Boulder**<br>**Abhishek Paul, CU Boulder**<br><br>**Study Manager:**<br>David Reeves, P.E., CDOT Research Branch, 303-757-9518<br><br>**Study Panel Members:**<br>David Wieder, Maint. & Operations (HQ)<br>Branch Manager Office (HQ)<br>Darrel Lingk, OTS Director (HQ)<br>Charles Meyer, Traffic & Safety (HQ)<br>David Swenka, Traffic & Safety (HQ) |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 07/01/12 | 100 | 07/02/12 | Notice to Proceed |
| 03/31/13 | 25 | | Task 1 – Develop risk methodology |
| 05/31/13 | 0 | | Meeting with CDOT Study Panel |
| 09/30/13 | 25 | | Task 2 – Methodology & critical decision-making metrics |
| 09/30/13 | 0 | | Meeting with CDOT Study Panel |
| 01/31/14 | 0 | | Task 3 – Propose a general CDOT policy in applying concept of risk- and consequent-based analysis |
| 06/20/14 | 12.5 | | 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

Objective 1 (25% completed)

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 (25% completed)

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

The primary focus will be on the continued collection and evaluation of information on risk-based systems as used by other states, as well as other documentation on risk-based approaches to project and infrastructure management. It is expected this will take about one more quarter, after which we will move into the development of a specific methodology recommended for CDOT.

Objective 2

Also doing the coming quarter we will be analyzing the mast arm data for application to a risk-based approach for design and maintenance.

## ISSUES

- No issues and project is on track.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Optimization of Stabilization of Highway Embankment Slopes Using Driven Piles (Phase II – Development and Verification)
## Study No: 74.91

<table>
<tr>
<td>Background<br><br>Slope stability problems are of special importance to CDOT because of the number of mountain highway embankments which are vulnerable to progressive lateral slope failure, causing pavement distress and settlement which can be hazardous to highway users. This is often triggered by increased soil saturation during spring snow melt periods. While maintenance crews can often repave an affected area to mitigate the highway settlement, the original failure often creates a slip surface which sets up subsequent failure of the remolded soil in future years. Driven piles have been used with some success to solve the local slope stability problem, however, geotechnical research and input can improve these efforts both in regards to performance and economy.<br><br>This phase of the study follows a preliminary investigation in Phase I, where it was found that the stabilization of laterally failing slopes using driven piles could be effective and economical. To develop these findings, a literature review, surveys of state DOTs, cost comparisons analyses and targeted field inspections were performed.<br><br>Using extensions of traditional two-dimensional methods of analysis together with modern finite element computational techniques, this study aims to better understand the effectiveness of driven piles in reinforcing at-risk highway embankment slopes. Additionally, the research will lead to practical guidelines by which lateral piles can be prescribed and implemented at optimal locations. Specifically, the guidelines will address the most economical pile size, spacing and driven depth based on observed site characteristics and geotechnical investigation.</td>
<td>Reporting Period: 10/12 through 12/31/12<br>Type: SP&R Start: Ver:<br>Contract: (P.O. #)<br><br>Principal Investigator(s):<br>Panos Kiousis, Colorado School of Mines<br>303-384-2205<br>D.V. Griffiths, Colorado School of Mines<br>303-273-3669<br><br>Study Manager:<br>Aziz Khan, Research Branch<br>303-757-9522<br><br>Study Panel Members:<br>Steve Laudeman, CDOT Materials and Geotechnical Branch<br>Craig Wieden, CDOT Region-2 Materials<br>Del French, CDOT Region-3 Maintenance<br>Russel Cox,<br>Rex Goodrich, R-3 Material Engineer<br>John Hart, Coggins and Sons, Denver<br>Alan Lisowy, H-P Geotech, Denver<br>Matt Greer, FHWA-Colorado</td>
</tr>
</table>

## MODIFIED RESEARCH TASKS

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 7/1/11 | 100% | Y | Task 1: Analysis of test site |
| 6/1/11 | 100% | Y | Task 2a: Spreadsheet-based model |
| 12/31/11 | 100% | Y | Task 2b: Finite Elements-based model |
| 1/1/13 | 20% | | Task 2c: Develop a plan for parametric study (see Note 5 below) |
| 6/15/13 | 10% | | Task 3: Numerical examination of pile load transfer and effects on stability |
| 6/1/13 | 0% | | Task 4: CANCELED |
| 5/1/13 | 0% | | Task 5: CANCELED |
| 8/1/13 | 0% | | Task 6a: Compare and calibrate results to develop design methodology |
| 12/31/13 | 0% | | Task 6b: Draft and Final Report |

# MILESTONES

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

# SIGNIFICANT EVENTS

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

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

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

**Note 3:** Pile implementation plans will be considered as a part of the update meeting scheduled for February 2012. At this point, it is believed that enough evidence is presented by which an optimized pile implementation plan can be reasonably developed. This comes from the realization that the best pile instrumentation data will come from a situation where the piles develop plastic hinges, but with small enough total deflection to still remain effectively in place (rather than being entirely swept away). This will reveal the precise point where the ability of the pile to contribute to slope stability is exceeded by the capacity of the soil to be supported by lateral piles. In this manner, both geotechnical modeling of the soil and structural modeling of pile fixation can be verified.

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

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

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

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Assessment of MSE Wall Attachment Details Meeting New AASHTO Seismic Connection Requirement and Implementation of End-of-Wall (EOW) Treatment for Bridge Worksheet
## Study No: 74.75

Background

This study aims to provide displacement-based seismic design recommendations for Mechanically Stabilized Earth (MSE) walls for the state of Colorado. The AASHTO LRFD Bridge Design Specifications, 2008 Interim, now mandate a more stringent 1000 year seismic return period as opposed to the previous 500 year return period. This change results in an increased in predicted maximum USGS peak ground acceleration (PGA) for Western Colorado from 0.025g to 0.14g. Given the importance of CDOT retaining walls on the operations of transportation corridors, the impact of the PGA contour upgrades on CDOT design practices should be examined.

The AASHTO LRFD Specifications provide guidelines for seismic design of MSE Walls in section 11.10.7. While the overall external stability requirements for MSE walls may be addressed through limit equilibrium analyses and their associated design methodologies, the behavior of the individual components of an MSE wall (e.g., the facing panels, modular blocks, coping, and the connections to the soil reinforcement) are not fully understood or codified. Such detailing issues cannot always be adequately addressed through typical limit equilibrium analyses of overall system behavior and may require a more explicit deformation-based approach.

This study therefore aims to provide displacement-based seismic design recommendations for MSE walls. Specifically, we will address the design of: (1) reinforcement of the cap element (coping), (2) the connection of the coping to the tops of MSE or soil nail facing, (3) the connections of the upper blocks in modular block MSE walls, (4) the design and detailing of the ends-of-the-walls, and (5) the connections between MSE facings and the soil reinforcement. This will be done a) by reviewing existing studies, b) by examining related practices of other state DOTs, and c) by performing a series of dynamic finite element analyses on typical MSE and soil nail walls, explicitly modeling all of the individual components and their interaction when subjected to a series of dynamic ground motions representing the extreme seismic events predicted by the Western Colorado PGA contours. General behavior tendencies will be determined from these analyses and will be used to inform the detail work for MSE walls.

Reporting Period: 10/1/12 through12/31/12
Type: SP&R Start: 03/03/10 Ver:
Contract: 10HAA11438 (P.O. # 271001132)

Principal Investigator(s):
Panos Kiousis, Colorado School of Mines
303-384-2205
Judith Wang, Colorado School of Mines
303-273-3836

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

Study Panel Members:
Nurul Alam
Russel Cox
Lynn Crosswell
Hsing-Cheng Liu
Cheng Su
Trever Wang
Steve Yip

FHWA Washington Contact:
Daniel Alzamora

## RESEARCH TASKS

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 3/03/10 | 100% | | Task 1: Literature Review |
| 3/03/10 | 100% | | Task 2: National DOT Survey |

| | | | |
|---|---|---|---|
| 6/03/10 | 90% | | Task 3: Displacement-Based Analysis |
| 12/03/10 | 100% | | Task 4: Interim Report |
| 7/03/11 | 85% | | Task 5: Draft and Final Report |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 11/15/09 | 100 | Y | Study Advertised (Proposals Solicitation) |
| 03/03/10 | 100 | Y | Notice to Proceed (NTP) to CSM |
| 03/31/10 | 100 | Y | Kick-Off Meeting with CSM |

## SIGNIFICANT EVENTS

**Note 1:** We have completed a literature review of material in academic journals and texts, from state DOT websites, and national reports which was included in the interim report submitted to CDOT on February 22, 2011.

**Note 2:** We have sent out a national survey in which we have received 40/50 responses. Of the state DOTs that have responded, 39/40 maintain existing MSE walls, 29/40 use the AASHTO LRFD Bridge Design Specifications, 18/40 mention seismic design in their current state standards, and 2/40 are currently performing research on seismic loading on MSE walls. This report was submitted to CDOT on October 12, 2010.

**Note 3:** It has been determined that ground motions in the range of desired accelerations for a 1000 year return period earthquake have not been recorded in Colorado. We have performed a deaggregation analysis for a site class D soil. Using spectrum matching of existing records, a maximum design acceleration was determined in accordance with ASCE 07. In order to produce a time history of a likely Colorado ground motion, this acceleration will be used as the peak value in the combination of a parabolic and an oscillating function which use the natural frequency of the wall structures to obtain a worst case ground motion. A more in-depth knowledge of the program LS-Dyna has been obtained. A modal analysis has been performed on a 15 foot high panel wall, a 15 foot high modular block wall, and a 30 foot high modular block wall. We have applied the created ground motions to the 15 foot walls and are completing the process of applying them on the 30 foot walls. A final report is being prepared on our findings for the CDOT Study Panel.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Real-time In-situ Monitoring of Infiltration-induced Instability of I-70 Embankment West of the Eisenhower Tunnel
## Study No. 74.92

Background

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

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

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

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

Completion/End Date: 09/30/2013

CDOT SAP # 27100300

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

Co-Principal Investigator(s):
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303-273-3961

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

Study Panel Members:
H-C., Liu, Materials & Geotechnical Branch (Panel Leader)
Bill Scheuerman, R-1 Resident Engineer
Mark Vessely, Shannon and Wilson, Inc.
Trever Wang, Bridge Design and Management Branch
Russel Cox, R-1 Resident Engineer
David Thomas, Materials and Geotechnical Branch
Tonya Hart, CTL Thomson, Inc
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 |
| 07/01/13 | 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

## Sustainable Stabilization of Sulfate-Bearing Soils with Expansive Soil-Rubber (ESR) Technology
## Study No: 74.95

Background

Pavement construction and maintenance problems due to the presence of sulfates in lime-stabilized subgrades have been reported in many transportation projects. In Colorado, problems associated with sulfate-induced distresses have been observed at the Denver International Airport and, more recently, at the U. S. Highway 287 Berthoud By-pass project. Although problems caused by conventional calcium-based stabilization of sulfate-bearing subgrade soils may be mitigated by carrying out preliminary tests to determine sulfate concentrations, it would be desirable if CDOT engineers could count on alternative soil stabilization techniques that are not affected by the potential presence of sulfates. A sustainable stabilization technique has been developed at Colorado State University (CSU) to mitigate the swell potential of expansive soils with rubber from scrap tires. The main objectives of this new stabilization technique are two-fold: (1) reduce the swell potential of expansive soil (including soils containing sulfates), and (2) maximize recycling of scrap tires in the state (Colorado has one of the largest inventories of stockpiled scrap tires in the country and one of the lowest recycling rates in civil engineering applications (CDPHE 2007).

Previous ESR research carried out at CSU with soils collected from the U. S. Highway 287 Berthoud By-Pass project suggest that both the swell percent and the swell pressure of ESR mixtures prepared with this new technology are significantly lower than the swell percent and swell pressure of the untreated natural soil (Seda et al. 2007). Thus, the proposed ESR technology may be used to reduce the swell potential of expansive soil layers in a variety of geotechnical and highway projects including (but not limited to) stabilization of subgrade soils and bridge abutment embankments. Since ESR technology does not rely upon conventional calcium-based stabilization mechanisms, it may be particularly suitable for projects where local soil deposits are rich in sulfates and traditional chemical stabilization techniques are either unsuitable or require additional mitigation efforts for implementation.

This study's goal is to help develop a new stabilization protocol that will allow CDOT and other state and federal transportation agencies to rely upon an alternative stabilization method that is not subject to the typical problems associated with calcium-based stabilization of sulfate-rich soils (the proposed technology is also appropriate to stabilize sulfate-free subgrade soils).

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 03/30/08

Principal Investigator(s):
Dr. J. Antonio H. Carraro, CSU (970)491-4660

Study Manager: TBD
Robert de Dios, DTD Research (303)757-9975

Study Panel Members:
James Chang, Region 6 Materials
Gary DeWitt, Region 4 Materials
Rex Goodrich, Region 3 Materials
Donna Harmelink, FHWA-CO Division
Alan Hotchkiss, HQ Materials and Geotechnical
Shamshad Hussain, Region 1 Materials
Aziz Khan, DTD Research Branch
C.K. Su, HQ Materials and Geotechnical

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 4/10/09 | 100 | 4/10/09 | Notice to Proceed |
| 05/18/09 | 100 | 5/18/09 | Task 1 – Pre-Kickoff Meeting-1, a meeting planned for end of July |
| 07/01/09 | 100 | | Task 2 – Literature Review |
| 05/18/09 | 100 | 9/11/09 | Task 3 – Material selection |
| 08/01/09 | - | | Task 4 – Laboratory Experimental Program – Phase I |

| | | | |
|---|---|---|---|
| | 100 | 5/25/11 | Sub-Task 4.1 – Characterization |
| | 100 | 2/15/11 | Sub-Task 4.2 – Compaction |
| | 100 | 9/30/11 | Sub-Task 4.3 – Resilient Modulus Testing I |
| | 100 | | Sub-Task 4.4 – Resilient Modulus Testing II |
| | 100 | 9/30/11 | Sub-Task 4.5 – Poisson's Ratio Evaluation |
| | 100 | | Sub-Task 4.6 – Swell Consolidation |
| 05/01/10 | - | | Task 5 – Laboratory Experimental Program – Phase II |
| | 100 | 9/30/11 | Sub-Task 5.1 – Triaxial Testing |
| | 100 | 9/30/11 | Sub-Task 5.2 – Bender Element Testing |
| 07/01/10 | | | Task 6 – Development of the MEPDG Database |
| 09/1/10 | | | Task 7 – Development of the ESR Stabilization Design Protocol |
| 06/1/10 | | | Task 8 – Construction of Small-Scale Test and Control Sections |
| 05/1/10 | | | Task 9 – Development of Construction, Monitoring and Documentation Procedures |
| 06/1/10 | | | Task 10 – Field Section Monitoring |
| Every 3 months | | 7/15/09(QR1)<br>10/7/09(QR2)<br>3/12/10(QR3)<br>2/15/11(QR4)<br>5/25/11(QR5)<br>7/14/11 (QR6)<br>10/5/11 (QR7) | Task 11 – Quarterly and Final Report Writing |
| 06/2010 & 06/2011 | 100 | | Task 12 – Research Results Presentation |
| 12/30/12 | | | Submit final report. |

# SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**9/30/2012** Dr. Antonio Carraro promised to submit the final report by 12/12.

**6/30/2012** The final report has not been delivered yet. The Study Manager ceased payment of the invoice and will communicate with CSU's Sponsored Program regarding the required submission of the final report for this study.

**1/27/2012** A Powerpoint presentation was given to the study panel on 1/27/12 as scheduled. The Principal Investigator moved to Australia but promised to complete the final report. He is still connected with CSU and has committed to provide the final report in due time.

**12/31/2011** Principal Investigator indicated he was in the process of completing the remaining work. He planned to make a PowerPoint presentation to the study panel on 1/27/12.

**9/30/2011 -** Majority of the tests required for Tasks 4 and 5 (Laboratory Experimental Program – Phases I and II) have been completed. A couple tests for Sub-Tasks 4.5 and 4.6 are still ongoing but should be completed in the near future. Activities related to Tasks 6 and 7 have started.

**7/12/2011 -** Resilient modulus testing resumed.

**7/11/2011 -** Resilient modulus equipment repaired and re-calibrated (vertical steel shaft and bronze bushing were damaged and had to be completely rebuilt at the CSU machine shop).

**5/25/2011 -** Resilient modulus equipment undergoing repair and re-calibration.

**2/15/2011 -** Research update provided to Roberto DeDios.

**9/23/2010 -** New research assistant started working on the project.

**9/23/2010 -** A summary of preliminary results was submitted on September 23, 2010.

**6/30/2010 -** No activity was reported in this quarter.

**3/12/2010 -** Verbal offer made to new research assistant.

**2/25/2010 -** New research assistant candidates shortlisted.

**12/11/2010 -** Preliminary search for new research assistant started.

**12/10/2009 -** PI notified of research assistant's health issues.

**10/01/2009 -** Task 4 Update (% progress for all subtasks provided below):

4.1 Basic material characterization: 30%

4.2 Compaction and time domain reflectometry: 25%

4.3 Resilient modulus testing: 10%

4.4 Resilient modulus testing: 0%

4.5 Poisson's ratio evaluation: 0%

4.6 Swell consolidation testing: 10%

**09/17/2009 -** Copy of the CDOT Field Materials Manual provided by Mr. Gray Currier.

**09/11/2009 -** Mr. Gray Currier visited the CSU geotechnical research laboratory to inspect the samples from the Berthoud site delivered by CDOT personnel. After inspecting the samples, Mr. Gray Currier pronounced them to be the correct samples for testing.

**09/07/2009 -** Documentation on pavement cross section for the Berthoud By-Pass project provided by Mr. Gray Currier.

**08/18/2009 -** Copy of the sulfate content analysis procedure (followed at CDOT laboratories) provided by CDOT.

**07/28/2009 -** Sampling at the Lafayette site conducted by Mr. Robert Gonser and Mr. Louie Lopez. Both intact samples and bulk samples from this site were delivered by CDOT to the CSU's geotechnical research laboratory.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

Chemical sealers, applied on the top concrete surface, are employed by CDOT for waterproofing bare new and existing bridge decks that do not have asphalt overlay. The type of sealers includes silane, siloxane, epoxy, and methacrylate. These and other commercially available sealers products have been developed to reduce the penetration of chloride ions from deicing salts and thereby preventing the corrosion of the reinforcing steel. Unfortunately CDOT material specifications allows for only limited types of sealers, silane for the "penetration sealers" and methacrylate for the "crack sealers."

This research should develop generic type of performance-based material and construction specification for penetration and crack sealers that would allow for acceptance of other type of sealers materials based on the results of performance tests. The study should present all the details for the types of these tests (laboratory and field) and for interpretation of the test results. Some of the tests that should be considered for the penetration sealers include the chloride ponding test, elongation test, skid test, UV stability test, freeze-thaw tests, and tests for quality assurance of the placed sealers during construction. Some of the tests that should be considered for crack sealers include skid test, UV stability test, freeze-thaw tests, depth of penetration into the typical size of cracks developed in bridge decks, and tests for quality assurance of the placed sealers during construction. The crack sizes for application of the crack sealers should be established. The construction requirements should include information on the surface preparation before application of the sealers.

Reporting Period: 10/1/121through 12/31/12

Fund 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<br>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 | 95% | | 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

## 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. As documented in the Department research study Report No. CDOT-2010-1, there 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: 10/1/12 through 12/31/12
Type: SP&R Start: 06/29/10

Principal Investigators:
Colorado School of Mines, Dr. Mike Mooney,
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Study Manager: TBD

Study Panel Members:
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Michael Stanford, Mat. & Geotech Branch
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Jim Noll, Kumar and Associates,
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# MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| 9/17/10 | 100 | 9/17/10 | Hold study panel kick-off meeting. |
| 10/31/10 | 100 | 6/30/11 | Perform comprehensive literature review |
| 12/31/10 | 100 | 6/30/11 | Develop a detailed plan and schedule of activities to complete the research project |
| 12/31/10 | 100 | 6/30/11 | Identify candidate projects |
| 12/31/10 | 100 | 6/30/11 | Select a project |
| 4/30/12 | 100 | 4/30/12 | Perform laboratory testing of lime-stabilized soil (LSS) design mix |
| 7/31/12 | 100 | 11/25/12 | Perform field testing of LSS |
| 8/31/12 | 50 | 12/31/12 | Perform additional laboratory testing of field LSS |
| 8/31/12 | 90 | | Conduct cost-benefit/usability analysis |
| 8/31/12 | 30 | | Perform data analysis |
| 9/30/12 | | | Develop Quality Assurance (QA) specification |
| 9/30/12 | | | Submit draft final report |
| 11/30/12 | | | Submit panel-approved final report |
| 12/31/12 | | | Present results of research work to the Materials and Advisory Committee (MAC) |

# SIGNIFICANT EVENTS

**The Study Manager, Roberto DeDios, retired from CDOT in January 2013**

**12/31/12** In Q4, we were able to perform field testing at Solterra in Lakewood and collect the necessary data to complete the field work. This does delay the project by 6 months. We anticipate submitting a draft final report by March 31, 2013.

**10/8/12** Lime stabilization at Candelas Development halted for the season due to temperatures. As only one third of expected work was completed at the site in the Fall of 2012, construction and further testing will resume when temperatures permit (March/April 2013). Because we were counting on this site for project data, we would like to extend the project and resume field work when another site becomes available.

**7/1/12** Identified final field test site to be Candelas Development in Arvada, CO. ARS will be doing the lime stabilization.

**2/02/12** Revised project task dates to accommodate additional field testing in 2012.

**10/10/11** Testing at Truth Christian Academy project site was completed with success. We still plan to conduct further testing in Fall 2011 and Spring 2012.

**7/15/11** The Truth Christian Academy project has been delayed until late July/early August. A second project – Candelas in Arvada, CO has been identified and is expected to be conducted in Fall 2011 and Spring 2012.

**4/20/11** Through conversation with ARS, our first candidate project is at the Truth Christian Academy (Bellevue/Quincy streets). This project is scheduled to begin in May.

**1/10/11** Through conversation with the major lime-stabilization contractor ARS, we learned that we must wait

until end of February (or thereabouts) to have a good idea for candidate project sites and project site selection. This is why we have not selected a project.

**6/29/10** CDOT Procurement Office issued Purchase Order No. 211010111 to have the Colorado School of Mines perform the research to evaluate the feasibility of using seismic testing for quality assurance of lime-stabilized soil.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

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

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

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

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

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 05/09 Ver:
Contract:

Principal Investigator
Dr. Rui Liu
Dr. Stephan Durham, Professor at UCD

Study Manager:
Aziz Khan, Research Branch

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

## MILESTONES

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

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

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

| | | | |
|---|---|---|---|
| 10/05/09 | 100% | 5/01/10 | Task 2: Develop a traffic, instrumentation, and data collection plan |
| 10/05/09 | 100% | 6/09/10 | Task 3: Install the approved products on I-76 and Weld County Road 53 east bound bridge at MP 36.54. Document installation process. |
| 08/22/10 | 100% | 6/24/11 | Task 4: Collect and analyze data to determine the effectiveness of the anti-wearing/anti-icing products. The examination will included, but not limited to: anti-icing, skid resistance, chloride penetration, permeability and snow melting. |
| 02/28/12 | 90% | | 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 | 40% | | Task 3: Data collection and analysis of thin-bonded overlays on structures F-17KK and F-17-OD |
| 10/14/2013 | 45% | | Task 4: Laboratory/field testing |
| 12/31/2013 | 40% | | 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 at 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 |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

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

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

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

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

Reporting Period: 10/1/12 through 12/31/12
Type: SP&R Start: 06/09 Ver:
Completion/End Date: 10/22/2013

**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

FHWA Washington Contact:

## 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 | | | Completion of preliminary FE Analysis |
| June 2013 | | | Interim report with all preliminary analysis to CDOT |
| Sept. 2013 | | | Physical Testing in the Lab |

## 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 | 80 | | Task 3: FEA Investigation |
| 12/31/11 | 100 | | Task 4: Investigate innovative approaches |
| 12/31/12 | 20 | | 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. |

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

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

# 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 | 20% | | 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. |
| 4/15/13 | | | Task 4: Develop design methodology, and construction worksheets for hybrid micropile-MSE walls for CDOT consideration. |
| 5/15/13 | | | Task 5: Draft and submit final report and recommendations |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

Background

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

Reporting Period: 10/1/12 through 12/31/12
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 | 95 | | 9 SAP bridge models have been developed in SAP. The simulation has been finished. Some post-processing work is remaining. |
| 07/01/2013* | 0 | | |

# 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 | 0 | | 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

## 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.<br><br>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).<br><br>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.<br><br>The mitigation of collisions at on-ramp merge lanes can be accomplished by safety treatments such as ramp metering or design modifications. Thus it is desirable to develop SPFs for these types of facilities. | Reporting Period: 10/1/12 through 12/31/12<br>Type: SP&R<br>Start: 05/14/12<br>PO: 211015884<br>PO Expiry: 12/31/2013<br><br>Principal Investigator(s):<br>Mr. David Hattan; Felsburg Holt & Ullevig Denver, 303-721-1440<br>Mr. Craig Lyon; 613-422-2542<br><br>Study Manager:<br>David Reeves, CDOT Division of Transportation Development, 303-757-9518<br><br>Study Panel Members:<br>~~Jake Kononov, DTD Research (Retired 7/1/12)~~<br>Charles Meyer, Traffic & Safety<br>David Swenka, Traffic & Safety<br>~~Bryan Allery, Traffic & Safety (Retired 7/1/12)~~ |

## MILESTONES

| Planned | % done | Achieved | Description, Discussion, and Related Issues |
|---|---|---|---|
| | 100 | 05/14/12 | Notice to Proceed |
| | 100 | 05/23/12 | Kick-Off Meeting |
| 09/30/12 | 50 | | Task 1 – Data Colection |
| | | | |
| 10/15/12 | 0 | | Task 2 – Develop Merge Zone SPF's |
| | | | |
| 12/15/12 | 0 | | Task 3 – Draft Report |
| 02/01/13 | 0 | | Task 3 – CDOT Review Draft Report |
| 02/15/13 | 0 | | Task 3 – Final Report |

## SIGNIFICANT EVENTS

- 05/23/12 Kick-off meeting held at CDOT with:
  - CDOT: Jake Kononov, David Reeves, Bryan Allery, David Swenka;
  - Consultant: David Hattan, Ryan Germeroth, Baghwant Persaud & Craig Lyon.
- June 2012 – Task 1 Data Collection
  - Gathering necessary geometric, volume, and crash data. Evaluating accuracy of data and make corrections to the merge area database.
  - Work efforts initiated to create a crash listing and a search file for the safety data. Consultant has begun downloading all the crash data for all study interchanges.

- July 2012– Both Jake Kononov and Bryan Allery retired from CDOT. Added Charles Meyer to the panel but essentially David Swenka and David Reeves will be the primary panel members.
- October 2012 – Task 1 Data Collection and Analysis
    - Work efforts continue to create crash data listing and a search file for the safety data. These efforts have been more complicated than anticipated since so many merges are really extended weaving areas and there are also many where the same direction of the same interchange has two on-ramps.

## ANTICIPATED WORK NEXT PERIOD

- Continue work efforts on gathering data to define merge zones
- Initiate efforts to develop merge zone SPF's

## 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: 10/1/12 through 12/31/12
Type: Experimental Feature


Principal Investigator:
Skip Outcalt, CDOT Research, 303.757.9984

Study Manager:
Skip Outcalt CDOT Research 303.757.9984

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


## MILESTONES

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

| | | | |
|---|---|---|---|
| | | | Castle Rock. |
| 07/07 | | 07/07 | Install approximately 1 mile of each of the 5 certified manufacturers' systems in the median of C-470 from mp 14 to 19 |
| 06/11 | 90 | | Evaluate accident and MMS system data. Write and distribute the final report. |

## SIGNIFICANT EVENTS

**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<br><br>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.<br><br>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.<br><br>Visibility testing was added to the scope of this study. Ron Gibbons, Virginia Polytechnical Institute and State University was hired to perform it.<br><br>Implementation<br><br>Findings of this study regarding the durability and cost effectiveness of barrier mounted LED lighting in lieu of overhead lighting can be used to justify the practice at future locations. | Reporting Period: 10/01/12 through 12/31/12<br>Type: Experimental Feature<br><br>Principal Investigator(s):<br>Nancy Clanton, Clanton & Assoc 303.530.7229<br><br>Study Manager:<br>Skip Outcalt, CDOT research 303.757.9984<br>Dave Reeves, CDOT research 303.757.9518<br><br>Study Panel Members:<br>Gregg Adams, Clanton & Assoc 303.530.7229<br>Joe Garcia, Reg 2 Design 719.546.5727<br>Darrell Dingus, Stds & Design 303.757.9083<br>Doug Lollar, R 2 Eng 719.546.5439<br>Dwayne Wilkinson, Safety 303.512.5134<br><br>FHWA :<br>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 | | | Schedule visibility evaluation line up panel of observers to participate in the test |
| 5/1/13 | | | Virginia Tech and panel of observers conduct visibility evaluation |
| 6/30/13 | | | Virginia Tech field testing report |
| 7/31/13 | | | Draft Final Report for study |
| 9/30/13 | | | Publish Final Report. |

# SIGNIFICANT EVENTS

**11/8/12 –** 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: 10/1/12 through 12/31/12
Type: SP&R Start: 03/06/12

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 | 50 | | Project kickoff meetings |
| 4/30/12 | 100 | 9/1/12 | Literature Review |
| 5/31/12 | 100 | 10/1/2012 | Survey and Interview Development |
| 6/30/12 | 20 | | Current CDOT Conditions |

| | | | |
|---|---|---|---|
| 7/31/12 | 10 | | Comparable Organizations |
| 10/31/12 | 20 | | Expert Panel Review |
| 1/31/13 | 0 | | Recommendation Development |
| 3/31/13 | 0 | | Final Report |
| 3/31/13 | 0 | | Final Presentations |

## SIGNIFICANT EVENTS

- 10/1/12 – Completion of survey for deployment to first CDOT region
- 10/15/12 – Initial set of data obtained from CDOT
- 10/1/12 – initial discussions with CDOT regarding refinement of goals completed

## ANTICIPATED EVENTS FOR Q4 2012

- Deployment of survey
- Meeting with Director of Safety
- Pilot interviews with RSOs
- Deployment of Social Network pilot

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Development of New Corrosion/Abrasion Guidelines for Selection of Culvert Pipe Materials
## Study No: 106.00

Background

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

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

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

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

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

Reporting Period: 10/1/12 through 12/31/12
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. |

# SIGNIFICANT EVENTS

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

| | |
|---|---|
| | highways. |
| 10/1/10 | Conducted a 3-day trip along I-70 and HW 50 and collected data from Grand Junction to Gunnison. Inspected culvert sites along HW 6, HW 340, and HW 141. Collected water and soils data and soil resistivity data from 29 sites along HW 50 and connecting highways. |
| 9/30/12 | Results of soil testing have been tabulated for final analysis. |

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

## Developing Design Procedure for Debris Culverts
## Study No: 106.3

Background

CDOT 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. 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; and new design procedures will guide the user to select proper sizes of culvert pipes.

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

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

Reporting Period: 10/1/2012 through 12/31/2012
Start: 10/5/12Complete: 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
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

## 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 |

# 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.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| | |
|---|---|
| Background<br><br>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.<br><br>Ken MacKenzie with the Denver Metropolitan Area Urban Drainage and Flood Control District will be undertaking a research study in partnership with Colorado State University to investigate an elliptical slot weir for metering water from settling ponds. | Reporting Period: 10/1/12 through 12/31/12<br>Start: 09/21/12 Contract Amount: $ $70,000<br><br>Principal Investigator:<br>Ken A. MacKenzie, P.E., CFM<br>Master Planning Program Manager<br>Urban Drainage and Flood Control District<br><br>Study Manager:<br>Bryan Roeder, CDOT ARIB, 303-512-4420<br><br>Study Panel Leader:<br>Mommandi, Amanullah, CDOT PDB Hydraulics Program Manager<br><br>Study Panel Members:<br>Rik Gay, CDOT EPB<br>Kenneth Quintana, CDOT R2 Maintenance<br>Al Roys, CDOT R4 Maintenance<br>Aziz Khan, CDOT ARIB |

## MILESTONES

| **Planned** | **% done** | **Achieved** | **Description, Discussion, and Related Issues** |
|---|---|---|---|
| 7/13/2012 | 100 | 7/18/2012 | Establish Study Panel: Panel meeting scheduled for 7/30/12. |
| 7/20/2012 | 100 | 8/8/2012 | Finalize scope of work that will be attached to the IGA. Purchase requisition submitted. |
| 8/19/2012 | 100 | 9/19/2012 | Execute an intergovernmental agreement (IGA) with the Urban Drainage and Flood Control District. |
| 10/1/2012 | 100 | 9/21/2012 | Begin Study. Notice to proceed issued 9/21/12 |
| 12/15/2012 | 50 | | 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 | 10 | | Debris modeling at the CSU hydraulics laboratory. The weir will be tested for debris handling efficiency and maintainability. |
| 2/15/2013 | 0 | | 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 | | CFD modeling of two additional weir heights for the three curvatures and three slot widths described above. |
| 4/30/2013 | 0 | | 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 | 0 | | Creation of design charts and/or an Excel spreadsheet computer model for water quality detention elliptical slot weir outlet designs. |

| | | | |
|---|---|---|---|
| 4/30/2013 | 0 | | 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.

# COLORADO DEPARTMENT OF TRANSPORTATION
# RESEARCH STUDY PROGRESS REPORT

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

| Background | Reporting Period: 10/1/12 through 12/31/12 |
|---|---|
| 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.<br><br>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.<br><br>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<br>Complete: 9/30/13<br>Contract:<br><br>Principal Investigator(s):<br>Michael Kohn, USGS, 303-236-6924<br><br>Study Manager:<br>Aziz Khan, Research Branch,<br>303-757-9255<br><br>Study Panel Leader:<br>Amanullah Mommandi,<br>Project Development Branch<br>303-757-9044<br><br>Study Panel Members:<br>Alfred Gross, R-1 Hydraulics<br>Jeffry Anderson, Bridge Design and Management Branch<br>Mark S Mueller, Maintenance and Operation<br>Carl Valdez, R-2 Maintenance<br>Hani Lavassani, R-6 RE South Program<br>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 | 95 | Expected: December 31, 2012 | Complete USGS publication |
| 7/31/13 | 0 | Expected: July 31, 2013 | Update Database with data from FY2012 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 database structure is complete and the web-interface of database is currently being completed. Currently, the Webpage that displays the database is live on the Web and was displayed at a meeting on 12/7/2011. Also, the Microsoft Excel database is completely populated with all USGS data; it is ready to hand over to CDOT. The USGS will wait to see if CDOT would like to include any of their post-flood bridge analysis before sending the Microsoft Excel database to CDOT.

The USGS held an internal meeting May 3, 2012 to demonstrate a preliminary version of the flood database in order to obtain some feedback to improve the database. This feedback will be incorporated into the database prior to demonstrating the database to CDOT at an upcoming meeting. The USGS report has been written and is approved for publication. It is currently waiting in line at the USGS printing office for final publication; hopefully, this will be complete by February 28, 2013 but it will depend on the length of the queue.

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 will soon have a link to the report, general project description, contact information, and Metadata along with a link to downloadable GIS shapefiles of all the sites and their drainage basins in the database. 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 will not be published until the Spring of 2012. After which time, the database will be updated to include data through water year 2012.

**Project completion**

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.