Issue 3, September 2018

COLORADO
Department of Transportation
Applied Research & Innovation Branch

Applied Research and Innovation Branch (ARIB) Newsletter/Innovation Frontline

2829 W. Howard Pl. Denver, CO 80204 www.codot.gov/programs/research/

Greetings,

It is my pleasure to provide you the Applied Research and Innovation Branch (ARIB) Quarterly Newsletter.

The mission of the ARIB is to save Colorado citizens' money, time, and lives while preserving the environment and quality of life through the development and deployment of innovative products, materials, and methods in transportation.

This mission is in part manifested through the review, selection and completion of research projects that reflect the CDOT and DTD missions, strategic areas, and goals.

Research can be formally defined as a systematic controlled inquiry involving analytical and experimental activities that primarily seek to increase the understanding of underlying phenomena. Research can be basic or applied.

Applied Research – The systematic study of phenomena relating to a specific known need or practical application. The primary purpose of this kind of research is to answer a question or solve a problem.

Basic Research – The systematic study of phenomena without specific applications or products in mind. The primary purpose of this kind of research is to increase knowledge. Basic research lays the foundation for advancements in knowledge that may lead to applied gains in the future.

The ARIB Program Areas:
The ARIB brings over twenty new and innovative ideas related to transportation to CDOT. Following are CDOT ARIB program areas of specialty:

1. **Environment and Water Quality**. Manages applied research in the areas of air and water quality, threatened and endangered species, vegetation management, noise abatement and more.
2. **Structures, Hydraulics and Geotechnical.** Manages applied research in the areas of bridge and retaining wall design, slope stability and foundations, geology, hydrology, and hydraulics.
3. **Safety, Operations and Planning.** Manages applied research in the areas of highway safety, worker's safety, traffic operations, geometric design, transportation planning, maintenance, and ITS.
4. **Pavements and Materials**. Manages applied research in the areas of materials, pavement management system, and pavement design.
5. **Local Technical Assistance Program (LTAP).** LTAP is a national network of technology transfer centers (one in each state, one in Puerto Rico, and 7 that serve Native American Tribal Governments). The LTAP mission is to bridge the gap between research and practice through training and demonstrations for local transportation agencies. The Federal Highway Administration (FHWA) with matching funds from state governments, universities, state highway agencies, and other organizations funds LTAP.
6. **Fieldwork and Skid Testing of Pavement.** Coordinates traffic control for field data collection and testing pavement skid resistance.
7. **Technology Transfer (T^2).** Technology transfer consists of activities that lead to the adoption of a new technique or product by users and involves dissemination, demonstration, training, and other activities.
8. **State Transportation Innovation Council (STIC).** This program provides one hundred thousand dollars of FHWA monies per year for funding innovative projects.

Research projects are selected and prioritized annually by the Research Implementation Council (RIC) through a process that insures that a broad array of topics is included and that CDOT mission, vision, and strategic goals are addressed.

In the next issue, we will include research findings, the research cycle, and who does what in initiating and conducting research, and in implementing the research findings and recommendations.

Amanullah Mommandi, P.E.
Director of the Applied Research and Innovation Branch

ARIB and the Research Library are located at the CDOT Headquarters Building in Denver, on the 4th floor. Photo courtesy of Shayna Lindeman.

Have a research idea?

Research managers are here to help.

In September, the Applied Research and Innovation Branch (ARIB) solicits for problem statements from CDOT staff and university researchers. ARIB seeks innovative research ideas that address a known need or have a practical application. ARIB requires researchers to provide research findings that CDOT can implement.

If you have an idea for a research project, the research managers listed below are available to help you brainstorm your idea and approaches to researching it.

Aziz Khan - Structures, Hydraulics, Soils, and Geotechnical, Aziz.Khan@state.co.us
Bryan Roeder - Environmental, Sustainability, and Water Quality, Bryan.Roeder@state.co.us
David Reeves - Safety, Operations, and Planning, David.Reeves@state.co.us
Roberto DeDios – Pavements and Materials, Roberto.DeDios@state.co.us
Amanullah Mommandi - Uncategorized research topics and ideas, Amanullah.Mommandi@state.co.us

2018 Completed Projects

Research Projects Completed in 2018

CDOT's Applied Research and Innovation Branch oversees research projects that seek to find implementable solutions to transportation problems. Over a dozen reports have been published so far in 2018, and they can be accessed at:
www.codot.gov/programs/research/pdfs

2018 Completed Research Projects

(In order of release)

A Multi-Perspective Study on Safety Performance at the Colorado DOT

Best Practices to Support and Improve Pavement Management Systems for Low-Volume Paved Roads-Phase I

Comprehensive Evaluation of Pavement Maintenance Activities Applied to Colorado Low-Volume Paved Roads-Phase II

Surface Chloride Levels in Colorado Structural Concrete

State Highway 9 Wildlife Crossings Monitoring – Year 2 Progress Report

Investigation of Seismic Performance and Design of Typical Curved and Skewed Bridges in Colorado

Evaluation and Performance of HDPE Pipes under CDOT Highways, T-REX, and Other Locations

Developing Bridge-Scour Equations for Colorado Mountain Streams

Joint Removal Implications – Thermal Analysis and Life-Cycle Cost

Dynamic Modulus of Cold-in-Place Recycling (CIR) Material

Evaluation of Tack Coat Bond Strength Tests

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

Evaluation of Different Types of Waterproofing Membranes (Asphaltic and Non-Asphaltic) as Cost Effective Bridge Deck Barriers in Reducing Corrosive Chloride Effects

FY19 New Studies

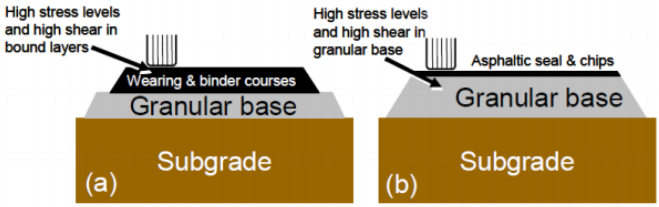
Geo-Tech	Drones for Measuring Changes Detection: Slope Stability and Landscape Monitoring (USGS)
Geo-Tech	Phase II Rock Cut Perimeter Blasting Management Practices
Hydraulics	Rapid Deployment Bridge Scour Alert System (USGS)
Pavement	Bond Strength in Concrete Overlays of Asphalt
Pavement	Field demonstration of Pavements using Colloidal Silica Admixtures
Pavement	National Partnership to Determine the Life Extending Benefit Curves of Pavement Preservation Techniques (MnROAD/NCAT Joint Study - Phase II
Safety	Assessing the Effectiveness of Friction as a Performance Management Tool
Safety	Autonomous Maintenance Technology (AMT) Pooled Fund
Safety	Comparing Effectiveness of using Safety Performance Functions (SPFs) and Diagnostic Norms with using Multiple SPFs for each Crash Type
Safety	Side-by-side Comparison of Ag-based Deicing Additives
Structures	Cure Time for Concrete Deck Repairs Prior to Placing Waterproofing Membrane
Structures	Development of age and state dependent stochastic model for improved bridge deterioration prediction
Structures	Driven Pile Testing Pooled-Fund Project (Wyoming DOT & UCD) $30k a year for 5 years

Research Highlights

Best Practices to Support and Improve Pavement Management Systems for Low-Volume Paved Roads: Phases I and II

Study conducted by Colorado State University, Fort Collins.

Low-volume roads (LVRs) are facing multiple challenges including: reductions in maintenance budgets, impact of industrial activities, and potentially not receiving the most cost effective treatments. This study documented current national and local practices and investigates treatment policies that are in place on LVRs by summarizing the results of multiple surveys. The surveys emphasized the need for some innovative maintenance activities for LVRs and integrating optimization techniques. It was also concluded that some surface maintenance strategies are effective long-term treatments for fatigue, longitudinal, and transverse cracking. However, the effectiveness of these treatments depends mainly on the initial condition index.



Profile of (a) high-volume road and (b) low-volume road (Brito, 2011, republished in the report on p.22).

An alternative maintenance strategy was proposed for CDOT considering a light rehabilitation technique with a surface treatment for poor roads. CDOT is advised to consider specific criteria while applying chip seals and thin overlays on roads. Chip seals shall be applied only while the pavement is still performing well. Pavement performance should be evaluated effectively considering the individual pavement condition indices rather than the overall drivability life value. Cold in-place recycling and full depth replacement are recommended to be integrated with the current applications of chip seals and thin overlays.

- Numan Mizyed

Read the Phase I and Phase II reports.

Research Highlights Continued

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

Study conducted by University of Colorado-Denver.

This study presents the development of ultra-high performance concrete (UHPC) using locally available materials, which reduces construction costs compared with commercial products. With the aim of achieving a specified compressive strength of 20 ksi, a UHPC mixture is formulated. The implications of various constituent types are examined with an emphasis on silica compounds (silica fume, silica powder, silica sand, finer silica sand, pyrogenic silica, and precipitated silica), including steel and polypropylene fibers. Bond tests are conducted to evaluate the development length of the UHPC. Cost analysis shows that the prototype UHPC is up to 74% less expensive than commercial products.

A step-by-step procedure is recommended in tandem with quality assurance and quality control for CDOT to implement the UHPC technology in bridge construction.

- Numan Mizyed

Read the final report.

Evaluation of Tack Coat Bond Strength Tests

Study conducted by Colorado State University.

Poor bonding between asphalt pavement overlays and the substrate pavement layer can greatly influence the long-term performance of hot mix asphalt (HMA) in the form of premature cracking and fatigue. The primary method to achieve bonding between layers is by using an asphalt emulsion tack coat.

This study evaluated four bond strength tests for SMA and HMA overlays on HMA and Portland cement concrete pavements. Results of this study indicate that bond strength of HMA overlays can be measured using pavement cores, that a significant difference in test precision was observed when CRS-2P was used a tack coat and that one of the test pavements demonstrated significantly poorer than recommended bond strength for the tack coat utilized.

Implementation of this research can be done as follows: specify a minimum tack coat application rate of 0.05 gal/sq-yd of 50:50 diluted CSS-1h or CRS-2P for construction of dense graded HMA over other dense graded HMA.

- Numan Mizyed

Read the Final Report.

Dynamic Modulus of Cold-in-Place Recycling (CIR) Material

Study conducted by Colorado State University, Pueblo:

This study investigated the dynamic modulus of Cold-in-Place Recycling (CIR) pavement material and its performance using pavement performance data, field-testing, laboratory testing, and Pavement Mechanistic-Empirical Design Guide (PMED) software analysis. Colorado Department of Transportation (CDOT) has 37 projects with over 8 million square yards using CIR materials. Sites from ten projects were selected to monitor the performances, and collect samples for laboratory testing. Field sampling, R-value testing of base/subgrade, and resilient modulus of base/subgrade were conducted.

Results show measured distresses of CIR rehabilitation techniques are mostly below the threshold values during the service period. International Roughness Index, rutting, and transverse cracking never exceeded the threshold values during the studied period.

Only two CIR pavements exceeded the threshold values for fatigue cracking after 8-10 years of service. Measured distresses of CIR rehabilitation techniques are similar to conventional pavement. The laboratory test results show CIR has about 50% less dynamic modulus compared to the traditional asphalt mixture. The CDOT-calibrated PMED software predicts the International Roughness Index (IRI) and the rutting of CIR overlaid pavement well but underestimates fatigue cracking.

The results of this research will be presented to the Materials Advisory Committee (MAC) for review and approval for incorporation into the CDOT Pavement Design Manual and the PMED software program. Considering the field performances of tested CIR pavements, this research recommends CDOT use the data derived from this study to support and implement the continued deployment of this recycling technology.

- Numan Mizyed

Read the final report.

Research Highlights Continued

Developing Bridge-Scour Equations for Colorado Mountain Streams

CDOT currently uses FHWA's HEC-18 methods to estimate bridge-pier scour values. Velocities, depths, and energy slopes for a bridge site are first computed in applying the FHWA methods. By applying these computed hydraulic parameters to pier-scour equations given in FHWA's HEC-18 design manual, scour values are computed for the bridge under consideration. The laboratory and field data used in developing the FHWA equations was based largely on streams with uniform sediments, subcritical-flow conditions, and flatter gradients. In western states where many bridges cross steep mountain channels, bridge-scour equations are applied beyond the range of conditions for which they were derived. Traditional equations overestimate bridge scour for hydraulic conditions encountered in steep mountain streams.

In this research study (re: Report No. CDOT-2018-10, published March 2018), a new bridge pier-scour equation has been developed suitable for streams flowing through mountainous regions of Colorado. This equation utilizes a dimensionless excess-velocity concept, and relates this flow parameter to pier scour. Dimensionless excess velocity, by including critical and scour-initiating velocities in its definition, accommodates the presence of cobbles and boulders through the critical-velocity term, as well as finer sand-gravel size material through the scour-initiating velocity term. The general form of the equation leads to calibration coefficients relating critical and scour-initiation velocities to representative fine material (D35 of parent-sediment material found on the riverbed), and to average coarse material that exists in abundance along mountain streams.

Report No. CDOT-2018-10 presents the development of the new scour equation, and applies this equation to compute pier scour at 16 different sites scattered across mountainous parts of CDOT Regions 3 and 5. Sources of data used in the analysis are derived from 16 bridges through a culmination of bridge-scour studies conducted for CDOT by Hydrau-Tech, Inc. for a Plan of Action (POA) for Scour-Critical Bridges study. Additional coarse-material data collected for this project is described, along with methodologies employed to determine pier-scour estimates.

Photo from the report cover of one of the studied bridges.

As shown in the report, measured and computed pier-scour values for the 38 piers included in the study show very good agreement through the entire range of observed scour values, which vary from 0 to 14 ft. Considering that the coarse material in the streams varied from 2 to 24 in, the computed velocities ranged from 2 to 15 ft/sec, and that the range of parent materials varied from sand and gravel to boulder sizes, it can be concluded that the equation was tested through a wide range of flow and environment conditions, and has been shown to be an excellent predictor

IMPLEMENTATION PLAN

Since excess velocity accounts for the presence of large particles found in abundance in Colorado stream beds, results of pier-scour computations using the new equation are more realistic. The use of the newly-developed equation is recommended for applications involving high-velocity mountain streams with large cobbles and boulders. Even though the laboratory database was adequate to derive the form of the new equation, the steep mountain scour database used in the calibration of the coefficients was limited. It is recommended that this database be expanded as new pier-scour data becomes available from mountain regions, and used in further refining the coefficients of the new equation.

- Aziz Khan

Read the final report.

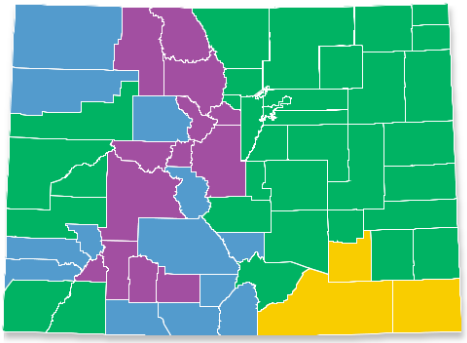
Surveying Transportation Agencies

Did you know that ARIB can help you distribute surveys to other transportation agencies? Contact CDOTLibrary@state.co.us for more information.

Research Highlights Continued

Surface Chloride Levels in Colorado Structural Concrete

Study performed by University of Colorado, Boulder.



The four climatic regions of Colorado factored into the study's sampling plan (graphic by Baechler et al., 2010, republished on page 8 of the report).

This project focused on the chloride-induced corrosion of reinforcing steel in structural concrete. The primary goal of this project was to analyze the surface chloride concentration level of the concrete bridge decks throughout Colorado. The study indicated three factors that can affect chloride concentration levels in bridge decks: age of the concrete, traffic, and weather. Samples were collected from decks and curbs of bridges in different climate regions with various concrete ages and traffic levels. Water-soluble chloride concentrations were tested for all samples. Chloride concentration profiles for all the locations were listed and plotted.

The chloride concentrations of most bridge decks were below the critical values at the rebar level. The chloride concentrations of bridge decks are usually greater than that of bridge curbs. However, these bridge curbs showed deeper chloride penetration than the bridge decks. Younger bridges had much lower chloride concentrations, which is expected. Heavier traffic resulted in higher chloride concentrations. The bridges built in colder regions had a higher chloride concentration up to 2" depth (the rebar level). Climate may be the most significant influential factor among age, traffic, and climate when considering chloride concentration of bridge decks in Colorado. Corrosion protection should focus on the bridges decks located in the cold climate zone and with high traffic volume.

- Numan Mizyed

Read the final report.

CDOT Research Library

The Research Library is located in HQ 441.

The CDOT Research Library contains a collection of resources from CDOT, AASHTO, FHWA, ITE, TRB, and other entities to support CDOT's staff. Collections include the ARIB's printed research reports, HQ NEPA document collection, HQ Historian's Corner, and Colorado Transportation History collection.

The growing CDOT online library catalog can be searched from the CDOT library's website. Electronic publications from FHWA and TRB covering 2007 to present are already searchable though the catalog. The library's physical collection is still being added to the online catalog.

Over the past year, the library has been seeking feedback from CDOT staff in the form of surveys and focus groups as part of a library improvement study. This feedback along with the study's findings will be utilized to improve the library's services and collection. Currently, the library offers literature searches, research assistance, and document scanning and delivery to CDOT staff, researchers, and contractors. The library is also open to members of the public and available to assist with transportation research.

- Jessica Weatherby

Acknowledgements

This newsletter would not be possible without the contributions of the ARIB director and staff members. There were so many contributions that some research highlights on environmental and safety studies still in progress will be included in the next newsletter.