The Impact of CDOT Research

CDOT-DTD-R-2002-1

Sponsored by the
Colorado Department of Transportation
In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

January 2002

Colorado Department of Transportation
Research Branch
4201 E. Arkansas Ave.
Denver, CO 80222

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Beth Moore
Editor

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Photo on cover page: Bicyclists voice their opinion on rumble strips placed along side the road. For additional information see page 29.

This report "The Impact of CDOT Research" is the latest in a series of status reports written over the years to keep you, our customers, informed and up-to-date on CDOT research studies. It highlights both completed and current research studies from 1999 to the present. The report has five focus areas: Pavements; Structures; Environmental; Traffic, Safety and Maintenance; and Policy and Planning.

Under each focus area there are two sections: one on completed research studies and the other on current research studies. Under completed research studies there is a brief background history, recommendations from the report, and an implementation statement. The implementation statement provides information on how the results of the study have been used within the department. Under current research studies there is an expected implementation product and a short write-up of the research study.

How does the Research Branch decide which studies will be funded?

Research needs, in the form of problem statements, are solicited every year from CDOT employees, the FHWA, Metropolitan Planning Organizations, and Colorado universities. A corresponding technical research oversight team composed of subject matter experts then evaluates the submitted problem statements. Combining literature searches from the national Transportation Research Information Service (TRIS) with the oversight team's technical knowledge and experience in the field, the oversight team submits recommendations to the Research and Implementation Council (RIC). The RIC then prioritizes these problem statements for funding in the next fiscal year. How the list is prioritized depends on the current strategic direction of CDOT.

Is this the only way to have some research work done?

If you need an evaluation and documentation of an experimental feature on a construction project you do not need to go through the steps above. Research staff members are available to conduct these evaluations upon the request of a Region office to the Research Coordination Engineer. An experimental feature is a method, material, or practice that is not a state or industry standard. All experimental features incorporated into Federal-Aid projects must be formally evaluated.

Where does the money for research come from?

For experimental features, funding for the first year is paid by the project. In subsequent years, the evaluations are funded by the Research Branch. For all other Research studies, funding is also provided by the Research Branch.

Research studies are funded through a federal set-aside called the State Planning and Research (SP&R) program. Federal law mandates that two percent of the federal funds provided to the states for transportation must be set aside for planning and research activities. Federal law further mandates that a minimum of 25 percent of SP&R funds must be used to conduct research.

Additional information about the Research Branch and program can be found on the Research Branch website at http://www.dot.state.co.us/Programs/Research/

CDOT Library Services

The CDOT Transportation Library, located in the Research Branch, has the largest, most comprehensive collection of transportation-related materials in the state. The library, which is open to the public, handles requests for information from all over the world. Circulation of library materials is limited to residents of the State of Colorado. The collection of more than 15,000 publications includes CD-ROMS, videos, and periodicals, as well as books and reports. The in-house collection is supplemented with electronic resources from the Internet and DIALOG. Approximately 150 customers per month take advantage of the library's resources.

The library website can be found at:
http://www.dot.state.co.us/Communications/Publications/Library.htm

The library catalog is available to CDOT employees as a shared file under pinamontj. Customers who are not employees should call the CDOT Librarian, Joan Pinamont, at (303) 757-9972.

If you have questions about any of the research studies, please call or email the research contact listed for each study.

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The CDOT Library

Pavement Studies – Completed

Investigation of Early Cracking on I-25 in Denver, Colorado

- Report Number: CDOT-DTD-R-01-10
- Authors: Mike Anderson, Asphalt Institute; John D'Angelo, FHWA; and Gerry Huber, Heritage Research Group
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Background: In 1997, an overlay was completed on the north and southbound lanes of I25, between SH7 and 120th Street, in Denver. In early 1998, CDOT investigated early longitudinal cracking appearing on this overlay. In some instances the cracking severity was rated high. In 2000, Region 6 requested a forensic evaluation of the project because the pavement appeared to be deteriorating rapidly.

A team of asphalt material and construction experts concluded that the early cracking could not have necessarily been predicted or prevented by CDOT, or the contractor, using the current specifications and tests. The premature cracking was caused by several factors including: higher in-place air voids than expected, a low effective asphalt content and segregation within the mat.

Recommendations from the report: In order to minimize the occurrence of similar pavement failures in the future CDOT can:

-evaluate alternate surface mixtures,
-evaluate methods of measuring in-place density,
-evaluate methods of measuring asphalt content, and
-evaluate methods of measuring mechanical properties of mixtures.

Implementation: A response team was organized to address the recommendations of the forensic team. The response team participants were from CDOT and industry. It was agreed that the focus of the response team should be the recommendations of the forensic team in lieu of validating the findings of the team. The response team will address these seven issues:

1. **surface mixture type,**
2. **density measurements,**
3. **asphalt binder content,**
4. **mechanical properties of asphalt,**
5. **testing for segregation,**
6. **pavement rehabilitation strategies, and**
7. **properties of the asphalt binder.**

PCCP Texturing Methods

- Report Number: CDOT-DTD-R-00-1
- Authors: Ahmad Ardani and William (Skip) Outcalt
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Background: This final report represents the construction details and five years of evaluation of nine concrete pavement test sections with varying pavement textures. Included are the methodologies used to texture the pavement, a discussion of frictional attributes of the various textures at different speeds, and their impact on noise properties. The report also has a description of texture-measuring devices and texture-installing equipment, a description of the state-of-the-art equipment that was used to acquire sound pressure levels, and a discussion of data acquisition/analysis.

Recommendations from the report: Final evaluations of the nine test sections indicated that longitudinal tining, while also providing adequate frictional property, is not only easier to install but also produces a much lower noise level than traditional transverse tining.

Implementation: CDOT has adopted longitudinal tining as the preferred method of texturing concrete pavements.

Rehabilitation Strategies for Asphalt Pavement

- Report Number: CDOT-DTD-R-2000-8
- Author: Bud Brakey
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Background: A Best Seller. It's Free Actually. This publication offers pavement designers and decision-makers guidelines to match rehabilitation strategies to the type and degree of pavement distress. These guidelines were developed after a small but persistent percentage of asphalt overlays in Colorado failed to reach their design lives. Design life is the service life of a pavement without loss of load-carrying capability from fatigue damage. Functional life is the years of service a pavement will provide without the development of excessive distress that adversely affects the highway user. Seven categories of distress were tabulated as the ones most likely requiring selection of a rehabilitation strategy from several options. Basing rehabilitation strategies on specific types of pavement distress will improve functional life expectancy for rehabilitated pavements.

Recommendations from the report: The recommended rehabilitation strategies are based upon the degree and type of existing distress and the traffic level. Decision tables in the guidelines provide paths to match rehabilitation strategies to the type and degree of pavement distress. None of the rehabilitation strategies are new to CDOT.

Implementation: A workshop was held to implement the rehabilitation guide. The workshop detailed the rehabilitation strategy selections and estimating pavement functional life using hands-on demonstrations.

Interstate Asphalt Demonstration Project NH 0762-038 (Rubblization) Construction Report

- Report Number: CDOT-DTD-R-2000-4
- Authors: Donna Harmelink, Werner Hutter and Jeff Vickers
- Research Contact: Donna Harmelink
- Phone Number (303) 757-9518

Background: This report documents the design and construction of the first rubblization project built by CDOT. It will be under evaluation for five years. The project was selected to demonstrate the resonant breaker and multi-head hammer methods of concrete pavement rubblization. The project consisted of removing the existing 2-inch asphalt bond breaker, rubblizing the concrete and placing three, two-inch lifts of HBP on the rubblized concrete. Evaluations will consist of crack mapping, rut measurements, falling-weight-deflectometer measurements and observation of the edge drains. Long-term performance information provided by this study will determine the overall life cycle cost of rubblization with an asphalt overlay. Although the initial cost for HMA with rubblization is lower, the long-term performance information provided by this study will determine the overall life cycle cost of rubblization with an asphalt overlay. This comparison will establish the basis for alternate life cycle costs for the two rehabilitation techniques.

Recommendations from the report: It was agreed by the CDOT Regions that until this research is complete and the performance of the pavement is fully evaluated no new rubblization projects would be constructed.

Implementation: A seminar and a field trip to the construction site have been completed. No other projects are planned pending completion of performance monitoring.

This multi-head hammer truck is rubblizing this concrete pavment.

Stone Mastic Asphalt in Colorado

- Report Number: CDOT-DTD-R-2001-1
- Author: Donna Harmelink
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Background: Stone mastic asphalt (SMA) is a hot mix asphalt consisting of two parts, a coarse aggregate skeleton and a binder rich mortar. The mixture is made of crushed coarse and fine aggregates, mineral filler, asphalt cement, and a stabilizer for the binder such as polymer or fibers. This report documents CDOT's first two SMA pavements, one of them on a bridge deck. SMA shows promise as a tough, stable, rut-resistant surface mixture. Both projects were successful.

Costs for SMA on both of the projects were substantially higher than the cost for hot bituminous pavement. Contractors have indicated that as they become more comfortable with the mix that costs will become more competitive with hot bituminous pavements.

Recommendations from the report: To date, the SMA projects, seven in all including the two in this study, have exceeded CDOT's expectations. With this performance history, SMA was chosen as the best product for wearing surfaces. It is recommended for any high profile, high volume roadway where a skid resistant durable surface is required. SMA applications should be limited to roadways with existing pavement conditions that have only moderate or lower level distresses for cracking or raveling.

Implementation: A task force was organized to develop guidelines and a best practice guide for SMA. SMA has been adopted for use as CDOT's wearing course. In addition, CDOT's Bridge Branch has developed a specification for using SMA as part of the overlay system. Based on overall performance, the design procedures and project selection guidelines have been adopted for statewide use.

Early Evaluation of LTPP Specific Pavement Studies –2, Colorado. Interim Report.

- Report Number: CDOT-DTD-R-2000-2
- Authors: Ahmad Ardani, Nadarajah Suthahar, and Dennis A. Morian
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Background: The SPS-2 experiment was developed as a coordinated national experiment to address the effects of various strategic environmental and structural factors on the performance of rigid pavements. This interim report, published four years after the study began, looks at the early results of the SPS-2 experiment, "Strategic Study of Structural Factors for Rigid Pavements," which documents the construction details of 13 different test sections with varying structural characteristics.

Certain sections included a widened 14-foot slab in addition to the standard 12-foot width. Some specific sections included the construction of pavement edge drains. Results are based on monitoring data collected by the Long Term Pavement Performance Program (LTPP).

Recommendations from the report: This research is not complete. However, early results of the SPS-2 experiment, in addition to a supplemental study that CDOT conducted, highly recommend the use of the 14-foot slabs. Wide slabs improved the load-carrying capacity of the outside lane by keeping the trucks away from the longitudinal joint at the shoulder.

Implementation: The 14-foot slab is now an option of CDOT designers, primarily in a rural setting.

Using Ground Tire Rubber in Hot Mix Asphalt Pavements

- Report Number: CDOT-DTD-R-99-9
- Author: Donna Harmelink
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Background: This project demonstrated the crumb rubber process on Platte Canyon (SH 75) from Bowles to C470. The amount of crumb rubber introduced into the mix was minimal to reduce the risk of premature failure of the road and because Colorado's experience with crumb rubber was limited. Four different mix designs were placed. Three mixes contained varying amounts of crumb rubber and one control section contained no crumb rubber.

Section 1038(d) of the ISTEA legislation required states to use a minimum amount of crumb rubber from recycled tires in the asphalt placed each year. Noncompliance with this legislation would have resulted in a severe reduction of federal funding. In 1995, this requirement was eliminated. Since CDOT had already begun the study, the evaluations continued as originally planned.

Evaluations showed no noticeable difference between the mix designs on the highway. However, more extensive research will be needed before CDOT can incorporate crumb rubber into their mixes. In addition, using crumb rubber was not an economical method for recycling waste tires. The cost-per-ton of mix was 21% higher when 20 lbs./ton of crumb rubber was used.

Recommendations from the report: Until the addition of larger quantities of crumb rubber in hot mix asphalt is shown to be cost-effective and enhances the long-term performance of the pavement, crumb rubber usage should be limited to research applications. CDOT does not have immediate plans to pursue the use of crumb rubber in hot mix asphalt pavements. CDOT is currently implementing Superpave performance graded (PG) binders. CDOT is also awaiting the results of a national study that is evaluating the use of crumb rubber as a PG binder modifier.

Implementation: Based upon these research results, crumb rubber is not being used by CDOT.

Pavement Studies – Current

In-place Voids Monitoring of Hot Mix Asphalt Pavements

- Study Number: 12.90
- Principal Researcher: Donna Harmelink
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Expected Implementation: Design Specification Change

The pavement design process assumes a pavement will consolidate to 4% air voids under traffic loading. Rutting can occur when pavements consolidate to less than 3%. Stripping and cracking distress is more likely to occur in pavements that consolidate at 6-7%. Due to different climates and traffic around the state, one pavement design process does not fit all. In light of this, customized designs were developed for each traffic and climate area. Pavement design and performance are tied together as they relate to air voids. By monitoring the air voids with time in asphalt pavements, areas needing adjustment in the mix can be identified. The projects being evaluated under this study were designed with the Texas Gyratory, which uses end point stresses for design. The Superpave Gyratory uses revolutions for design. This study will correlate both methods.

Unsealed Joints in Concrete

- Study Number: 21.58
- Principal Researcher: William (Skip) Outcalt
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Expected Implementation: Construction Specification Change

Concrete pavement, as constructed in Colorado, has transverse joints every 15 feet and longitudinal joints separating the lanes and shoulders. During construction these joints are blasted clean, dried, and sealed with one of several joint sealant materials designed to prevent moisture from penetrating to the base under the pavement. During the life of the pavement these joints are cleaned and resealed several times. Questions are now arising as to whether these seals actually prolong the life of the pavement or facilitate its demise. Not having to seal the joints could result in significant savings in time, materials, and money during construction and maintenance.

This research is evaluating 100 unsealed and 100 sealed joints along I70 between Denver and the Kansas border. Evaluations will continue through 2005.

This concrete pavement joint has been left unsealed.

Vehicle Handling Problems Related to Tining and the Need of Tining of Concrete Pavements

- Study Number: 21.80
- Principal Researcher: Ahmad Ardani
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: Construction Specification Change

CDOT adopted the use of longitudinal tining with 19 mm (3/4") spacing in 1997. CDOT has, however, received complaints concerning vehicle handling on some newly constructed Portland cement concrete pavements textured with this longitudinal tining. Owners of lighter vehicles have reported some dramatic handling problems.

This study will investigate and determine the extent of the vehicle-handling problem. The outcome of this study will prove that either the recommended tine spacing of 19 mm is inadequate to address the vehicle-handling problems or that the tine spacing specifications are not being adequately enforced.

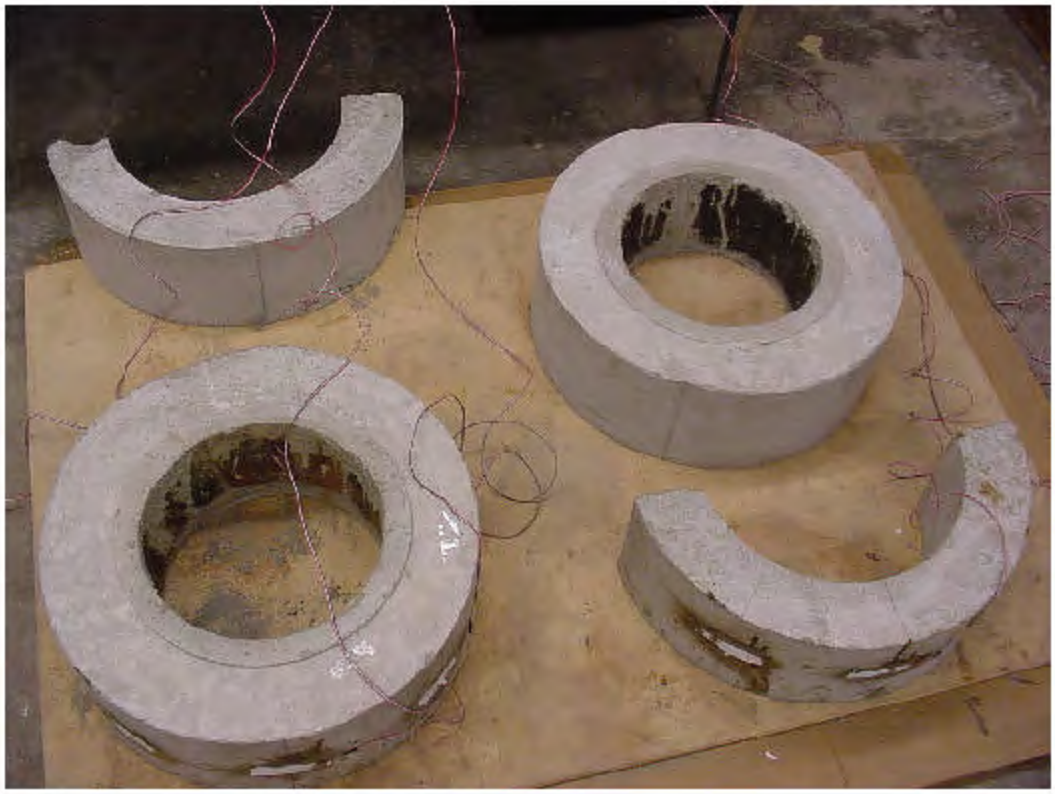
Optimization of Mix Design for Concrete Pavements in Colorado

- Study Number: 22.5
- Principal Researcher: Dr. Robert Rasmussen, Transtec Group
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: Materials Specification Change

The most expensive ingredient in Portland cement concrete pavement (PCCP) is Portland cement. CDOT, along with other state DOT's, is beginning to recognize that the addition of more cement to

already cement-rich mixes may not be the best approach in addressing long-term PCCP performance. With the escalation of costs for concrete materials - especially cement, maintaining or even extending the performance of PCCP, while reducing the initial costs, is desirable. This research will demonstrate that a lower cement content for pavement maintains durability, and results in reduced shrinkage and thermal cracking, while maintaining current standards for workability and strength.



The ASTM 14-day Ring Test examines the cracking potential of concrete mixes.

Evaluation of Preventative Crack Treatment for Asphalt

- Study Number: 10.125
- Principal Researcher: Werner Hutter
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Materials Specification Change

In early 1997, Senate Bill 97-128 was passed which required CDOT to put into place warranty projects under a pilot program before 1998. The projects selected incorporated a warranty specification, which required the contractor to guarantee the pavement for three years.

Originally this study was designed to provide verification of the mix design properties during construction on each of the warranty projects. Results from the data obtained during this testing were to be used to assure that the mix placed met the required specification for performance. However, following the construction of these projects the scope of the research was reduced.

The study will now be limited to the evaluation of the performance of the various techniques and methods for rehabilitating longitudinal and transverse cracking incorporated by the contractor on the I25 Fountain project.

Hamburg Rut Tester Implementation

- Study Number: 10.145
- Principal Researcher: Donna Harmelink
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Expected Implementation: Design or Construction Specification Change

The Hamburg Rut Tester is a piece of asphalt testing equipment developed in Europe. It has been used here in Colorado since 1991. This research will evaluate the long-term field performance on selected projects constructed between 1994-1998 to determine if there is a correlation between Hamburg tests on project-produced mix and actual field performance. The information will be used to determine a proper test temperature for performance prediction and will allow the European equipment to be implemented into Colorado's asphalt mix program. It will also supplement the SHRP mix design and evaluation methods, which will be implemented at the same time.

Improving Longitudinal Joints in Hot Mix Asphalt (HMA)

- Study Number: 10.155
- Principal Researcher: Donna Harmelink
- Research Contact: Donna Harmelink
- Phone Number: (303) 757-9518

Expected Implementation: Construction Specification Change

The longitudinal joint between asphalt mats is a major area for pavement distress. Because of the difficulty in compacting the unconfined edges, these joints typically exhibit lower densities than the remainder of the asphalt mat. CDOT and the paving industry have formed a task force to develop a draft end result type specification based on density. In 2000, seven projects were monitored during construction to document the current state of practice. In 2001, data sheets on all HMA projects will be collected to develop a final specification.

SHRP Chip Seal Demonstration

- Study Number: 12.60
- Principal Researcher: Mike Mamlouk, Arizona Univ. and Skip Outcalt
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: Maintenance Practice Change

FHWA, in cooperation with Arizona State University, developed the Test and Evaluation (TE) Program to encourage transportation agencies to gain "hands on" experience with SHRP preventative maintenance treatments. This study will demonstrate the effectiveness of properly designed and timely applied chip seals in extending pavement life. The study is looking at different combinations of emulsions and chips, including the use of light chips. This project is scheduled for completion in early 2002.

Development of New Pavement Design Equivalent Single Axle Load (ESAL)

- Study Number: 8.50
- Principal Researcher: Dr. Sirour Alavi, Nichols Consulting Engineers
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: Design Methodology Change

A key input parameter for designing new and rehabilitated pavements is traffic loading based upon equivalent single axle load (ESAL) applications. This research will look into the accuracy of the axle load data that is being used for pavement design by CDOT's pavement engineers.

Currently, CDOT is using generalized, averaged, and non-site specific equivalency factors for calculating the number of ESAL applications. These applications were developed using a 3-bin vehicle classification scheme instead of the FHWA recommended 13-bin classification scheme. Use of 3-bin vehicle classification has caused some CDOT roads to fail prematurely. The goal of this research will be to improve the accuracy of the existing and forecasted traffic loads.

Establish a Sound/Vibration Level Requirement for Rumble Strips

- Study Number: 55.20
- Principal Researcher: William (Skip) Outcalt
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Expected Implementation: Design Specification Change

There is concern in Colorado, and other states, about rumble strips that are ground-in on the shoulder of the highways. These rumble strips help redirect errant motorists but are hazardous to bicyclists using the shoulder for riding. While a more shallow rumble strip would be more acceptable to cyclists, their effect on errant motorists is also reduced. This research will establish a standard for sound and/or vibration rumble strips.

Correlation of Sub-Grade Module and Stabilometer R-Values

- Study Number: 71.20
- Principal Researcher: Werner Hutter
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Design Methodology Change

This research will improve the equation used to convert a soil R-value to a resilient modulus for input into the AASHTO pavement design equation. The sub-grade resilient modulus is one of the key inputs to the AASHTO flexible pavement design equation. Improving the reliability of these pavement design parameters will result in more efficient and/or reliable structural sections. When complete, CDOT will incorporate the improved equation into the Pavement Design Manual.

Validation and Fine-Tuning of CDOT's Whitetopping Design Procedure

- Study Number: 21.00
- Principal Researcher: Chung Wu, CTL
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9975

Expected Implementation: Design Methodology Change

Whitetopping, or putting a thin concrete overlay over a deteriorated asphalt pavement, was introduced as a rehabilitation method in Colorado in 1990. To date, several whitetopping projects have been completed in Colorado. While there are guidelines and procedures for whitetopping, this research will look at obtaining the necessary information through field and laboratory testing and analysis to validate these guidelines and procedures. This study is being conducted as part of a national effort sponsored by the FHWA and the Innovative Pavement Research Foundation.
(See related photo on next page.)

Whitetopping is a thin concrete overlay over asphalt pavement.
It is used as a rehabilitation method.

Structure Studies – Completed

The Founders-Meadows Parkway bridge in Colorado Springs uses geosynthetic-reinforced soil walls.

Performance of Geosynthetic-Reinforced Walls Supporting the Founders/Meadows Bridge and Approaching Roadway Structures

Report 1: Design, Materials, Construction, Instrumentation, and Preliminary Results
Report 2: Assessment of the Performance and Design of the Front GRS Walls and Recommendations for Future GRS Abutments

- Report Numbers: CDOT-DTD-R-2000-5; CDOT-DTD-R-2001-12
- Authors: Naser Abu-Hejleh, William (Skip) Outcalt, Trevor Wang, Jorge G. Zornberg
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Background: In 1999, CDOT successfully completed the construction of the Founders/Meadows Bridge structure over I25 in Castle Rock. This was the first major bridge in the United States built on footings supported directly by geosynthetic-reinforced soil (GRS) walls - eliminating the traditional use of deep foundations altogether. When compared to the use of deep foundations, this structure has the potential to alleviate the common bridge approach bump problem. It also allowed for construction in stages and a smaller work area in the vicinity of a very busy section of I25. The Founders/Meadows Bridge was considered experimental. Comprehensive material testing, instrumentation, and monitoring programs were incorporated into the construction operations. Performance data was collected for the movements of the wall facing, settlement of the bridge footing, and loads inside the reinforced soil mass and against the wall facing. This monitoring data was collected during six construction stages and while the structure was in service for more than a year.

Recommendations from the reports: The first report, CDOT-DTD-R-2000-5, is an overview of the reinforced soil wall system design, materials, construction stages, and the instrumentation program. The second report, CDOT-DTD-R-2001-12, is a summary and analysis of the collected instrumentation data, and an assessment of the performance and design of the front GRS walls that support the bridge structure and embankment behind the bridge abutment walls. The data have shown excellent performance because the monitored structural movements, strains, and loads were smaller than those expected in the design or allowed for by the performance requirements.

Implementation: CDOT Bridge engineers now consider the use of spread footings on GRS abutments as an adequate foundation alternative when appropriate. To facilitate the implementation of this alternative, features and limitations of this system and possible changes in the design and construction of future GRS abutments from those utilized for the Founders/Meadows structure are provided. A presentation and short design guideline will also be offered to bridge engineers for the design of such systems.

Results and Recommendations of Forensic Investigation of Three Full-Scale GRS Abutment and Piers in Denver, Colorado

- Report Number: CDOT-DTD-R-2001-6
- Authors: Naser Abu-Hejleh, Jorge G. Zornberg, William (Skip) Outcalt, and Mike McMullen
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Background: In 1996, a full-scale geotextile-reinforced soil bridge abutment and two bridge piers with block facing were constructed at the Havana maintenance yard in Denver. The abutment and outer GRS pier were load tested to demonstrate that GRS abutments and piers with block facing are viable alternatives to conventional bridge piers and abutments. The performance of the loaded GRS abutment was satisfactory. Four to six months after the surcharge load was placed, the top several block layers of the outer pier structure began experiencing excessive movement and cracking. Because of concerns about further deformation, and possible toppling of the massive surcharge, the structure was dismantled. This report summarizes the measured in-situ conditions and characteristics of the structures materials (backfill, blocks, and geotextile fabric) after almost three years of being in place and identifies possible causes for the excessive deformation and cracking of the outer loaded pier structure.

Recommendations from the report: GRS abutments and piers, constructed using closely spaced and high-strength/stiffness geosynthetic reinforcements, well-compacted quality granular backfill, and strong blocks are a viable alternative to conventional bridge piers and abutments. Durability and creep of reinforcements were not identified as a problem for this system.

Implementation: Findings of this study were used in developing the GRS abutment design recommendations incorporated in the report, "Assessment of the Performance and Design of the Front GRS Walls and Recommendations for Future GRS Abutments," already summarized. Implementation efforts of this report will also be the same. The implementation of GRS piers will not be pursued at this time because of additional design issues that need to be resolved and the expected limited, cost-effective application on CDOT projects.

Design and Construction Guidelines for CDOT Standard Use of MSE Walls With Independent Full-Height Facing Panels

- Report Number: CDOT-DTD-R-2001-5
- Authors: Naser Abu-Hejleh, Michael McMullen, George Hearn, and Jorge G. Zornberg
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Background: In 1996, CDOT completed the construction of a unique mechanically stabilized earth (MSE) wall with independent full-height facing (IFF) for the ramp connecting northbound I25 to I70 in Denver. The new MSE/IFF wall has four major components:

-a welded wire fabric reinforced soil mass,
-full-height concrete facing panels not attached to the soil reinforcements (i.e., independent) that are allowed to tilt around their bases,
-flexible face anchors to provide attachment of facing panels to the reinforced soil mass, and
-a trench with flow fill to temporarily brace the panels before face anchors are placed.

When compared to other conventional retaining walls, this new wall system requires little or no over-excavation in front and beneath the wall, costs less, and requires less construction time and maintenance work. Since this MSE wall system was the first and possibly the only of its kind, it was considered experimental. A comprehensive instrumentation and monitoring program was incorporated into the construction operations. Performance data was collected during construction for the movements of the wall facing, loads inside the reinforced soil mass and loads against the wall facing.

Recommendations from the report: The report provides insight into the details, materials, design, and construction of the I25/I70 MSE/IFF walls. The collected instrumentation results are also presented and utilized in the assessment of the design and performance of the MSE/IFF wall structure. The flexibility of the MSE/IFF wall system smoothly accommodated the wall movements and kept the lateral earth pressure against the wall facing to a low value of 32 psf. The report also provides thorough details and the basis for future standard use of MSE/IFF walls.

This mechanically stabilized earth wall, with independent full-height facing, is part of the ramp connecting N.B. I25 to I70 in Denver.

Implementation: CDOT Staff Bridge is developing standard worksheets for this wall design based on the recommendations in this report for use by designers when appropriate.

Strength Parameters of Backfills for Design and Construction of Retaining Walls

- Report Number: CDOT-DTD-R-2001-7
- Authors: Thanarach Aksharadananda and Jonathan Wu, UC/D
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Background: Prevailing specifications for reinforced soil retaining wall construction require that the backfill be Class-1 material. Field experience has indicated that many reinforced soil retaining walls, constructed with backfill not meeting the Class-1 criteria, have performed satisfactorily. The objectives of this study were to evaluate the current practice employed by CDOT for determination of backfill design soil strength parameters and to propose improved criteria for determination of these parameters. To meet these objectives, laboratory tests were performed to compile the strength parameters and index properties of 100 soils. This report summarizes the test and analysis results.

Recommendations from the report: The research found that the current practice of requiring Class-1 soils for retaining walls is conservative and could be continued. It was also found that some non-Class-1 soils are also suitable as a retaining wall backfill. In lieu of Class-1 criteria, acceptability of these soils for retaining wall backfill can be determined through a decision tree developed in this report or with direct strength testing along with two simple, standard index soil tests.

Implementation: The findings of Phase I of this study will be considered by CDOT geotechnical and bridge engineers on special construction projects with good on-site soils. The study panel decided to terminate Phase II of this study after it realized that more funds and resources were needed to perform the large number of various types of soil tests, and then determine with confidence, implementable specifications. To better address the original study objectives, the CDOT Research Branch submitted a problem statement to NCHRP titled "Economical and Performance Optimization for Using Wider Range of Backfill Materials for Retaining Wall Structures."

Cracking in Bridge Decks: Causes and Mitigation

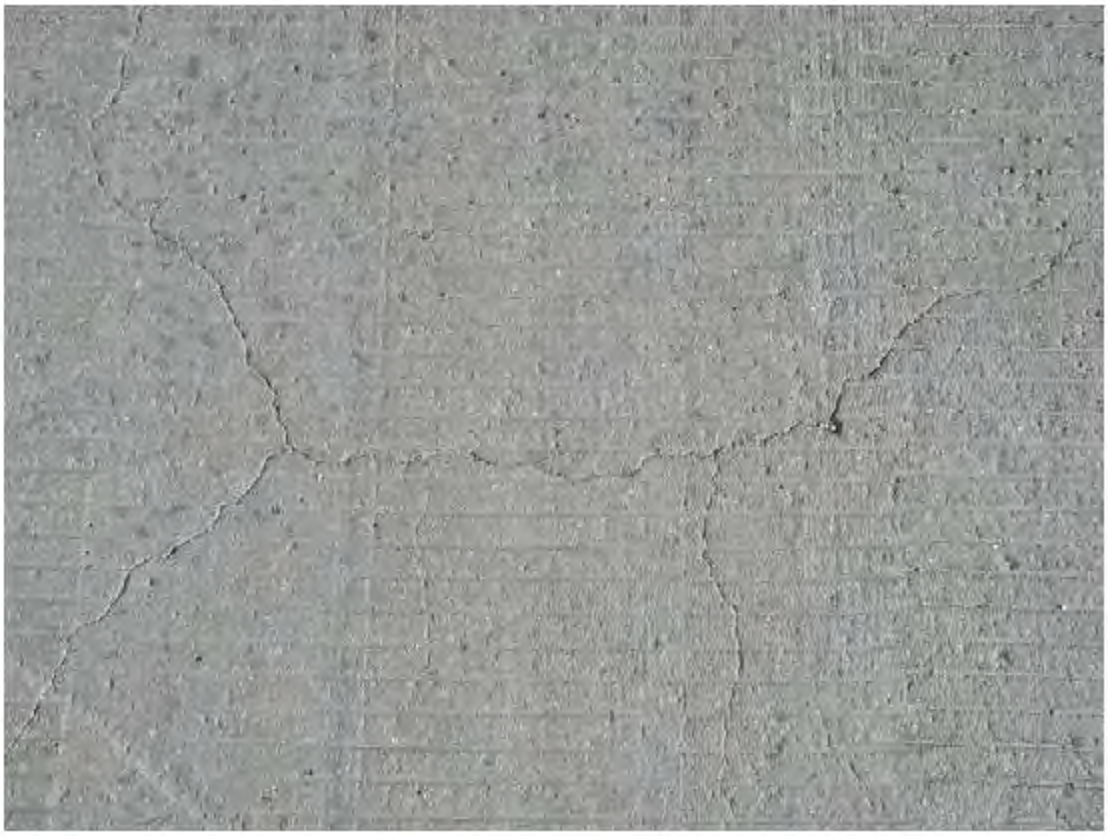
- Report Number: CDOT-DTD-R-99-8
- Authors: P. Benson Shing and Naser Abu-Hejleh
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Background: This study sought to determine the cause of extensive transverse cracking observed in existing bridge decks and to identify the changes in materials specifications and construction practices needed to reduce this deck cracking. The authors reviewed recent studies on bridge deck cracking and conducted a study to compare the shrinkage properties of several concrete mixes. They also reviewed current CDOT materials, construction, and design specifications to identify areas needing improvement. A survey was then conducted on seven newly constructed CDOT bridges to examine the extent of cracking in concrete decks that were constructed with different mix designs and curing procedures.

Recommendations from the report: Recommendations on the design and construction of bridge decks to reduce deck cracking were identified. Several materials factors to reduce deck cracking were also identified– using Type II cement, reducing the cement content in concrete, using Type F fly ash to reduce the heat of hydration, and the use of silica fume to reduce chloride permeability.

Based upon the information available the report recommends a new mix, class DSL (class D concrete with low shrinkage). The DSL mix uses Type II cement, a silica fume content limited to 6% by weight of cement, Type F fly ash is 20% by weight, and the total content of cementitious materials is limited to 568 lb. per cubic yard of concrete. The mix is designed to be used only during warm weather.

Implementation: Most of the construction recommendations to alleviate bridge deck cracking problems were incorporated in CDOT specifications. Some of the design recommendations were implemented in the design of the IBRC (Innovative Bridge Research and Construction) structure at I225/SH83 interchange. The DSL concrete mix recommended in this study was investigated further in the IBRC research study for developing a high performance concrete mix for CDOT.



This bridge deck is showing extensive cracking.

Structure Studies – Current

Proposed Revisions of the AASHTO Guidelines for Design and Construction of GRS Retaining Walls

- Study Number: 70.23
- Principal Researcher: Jonathan Wu, UC/D
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: New Design Option

The study will present four proposed revisions of the AASHTO Guidelines for Design and Construction of GRS Retaining Walls (AASHTO, 1996). The suggested revisions will regard:

-lateral earth pressure against wall facing,
-long-term creep of GRS wall structures,
-truncated reinforcement at wall base and the CTI tails, and
-embedment and leveling pads.

These revisions are for GRS walls with the following features: granular and well-compacted backfill, stiff and closely spaced reinforcements, strong, dry-stacked modular blocks, and competent foundation soil.

Based on the findings and recommendations of this report, CDOT Research/Bridge plans to develop design plans and specifications as revisions to Section 504 of CDOT's Standards for Roads and Bridges. Nationally recognized experts on GRS technology will be invited to provide more comments, input, and perform more in-depth analyses to justify/refine/enhance the recommendations of this study.

Strength and Deformation Analysis of MSE Walls at Working Loads and Failure (Pooled Fund Study)

- Study Number: 74.7
- Principal Researcher: Richard Bathurst, Royal Military College in Canada
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Design Standard Change

Based on the available measurements of reinforcement strains and loads in full-scale MSE structures it appears that the current design procedure is overly conservative, especially for GRS structures. The goal of this study is to develop an improved design methodology, which more accurately predicts reinforcement loads and deformation in MSE walls, and to eventually move this design methodology into design code. This goal will be achieved through analytical modeling and a series of full-scale (3.6 m high) MSE test walls taken to failure.

An expected benefit of this research is to avoid the high cost of overly conservative designs. It is anticipated that the amount of soil reinforcement needed for geosynthetic MSE walls can be reduced by two or more. Furthermore, the data gathered through this study will be used to better define Load and Resistance Factor Design (LRFD) for walls.

The final findings of this study are expected to move to the AASHTO design code and then to all state DOT's specifications. The AASHTO Bridge Subcommittee (in particular the T-15 Technical Committee on Foundations and Walls) decided at its last meeting, in May 1998, to refrain from making additional changes to the AASHTO design code until the results of this study are available.

Three-Dimensional Load Transfer Mechanism and Level of Damage of Concrete or Steel Rail Mounted on MSE Retaining Walls

- Study Number: 74.80
- Principal Researcher: Dr. N.Y. Chang, UC/D
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Design Standard Change

There is some evidence that the performance of rails mounted on top of retaining walls is better than what is estimated from the current design procedure. This study will develop a more rational and economical design for CDOT rail systems mounted on top of Mechanically Stabilized Earth (MSE) retaining walls. The design will utilize a powerful three-dimensional finite element software

program that can simulate soil-structure interaction problems under static and dynamic loads. This software will be utilized to simulate the 3-dimensional impact load transfer mechanism as well as the extent and characteristics of damage and movements of the entire railing system. The study will focus on understanding the capabilities of the current CDOT Type 7 and Type 10 traffic railings.

The study will prepare draft design guidelines for CDOT implementation and will compare the cost of designing the rail system using the current and proposed design procedure. CDOT Research has submitted a research problem statement on this subject to NCHRP.

Calcium Nitrate Corrosion Inhibitor

- Study Number: 80.10
- Principal Researcher: Naser Abu-Hejleh and James Meyer, W. R. Grace & Co.
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Materials Specification Change

Calcium nitrate has been successfully used by other states as a corrosion inhibitor for several years. This study is an evaluation of a bridge deck constructed at Kettle Creek, near Colorado Springs, that used half black steel w/calcium nitrite and half epoxy-coated steel. Corrosion monitoring devices have been installed in the deck and will be monitored at three- to five-year intervals. At the end of the structure life, or when significant bridge deck deterioration is noticed, cores will be extracted from both halves of the bridge and will be examined thoroughly.

This research will give insight into the effectiveness of calcium nitrite as a steel corrosion protection measure. If found effective, the use of calcium nitrite will become standard and routine in CDOT operations.

Optimization of CDOT's Foundation Design Practice and LRFD Strategic Plan

- Study Number: 80.12
- Principal Researcher: Dr. N.Y. Chang, UC/D
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Design Methodology Change

Design procedure of foundations requires the estimation of the nominal response (ultimate strength and deformation) of the highway foundation when subjected to loading. The implementation of Load and Resistance Factor Design (LRFD) in CDOT design procedures requires proper estimation of the ultimate ground resistance and calibrated resistance factors. One of the problems with the current CDOT procedure to estimate the nominal ultimate soil and rock resistance is the so-called "Denver Magic Formula (DMF)." This formula is geared towards the allowable stress design method because it predicts the allowable soil and rock resistance using the standard penetration test (SPT) blow count alone. We know of no mechanism or sufficient data that allow a designer to reasonably evaluate the ultimate ground resistance using the SPT blow count alone.

This research will identify feasible, accurate, and cost-effective methods to predict the appropriate nominal response (strength and performance) of typical Colorado highway foundations (bridges, sound barriers, sign and signal structures) placed in Colorado's typical rocks and soil and subjected to vertical and/or horizontal loading. The study will conclude with the development of a plan to implement these methods at CDOT by identifying the resources required and the impact on design cost and time. Guidelines will also include a strategic plan to establish Colorado specific LRFD factors not available in AASHTO guidelines.

Evaluation of CDOT Current and New Steel Corrosion Protection Measures

- Study Number: 80.085
- Principal Researcher: Yunping Xi, CU/B
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Construction Specification Change and Materials Specification Change

Corrosion of reinforced concrete, especially in bridge decks, is a significant problem. Rust that forms from corroding steel accelerates the cracking and spalling of concrete and can result in costly repairs. Much of CDOT's corrosion problems are at the pier caps, and to a lesser extent, at abutment seats. Regardless of what solutions CDOT has come up with for decks both rehabilitative and preventative, leaking joints are here to stay and make the condition worse. CDOT currently applies several routine and experimental measures to prevent corrosion of the rebar including epoxy coated rebars, calcium nitrite, organic corrosion inhibitors, a thick cover of quality concrete, and waterproofing membrane covered by an asphalt overlay.

This study will determine the extent of steel corrosion occurring in Colorado's concrete structures (i.e., bridge decks, pier caps) and the effectiveness of the various steel corrosion protection measures. In addition, the study will offer guidelines for CDOT design engineers in applying corrosion protection of reinforcing steel to new and existing reinforced and prestressed concrete structures. Based on these results of this study, design and materials standards will be adjusted to better protect bridge components from corrosion.

Post-Tensioned Masonry Sound Walls

- Study Number: 80.20
- Principal Researcher: David Woodham, Atkinson-Noland and Assoc., Inc.
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: New Design Option

Prestressed masonry offers a competitive alternative to reinforced masonry and reinforced concrete in certain applications. These walls provide savings in both time and money over conventional reinforced masonry construction methods. This research will quantify the prestress losses due to creep and shrinkage of the masonry concrete. It will also determine anchorage efficiency and safety when used in conjunction with a grouted masonry bond beam.

Innovative Bridge Research and Construction (IBRC) – Evaluation of FRP and HBC for I-225/SH 83 Interchange

- Study Number: 81.30
- Principal Researcher: Benson Shing, Yunping Xi, Dan Frangopol; CU and Ahmad Ardani
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: Materials Specification Change and New Technology

As part of a national experiment under the IBRC program, CDOT is participating in the evaluation of fiber-reinforced polymer (FRP) in a precast bridge deck and bridge rail for the Parker Road interchange at I225. As part of this experiment, and as a extension of previous work done on high performance concrete (HPC), CDOT will also develop an HPC mix for bridge decks to improve durability by reducing shrinkage cracking, thermal cracking, and permeability while maintaining current standards for workability and strength. With this project, CDOT is replacing the reinforced and prestressed steel in the precast panel and rails with FRP products. Evaluations are continuing. (See related photo on next page.)

This photo shows a prestressed carbon fiber precast bridge panel. This project is the first time that CDOT has not used steel for reinforcement.

Field Investigation of Cracking in Newly Constructed Bridge Decks

- Study Number: 84.20
- Principal Researcher: Yunping Xi and Benson Shing, CU/B
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Construction and Materials Specification Change

In 1999, CDOT Research concluded a study "Cracking in Bridge Decks: Causes and Mitigation." Cracking in bridge decks is a problem both nationally and in Colorado. In this study, a limited survey was conducted on seven newly constructed bridges to examine the extent of cracking in concrete decks that were constructed with different concrete mix designs and curing procedures. Because information on seven bridges provided only limited information, the scope of work for the 1999 study was extended.

Additional existing and newly constructed bridges will be surveyed to help determine the extent and cause of the cracking problem. Based on the results of this study, changes to material specifications, construction processes, and design specifications to alleviate the bridge deck-cracking problem will be made if necessary.

Design Guidelines for the Drilled Shafts as Foundations for the Noise Walls and Overhead Signs

- Study Number: 80.19
- Principal Researcher: Not Yet Determined
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Design Methodology Change

Sound barriers, signs, and signals are not heavyweight structures but they are subjected to predominantly lateral loads from wind. CDOT uses drilled shafts to support the noise barrier walls and the large overhead signs and signals placed along the highways. The current design practices for these drilled shafts subject to lateral loads are very conservative, non-uniform, and therefore very costly, especially on design work performed by the private consultants. Significant savings to CDOT are expected if the improved and uniform design guidelines generated from this research study are adopted in future CDOT projects.

This research study will first identify the most accurate approximate design methods to predict the nominal response (ultimate capacity and deformation) of drilled shafts embedded in typical Colorado foundation soil conditions and subjected to typical Colorado loads (vertical, lateral, moments, and torsional loads in case of cantilever signs and signals). This will be achieved using load tests and advanced numerical analysis. Next it will develop a practical procedure to perform instrumented load tests during the early stages of sound barrier wall construction, analyze the results of the load tests, and update the design for the later stages of sound barrier wall construction. This procedure should be in feasible construction projects that have a large quantity of drilled shafts and should be attractive to contractors.

Fiberglass Composite Bridge Deck at O'Fallon Park

- Study Number: 87.30
- Principal Researcher: Benson Shing, Yunping Xi, Dan Frangopol, CU and Ahmad Ardani
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Expected Implementation: New Technology

CDOT has been awarded a grant for $500,000 to participate in the evaluation of a fiberglass composite bridge deck under the Innovative Bridge Research and Construction (IBRC) project. The project will be the replacement of an existing bridge over Bear Creek in O'Fallon Park, a park property in Jefferson County. The evaluation will review the constructability and performance of fiberglass panels as a bridge deck. It will also validate the quality and mechanical properties of fiberglass materials. This is the second IBRC grant CDOT has been awarded.

Durability of Segmental Concrete Block Retaining Walls (Pooled Fund Study)

- Study Number: 76.07
- Principal Researcher: Not Yet Determined
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522

Expected Implementation: Materials Specification Change

In the late 1990's, some walls constructed in the midwestern region of the U.S. began to show signs of premature deterioration. Preliminary results of a survey of more than 100 walls in the Minneapolis/St. Paul, Minnesota area conducted by the University of Minnesota indicate that

approximately 75% of the walls surveyed contained at least some blocks with freeze/thaw damage or scaling that was rated “low severity” or worse. Walls partially or fully covered with snow, and/or exposed to deicing salts and fertilizers, showed an increased frequency of distress.

The research will address these topics:

1). Examine existing wall installations, conduct forensic investigations, determine and verify why some blocks are not durable. Determine environmental factors influencing block durability. Examine influence of concrete components such as aggregates, cement content, cement type, and additives on block durability.
2). Examine/correlate existing test procedures (ASTM C 1262, C 666, etc.) or develop new test procedures that correlate laboratory performance to field performance and accurately predict length of service.
3). Based on the results of parts 1 and 2, develop a performance-based specification to insure a 75-year design life for different climates or regions.

The research will also address CDOT needs and recommend better material specifications for blocks of retaining walls for typical Colorado field, environmental, and material conditions.

The Needs and Benefits of Developing a New Management Program for Colorado Retaining Walls

- Study Number: 80.21
- Principal Researcher: Not Yet Determined
- Research Contact: Naser Abu-Hejleh
- Phone Number: (303) 757-9522f

Expected Implementation: New Program

CDOT Bridge Branch proposed that a new and separate management program for CDOT retaining walls be developed. The PONTIS bridge management system is not suitable for retaining walls because the appropriate data elements and analysis tools are not available. The new database could provide a knowledge base for avoiding malfunctioning wall types as well as providing evidence for better design practices. The database would also assist in budgeting and cost-effective planning for the maintenance and repair of existing retaining walls and the construction of new and better retaining walls. This research study will determine the feasibility (needs and benefits versus additional required resources) of a separate management system for Colorado’s new and existing retaining walls.

Environmental Studies - Completed

Effect of Magnesium Chloride on Asphalt Pavement. Quick Study.

- Report Number: CDOT-DTD-R-99-2
- Author: Werner Hutter
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Background: Magnesium chloride is used in the Denver Metropolitan Area, and some other areas around Colorado, to prevent the formation of ice on roadways. CDOT began using magnesium chloride in 1989. Prior to 1989, CDOT used a mixture of salt and sand for snow and ice control. Salt and sand mixtures can cause corrosion, leave sediment in streams and increase air pollution as dust particles are crushed and propelled into the air by traffic. Statewide use of magnesium chloride at the time of this report had reached five million+ gallons per year.

This research report focused on the effect magnesium chloride has had on asphalt pavements. Region 6, in the Denver Metropolitan Area, had some stripping occurring on pavement surfaces and suspected it was due to magnesium chloride. It was also noted that when pavements were placed in two lifts, one in the fall and the other the following spring, the bond between the two was weaker. It was suspected that this poor bond was attributable to the magnesium chloride placed during the winter months. On a different note, but equally troubling, was the lack of adhesion of thermoplastic pavement marking to roadways treated with magnesium chloride.

The pavement sample being tested was soaked in magnesium chloride before an overlay was added. This machine is testing the sample for shear strength.

Recommendations from the report: Based upon research data, magnesium chloride does not contribute to stripping of asphalt pavements, nor does it negatively affect the bonding strength in overlays. Testing of the preformed pavement marking tape PREMARK 20/20 in a controlled outdoor test shows that if the pavement is cleaned using a high pressure rinse and dried thoroughly, successful application of the preformed marking will occur. As a side note, Research also tested the metric version of PREMARK 20/20. Its use is not recommended at this writing.

Implementation: Findings from this quick study did not support any concerns regarding overlay bond strength, pothole patching problems, or permanent pavement marking tape. Material engineers and maintenance personnel were advised to continue with current practices in overlay construction, pothole repairs, and permanent marking applications following manufacturers' instructions.

Studies of Environmental Effects of Magnesium Chloride Deicer in Colorado

- Report Number: CDOT-DTD-R-99-10
- Author: William M. Lewis, Jr.
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Background: As CDOT continued to increase the use of magnesium chloride as a deicer, a research study was undertaken to determine its environmental impact. This study concluded that magnesium chloride deicer is highly unlikely to cause or contribute to environmental damage at distances greater than 20 yards from the roadway. Close to the roadway, magnesium chloride causes less damage than other factors (salt and sand) used in maintenance. In fact, magnesium chloride may offer a benefit to the environment by reducing the amount of salt and sand used. However, it is important that appropriate specifications are in place and that frequent testing insures a low concentration of contaminants and the avoidance of rust inhibitors that contain phosphorus.

Recommendations from the report: CDOT should develop specifications for deicers from vendors, including separate specifications for low and high elevations. Deicers provided by vendors should be monitored by CDOT for chemical characteristics. Vendors should also be required to report any significant changes in processing or source of material.

Implementation: Based on the findings of this study, maintenance management became more aware of the potential problem of contaminates and phosphorus in the liquid deicer and started testing the material for such. A more systematic QA/QC program is also being pursued. As a result, vendors have modified their processes and formulations to comply.

Environmental Liability Study

- Report Number: CDOT-DTD-R-2000-11
- Author: Joshua B. Epel
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Background: When CDOT acquires right-of-way it makes every attempt to minimize its environmental liabilities associated with ownership of the property. It has been CDOT's expectation that the property owners conduct the necessary remediation prior to acquisition and construction by CDOT. This research examines different mechanisms by which CDOT can either limit or avoid incurring any cleanup costs and liabilities or recover those costs from the property owners if necessary.

Recommendation from the report: A training program, with the help of trained environmental professionals, should be established for CDOT appraisers. With the training, CDOT personnel can develop a consistant and defensible methodology to appropriately value contaminated sites that might be acquired by CDOT. In almost all cases, the necessary information, as early in the process as possible, is needed to identify and remedy potential contaminated sites in the early stages of condemnation.

Implementation: Because Right-of-Way personnel worked closely with the PI during the study, research findings were incorporated into practice and training before the report was published. No further implementation is planned.

Why do Cattails (Typha spp.) Dominate Wetlands on the Western Great Plains?

- Report Number: CDOT-DTD-R-99-11
- Authors: David Cooper, Scott Woods, and Donald D'Amico
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Background: Cattails are among the most widespread and abundant plant species in wetlands throughout the northern temperature zone. This is not good. Cattails tend to take over and dominate other plants. This research looks at understanding how to create and restore wetlands that are dominated by species other than cattail.

Two major areas were reviewed during the 1998-growing season on the eastern plains of Colorado. The first, does the establishment of vegetation by the planting of nursery grown stock provide any short-term or long-term resistance to the invasion of cattails in newly created wetlands. The second, is it possible to determine the hydrogeologic niche of cattail, so that sites that are not conducive to cattail invasion can be created.

Recommendations from the report: Results of the study demonstrated that cattails could be limited, at least in the short term, by planting other tall wetland species such as soft-sheet bulrush and prairie cordgrass. Cattails were also controlled by flooding the site with water to a depth of 50 centimeters in the early summer, followed by varying water levels during the growing season and keeping the salinity of the water as high as possible.

Implementation: Confidence in findings was inadequate to support any implementation due to the relatively short evaluation period of the research in relation to growth patterns. Inconsistencies in controlling the water level throughout the research compromised findings.

Environmental Studies – Current

Identifying Cost-Effective Measures to Mitigate Highway Impacts on Wildlife

- Study Number: 32.4
- Principal Researcher: Sara Barnum, Dr. Willem van Vliet, UC/D
- Research Contact: Werner Hutter
- Phone Number (303) 757-9975

Expected Implementation: Design Methodology Change

Wildlife/highway conflicts cause negative impacts to both human and animal populations in terms of property damage, injuries, and death as a result of collisions. This research will be used to define what cues, natural and man-made, animals use to choose road crossings. These findings will be used to build a model to identify high-use crossing areas, and to design crossings that will be readily accepted by the wildlife in those areas. A final report is expected in mid-2002.

Development of Wetland Mitigation Options of Transportation Development: A Cost Per Acre Analysis

- Study Number: 32.61
- Principal Researcher: Beth Chase, DTD
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Assessment Methodology Change

CDOT often has impacts to wetlands as a result of the construction and maintenance of its roads. Federal environmental law and FHWA policy require the department to mitigate for impacts on a one-to-one basis. This project will determine the most effective way for CDOT to develop wetland mitigation by taking into account regulatory requirements, problems of scale, level of effort to achieve desired outcomes and landscape ecology. It will compare and contrast the cost-effectiveness of all options available and will review their potential to produce quality replacement wetlands.

Cost of Sanding

- Study Number: 40.1
- Principal Researcher: N.Y. Chang, UC/D
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Maintenance Specification Change

CDOT Maintenance can spend one-third of its budget every year handling snow and ice removal. While sand/salt have been traditionally used, chemical deicers have also been found to very effective. This study addresses only the true economic cost of using sand/salt. While the CDOT Maintenance Division keeps good records on the amount spent for sand/salt, there are several other costs associated with street sanding. This study will identify those costs and an overall cost/benefit analysis of the street-sanding program. In addition, the study will look into vehicle damage which may/or may not be caused by either method. This report will be available in late 2001. Early recommendations from the report call for enforcing the maximum gradation specification for sand and encouraging the shift from the sand/salt mixture to deicing chemicals.

This high speed video camera is observing sand particle movement.

Caliber M-1000 and M-2000 Deicer Evaluation

- Study Number: 41.31
- Principal Researcher: William Lewis, Western Environmental Analysis
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Materials Specification Change

Due to the popularity of deicers in controlling snow and ice, chemical deicing manufacturers are bringing new products to the market. Some of these deicers contain magnesium chloride, but may also contain other substances designed to reduce potential environmental problems. This research looks at one of those chemicals, Caliber M1000. The original study is complete. Concerns were raised about the amount of phosphorus and ammonia in Caliber M1000 and if, or how, those chemicals can reach water supplies. Additional research will be completed to answer that question. M-2000 will not be studied.

CAST Magnesium Chloride Research Synthesis

- Study Number: 41.35
- Principal Researcher: Marion Fischel
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: Materials Specification Change

Members of the Colorado Association of Ski Towns (CAST) have requested that CDOT help them assess possible water quality and human health impacts of magnesium chloride and to determine whether better alternatives may exist for deicing roadways. CDOT, the U.S. Geological Survey, and CAST are funding this research that will include:

-review and analysis of other relevant studies,
-literature search for other relevant data,
-analysis of the data received from the literature search and other studies,
-establishment of impact assessment criteria,
-investigation of alternative deicers available,
-review of current practices by CDOT and other states, and
-a survey of workers for possible health impacts.

Effects of Magnesium Chloride on Vehicles – Bare Steel Testing Supplement

- Study Number: 41.6
- Principal Researcher: Yunping Xi, UC/B
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Materials Specification Change

This study is Phase II of a previous research study, “Effects of Deicing Agents on Corrosion.” Deicing agents, mainly magnesium chloride, have been used for several years by CDOT for snow and ice control. This research is looking into concerns that have surfaced regarding the chemical effects on various components of cars and trucks caused by chemical deicers. Although chemical deicers contain a corrosion inhibitor there have been questions as to whether the deicing chemical attacks aluminum and other vehicle components. When completed, these two studies will be expected to result in chemical deicer specification changes. (See related photo on next page.)

This CDOT Maintenance chemical deicing distributor truck has five test "coupons" (steel squares) mounted on the back of the truck to determine corrosion rates due to chemical deicing.

Evaluation and Mitigation of Environmental Impacts Prior to Project Selection

- Study Number: 32.10
- Principal Researcher: Roland Wostl and Beth Chase, DTD
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Assessment Methodology Change

CDOT is under continually increasing pressure to implement projects quickly while complying with environmental requirements. A significant portion of the project development process is the environmental evaluation and clearance process. Opportunities do exist to streamline the project development process through early identification of key geographical information. It appears that some environmental resources within a corridor can be evaluated and mitigated prior to the selection or design of specific projects. Early evaluation and mitigation of environmental resources in high investment corridors can streamline the project development process and reduce impacts to the affected resources.

Monitoring the Restoration of a Streamside Riparian Ecosystem

- Study Number: 32.35
- Principal Researcher: Mark Bakeman, Ph.D., Ensight Corporation
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: Manual; some design features

East Plum Creek flows through the Town of Castle Rock. The stream has been affected in recent years by rapid urbanization in the region, including highway improvements from I25. The water

table has been depressed and streamside riparian vegetation is declining. Existing wetlands are also decreasing in size. This area also supports habitat and a population of the Preble's Meadow Jumping Mouse, a federally threatened small mammal. CDOT is proposing that check dams be installed on East Plum Creek at three or more locations to restore stream hydrology and raise the water table. This approach will target restoring the entire ecosystem, rather than just isolated components.

This research will monitor two important ecosystem variables:

-the response of the Preble's Meadow Jumping Mouse population to project impacts and their response to the check dams, and
-the extent of the riparian vegetation recovery following the check dams installation.

Environmental Justice

- Study Number: 32.45
- Principal Researcher: DMJM+Harris
- Research Contact: Leah Lane, DTD
- Phone Number: (303) 757-9761

Expected Implementation: Planning Process Change

This research will assist CDOT in responding to requirements that prevent discrimination and disproportionately high adverse effects of transportation on select populations in the statewide and regional transportation planning process, specifically those who are minority and/or low-income. The first phase of the study will be to develop recommended enhancements to CDOT's methods for including specific groups in the regional and statewide transportation planning process and identifying the types of demographic data and level of geographic specificity applicable for considering environmental justice requirements in the statewide and regional transportation planning process. This information will be utilized in the second phase of the study when a recommended framework for environmental justice considerations will be provided to assist in updating the 20-year regional transportation plans.

Traffic, Safety, Maintenance Studies – Completed

Bicycle-Friendly Rumble Strips

- Report Number: CDOT-DTD-R-2001-4
- Author: William (Skip) Outcalt
- Research Contact: William (Skip) Outcalt
- Phone Number (303) 757-9984

Background: It is a common practice among highway departments to place rumble strips alongside the road to reduce run-off-the-road type accidents. They can also cause problems for bicyclists that ride on the side of these roads. This study compared three styles of rumble strips in an effort to find one that is both a warning method for motorists and a shoulder suitable for bicyclists. The three styles were:

-Colorado standard ground-in asphalt rumble strip,
-Colorado standard concrete rolled-in rumble strip, and
-a new two-inch-groove rumble strip.

Recommendations from the report: Your best choice? The standard ground-in asphalt rumble strip, 12 inches wide, with a groove depth of 3/8 inch +/- 1/8 inch, ground in an interrupted pattern is the recommended configuration for asphalt strips based on the data collected for this report. No recommendations were made concerning the rolled-in concrete rumble strips.

Implementation: The results of the study were presented to the Discussion Group Panel for Standard Plans who determined that a revision to the Colorado Plans was appropriate. The standard for ground-in rumble strips was changed from ½" deep to 3/8" deep for all future construction.

Bicyclists test rumble strips placed along side the edge of the road.

Centerline Rumble Strips

- Report Number: CDOT-DTD-R-2001-8
- Principal Researcher: William (Skip) Outcalt
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Background: SH119, west of Boulder, has an accident history of vehicles crossing the centerline and causing head-on collisions. In 1996, Region 4 ground rumble strips into the center of a highway in an effort to reduce the accidents caused by wandering vehicles. The Research Branch was asked to monitor the construction and provide evaluations on the effectiveness of the rumble strips. The effectiveness of the rumble strip was determined by reviewing accident data before and after installation of the rumble strips. This was the first application of centerline rumble strips by CDOT.

Recommendations from the report: Centerline rumble strips are recommended for installation on two-lane highways where there is a history of crossover (head-on and sideswipe from opposite directions) type accidents. The results of this study demonstrate the effectiveness of centerline rumble strips in reducing accidents to vehicles that are traveling in opposite directions on two-lane highways. Because of the potential of increased danger to motorcyclists and bicyclists centerline rumble strips should not be indiscriminately used.

Implementation: A poll of the Region Traffic Engineers has been sent to determine if there is sufficient interest in the use of centerline rumble strips to merit a Project Details Standard Drawing for centerline rumble strips. The results of the poll will be sent to Project Development.

Effects of Geometric Characteristics on Interchanges on Truck Safety

- Report Number: DTD-DTD-R-99-3
- Authors: Bruce Janson, UC/D; Jake Kononov, CDOT; Wael Awad, UC/D; Juan Robles, UC/D; and Brian Pinkerton, CDOT
- Research Contact: Rich Griffin
- Phone Number: (303) 757-9973

Background: Is there a relationship between truck accidents and selected geometric characteristics of intersections? Can CDOT develop short- and long-term strategies to mitigate problems at Colorado interchanges? This research examined datasets containing information on truck accidents at interchanges, traffic exposure and selected geometric characteristics that emphasized interchange and ramp configurations. The study also looked at freeway truck accidents. These truck accidents were grouped by ramp type, accident type and by four conflict areas of each merge or diverge ramp and compared to the number of truck accidents per location and per truck mile of travel. A critical review of the AASHTO Policy on Geometric Design of Highways and Streets was also undertaken.

Recommendations from the report: Designers should consider applying the AASHTO Design Guide for larger trucks to allow for off tracking and sweep where a significant number of these vehicles are expected. Current AASHTO design guidelines for horizontal curves provide a very narrow margin of safety for the operation of large trucks and don't allow for adequate acceleration distances at entrance termini. Because the cost to address these issues through roadway design may not be economically feasible, the strategies to address this important issue include: providing a desirable range of design values, better signing and a predictable roadway environment, and driver education.

Implementation: Following the statistical analysis of truck accidents at interchanges, a cloverleaf interchange in northern Colorado was identified as having a higher than

expected frequency of truck rollovers. To address this, larger warning signs were installed at all entrances to the ramp. Following this installation, an observational before and after study was conducted to evaluate the effectiveness of the larger signs. The study concluded that the warning signs did not have a significant impact on safety. A recommendation was made to the Regional Office to consider this site for potential improvement under the Hazard Elimination Program.

Colorado Rockfall Simulation Program Update

- Report Number: CDOT-DTD-R-99-1
- Author: U. S. Geological Survey
- Research Contact: Rich Griffin
- Phone Number: (303) 757-9973

Background: This report is an update to the manual for the popular Colorado Rockfall Simulation Program (CRSP). CRSP, originally released in 1989, is a rockfall computer program that simulates rocks tumbling down a slope, predicts the statistical distribution of speed and bounce height, and can be used for locating and designing rockfall barriers.

Recommendations from the report: This report serves as a user's manual for the CRSP software. Only professionals actively involved in rockfall control should be using this program.

Implementation: CDOT Geological Staff use this program on a limited basis in determining bounce height and energies associated with potential rockfall events. There have been several technical questions about the program, which indicate that there may be some bugs in it. Some of the problems include metric to English conversions and the statistical methods used. It is not clear whether or not these are glitches in the program or input errors. The CDOT Rockfall Program currently has a consultant preparing a "Rockfall Manual of Practice." The manual will compare the CRSP program to others currently on the market. This manual should be completed in early 2002.

Traffic, Safety, Maintenance Studies – Current

Above: Installation of erosion control materials on SH 40, west of Berthoud Pass. Left, counting the type and number of plants that are growing on the rehabilitated slope. And yes, the man is attached to a safety line.

Evaluation of Slope Stabilization Methods (Berthoud Pass)

- Study Number: 30.01
- Principal Researcher: Mike Banovich,
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Expected Implementation: Materials Specification Change

SH40, west of Berthoud Pass, was built in the early 1960's. Standard practices for erosion control were applied to the cut and fill slopes. The slopes consist of highly eroding and unstable sandy soils on 1-to-1 slopes where vegetation was not able to establish itself. In 1995, enhancement funds became available to rehabilitate some of the eroded slopes. This project is testing various cost-effective erosion control materials and installation techniques for future application on similar areas. A final report is expected in late 2001. (See related photo on previous page.)

Avalanche Detection (Pooled Fund Study with UDOT, WYDOT, and IADOT)

- Study Number: 30.80
- Principal Researcher: Rand Decker, Univ. of Utah
- Research Contact: Werner Hutter
- Phone Number: (303) 757-9975

Expected Implementation: New Technology

During the summer and fall of 2000 an avalanche detection system was installed on two avalanche paths of the Seven Sisters avalanche area. The purpose of this system is to alert CDOT workers and highway users of US 6 on Loveland Pass that an avalanche has occurred. It is intended to stop traffic before back ups occur under the other avalanche paths of Seven Sisters that are larger and more dangerous. Performance of the system at the start of 2000-2001 winter season was mixed and several adjustments needed to be made. Evaluations are continuing.

Sites with Promise for Safety Improvement

- Study Number: 90.70
- Principal Researcher: Jake Kononov, Staff Traffic
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Expected Implementation: Assessment Methodology Change

Highway safety has historically been measured in terms of accident rates. The use of accident rates is based on the assumption that the number of accidents on a segment of road is directly proportional to the amount of traffic. Recent research findings, independently confirmed by an analysis performed by the Accident Records and Analysis Group (ARAG) show this assumption to be invalid and may lead to poor investments in safety improvements. The same ARAG developed Safety Performance Functions (SPF) for all road classes on the Colorado highway system. SPF more accurately reflects the complex relationship between the amount of traffic measured in average daily traffic and accident counts for a unit of road section over a unit of time.

This research will examine and evaluate simple SPF developed by CDOT and recommend modifications or improvements. Following the development of multivariate models of the selected road sections and junctions, the research will apply an empirical Bayes- based procedure for selecting and ranking candidate sites for safety improvements.

Interaction Between Pedestrians and Vehicles Using Smart Signing

- Study Number: 92.06
- Principal Researcher: Jim Nall, CDOT Region Three
- Research Contact: Rich Griffin
- Phone Number: (303) 757-9973

Expected Implementation: New Technology

The Roaring Fork Transit Authority serves the communities along SH82 from Glenwood Springs to Aspen. There are over 15 bus stops along this route. Passengers departing these buses cross over the road to the other side and have created a potential hazard on this high-speed highway. This research is testing the effectiveness of a passively activated warning sign that notifies motorists of pedestrians in the roadway. The research will also determine the most effective message, the best method to activate the sign, and the driver and pedestrian response.

Integration of Ramp Metering with Ramp Traffic Signals

- Study Number: 92.07
- Principal Researcher: Sarosh Khan, UC/D
- Research Contact: Rich Griffin
- Phone Number: (303) 757-9973

Expected Implementation: New Technology

The first part of this project will develop traffic control strategies to coordinate ramp metering and the adjacent traffic signals to reduce delay and queue lengths on the ramps and nearby signalized streets. The second part of this project will focus on testing the traffic control strategies at two or three interchanges.

Next Generation Retro–Reflective Beads for Traffic Paint (Pooled-fund Study, Univ. of New Hampshire)

- Study Number: 93.20
- Principal Researcher: Univ. of New Hampshire
- Research Contact: William (Skip) Outcalt
- Phone Number: (303) 757-9984

Expected Implementation: Materials Specification Change

The University of New Hampshire, the lead researcher on this study, will replace silanized glass beads, currently used to provide retro-reflectivity in traffic paints, with surface polymethylmethacrylate (PMMA) beads. While the silanized glass beads offer excellent retro-reflectivity when newly applied, little is quantitatively known regarding their lasting properties. By modifying the surface of the beads with chemical functions to react with the binder, these new beads could offer a significant improvement in the retention of minimum retro-reflectivity. This project will also include a measurement of the retro-reflectivity of current paint to offer a rational comparison with the next generation of beads.

Policy and Planning Studies – Completed

Review of the Public-Private Initiatives Program of the Colorado Department of Transportation

- Report Number: CDOT-DTD-R-2001-2
- Authors: Dr. Porter Wheeler and Sasha Page, Infrastructure Management Group, Inc.
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Background: In 1995, the Colorado legislature authorized public-private initiatives (PPI) to fulfill unmet needs in its transportation infrastructure. While CDOT developed guidelines and instituted a PPI program, results were not satisfactory. This review assessed the current public-private initiatives program from the perspective of all participants, incorporating the best practices from other states. The goal of this research was to enhance CDOT's understanding of the issues surrounding PPI.

Recommendations from the report: CDOT should focus on making the PPI process more proactive in four key areas:

-CDOT needs to establish and communicate clear, proactive policies toward the PPI program,
-it must make legislative/legal clarifications that would make the program work more effectively,
-the ad hoc quality of CDOT's PPI procedures will improve with a pro-active policy, and
-the lack of acceptance of the commercially oriented PPI program may reflect strains in CDOT's culture.

Implementation: CDOT has implemented the second recommendation to make legislative and legal clarification. HB 01-1369 was passed in the spring of 2001 and made legislative clarifications to the PPI statutes. Further work will be needed on the three remaining recommendations during 2002.

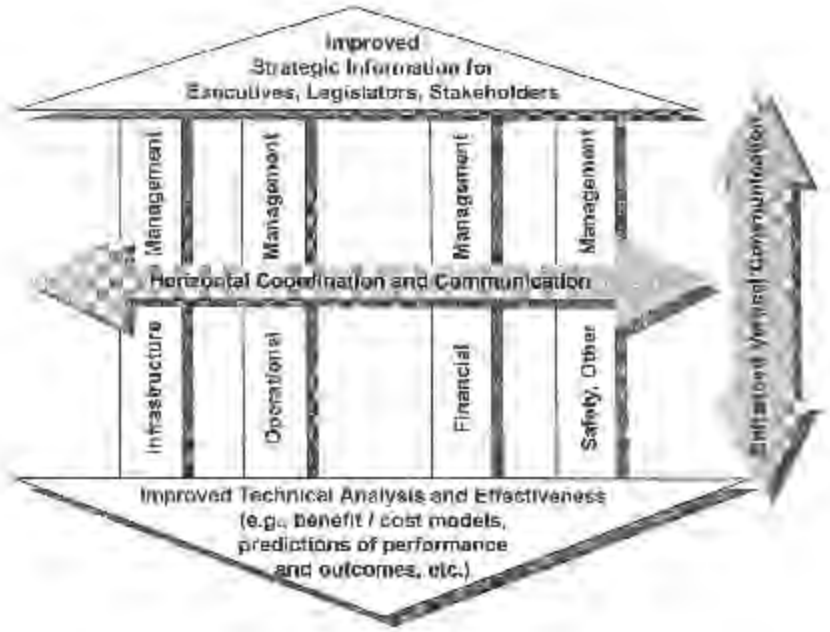
Asset Management Implementation Plan and Tiered System Development

- Report Number: CDOT-DTD-R-2001-13
- Principal Researcher: Michael J. Markow, Cambridge Systematics; and Joe Racosky, BRW, Inc.
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Background: Asset management is a system of managing transportation infrastructure. It provides a set of principals that will guide CDOT in improving how it conducts business, how it reaches decisions, and how it processes, uses and communicates information related to the management of its infrastructure. Asset management is a results-oriented system, driven by policy goals and objectives with clear measures of system performance and accountability. Elements of asset management include: an inventory of assets, benchmarking (condition assessment and asset evaluation), performance prediction measures and trend indicators, cost estimates of asset management options and resulting impacts, and engineering/optimization tools. This report documents a review of asset management and related practices at CDOT and other leadership states.

Recommendations from the report: Based on this review and with input from the Transportation Commission and the Executive Management Team a five-year transportation asset management plan is presented. The report demonstrates how asset management can work with CDOT's unique investment category structure and suggests a process for tiering assets.

Implementation: The CDOT Deputy Executive Director will oversee a task force for implementing this plan. There is also a study underway to establish a tiering structure for transportation infrastructure of state interest in Colorado to use in planning and asset management. That study will reference the tiering process identified in this report.



This graphic illustrates the implications of asset management for agency processes and information flows.

Evaluation of Design-Build Practice in Colorado. Project IR IM(CX) 025-3(113)

- Report Number: CDOT-DTD-R-2001-3
- Author: Pete Graham, CDOT Region 4
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Background: During 1997, CDOT Region 4 advertised its first ever design-build contract under a FHWA pilot program. The design-build concept combines the design and construction phases of a project into a single contract and allows for overlapping of the two. Design-build has been credited for accelerating project completion time, promoting innovation, reducing user's cost and assigning more responsibilities to the bidding firms. Evaluations of the project were required as part of this pilot program. This report identifies and documents the pros and cons of the design-build practice and examines its overall applicability to CDOT.

Recommendations from the report: The design-build method of contracting has the potential of promoting innovation, reducing the overall project time, and reducing user's costs. Using design-build does not necessarily reduce the overall agency costs.

Implementation: This report was written to meet FHWA requirements since CDOT had deviated from the standard design-build process. The report's findings re-enforce experiences from similar design-build projects. Since CDOT is using the design-build method when appropriate, no further implementation efforts will be pursued. The report is available for engineers as they formulate future design-build projects.

Estimating Link Travel Time on I70 Corridor: A Real-Time Demonstration Prototype

- Study Number: CDOT-DTD-R-2000-15
- Authors: Sarosh Khan and Kittichai Thanasupsin, UC/D
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Background: This study reports on the feasibility of estimating link travel time and speed in real time for rural, mountainous sections of interstate freeway in Colorado using vehicles instrumented with global positioning system receivers serving as probes in traffic streams. The study was carried out in two phases. The first phase identified a cost-effective means of monitoring traffic within a rural, mountainous stretch of I70. In the second phase, a real-time demonstrational prototype was developed to receive, process and estimate link travel time and speed statistics.

Recommendations from the report: The low-cost system developed can be a useful tool to monitor travel times where there are a sufficient number of vehicles that continuously operate in a corridor, such as shuttle van. CDOT can make arrangements with van services to carry the fully automatic devices, which periodically determine their position using the Global Positioning System, and radio it in to an internet site.

Implementation: The ITS Office has entered into a contract to deploy the technology developed by this research for I-70 West Corridor. The deployed system will provide real time travel times to the operations center and the public through the Internet.

Improvements to Mobility Performance Measure Calculations

- Report Number: CDOT-DTD-R-2000-14
- Author: BRW, Inc.
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9972

Background: In the last decade, CDOT has undertaken many activities to advance the use of system performance measures that would help CDOT make informed investment decisions related to Colorado. This report presents research findings and recommendations for improving several mobility performance measure data collection sources and measurement estimation techniques. Major sections of the report address criteria to report statewide congestion, required enhancements to the existing CDOT travel data collection and analysis system, short-term improvements, and long-term improvements.

Recommendations from the report: Until further research and broadbased data is available, the basis for mobility measurements should be based on congestion on state highways. Indexes, like the amount of time during the day, week, or year the V/C (traffic volume divided by the highway capacity) exceeds .85, is recommended. Use of broader indexes for a broader set of facilities and modes should first be focused on a few strategic corridors.

Implementation: CDOT is moving toward performance-based budgeting using five investment categories. In order for this process to be effective, good performance measures are needed in each of the investment categories. Toward this objective, findings of this study are being used as a part of the basis for the evolution of performance measures for the mobility investment category.

Long-Range Cost Estimation Research Project

- Report Number: CDOT-DTD-R-2000-7
- Author: Info Teck, Inc.
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9972

Background: This project researched long-range (parametric) cost estimation at CDOT using AASHTO's Trns.port Cost Estimation and Decision Support software. CDOT's current long-range estimation practices were reviewed and revisions were identified that could meet CDOT's future cost estimating requirements.

Recommendations from the report: AASHTO's Trns.port Cost Estimation System (CES) offers a potential tool for improved cost estimation. At the time of this project, CES was undergoing a major rewrite. The CES is intended to be a cradle-to-grave application for transportation project cost estimation. CES enhancements should include: parametric estimation of quantities, multi-modal parametric related estimation, multiple contract classifications and inflation factors by group.

Implementation: Following completion of this research, the Cost Estimation Squad developed a business plan to implement the recommendations of the research and establish parametric cost estimating capability at CDOT. The plan call for one FTE, over the course of several years, to map all the work types in the historical database, clean the data, make it work with new software, and train the related personnel on using the system. Because CDOT was unable to allocate an FTE for this activity the plan never went any further.

Common Performance Measures: Practitioner's Guidebook

- Report Number: CDOT-UCD-UCCS-99-7
- Authors: Sarosh Khan, Larry Eubanks, Michael Mueller, and Juan Robles
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Background: As interest in investing in non-automotive transportation increases, tools to measure the performance, costs, and benefits of various modes of transportation, in terms common to all decision makers, are needed. The Common Performance Measures (CPM) process employs two frameworks - economic efficiency analysis (EEA) and measures of effectiveness (MOEs) - to assess and prioritize various transportation actions.

Recommendations from the report: This report is a practitioner's guidebook. It provides the process steps a practitioner would follow to perform an MOE or EEA analysis. Files containing an electronic version of the spreadsheets, as well as templates for the manual worksheets, are provided with the report.

Implementation: Because the methodologies developed in this study require data generally not readily available to the rural communities during the planning process, the use of this guidebook is limited. However, a reference to this document as a useful tool, will probably be included in the "Regional Planning Guidebook" now being developed by the Statewide Planning Section of the Division of Transportation Development. When it was published, the document was shared with Regional Planning and Environmental Managers for possible use in corridor analysis. A follow-up effort is planned.

Evaluation of Design-Build Practice in Colorado

- Report Number: CDOT-DTD-R-99-5
- Authors: Ahmad Ardani and Paul Jesaitis
- Research Contact: Ahmad Ardani
- Phone Number: (303) 757-9978

Background: This report summarizes the activities that took place on a design-build project in Region 1. Under the Special Experimental Project No. 14, the FHWA approved the design-build concept for 12 miles of reconstruction of I70, east of Denver. The report is an overview of the design-build concept, discussion of significant events and the results of a questionnaire on design-build methodology. The report also includes a description of all the construction modification orders and a discussion of quality control and quality assurance processes.

Recommendations from the report: Design-build methodology for awarding construction projects looks promising. There is a need for improvement in a fully implemented design-build concept. CDOT pursuance of the best value concept along with the extended warranties for larger and more complex projects is a step in the right direction. The passage of House Bill 99-1324 authorized CDOT to award contracts based on the best value offered. In addition, this same bill authorized CDOT to include a warranty provision that requires the design-build firm to perform maintenance services on the completed transportation project.

Implementation: Since CDOT is using the design-build method when appropriate, no further implementation efforts will be pursued. See also Report CDOT-DTD-R-2001-3 "Evaluation of Design-Build Practice in Colorado. Project IR IM (CX) 025-3(113)"

Policy and Planning Studies - Current

Colorado Highways of Historical Content

- Study Number: 34.1
- Principal Researcher: Sally Pearce
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: Assessment Methodology Change

This photo is of the Million Dollar Highway, near Silverton.

This project will develop a Colorado Highways Context - examining those resources that relate directly to the design, construction, use, and maintenance of Colorado's roads. This context will assist in determining which of these resources are potentially eligible to be listed in the national and/or state registers of historic places.

Development of Statewide Mobility Measures Through Support of National Mobility Measure Development (Pooled Fund Study)

- Study Number: 60.2
- Principal Researcher: Myron Swisher
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: Planning Process Change

It is expected that this project will develop multi-modal measures of mobility which will be able to be used for planning, ITS programs, and performance-based budgeting. The project also provides an annual report on mobility for over 50 US cities. By applying various measures, Denver, Colorado Springs, and Boulder are compared. These measures are primarily based on traffic delay. The project is expected to establish methodologies that can incorporate travel time for other modes.

Land Use and Transportation Components that Support a Successful Commuter Passenger Rail Project

- Study Number: 61.3
- Principal Researcher: Charlier Assoc.
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: Planning Process Change

This product of this research will be the development a of "Best Practices" handbook and implementation plan which will describe land use design and decisions that could ultimately make passenger rail a cost-effective alternative for a community.

Using Data from RTD's Transit Vehicles to Develop Freeway Speed Maps

- Study Number: 90.46
- Principal Researcher: Sarosh Khan, UCD
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: New Technology

CDOT currently has limited infrastructure to monitor its freeways for traffic management. Existing infrastructures include loop detectors installed to display the speed of vehicles traveling on I25 but only in certain sections. On the other hand, all RTD buses are equipped with automatic vehicle location (AVL) systems that they use to improve fleet management. This research proposes using the bus location data collected by the RTD bus AVL system to estimate traffic speed for display on a color-coded map. This will allow CDOT to extend its coverage to include freeway sections, where detectors are not installed, and RTD buses operate. It will also serve as an indicator for congestion and potential "hot spots" in the freeway system.

Development of an Analytical Framework for Determining Long-Range Local County Roadway and City Street Needs, Including Bridges

- Study Number: 61.35
- Principal Researcher: David Rose, Dye Management Group
- Research Contact: Richard Griffin
- Phone Number: (303) 757-9973

Expected Implementation: Planning Process Change

Municipal/county roads and bridges are a vital component of Colorado's 80,000+ public roadway system. This local roadway network is eligible for state funding through the Highway Users Tax Fund (HUTF). Previous attempts, including efforts in the 2015 and 2020 State Transportation Plan have not resulted in an agreed upon methodology to assess local road and bridge needs. While CDOT has a twenty-year needs picture for state highways there is a deficiency in the local roads needs picture. This study will address those deficiencies.