

RESEARCH STATUS REPORT

1989 : 1990

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Colorado Department of Highways
Technology Transfer Unit

**COLORADO DEPT. OF HIGHWAYS
DIVISION OF TRANSPORTATION PLANNING
RESEARCH BRANCH**

90-9

Research Status Report
CDOH-DTD-R-90-9
December 1990

Colorado Department of Highways
Division of Transportation Planning
Research Branch
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The Research Branch of the Division of Transportation Planning is responsible for research, development and implementation of research findings for the Colorado Department of Highways. This program supports and coordinates national research efforts (SHRP, NCHRP, and TRB), drives the implementation of research findings, demonstrates research findings, evaluates new materials and methods, performs research studies which address state needs, and disseminates the research information to the transportation practitioners.

The primary customers of the program are the people responsible for the planning, design, construction, and maintenance of transportation systems in Colorado.

Research of national issues are supported by the department through contributions to the National Cooperative Highway Research Program and the Transportation Research Board. Research of regional issues is supported by pooling funds with other state highway agencies. Research which primarily addresses Colorado issues is administered through the Research Branch of the Division of Transportation Development. This research is performed by Research Branch staff, other department staff, Colorado universities, and private consultants when appropriate.

Organization

In order to provide a responsive program, easily adapted by the user, most research and development activities are performed in-house and the Research Branch staff is available to respond to research and implementation issues of the department. The Research Branch is organized by technical areas as shown in the organizational chart.

Research activities are guided by the Research Council and the Research Implementation Committee. The Research Council prioritizes research problems and makes recommendations on the direction of the research program. The Research Implementation Committee reviews research findings developed in-house, and those published by others, for possible incorporation into the department's program. Recommendations are made for the use of new procedures, materials, specifications, and other technological advances. The Technology Transfer unit is the operating arm of this committee. Both groups have a membership designed to represent the full spectrum of activities in the department.

Research Management Option

In the spring of 1990, the Research Branch developed a procedure manual and approval was obtained from FHWA to operate under the Research Management Option. With the Research Management Option all but the largest HPR research studies are approved in-house by the Division Director after getting a positive recommendation from each of the study panel members. The study panel for each of the research studies is now the primary oversight body for the principle investigator. The panel must review and approve the study plan, periodically review the activities of the principle investigator, and review and comment on the final research report.

Funding

The primary funding source for the research program is the HPR (Highway Planning and Research) program. A small amount of Federal Highway Administration money is also available through the demonstration projects, FHWA implementation funds, and the FHWA Special Experimental Features Programs. These funds are limited in both the amount of money available and the scope of their research activities. The moneys are made available to meet certain objectives which have been determined to be a priority by the FHWA. State money is also available for research and is part of the M & O budget for the Division of Transportation planning as approved by the Highway Commission.

PROGRAM OVERVIEW

Equipment

State-of-the-art technology and equipment are used whenever possible in the research program. Commercial suppliers are often selected when equipment is needed for research activities such as pavement monitoring, laboratory tests, other data collection, and data analysis. However, equipment designed and fabricated as part of a research activity is a common practice by the Research Branch. Quite often, it isn't long before a standard computer or data analyzer is modified for use on a specialized research study. When specialized equipment is not available within the department, local universities or private consultants participate in the program as described later in this report.

Future

Strategic management is expected to play a key role in the research program in the future. As the mission, goals, and objectives are developed for the department, research activities will be tailored to help the department meet these goals as quickly as possible.

Listed here are the objectives for the department's research program. Because the research program should be responsive to CDOH's needs, any future research objectives are simply a prediction of the future needs in transportation and are subject to change as needs change or become clearer.

1. Provide responsive, cost-effective, problem-solving research to the department through the use of the QUICK STUDY program and low-level Type B studies. This is an ongoing effort, but we hope to improve responsiveness through the 1990 implementation of the Research Management Option. Two areas of particular emphasis we expect to address are: low-pollution snow and ice control, and enhancements of the signing and delineation to compensate for the loss of visual acuity in the aging driver population.

2. Development of rut-resistant, crack resistant, non-stripping AC mix through appropriate use of new materials such as AC modifiers and anti-stripping agents. And through new acceptance test procedures

developed under SHRP, appropriately tested in the field through experimental features. With the increase in truck loadings, changes in asphalt cement and aggregates used in asphaltic concrete, rutting and stripping have become a severe problem on Colorado's highways.

3. Establish a national leadership role in geotextile research through our staff, UCD, and CSM. Through pioneering effort of fabric retaining walls by CDOH and the development of expertise at UCD and CSM in this area, Colorado has the opportunity to become nationally known for its geotextile research and to attract national research money. Geotextiles have the potential to greatly reduce construction and maintenance costs for highways.

4. Establish a nationwide leadership role in rockfall, modeling, and mitigation measures development. Colorado may have the most extensive rockfall problem in the country. With the increase in population and traffic in the mountainous area, rockfall hazards must not be left to luck, but should be addressed with a systematic program of identification and mitigation. CSM, UCD at Boulder, and the Colorado Geologic Survey all have expertise in this field which could drive a leadership role in rockfall.

5. Move research library data base to the VAX system. This will allow direct access for practitioners throughout the CDOH.

6. Implement the findings of SHRP. This will be a significant addition to our implementation program because SHRP as a multi-million dollar research effort, will result in many implementable findings.

7. Evaluate the effectiveness of advanced driver information systems. Much research is and will be occurring worldwide in the area of Intelligent Highway/Vehicle Systems (IVHS). Because of the congestion, air pollution, and limited highway corridor problems in Colorado, it is important that IVHS development be implemented rapidly in Colorado. We see the advanced traffic management systems as the first development in this long-term IVHS program.

8. Develop new techniques for mitigating and evaluating environmental impacts. This will follow the lead at the national level and will address integrating environmental issues into the whole design-construct process rather than as an external competing element.

Implementation

The implementation program consists of efforts to facilitate the inclusion of research findings in Colorado's overall transportation program. This includes Research Branch personnel participation in operating committees of the department, training in new technology by research personnel, presentation or preparation of articles on research findings not related to an active study, and the execution of a QUICK STUDY.

The QUICK STUDY program was established to provide fast response to CDOH issues related to implementation of new technologies. A QUICK STUDY may be a "paper study" where Research Branch personnel review research reports in a specific area and prepare recommendations for engineering, construction, maintenance, or planning personnel. A QUICK STUDY may also be a low-level evaluation of a new material, method, or prod-

uct which represents a significant change over standard practice.

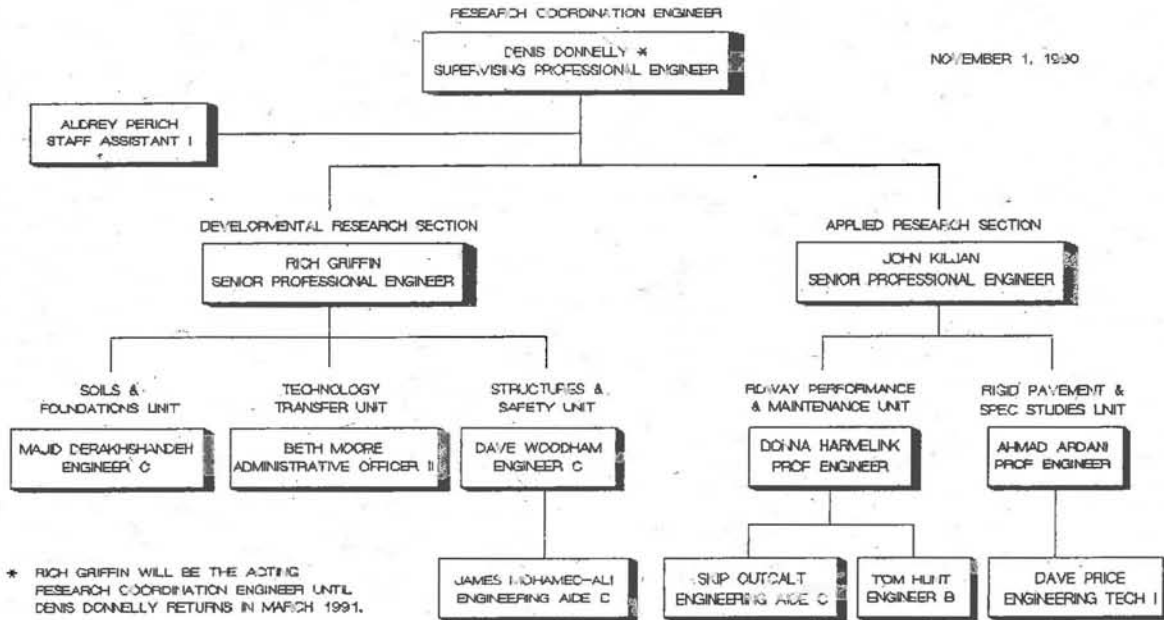
Each QUICK STUDY culminates in a one page summary. Other documentation, such as field notes, review notes, or a bibliography, may also be developed and kept on file. These summary sheets are presented to the Implementation Committee and kept by the Technology Transfer unit and logged into the data base.

The following is a list of QUICK STUDIES currently underway or completed:

- 90-A Bridge Deck Grooves
- 90-B White-Topping
- 90-C Percol
- 90-D Paraho
- 90-E Evaluation for Industrial Acrylic Paint
- 90-F Removable Marking Paint Evaluation
- 90-G Lightning Protection for Automated Traffic Recorders

STAFF ORGANIZATION

Research Organizational Chart



Research staff from left to right, standing: Beth Moore, John Kiljan, Dave Woodham, Skip Outcalt, Ahmad Ardani, James Mohamed-Ali, David Price, and Audrey Perich sitting: Majid Derakhshandeh, Tom Hunt, Donna Harmelink and Rich Griffin

(303) 757-9506

Ahmad Ardani

- >concrete pavements
- >subgrades
- >traffic loadings and analysis
- >SHRP coordination
- >snow fences

Majid Derakhshandeh

- >foundations
- >retaining walls
- >embankments
- >soil reinforcement

Denis Donnelly

- Research Coordination Engineer**
(on leave to SHRP program till 2/28/90)
>research program administration

Richard Griffin

- Acting Research Coordination Engineer**
(through 2/28/91)
>developmental/implementation programs
>electrical engineering
>natural hazards
(rockfall and snowshed activities)
>air quality studies

Donna Harmelink

- >asphalt pavements
- >maintenance coordination

Thomas Hunt

- >asphalt mix design
- >asphalt pavement studies
- >hydrology

John Kiljan

- >experimental features
- >asphalt pavements
- >concrete pavements
- >pavement and construction management
- >electronics and communications
- >IVHS

James Mohamed-Ali

- >research support
- >technology transfer support

Beth Moore (757-9220)

- >technology transfer
- >RTAP

Skip Outcalt

- >maintenance research
- >research support

Audrey Perich

- >"everyone's support"

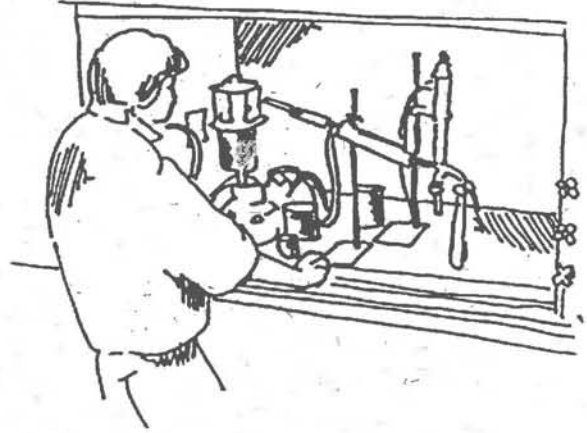
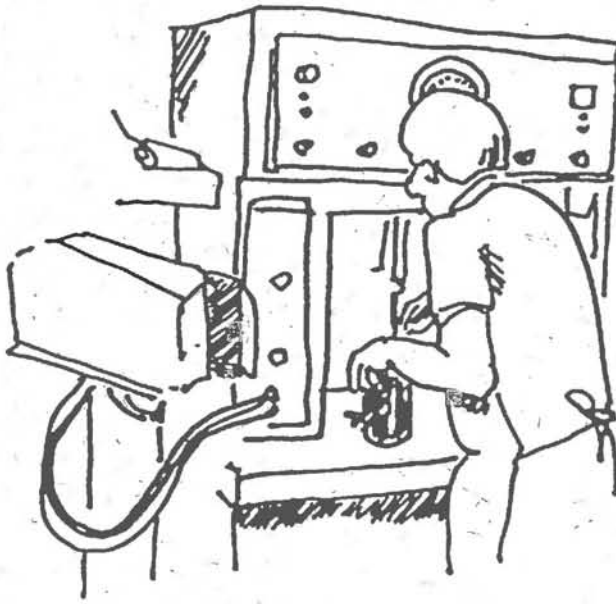
David Price

- >concrete pavements
- >shoulder treatments
- >asphalt studies
(large aggregate)

Dave Woodham

- >traffic/safety
- >structures and roadside facilities
- >environmental
- >energy
- >hazardous waste

LABORATORY FACILITIES



The laboratory testing facilities of the Staff Materials Branch play an important part in the evaluation of research features. Various soils, asphalt, concrete, and steel testing equipment are routinely used in evaluating experimental materials. Laboratory personnel play a significant role in developing and implementing these new technologies.

Each year, about a hundred asphalt cores are tested for research purposes in the lab's flexible pavement unit.

In the field, the Staff Materials Branch has provided falling weight deflectometer testing, as well as geotechnical testing used in research projects.

New equipment is added periodically to the lab to better predict field performance of construction materials and more accurately measure materials for acceptance. The newest additions to the flexible pavement laboratory are a creep and modulus tester that helps predict rutting, and a gyratory compactor which more closely simulates the compaction the pavement receives in the field. The chemical unit has added a new micro-processor controlled potentiometric titration device. This device can accurately and efficiently measure the concentration of ions such as calcium, magnesium, or chloride content and pH in various types of samples.

The university system in Colorado continues to be a valued partner in the CDOH research program. The diversity of the technical expertise and the excellent laboratory facilities of the universities are valuable resources.

University of Colorado at Denver

The University of Colorado at Denver (UCD) has several current contracts with the department. In the geotechnical area, UCD will be investigating the interaction between cohesive soils and geofabrics using finite-element methods. The model will be verified with the construction of a large-scale geofabric test wall. This work will lead to a deformation-controlled design method for using low-quality backfills in geofabric walls. Dr. James Guo has used dimensional analysis to derive a computer model for predicting peak runoff. The program takes account of such factors as basin area, slope, shape factor, precipitation (amount and intensity), vegetation, and soil type, to predict peak flow rates for use by the CDOH Hydraulic Design Squad. In the area of Traffic Engineering, UCD is studying the performance of Single Point Urban Interchanges (SPUI) under contract with the department. The study is concentrating on the before and after capacity and safety of the Garden of the Gods interchange in Colorado Springs. However, researchers also incorporated results from Colorado's first SPUI at Santa Fe and Evans Avenue and the SPUI at Morrison Road and C 470. The study will provide suggestions on improving the functioning of SPUIs.

University of Colorado at Boulder

Several contracts are being completed by the University of Colorado at Boulder (CU). A recently completed study compared the public perception of pavement rideability to the ratings achieved with a K.J. Law Model 8300 roughness surveyor. The results will have implications for Colorado's pavement management program. Another study being conducted by CU will model the way chlorides diffuse through bridge decks. The goal of this research is to develop a predictive capability for bridge deck corrosion to use in a comprehensive bridge deck maintenance program. A study of the dynamic forces and

accelerations present during the Standard Penetration Test (SPT) is expected to yield improvements in determining pile unit skin friction and end bearing. The results from these tests are expected to improve the calculation of pile lengths with the advantage that foundation costs can be determined more accurately.

Colorado State University

Colorado State University is administering the Rural Technical Assistance Program (RTAP) for the department. One of 46 nationwide, this program provides technical information on design, construction, management, maintenance, and operations to cities and counties throughout Colorado.

Colorado School of Mines

The Colorado School of Mines in Golden has developed a computer program for simulating the rockfall trajectory, energy, and impact locations. The program is a useful tool for determining the optimal size, height, and location for rockfall barriers as well as optimizing sideslope profiles to minimize rockfall hazards.

Consultants

Consultants provide additional expertise to the research program and, in many cases, only a consultant has the necessary knowledge to complete a research study. Currently, there are three research studies under contract with consultants outside the department.

Wels Research Corporation is developing a weather prediction model for use in highway operations. The model uses artificial-intelligence-enhanced programming to predict and display road conditions using CDOH Geographic Information System (GIS) data. The program will respond to maintenance actions and user observations (such as plowing a road, or an observed road condition) and re-display the road network reflecting the new changes.

Arthur Mears, an internationally known natural hazards consultant, is studying the behavior of snow during avalanche events in order to better predict

loads on avalanche control structures. Very little information is available on what loads are produced by an avalanche and, as a consequence, most avalanche structures may be over-designed. The department will find this information useful for future avalanche control structure design.

The Colorado Geological Survey is conducting a pilot study to develop a method for prioritizing highway rockfall hazards. The method developed will provide the necessary tools for inventorying, categorizing, and evaluating rockfall hazards so that resources are directed in the most cost-effective manner.

GEOFABRIC WALLS USING COHESIVE BACKFILLS

Principal Investigators: Jonathan Wu and Nelson Chou
Anticipated Completion Date: July 1992

PEAK RUNOFF PREDICTION MODEL

Principal Investigator: Dr. James Guo
Anticipated Completion Date: November 1990

SINGLE POINT URBAN INTERCHANGE EVALUATION

Principal Investigator: Dr. William Pollard
Anticipated Completion Date: December 1990

PUBLIC PERCEPTION OF PAVEMENT RIDEABILITY

Principal Investigators: Bruce Suprenant and Scott Arterburn
Research Report: CDOH-UCB-R-90-10

PLANNING BRIDGE DECK REPAIRS BASED ON CHLORIDE CONTENT

Principal Investigator: Bruce Suprenant
Anticipated Completion Date: August 1991

DYNAMIC MEASUREMENTS ON PENETROMETERS

Principal Investigator: George Goble
Anticipated Completion Date: December 1990

ROCKFALL MODELING AND ATTENUATOR TESTING

Principal Investigators: Robert Barrett, Timothy Bowen, Timothy Pfeiffer, and Dr. Jerry Higgins
Research Report: CDOH-DTD-ED3/CSM-89-2

WEATHER PREDICTION FOR MAINTENANCE OPERATIONS

Principal Investigator: Elmar Reiter
Anticipated Completion Date: January 1992

AVALANCHE PROPERTIES FOR SNOWSHED DESIGN

Principal Investigator: Arthur Mears
Anticipated Completion Date: December 1990

ROCKFALL INVENTORY PILOT STUDY

Principal Investigator: Colorado Geological Survey
Anticipated Completion Date: December 1990

Ninety-five percent of Colorado's highways are paved with asphalt. Each year, a huge percentage of our limited construction and maintenance dollars goes into asphalt pavements. In recent years we have seen rutting occur in these pavements at a faster rate, possibly because of increased truck loads and higher tire pressures. Researchers around the country are looking at ways of improving rut resistance without making the pavements more susceptible to cracking or stripping.

Rut-Resistant Composite Pavement

One idea, using a low AC content, high stability pavement covered by a high AC content seal coat to prevent stripping, has been discontinued for now. The seal coat appears not to have prevented stripping, but rather promoted it in some circumstances. When moisture is trapped below a seal coat, a combination of heavy traffic and hot wet weather can cause stripping in the subsurface layers.

Asphalt Additives

A wide range of asphalt additives are on the market. The most commonly used are anti-stripping additives which increase the adhesion of the asphalt cement to the aggregates of hot-mixed asphalt. Other additives are generally designed to enhance the properties of the asphalt in one of two ways: The first way, is to stiffen the pavement and reduce rutting at high tem-

peratures without affecting its low temperature properties. The second way, is to increase the asphalt's low temperature ductility, thereby reducing cracking, without affecting its high temperature stiffness.

The stripping properties of asphalt pavements are a continuing interest for the Colorado Department of Highways. Some aggregate sources in the state are unacceptable for use in asphalt pavements because they bond so poorly to the asphalt binder. Others considered to be marginal strippers are acceptable only when used with an anti-stripping additive. A recently completed study comparing the performance of a premium liquid anti-stripping additive with a less expensive additive found little difference in pavement performance in two trial sites.

Polymer additives are currently in common use in the state. They have reduced the cracking in our test sections early in the life of the pavement but long term benefits are not known. One other state has reported that the cracking in the polymerized pavement eventually reaches the same level as other pavements, possibly due to the aging of the polymer. Eight sites around the state with polymerized pavements as old as four years are being studied in two different research projects. In addition to tracking their field performance, laboratory testing will be performed to determine how climatic and traffic conditions have affected the asphalt cement.



On the right is a polymer-modified asphalt cement. On the left is the standard AC-10F pavement.



This core compares the large aggregate pavement, Grading G, with the existing Grading E pavement.

In two separate studies, regionally produced additives, Paraho Somat (from oil shale) and Gilsonite (mined asphalt), have been found to increase the rate of cracking in experimental sections, probably due to hardening of the asphalt. It is difficult to tell whether they have reduced the rutting. At this point, the benefits do not appear to justify the additional cost of the additives.

Adding polypropylene fibers does appear to slightly increase the strength and rut resistance of a pavement, without increasing its propensity to crack. These fibers were added to the asphalt mix on a project on US 34 near Wiggins. The performance of this pavement will be monitored for another year to try to determine its long-term cost benefit.

Large-Aggregate

Large-aggregate asphalt pavements are now being promoted by various asphalt associations, including the National Asphalt Pavement Association (NAPA), as an answer to rutting problems with existing pavement designs. Since the CDOH had little or no experience with the construction and related problems of using large aggregates, a research study was initiated.

Large-aggregate pavements have been designated as Grading G with a maximum aggregate size of 1-1/2 inches. In the past, the largest aggregate size allowed in Colorado highways was 3/4-inches (Grading C). The larger aggregate allows for better aggregate interlock within the pavement, reducing the rutting that occurs in wheelpaths, and as an added benefit, reduces the expense of asphalt by reducing the required asphalt content. At present, six projects have been constructed in Colorado with these mixes. Three of these projects include test and control sections for evaluation.

The evaluation of these pavements is expected to last three years after the construction of the projects. After one year, the test sections have shown little wear and are in good condition.

Recycling

In addition to studies dealing with the prevention of rutting, cracking, and stripping, we are studying rehabilitation of distressed pavements. Recycling of asphalt pavements is not a new idea, but is becoming more cost effective and politically advantageous with rising public concern about damaging the environment. In Colorado, recycled asphalt pavement has been added to hot asphalt mixes at the mixing plants in quantities up to about 30%. Cold in-place recycling is a new concept in this state. It has been used on a few projects recently. In cold recycling, the asphalt pavement is milled out (to varying depths), mixed with a rejuvenating agent and sometimes a percentage of virgin material, and recompact in place. It is then usually covered by a hot-mix asphalt overlay. A report on the recycling project on US 24, east of Colorado Springs, has just been completed. Despite some problems with some of the overlay treatments, the recycling performs well provided it is covered with a thin virgin overlay. Another project on SH 14 near Briggsdale will be studied to compare the performance of cold recycling to a standard overlay.

Hot in-place recycling is also being studied. In this process the pavement is first heated to around 250 degrees F with large banks of propane-fired infrared heaters. It is then milled and placed in a windrow where a small amount of asphalt rejuvenating agent is added. This windrow is mixed with a percentage of hot-mix asphalt and recompact. Much better compaction can be achieved with hot recycling than cold recycling; therefore, a surface overlay is not always needed. The first application of this was on US 50 in Fremont County this past summer. This six-mile long project included remixed sections with and without an overlay, as well as a control section that was not remixed.

Glasgrid

Glasgrid is a fiber-grid paving fabric with higher tensile strength and modulus than most engineering fabrics. It was installed under a 2-inch asphalt overlay on I 70 westbound near Silverthorne with the hope that it would reduce the cracking being reflected up



These are before and after photos of a hot in-place recycling project on US 50 near Penrose.

ASPHALT PAVEMENTS

from the old mat. The Research Branch is monitoring the cracks in a 970-foot section containing Glasgrid and comparing them with cracks in the section treated with another fabric, Trevira Spunbond, and an untreated control section. Following the second performance evaluation, the Trevira and Glasgrid paving fabrics do not appear to be effective in reducing reflective cracking. A final determination on the fabric's effectiveness will be made following the spring 1991 evaluation.

Rehabilitation of a Rutted Asphalt Pavement

The most economical method of rehabilitating a rutted but otherwise adequate pavement is not known. On a rutting rehabilitation project on I 25 near Longmont, the top 2-inches of the driving lane was milled and replaced with a high stability hot-mix asphalt. A 1000-foot test section, consisting of milling 1/2-inch to remove the ruts, was included in the project. The entire roadway was then covered by a plant-mixed seal coat, including the passing lane which was not milled. Although rutting is returning to this heavily traveled interstate, the bulk of the project with the high stability inlay is performing better than the test section which was milled to only 1/2-inch.

Rut-Resistant Composite Pavement Design
Principal Investigator: Donna Harmelink
Anticipated Completion Date: December 1993

Carstab Anti-Strip
Principal Investigator: John Kiljan
Anticipated Completion Date: January 1991

Polymer Modified Asphalt Cements
Principal Investigator: John Kiljan
Anticipated Completion Date: February 1992

Polymer Modified Pavements
Principal Investigators: John Kiljan and Tom Hunt
Anticipated Completion Date: December 1991

Paraho
Principal Investigator: Donna Harmelink
Anticipated Completion Date: Quick Study 90-D

Gilsonite, An Asphalt Modifier
Principal Investigator: Donna Harmelink
Anticipated Completion Date: Fall 1991

Fiber-Pave
Principal Investigator: Donna Harmelink
Anticipated Completion Date: Fall 1991

Large-Aggregate Asphalt Pavements
Principal Investigator: David Price
Anticipated Completion Date: December 1991

In-Place Cold Recycling of Asphalt Pavement
Principal Investigator: Donna Harmelink
Report Number: CDOH-DTD-R-90-3

Hot In-Place Recycling
Principal Investigator: Tom Hunt
Anticipated Completion Date: Fall 1992

Glasgrid Pavement Reinforcement
Principal Investigator: Donna Harmelink
Anticipated Completion Date: Fall 1991

Rehabilitation of Rutted Asphalt Pavement
Principal Investigator: John Kiljan and Ahmad Ardani
Anticipated Completion Date: September 1992

Concrete pavements presently comprise only five percent of the total state highway system. In the past, concrete pavements were considered only in locations where heavy truck traffic was prevalent and new or reconstruction could be performed without severe delays to the motoring public. With new accelerated concrete paving techniques, roadways can be opened to traffic within hours of paving rather than days. This technique is being investigated along with other time and material saving procedures that may allow concrete pavements to become more competitive with asphalt pavements. Investigations are also focusing on the rehabilitation of existing concrete pavements that are nearing their design life.

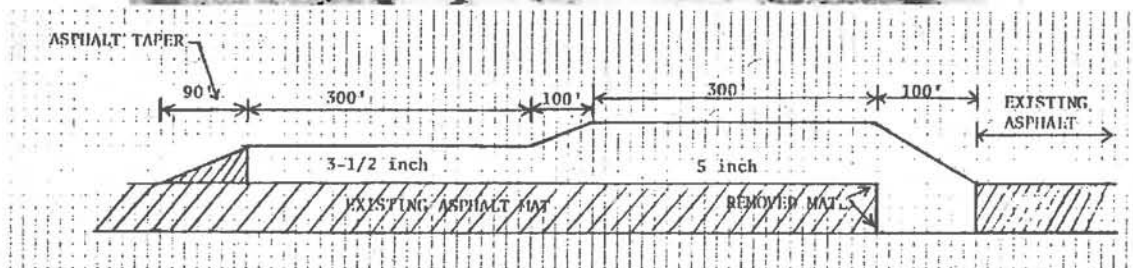
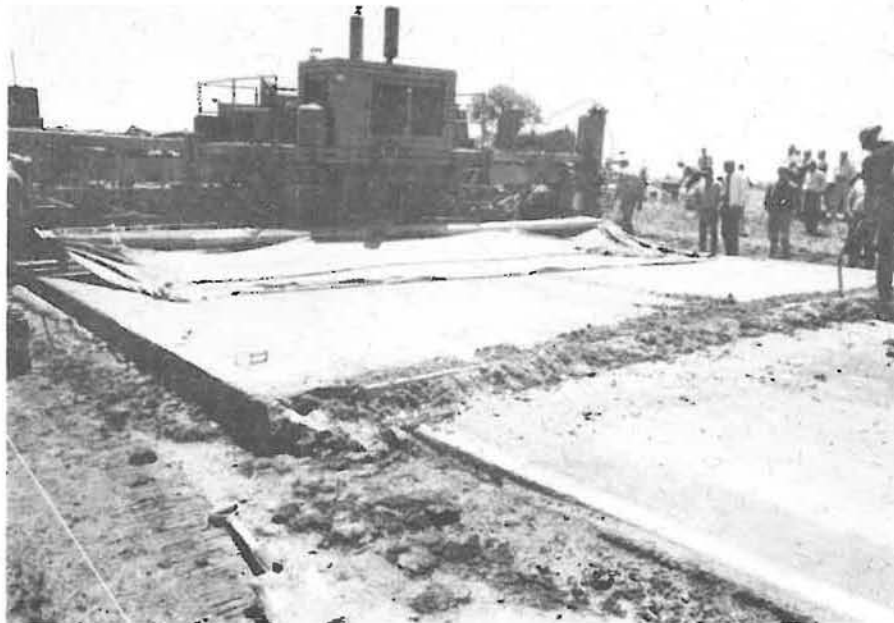
White-Topping

Asphalt overlays are common procedure for repairing distressed asphalt and concrete pavements in Colorado. However, CDOH had no experience with concrete overlays on asphalt pavements until the summer of 1990, when a 1000 ft. test section was

placed on SH 68 (Harmony Rd.) in Ft. Collins. The project was completed by a group of contractors who not only volunteered their time but also the materials. They were assisted in the project by FHWA and CDOH personnel.

The first half of the test section was paved at a depth of 3-1/2 inches, followed by a transition to 5-inches to the end of the section. The 5-inch overlay has a design life of 20 years. The 3-1/2 inch overlay, whose design life is not known, will be evaluated to see how long it can hold up against rutting and deterioration. The experiment is an attempt to prove that you can overlay with a thinner concrete surface and thereby make concrete more cost-effective to use. The current design procedures indicate a minimum of 8-inch concrete for new construction.

This project also demonstrated the use of fast setting concrete. The roadway was reopened to traffic within 28 hours of initial closure and only 24 hours after paving began.



Construction and profile of the SH 68 white-topping project.



Trucks on I 76 use the passing lane to slow deterioration of the right driving lane.

Pavement Deterioration vs. Truck Weight

One of the main factors in deteriorating pavement is the heavy loads that are imposed upon them. But, some of the deteriorative causes may also be attributed to environmental conditions. Many engineers believe that the environmental factors and the heavy load factors are intertwined, one reinforcing the other, to cause pavement distress. The objective of this study is to isolate the non-load related pavement deterioration (environmental effects) and solely focus on that which is load-related (truck weight effects) and incorporate this information into future pavement design.

Stabilizing Agents in Concrete

One technique that is presently being evaluated that could save concrete contractors time and money, is the use of a stabilizing agent to slow concrete hydration at the end of a work day, leaving the concrete in a plastic state until the next morning when paving can be resumed. If successful, this technique will eliminate the time required to set a night header, plus eliminate the need to grind the pavement at the joint where the night header was removed due to the bump normally associated with this area. At present

this concrete additive has been used only at one site, I 76 at the Proctor interchange.

I 76 Truck Study

Portions of the driving lane on I 76 are seriously distressed. Both driving and passing lanes are subject to the same environmental stresses but it is because of the load-related damages that the driving lane has become prematurely distressed. To help prolong the life of the pavement in this area, District 4 has placed signs advising truckers to use the passing lane from the town of Roggen to the Nebraska state line. The Research Branch is evaluating the impact of diverting truck traffic from the driving lane to the passing lane. The economic feasibility, safety, and the overall impact on the concrete pavement is being evaluated. If the study is successful, this method may be used in other locations to extend the life of concrete pavements to the point where money becomes available to replace or rehabilitate.

Accelerated Rigid Paving Techniques

The concrete industry has been working hard in becoming more cost competitive with the asphalt industry. One of the breakthroughs has been the use of fast-track paving. This technique eliminates the

long waiting period to reopen the roadway normally associated with the use of concrete pavements.

Accelerated paving techniques have been developed to minimize the impact of street closures encountered with repairs or rehabilitation work in urban areas. The major objective of this project was to achieve high, early strength gain in the pcc pavement without compromising the ultimate strength or durability, thereby permitting opening the facility in a day or two.

A secondary objective of this study was to examine the applicability of a maturity meter in monitoring the strength gain of concrete using type III cement. The accelerated rigid paving technique was used in a project located in the town of Sterling. This project consisted of 13,400 sq. yds. of 8-inch plain jointed, non-dowelled, high, early strength concrete covering six intersections. Closing these intersections for an extended periods was a major concern, to the town people, including the local merchants. The results of this study showed that accelerated paving can reduce the time needed to complete a project, and minimize traffic delays.

PCCP Joints and Dowel Basket Evaluation

This study examines the performance of various joint designs with or without load transfer devices. It is the general consensus that transverse joints equipped with dowel baskets cause the load to be transferred from one slab to another. This in turn prevents the slab from faulting. The bi-annual evaluation of the project performed during the month of May and June, 1990 revealed no faulting for the test (doweled) or the control (non-doweled) sections. It is possible that more time is needed for the control section to show any faulting. This project will be evaluated for the next six years.

White-Topping

Principal Investigator: David Price
Anticipated Completion Date: Quick Study 90-B

Pavement Deterioration vs. Truck Weights

Principal Investigator: Ahmad Ardani
Anticipated Completion Date: September 1993

Stabilizing Agents

Principal Investigator: David Price
Anticipated Completion Date: Undetermined

I 76 Truck Study

Principal Investigator: David Price
Anticipated Completion Date: Winter 1992.

Accelerated Rigid Paving (Fast Tracking)

Principal Investigator: Ahmad Ardani
Anticipated Completion Date: Undetermined

PCCP Joints and Dowel Basket Evaluation

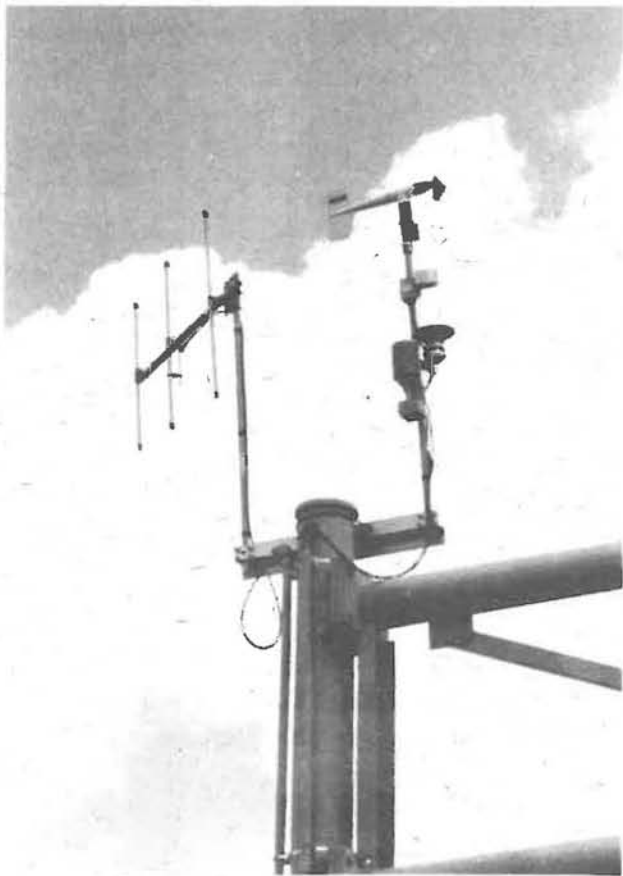
Principal Investigator: Ahmad Ardani
Anticipated Completion Date: September 1996

MAINTENANCE

Maintenance operations present an area where research has the potential for large savings. Colorado's maintenance forces are continually forced to do "more with less." The appropriate application of high technology tools and methods will allow them to accomplish their jobs in a safe and efficient manner.

Ice Detection System Evaluation

The Research Branch is involved in three separate activities in the area of ice detection equipment and their use. A study of the accuracy and reliability of this equipment is nearing completion. Results indicate that both personnel and equipment can be more efficiently utilized by using the trademarked SCAN ice detection system. A second study, conducted under the Demonstration Projects Division of FHWA, is investigating the human element of ice detector use. The use of the SCAN system is being documented and how the information that the system provides is being used in the decision process. The last effort in this area is to provide information to the SHRP contractor working towards ice detection standards and siting criteria.



One of several ice detectors located in the Denver Metro Area.

Deicing Chemicals

Section 8 Maintenance and the Research Branch are planning a series of tests designed to evaluate the performance and costs of various salt/sand ratios for deicing use. In addition, this study plans to evaluate several alternative deicing chemicals which have advantages over sodium chloride. The use of these alternative chemicals may be more cost effective once more is known about their deicing capabilities and their corrosive nature. Several of the alternative deicing chemicals have been shown to have minimal environmental impact and may be useful in ecologically sensitive areas.

Industrial Snow Fences

The primary objective of this study was to compare and to demonstrate the economic and functional practicability of several types of industrial snow fences against the traditional wooden fences. The industrial snow fences are made of high-density polyethylene with a laminar setting which possesses a very high tensile strength (7000-8000 lbs. per four-foot roll width). They are one-quarter the weight of wooden fences and require substantially less room for storage or hauling. They are effective in controlling snow during the winter; however, they are damaged by cattle during the summer.

Experimental Gravel Shoulders

A study was completed in early 1990 determining the long-term effectiveness of gravel shoulders as compared to paved asphalt shoulders. Gravel shoulders proved to be 71 percent less expensive to construct than those paved with asphalt. However, there were concerns with three items: 1) the maintenance costs of the gravel section may exceed the savings within a few years, 2) the safety of the gravel shoulders, 3) and premature failure at the edge of pavement between the gravel shoulder and the roadway.

Two sites were constructed for evaluation of the above concerns. After several years of study, the recommendation for the use of gravel shoulders is as follows. Gravel shoulders need to be implemented on a project by project basis, looking at each project's traffic volume, for possible implementation. Evaluations show that gravel shoulders work well on low

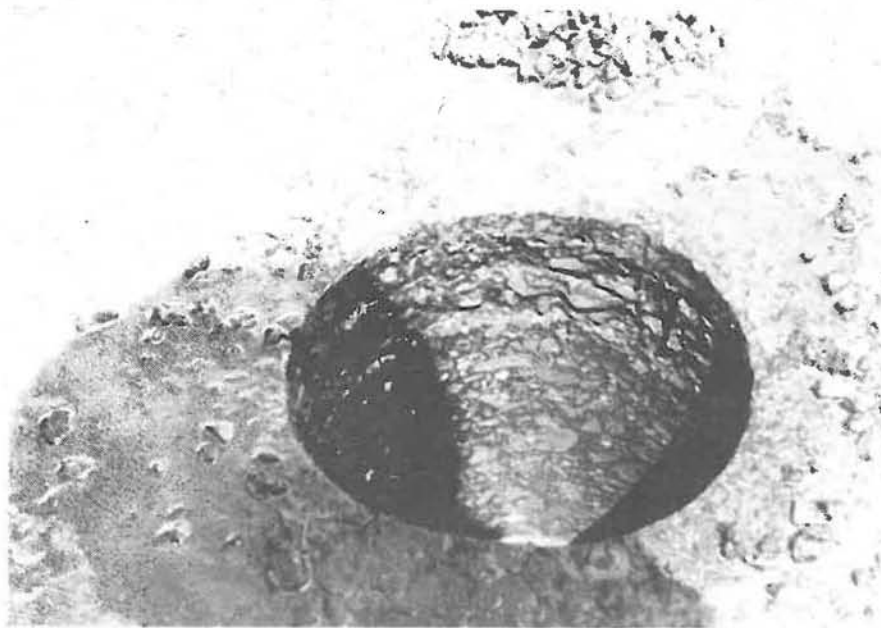
volume roadways. However, as daily traffic rises, maintenance requirements become greater and overall cost savings of the gravel shoulder are reduced along with safety.

Rehabilitation of Stripping Pavements

One highway in eastern Colorado has provided an opportunity to study various low-cost techniques for rehabilitating a pavement that is undergoing stripping. Large ruts developed in this pavement in the summer of 1990. After drilling cores, it was discovered that the underlying Grading F sand mix was being stripped of its asphalt cement. It was then shoved aside by traffic, leaving severe rutting in the plant-mix seal coat on top. The rehabilitation methods being studied are: milling out 2-1/2 inches and replacing it with well-graded asphalt pavement, milling off just the top 3/4-inch PMSC and replacing it with a 1-inch overlay, and two sections with patching and two different depths of overlay. The information gathered will be used to develop future rehabilitation strategies.

Micro-Surfacing

Micro-surfacing is gaining in popularity for repairing rutted pavements and restoring a level, skid resistant surface to older pavements. In this process, a latex-modified emulsion is mixed with crushed aggregate, mineral filler, and a special additive which controls the breaking rate of the emulsion. This mixture is spread over the roadway like a slurry seal, filling in ruts and other surface depressions. About one hour after paving, the mixture has set and traffic may be allowed on the roadway. The initial cost of this process is high compared to a standard 1-inch overlay, but micro-surfacing may reduce the rate at which rutting returns, and increase the skid-resistance and durability of the roadway surface. Mixed reviews of the cost effectiveness of this process have come from other states, while informal studies done in this state have been inconclusive. More extensive testing is anticipated in the near future.



This core hole shows how the pavement is stripping in the pavement layers.

MAINTENANCE

Rockfall Research

With the increased traffic and roads in mountainous areas, rockfall has become an increasing concern to both the travelling public and the highway industry. Protecting the travelling public from rockfall can range from: preventing the rocks from breaking loose at the source, removing the potentially hazardous rocks, redirecting the rocks, and/or stopping the rocks as they travel down the slope.

Rockfall research has, so far, been in three different areas: development of a rockfall model, development of an inventory methodology for rockfall hazard locations, and testing of rockfall barriers.

First, a rockfall computer model has been developed that estimates rock speed and bounce height as they travel down the slope toward the highway. The model provides the necessary information to determine the best location, height, and strength for rockfall barriers.

Next, a rockfall inventory program was developed. Before rockfall hazards can be mitigated they must first be identified. The Colorado Geological Survey, through an HPR funded research project, has developed a rockfall inventory program which will provide the highway department with a method to identify and classify rockfall hazards and set priorities for construction of mitigation measures.

Finally, fabric reinforced earth walls have been used as retaining walls for several years, but this cost-effective wall design could also be used as a rockfall barrier. Use of on-site soils would increase the economy of this system even more. However, the behavior of earth reinforced structures under the dynamic loading of flying rocks was unknown, so testing of such a system was undertaken.

Through an HPR research study, data was analyzed and a report prepared. Results indicate that fabric reinforced earth and Gabion walls perform well as rock fall barriers, and the deformation of the walls provide a mechanism to absorb the energy of the rock.

In-Service Evaluation of Ice Detection System

Principal Investigator: Dave Woodham
Anticipated Completion Date: July 1991

Ice Detection Evaluation (EP13)

Principal Investigator: Dave Woodham
Anticipated Completion Date: July 1991

Reduced Sand Mixes for Urban Areas

Principal Investigator: Dave Woodham
Anticipated Completion Date: July 1992

Industrial Snow Fences

Principal Investigator: Admad Ardani
Anticipated Completion Date: March 1991

Experimental Gravel Shoulders

Principal Investigator: David Price
Research Report: CDOH-DTD-R-90-2

Rehabilitation of Stripped Pavements

Principal Investigator: Tom Hunt
Anticipated Completion Date: Fall 1991

Micro-Surfacing

Principal Investigator: Tom Hunt
Anticipated Completion Date: Undetermined

Rockfall Inventory Pilot Study

Principal Investigator: Colorado Geological Survey
Anticipated Completion Date: December 1990

Fabric Reinforced Earth Rockfall Barrier

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: December 1990

The Research Branch is involved in several studies in the area of highway safety and the evaluation of new products and methods.

Reflective Sheeting Exposure Deck

Historically, the CDOH has approved sign sheeting based on data obtained using a weatherometer, a device that produces artificial weather in an accelerated time. While the weatherometer gives some comparative performance data related to UV stability and resistance to moisture damage, the true performance is more accurately measured under actual field conditions. An outdoor test deck for reflective sheeting was constructed in May of 1987 for the purpose of exposing reflective sheeting materials to actual Colorado weather conditions. The data that has been gathered from the deck is presently being correlated to data from the weatherometer in order to improve data interpretation from the weatherometer.

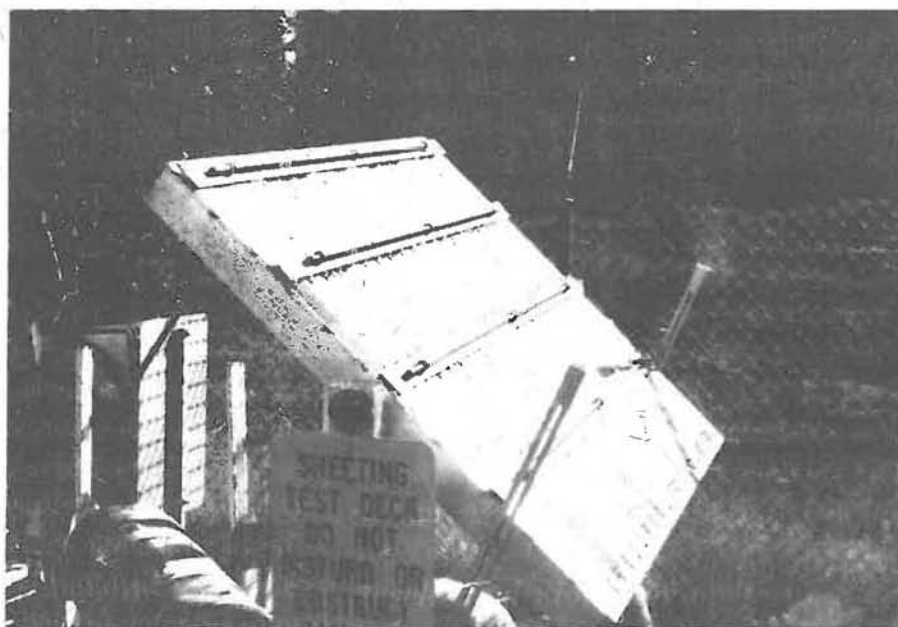
After three years of testing panels exposed to actual Colorado weather conditions, the average reflectance

of all sheeting types show approximately a 8% loss of original reflectance. The panels tested in the weatherometer were exposed for 2,000 hours and lost approximately 33% of original reflectance. If reflectance loss due to weather exposure is linear (or nearly linear), then 2,000 hours in a weatherometer is approximately equivalent to 12.75 years of Colorado weather.

High Performance Safety Devices

Because of the high public awareness of the C 470 project, Phase III projects near Morrison will incorporate state-of-the-art sign sheeting, pavement markings, flexible delineators, guardrail delineation tabs, and sign post breakaway devices. The use of these high performance devices will further the goal of a positive public image for this facility.

The objective of this study is to determine if the use of high performance highway safety devices has a measurable effect on accident rates. If an increase in traffic safety is observed, these high performance safety devices could be used on future projects.



This outdoor test deck for reflective sheeting exposes the sheeting materials to actual outdoor conditions.

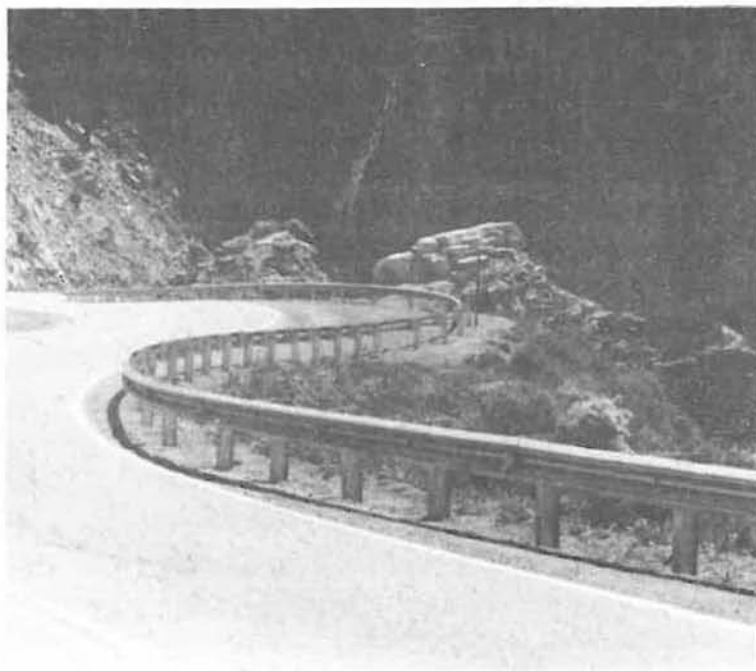
Guardrails

Research is currently investigating three experimental safety features. They are 10-gauge guardrail, the Brakemaster End Terminal system, and the Crash-Cushion Attenuating Terminal (CAT) system. The 10-gauge w-beam guardrail will be evaluated on Battle Mountain Pass and its effectiveness compared to the lighter weight 12-gauge guardrail. The two terminal systems will be used in narrow medians in bi-directional traffic. The Brakemaster End Terminal is designed for use in low-frequency impact areas and for easy installation. The system's construction features w-beam guardrail panels and a braking mechanism which will move back telescopically during a head-on impact, bringing the vehicle to a controlled stop. Brakemaster can also redirect vehicles in low-angle side hits. The CAT is similar to Brakemaster in that it also moves back during impact while bringing the vehicle to a controlled stop. These safety devices will be evaluated for in-service performance for two years.

Pavement Marking Materials

A comprehensive pavement marking study concluded in 1990 with a final report. The report covers the performance of materials installed transverse to the road and a panel review of several long-line striping projects with higher type pavement marking.

The transverse test deck included several brands of both permanent and removable grades of preformed plastic, extruded thermoplastic, epoxy paint, standard alkyd traffic paint, and fast dry alkyd traffic paint. These materials were applied on both asphalt and concrete.



Ten-gauge guardrail on Battle Mountain Pass.



Installation of pavement marking on the test section.

Stamark 380 Pavement Marking Material

The 3M Company has recently developed a new preformed pavement marking material called Stamark 380. The product is an upgrade to 3M's 350 material already tested by the department. The main difference in Stamark 380 is that it features hard ceramic beads instead of glass. This gives Stamark 380 better reflectivity, confirmed with Mirolux readings and by visual inspection.

The evaluation will include not only monitoring the tape for its reflectivity and durability but for its ability to stick to the new pavement surface.

Polyethylene Pipes for Cross Culverts

This study, which will soon be completed, evaluated the structural adequacy of 18-inch to 36-inch polyethylene pipes used as cross culverts. The first installation of these pipes was under US 50 north of Olathe. They have performed well except for one that was damaged after sawdust ignited inside of it.

Project-Level Pavement Management

This study was carried out in several phases, including documentation of current policies and procedures and review of existing state-of-the-art project-level pavement management systems from other states and agencies. During the development of Colorado's pavement management system the subsequent study phases were focused on the modification of flexible and rigid pavement design process, followed by the rehabilitation of pavements and life-cycle cost analyses. All changes were incorporated in the CDOH design manual subsequent to approval by the FHWA. Computer programs were developed for the pavement design process, pavement rehabilitation, and life-cycle cost analyses. These programs are currently being tested by the department's designers, and changes will be made upon findings from the users as warranted.

Reflective Sheeting Exposure Deck

Principal Investigator: David Price
Anticipated Completion Date: December 1990

High-Performance Safety Devices

Principal Investigator: Dave Woodham
Anticipated Completion Date: December 1993

In-Service Evaluation of Highway Safety Devices

Principal Investigator: James Mohamed-Ali
Anticipated Completion Date: Fall 1992

Pavement Marking Materials

Principal Investigator: Richard Griffin
Research Report: CDOH-DTD-R-90-5

Pavement Marking Materials (Stamark 380)

Principal Investigator: James Mohamed-Ali
Anticipated Completion Date: Fall 1994

Polyethylene Pipes for Cross Culverts

Principal Investigator: Tom Hunt
Anticipated Completion Date: December 1990

Project-Level Pavement Management System Development

Principal Investigator: Stephen Horton
Research Report: CDOH-DH-SD-90-7

The Soils and Foundations Unit has been active the past two years with six new studies being funded.

Retrievable Test Rig for Drilled Pier Bridge Foundations

In the design of deep foundations, the values of the end bearing and side shear of a soil or rock deposit are needed in the design process. This task is generally accomplished by laboratory testing of the in-situ soil or rock samples. During this research study, a field testing device was designed, manufactured, and tested to measure the actual side shear and the end bearing of a soil in the field to minimize the assumed safety factors and the errors involved in laboratory testing procedures.

Resilient Properties of Colorado Soils

For over 30 years, pavement engineers have used the elastic layered system theory to predict the physical response of pavement structures in order to determine a proper pavement thickness. During this research study, attempts were made to find a correlation between the resilient modulus and the R-value for Colorado soils. To accomplish this task, an extensive laboratory testing program was conducted and the following correlation was established: $M_r = 3500 + 125 (R\text{-value})$.

Geotextiles to Stabilize Bridge Abutments

Based on the experienced gained by the Wyoming Highway Department, a geogrid (Tensar SS-2) and a geofabric (Tytar 3601) were selected and used to reinforce two bridge abutments on I 76 in northwest Denver. This was done to reduce the bump at the end of the bridge abutments. Currently under evaluation, the study will be monitored through 1991.

Geotextile Retaining Wall Design

This study was developed to examine the available design methods currently used to design fabric walls, and choose the most appropriate one for the application of CDOH related projects.

Dr. T.H. Wu from the University of Colorado was the principal investigator for this study. He has completed his work and is finishing the final report.

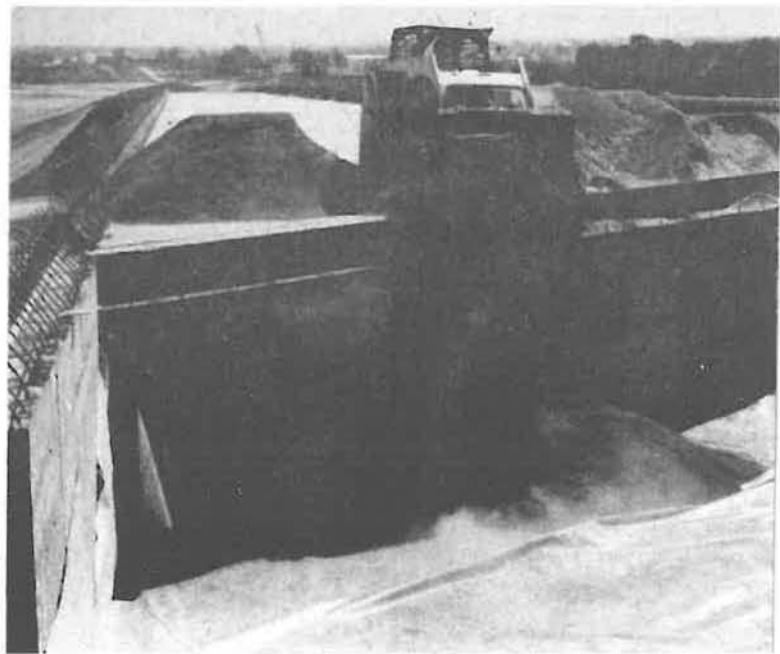
Monitoring a Criblock Retaining Wall

Two criblock retaining walls were constructed on County Road 17 in Pitkin County in western Colorado. Due to the proprietary nature of the criblock system, and the requirement of FHWA, it was proposed to consider the criblock wall construction as an experimental feature, and monitor the performance of the walls during and after construction.

After 14 months of monitoring, it was concluded that, structurally, the walls performed well, and their selection from an aesthetic point of view was a correct choice.

Dynamic Measurement on Penetrometers

This study measured the actual force and acceleration during standard penetration tests in order to obtain more reliable soil properties. Dr. Goble from the University of Colorado served as principal investigator for the study. He has concluded that using the currently available transducers it will be possible to obtain good force and acceleration measurements during standard penetration tests and that more reliable in-situ soil properties can be predicted.



Bridge abutment using geotextiles under construction on I 76.



This geotextile is being laid to reinforce a 30-foot high embankment on top of a sanitary landfill filled with uniform fly ash.

Consolidation Testing Using Triaxial

Apparatus

During this study, a completely automated triaxial testing system was prepared to examine the feasibility of using one sample for both consolidation and triaxial tests to find material properties. It was found that the triaxial system can be used effectively in obtaining multiple engineering properties of soils from one sample. However, it is not advised to use this system to predict the in-situ three dimensional consolidation behavior of soils. The in-situ three dimensional consolidation is very much affected by stress paths and boundary conditions.

Dr. N.Y. Chang, University of Colorado, was the principal investigator for this study. The final report was published in December, 1989.

Monitoring of Nondurable Shale Fills in Semi-Arid Climates

The objective of this study was to monitor the performance of three shale fill embankments on I 70 in the western slope of Colorado. It was discovered that two relatively simple laboratory tests such as "jar-test" and "slake durability test" can be adopted to determine the degree of durability of the cut shales. Once this is accomplished, it is recommended that 8-inch lifts be used for durable shales and only 24-inch

lifts for non-durable shales during the compaction process in construction of highway embankments. Since January, 1990, this procedure has been fully implemented in all projects using cut shale as highway embankment material.

Geotextiles in Landfills

This research study consisted of using four different types of geosynthetic materials to reinforce a 30-foot high embankment on top of a sanitary landfill filled with uniform fly ash.

The embankment experienced a total of 14 to 18 inches of differential settlement over a nine-month period. The embankment was then removed, and samples of different geotextiles were obtained for further testing.

It was concluded that all selected geosynthetics (two different geogrids, a woven, and a non-woven geofabrics) performed well and any one of them could have been safely selected for this study. The author suggests that in selection of a particular geosynthetic, one must consider the degree of the problem at hand and the additional costs of a particular geotextile for a specific project.

In addition to the geotextile studies, a geosynthetic forum was organized and funded by the Research Branch to collect the state-of-the-art techniques in design and application of geosynthetic materials. This gathering turned out to be very successful, since for the first time, qualified members of the geosynthetic industry, universities, and CDOH had a chance to exchange their thoughts and ideas during this event. As a result of this meeting, a report "Geosynthetic Forum" was organized and published by Dr. T. H. Wu from the University of Colorado in Denver.

Geotextile Style Rockfall Barriers

This study was performed to analyze strain gage data obtained during the field testing of geotextile barriers. The analysis has been completed and a draft report is currently being reviewed by the research panel members.

Expansive Soil Treatment Method

Colorado highways are normally designed for a 20-year life expectancy; however, some of these highways will lose their rideability due to the swelling potential of the underlying subgrade. This study

reviewed and summarized the effectiveness of past expansive soil treatment methods used by the Colorado Highway Department. Work on the final report is being initiated and a report should be ready in the spring of 1991.

Curtain Drains

An alternative twelve-foot deep drainage system was installed on a slope above US 550 north of Durango. A "drain curtain" that transverses the earth mass consists of a polyethylene "egg carton" shaped core covered by a plastic filter cloth. Water is intercepted and collected by the core into an 8-inch collection pipe placed at the bottom of the curtain. The pipe transports the water out of the soil mass into an appropriate drainage system. The main advantage of such a system is that unclassified on-site material can be used for backfilling the trenches in place of expensive, sometimes imported, filter gravel used in conventional drains. After three years, the curtain drain was excavated and found to have collapsed during construction, reducing the cross-sectional area of water interception. The inside of the curtain drain was free of contamination but the overall moisture flow from the system was light.



A portion of this curtain drain has been cut in order to evaluate it's effectiveness.

RETRIEVABLE TEST RIG FOR DRILLED PIER BRIDGE FOUNDATIONS

Principal Investigator: R.H. Atkinson
Research Report : CDOH-DTD-R-88-16

RESILIENT PROPERTIES OF COLORADO SOILS

Principal Investigators: Shan-Tai Yeh and Cheng-Kuang Su
Research Report : CDOH-DH-SM-89-9

GEOTEXTILES TO STABILZE BRIDGE APPROACH SETTLEMENTS

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: Winter 1991

GEOTEXTILE RETAINING WALL DESIGN

Principal Investigator: Dr. T.H. Wu
Anticipated Completion Date: Winter 1990

MONITORING A CRIBBLOCK RETAINING WALL

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: Winter 1990

DYNAMIC MEASUREMENT ON PENETROMETERS

Principal Investigator: G. G. Gobel
Anticipated Completion Date: Winter 1990

CONSOLIDATION TESTING USING TRIAXIAL APPARATUS

Principal Investigator: Dr. N.Y. Chang
Research Report: CDOH-DTD-R-89-10

MONITORING OF NONDURABLE SHALE FILLS IN SEMI-ARID CLIMATES

Principal Investigator: Majid Derakhshandeh
Research Report : CDOH-DTD-R-89-8

GEOTEXTILES IN LANDFILLS

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: Winter 1990

GEOTEXTILE STYLE ROCKFALL BARRIERS

Principal Investigator: E. Kheirkhohi
Anticipated Completion Date: Winter 1990

EXPANSIVE SOIL TREATMENT METHODS

Principal Investigator: Ahmad Ardani
Anticipated Completion Date: March 1991

CURTAIN DRAINS

Principal Investigator: Tom Hunt
Anticipated Completion Date: December 1990

STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP)

SHRP is a five-year, \$150 million program to address high priority research areas that are national in scope. The SHRP study will include four separate areas: pavement performance, asphalt, highway operations, and concrete and structures. The states are directly involved with the long-term pavement performance studies, of which Research monitors 21 sites around Colorado. Sixteen are general pavement studies (GPS), and five are specific pavement studies (SPS).

SHRP SPS-3 Construction

In addition to the sixteen general pavement studies (GPS), Colorado is also participating in five specific pavement studies (SPS). These specific pavement studies are primarily related to preventive maintenance and rehabilitation. Among the SPS studies constructed in Colorado is the SPS-3 study. SPS-3 is an experiment which will determine the effectiveness of certain preventive maintenance treatments for flexible pavements.

There are four treatments included in SPS-3:

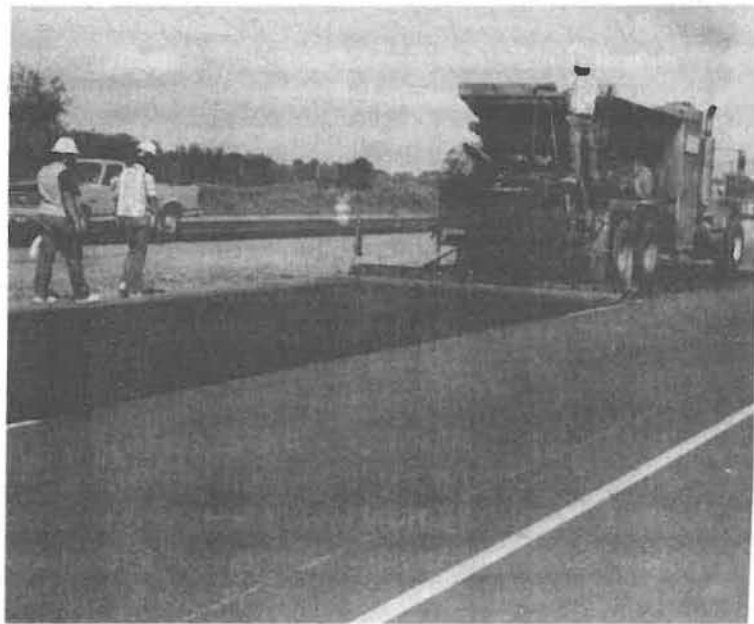
- >Thin overlay. A dense graded overlay which is between 3/4-inch and 1/4 inches thick.
- >Slurry seal. A designed mixture of emulsified asphalt and fine aggregate spread with powered equipment.
- >Chip seal. A sprayed application of asphalt over which a uniform amount of specifically graded aggregate is spread.
- >Crack sealing. All cracks in the asphalt pavement are cleaned out and sealed with crack sealant material.
- >Control Section. At each of the SPS-3 sites, there is a control section on which no maintenance is performed.

All of the work for a SPS-3 site within a region was done by the same contractor, using the same equipment, with the same materials, and to the extent

practicable, with the same personnel. There are two sites in Colorado for the SPS-3 experiment:

- US 50 east of Las Animas
- US 50 south of Delta

SHRP will monitor the performance of these treatments, and evaluate their effectiveness over the next several years.



A slurry seal being applied to one of the SPS sites.

Strategic Highway Research Program (SHRP)
Field Coordinator: Ahmad Ardani
Anticipated Completion Date: Undetermined

Highway structures represent a large expenditure by the department. In 1989 alone, CDOH let construction contracts for structures totaling \$53.5 million. Research in this area holds the potential for large dollar savings.

Avalanche Control Structures

Arthur Mears, an internationally known natural hazards consultant, is studying the dynamic behavior of snow during avalanche events in order to better predict loads on avalanche control structures. Very little information is available on what loads are produced by an avalanche and, as a consequence, many avalanche structures may be oversized. The department will find this information useful for the design of future avalanche control structures.

Bridge Deck Protective Systems

Chlorides used in de-icing operations eventually permeate bridge decks and react with the reinforcing steel placed in decks. In an effort to slow the entrance of chlorides, several bridge deck protective systems are generally used. Currently, in Colorado, several treatments are used to reduce chloride influx.

This study will investigate the performance of individual treatments against chloride intrusion. The objective is to gather information on how each system performs (individually and together with other treatments) and what the "as constructed" costs are in order to find what combinations of systems are the most cost effective. Other objectives are to:

- > document the decisions made in Colorado and the sequence of events which led to current practices in Colorado.
- > review methods used in other states with similar geography and climate.

Fly Ash Use In Structural Concrete

The Research Branch is monitoring the performance of several bridge decks constructed in 1985 using fly ash. Some construction problems were encountered including delayed set, and a rough and open surface texture. Monitoring of the decks is continuing to see if other problems will occur or if the initial problems prove to be significant.



This snowshed, north of Durango is being monitored for avalanche activity.

STRUCTURES

Bridge Deck Repair Demonstration

This study monitored the comparative performance of six bridges on I25 which were rehabilitated in 1984. Long-term monitoring of the three deck toppings (Colorado DT, low slump with fly ash, and latex modified) was done to evaluate each toppings ability to protect the reinforcing steel from chlorides applied on the surface. Comparisons between the low slump (LS) with fly ash and latex-modified bridge toppings showed that the LS was easier to work with, was a more uniform product and limited chloride intrusion as well as the latex-modified concrete. Half-cell testing was performed yearly on the decks as well as visual checks on the condition of the deck surface. From the cost and workability data gathered, Colorado's DT mix design appears to be the best compromise between performance and cost. The results of this study validate the current construction practice.



AVALANCHE PROPERTIES MEASUREMENT FOR SNOW SHED DESIGN

Principal Investigator: Arthur Mears
Anticipated Completion Date: September 1991

BRIDGE DECK PROTECTIVE SYSTEMS

Principal Investigator: Dave Woodham
Anticipated Completion Date: June 1992

USE OF FLY ASH IN STRUCTURAL CONCRETE

Principal Investigator: Dave Woodham
Anticipated Completion Date: July 1991

BRIDGE DECK REPAIR DEMONSTRATION

Principal Investigator: Dave Woodham
Anticipated Completion Date: October 1990



Research staff performing tests of a bridge deck protective system.

The FHWA describes Technology Transfer (TT) as a "process by which research findings and new technology are transferred into useful processes, products, or programs." It's a wide open definition and subject to a great deal of interpretation. This became evident when the TT Unit was chosen to be one of the eight states written about in the National Cooperative Highway Research Program Synthesis of Highway Practice #150 - "Technology Transfer in Selected Highway Agencies." We have always tried to direct our services to fit the need of the department and best use our available resources. To remain flexible it can mean that sometimes we add new services when the need arises; or discontinue services that are no longer beneficial in terms of the time and money invested.

Reference Library

The TT unit may be best known for its accumulation of FHWA sponsored research reports. Numbering in the 1,000's, the Research Branch has one of the best collections of transportation/construction related materials in the state. In addition, the TT unit in 1990 began collecting video tapes from other states on various subjects and is now in the process of reviewing the tapes and organizing a manual. Also new in 1990, is the bi-monthly acquisition listing of new reports and videos that have arrived in the TT Unit. Open to the public, the TT Unit gets approximately 125 reference calls a month requesting information and/or materials.

Special Projects

In 1990 the TT Unit started getting more involved in special projects. So far they have included a special map of construction, research, and SHRP sites in Colorado for the Strategic Highway Research Program held in Denver in early August. TT also became involved in organizing the "Research Status Report", the results of which you are reading here.

Newsletters

The "CDOH Research Newsletter" is produced by the TT Unit. This quarterly newsletter aimed at keeping CDOH employees informed of new and

ongoing research happenings is sent out across the country. It has a current circulation of 850 readers.

In addition to the research newsletter, TT serves as editor to the newly created Division of Transportation Development newsletter.

Database Searches

Because keeping ahead in this age of information can be a chore, the TT Unit has access to millions of article citations and abstracts through its use of database searching. Most familiar are the searches of the Transportation Research Information Service (TRIS) performed for us by the TRB staff. When time is short or other databases are deemed necessary, the TT Unit can perform searches of over 300 databases.

ReACH

The Research Activities on Colorado Highways (ReACH) program celebrated its tenth anniversary in January of 1990. ReACH is an audio and visual display of research happenings that is held every January in CDOH headquarters. It is then taken out on the road to the six districts and to special functions as requested.

Implementation

Another way in which in which the TT Unit encourages the use of new research findings is the "Ideas At Work" implementation program. This new program, just getting off the ground, condenses new ideas from other states into a one page summary and sends them to appropriate users within the highway department.

The TT Unit also serves as the operating arm of the Research Implementation Committee, scheduling and maintaining the yearly program of branch and district head input into the implementation of CDOH research results.

RTAP

Acting as a liaison to the Rural Technical Assistance Program in Fort Collins, the TT Unit provides input and guidance in the administration of this program.

The Colorado Transportation Information Program (COTIP) is a branch of the national Rural Transportation Assistance Program (RTAP). Located up in Fort Collins, COTIP is located on the campus of Colorado State University. It is a joint venture between the Federal Highway Administration, the Colorado Department of Highways and Colorado State University.

The objective of both the Colorado and national program is to provide coordinated information dissemination, technical assistance, and training activities to rural transportation agencies. The targeted audience includes but is not limited to: city and county engineers, supervisors and employees, directors of public works and public transit organizations and council of government organizations. Through the program, these local communities can get personal assistance in such areas as snow removal, pothole repair, bridge maintenance, traffic signal timing, management techniques and other timely issues.

Putting an emphasis on training, the Center held over 100 classes and workshops in the past two years, with approximately 3,500 in attendance. Most recently the training has emphasized workshops on the Commercial Drivers License. They also provide specialized training where the requesting organization can have a workshop tailored to meet their specific needs.

Having just obtained the entire collection of the FHWA regional office library, the COTIP Center has an impressive inventory of FHWA publications. They also have a large collection of transportation related video tapes for loan.

In addition, COTIP produces a quarterly newsletter called THE WHEEL that is filled with informative articles, dates for upcoming classes, and new publications.

RABBIT

The Research Activities Bulletin Board in Transportation is operated for Research by the TT Unit. Operating 24 hours a day, it provides a steady base of users with information on construction, research happenings, new publications, shareware programs, etc.

Where we are going is as important as where we have been. In 1991 the Surface Transportation Act comes up for renewal. Many highway advocacy groups are promoting an increased roll for transportation research in the upcoming bill -- particularly in the application of electronics and information processing for road congestion. The department hopes to be active in promoting and evaluating "smart highways" in metropolitan areas.

The next several years will also bring to fruition the efforts of the national Strategic Highway Research Program (SHRP). The SHRP results, as well as those from the Asphalt Aggregate Mixture Analysis System (AAMAS), will cause this and most other states to re-examine their asphalt mix design criteria.

In the more immediate future the Colorado Department of Highways will be looking at these more traditional research areas:

- > Ways to **recycle old automobile tires** are always of interest. The Research Branch will investigate the constructability and performance of shredded tires in roadway embankments.
- > Recycling is also the theme of another study that will use **expanded polystyrene from fast-food restaurants as a light-weight backfill** for bridge abutments and roadways.
- > A **shoulder erosion** control study will do comparison studies of several ways to mitigate shoulder erosion. The study will look at the economic benefits of tackifiers, soil binders, gravel shoulders, slope flattening, and seeding.
- > The department also hopes to initiate a finite-element study of the design parameters used in **thick un-bonded concrete overlays** over existing concrete pavements. These overlays are becoming common in Colorado, but the design criteria is still partially subjective.
- > The analysis of **low-cost geofabric earth walls** is expected to continue. A study that models walls with clayey backfills is expected soon.
- > **Rumble strips** on asphalt shoulders will also be the subject of a research study. Cut strips, raised strips, chip seals, and various rumble patterns will be examined.
- > **Infrared traffic monitors** will be examined as a less expensive and more reliable alternative to conventional vehicle counts and classifications.
- > **Rut-resistant asphalt mixes** get a new look in a series of lab tests designed to identify rutting potential.
- > The **durability of glass beads** in pavement marking paint is now an issue because of the improved durability of epoxy paints. A study will search for the optimal size for the reflective glass beads.

FUTURE RESEARCH

SHREDDED TIRES IN HIGHWAY EMBANKMENTS

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: August 1991

LIGHT-WEIGHT RECYCLED POLYSTYRENE IN HIGHWAY CONSTRUCTION

Principal Investigator: Majid Derakhshandeh
Anticipated Completion Date: September 1991

SHOULDER EROSION CONTROL

Principal Investigator: David Price
Anticipated Completion Date: Spring 1993

PCCP DISTRESS EVALUATION USING ILLI-SLAB ANALYSIS MODEL

Principal Investigator: Ahmad Ardani
Anticipated Completion Date: September 1992

LOW-COST GEOFABRIC WALL

Principal Investigator: Nelson Chou
Anticipated Completion Date: September 1991

EVALUATION OF RUMBLE TREATMENTS OF ASPHALT SHOULDERS

Principal Investigator: David Price
Anticipated Completion Date: Fall 1993

INFRARED TRAFFIC MONITOR

Principal Investigator: Rich Griffin
Anticipated Completion Date: Fall 1992

SANDING MATERIALS FOR WINTER MAINTENANCE

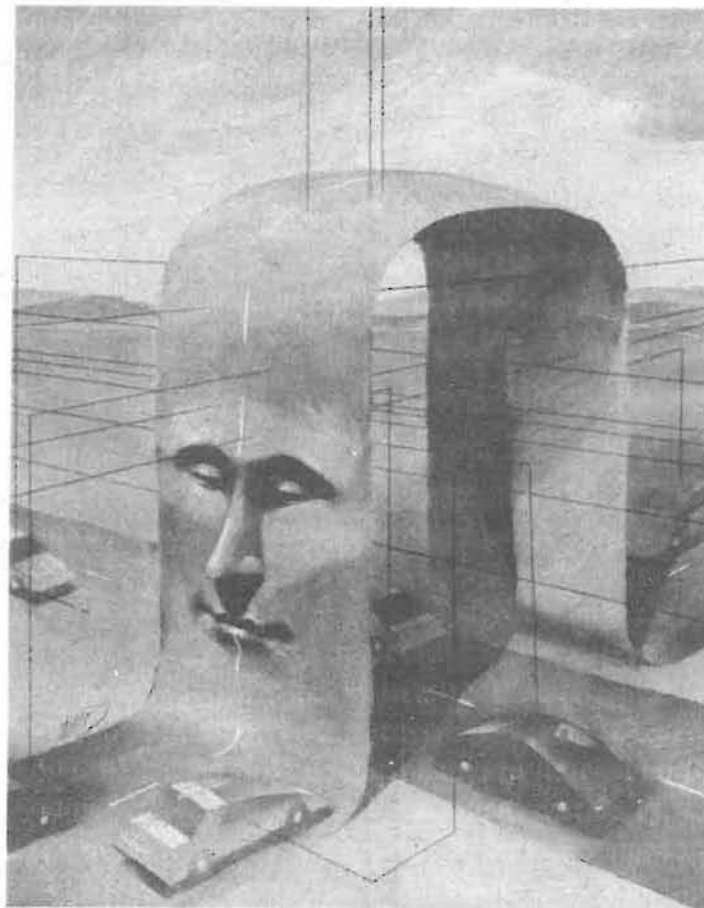
Principal Investigator: Dave Woodham
Anticipated Completion Date: June 1991

RUT-RESISTANT ASPHALT MIXES

Principal Investigator: Tim Aschenbrener
Anticipated Completion Date: 1991

GLASS BEAD DURABILITY STUDY

Principal Investigator: Rich Griffin
Anticipated Completion Date: 1992



*Intelligent Vehicle Highway Systems **

* From the Highway Users Federation report "Smart Cars, Smart Highways"

1989

TRUCK TIRE PRESSURES IN COLORADO

CDOH-DTP-R-89-1

Dr. Charles L. Bartholomew

ROCKFALL MODELING AND ATTENUATOR TESTING

CDOH-DTD-R-89-2

Robert Barrett, Timothy Pfeiffer, Dr. Jerry Higgins, and Timothy Bowen

FROST HEAVE CONTROL WITH BURIED INSULATION

CDOH-DTD-R-89-3

Ahmad Ardani

VERGLIMIT EVALUATION (BOULDER)

CDOH-DTD-R-89-4

John Kiljan

USE OF ROAD OIL BY MAINTENANCE

CDOH-DTD-R-89-5

Herbert Swanson

ACCELERATED RIGID PAVING TECHNIQUES

CDOH-DTD-R-89-6

Werner Hutter

IBC MEDIAN BARRIER DEMONSTRATION

CDOH-DTD-R-89-7

Dave Woodham

MONITORING OF NONDURABLE SHALE FILLS IN SEMI-ARID CLIMATES

CDOH-DTD-R-89-8

Majid Derakhshandeh

RESILIENT PROPERTIES OF COLORADO SOILS

CDOH-DH-SM-89-9

Shan-Tai Yeh and Cheng-Kuang Su

CONSOLIDATION TESTING USING TRIAXIAL APPARATUS

CDOH-DTD-R-89-10

Nien Yen Chang

REACTIVE AGGREGATE IN STRUCTURES

CDOH-DH-SML-89-11

Reza Akhavan

1989 : 1990 RESEARCH PUBLICATIONS

FIVE-INCH ASPHALT OVERLAY REHABILITATION

CDOH-DTD-R-89-12

John Kiljan

****AVALANCHE - INTERIM REPORT***

CDOH-89-13

Authur Mears

SAWED JOINTS IN AC PAVEMENT

CDOH-DTD-R-89-14

Donna Harmelink

EVALUATION OF MIRAMAT EROSION CONTROL FABRIC - PROJECT BRS 0037(2)

CDOH-DTD-R-89-15

Thomas Hunt

EVALUATION OF HIGH-DENSITY POLYETHYLENE PIPE

CDOH-DTD-R-89-16

Dave Woodham

GEOSYNTHETICS FORUM

CDOH

Jonathan Tzong H. Wu

1990

PRETREATMENT OF AGGREGATES

CDOH-DTD-R-90-1

Donna Harmelink and Thomas Hunt

EXPERIMENTAL GRAVEL SHOULDERS

CDOH-DTD-R-90-2

David Price

COLD-RECYCLING OF ASPHALT PAVEMENT - U.S. 24 - PROJECT CX-04-0024-25

CDOH-DTD-R-90-3

Donna Harmelink

PAVEMENT MARKING MATERIALS

CDOH-DTD-R-90-4

Richard Griffin

***GEOTEXTILES IN LANDFILLS**

CDOH-DTD-R-90-5

Majid Derakhshandeh and Nelson Chou

***CRIBLOCK RETAINING WALL**

CDOH-DTD-R-90-6

Majid Derakhshandeh

PROJECT-LEVEL PAVEMENT MANAGEMENT SYSTEM DEVELOPMENT

CDOH-DH-SD-90-7

Stephen Horton

***PEAK RUNOFF PREDICTION METHOD FOR SMALL WATERSHEDS IN COLORADO**

CDOH-90-8

Dr. James Guo

RESEARCH STATUS REPORT 1989 : 1990

CDOH-DTD-R-90-9

***PUBLIC PERCEPTION OF PAVEMENT RIDEABILITY**

CDOH-UCB-R-90-10

Bruce Suprenant and Scott Arterburn

***BRIDGE DECK REPAIR DEMONSTRATION**

CDOH-DTD-R-90-11

Dave Woodham

***REFLECTIVE SHEETING**

CDOH-DTD-R-90-12

David Price

(* indicates reports not yet published)

the 1990s, the number of people with a mental health problem has increased in all developed countries (Meltzer 1999).

There are a number of reasons for this increase. One of the most commonly cited reasons is the fact that people are living longer, and the prevalence of mental health problems increases with age (Meltzer 1999). Another reason is the fact that people are living in a more stressful environment (Meltzer 1999). The fact that people are living longer and in a more stressful environment means that they are more likely to experience mental health problems. A third reason is the fact that people are more likely to seek help for mental health problems (Meltzer 1999). This is because people are more aware of mental health problems and are more likely to seek help for them.

The fact that people are more likely to seek help for mental health problems means that there are more people with mental health problems who are seeking help.

There are a number of reasons why people are more likely to seek help for mental health problems. One of the main reasons is that people are more aware of mental health problems and are more likely to seek help for them.

Another reason is that people are more likely to seek help for mental health problems because they are more likely to be diagnosed with a mental health problem.

The fact that people are more likely to be diagnosed with a mental health problem means that there are more people with mental health problems who are seeking help.

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