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Expansive Soil Treatment Methods In Colorado

Ahmad Ardani
Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222

Final Report
March, 1992

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

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4201 East Arkansas Avenue, Room A-100
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16. Abstract
This report reviews and summarizes the effectiveness of past expansive soils treatmemt methods used by Colorado DOT and other transportation agencies. Among the treatment methods evaluated were the following:

- Sub-excavation and removal of expansive soils and replacement with non-expansive soil.
- Application of heavy applied load to balance the swelling pressure
- Preventing access of water to the soil by encapsulation
- Stabilization by means of chemical admixtures
- Mechanical stabilization
- Explosive treatment to correct swelling shales
- Pre-wetting the soil
- Avoiding the expansive soil

A survey questionnaire was designed and sent to the District Materials Engineers to obtain their consensus on the treatment techniques used in Colorado. The results of this survey are presented in Part VIII of the report.

IMPLEMENTATION: The results of this study showed that the performance of some of the swelling soil treatment methods used in Colorado have been poor. As a result, initiation of the second phase of this is recommended. The ultimate goal of the second phase will be to establish up-to-date design guidelines that offer specific strategies for highway construction on swelling soils and swelling shales in Colorado.

17. Key Words
Swelling Soils, Expansive Soils, Clay, Soil Suction, Shales, Treatment Alternatives

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Final Report

January 1992

I Literature Review and Problem Discussion

Expansive soils is a nationally recognized problem which has plagued individuals concerned with the design, maintenance, and operation of highway systems. A 1972 survey of the highway departments in the 50 states, District of Columbia, and Puerto Rico indicated that 36 states have expansive soils within their geographical jurisdictions (1). Figure 1 shows the distribution of potentially expansive materials in the United States; FHWA Region 7 and 8. The annual costs of maintaining the streets and highways built on expansive soils is estimated to be in the billions of dollars. Colorado DOT spends thousands of dollars to repair the damages incurred by expansive soils every year. Yet no stringent guidelines have been established to treat swelling soils and to eliminate or reduce such huge costs.

Colorado highways are normally designed for a 20-year life expectancy; however, some of these highways will lose their rideability due to the swelling of the underlying subgrade. It is obvious that any attempt to reduce the high costs of repairs due to the damages caused by expansive soils will be a step in the right direction.

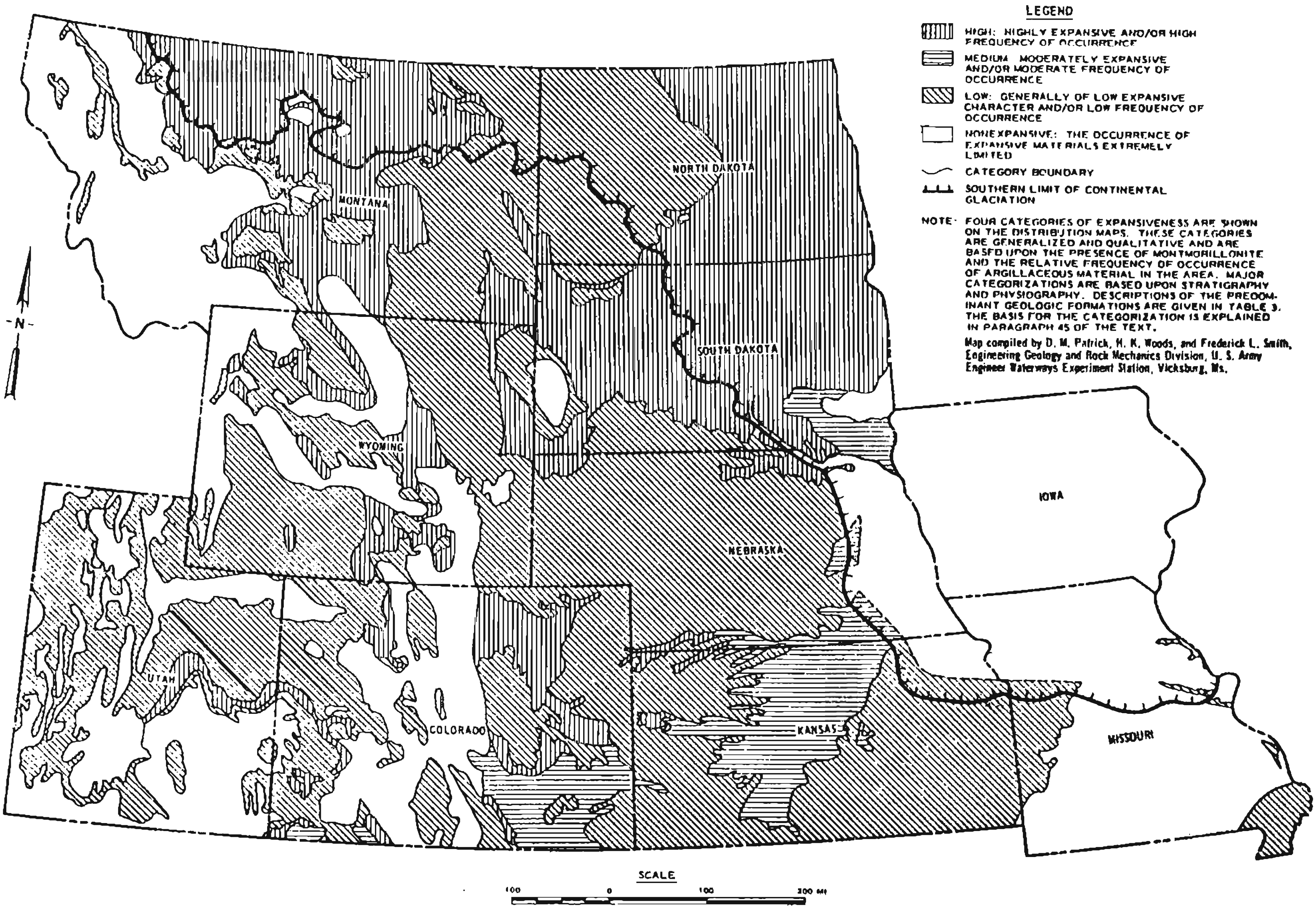


Figure 1. Distribution of potentially expansive materials in the United States; FHWA Regions 7 and 8

Perhaps the two most important factors in treating expansive soils are: identifying and estimating the anticipated potential volume change of the subgrade soils. There are numerous techniques and methods used by agencies, such as highway departments, transportation departments, Army Corps of Engineers, and others, to identify and to estimate the magnitude of volume change of expansive soils. The following is a brief description of methods used to identify and to estimate the magnitude of volume change of expansive soils.

II <u>Identification Of Expansive Soils</u>

Identification methods can be divided into two general groups; those used for mineralogical identification, and those used for direct physical properties (2). The following are listings of the methods used in each group.

Mineralogical Identification:

- Microscopic examination
- X-ray diffraction
- Differential thermal analysis
- Infrared analysis
- Dye adsorption analysis
- Chemical analysis

Physical Properties:

- Free swell test
- Atterberg limits
- Colloid content determination
- Measurement of linear shrinkage
- Direct measurement of volume change by means of

mechanical apparatus

Mineral identification methods are too time-consuming and demanding special skills and equipment. For this reason most laboratories prefer simple identification procedures based on physical properties of the soils.

III **Predicting Potential Volume Change**

Accurately predicting the potential volume change of expansive soils are requisite for the selection of treatment methods. It should be noted that there is no definite dividing line between some identification methods and methods used to predict the magnitude of volume change. In general the techniques that are used to predict volume change fall into three categories:

- Soil suction test
- Odometer swell test (consolidometer testing)
- Potential vertical rise (PVR)

Once an expansive soil has been identified and characterized using the above mentioned methods, measures must be taken to mitigate the anticipated volume change.

IV **Expansive Soil Treatment Methods**

The following are description of treatment methods used by Colorado DOT and other transportation agencies in alleviating detrimental volume change of expansive soils:

- Sub-excavation and removal of expansive soil and replacement with non-expansive soil

- Application of heavy applied load to balance the swelling pressure
- Preventing access of water to the soil by encapsulation
- Stabilization by means of chemical admixtures
- Mechanical stabilization
- Explosive treatment to correct swelling shales
- Pre-wetting the soil
- Avoiding the expansive soil

A complete description of the above techniques will be presented in Part VII of this report. Colorado DOT has conducted some research studies on expansive soil treatment, and the last implementation package dates back to 1974. Based on the opinions of some of the materials engineers in Colorado, the success of some of the above-mentioned techniques has been poor, and repair or overlay has been required.

V Objective

The primary objective of this study was to update the guidelines for highway construction on swelling soils by examining the following items:

1) Review and summarize the effectiveness of past expansive soils treatment methods used by Colorado DOT.

2) Identify the treatments that have worked.

3) Identify those treatments that have not worked and why.

4) Determine the need for updating the implementation package prepared in 1974.

VI Mechanics of Expansive Soils

Expansive soils are those that exhibit unusually large volume changes as a result of moisture variations and environmental changes (4). Such soils contain clay particles of one or more minerals which have a strong affinity for water. Upon absorbing water, their particles grow, resulting in expansion of the material in which the clays are contained (5). Of all clay minerals, MONTMORILLONITE minerals undergo the largest volume changes.

In a highway cut of some depth, release of the overburden load by the excavation causes some minor rebound. This rebound itself would not be sufficient to cause pavement distortion. However, water can enter the soil more easily and, if wetting occurs, pavement heave results. The amount of heave depends on the expansiveness of the material at its in-situ condition, and on the thickness of the wetted zone (5).

Three basic factors affect the potential expansiveness of a given soil (5). These are:

1) The type and swelling potential of the clay mineral.
2) The density of the soil.
3) The moisture content of the soil

Expansive soils cover large areas of Colorado. The soils that exhibit significant swelling potential in Colorado can be divided into three general groups:

- The Mancos and Pierre shales, which are found in large regions of the state except the central mountainous portions (6). Substantial areas of the valley floors in western Colorado are made of Mancos shales. Most of the eastern plains are underlain by Pierre shales.

- The Laramie Formation, which overlies the Pierre shales, covers beginning at a point approximately 75 miles southeast of Denver extending north almost to Wyoming.

- The Denver formation covering approximately 4000 square miles completely surrounding Denver.

VII <u>Past Experiences & Present Practices</u>

A. Treatment Methods:

The following is the description of some of the past and present remedial measures taken by Colorado DOT's materials engineers to solve their swelling problems:

Sub-Excavation And Removal Of Expansive Soil And Replacement With Non-Expansive Soil

Sub-excavation and replacement requires removal and replacement of the expansive subgrade soils. The material being put back should not cause problems with respect to the in situ material (1). For example, granular soils should never be used as backfill for sub-excavation and replacement projects. The use of granular materials encourages collection of water at the surface of the underlying in situ materials. In one case, on Interstate 70 east, between Watkins and Byers, the replacement consisted of 18 to 30 inches of sand. The performance of this treatment was noted as unsatisfactory (5).

Backfill materials should be impermeable and preferably non-swelling (silts, clayey silts, silty clays, or some clays). Backfill material, particularly remolded in situ soil, should be replaced and compacted with careful moisture and density control (AASHTO T-99).

Colorado DOT uses the DOH Memo #323 as a criterion to determine the depth of sub-excavation and replacement. This criterion is primarily based on the Plasticity Index (P.I) of the subgrade soil. For a complete description of this criterion refer to appendix A.

Catalytically Blown Asphalt Membranes

Catalytically blown asphalt membranes have been used successfully to minimize subgrade moisture variations and the associated volume change of expansive soils in Colorado. The use of asphalt membrane was quite popular during the late 1960's and early 1970's. As a direct result of some of the early findings related to asphalt membrane on the experimental project north of Grand Junction, a full size, non-experimental project was constructed in northwestern Colorado during the summer and fall of 1967 (7).

Located just west of the village of Elk Springs on US 40, the project had catalytically blown asphalt membrane placed on all the bases of all expansive soil cuts. Four hundred forty five tons were used to cover two miles of 2-lane roadway (7). The rate of application was 1.3 gallons per square yard (approximately 3/16 of an inch).

Catalytically blown asphalt membrane was also placed on a cut base on the Agate - North project, located 65 miles east of Denver on Interstate 70. Moisture cells were placed to monitor the moisture variation under the asphalt membrane and under the control sections. Moisture readings taken showed soil moisture directly under the asphalt membrane to be quite uniform and holding at optimum, while in the control section it was seven to eight percent higher than the optimum.

Care should be taken to provide a smooth and uniform surface prior to placement of membrane. Appendix B shows the specification for catalytically blown asphalt membrane.

Explosive Treatment To Correct Swelling Shales Project I-70-1(61)

Swelling bedded shale is the primary cause of pavement distress in the western slopes of Colorado (District III). Low-level explosive was used on project I-70-1(61) north of Grand Junction to disorient the bedded shale and lower its density similar to treatment by sub-excavation and recompaction. The District III Materials personnel determined that adequate fracturing of the bedded shale would be accomplished with blasting using holes eight feet deep with a seven foot spacing (8). This provided a grid system of 5 holes across the pavement through the length of the affected area (Figure 1).

After a series of trial and error it was determined that a charge of 1/3 pounds of 90 percent dynamite and 2 1/2 of pounds ANFO (ammonium nitrate and fuel oil mixture) was adequate enough to yield the desired pavement lift (Photograph 1 and 2). Following the completion of blasting, the pavement was removed as part of a concurrent pavement recycling project. The test area was then wetted and compacted using repeated passes of spray truck and rolling equipment.

According to an economic evaluation performed by the District

Geologist of the Colorado DOT (Bob Barret), the cost of treating swelling shales using low-level explosive was one-fifth the estimated cost of sub-excavation and recompaction (9). Blasting as a treatment technique for swelling shales, requires careful drill patterns and precise charges. The characteristics of each site should be investigated to determine the optimum hole spacing and explosive charge to obtain adequate fracturing of the shale.

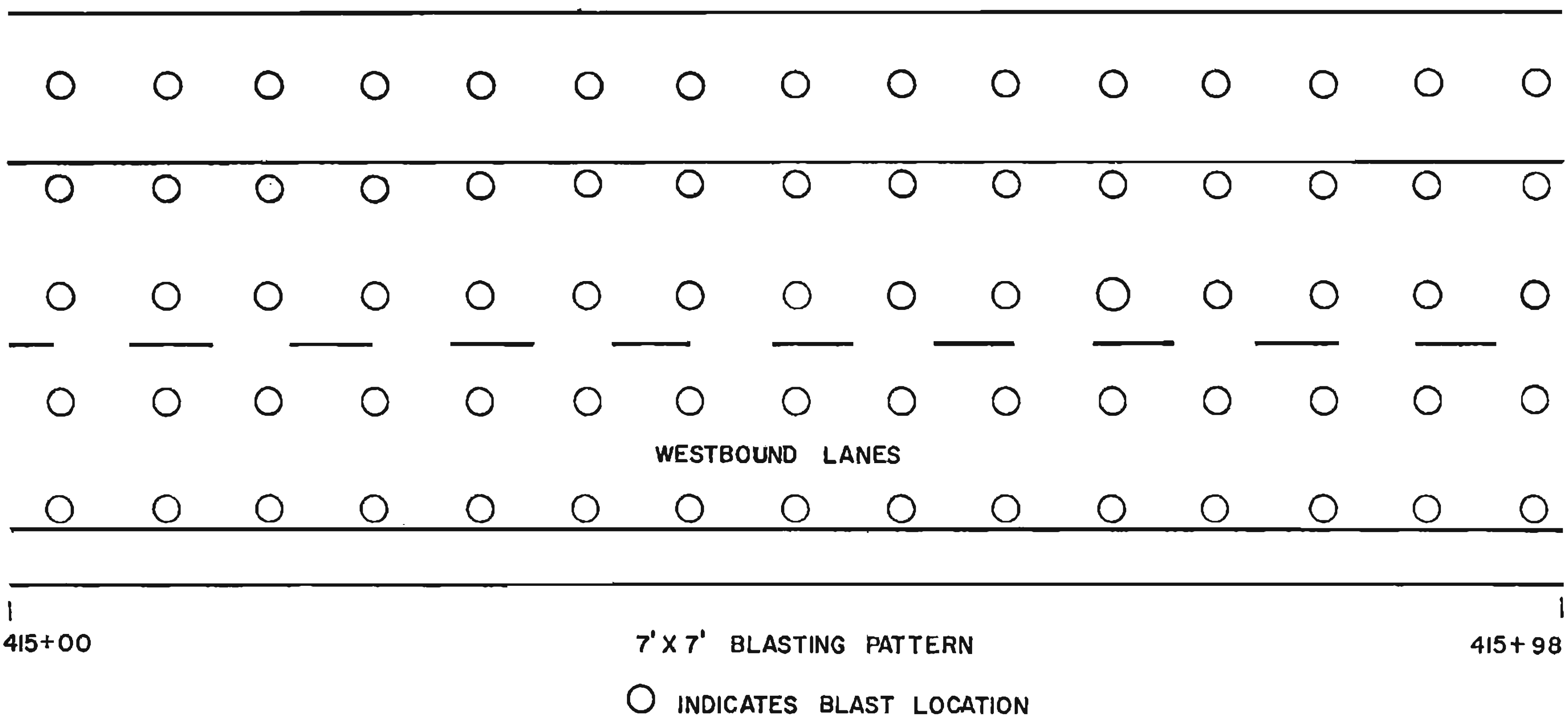
Because of the success of this research project, Colorado has used this technique in treating swelling shales in three sites on US 50 near Whitewater and in seven sites on US 40 in northwest Colorado (8).

Appendix C contains the special provisions concerning blasting from the project plans.

FIGURE 1

LOCATION OF BLAST AREAS

Low Level Explosions to Correct Swelling Soils
Project I 70-1(61)



PHOTOGRAPH 1: Result of section being overloaded. 3 pounds of ANFO and 1/3 pound of dynamite were used.

PHOTOGRAPH 2: Properly disrupted pavement using 2.5 pounds of ANFO and 1/3 pound of dynamite.

Stabilization By Means of Chemical Admixtures

Chemical admixtures have been used to alter the characteristics of clay mineral and reduce its potential for swelling. Lime is perhaps the most effective of all the chemicals used to stabilize the expansive soils. The major limitation of its routine use is the application of the chemical to sufficient depth (1). Conventional techniques generally limit the depth of treatment to approximately 8 t0 12 inches.

Lime stabilization can be applied using a variety of methods. Lime shaft and lime-tilled stabilization are the two methods used most by Colorado DOT. Attempts to distribute lime through natural soils with water in drill holes have not been proven

successful, because the lime is only slightly soluble in water (5).

Expansive soils in five locations were treated using the lime shaft method with a marginal degree of success. The five projects stabilized by lime shafts were constructed with 1 foot diameter shafts filled with a slurry composed of approximately 1 pound of lime to 1 gallon of water followed by backfilling with an open graded sand (10).

The mechanism of stabilization observed showed that lime does not migrate over 2-3 inches from the periphery of the hole. The swelling potential is reduced due to the moisture increases in the soil (similar to ponding action) and stress relief (2). From these considerations, it would appear that lime is of little benefit to the technique; however, experiments suggest that water migration is more effective when water is added as lime slurry than as water alone (2). According to A. G. Peterson (District I Materials Engineer), the success of lime shaft treatment has been poor in District I. He believes the lime can not be dispersed enough.

Many projects have been stabilized by mixing the soil and lime (1% to 5% hydrated lime) to depths varying from 1 foot to 3 feet with varying degree of success. Lime till stabilization will effectively seal and reduce the swelling potential if adequately mixed with the soil to a proper depth.

According to some of the literature reviewed, a thorough understanding of lime-soil interaction is still lacking. Soil-lime reactions are complex; more research is needed in this area to identify the depth of treatment for various expansive soils and proper amounts of lime. Soil type, lime type, lime percentage, and curing conditions including time, temperature, and moisture, are all important variables (11) . Preferably, the research should be based on tests that provide fundamental engineering properties rather than empirical test results.

Pre-Wetting of Soil

Theoretically, expansive soils can be wetted and caused to expand prior to construction. This has been attempted in many parts of the country, including Colorado, and for a variety of structures, with varying degrees of success (5). The most commonly applied method for accelerating swelling by this technique is ponding (3). The questions of how long the material should be ponded and to what depth the moisture should penetrate to be effective are still unknown (3).

In general, the best time to apply ponding is during the dry season when the natural cracks and fissures are open due to desiccation (1).

It is quite possible that the water penetration could be assisted in the problem cuts by drilling of a large number of small holes into the swelling materials which would allow irrigation water freer access to them (5). Even though pre-wetting is probably the most economical of all the treatment methods examined, it is still not a practical one because of the difficulty of achieving uniform moisture penetration in a reasonable time (5).

Application of Heavy Applied Pressures To Balance The Swelling Pressures

Loading the expansive soil with pressure greater than the swelling pressure is a method by which swelling can be prevented. However, pavement loads are generally insufficient to prevent expansion, and this method is usually applied in the case of large buildings or structures imposing high loads (3). The use of this method in the highway construction is limited to swelling soils with low expansive pressures.

Avoid The Expansive Soil

Avoiding the expansive soil in lieu of more favorable subgrade conditions is a viable alternative. However this is only applicable in limited situations, since route selection is generally based on local social, economic, environmental, or political considerations prevalent at this point in the design sequence (1).

B. Expansive Soils Survey:

A questionnaire was designed and sent to the District Materials Engineers in order to obtain their consensus on the subject of expansive soils treatment methods in Colorado (Appendix D). The following is a summary of their responses:

- **District VI (Respondent: Sidney Motchan)**

According to Sid, the magnitude of swelling problems is high in District VI. Index properties (Atterberg Limits) are used as a tool to identify expansive soils, and the DOH Memo No. 323 is used as a criterion to control it. However, Sid feels that this criterion is not stringent enough and, for treatments of 2 or 3 feet have questionable results.

The following is the list of remedial measures taken by District IV Materials to solve their swelling problems:

1. 6 feet subexcavation and replacement at optimum moisture and 92 percent or greater density by AASHTO T-99 for all cut sections on phase 2 and 3 of C-470.

2. 12-inch lime stabilization plus 24-inch moisture/density control at select cuts on Phase 1 of C-470.

3. 24-inch lime stabilization in two 12-inch lifts at select cuts on Phase 1 of C-470

According to Sid, the success of the last two treatments has been poor, and there are various locations on C-470 that are severely damaged due to swelling. Treatment No. 1 appears to be working for a stretch of C-470 between Wadsworth and Ken

Caryl. However, the same treatment has caused swell-related distress occurring on Morrison Road, east and west of C-470, and on mainline C-470 north of Morrison Road.

Improper moisture control during construction is said to be the possible factor for swelling at these two locations. Another severely damaged highway due to swelling is I-225 at Alameda. However, the method of treatment is unknown at this location, and the causes of swelling are attributed to poor drainage.

- **District V (Respondent: N. C. Peterson)**

The magnitude of swelling problems is high in District 5, and soil classification and swell tests are used to identify them. The DOH Memo No. 323 was used in the late 60's as a criterion to control swelling. Presently, prewetting and non-swelling borrow material are used to alleviate swelling problems. The four corners area in the southwest part of District 5 is considered as the most severely damaged area due to swelling.

- **District IV (Respondent: Ken Wood/Rose McDonald)**

According to Rose, the magnitude of swelling problems is low in District IV and, in the last decade, they only had two areas where heavy clays were a concern. The first one involved a 50 feet cut section on Project FC 287-3 (43). The entire cut section was treated by excavating the material to a depth of 4 feet and placing it back under moisture/density control using AASHTO T-99 procedure. The embankments on this project were built with the same clay materials excavated from the above cut, and the top 8 inches were treated with a lime slurry. No swelling distress has been detected on this embankment and the cut sections to date, and it appears that the treatment is working well.

Rose feels there is little impact from expansive soils in District IV. However, she thinks it is appropriate to have a guide that could offer strategies for a given condition found on a project. DOH Memo No. 323 is not used as a criterion to control swelling soils in District IV.

- **District III (Respondent: Bob Barrett)**

"Expansive soils are of low priority in District III", said Bob Barrett, District III Geologist. He believes swelling shale is of the primary concern and he also strongly suggests that it is critical to this survey to define swelling soils and swelling shale. According to Bob, environmental parameters (geologic formation) should be given special attention in identifying and controlling the swelling problems.

Morrison, Wasatch, and Mancos shale, in particular, are sources of swelling problems in District III. Low-level explosives were used to disorient the bedded shale and lower its density similar to treatment by sub-excavation and recompaction. This technique was used at three sites on US 50 near Whitewater, one site on SH 340 near Fruita, seven sites on US 40 west of Elk Springs, and one site on I-70 north of Grand Junction. Based on an economic analysis performed by the District III Geologist (Bob Barrett), the cost of treating swelling shales using low-level explosives was approximately one-fifth the estimated cost of sub-excavation and recompaction. Memo No. 323 is not used by

District III.

- **District II (Respondent: Dave Gonser)**

The magnitude of swelling problems appears to be medium in District II. Index properties are used to identify expansive soils, and the DOH Memo No. 323 is used as a criterion to control it. According to Dave, sub-excavation and recompaction with moisture/density control is the only method used in District II to control swelling problems.

- **District I (Respondent: A.G. Peterson)**

The magnitude of swelling problems is low in District I. Visual observation and laboratory tests are used to identify swelling soils, and DOH Memo No. 323 has been used as a criterion to control swelling. However, a variety of other treatment methods have also been used. The following is the list of all these treatments:

- Lime shafts
- Lime treated subgrade
- Catalytically blown asphalt membranes
- Replacement with higher quality material
- Sub-excavation and recompaction with moisture/density control (AASHTO T-99).

According to A. G. Peterson, the success of some of the above treatments has been poor; especially the lime shaft treatment. This will conclude the results of the survey.

VIII Conclusions and Recommendations

Based on the literature reviewed and the result of the survey questionnaire received from the District Materials Engineers, the following conclusions and recommendations are presented.

The use of DOH Memo No. 323 as a criterion to treat swelling soil problems appears to be adequate for some locations. However, its use is not recommended for very dense subgrade such as the type in western Colorado.

Granular soils alone should never be used as backfill for sub-excavation and replacement projects. The use of granular materials encourages collection of water at the surface of the underlying in situ materials. However granular soils may be used in conjuction with a filter-separator layer and edgedrain to collect and divert the water from the pavement structure.

Catalytically blown asphalt membranes have been used successfully to minimize subgrade moisture variations in Colorado. Care should be taken to provide a smooth and uniform surface prior to placement of membrane.

Swelling bedded shale is the primary cause of pavement distress in the western slopes of Colorado (District III). A low-level explosive is a viable alternative for disorienting the bedded shale and lowering its density similar to treatment by sub-excavation and recompaction. The cost of treating swelling shales using a low-level explosive was estimated to be one-fifth of the cost of sub-excavation and recompaction. Blasting as a treatment technique for swelling shales requires careful drill patterns and precise charges.

Lime shaft stabilization has not been proven successful because the lime is only slightly soluble in water and, as a result, cannot be dispersed enough.

Lime till stabilization can be used effectively to seal and reduce the swelling potential if adequately mixed with the soil to a proper depth. Soil-lime interaction is a complex process; more research is needed in this area to identify the depth of treatment for various expansive soils and proper amounts of lime.

The most commonly applied method for pre-wetting of soil is ponding. The questions of how long the material should be ponded and to what depth the moisture should penetrate to be effective are still unknown. In general, the best time to apply ponding is during the dry season when the natural cracks and fissures are open due to desiccation.

IX Implementation

This research study has demonstrated that the performance of some of the swelling soil treatment methods used in Colorado has been poor. As a result, we recommend initiation of the second phase of this study.

The ultimate goal of the second phase will be to over haul the existing guidelines and establish up-to-date design guidelines for highway construction on swelling soils and swelling shales in Colorado.

For any specific treatment method, the laboratory and field personnel should be trained.

The cost-effectiveness of each individual treatment method needs to be evaluated for a given condition.

Environmental conditions and geologic formation should be given special attention in identifying and controlling the swelling problems.

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Appendix A

DOH Memo #323
1/5/66

(CONSTRUCTION)
Swelling Soils

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
4201 East Arkansas Avenue
Denver, Colorado 80222

TO STAFF DIVISION ENGINEERS AND DISTRICT ENGINEERS:

For a number of years the Department has been studying the problem of swelling soils. To date we do not have the complete answer to this problem. However, sufficient research work has been performed that we feel the following method of control of swelling soils should be used by the Department until more information is available.

Pavement distortion from swell has been found only on expansive soils and was most prevalent on soils of the A-6 and A-7 groups and on borderline soils between the A-4 and the A-6 and A-7 groups. Also, certain A-2-6 and A-2-7 soils which are borderline with the A-6 and A-7 groups have produced some swell.

Critical problems in the past have occurred primarily in cut areas where moisture-density treatment has been to comparatively shallow depths (one foot or less).

The following tables are intended as a guide to determine the depth of treatment in cuts for the soil types described above.

SUGGESTED TREATMENT BELOW NORMAL SUBGRADE ELEVATION
FOR PROJECTS ON INTERSTATE AND PRIMARY SYSTEM

Plasticity Index	Depth of Treatment
10 - 20	2 feet
20 - 30	3 feet
30 - 40	4 feet
40 - 50	5 feet
over 50	6 feet

SUGGESTED TREATMENT BELOW NORMAL SUBGRADE ELEVATION
FOR PROJECTS ON SECONDARY AND STATE SYSTEM

Plasticity Index	Depth of Treatment
10 - 30	2 feet
30 - 50	3 feet
over 50	4 feet

Appendix B

SPECIFICATIONS FOR CATALYTICALLY BLOWN ASPHALT

Asphalt used as a membrane shall be 50-60 penetration grade. This material shall be prepared by the catalytic blowing of petroleum asphalt. The use of iron chlorides or compounds thereof will not be permitted. The asphalt shall be homogeneous, free of water and shall not foam when heated to 347° F. It shall meet the following specific requirements:

TEST DESIGNATION	TEST METHOD ASTM	50-60 PENETRATION GRADE
Flash Point	D 92	425° F. Min.
Softening Point	D 36	175°F.-225° F.
Penetration, 77° F., 100 gms., 5 sec.	D 5	50-60
Penetration, 32° F., 200 gms., 60 sec.	D 5	30 Min.
Penetration, 115° F., 50 gms., 5 sec.	D 5	120 Max.
Ductility, 77° F. (5 cm per min) cm	D 113	3.5 Min.
Loss of Heating, 325° F. in 5 hrs.	D 6	1.0 Max.
Penetration of residue, 77° F. (100 gms., 5 sec. compared to original) %		60.0 Min.
Solubility in CCl_4, %	D 165	97.0 Min.

TABLE I. Specifications for Catalytically Blown Asphalt Cement.

Treatment shall consist of removing the material throughout the cut to the required depth. Swelling soils removed can be used elsewhere on the project because they will have been broken up and soil particles will have been disoriented. We have not experienced problems in embankments constructed of swelling soils. Backfill materials may be obtained from any other cut or source developed on the project and may be of the same soil classification as materials removed. Also, if it proves to be economically sound, the materials removed may be hauled back in and used as backfill. All backfill materials are to be compacted in accordance with plans and specifications. It is of primary importance that any swelling soils used either in embankments or as backfill be thoroughly broken up with sheepsfoot rollers or other suitable equipment which will assure complete disorientation of soil particles.

Agreement on actual depth to be treated should be reached between the Design Engineer, Materials Engineer and District Engineer prior to completion of the plans of each project involving swelling soils.

L. C. BOWER
Deputy Chief Engineer

TCR:ntw

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Appendix C

August 16, 1978

REVISION OF SECTION 203
DRILLING AND BLASTING
COLORADO PROJECT NO. I 70-1(61)32

Description and Requirements:

Subgrade stabilization between stations 409+63 and 419+85 EB and 410+12 and 420+20 WB is required on this project.

This work will consist of drilling 1,295 holes, approximately 2" in diameter, as shown on the Drill Hole Plan Sketch.

These holes will be drilled, in the existing pavement to a depth of 8 feet and "SHOT" before removing the old pavement.

Initially, the holes are to be loaded by placing ¼ lb. of 60% Dynamite in the bottom of the hole, followed with 1 lb. of "Factory Mixed ANFO". (Ammonium Nitrate and Fuel Oil Mixture). The holes will be stemmed with a mixture of 70% sand and 30% hydrated lime (by volume). The amount of ANFO to be loaded may be adjusted by the Engineer to obtain desired results.

No more than 2 adjacent lines in either direction will be detonated at one time. A minimum of 25 Milliseconds delay must be used between subsequent detonations.

Initially, it is anticipated that 3 sets of 2 transverse rows (12 holes) will be detonated as "calibration" holes.

Detonation will be coordinated with other activities and with the approval of the Engineer.

All traffic will be stopped during the blasting operation and will not be allowed to proceed until it has been determined as safe to do so.

Basis of Payment:

Payment for this item shall be based on the accepted quantities at the contract price per lineal foot of drill hole for "Drilling and Blasting."

This will be full compensation for this item and include all work necessary to complete this item.

Payment will be made under:

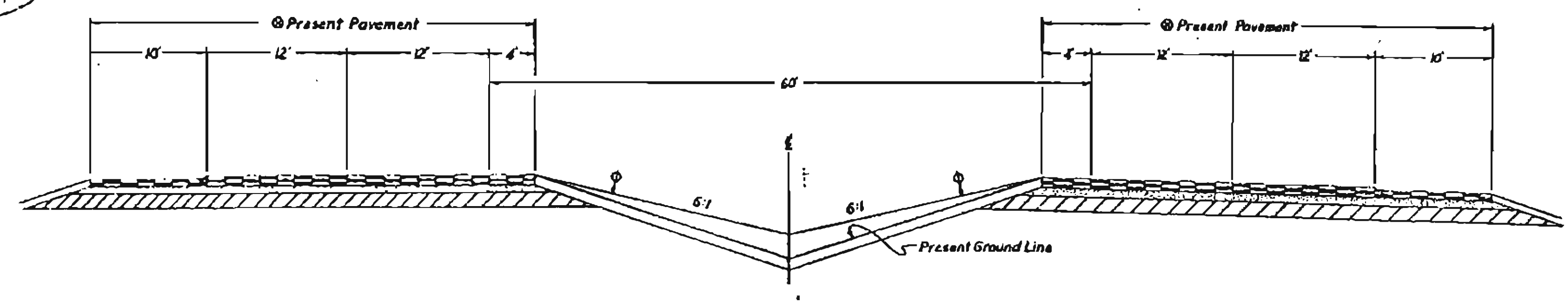
Pay Item	Pay Unit
Drilling and Blasting	Lin. Ft.

AS CONSTRUCTED		
NO REVISIONS	REVISED	VOID

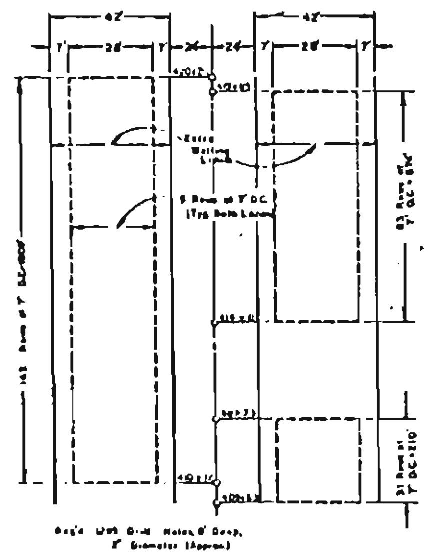
FEDERAL ROAD REGION NO.	DIVISION	PROJ. NO.	SHEET NO.	TOTAL SHEETS
VIII	COLORADO	I 70-1(61)	2	

TYPICAL SECTION

(R-1) ~ 8-16-78, Revised Sign Tab ~ M.E.K.



BASE STABILIZATION DETAILS
Drill Hole Plan



General Notes

This Project Will Be Combined With Project No. IR 70-1(57).

⊗ The Present Pavement Will Be Removed & Recycled Under Project No. IR 70-1(57) (See The Special Provisions & Details For Additional Information.)

ɸ The Contractor Will Be Required To Place Embankment Material To This Line. The Embankment Material For Slope Flattening Will Be Obtained From The Landscape Excavation Area Located Approximately 100' Lt and Rt of Sta. 587+98.

The Guard Rail, Posts, Concrete Pipe End Sections & Inlet Grates To Be Removed Shall Be Temporarily Stockpiled For "Pick UP" By State Maintenance Personnel.

Delineators, Milepost Markers, Median Barrier Fencing Will Be Removed By State Forces.

State Forces Will Adjust The "J" Box Shown Near Sta. 361+00 (Nonparticipating.) Contact The Maintenance Traffic Representative 48 Hours In Advance Of When This Work Is To Be Done.

It is estimated that 500 Hours of Flagging will be required on this project.

Shale or rock fragments greater in size than 6" nominal diameter, remaining on the surface of the slope flattened areas in the median, will be removed (or broken down) before the job is completed.

Wetting has been estimated for the drilling and blasting area on the basis of applying 0.04 M. Gal./Cu. Yd. to a depth of 6 ft. and will be paid for on the actual quantities applied. The intent here is to obtain as much penetration as possible through the subbase gravel into the drill holes and shale below. This will require several applications of water as determined by the Engineer.

General Notes (Cont.)

Final Striping will be accomplished by State Forces. Temporary Striping will be done on Project IR 70-1(57) and will be accomplished by State Forces.

FILE
RETURN TO:
(R-1)

CONSTRUCTION TRAFFIC SIGNS

SIGN CODE OR LEGEND	DIMENSIONS	PANEL SIZE A B C	QUANTITY REQUIRED
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

IT IS ESTIMATED THAT [illegible] L.F. OF CONC. BARRIER (TEMP.) AND [illegible] DRUM CHANNELIZING DEVICES WILL BE REQUIRED ON THIS PROJECT.

Appendix D

QUESTIONNAIRE 76.96

EXPANSIVE SOIL TREATMENT METHOD IN COLORADO

Name of Respondent_______________________________________

District No.________________________

1. Has your district dealt with swelling soil during the past two decades? ____YES ____NO If the answer is yes, please try to answer the following question to the best of your knowledge.

2. What is the magnitude of swelling problems in your district? ____HIGH ____MEDIUM ____LOW

3. List remedial measures taken to eliminate or alleviate swelling problems. Please use additional pages as necessary. ____

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4. How do you identify expansive soils on fill or cut areas, and how do you quantify its potential? ________________

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5. Identify the treatments that have worked. ____________

____

____

6. Identify the treatments that have not worked, and why.

____

____

7. Where is the most severely damaged area of treatment and untreated expansive soils in your district?

____

____

8. Do you use the DOH Memo #323 as a criterion to control swelling soils? ____YES ___NO

9. If your answer to question 8 is yes, please express your opinion about it. ________________________________

____

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10. Please provide us with any suggestions or comments that you may have regarding expansive soils in Colorado. ________

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____

PROJECT NO. ____________________

PROJECT LOCATION: ____

____

COMPLETED DATE: (Approximate) ____________________

SOIL TYPE AND GROUP INDEX: (Use AASHTO Class) ________________________

METHOD OF TREATMENT: ____

____

____

WAS SWELLING POTENTIAL DETERMINED? PLEASE EXPLAIN. ____________________

____

____

BASIS FOR TREATMENT SELECTED: _____________________________________

____

____

DRAINAGE CONDITIONS: ____

____

____

PERFORMANCE:
1. Excellent
2. Good
3. Average
4. Poor
5. Very Poor

COMMENTS:

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