A RESEARCH STUDY ON SOIL STABILIZATION

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

G. C. Blomquist

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A Research Study on Soil Stabilization

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by

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Candidate for the Degree of

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THESIS

TABLE OF CONTENTS.

Part 1.

INTRODUCTION

This report is the result of a study of the factors that influence the service behavior of stabilized and surface consolidated soil-aggregate mixtures when calcium chloride is used either as an admixture or as a surface application or both. The experiment will be carried on in conjunction with the Michigan State College and the Research Division of the Michigan State Highway Department, who desire information regarding this type of road materials for maintenance of secondary roads with a decreased expense.

Highway development, during the recent years, has been toward the improvement of secondary roads. The rural residents are no more pleading for, but are demanding, year around road service, and as a result of these pleas and demands the highway departments are trying to find a type of road surfacing to fulfill it. Before any appreciable progress can be made on this type of roads, there is the problem of finding a low-cost type of surfacing.

Prominent in the field of low-cost construction is the stabilized wearing course, made up of a balanced mixture of aggregate, sand, clay, silt, with an admixture of some moisture retentative chemical for maintaining the moisture content in the mixture. This type of construction is very good both from the engineering and economic standpoint. These surfaces will provide an adequate and very satisfactory secondary road, and will also provide a very good base for later construction of higher type roads.

It is the aim of this report to afford and discover practical and serviceable information to the above mentioned cooperative agencies, and also to the engineer and contractor in road design, construction and maintenance.

Part 11

PRINCIPLES OF STABILIZATION

Stability is the resistance to lateral flow when loaded. This principle, in the case of road stability, is mainly dependent on the shear strength of the road metal, and the shear strength is controlled by the amount of internal friction and the cohesive properties of the materials.

The adoption of these principles in the construction of low cost roads should not be thought of as something entirely new, but rather an old principle with new ideas added to it. Low-cost roads have been built for many years and have been successful as far as practical, but due to the concentration of the construction of primary roads, there is a general lack of interest in the secondary road types. The road building in the secondary class were carried on in such a manner and with such plans that if a road was a success it was more accidental than intentional.

The application of the principles of stabilization to low-cost roads overcomes the faults with the secondary type roads and assures quality by properly combining the graded aggregates and materials to produce a stable road mixture.

In a stabilized road the function of the coarse aggregate is mainly to resist the wear of the heavy traffic the road will carry, the combination of the fine and coarse aggregate furnished the internal friction and the binder soil supplies the cohesion with a properly controlled moisture content.

Part 111

Stability is an old English word which, Webster informs us, means "having the properties of durability, permanency, fixity or of standing firm in place". From this it can readily be seen that stabilization as applied to soils, or to a combination of soil aggregates, is the resistance to flow laterally when loaded. The principle of stability is mainly dependent on the shear strength of the road metal, and the shear strength is dependent on the internal friction and the cohesive properties of the soil. Stabilization is the adoption of the recognised principals of soil mixture for acquiring the maximum density and durability after proper compaction.

Stabilization has been a practice on roads for a number of years, but their success fell far short of the value of the roads. Sand-clay roads were about the first type of stabilized roads that were built. They applied the principles of stabilization unknowingly. They used the sand for supporting and the clay for the binder or cementing value. This type of road was satisfactory without radical climate changes and under light traffic.

The next type of road to be tried was a combination of sand, clay, gravel or crushed stone. The addition of the gravel or crushed stone increased the stability and also the wearing quality of the road surface. At this stage of the development the value of gradation was realized.

With increasing investigation, it was found that certain clays served to lubricate, instead of bind, the larger particles. The lubrications of the clays vary with the molecular composition of the clay particles.

Commercial interests came into the picture and research projects were studied on the value of chemical admixtures to control the moisture content in the mixtures. The admixtures were found to aid in the high degree of compaction and retaining the quality over a long period of time. The action of the water, even after heavy rains was found to be negligible except for a fraction of an inch at the surface of the road metal.

With all of the experimentation it was found that regardless of the type of stabilization to be practiced there were basic principles that must be followed. A uniformly graded mixture from the maximum to the extreme fines is required. The larger percentage of any one size of particles the more void space there will be and as a result less stability.

It has been found from experiments that mixtures showing alkaline characteristics are more effective in stabilization than those which are acid.

There is a definite and extreme necessity of the control of moisture in the sub-surface of a stabilized road. One of the first investigations in a road project should be to determine the free moisture variations over different seasons of the year and the control of the extremes in the variations. There should be means of controling underground water sources and surface water.

In a stabilized road, the selection of the material is an essential consideration and should be carefully considered. The aggregate from a local source may have the desirable physical characteristics - that is, hardness, toughness, and ability to resist wear - but yet be so sized that additional material to correct the deficiencies will have to be obtained from other sources.

Either gravel or stone can be used and a binder soil to produce the proper density. Many times pit run gravel can be found to fit the requirements with only the addition of a small amount of clay and fines.

While the stability of a cohesionless material may be less than 500 pounds per square foot and the binder soil will have a supporting value of 5,000 pounds per square foot, the proper combination of the two will give a mixture that will have a supporting value of more than 1,700 pounds per square foot. The internal friction is furnished by the sand, gravel, slag or crushed stone, which is usually referred to as the coarse aggregate.

Cohesion is furnished by colloidal clays and moisture films in the top soil, sand-clay, light textured soils and moisture film alone.

Whether the mixture of granular materials becomes a stabilized subgrade, soil road surface, or a higher type pavement, the grading and the method of construction are of greater importance than the kind of materials used or on the basic theory.

Regardless of the type of construction the ultimate stability of the mixture depends upon the permanent adhesive strength which can be developed by the binder films between the soil particles. This strength depends not only on the characteristics of the moisture or chemical admixtures, but also depends on the composition of the soil particles and films of gas surrounding it or other substances which may cover the soil particles.

The wetting power of a soil is an important factor in stabilization. The greater the adhesion, the higher the moisture will rise above the water table. The high tensile strength of water caused the moisture to be drawn up into the soil as a surface coating film for the particles, acting as rubber diaphrams to hold the particles in place. The smaller the pores

the higher moisture will rise in the soil due to adhesive attraction. This adhesive action is very important in soil stabilization and the use of chemical admixtures, mechanical consolidation and water proof coverings are used to aid it and provide the necessary conditions.

Some of the admixtures used are; properly proportioned soil materials, deliquescent chemicals to provide moisture films, chemicals to act to replace air films surrounding the particles with moisture films.

The consolidation required to furnish a well compacted mixture of graded aggregates is obtained by rolling during construction and by the action of traffic afterward.

The graded materials required to make a firm and well stabilized road consist of a coarse aggregate and a soil mortar. The coarse aggregate is that portion of the sample passing a No. 10 and retained on a No. 40 sieve, and contains natural gravel or supplemented with crushed stone or slag. The binder soil is all material passing a No. 40 sieve. The binder soil is silt, clay and colloidal material. The coarse aggregate acts as a bed for other materials and furnishes desired hardness and structural strength, the finer sand is a filler in voids of coarse aggregate, the silt is a filler to keep particles from rocking and clay and colloids furnish pores small enough for moisture films to cause cohesion necessary.

Satisfactory mixtures are designed to have interlocking grains and capillary moisture forces sufficient to furnish the mixture with high stability during wet weather and enough cohesion in the binder soil to maintain the integrity of the surface during dry seasons. The degree of satisfaction of mixtures to meet those requirements are indicated by the plasticity limits of all the soil passing a No. 40 sieve.

Liquid limits of 25-35 indicate the properties of capillarity in the soil that will serve for a satisfactory binder soil.

The greater the plasticity index of a soil will show greater presence of clays that will furnish cohesion, therefore, the greater the plasticity index the higher the cohesion. Plasticity indexes of 5 or less will be satisfactory for wet conditions, 5-9 under average moisture and 9-15 under arid conditions.

Absence of moisture films in a road surface will cause raveling and dust while too much moisture will cause rutting. The more a road surface dries out by evaporation the wetter future rains will make it.

Another reason soil road surfaces should retain moisture is that most of them are compacted partly by traffic. When the surfaces are allowed to dry out a large amount of the binder soil is lost by dust action and raveling action. If the moisture films are between the particles of soil compaction will progress and the soil particles will wedge themselves together As the soil particles get closer together the cohesion increases and the graded mixture becomes a soil road surface closely bound.

Calcium chloride is the principal chemical used as a mosture retentative in soil stabilized roads. The hygroscopic properties of the chloride cause it to take moisture from the air during periods of high humidity and also slows up the action of evaporation of moisture from the soil. Calcium chloride aids in the compaction by retaining the moisture. The high density attained is shown by weight of 150 pounds per cubic foot for wearing courses treated with calcium chloride.

There is an optimum mosture content that will achieve the highest density and the greatest degree of compaction. This condition can be determined in the laboratory by the Proctor tests.

The stabilized material may either be mixed on the road by scarifying the existing road surface and adding needed ingredients for a stabilized surface or the materials may be mixed in a mixing plant and spread on the road surface ready for compaction. The calcium chloride is added to the mixture at the rate of about 1/2 pound per square yard per inch of thickness and then about 1/2 pound per square yard on surface later.

Any maintenance of a soil stabilized road should be done following a rain since it will soften the road metal so it can be worked without tearing up the surface, and also since the chloride solution will penetrate farther into the road following a rain and in this way the calcium chloride will not be exposed to the surface to be wasted.

Calcium chloride should be added in light applications to the road surface two or three times a year. About two pounds per square yard is added each year. The chloride should be added either following a rain or in the early morning to allow it to be used effectively and be able to absorb moisture easily.

The economic advantage of constructing stabilized roads seem to deem their value along with higher type construction and roads. With this type of construction the money for roads can be better utilized and cover more miles of secondary type roads.

Part IV

OUTLINE OF PROCEDURE

A. EQUIPMENT

1. Circular test track and treadometer in the Highway Department Research Laboratory.
2. Soil testing equipment in the Highway Research Laboratory.
   (a) Proctor tests equipment
   (b) Mechanical analysis equipment
   (c) Liquid limit equipment
   (d) Ovens and equipment for determination of shrinkage limit.
3. Hydraulic stability testing machine, furnished by Calcium Chloride Association.
4. Camera and equipment for taking progressive pictures of the track tests.
5. Profilometer, or some device designed to determine the longitudinal and sectional profile of the track as the test progresses.

B. RECONSTRUCTION OF THE TEST TRACK AND TREADOMETER

1. Center to be taken from track to provide a cistern in the track section for a supply of water, and will enter from the bottom of the track sections. Drawing included to show finished section.
2. Some alterations are to be arranged for on the treadometer in the driving gears to silence them and also to eliminate jerking and jumping of the treadometer.
   (a) Use balloon type tire
   (b) New gear box
   (c) New arrangement of gear ratio for drive

A. Materials

1. Coarse Aggregate - All coarse aggregate will conform to Michigan State Highway Department Specifications.

   (a) Gravel aggregate

   (b) Crushed stone aggregate

   (c) Obtained pit run and graded in laboratory.

2. Fine Aggregate - All fine aggregate will conform to Michigan State Highway Department Specifications.

   (a) Natural sand will be used

   (b) Obtained from local source

3. Binder Soil - Binder soil will conform to Michigan State Highway Department Specifications.

   (a) Binder soils will be from different sources to have different compositions.

   (b) Plasticity indexes of the binder soils will be kept within a practical range.

4. Calcium Chloride - As specified by the Calcium Chloride Association.

B. PREPARATION OF MATERIALS

1. Coarse Aggregate - Will be kept in stock and will be graded into different screen sizes (1", 3/4", 1/2" and No. 4)

2. Sand - Will be in stock and will be graded into screen sizes of (No. 4, No. 10, No. 40 and No. 100) and stored in convenient form and place.

3. Binder Soil - Will be in stock and will have plasticity indexes such as to give 0, 5, 8 and 9 plasticity indexes to the resultant stabilized mixture, which also shall have a dust ratio for the four sections of 52,49, 63 and 51 respectfully. Binder soil will be stored in a dry place in bags.

4. Calcium Chloride - Flake chloride will be in bags and kept in a dry place for future use on track tests.

5. Final base course mixture - Will conform to the following:

Sect. No.	Gradation - Percent Passing						Dust Ratio	P.I.
	1"	3/4"	No. 4	No. 10	No. 40	No. 200		
1	100	98	80	69	46	24	52	0
2	100	93	62	48	31	15	49	5
3	100	79	42	32	20	12	63	8
4	100	98	84	65	48	25	51	9

C. PHYSICAL TESTS TO BE CONDUCTED

1. Coarse Aggregate - The following physical tests will be performed

   (a) Sieve analysis

   (b) Absorption

   (c) Specific gravity

   (d) Fineness Modulus

2. Fine Aggregate - The following tests will be conducted on the fine aggregate

   (a) Sieve analysis

   (b) Absorption

   (c) Specific gravity

   (d) Fineness Modulus

   (e) Percent silt and clay

3. Binder Soil - The following soil tests will be conducted on the binder soil:

   (a) Liquid limit

   (b) Plastic limit

(c) Shrinkage limit

(d) Field moisture equivalent

(e) Shear strength

(f) Compaction (Proctor test)

4. Calcium Chloride - Should meet requirements of the A.S.T.M.

D. SUBGRADE STUDY

Purpose: To determine best graded mixture and rate of compaction for a subgrade under tests.

1. Mixing the materials

(a) Mix materials thoroughly in concrete mixer.

(b) Add any admixtures to mixture and mix them thoroughly in mixer.

2. Placing material and compaction

(a) Split sample in two portions and store half for later tests

(b) Divide track into four sections in some convenient arrangement with means of keeping sections separated.

(c) Place material in track, on top of 12" of coarse gravel in bottom, in two layers and compact it with regulated traffic. Add layers with compacting until within 5" - 4" from top of track walls.

(d) Moisten mixture, before placing it in the track, to aid in compaction.

(e) Continue compaction until sections show failure or complete compaction with no further subsidence.

(f) Determine best sections with continued regulated traffic and then fill track with mixture of best sections and repeat building up process to subgrade for further tests.

(g) Control temperature and humidity in room with test track.

(h) Use sections in track with calcium chloride admixture as comparison with subgrade materials, without chloride.

(i) Vary the water level in the track and note the action on sections at different elevations.

(j) Trim sections smooth for the application of the road metal for further tests.

3. Subgrade study tests

(a) Shear test with hydraulic shear testing machine

(b) Wear test

(c) Tests on water content

(d) Rate of compaction by record with profilometer

4. Sub-base variations

(a) Add chloride to portion of exact sample and run same operation again for comparison without calcium chloride

(b) Use portion of same sub-base material and run tests on it with surface stabilization. Use same procedure as in previous experiment with same tests.

E. ROAD METAL

Purpose: To test different graded mixtures and determine the effects of admixtures of chloride in varying amounts on action.

1. Mixing

(a) Mix materials thoroughly by blading materials with a spade.

(b) Add water sufficient to dissolve calcium chloride and in amount to bring mixture to it's optimum moisture content predetermined by the Proctor test.

(c) Vary amounts of calcium chloride in mixtures to get relative comparison and results.

2. Placing material and compaction

(a) The mixture is added to the compacted subgrade in sufficient amount to have 1-1/2" of road metal when compacted.

(b) Surface is compacted with pneumatic tire and uniformly distributed traffic until no subsidence is noted and then sections are in condition suitable to testing.

3. Tests on track with continued traffic

(a) Rate of compaction should be noted at intervals and recorded

(b) Profile of track, longitudinal and sectional, should be recorded.

(c) Pitting action and loss of material should be noted.

(d) Drying out and raveling of surface should be noted.

(e) Action of artificial rain action should be tried and reaction to surface noted.

(f) Vary height of the water table and note action of the road metal at the different heights.

(g) Test sections with hydraulic stability machine designed by Mr. Fred Burggraf.

(h) Add bar to track to give bumping action and cause chatter bumps and give impact.

(i) Vary thickness of a stabilized base and also the thickness of the seal coat to give comparative results of the value of heavy coating and thin base or thin coating and heavy stabilized base

Section 11

FIELD STUDY

PURPOSE: To study stabilized gravel road in place for the purpose of correlating test track results with field conditions.

A. Survey of certain existing gravel roads

1. Observations to be made

a. General surface conditions

b. Failures

c. Subgrade condition

d. Shoulder condition

e. Drainage

B. Selection of gravel roads to be studied

1. With relation to geographic position

2. With relation to traffic count

3. With relation to materials

4. With relation to degree of maintenance care they have received

5. With relation to type of construction

6. With relation to appreciation of chemical conditions

7. With relation to public reaction.

C. Factors to be studied

1. Road failures and Causes

2. Maintenance

3. Physical characteristics

a. Condition when wet

b. Condition when dry

c. Calcium chloride content

d. Moisture and density

e. Gradation

f. Plasticity Index

D. Track tests on materials

1. Sample of road to fill sections of track will be sent to laboratory and tested there to determine deficiencies.

2. Carry same procedure as described in laboratory work on track tests.

3. Make necessary corrections in mixture to provide satisfactory stabilized road and proceed with tests on test track under conditions that gave poor results in the field.

Part V.

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MICHIGAN
STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 3/27/40

ABSTRACTS

Subject: Subgrade Stabilization

Purpose: Study on Research Problem

Reference:

Author: Arthur R. Smith

Title: The ABC's of Soil Stabilization

Source: Burton Publishing Co. (Reprint)

Date: June 1938- January 1939 inc.

Volume and page: The Earth Remover and Road Builder

Contents:

(1) General discussion of terms applying to stabilization of soils.

(2) Drainage of soils and values of drainage to soils stabilization.

(3) Soil identification and the grouping of soils.

(4) Importance of gradation of soils and Stabilized mixtures.

(5) Importance of stabilization and tests to determine varying properties of the soils that affect stabilization.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date #3/27/40

ABSTRACTS

Subject: Stabilising Effects of Calcium Chloride

Purpose: Study on Research Problem.

Reference:

Author: Calcium Chloride Association Bulletin.

Title: Stabilising Effects of Calcium Chloride.

Source: Calcium Chloride Association Bulletin.

Date: April 1938

Volume and page: Brief No. 134

Contents:

(1) Increasing Density by using calcium chloride in soil stabilization.

(2) Increase compaction by retaining moisture in the soil and therefore getting progressive consolidation.

(3) Adding calcium chloride will give base stability and add additional strength to the graded material.

(4) Calcium chloride added may determine success or failure of the road.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 3/22/40

ABSTRACTS

Subject: Calcium Chloride Stabilization.

Purpose: Study on Research Problem.

Reference:

Author: Arranged by Fred Burggraf.

Title: Soil Mechanics & Soil Stabilization.

Source: Proceedings Eighth Annual Meeting of Highway Research Board.

Date: 1933

Volume and page: Part 2 pp. 209 - 256

Contents:

(1) Study of principals of stabilization.

(2) Designing mixtures of soil and calcium chloride for stabilization.

(3) Properties of calcium chloride and functions in stabilization.

- (a) Moisture attraction.
- (b) Vapor Pressure.
- (c) Surface tension.
- (d) Binding properties.
- (e) Effects on density of mixtures.

(4) Surface consolidation.

(5) Design stabilized roads.

- (a) Mixing plants.
- (b) Methods of using and amount of calcium chloride used.
- (c) Compaction methods.
- (d) Crown design.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 3/28/40

ABSTRACTS

Subject: Stabilization with calcium chloride.

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: 1939 Brought States more Miles of Better roads for Less Money

Source: Calcium Chloride Association News.

Date: January & February 1940

Volume and page: _____

Contents:

Photographic study and discussion of typical surface consolidation and stabilizing effects on experimental roads.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/1/40

ABSTRACTS

Subject: Stabilized Road Surfaces.

Purpose: Stuy of Research Problem.

Reference:

Author: PRoject Committee on Stabilized Road Surfaces.

Title: Highway Research Board

Source: Highway Research Information Service.

Date: 1935

Volume and page: _____

Contents:

(1) Study of general theory of soil stabilization.

(2) Design of soil mixtures for stabilized road surfaces.

(3) Treatment for soils with calcium chloride.

(a) Calcium chloridd as a dust layer.

(b) Construction primcipals with calcium chloride as an admixture.

(c) Control of loose mulch on the stabilized mulch.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/2/40

ABSTRACTS

Subject: Stabilization with Aggregates, Binder soil & Calcium Chloride.

Purpose: Study on Research Problem.

Reference:

Author: Calcium Chloride Association.

Title: Low Cost Roads.

Source: Calcium Chloride Association.

Date: 1939 Edition.

Volume and page: Bulletin No. 25

Contents:

(1) Principals of stabilization of soils.

(a) Specifications.

(2) Designing mixtures of stabilized Materials.

(a) Calcium chloride admixtures.

(b) Calcium chloride surface applications.

(3) Construction principals of stabilized road surfaces.

(a) Road mixing.

(b) Plant mixing.

(c) Drainage methods.

(4) Maintenance of stabilized roads.

(a) Application of calcium chloride.

(b) Patching.

(c) Shoulder maintenance.

(5) Values of stabilized roads.

(6) Properties of calcium chlordie in connection to road stabilization.

(7) Standard specifications and tests of soils.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/2/40

ABSTRACTS

Subject: Stabilization of soils.

Purpose: Study of Research Problem.

Reference:

Author: R. W. Miller.

Title: Effects of Quality of Clay on Soil Mortar.

Source: Highway Research Board.

Date: November 1936

Volume and page: _____

Contents:

Correlation of swell tests and compaction tests, with plasticity index, on stabilized road soils.

The maximum plasticity index depends on clay binder soil which is being used.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

RESEARCH DIVISION

Project
No. _____

Date 4/8/40

ABSTRACTS

Subject: Road Stability.

Purpose: Study on Research Problem.

Reference:

Author: Fred Burggraf

Title: Stabilization with Calcium Chloride.

Source: Calcium Chloride Association Bulletin.

Date: 1939

Volume and page: _____

Contents:

The major advancement in the stabilized road composition with calcium choride is the joint importance of gradiation and the plastic properties of the silt and soils passing the no. 40 sieve. The upper limit of the plasticity index used should be about 6, and the amount of fines should be lowered. The relative stability varies with the moisutre content.

The are two methods of construction; (1) surface consolidation, (2) Stabilization.

The addition of calcium chloride to the soil will increase the density appreciably and will also speed up the compaction.

Calcium chloridd treatment saved about 60% on the loss of road metal due to raveling and dust losses on an experment run in conjunction with the University of Michigan on their tests.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/3/40

ABSTRACTS

Subject: Use of Calcium Chloride on Highways

Purpose: Study on Research problem.

Reference:

Author: T. W. Delahanty

Title: Chemical Products & Highway Progress.

Source: Chemicals

Date: January 12, 1931

Volume and page: Page 10

Contents:

Calcium Chloride was originally used as a curing agent in concrete and for a dust pallative on highways. Calcium Chloride is now coming into use as a binder in gravel roads and as a stabilizer.

The production of calcium cholorde increased from 45,000 tons in 1914 to 200,000 tons in 1930. The original cost of calcium chlorde was $40-$50 per ton and it is now only $20-$23 per ton.

Canada imported calcium choloride from the United States for the use of highway maintenance.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

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No. _____

RESEARCH DIVISION

Date 4/3/40

ABSTRACTS

Subject: Calcium Chloride for Construction & Maintenance.

Purpose: Study on Research Problem.

Reference:

Author: H. F. Clemmer

Title: Use of Calcium Chloride in Construction and Maintenance

Source: Roads & Streets

Date: December 1932

Volume and page: Vol. 75 pp. 497 - 8

Contents:

Calcium Chloride carries a direct value as a stabilizer on gravel roads and soil combinations.

Calcium Chloride is valuable as a dustpallative since it retains moisture and has a natural affinity for water. Calcium Chloride solution has a low vapor pressure as comapred with water and this accounts for the slow evaporation.

Calcium Chloride is lost from the roads through three methods which are (1) Rainfall, (2) Chemical reaction with the soil (base exchange), (3) Maintenance manipulation. Calcium chloride is a practically industractable materail if taken care of properly.

Calcium chloride flocculates soils thus bringing small particals together, giving permeable soil, and in this way it reduces the loss of the road metal by dust or rutting and raveling.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

RESEARCH DIVISION

Project
No. _____

Date 4/3/40

ABSTRACTS

Subject: Roadway Stability.

Purpose: Study on Research Problem.

Reference:

Author: H.F. Clemmer.

Title: Road Stability using Calcium Chloride.

Source: Roads & STreets.

Date: May 1933

Volume and page: Vol. 76, pp. 184-6

Contents: Road stability required a graded granular aggregate with binder soil. The binder consists of inner filler and cohesive cement. Silt is a good filler for soil road slabs since it does not expand much on moisture change and is fairly stable in the particals themselves. Colliods furnish cement for the granular soil particles.

The Clacium chloride added to maintain moisture in the soil, thus aiding in the stabilizing action of the soil, and it also reduces losses of dust and road metal considerably.

The losses of the calsium chloirde is due to chemical action in the soil and is dependent on soil acidity, losses due to rain and the maintenance manipulation. Maintenance should be carridd on following a rain when calcium chloride layer is down below surface considerable.

The amount of binder soil used in road metal is dependent on expansive properties of binder soil so as to fill the voids to a maximum.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/4/40

ABSTRACTS

Subject: Calcium Chloride Stabilizations.

Purpose: Study on Research Problem.

Reference:

Author: C. A. Hogentogler, Jr.

Title: Stabilization of low cost Roads by Calcium Chloride.

Source: Roads & Streets.

Date: October 1933

Volume and page: Vol. 76 pp 359 - 60

Contents: Low cost roads consist of granular particles and silt filler with clay binder soil to furnish the cohesive properties within the structure.

The absence of water within the road and on the surface causes ravelling and rutting of the surface. The proper gradiation of granular soil particles & binder soil with proper proportions of moisture stabilizing chemicals will give a stabilized road surface.

Stability is defined as the resistence of a road metal to rutting and ravelling.

The weight of the soil particles has a definate bearing on the stabilizing power of given soil mixtures.

The moisture film between particles is the factor with which high stability in soil structures are determined. Moisture films have produced higher pressures in soils than can be attained with mechanical means on the same soil sample.

The Calcium Chloride is added to soil mixture to retain soil moisture & absorb moisture from the air for storage in the maintance of the road metal.

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MICHIGAN
STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/4/40

ABSTRACTS

Subject: Soil Moisture Obtainence

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: Chemical "Rainmaker" Helps Modern Highways.

Source: Scientific American

Date: September 1930

Volume and page: Volumn 143, pp. 218

Contents:

Chemical "Rainmaker" in the form of calcium chlordie is used to draw moisture from the air, even on the hottest and driest days, to be used in the soils. The chemical acts during the periods when the humidity is high to collect mositure and hold it for later use in use as a dust pallative and also for use as a binding moisture film to increase the stability of the soil structure.

The usual procedure is two applications during hot summer months to the road surface and this will give the same effect as a shower each day as far as the dust preventive power is concerned, and will also give the required amount for the stabalizing qualities desired.

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RESEARCH DIVISION

Date 4/4/40

ABSTRACTS

Subject: Stabilization of Soils.

Purpose: Study on Research Problem.

Reference:

Author: Ray A. Giddings.

Title: Soil Concrete.

Source: Chemicals.

Date: September 18, 1933

Volume and page: pp. 9

Contents:

Stability and durability are the primary requisites of a good surfaced highway.

Soil concrete is an intimate mixture of natural graded soils proportioned so as to give the maximum density and stability. The stability of a simple structure of soil depends directly on the soil mortar, or the portion as used that passes a number ten sieve.

The primary factors in stability are, (1) Internal friction, (2) cohesion.

Calcium chlordie used on soils to build up and maintain the very essential property of water films between soil particles to maintain stability at all times.

Roads treated with calcium chloride should not be scraed or bladed except after rain when the chloride layer, has gone down considerably below the road metal.

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RESEARCH DIVISION

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No. _____

Date 4/4/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: Chemicals in Highway Construction.

Source: Chemicals.

Date: January 18,1932

Volume and page: Page 3

Contents:

Calcium chloride has been used as a dust pallative for many years, and throught its use as a dust pallative it has been found usfull as a binder in sand and gravel roads.

Calcium chloride is exported into foreign countries for use in road building and soil stabilization. In 1930 42,700,000 pounds were exported to Canada for road building purposes.

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RESEARCH DIVISION

Date 4/5/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study on Research Problem.

Reference:

Author: R. P. Traver.

Title: Low cost Stabilized Road Construction in Onondaga County, N.Y.

Source: Roads and Streets.

Date: March 1934

Volume and page: Page 120 -24

Contents:

Stabilized gravel roads are used in sections where concrete isn't practical but road improvements are necessary.

Stabilized gravel roads are a combination of coarse gravel, fine aggregate, silt, clay and calcium chloride. Ample drainage is a very important factor in stabilized roads.

Material in the base coarse, passing a forty mesh sieve, should have a plasticity index between 8 and 12, since the plastic index is a measure of the cohesive properties of the mixutre. The function of the gravel is to give rigidity and high internal friction, the fine sand fills the voids in the coarse aggregate, the silt has capillary properties and serves as a reservoir for the calcium chloride solution, and the clay in the mixutre supplies the cohesion. The clay also acts as a reservoir for the calcium chloride.

When the road has to much coarse material on it some of the sholder material, if suitable may be bladed in, and if not suitable material for the addition has to be hauled in.

(Cont.)

with ordinary type gravel roads. It is very important that stab ilized gravel roads be maintained at the proper time. Patching cone with mixture of clay, sand, chlorde, close to mixture of original preparation used.

Blading should be done only follwing a rain when the calcium chloride has gone into the road metal considerably.

An advantage of stabilization is the increased benifits obtained from the use of calcium chloride, by two or three applications and will act as a dust palliative for the entire year.

4/5/40

Subject: Road Stabilization

Purpose: Study on Research Problem.

Author: Walter O. Dow.

Title: Method and Cost of Stabilization of gravel Roads in a Mich. County.

Source: Roads & Streets.

Date: May 1934

Volume and page: Vol. 77, pp. 203 - 6

Contents:-

Stabilization of loose gravel roads by the addition of clay and silt with applications of calcium chloride. Drainage is of prime importance and should be carefully exercised on a stabilized road project.

Soil samples taken from road and are tested in the labrationy to determine what was needed for the stabilization of the soil. The plasticity index of the soil mixture should range between 5 - 10.

Clay and gravel should be throughly mixed on the road bed and spread out uniformly on the surface. The road should be shaped with a crown at least of $\frac{1}{2}$" per foot and up to $\frac{3}{4}$" per foot. When the final shaping is done the calcium chloride is added at about $\frac{1}{2}$ cu. foot per sq. yd., and it will absorb moisture which will be used to aid in the process of compaction.

Maintenance cost on stabilized road is very low compared

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Date 4/8/40

ABSTRACTS

Subject: Admixtures for Frost Prevention.

Purpose: Study on Research Problem.

Reference:

Author: H.H. Miller & Don N. Smaith.

Title: Methods for Prevention of Road Failures due to Frost.

Source: Roads & Streets.

Date: June, 1934

Volume and page: Vol. 77 pp.210 - 21

Contents:

Failure of the road surfaces are due to the lateral or vertical flow of the subgrade. Failures are also due to frost action and they are vertical flow.

There are two methods of applying calcium chloride to the road subgrade; (1) drilling holes in the road metal and about 8 ft. deep and filling them with a misture of pea gravel and calcium chloride. The holes are spaced uniformly on the road surface so the entire road is serviced by at least one of the wells of chloride and pea gravel, (2) pumping solution of calcium chloride under the road to prevent frost action. This operation is done during the winter and has proven very successful. The first method is the best and the most practiced method of the two mentioned.

These methods also serve as aids to stabilization of the soils by the addition of the calcium chloride.

(cont.)

a proper amount of cohesive material such as clay, is kept constantly damp, it consolidates and hardens under traffic and continues highly stable against lateral displacement. The function of the calcium chloride is to retain moisture in the soil.

The stability of a soil to lateral displacement is a direct function of the internal friction and cohesion. The clay supplies the dircet cohesion and it is a maximum when each particle is surrounded with a film of water.

Losses of calcium chloride due to (1) base exchange, (2) washing out by rain, (3) improper maintenance methods.

Calcium chloride when a plied to a stabilized raod surface acts as a primer to attract moisture into the capillary ducts, and by hygroscopic nature sets up surface tension which limits evaporation of the soil moisture into the air. As an addative valie of the calcuim chloride it alos acts as a dust palliative,

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RESEARCH DIVISION

Date 4/8/40

ABSTRACTS

Subject: Road Stabilisation.

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: Stabilizaing Gravel Roads in Onondaga County, N.Y.

Source: Engineering News Record.

Date: December 2, 1933

Volume and page: Vol. 111 pp. 529 - 32

Contents:

Roads are constructed from pit run gravel and when it does not have a balanced grading the defecieneies are added to it to the correct the needed amount. The difference of this type of road to common gravel is in the addition of calcium chloride to the surface. Penetration of the surface layers by the chemical develops moisture film cohesion, consolidation of the clay which produces high internal friction, giving high induration of the road surface.

Maintenance of this type of road calls for honing down of the surface and retreatment at intervals with calcium chloride. Retreatment comes about twice a year with about ¾ of a pound per square yard. Honing should be done following a rain so as not to waste the calcium chloride, since chloride goes down with rain to return by capillary action when the soil drys out on the surface.

The theory of calcium gravel road is: If a gravel- sand mixture, graded to obtain maximum interlocking and supplemented by

(Cont.)

capillary action. Calci m chloride should be applied during the dryout period following a rain, when the surface has been properly leveled and bladed with a grader. When not able to apply it following a rain it should be applied in the early hours of the day. Calcium chloride should never be applied just proir to a rain since most of it is wated by washing away.

An important factor in a stabilized road is to always maintain a crown of at least $\frac{1}{2}$" per foot and not more than $\frac{5}{4}$" per foot. Another important factor is the drainage of the surface and the subgrade for a well maintained stabilized road.

For the best maintenance the thin layers of stabilized road material should be added periodically.

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RESEARCH DIVISION

Date 4/4/40

ABSTRACTS

Subject: Maintenance of Stabilized Gravel Roads.

Purpose: Study on Research Problem.

Reference:

Author: R. C. Tiney.

Title: Maintenance Methods of Stabilized Gravel Roads.

Source: Engineering News Record.

Date: November 16, 1933.

Volume and page: Vol. 111, pp. 594 - 5

Contents:

The old theory was that there should be a thin mulch of fine gravel on the road and it should be bladed frequently, but today the practice is to stabilize the road and no loose mulch or raveling occurs, and blading is done only following a rain.

With long periods of dry weather the road may develope small holes and these should be patched with the same grade of gravel as the surface is made up of mixed with calcium chloride added to provide the mositure for the compaction operation. When the time comes for blading and scraping it should be done intensivly before the road dries out and the calcium chloride returns to the surface layers by capillary action.

Calcium chloride added to a road surface to maintain constant moisture content in the road at all times and prevents raveling and dust hazards. During a rain the calcium chloride solution in the soil goes deeper into the road bed and on the drying action of the road bed it comes to the surface again by

(Cont.)

moisture change and calcium chloride is added to obtain this condition.

The elementary soil properties which effect stability are: the internal friction, cohesion, capillarity, compressibility and elasticity. Internal friction and cohesion are the properties most desired in stabilizing soils.

Soil fines are made up of the fine sand, silt and clay. Soil mortar includes all of the material passing a No. 10 sieve, and on which mechanical analyiss is determined.

The plasticity index is a measure of the cohesion of a soil. Plasticicty index is the difference of liguid limit and the plastic limit of a given soil.

For maximum stability you must have: (1) true cohesion of soil fines, placticity indes between 6 - 14; (2) resistance of soil fines to water absorbtion; (3) moisture film cohesion in soil fines. Calcium chloride serves this purpose by absorbtion of water from the stmosphere; (4) internal friciton of soil fines, which requires about ore third of the soil fines to be fine sand; (5) quantity of soil fines, 30 - 50% of soil fines by weight are required.

The function of the calcium chloride is to provide the moisture for the proper cohesion in dry weather. Calcium chloride will desolve in one pound of water approximatly one pound of flake. The absorbtion power of calcium chloride varies with the relative humidity of the stmospher.

Evaportion from calcium chloride solution decreases as the solution increases wuntil a point of balance is reached.

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RESEARCH DIVISION

Date 4/9/40

ABSTRACTS

Subject: Stabilized Soil Pound Road Surfaces.

Purpose: Study of Research Problem.

Reference:

Author: W. R. Collings & L. C. Stewart.

Title: Theory of Soil Stabilization (Part 1)

Source: Engeneering News Record.

Date: May 24, 1934.

Volume and page: Vol. 112 pp. 660 - 64

Contents:

Soil stabilization is defined as the proper combination or adjustment of the various soil fines and coarse material to produce a mixutre that is stable in all kinds of weather and under all conditions of traffic, using local materials. The stabilization of a road surface is the same principal with calcium chloride addeddto supply the necessary moisture for cohesion of the various materials.

The reasons for the growing popularity of stabilized roads are (1) low cost, (2) minimum of maintenace required to maintain good roads, (3) hazard of loose pebbles and dust is eliminated.

The constituents of a stabilized road surface are gravel, coarse sand, fine sand, silt and clay. The moisture content is a very important factor in soil stability. Small amounts of water will act as a binder and excessive amounts will act as a lubricant. The most stable soils will resist any radial

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RESEARCH DIVISION

Date 4/9/40

ABSTRACTS

Subject: Stabilized Soil Bound Road Surfaces.

Purpose: Study on Research Thesis.

Reference:

Author: W. R. Collings & L. C. Stewart.

Title: Traffic Tests on Trail Roads. (Part 11)

Source: Engineering News Record.

Date: June 7, 1934.

Volume and page: Vol. 112, pp. 738 - 43

Contents:

General discussion of the construction of a test track and of the operation of the same.

Some of the obervations were:

(1) Wearing coarse mixtures haveing 50% soil mortar, P.I. should be tween 10 - 15 for the best wearing qualities.

(2) Some silt is valuable in improving both wet and dry stability.

(3) Dry-weather raveling reduced by addtion of ½ pound of calcium chloride per square yard.

(4) A P.I. of 5 or more required to obtain the desired resistance to ravelingunder dry conditions when used with calcium chloride.

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RESEARCH DIVISION

Date 4/9/40

ABSTRACTS

Subject: Stabilized Soil-bound Road Surfaces.

Purpose: Study on Research Problem.

Reference:

Author: W. R. Collings & L. C. Stewart.

Title: Construction & Maintenance (Part III)

Source: Engineering News Record.

Date: June 14, 1934

Volume and page: Vol. 112, pp. 772 - 75

Contents:

Drainage is the first essencial to consider in stabilized road construction.

Road mixing has been found to be the most adaptable and most used method of mixing stabilized road materials.

The most desirable clays are very cohesive and sticky. Clay put on road and then pulverized with pring tooth harrows or rolled to crush lumps of clay. Most of the mositure must be removed to obtain degree of fineness desired.

When shaping is started the materials are dampened slightly and extra material from windrows is bladed in for compaction. Compaction should be continued until the surface is dried out.

Claeium chloride added to surface and its purpose is to retain moisture and increase the cohesive powers. The crown should be maintained at 1/2" per foot.

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RESEARCH DIVISION

Date 4/11/40

ABSTRACTS

Subject: Stabilized Soil Bound Road Surfaces.

Purpose: Study on Research Problem.

Reference:

Author: W. R. Collings & L.C. Stewart.

Title: Construction & Maintenance Costs. (part IV)

Source: Engineering News Record.

Date: June 21, 1934

Volume and page: Vol. 112 pp. 806 - 8

Contents:

Cost practically the same to build a stabilized road as it does to resurface and stabilize the surface of an old gravel road. The large item of the cost is the purchasing and transportation of the clay.

The average cost of the materials, labor, and incidentals per mile was between $275 and $300 for a stabilized road.

The maintenance cost is made up of: (1) scraping expense, (2) replacement of material lost from surface, (3) the cost of the calcium chloride for surface treatment. The scraping cost on a stabilized road is only about one half that on a gravel road.

Stabilization with calcium chloride reduces the loss of material from the road surface as dust and raveling.

(Cont.)

materail passing the No. 40 sieve should be between 1 - 15, and a liquid limit not exeeding 35.

A crown of not more than $\frac{5}{4}$" and not less than $\frac{1}{2}$" should be maintained, for surface drainage and any other precautions for drainage should be carefully considered.

Use about two pounds of rock salt per square yard of road surface and build up road in layers of 1 to 2 inches in thickness.

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No. _____

RESEARCH DIVISION

Date 4/15/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: Salt Stabilized Road Practice Developing Rapidly.

Source: Engineering News Record.

Date: July 4, 1935

Volume and page: Vol. 115, pp. 11 - 13

Contents:

Soil stabilizati n is a process of combining the friction aggregates and the clay binder to produce a stable mixure. For the clay to have it's maximum binding qualities it must have moisture and under evaporation the retention of th moisture calls for the addition of a miosture holding element to the soil, and in a salt stabilized road common salt is used. The addition of the salt also aids the clay as a binder and reduces the volumn of shrinkage and causes very little change in the field moisture percentage.

When evaportati n takes place the salt brine crystallizes and forms a crust which seals the surface from any further evaportation. When rain occures the crystals are desolved and the brine solution settles into the road to rise again by cappillary action when evaporation starts again.

For Salt-stabilized roads the plasticity index of the

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RESEARCH DIVISION

Date 4/15/40

ABSTRACTS

Subject: Stabilized Road Surfaces.

Purpose: Study on Research Problem.

Reference:

Author: L. C. Stewart & S. J. White.

Title: Premixed Stabilized Soil for Road Surfaces.

Source: Engineering News Record.

Date: September 19, 1935

Volume and page: Vol. 115, pp. 389 - 91

Contents:

The general practice is to mix the materials on the roadbed for stabilized roads, but now the practice is leaning tword plant mixing and hauling it to the job in trucks.

The aticle gives a general plan and layout of mixing plant and details concerning it's operation.

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RESEARCH DIVISION

Date 4/15/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: C. A. Hogentogler.

Title: Practical Soil Stabilization.

Source: Roads & Streets.

Date: March 1935

Volume and page: Vol. 78, pp. 92 - 99

Contents:

The materials that furnish internal friction in the soil are sand, gravel, ground slag or crushed stone, and the cohesion is furnished by the clays and the moisture films in the soils.

The grading of the material is a deciding factor as to stabilized conditon will be obtained with a soil. The ultimate stability depends on the permanent adhesive strength of the binder films between the soil paticles.

(Con't)

factor and should be very carefully controlled. There is no need for an excessive crown, but one of about .4 to .5 of an inch should be amintained and this give plenty for good drainage too.

Maintenance on a stabilized road is different than on oridnary gravel roads. Blading should be done only following a rain for two reasons, (1) Easier workability, (2) Presence of sufficient moisture to permit consolidati n and reshaping loose laying material under traffice. Patching can be coarried on with roads when weather does not permit blading, and patching material same as original road metal.

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No. _____

RESEARCH DIVISION

Date 4/16/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study on Research Problem.

Reference:

Author: Fred Burggraf

Title: Progress in Road Stabilization.

Source: Roads & Streets

Date: April 1935

Volume and page: Vol. 78, pp. 155 -6

Contents:

The stabilization depends on the gradiation and proportioned quantities, quality of the binder siol, and the degree of compaction with calcium chloride added to give proper moisture films.

Calcium chloride was originally used only as a surface treatment, but is now used as an integral treatment too. With the integral use of it, the compaction has been greatly accelerated and the moisture is regulated.

The materials were originally mixed on the surface of the road with graders but at present they are mixing the materials in either portable mixers or plant mixers on the roads. The compaction was originally handled with rollers butit is present practice to do compacting with truck traffic to a better advantage.

The crown on the stabilized road is a very improtant

(con't.)

a thin layer of the mixed material is added. This operation continues until all of the mixed material is placed and the crown is maintained at ¼" per foot during the compaction with controlled truck traffic; (8) after sufficient compaction the road is smoothed with a blade grader.

With a plant mix the mixutre is hauled to the road and applied instead of previous discription.

Average cost per mile of stabilized surface 3" thick is about $1,650. The plant mix averages a saving of $200 per mile. The average yearly cost of maintenace per mile is $320 over an 18 mile section.

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RESEARCH DIVISION

Date 4/23/40

ABSTRACTS

Subject: Stabilized Roads.

Purpose: Study on Research Problem.

Reference:

Author: John H. Barr.

Title: Stabilized Surface Methods & costs.

Source: Engineering News Record.

Date: June 27, 1935

Volume and page: Vol. 114 pp. 907 - 8

Contents:

The first consideration in stabilized projects is the location of materials in proximity of the project. Clays used for stabilization should have a high P.I. since it is a measure of the cohesive properties of the clay. One of the prime requisis is a proper gradiation in the mixutre and the proportions of each grade.

The steps in the construction are as follows: (1) Windrows all lloose material on the road to the center; (2) add the material to the windrow to give a cousre 3" thick and 20' wide; (3) Clay is added to give desired mix with the proper P.I.; (4) dry clay out and blade it back to the shoulders of the road; (5) spread the windrows of gravel and then the clay over it with the addition of calcium chloride at the rate of 4 tons per mile; (6) mix the materials throughly by blading and windrow it to the shoulders again by blading; (7) Road bed is moistened and then

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RESEARCH DIVISION

Date 4/24/40

ABSTRACTS

Subject: Stabilized Surfaces.

Purpose: Study on Research Problem.

Reference:

Author: H. G. Sours.

Title: Stabilized Soil Road Maintenance.

Source: Engineering News Record.

Date: June 27, 1935

Volume and page: Vol. 114 pp. 910

Contents:

All of the loose and floating material should be avoided on a stabilized roads during dry weather since it acts as an abrasive and breaks down the road metal., to cause raveling.

Blading should be done only following rains so that the surface is workable and the calcium chloride has penetrated into the road so it will not be disturbed by the blading operations.

Small amounts of loose aggregate with sufficient binder soil may be bladed over the surface to fill the small holes. Material for blading is stored on the shoulders.

Patching small holes is not advisable but large holes should be filled with 50% graded gravel and 50% sand and clay mixture, with 100 - 150 pounds of calcium chloirde per cubic yard.

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RESEARCH DIVISION

Date 4/ 22/40

ABSTRACTS

Subject: Stabilized Road Surfacing.

Purpose: Study on Research Problem.

Reference:

Author: L.C. Stewart & S. J. White.

Title: Plant Mixing of Stabilized Soil Road Surfacing Materials.

Source: Roads & Streets.

Date: November 1935

Volume and page: Vol. 78, pp. 353-57

Contents:

The trend has been to have centrlized mixing plants to deliver stabilized road mix to the roadbed for compaction.

The advantages of a central mixxing plant are: (1) the use of expensive equipment is eliminated; (2) dust nuisance of mixing operation is eliminated, since the accurate is delivered to job damp; (3) more accuarte control of properties and better mixing can be attained; (4) costly delays are eliminated while waiting for materials to dry; (5) road building season lengthed to nearly entire, year; (6) may be used by communities who don't own equipemtn for doing their own mixing.

There is a gereral discussion and discription of the central mixing plant and its operation.

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RESEARCH DIVISION

Date 4/24/40

ABSTRACTS

Subject: Stabilization.

Purpose: Study on Research Problem.

Reference:

Author: J.W. Reppel.

Title: Experimental Stabilization in Ohio.

Source: Roads & Streets.

Date: December 1935

Volume and page: Vol. 78 pp. 377 - 380

Contents:

Stabilized construction involves the use of a large part of the existing road metal and subgrade in conjunction with addition of binder siol as a cementing medium.

The road selected was graded down and loose material was windrowed on the sides. The stabilizeing material ingredients were added to the road and mixed throughly. There were three sections tested, (1) with calcium chloride, (2) calcium magnesium chloride, (3) roack salt. All sections were compacted and worked in the same manner and after compaction the only variation was in the moisture contents. Calcium magnesium chloride was the most and rock salt the least satisfactory, but all were found to give satisfactory surfaces.

(Con't.)

act to furnish structural strength, hardness and friction. The fine sand adds inbedment support to the coarse sand. Silt acts as a filler to prevent the granular particles from rocking. Clay and colloids furnish close texture to have fine moisture films to produce high cohesion.

The necessity for maintaining the moisture in the clay binder is taken care of by adding salt to the stabilized mixture and this acts to retain the soil moisture.

It is very essential to have proper drainage on stabilized roads and without it the roads are not satisfactory.

Roads of this type need very little maintenance and when bladed it should be done following a rain or in the spring., when the surface is workable and will not tear up when worked. Applications of salt and new material are made in the spring and compacted down as part of original road metal. Binder materials may be taken from the shoulders when needed.

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RESEARCH DIVISION

Date 4/24/40

ABSTRACTS

Subject: Road Stabilization.

Purpose: Study on Research Problem.

Reference:

Author: _____

Title: Use of Rock Salt in Stabilized Road Construction.

Source: Roads & Streets.

Date: August 1935

Volume and page: Vol. 78, pp 269 - 71

Contents:

The secondary roads can be divided into two classes: (1) floating surface type; (2) soil stabilized type. On the floating surface type the material is loose and requires some constant maintenance to have good surface while on soil stabilized type the coarse material is held in place by the binder soil. This type does not require constant maintenance and remains a good surface.

A stabilized road consists of a compacted wearing course of gravel, sand, and the natural soil binder, which includes sand, silt and clay. These materials are mixed to give all weather stability.

The requirements of a stabilized soil road are that it be laid and compacted to conform to a satisfactory grade, typical cross-section and satisfactory finished surface.

In a stabilized road the coarse aggregate and coarse sand

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Date 4/23/40

ABSTRACTS

Subject: Stabilized Construction.

Purpose: Study on Research Problem.

Reference:

Author: J. C. Black

Title: Plantmixed Stabilized Construction in Illinois.

Source: Roads & Streets.

Date: August 1936

Volume and page: Vol. 79, pp.21-24

Contents:

Job consists of mixutre of one part clay by weight to ten parts of sand and one pound of calcium chloride per square yard laid. After surface as been down two to four weeks, and well compacted, an additional ½ pound of calcium chloride per square yard is spread only on surface.

Article gives a general procedure of consturcting old road into new stabilized surface and a discussion of the mixing plant and its operation for stabilized materials.

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RESEARCH DIVISION

Date 4/25/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study On Research Problem.

Reference:

Author: S. O. Linsell.

Title: Stabilized Road Surfacing in Ohio.

Source: Roads & Streets.

Date: November 1936

Volume and page: Vol. 79, pp. 56 - 60

Contents:

This article deals with the discussion of the building up of a road and finding it not suitable for traffic, they proceeded to stabilize it by the addition of soil binder and calcium chloride which produced a very satisfactory road.

The aggregate on the road was mixed with fine sand and clay. The clay had a plasticity index of 14. The proportions were, 55% coarse aggregate, 20% sand, and 25% clay. One pound of calcium chloride was added per sq. yd. of surface and one pound per sq. yard added later on surface.

The maintenace cost was cut condisderably on the stabilized roads.

(Con't)

There is a general grading scale given and the amounts of each used for the best results. The P.I. for the materialpassing a No. 40 sieve is given as between 6 - 15, and the liquid limit not to exceed 25.

There is a general discussion of construction methods and the mixing of the stabilized materials.

The seasoning period is the period during compaction and the calcium chloride plays an improtant part during this period. It lowers the vapor pressure of the contained moisture and thus reducing evaporation, thereby giving greater density with the same degree of compation.

There is a dixcussion of the maintenance of stabilized roads. Blading should be done only following a rain, when the surface is workable and the chloride solution is far enough in the road bed so it will not be exposed and wasted. Calcium chloride should be applied to the surface to maintain, the stabilized surface and these applications are made following a rain or early in the mornings.

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MICHIGAN
STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/25/40

ABSTRACTS

Subject: Stabilization

Purpose: Study on Research Problem.

Reference:

Author: H. F. Clemmer

Title: Stabilization of soils

Source: Roads & Streets.

Date: December 1936

Volume and page: Vol. 79, pp. 41 -44

Contents:

Main principle in stabilization is to obtain the maximum density from the existing sources of materials to give year around stabilization.

Too much clay makes roads rutty when wet and not enough clay will make them dusty and cause a lose of the road metal.

A stabilized road is vitally dependent on the continued presence of moisture in an optimum amount and this is obtained by many engineers by the use of calcium chloride as a moisture retentive.

The grading of soil materials should be such as to furnish sufficient coasre aggregate to assure resistance to abrasive action and to provide coarse and fine sand in proper propertions to interlock and prevent sliding during wet weather.

(con't)

The base is compacted in 1 yers about 3" thick and with regulated truck traffic or pneumatic tire rollers.

Both sodium & Calcium chloride have been used to retain the moisture during the compaction peridd, and they have both been found very effective.

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STATE HIGHWAY DEPARTMENT

Murray D. Van Wagoner
State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 4/ 26/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study of Research Problem.

Reference:

Author: A. E. Stoddard.

Title: Stabilized Base Construction.

Source: Engineering News Record.

Date: January 28, 1937

Volume and page: Vol. 118 pp 122 - 3

Contents:

Common practice is to have a stabilized base from 3" to 12" thick and the average runs around 3". The stabilized base should be 2' - 4' wider than the road metal to prevent wearing of the edges.

The binder soil, clay, should be throughly pulverized before applying the compaction to the road survace. The clay may be pulverized on the road bed of in the pit with pulvering machinery.

The materials may be either road mixed or plant mixed depending on the conditions and the distance of haul. In the final stages of the mixing the moisture content much be corrected to the plastic limit of the mixture. The moisture content has a direct bearing on the density that can be attainted upon compaction, and the moisture content must be maintained throughout the compaction period.

(Con't)

cium chloride is specified to mixture about 2/3 is added to mixture and remaining 1/3 added to surface of the compacted road metal.

Experience has shown that a pneumatic tire roller is the best method of compaction since it provides a kneading action along with the straight compaction. When compactingthe proper crown should be maintained since it will allow surface water to run off and will prevent raveling.The crown should be maintained between 1/2" and 5/8"per foot.

All blading of surface should be done following rains when the road metal is workable and the chloride is below the road metal sufficiently to prevent it from being exposed directly to the dair and wasted.

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RESEARCH DIVISION

Date 4/26/40

ABSTRACTS

Subject: Road Stabilization

Purpose: Study on Research Problem.

Reference:

Author: L. L. Allen.

Title: Methods & Costs of Road Stabilization in Minnesota.

Source: Roads adn Streets.

Date: March 1937

Volume and page: Vol. 80 , pp. 63-68

Contents:

The classification of stabilized roads are;(1) naturla soil mixqures, (2) treatment with substances involving chemical reactions productive of permanent crystallization, (3) treatment with bituminous material, (4) treatment with a flocculating substances, (5) treatment with a flocculating chemical, as calcium chloride.

The plasticity index ranges between 6-15 for material passing a 40 mesh sieve. The thickness varies from 3-12 inches depending on the base.

The soil binder is pulverized on the road bed by traffic and also by working it with harrows and dishs. When properly pulverized the soil binder is mixed with the gravel materila and spread on the orad bed to insure through mixing. When spread out on the road it is sprinkled with water and compaction of layer about 3" thick is started. When cal-

(Con't)

There are three methods of constructing soil graded roads: (1) Plant mix; (2) Road mix; (3) Stage Construction. In stage construction the material is just added to the road in amounts needed and it is depressed with traffic action and is regulary bladed and dragged.

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RESEARCH DIVISION

Date 4/29/40

ABSTRACTS

Subject: Stabilized Roads.

Purpose: Study on Research Problem.

Reference:

Author: C. A. Hogentogler & E. A. Willis.

Title: Stabilized Soil Roads.

Source: Civil Engineer.

Date: December 1935

Volume and page: Vol. 5 , pp. 758 - 60

Contents:

Admixtures of soil materials are to provide a road material containing enough coarse aggregate to resist the abrashive action of traffic, coarse and fine sand to provide interlocking action and prevent sliding, silt to act as a filler, and provide capillary bod and clay to retain minute cohesive films to give stability. A delequesent chemical is added to maintain the surface dampness and calcium chloride is used for this. These chemicals have the property of absorbing moisture from the air and slows up action of evaportation.

The stability of a soil is dependent on the thin films of moisture surrounding the soil particals and the funtion of the calcium chloride is to displace the air films, that originally surround the particles, with moisture films.

(con't)

Shrinkage and swell must be under complete control is soil is to have proper stability for use in road building. Drainage is one of the prime requisits for good road construction.

Potassium clay is the most stable since it has less molecules surrounding it, and lithium clay the most unstable.

The principal aims of soils stabilization are; (1) make soil as dense as possible; (2) to prevent moisture films from changing.

Subgrade soils for the maximum stability must have the proper proportions of additional aggregate and binder soil. The density of the proportions depends on the thickness of the moisture films.

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Date _____

ABSTRACTS

4/29/40

Subject: _____

Purpose: ~~Soils Stabilization~~

Reference: Study on Research Problem.

Author: _____

Title: ~~V. J. Brown~~

Source: ~~Soil Stabilization (Part 1)~~

Date: ~~Roads and Streets.~~

Volume and page: ~~February 1938~~

Contents: Vol. 81, pp. 25 - 30

Soil stabilization is the process of giving natural soils enought adrasive resistance ans shear strength to accomodate traffic or loads uden prevalent weather conditions, without detremental deformation.

The optimum water content is fundamental with gradiation.

The general methods of accomplishing stabilization are as follows:- (1) selection of natural soil with binder which furnishes high stability; (2) Adding soil binder to granular material or adding granular materials to clays; (3) Treating graded soils with delequesent substance; (4) waterproofing soil with bituminous surface; (5) densification of naturla soil by any means. The blocation will decide the method to be used and the materials to be used.

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RESEARCH DIVISION

Date 4/29/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: V. T. Brown & C. A. Hogentogler, Jr.

Title: Soil Stabilization (Part 2)

Source: Roads & Streets

Date: March 1938

Volume and page: Vol. 81, pp. 33 - 40

Contents:

Article deals with testing methods and the classification of soil. The important properties of a soil are; (1) Texture; (2) Color; (3) Structure; (4) Consistency; (5) compressability; (6) Chemical composition. These are the properties that are noticed during the soil survey.

General discussion and discription of the tests run to determine properties of the soil. Surch tests as plastic limit, liguid limit, Mechanical analysis, Moisture equivalents and shrinkage tests.

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RESEARCH DIVISION

Date 4/30/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: V. J. Brown.

Title: Soil Stabilization (Part 3)

Source: Roads & Streets.

Date: April 1938

Volume and page: Vol. 81, pp 33 - 40

Contents:

Article contains a general discussion of the methods of mixing aggregates and the mixes used with gradation scales.

Discussion of four types of stabilized road surfaces; (1) Graded mix of test local materials, (2) Graded mix with proportioned mix, (3) Graded mix with bituminous surface treatment, (4) Natural soil base stabilized with admixtures.

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RESEARCH DIVISION

Date 4/30/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: V. J. Brown

Title: Soil Stabilization (Part 4)

Source: Roads & Streets

Date: May 1938

Volume and page: Vol. 81, pp. 33 & 39

Contents:

General discussion of soil tests concerning internal friciton, cbhesion, shear and moisture variations.

By constructing curves of different properties and conditions of saturation or maximum density, from these curves you can determ ne the future behavior of the soils for different field conditons.

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Project
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Date 4/30/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study on Research Problem.

Reference:

Author: Frank H Newman, Jr.

Title: Soil Stabilization (Part 5)

Source: Roads & Streets.

Date: September 1938

Volume and page: Vol. 81, pp. 44 - 49

Contents:

The article deals with a discussion of the test methods in the Texas Highway Department in soils stabilization work.

The most importand soil tests used are liguid limit, plasticity index and linear shrinkage.

There is a comparison of a number of tests samples taken from highways of known behavior and correlated and charted.

The present requirements of the Texas Highway Department are: (1) Passing 2" 100%

Passing 40 mesh ..... 15% - 50%

Passing liquid limit of binder .. Less than 45

Plasticity index of soil binder.. Less than 15

Linear shrinkage soil binder .... Less than 8.5

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Project
No. _____

RESEARCH DIVISION

Date 6/30/40

ABSTRACTS

Subject: Soil Stabilization

Purpose: Study of Research Problem.

Reference:

Author: V. J. Brown

Title: Soil Stabilization(Part 6)

Source: Roads & Streets.

Date: Decemeber 1938

Volume and page: Vol. 81. pp. 43.-46

Contents:

The article expleains the use of and advantages of a stabiliometer for determining usuable valnes and the principle upon which it is built.

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RESEARCH DIVISION

Date 4/30/40

ABSTRACTS

Subject: Stabilization of Soils.

Purpose: Study on Research Problem.

Reference:

Author: J. C. Black

Title: Production and use of stabilized Maintenance Material in Southern Michigan.

Source: Roads & Streets.

Date: June 1938

Volume and page: Vol. 81, pp. 35 - 39

Contents:

The article gives the specifications set up by the Highway Department for the job and the amount of materials or ingrediants to use for said job.

There is a general discussion and discription of the equipment and operation of such equipment and the stabilisation practice.

The author tells of the hauling and placing of the stabilized material on the road shoulders and the compaction used. The project proved very satisfactory and is used a great deal today in all sections of the country.

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Project
No. _____

RESEARCH DIVISION

Date 5/1/40

ABSTRACTS

Subject: Stabilized Soils.

Purpose: Study on Research Problem.

Reference:

Author: E. A. Willis

Title: Graded soil Mixtures for Road Surface and Base Courses.

Source: Roads & Streets.

Date: January 1939

Volume and page: Vol. 82, pp. 25 - 30

Contents:

The following principles were presented in the article:

(1) Control of both grading and plasticity index of the mixtures necessary to assure satisfactory service behavior over a peroid of years.

(2) Through mixing is necessary to insure uniformity.

(3) Presence of controlled amount of water is necessary before compacting action can produce maximum density. About 8%- 12% of water needed.

(4) Should have completed and stufficient compaction of base course before adding surface course, to reduce movement in the base course.

(5) Local materials can be used if properly proportioned.

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State Highway Commissioner

Project
No. _____

RESEARCH DIVISION

Date 5/1/40

ABSTRACTS

Subject: Stabilization of Soils.

Purpose: Study on Research Problem.

Reference:

Author: D. M. Burmistuer

Title: Essential Consideration in Stabilization of Soils.

Source: American Society of Civil Engineers Proceedings.

Date: April 1938

Volume and page: Vol. 64, pp. 792 - 97

Contents:

Article contains a discussion of the essential qualities of soils for stabilization, and also a number of physical relation that are fundamental.

Some of the physical relations considered are, fineness, grading, plastic characteristics, coarse fractia of soil and clay content. There is also a general discussion on compaction tests and the grain size determination.

Part VI

BIBLIOGRAPHY

Periodicals

1. "Chemical Products and Highway Progress", by T.W. Delahanty, "Chemical", January 12, 1931.
2. "Use of Calcium Chloride in Construction and Maintenance", by H.F. Clemmer, "Roads and Streets", December 1932.
3. "Road Stability Using Calcium Chloride", by H.F. Clemmer, "Roads and Streets", May 1933.
4. "Stabilization of Low Cost Roads by Calcium Chloride", by C.A. Hogentogler, Jr., "Roads and Streets", October 1933.
5. "Chemical 'Rain Maker' Helps Modern Highways", "Scientific American", September 1930.
6. "Soil Concrete", by R.A. Giddings, "Chemicals", September 18, 1933.
7. "Chemicals in Highway Construction", "Chemicals", January 18, 1933.
8. "Low Cost Stabilized Road Construction in Onondaga County, New York", by R.B. Traver, "Roads and Streets", March 1934.
9. "Method and Cost of Stabilized Gravel Roads in Michigan", by Walter O. Dow, "Roads and Streets", May 1934.
10. "Methods for Prevention of Road Failures Due to Frost", by H.H. Miller and D.N. Smith, "Roads and Streets", June 1934.
11. "Stabilization of Gravel Roads in Onondaga County, New York", by R.B. Traver, "Engineering News Record", December 2, 1933.
12. "Maintenance Methods of Stabilized Gravel Roads", by B.C. Tiney, "Engineering News Record", November 16, 1933.

13, 14, 15 and 16 - "Theory of Soil Stabilization" (four parts), by W.R. Collings and L.C. Stewart, "Engineering News Record", May 24, 1934, June 7, 1934, June 14, 1934 and June 21, 1934.

17. "Salt Stabilized Road Practice Developing Rapidly", "Engineering News Record", July 4, 1935.

18. "Premixed Stabilized Soil for Road Surfaces", by L.C. Stewart and S.J. White, September 19, 1935.

19. "Practical Soil Stabilization", by C.A. Hogentogler, "Roads and Streets", March 1935.

20. "Progress in Road Stabilization", by Fred Burggraf, "Roads and Streets", April 1935.

21. "Stabilized Surface Methods and Costs", by J.H. Barr, "Engineering News Record", June 27, 1935.

22. "Stabilized Soil Road Maintenance", by H.G. Sours, "Engineering News Record", June 27, 1935.

23. "Plant Mixing of Stabilized Soil Road Surfacing Materials", by L.C. Stewart and S.J. White, "Roads and Streets", November 1935.

24. "Experimental Stabilization in Ohio", by J.W. Reppel, "Roads and Streets", December 1935.

25. "Use of Rock Salt in Stabilized Road Construction", "Roads and Streets", August 1935.

26. "Plant-mixed Stabilized Construction in Illinois", by J.C. Black, "Roads and Streets", August 1936.

27. "Stabilized Road Surfacing in Ohio", by S.O. Linzell, "Roads and Streets", November 1936.

28. "Stabilization of Soils", by H. F. Clemmer, "Roads and Streets", December 1936.

29. "Stabilized Base Construction", by A.E. Stoddard, "Engineering News Record", January 28, 1937.

30. "Methods and Cost of Road Stabilization in Minnesota", by L.L. Allen, "Roads and Streets", March 1937.

31. "Stabilized Soil Roads", by C.A. Hogentogler and E.A. Willis, "Civil Engineer", December 1935.

32, 33, 34, 35, 36 and 37 - "Soil Stabilization" (six parts), by V.J. Brown, "Roads and Streets", 1937.

38. "Production and Use of Stabilized Maintenance Materials in Southern Michigan", by J.C. Black, "Roads and Streets", June 1938.

39. "Graded Soil Mixtures for Road Surface and Base Courses", by E.A. Willis, "Roads and Streets", January 1939.

40. "Essential Consideration in Stabilization of Soils", by D.M. Burmister, "American Society of Civil Engineers", April 1938.

Bulletins

1. "The Stabilizing Effects of Calcium Chloride", Calcium Chloride Association, April 1938.

2. "Calcium Chloride Association News", January and February 1940.

3. "The A B C's of Soil Stabilization" by A.R. Smith

4. Highway Research Board, Progress Report of Project Committee on Stabilized Soil Road Surfaces.

5. "Low Cost Roads Stabilized with Aggregates, Binder Soil and Calcium Chloride", by Calcium Chloride Association, Bulletin No. 25, 1939 Edition

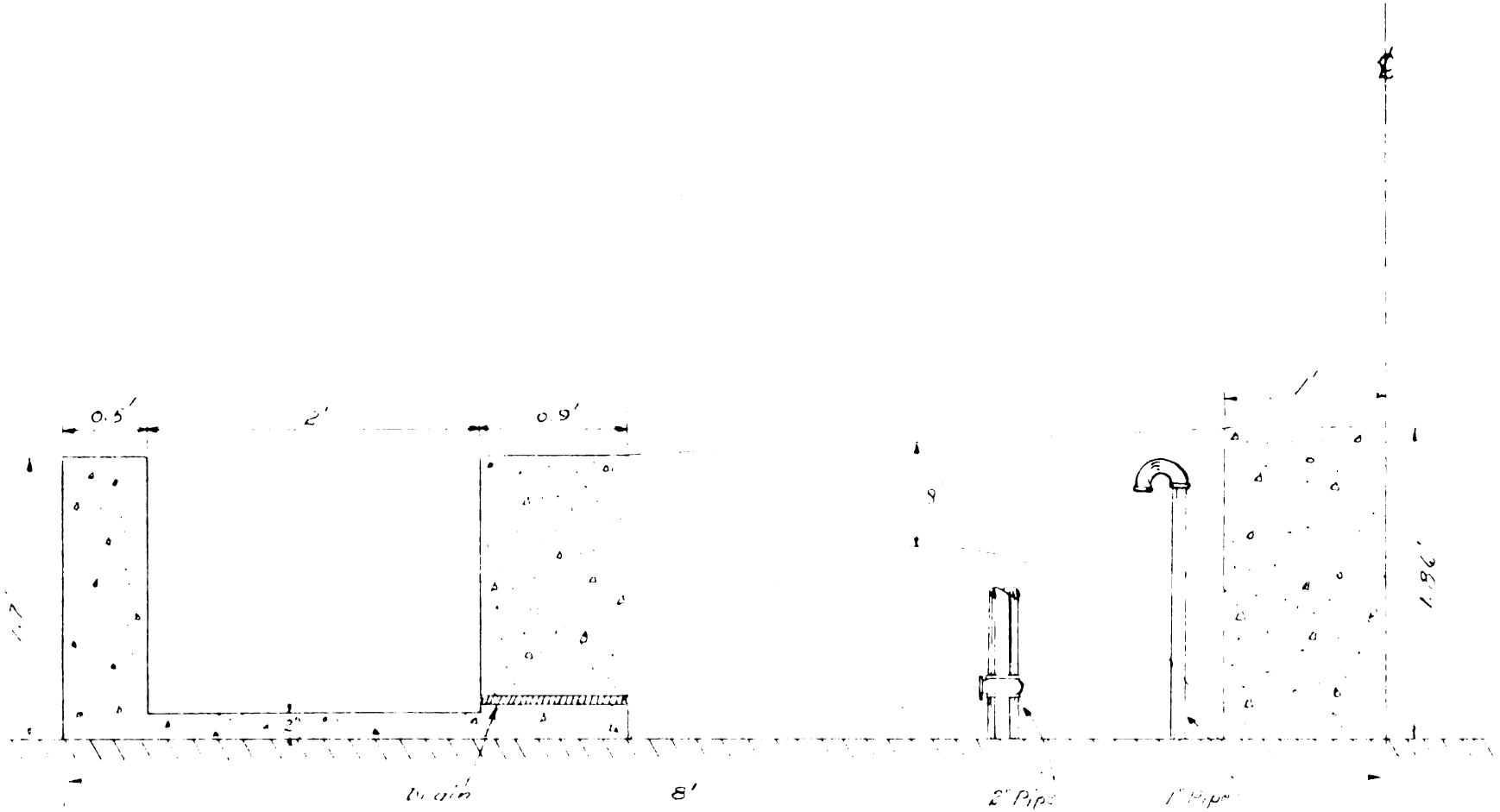
6. "Effects of Quality of Clay Soil on Soil Mortar", by R.W. Miller, Columbia Alkali Corporation, Proceedings of Sixteenth Annual Meeting of Highway Research Board, November 1936.

7. "Stabilization with Calcium Chloride", by Fred Burggraf, Calcium Chloride Association, Reprint No. 145, March 1939.

Books

1. Soil Mechanics and Soil Stabilization, Proceedings Eighteenth Annual Meeting, Highway Research Board 1938, Part II

Part VII



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