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AN INVESTIGATION OF THE USE
OF EMULSIFIED ASPHALT WITH
NATURAL SOIL

THESIS FOR THE DEGREE OF B. S.

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1933

THESIS

Road materials

Civil engineering

Highway engineering

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At this time we wish to take the opportunity to thank Mr. E.A. Finney and the American Bitumuls Company for the guidance and materials that were used in this investigation.

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J. L. Scott

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An Investigation of the Use of Emulsified
Asphalt with Natural Soil

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

By

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THESIS

INTRODUCTION

The present economic conditions of today has brought about extensive research in the line of cheaper roads. The cost of construction of asphalt roads in the past has been greatly encumbered with the increasing high cost of shipment of materials. It is thru this feature of the construction which we aim to strick our blow. It is our aim to take the materials on hand (natural soil) and by proper amounts of an emulsified asphalt, with with mixed-in-place construction, construct a cheap durable road. We intend to limit our investigation to Michigan, although it is the poorest state in the lot because of its abundant supply of natural gravel beds. After studying a surface map of this state we think that this type of construction is feasible even in Michigan. We do not intend to replace the high cost concrete roads, of which Michigan has some 80,000 miles, but to cover the so called township or secondary roads, of which she has about 60,000 miles that are in a very deplorable condition. One of Michigans leading industries is- its tourist trade and it is an undisputable fact that good roads would further the betterment of this industry.

Before going into the effects of emulsions on soil we would like to site some comparative studies and investigations that have been tried with soils.

Sand and Clay are two of the most widely distributed materials, and sand clay roads have been constructed in

many parts of the country under various conditions. It is desired to determine under what conditions they have proven most successful and whether it is practical, when suitable sands and clays are close at hand, to use sand clay mixtures not only as a wearing surface for light traffic roads, but also as a subgrade for higher types of pavement where the natural foundations are inadequate.

If a road is constructed of a sandy soil, it is fairly stable during wet weather but is very unsatisfactory in dry weather. The sand, which consists of small particles of rock has in itself very little power of cementation due to the fact that it undergoes practically no further decomposition under weathering. When moist, however, each sand grain is surrounded by a film of water which possesses a small binding power. This, together with the mechanical bond existing between the particles, produces a mass that is firm and stable.

On the other hand, if the natural soil is clay, it produces a road that is hard and compact during dry weather but becomes practically impassible in wet seasons. Clay, which is composed of small particles of stone dust has practically no mechanical bond but does possess cementing properties. This is especially true when the clay is in a rather dry condition. When wet, it becomes plastic, sticky or slushy depending upon the amount of water present.

A road surface consisting of a mixture of sand and clay combined in proper proportions, has been found to possess the resisting powers of the sand in wet seasons and the

cementing powers of the clay in dry season. The term " sand clay road" is applied to an earth road which has surfaced w with especially selected or prepared earth containing sand and clay combined in such proportions as to increase the resistance of the road to wear.

The theroy of a sand clay mixture is that the sand grains shall be in contact and interlock with just sufficient clay to fill the voids, hold the sand particles together and prevent disintegration in dry weather. The road receives its stability from the sand and must contain enough of this aggregate to support the traffic and to resist grinding and crushing action. The purpose of the clay is to act as a binder for the particles of sand, and the use of a proper amount of clay is absolutely essential if this type of road is to be a success. If an excess of clay is used in the mixture the grains of sand, which are forced out of contact with other. are free to move about in the mass so that they offer no more resistance to pressure than if the entire mass were made of clay. If an insufficient amont of clay is present, the mixture will lack binding power and will disintegrate.

It was with the intent of widening this limit of proportion that a foreign material was sought that would both waterproof and increase the stability of such a mix.

Because of the extensive application of surface treatment to the construction of low cost roads and the need for futher information on this subject, representatives

of the tar industry and the Bureau of Public Roads have recently made a field and laboratory study, in North Carolina of surface treated roads on which tar was used. The particular type of treatment consists essentially of the application of a light tar to the untreated road or prepared base followed by an application of hot tar with a cover of mineral aggregate. A third application of tar, sometimes called the seal coat is applied with a mineral aggregate cover after the surface has been subjected to traffic for a period of time. This method of treatment is designed to provide a wear-resisting surface which will adequately protect the base from deterioration and which can be economically maintained in a satisfactory condition.

The development of the double surface treatment as practiced in North Carolina resulted from early experiments in which a light tar was used on gravel or macadam bases. These tar-treated surfaces were very satisfactory for some time, as the tar penetrated into the road, allaying the dust and producing temporarily a bonded surface. However, under summer conditions, these surfaces disintegrated under traffic and only by repeated re-treatments could the road surface be kept in good condition.

Later, more viscous tars applied hot were used. It was found that these hot tars produced a more durable surface on clean, hard bases but would not penetrate any existing dust film on the road. Because of lack of bond with the base

the road surfaces often corrugated badly or were picked up by traffic.

In order to obtain the advantages of both materials, the double surface treatment was developed, in which cold application tar was used as a prime and a hot application tar for the second coat. In this way a wearing surface of greater thickness and stability was developed, which did not pick up under traffic but remained plastic and smooth under a wide range of weather conditions. Later, this same method of treatment was applied to topsoil and sand clay surfaces.

As a result of this survey the following conclusions seem warrented:

Surface treatment provides a satisfactory low-cost waer-ing surface on several types of bases.

Surface treatment has the advantage over the thicker surfaces mates in that it is more pliable and can therefore adjust itself to the movement on a flexible base with a ~~minmun~~ amount of cracking.

New roads or base construction should be subjected to traffic for some time before being surface-treated, in order to produce adequate compaction and to determine the suitability of the base for treatment. Compaction under traffic is valuable as a means of detecting an excess of plasticity in the base, a condition which should be corrected.

In order to avoid failures in the surface treatment resulting from unstable bases, research should be directed

toward finding a means of reducing the plastic properties of the clay present, particularly in the natural soil.

A priming application is desirable as a final preparation of the base, not only to stabilize and waterproof the top but also to insure a bond between the base and the surface mat.

Tar of light consistency, because of its excellent penetrating and binding properties, makes a very satisfactory prime or stabilizing material.

Hot application tars are more satisfactory for the second application medium and heavy cold application tars have many advantages in seal and re-treatment work.

A tough aggregate should be used as a cover material in order to reduce crushing under traffic to a minimum so that the original texture of the surface and the stability of the mat may be retained.

Very fine sand or roadside material should not be used for blotting purposes because it has a tendency to produce either a brittle or a unstable surface.

A seal application is highly desirable as the final step in insuring a dense and waterproof surface.

Cold application tar is preferable to hot application tar in re-treatment work because it permits dragging and blading of the cover stone to produce a smoother surface. The finished road shows less tendency to bleed and is likely to retain its original texture for a longer time.

The principal requirement of bases fpr surface treatment is that they shall neither soften nor undergo appricable change in volume with current changes of climate or ground moisture conditions.

Soil tests serve to disclose those characteristics of the base material which materially affect the preformance of the surface treatmeht. In this connection the mechanical analysis is of asistance but by itself is not adequate for distinguishing good ftrm poor base material.

Determine the suitability of base soils according to their physical characteristics instead of by rule of thumb methods may show that the material road soil, either alone or in some combination with other local soils, will serve as well or better than the more expensive base materials of recognized value.

A content of clay binder as low as 5 % has proved satisfactory in surface-treatment bases. However, clay with capillary and cohesive properties as high as thoes of average or "statistical" soils and shrinkage properties considerably lower, may not prove detrimental in base mixtures even where present in amounts as great as 20 percent of highly plastic clay and all cases of highly micaceous material should be regarded with suspision.

Some methods of correcting insatisfactory base material may often prove desirable. Fine sand is used satisfactorily as an administure to reduce clay content. Coarse material has not much value for this purpose and may be used to better

advantages as a top course. The best method and material to use in stabilizing a soil will depend upon the soil character of the particular soil or base material. Often a thin top course of suitable material will increase the stability of the base sufficiently. In other cases, it may be advantageous to use a tar primer or to mix tar into the base.

Very similar investigations have been made with natural soil as a base with oils, cut-backs and very recently with calcium chloride. The results being mainly that stability of the soil must first be reached and then the mixture water-proofed.

In all these investigations asphaltic emulsions seem to be left in background supposedly because of their newness in the field. However, we think that emulsions' advantages over these others as follows:

An emulsion saves the cost and inconvenience of heating, eliminates the danger of over heating and makes possible application by inexpensive equipment.

Its high penetrating quality permits a high percentage of aggregate without affecting the proper coating with asphalt.

Its high penetrating quality enables the asphalt to infiltrate to the very bottom of the coarse.

Used cold, it is practically the same temperature as the aggregate to which it is applied; hence, there will be no sudden congealing to affect its infiltration.

It may properly be used on moist or wet aggregate eliminating many wet weather delays.

The likelihood of excess asphalt or fat spots is minimumized - thoroughly non-skid surfaces are characteristics of emulsion construction.

It permits the use of a wide variety of aggregate that would not always be suitable for binding by penetration methods.

In light surface dressing work it sets quickly so that there is no throwing or spattering upon cars using the surface immediatlly upon completion.

With these advantages in mind, we set about to investigate the feasibility of mixing an emulsion with various proportions of sand, clay and silt that will resist weather and be suitable for a secondary road.

THE INVESTIGATION

Our first problem was to find suitable soils that would give us the various proportions of sand, clay and silt that we thought might apply. Instead of trying to find the proportions as they occurred in nature we attempted to find pure samples of each. Then we could mix the soils as we saw fit.

In this attempt we were fairly successful for with our finds we could get a range that the soil would occur in nature in large quantities.

A mechanical analysis of the soil was run by the hydrometer method under the directions of a bulletin by G.J. Bouyoucos of Michigan State College.

The mixing of the soil with the emulsion we divided into two parts:

Part one- Emulsion HRT was used and all samples were mixed dry. The samples were mixed by hand with the asphalt content varying from 18 to 7 percent, also the amounts of sand clay and silt were varied as much as possible. The mixed sample was placed in steel cylinder six inches in diameter and six inches high. Enough material (1200 grams) was added to turn out a sample about one and one-half inches thick. Fifteen hundred pounds pressure was applied to the sample which is equivalent to an average size road roller. (this pressure was pounds per square inch). After the sample was pressed it was removed from the cylinder and

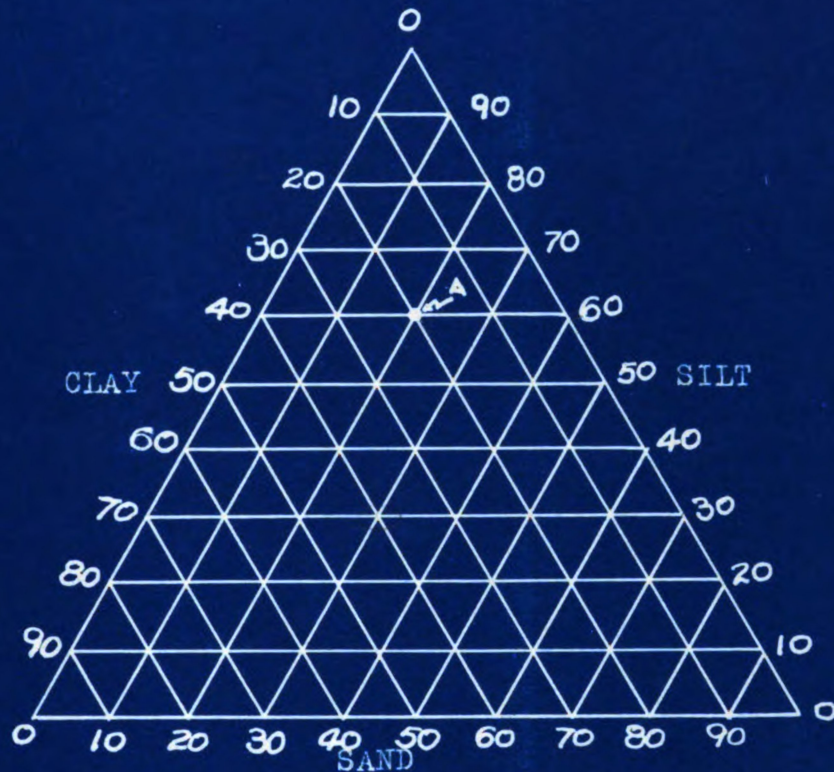
allowed to stand in the air for seven days. On the seventh day four briquettes were cut from the sample, three were tested for shear and the other was placed in a water bath for a week - the absorption and the deterioration noted on each day. A penetration test was tried by placing a one inch square area round rod in the center of each sample and applying a five hundred pound load, and measuring the depth of penetration measured. This test was found to vary directly with the shear and as it interfered with the cutting of the briquettes it was abandoned.

Part two- Emulsion XPM was used for this part and the procedure was the same except that the samples were mixed wet - that is, enough water was added after the sample had been weighted to just moisten the mixture- and the samples were left set twenty-four hours before they were pressed. The range of the asphalt and the impractical mixtures ^Cwere cut down from observations taken on part one.

The shear test was run by placing the briquettes in a cylinder with an inch and one-half knife-edged throat and the pressure noted at which the briquette pushed through the throat.

All samples of soil were ^{thoroughly} dry and screened through a 10 mesh sieve before being used in the mixtures.

TRIAXIAL DIAGRAM



Explanation of Diagram

The object of this diagram is that any point inside the triangle, will - if the percentages of sand, clay and silt are added- be equal to 100 %. To read the diagram place the base in front of you with the point away and read the figures on the right. Thus - point A is 60 % sand, 20 % clay and 20 % silt.

PART ONE - EMULSIFIED ASPHALT HRT GRADE

Emulsified Asphalt HRT Grade shall be a homogeneous emulsion of asphalt and alkaline water containing a total of not more than 1 % of emulsifying and stabilizing agents. It shall be miscible with pure water in all proportions and shall show no separation of asphalt after thorough mixing, within thirty days after delivery, provided separation has not been caused by freezing. It shall conform to the following requirements:

Viscosity - Saybolt Furol - 60 cc. at 25° C.
(77° F. - - - - - not more than 100 sec.

Miscibility - - - - - No appreciable separation in 2 hrs.

Coating - It shall not show appreciable separation when mixed with clean, wet stone for three minutes and shall coat the stone thoroughly.

Specific Gravity - 25°/ 25° C. (77°/77°F.) Not less than 1.0

Residue at 163° C. 3 hrs. 50 gms. - - - Not less than 55 %
more

Settlement - - - - - Not less than 3 %

Demulsibility - - - - - Not more than 20 %

The petroleum asphalt prior to emulsification shall conform to the following requirements:

Penetration at 25° C. (77° F.) - - - - - 150 to 200

Solubility in carbon disulphide Not less than 99 %

Loss at 163° C. 5 hrs. - - - - - Not more than 3.5 %

In lieu of the requirements for "Residue at 163° C.", at the engineer's option, there may be substituted the following requirements:

Distillation by Weight:

Oil distillate to 260° C. (500° F.) Not more than 2%
 Residue at 260° C. - - - - - Not less than 55%
 Penetration Residue at 25° C. 100 to 200
 Ash - - - - - Not more than 1.5%

The following samples of soil were used in the mixtures:

SAND

1	2
sand - - - - 96.0 %	sand - - - - 80.0 %
clay - - - - 3.0 %	clay - - - - 15.0 %
silt - - - - 1.0 %	silt - - - - 5.0 %

CLAY

1	2
sand - - - - 56.0 %	sand - - - - 17.0 %
clay - - - - 26.0 %	clay - - - - 65.0 %
silt - - - - 18.0 %	silt - - - - 18.0 %

3

sand - - - - 9.0 %
 clay - - - - 67.0 %
 silt - - - - 24.0 %

Number 3 clay was composed of a very fine clay along with the indicated amount of silt. The actual amount of silt was well above the 24 % by seive analysis but in order to hold to the simple mechanical test the results left as appears.

Key for Part's One and Two Tables:

V = shear in pounds per square inch.

P = percent absorption

X = percent of asphalt by weight.

S = percent sand by weight.

C = percent clay by weight.

D = percent silt by weight.

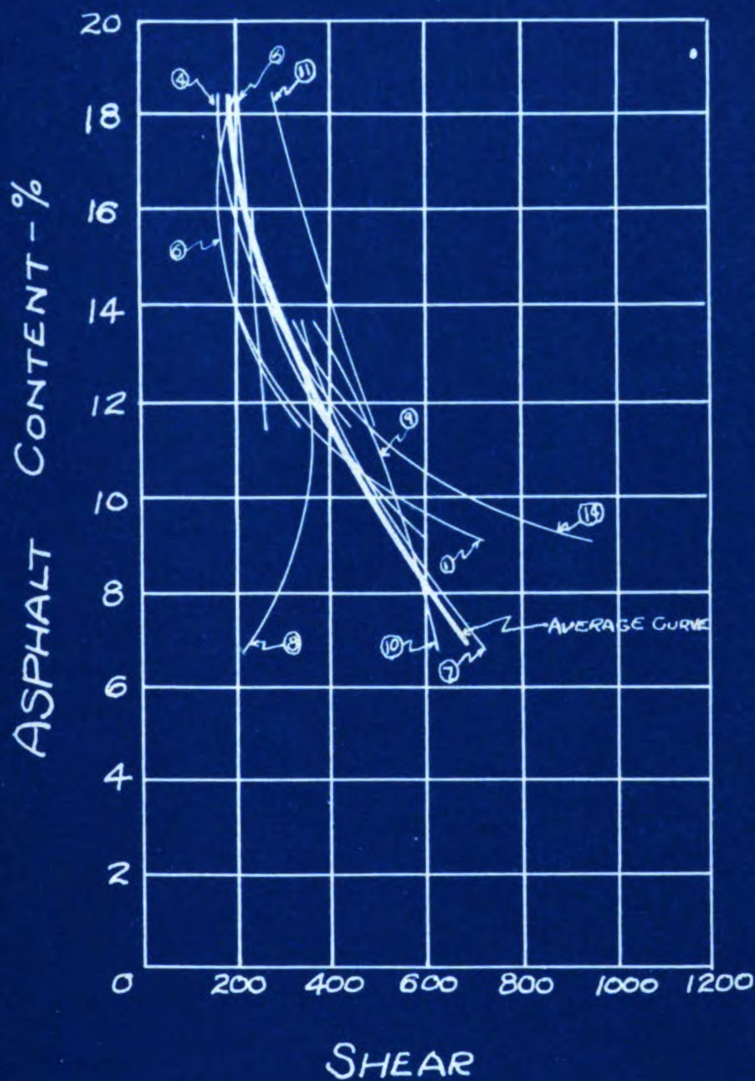
DATA FOR PART ONE

No.	A					B			
	S	C	D	V	X	P	V	X	P
1	82.5	10.8	6.7	332	16.0	5.4	222	13.7	9.0
2	56.0	29.0	19.0	303	16.0	5.6	222	13.7	3.6
3	80.0	15.0	5.0	206	16.0	8.2	256	13.7	8.7
5	76.0	14.5	9.5	200	18.4	8.2	222	16.0	8.7
6	69.3	18.4	12.3	194	18.4	7.0	166	16.0	7.5
7	62.5	22.3	15.2	355	13.7	7.5	413	11.5	
8	89.5	6.7	3.8	355	13.7		320	11.5	
9	66.0	20.3	13.7	222	16.0	7.0	268	11.5	7.4
10	86.2	8.7	5.1	376	13.7	6.9	486	11.5	7.6
11	17.0	65.0	18.0	486	16.0		423	13.7	
12	52.5	35.0	12.5	205	16.0			13.7	
13	63.1	28.8	8.1	340	16.0				
14	69.5	22.8	6.7	303	13.7	8.0	500	9.2	10.1
15	56.0	30.0	14.0m	245	13.7				
16	9.0	67.0	24.0	300	13.7				

DATA FOR PART-ONE CONT.-

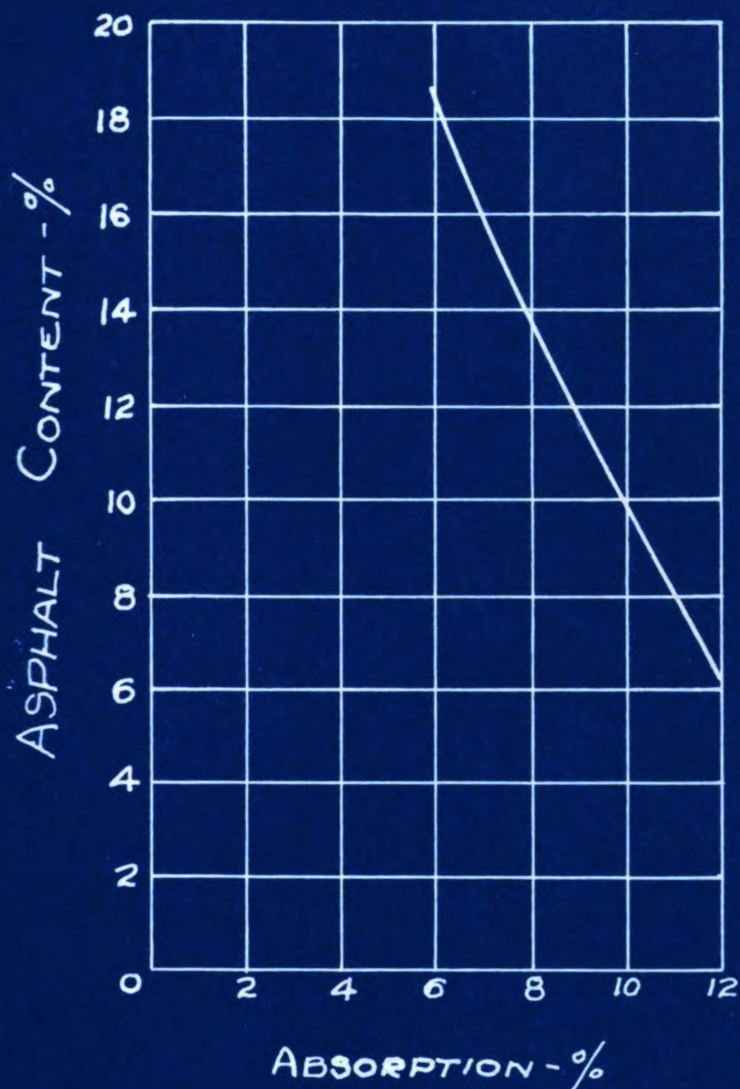
1	82.5	10.8	6.7	332	11.5	7.3	728	9.2	5.3
2	56.0	29.0	14.0						
4	80.0	15.0	5.0	425	11.5		175	18.4	5.5
5	76.0	14.5	9.5	222	13.7	7.2	255	11.5	6.5
6	69.3	18.4	12.3	280	13.7	8.0	388	11.5	8.5
7	62.5	22.3	15.2	607	9.2	7.2	710	6.9	
8	66.0	20.3	13.7	387	11.5	7.4	606	9.2	8.5
9	89.5	6.7	3.8	332	9.2		190	6.7	
10	86.2	8.7	5.1	547	9.2	7.8	610	6.9	
11	17.0	55.0	18.0	485	11.5	9.0	278	18.4	6.2
14	69.5	22.8	6.7	950	6.7				

- AVERAGE SHEAR CURVE



The numbers of curves are taken from table under Part-One. The heavy line representing the average shear for various amounts of asphalt.

AVERAGE ABSORPTION CURVE



This is an average curve taken from
table under Part-One

PART-TWO-EMULSIFIED ASPHALT XPM GRADE

Bitumuls XPM shall be homogeneous emulsion of asphalt, water, emulsifying and stabilizing agents. It shall be miscible with pure water in all proportions and shall show no separation of asphalt, after thorough mixing, within thirty days after delivery, provided separation has not been caused by freezing. When tested as hereinafter specified, the emulsions shall confirm to the following requiring:

Viscosity - Saybolt Furol - 60 cc at 25° C.

Not more than 60 sec.

Miscibility - - - - No appreciable separation in 2 hrs.

Mixing - - - - - Break, not more than 2 %

Total combined amount of all saponifiable substances, including petroleum

acids - - - - - Not more than 1 %

Residue at 163° C. 3 hrs, 50 gms. Not less than 55%

Settlement, 10 days - - - - - Not more than 3 %

Demulsibility - - - - - Not more than 1 %

The residue obtained from the test at 163°C. shall conform to the following requirements:

Penetration at 25° C. - - - - - 200 to 300

Solubility in carbon disulphide - Not less than 95%

Ductility at 25° C. - - - - - Not less than 60 cm.

Ash - - - - - Not more than 3 %

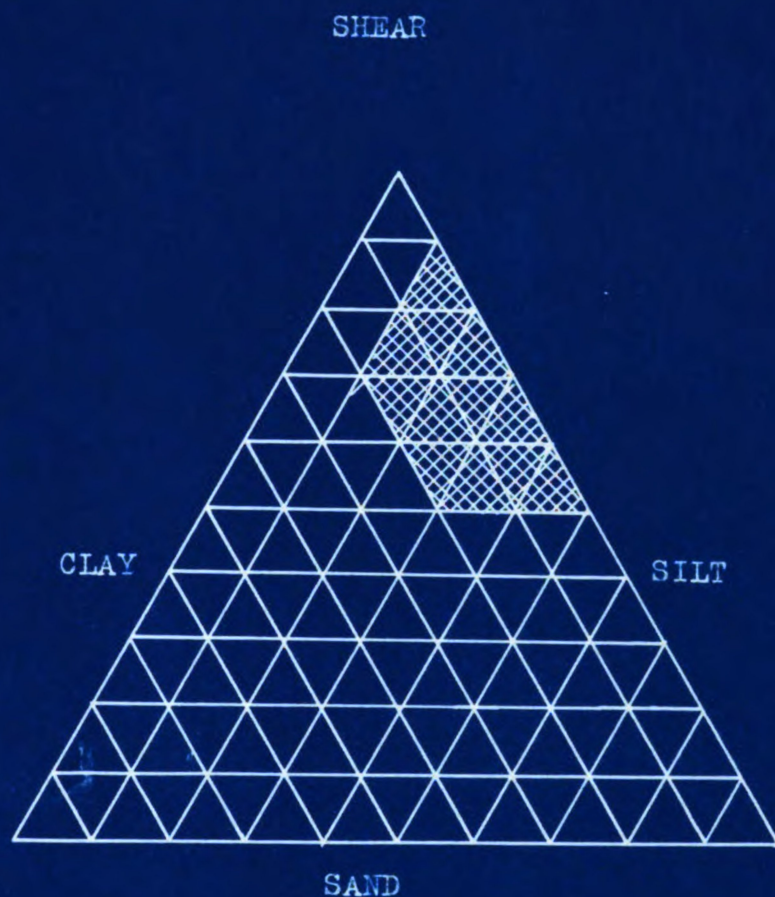
DATA FOR PART- TWO

no.	A						B		
	S	C	D	V	X	P	V	X	P
1	82.5	10.8	6.7	682	11.5	2.0	714	9.2	4.0
2	69.5	22.8	6.7	576	11.5	5.4	.		
3	80.0	15.0	5.0	334	11.5	2.9	705	9.2	9.8
5	76.0	14.5	9.5				705	9.2	5.8
6	52.5	35.0	12.5	622	11.5	6.3	832	9.2	7.3
7	63.1	28.8	8.1	554	11.5	6.2	900	9.2	8.3
8	79.3	12.6	8.1	555	11.5	3.0	693	9.2	2.9
9	48.5	40.0	11.5	450	11.5	13.8	576	9.2	12.7
10	56.5	34.0	9.5	594	11.5	7.2	770	9.2	12.0
11	49.5	32.4	18.0	385	11.5	8.6	512	9.2	8.7
12	55.2	34.3	10.5	535	11.5	6.9	740	9.2	9.2
13	44.5	41.0	14.5	370	11.5		432	9.2	
14	53.7	35.9	10.4	535	11.5	9.7	576	9.2	
15	68.2	23.6	8.2	450	11.5	8.0	357	9.2	7.6
16	64.4	27.4	8.2	385	11.5	9.6	532	9.2	11.5
17	74.2	19.0	6.8				664	9.2	

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
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753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768
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777	778	779	780	781	782	783	784
785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808
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857	858	859	860	861	862	863	864
865	866	867	868	869	870	871	872
873	874	875	876	877	878	879	880
881	882	883	884	885	886	887	888
889	890	891	892	893	894	895	896
897	898	899	900	901	902	903	904
905	906	907	908	909	910	911	912
913	914	915	916	917	918	919	920
921	922	923	924	925	926	927	928
929	930	931	932	933	934	935	936
937	938	939	940	941	942	943	944
945	946	947	948	949	950	951	952
953	954	955	956	957	958	959	960
961	962	963	964	965	966	967	968
969	970	971	972	973	974	975	976
977	978	979	980	981	982	983	984
985	986	987	988	989	990	991	992
993	994	995	996	997	998	999	1000

DATA FOR PART-TWO CONT. -

no.	C					
	S	C	D	V	X	P
1	82.5	10.8	6.7	1040	6.7	2.8
2	69.5	22.8	6.7	1180	6.7	10.5
3	80.0	15.0	5.0	705	6.7	11.8
5	76.0	14.5	9.2			
6	52.5	35.0	12.5	1280	6.7	9.0
7	63.1	28.8	8.1	1450	6.7	8.7
8	79.3	12.6	8.1	940	6.7	8.4
9	48.5	40.0	11.5	1040	6.7	10.5
10	56.5	34.0	9.5	1150	6.7	13.0
11	49.5	32.4	18.0	640	6.7	
12	55.2	34.3	10.5	1150	6.7	.9.5
13	44.5	41.0	14.5			
14	53.7	35.9	10.4	680	6.7	9.5
15	68.2	23.6	8.2			
16	64.4	27.4	8.2	834	6.7	12.3
17	74.2	19.0	6.8			



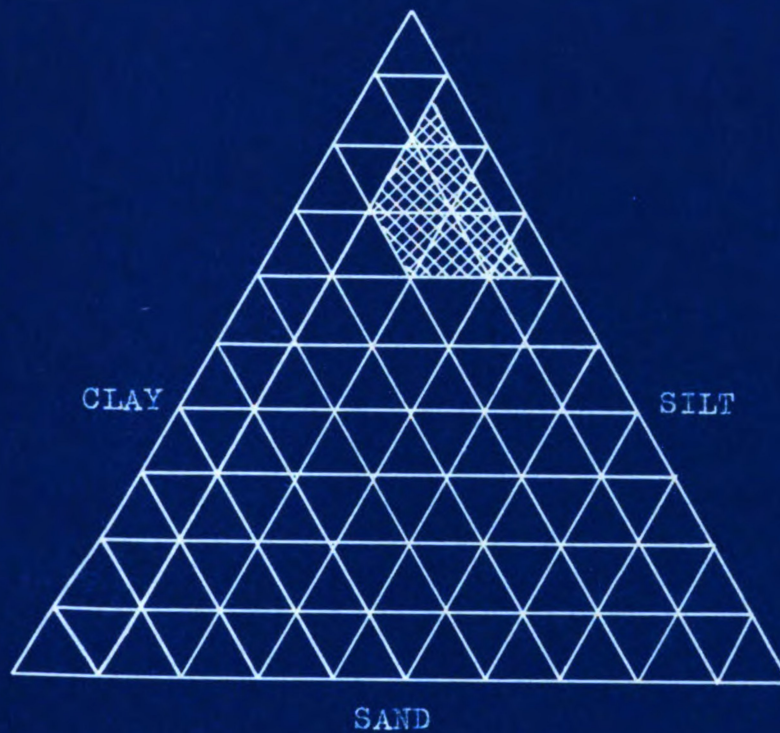
The shaded area represents the mixtures whose shear averaged 500 # / sq. in.

If the asphalt content is held constant at 11.5 % by weight.



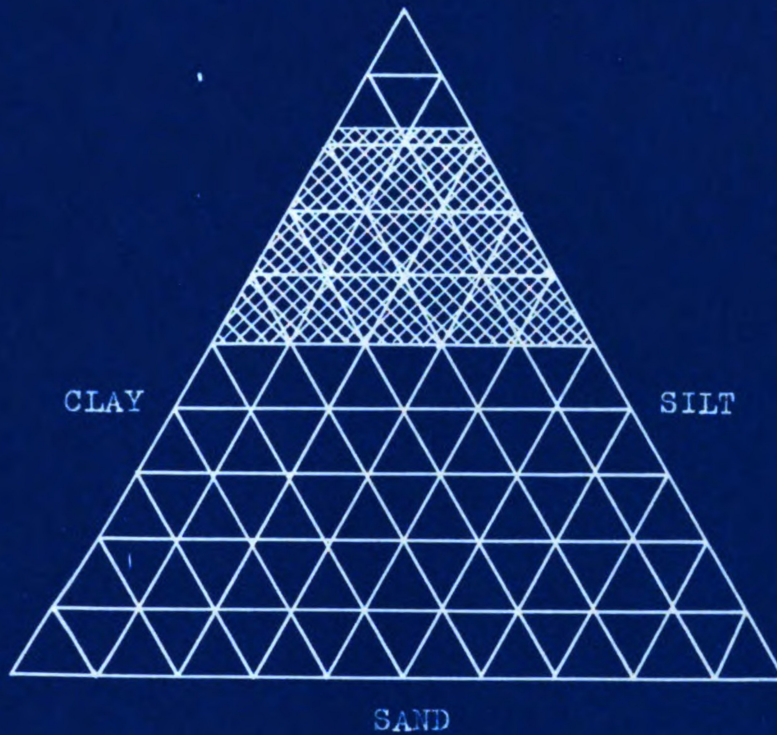
The shaded area represents the mixtures
whoes shear averaged 700 # / sq. in.
If the asphalt content is held constant
at 9.2 % by weight.

SHEAR



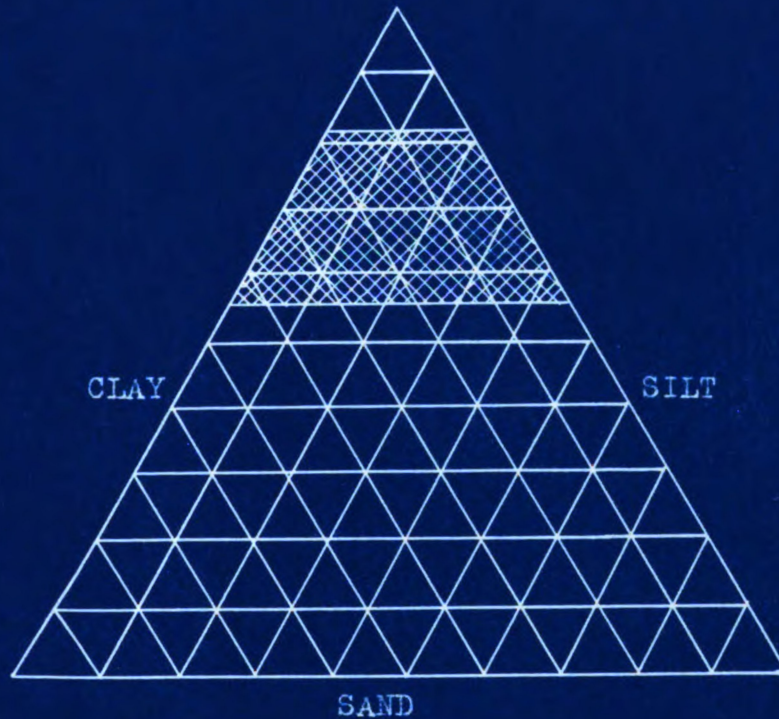
The shaded area represents the mixtures whose shear averaged 1000 # / sq. in. If the asphalt content is held constant at 6.7 % by weight.

DETERIORATION



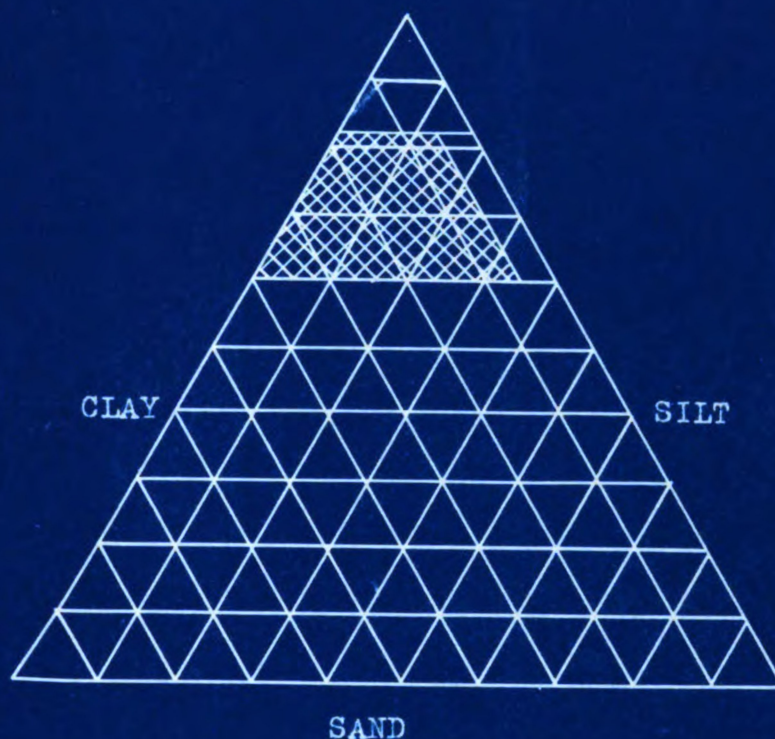
Shaded area represents mixtures that will not deteriorate under excess water conditions if the asphalt content does not go below 11.5 % by weight.

DETERIORATION



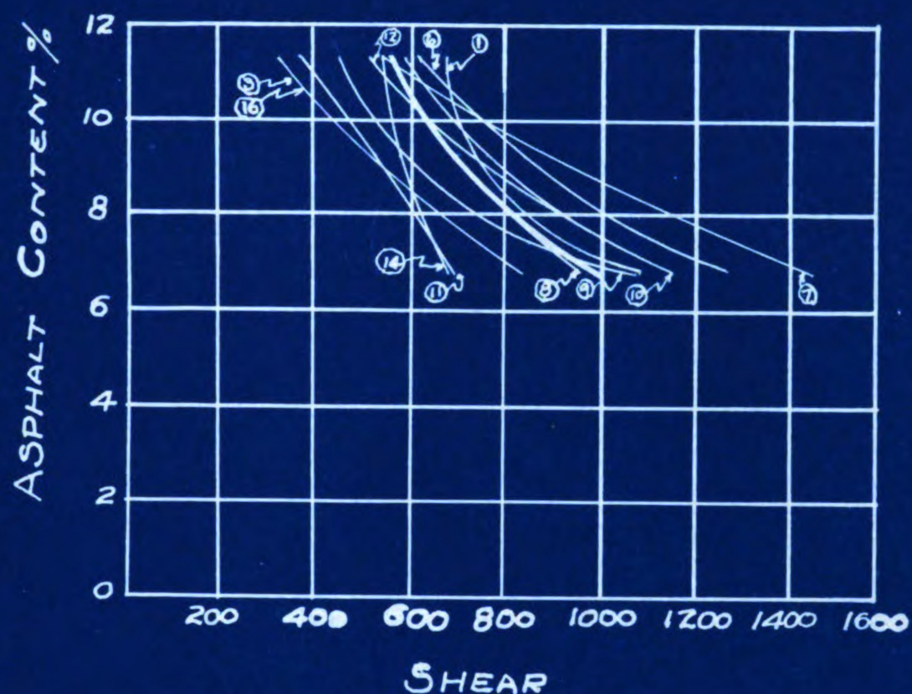
Shaded area represents mixtures that will not deteriorate under excess water conditions if the asphalt content does not go below 9.2 % by weight.

DETERIORATION



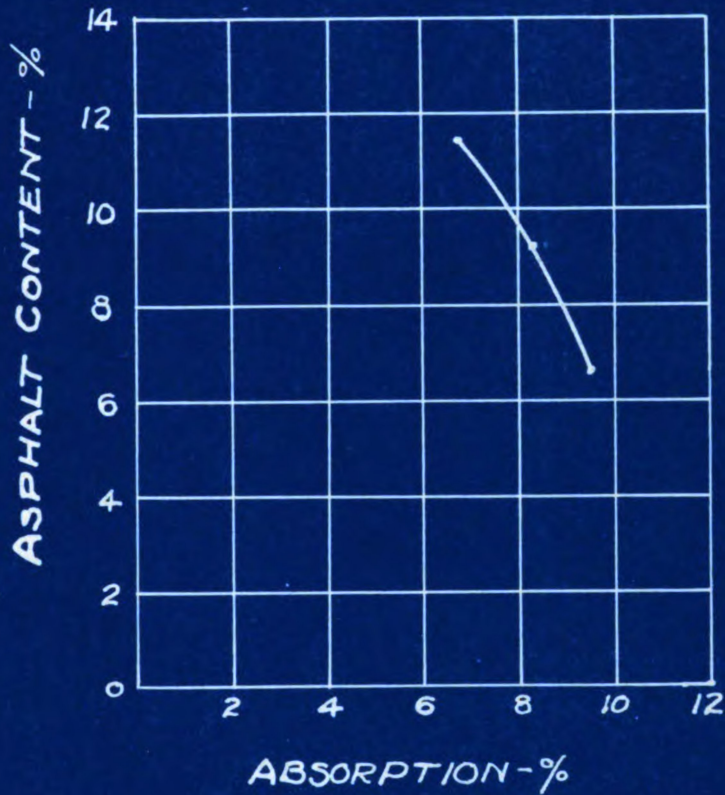
Shaded area represents mixtures that will not deteriorate under excess water conditions if the asphalt content does not go below 6.7 % by weight.

AVEPAGE SHEAR CURVE



The numbers of curves are taken from table under Part-Two. The heavy line representing the average shear for various percentages of asphalt.

AVERAGE ABSORPTION CURVE



This curve was taken from the data as indicated and plotted as an average curve. For detail results see the table under Part-Two.

CONCLUSION

As a result of this investigation we feel that the following conclusions are warranted:

1. That the proper proportions of sand, clay and silt will not disintegrate under extreme water conditions, with the proper amounts of emulsified asphalt.

2. That a mixture can be obtained with proper proportions of sand, clay and silt and emulsified asphalt which is suitable for secondary road purposes.

3. That any mix above 82.5 % sand by weight was unstable and if the sand content is below 50 %.

4. That any sample with clay content more than 45 % by weight is unstable.

5. The maximum amount of shear and least amount of water absorption is obtained when the samples are mixed wet and left stand for a day before compressing or rolling.

6. A study of the diagrams on deterioration will show the limits that are practical.

7. A study of the diagrams on shear will show what limits of sand, clay and silt are practical.

8. The standard limits (7 to 12) of asphalt percent are the same as in other asphalt products.

9. In low percentage asphalt content, silt content over 6 % is necessary to make the sample waterproof.

10. Silt content is not injurious except when there is not an sufficient amount as in no. 9.

11. That the soils of Michigan are adaptable to this kind of mixture.

12. As a proposed method of construction of such a type of road, We think the following procedure could be carried out:

Trench out to a depth of about four inches and lay forms. Apply a light quick setting penetration emulsion or a penetration tar to the subgrade. With a common concrete mixer mix the soil and the emulsion. The materials could be taken from two borrow pits or one if the content was right. A rough estimate could be made of the proportions by part loads or so many dippers full. It could be dumped directly into the mixer and the emulsion could be added the same as the water is added to the present concrete mixer. The mixture could be finished off by a concrete finisher or a common screed and allowed to set until the next day or whenever it set up. It could then be rolled and ready for use.

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