THE PROPER GRADING OF AGGREGATE FOR USE WITH BITUMINOUS CUT-BACKS

THESIS FOR THE DEGREE OF M. S.

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THESIS

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THE PROPER GRADING OF AGGREGATE FOR USE WITH BITUMINOUS CUT-BACKS

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INTRODUCTION

One of the greatest problems facing the highway builders of today is the economical construction of durable hard surfaces for our highways, - also the resurfacing of some of our old highways which have become very rough, and are a real menace to high speed traffic.

Many of these highways are on through routes carrying less than 1500 vehicles per day, excepting perhaps within a short radius of our larger cities. Most of our heavy traffic highways have been surfaced with high cost pavements, but the tremendous cost for this type of construction, together with the large mileage of unsurfaced highways has brought about a realization that we must construct less expensive roads for our lighter through traffic highways and secondary roads, if we are to even approach the resemblance of an adequate hard surface highway system.

One of the best ways to meet this problem is by utilizing the old stone, slag and gravel roads as a base, or by constructing inexpensive bases from suitable local aggregate and surfacing them with a low cost durable pavement.

The mixed-in-place surface, composed of stone, slag or gravel aggregate mixed with bituminous material gives an economical and extremely durable, smooth riding surface meeting the requirements for a serviceable low cost surface.

Each year an increased mileage of mixed-in-place surfacing has been constructed, and, because of its low maintenance cost this type of road mix is rapidly gaining favor with highway engineers throughout the country.

Standard gradings of the mineral aggregate have long been established for concrete construction and recently the Michigan State Highway laboratories at Ann Arbor have established a standard grading for the aggregate used with road oils.

It is the writer's purpose to establish such a standard for use with mixed-in-place or premixed cut-back asphalt.

HISTORY

Mixed in place construction is a new type evolved in the last few years and made possible by the development of heavy tractor grader and hauling equipment. This type of construction probably evolved from efforts made to drag surface treatments in order to make them smoother.

Various names have been given to this type of construction such as retread, oil processed roads, and even heavy surface treatments.

Obviously there is a wide variation in this type of construction both as to thicknesses and materials used. This variation extends from the lower limit of what is not much more than a dragged surface treatment of only a fraction of an inch in thickness to the upper limit of what is virtually an asphaltic concrete wearing surface from 2 to 3" inches in compacted thickness. The range for this type of construction then, will run from the surface treatment, or the or the mat or carpet coat to the cold pre-mix types, and the lines of demarcation between them are indistinct.

Some definition is desirable, particularly to mark the line between dragged surface treatments and "mixed in place" construction. A number of states are now requiring all surface treatments to be dragged. A suitable differentiation would be to call any work requiring dragging and rolling only a surface treatment; and any work requiring the use of grader blades or disc harrows or both, mixed-in-place or retread construction.

Mixed-in-place construction is that type which is mixed upon the surface of the road and any type that involves mixing the aggregates and bituminous material in a mixer belongs in the pre-mix group.

The mixed in place type may be divided into two groups, in respect to the source of aggregates, namely mulch treatments, and retreads.

Mixed in place
- Mulch
  - 1. No aggregate under 1/8"
  - 2. Considerable aggregate under 1/8"
- Retread

Mulch treatments are those involving the treatment of aggregates in the form of a mulch already on the road bed surface; and retreads are those treatments where the existing surface or base is swept clean of all loose materials. For retreads the clean surface of the road bed is primed with bituminous material before applying the aggregate, for mulch treatment the loose material is shot directly with bituminous material without first priming the underlying hard compacted material.

The mulch type may also be divided into two further groups as to the character of aggregates; one being the mulch of gravel or crushed stone free or almost free of any material under 1/8 inch in size, and the other being the mulch of gravel and sand with a considerable quantity of material less than 1/8 inch in size. This latter type will produce a sand asphalt or a closed type of mix similar to sheet asphalt or

asphaltic concrete such as the so called Topeka Mix, depending upon how little or how much material over 1/8 inch is in the aggregate. The first mulch group and the so-called retread will produce a surface similar to the mixed bituminous macadam or cold patch, or as it is sometimes called open mix type.

The definite advantage of mixed-in-place construction, over the earlier types of similar surfaces mentioned above, is that it can be and is constructed in many instances so as to produce a much smoother riding surface than any other type of bituminous surface. This development is of the greatest importance because of the doubling of the speeds of all of the motor vehicles traveling over roads in the past ten years. This smoothness of riding surface is produced by the heavy and long wheel base equipment now available for blading and dragging this mixed-in-place work.

The additional advantage of mixed-in-place construction, over these same earlier types, is cheapness of construction. Mixed-in-place construction can be built at less than half of the cost per square yard of any of these earlier types.

On dusty gravel and crushed stone roads of low construction cost and with maintenance costs increasing out of all proportion to the traffic increase, this type of construction has been successfully used to produce smooth, dustless, riding surfaces, fully equal from the standpoint of traffic to the best asphaltic types. Old worn waterbound

macadams have been rehabilitated as smooth modern type roads at a very low cost by this mixed-in-place or retread construction. Rough penetration macadam surfaces, the despair of the maintenance engineers for years, have been made comfortable good riding surfaces by the use of retreads, sometimes almost amazingly thin. As a more recent development, comes the use of this retread or mixed-in-place construction as a top course placed on crushed or knapped broken stone bases at half the cost of any other type of bituminous surface hitherto used.

Mixed-in-place construction has now been used in so many states and counties, and under so widely varying conditions that it will obviously be impossible to even mention all of them, and it will be necessary to limit the descriptions of those mentioned. As far as can be learned the first mixed-in-place construction was done in 1923 by Wisconsin on gravel roads. California and Oregon have constructed considerable mileages of oil processed roads or mixed-in-place construction since 1926. This construction has been applied to gravel and crushed rock roads, and has been of the mulch construction, the aggregates being either loose on the surface of the road, or the road surface being scarified to a sufficient depth to loosen it. New Mexico has recently adopted similar methods and up to the first part of 1931 had constructed 300 miles of oil processed roads at an average cost of about $2,100 per mile. The rate of application of bituminous material varied on this work from

1-¼ gallon to 2-¼ gallons per square yard; and the roadway materials were sandy gravels.

The Ohio Highway Department has provided mixed-in-place construction by the mulch treatment method on quite a mileage of gravel roads.

The Missouri Highway Department has used both the mulch and retread type of mixed-in-place construction, and also reports the use of finely ground flint aggregate mixed with stone and cutback asphalt to produce a mixed-in-place construction.

Macomb County in Michigan reports resurfacing gravel roads with an asphaltic mixture produced at county owned gravel pits.

The Tennessee Highway Department is constructing from 350 to 400 miles annually of a mixed-in-place, or re-tread type; and now has about 1600 miles of this type which has been placed on gravel, chert or traffic bound stone bases at an average cost of 30 cents per square yard. This work has taken about 3/4 gallon bituminous material and about 80 pounds of crushed stone or gravel, ranging in size from ¼ to 1¼ inches.

The South Carolina Highway Department has done some mixed-in-place construction on top soil roads.

During 1930 there was built in West Virginia 164 miles of mixed-in-place top course; ranging from thin re-surfacings to smooth up rough macadam to 2 inch top courses constructed of knapped or crushed stone bases. The cost of

this work was approximately $1,000,000. Of this mileage, 116 miles were built under contract and the rest was done by state forces. The bases on which this type of top was constructed included native gravel, Ohio River gravel, crushed stone, knapped stone, traffic bound stone, bituminous macadam and brick. The widths of construction varied from 16 to 20 feet. For aggregates crushed gravel, crushed stone and crushed slag were used, together with cutback asphalt and excellent results were obtained.

Another very valuable use found for the mixed-in-place or retread construction has been in the smoothing up of rough bituminous macadam roads. Some bituminous macadam roads were built on knapped stone base, similar to the sub-base construction, and were not originally built very smooth. This did not matter when average traffic speeds were from 20 to 25 miles per hour, but with the doubling of these speeds it has become important.

Experiences with the mixed-in-place process in the Western States have led engineers to the following conclusions;

1. The amount of oil necessary to give satisfactory surface depends largely on the grading and character of the aggregate and to some extent on the type of oil used. The finer the material the more oil is necessary, which is also the case when the aggregate is of a character which absorbs the oil. Generally the heavier the bituminous material the more of it is required. Allowance should also be made with

the use of cut-back materials for a certain per cent of loss of the solvent used.

2. The mixed-in-place method as constructed in the west gives unexcelled riding qualities to the surface.

3. This method of construction is adaptable to many types of aggregates and slow drying bituminous materials.

4. The results obtained compare favorably, under the best conditions, with those obtained with plant mixing using the same aggregate and oil.

5. The development of satisfactory portable road mixing equipment for handling the aggregate directly from the road windrow may be expected in the near future. This should still further increase the possibilities of the mixed-in-place method of construction for use with certain types of material which are not quite suitable for the present machine mixing.

6. The light oil mixed-in-place treatment is proving highly satisfactory in the arid and semi-arid sections, while in the colder and moister areas results have not been as favorable.

7. The character of the aggregate rather than any difference in the light oils is believed to be responsible for many rapid failures occurring, particularly under moist conditions. Preferential absorption of an appreciable portion of the aggregate for water as compared with oil may be the cause of these failures. It is felt that data

secured from the swell test and the emulsification test will aid in showing the suitability of the mineral aggregates for this type of construction and minimize the failures from this source.

8. Recent experimental work indicates that a heavy asphaltic oil or soft asphalt cement cut-back with a distilate, such as kerosene, naphtha, a combination of both or a suitable asphalt mixing emulsion, should be used in the mixed type where aggregate and moisture conditions are not highly favorable.

9. When the gravel or crushed stone road is stable and well bonded a surface treatment, using a hot application material, a quick drying asphalt cut-back or a suitable asphalt emulsion, should prove more satisfactory and economical than a light oil mix treatment. A considerable mileage of light oil mix surfaces has been built in the west where conditions were more suitable for the surface treatment type.

10. Light surface treatment to give a wear resistant mat may often be added economically to an oil mixed surface as maintenance rather than scarifying and remixing with additional oil as is now generally done.

After extensive research, the laboratories of the Michigan State Highway Department, located at Ann Arbor, have found that with the oil-processed roads the most satisfactory results were obtained using the following grading of the mineral aggregate:

Total % coarser than 1" screen 0.0

Total % coarser than 3/4" screen 4.8

Total % coarser than 1/2" screen 11.7

Total % coarser than 1/4" screen 30.1

Total % coarser than 1/8" screen 32.8

Total % coarser than 20-mesh sieve 64.1

Total % coarser than 50-mesh sieve 82.2

Total % coarser than 100-mesh sieve 92.2

Total $ coarser than 200-mesh sieve 96.1

PROCEDURE

After considering several methods of conducting the tests it was decided to build a circular form or track sixteen inches deep and two feet between the inner and outer circles. This form to be divided into sixteen compartments by radial partitions, each two feet wide and serving the purpose of ties and separators between the two circles.

The next problem was to design a machine to take the place of the automobile in wearing out the road. This machine will be described later.

Strips of eighteen guage galvanized iron sixteen inches wide were riveted together, set on edge and bent into two concentric circles nine and thirteen feet in diameter. Sixteen partition walls of the same material two feet long and sixteen inches high were fastened between the two circles and spaced equally forming a like number of compartments.

Inasmuch as the retread is put upon a well compacted gravel road it was decided to simulate those conditions so into these compartments subsoil was water-tamped to a depth of eight inches. Upon the subsoil a six inch gravel base was tamped.

The gravel was primed with road oil and Lincolnite powdered asphalt and the two inch wearing surface of cut-back asphalt and open-mix type gravel, with

a different grading in each compartment, was tamped and rolled into place. One half gallon of type A. C. Standard Oil Company cut-back asphalt was mixed with one hundred twenty pounds of gravel or .7 gallons per square yard, to form this wearing surface.

The automobile was simulated by bolting two model T. Ford axles to a steel plate and set at an angle of about forty-five degrees to each other. The steel plate was in turn bolted to a ball and socket joint located at the center of the circles.

Wheels with balloon tires were mounted on the outer ends of the axles, and an electric motor mounted so that a small pulley on the shaft rubbed the perifery of the tire to propel the machine. The current was brought to the motor through slip rings at the ball and socket joint.

The machine was then loaded with sand bags until there was an unsprung load of two-hundred fifty pounds on each tire.

The wearing surface was given ten days to cure and then the machine was started.

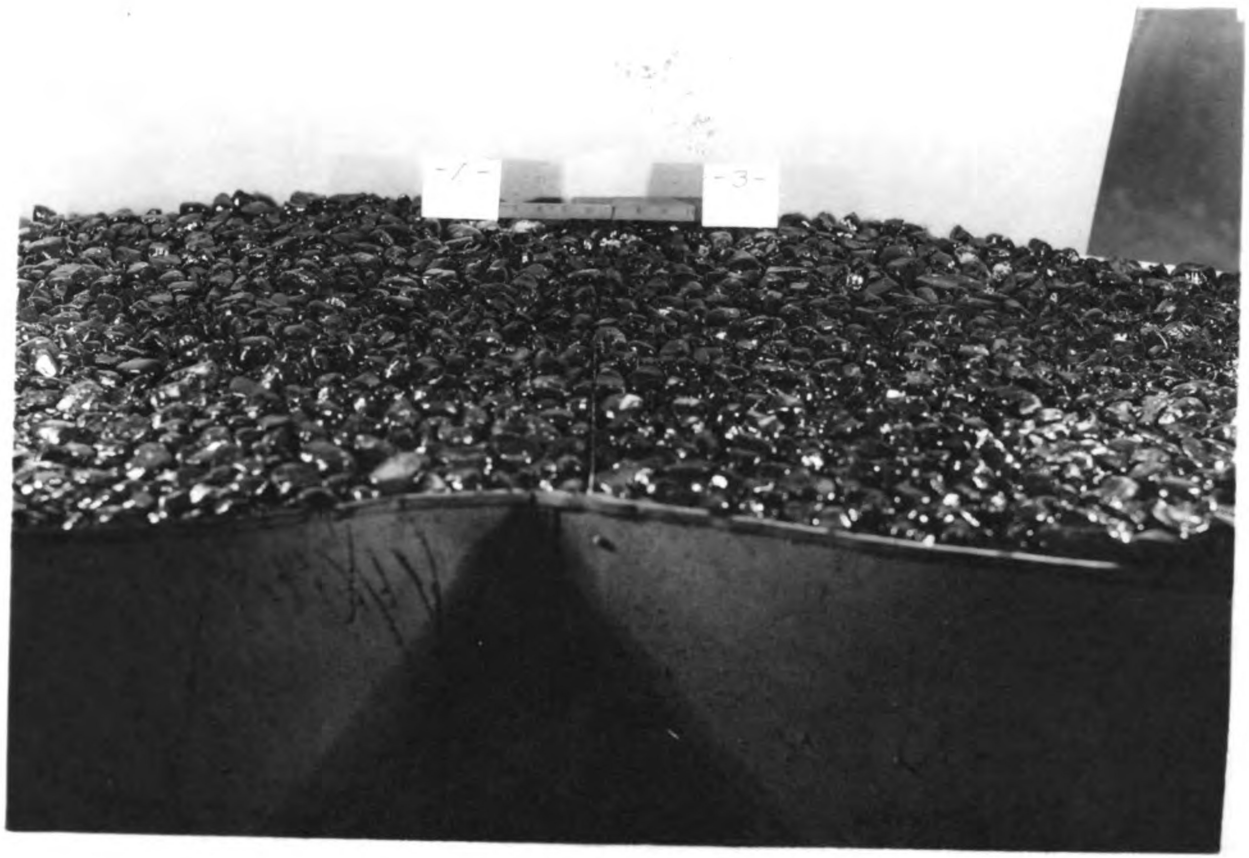
In a short time the finer and coarser gradings began to rut and ravel to such an extent that it was necessary to repair them before the experiment could continue.

After sixteen hours of running time all surfaces except that of No. 6 (see table and curves) had failed. The test was then stopped and the void content of that sample was determined and found to be 34.5%.

Surfaces Nos. 8 and 4 were second and third respectively in their endurance. No. 8 failed by rutting and No. 4 raveled. The finer gradings began to rut and shove out from under the wheels almost as soon as the machine was started, while the coarser mixes soon began to ravel. The reason for their failures was that there was not enough interlocking or keying qualities in the mixtures.

TESTING APPARATUS

SECTIONS 2 & O



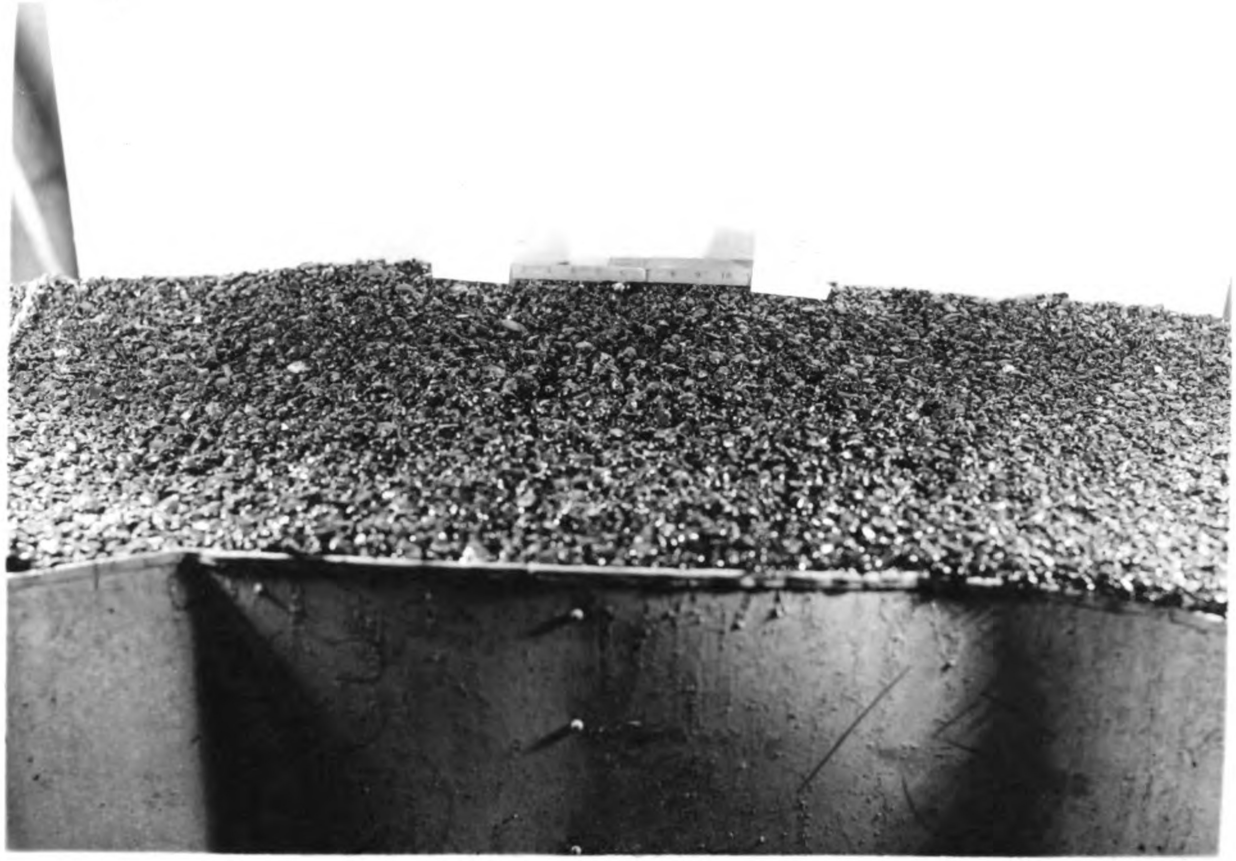
SECTIONS 1 & 3

SECTIONS 5 & 7

SECTIONS 6 & 4

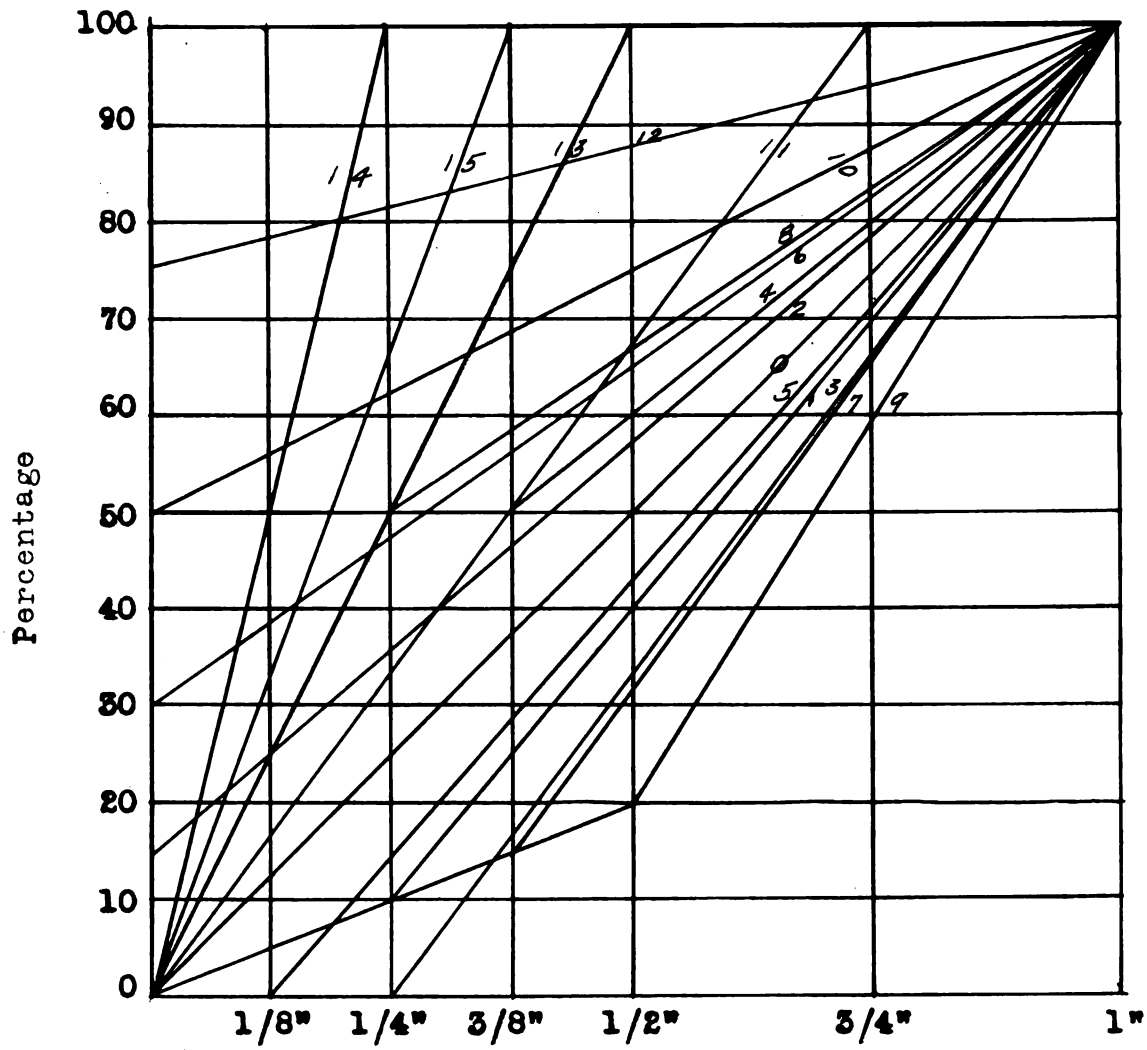
SECTIONS 10 & 8

SECTIONS 9 & 11



SECTIONS 13 & 15

SECTIONS 14 & 12



Square Screen Openings

Curves Used For Grading Aggregates

Ordinates represent percentage by weight of the total aggregate passing the next larger screen, except that none passed the 1/8" screen.

PERCENTAGE GRADING OF AGGREGATE

BY WEIGHT

No.	Passing 1-1/2" Retained on 1"	1" 3/4"	3/4" 1/2"	1/2" 3/8"	3/8" 1/4"	1/4" 1/8"
0	25.00	25.00	12.50	12.50	12.50	12.50
1	30.00	30.00	15.00	15.00	5.00	5.00
3	33.33	33.33	16.67	16.67		
5	28.57	28.57	14.29	14.29	14.29	
7	34.00	34.00	17.00	5.00	5.00	5.00
9	40.00	40.00	5.00	5.00	5.00	5.00
11		33.33	16.67	16.67	16.67	16.67
13			25.00	25.00	25.00	25.00
15				33.33	33.33	33.33
2	21.25	21.25	10.625	10.625	10.625	25.625
4	20.00	20.00	10.00	16.67	16.67	16.67
6	17.50	17.50	8.75	8.75	8.75	38.75
8	16.67	16.67	8.33	8.33	25.00	25.00
10	12.50	12.50	6.25	6.25	6.25	56.25
12	6.25	6.25	3.125	3.125	3.125	78.125
14					50.00	50.00

CONCLUSIONS

Heretofore it has been the practice to apply the retread in layers. A layer of stone larger than one inch, another of the intermediate sizes and a top coat of fine stone or chips, with an application of cut-back between each layer.

The results obtained in the foregoing tests seem to indicate there need be but one application of mineral aggregate provided that it is graded properly and obviously a great deal of time, labor, and money could be saved.

The machine was traveling at the rate of about 725 revolutions an hour. This meant that one hour on the machine would be equal to a day on most secondary roads. Coupled with the fact that on account of the short radius, there was a twisting effect between the tires and the road surface; this constituted a greatly accelarated test.

Owing to the fact that the wheels were constantly traveling in the same track and that there was the lack of the ironing out tendency found in practice, some rutting was discovered even in the best sample.

The fact was brought out that the aggregate, so graded to be most stable alone, was the most stable when used with cut-back.

It is admitted, however, that there is a possibility of further refinement in the grading and experiments along

this line is to be encouraged.

Another series of tests should be made to ascertain the effect of temperature changes upon the stability of the road surface.

It would also be of interest to determine the effect of changing the type and quantity of asphalt.

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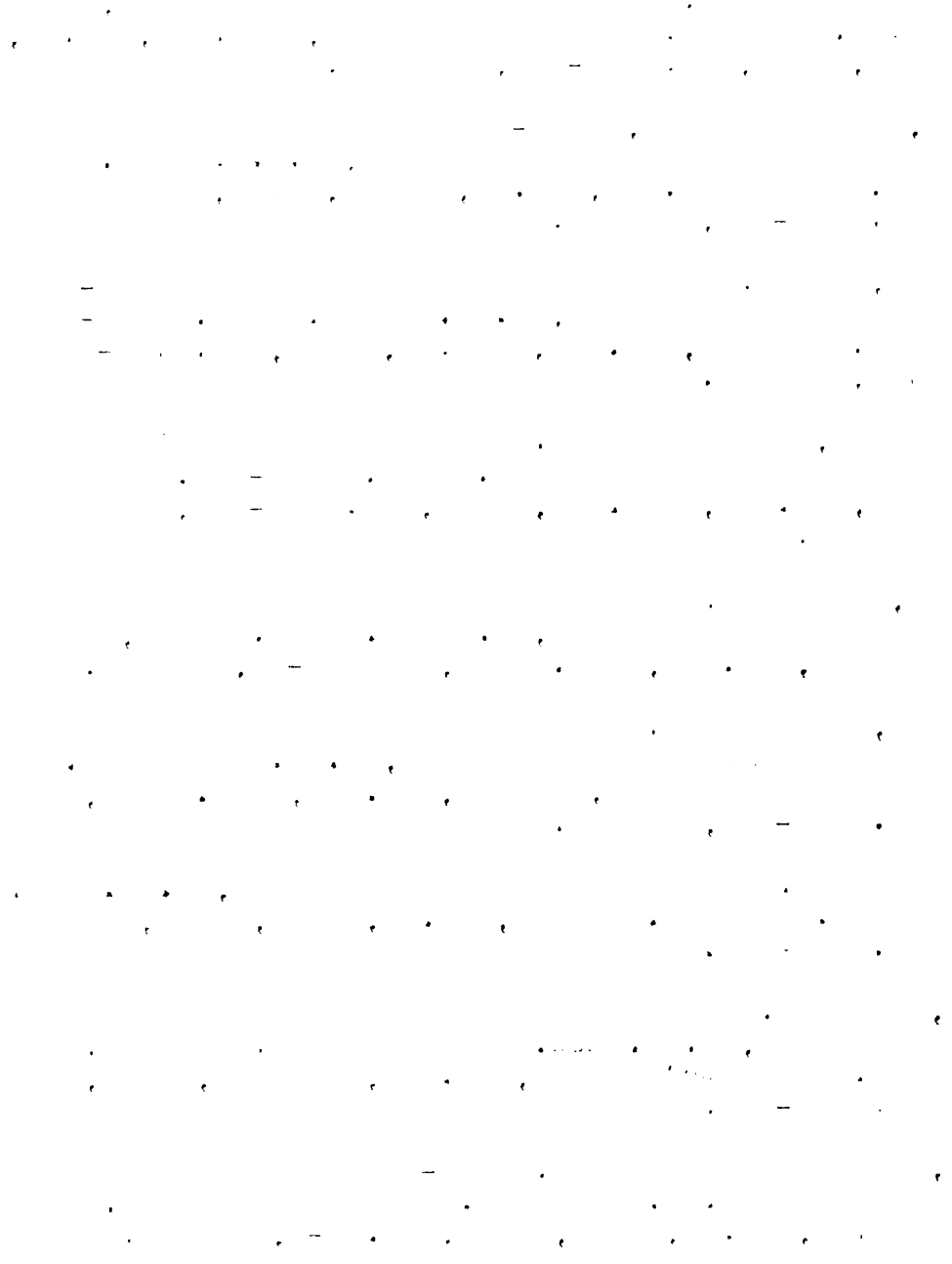

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