DESIGN OF BITUMINOUS SURFACE MIXES WITH HIGH SKID RESISTANCE

by

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Virginia Highway Research Council
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SUMMARY

The Virginia Highway Research Council has proposed a study of the skid resistance of bituminous surfaces incorporating relatively hard and expensive aggregates. The hardness of the aggregates to be used — aluminum oxide (Exolon) and calcined kaolin — is expected to contribute appreciably to the lasting skid resistance of the surfaces. Since these hard aggregates are expensive, this study was undertaken to explore the possibility of using them in the sprinkle method of resurfacing pavements, which requires less high quality aggregate than does paving with conventionally designed mixes. Inasmuch as the entire study should cover a period of approximately two years, with the author being involved only in the first part, this report presents only the results of the preliminary work. Final results and evaluations will be reported by Council personnel when substantial data have been collected.

In the preliminary work, small test beams were fabricated and implanted in newly resurfaced pavements. Periodic skid values are to be obtained with the British portable tester.

The texturing of newly resurfaced pavements has also been proposed and attempted. A solvent was used in conjunction with normal traffic wear to produce a coarse surface and hopefully a high skid value.

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INTRODUCTION

It has become recognized that particular traffic locations require a higher skid resistance than that normally obtained with regular mixes. The problem areas include intersections and locations at which sudden directional changes occur, such as curves or merging lanes. To help design mixes that will provide the levels of friction needed at those locations it was proposed that beams with surfaces designed for high skid resistance be fabricated in the laboratory and implanted in newly resurfaced roads. Certain variables such as type of aggregate and surface texture were to be investigated.

This report describes the design of the mixes and the fabrication and installation of the beams. Periodic skid resistance testing and the final evaluation will be made by Research Council personnel.

PURPOSE AND SCOPE

The purpose of this study is to design several bituminous surface mixes that will hopefully develop relatively high skid resistance values. The main emphasis will be on the type of aggregate used in these mixes, with secondary consideration being given to texturing.

Of the four mixes used, one (slag aggregate) was known to exhibit good skid resistance and one (limestone aggregate) poor skid resistance. These mixes were used for comparison purposes.

PROCEDURE

Mixes

It was planned, wherever possible, for aggregate gradations of the resurfacing and test beam mixes to be similar. Therefore, an S-5 gradation was chosen because of its common use for resurfacing operations. Use of this gradation increased the probability of finding a desirable location on highly trafficked roads for the test beam installation.

It was also planned to have the maximum size of the sprinkle aggregate [1] and corresponding mix aggregate about the same. The S-5 gradation was a good choice for the calcined kaolin but an exception was necessary for the aluminum oxide. For this sand size aggregate a fine S-1 gradation was used. Figures A-1 and A-2 in the appendix show the S-1 and S-5 gradations of the mixes.

Three aggregates — granite, slag, and limestone — and a mineral filler were used in the mix designs. Table 1 shows the gradation of the granite, mineral filler, and sprinkle aggregates used. AC-20 asphalt cement was used in the base mix and to precoat the sprinkle aggregate.

TABLE 1

AGGREGATE SIEVE ANALYSIS

Screen	#10 Granite*	#68 Granite*	Mineral* Filler	Calcined* Kaolin 3 x 4	Calcined Kaolin 1/2 x1/8	Aluminum* Oxide
3/4	100.0	100.0	100.0	100.0	100.0	100.0
1/2	100.0	96.0	99.4	100.0	100.0	100.0
3/8	100.0	62.6	98.4	100.0	83.7	100.0
4	97.7	12.6	95.0	13.7	1.3	99.6
8	82.9	.7	81.0	1.0	.3	0
30	47.0	.3	11.8	0	0	0
50	36.0	.3	2.9	0	0	0
200	16.0	.2	.8	0	0	0
-200	0	0	0	0	0	0

*Percentages by weight passing square mesh sieves.

Granite, used as an S-5 and S-1 gradation, was prepared by blending approximately 50% of #68, 25% of #10 and 25% mineral filler. Since it is used widely, granite was chosen as a control.

Slag and limestone were used for comparison to the calcined kaolin and aluminum oxide. It is expected that slag will show less polishing and greater skid resistance than granite and that the high calcium limestone will polish readily.

The S-5 slag mix contained coarse slag (3/8 — #8 sieve) and fine granite. The limestone mix contained 100% limestone.

Referring to Figure 1 and Table 1, the relative sizes of the sprinkle aggregate can be compared.

As the calcined kaolin was received in two sizes they were tested separately. For both of these sprinkle aggregates a base of S-5 granite mix was used.

As mentioned, the aluminum oxide was sand size and an S-1 granite mix was used for its base.

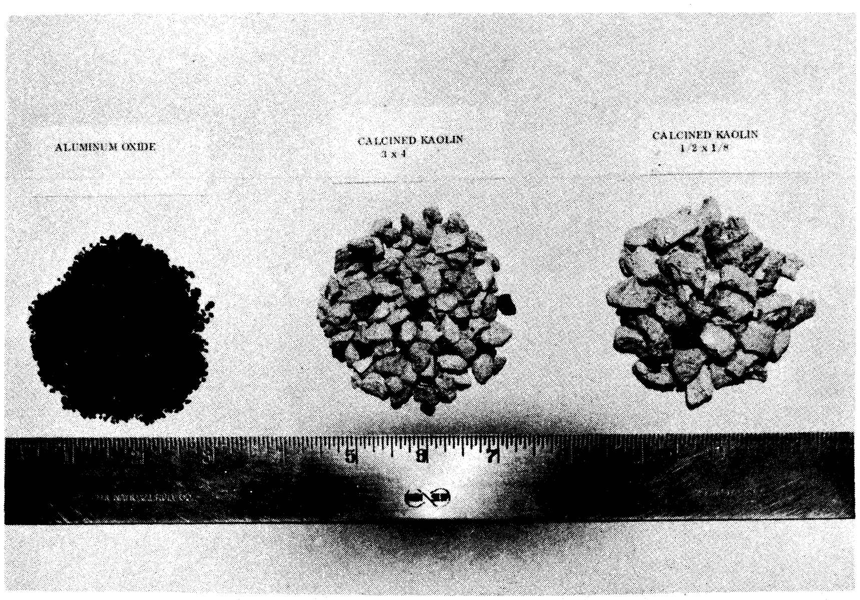


Figure 1. Sprinkle aggregate.

Mix Design

The Marshall design method [2] was used to obtain the optimum asphalt content for each of the four mixes. Four Marshall specimens were made at each of four to five asphalt contents, in the proximity of the expected value, for each mix. A total of 60 Marshall specimens were made and tested for density and stability. Results from each were averaged and plotted on Marshall design charts.

The criteria in selecting the optimum asphalt content of the S-5 mixes were:

1. Stability — at peak of curve, if obtained, or suitable value above 1,450 psi.

2. Voids total mix — between 3% and 6%, or 4.5% optimum.

3. Voids in mineral aggregate — above 15%.

4. Voids filled with asphalt — 75% optimum, or between 65% and 85%.

The criteria for the S-1 mix were primarily voids total mix and previous experience.

The optimum asphalt contents selected for the four mixes were:

slag — 7.75%
limestone — 5.6%
S-1 granite — 9.5%
S-5 granite — 5.8%

Test Beams

The Research Council had previously devised a method of fabricating beams to be used in fatigue testing. This method was followed for test beams with the exception of using about half the total mix required. By cutting back on the mix, the thickness of the test beams was decreased to about one and a half inches. At this thickness the beam could be cut to a previously determined satisfactory thickness of 9/16 inch and little material was wasted. If beams were compacted to 9/16 inch, crushing of the large aggregate would result.

A mold (Figure 2) for forming beams was used in conjunction with the California kneading compactor. The procedure was as follows for beams without sprinkle aggregate.

1. Mix preheated aggregate and AC-20 asphalt cement until aggregate is sufficiently coated.

2. Place half of mix evenly into mold and compact four times at 166 psi.

3. Increase compacting pressure to 202 psi and knead and additional four times.

4. Add remainder of mix and repeat steps two and three.

5. Cover mix in mold with metal plate and compact six times at 227 psi.

6. Remove beam from mold after it has cooled to room temperature.

7. Cut beam to desired dimensions.

For sprinkle test beams, the precoated sprinkle mixture was first placed in the mold and evenly distributed. At this point, steps 1-7 were followed in making beams. Table 2 gives the percentages of asphalt cement used to precoat the aggregate and the rates at which the sprinkle aggregates were applied.

Figure 2. Test beam mold.

TABLE 2

SPRINKLE AGGREGATE AND ASPHALT CEMENT
PERCENTAGES AND APPLICATION RATES

Aggregate	Percent AC-20	Rate (psy)
Calcined Kaolin (3 x 4)	5	11.7
Calcined Kaolin (1/2 x 1/8)	5	11.1
Aluminum Oxide	4	7.6

Each beam, which was 15 inches in length, 3.25 inches in width, and 1.5 inches in height, was cut into two beams 7.5 inches in length, 3.25 inches in width, and 9/16 inch in height. Test beams are shown in Figure 3.

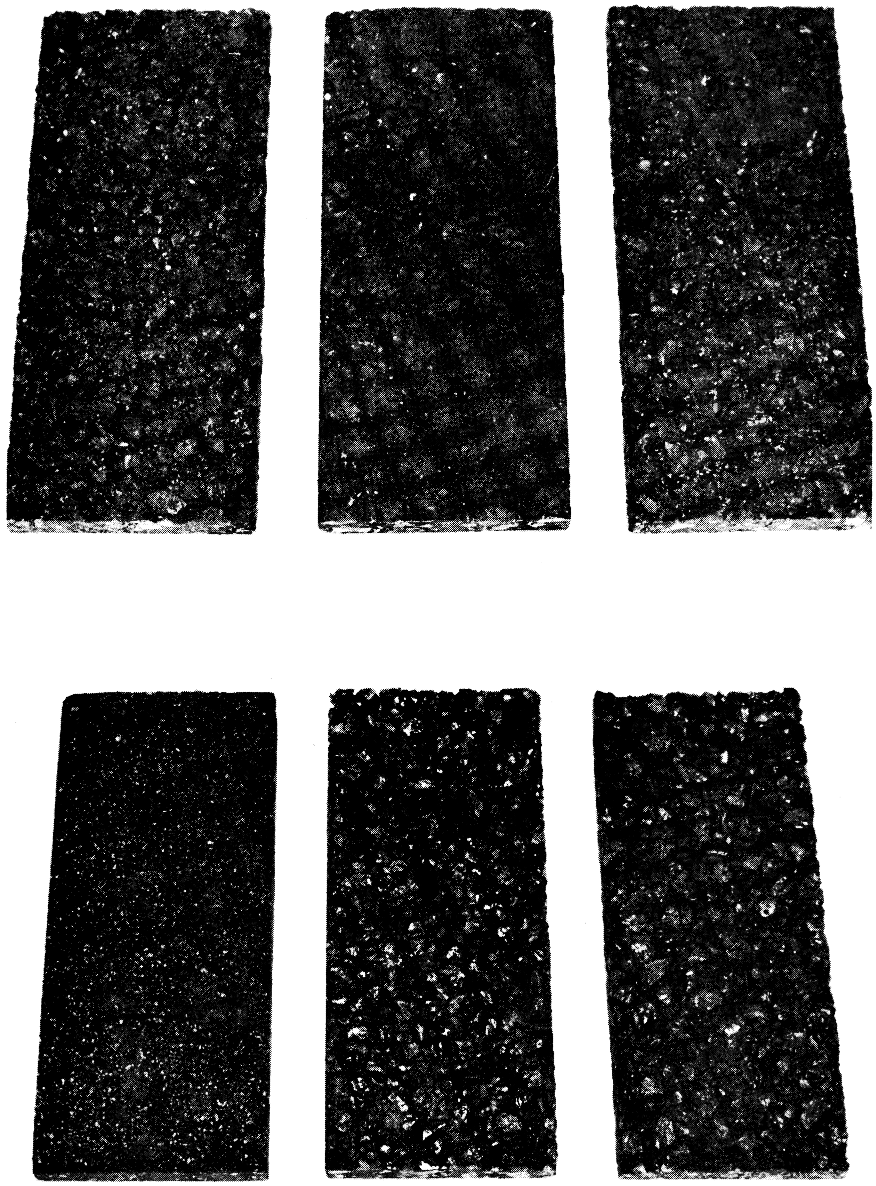


Figure 3. Test beams: top row — left to right — slag, granite, and limestone; bottom row — sprinkle test beams, left to right — aluminum oxide, calcined kaolin 3 inches x 4 inches, and calcined kaolin 1/2 inch x 1/8 inch.

Field Work

Location

Six types of beams were implanted within close proximity of each other. The factors determining the location were availability of a resurfacing project[3] and traffic volume[4] carried by the highway. The test site chosen (Figure 4) carries a daily traffic volume so the results of this study can be obtained in the shortest reasonable period of time. A traffic survey taken August 1, 1973 showed 1,190 vehicles daily in the test lane.

Installation

Table 3 gives the numbers and types of beams included in a set. In all, three sets, totaling 36 test beams, were placed. The beams were placed in the western most observed wheel path of the southbound traffic lane, 39 inches from the edge of pavement, and those in sets were separated by 1.5 feet.

TABLE 3

BEAM DISTRIBUTION PER SET

Aggregate	Sprinkle Method	Non-Sprinkle Method	Total
Limestone	0	2	2
Slag	0	2	2
Granite	0	2	2
Calcined Kaolin 3 x 4	2	0	2
Calcined Kaolin 1/2 x 1/8	2	0	2
Aluminum Oxide	2	0	2
		Total	12

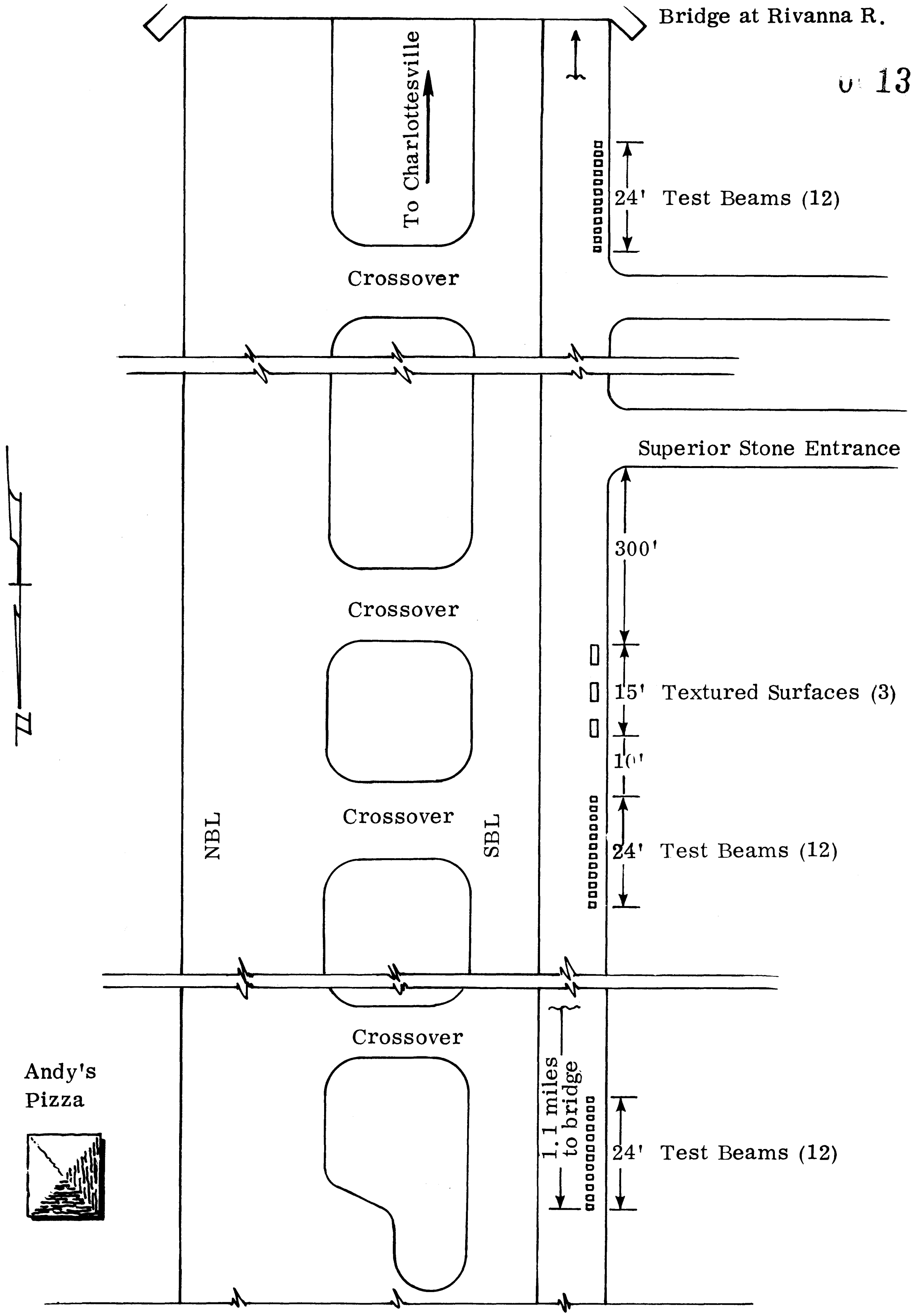


Figure 4. Test site.

During installation, test beams were laid (sawed surface down) on the hot resurfacing asphalt mix immediately behind the paver and rolled by three-wheel and tandem steel wheel rollers. The beams received the same number of passes as did the adjoining resurfacing mix. In Figure 5 the beams are seen just after being rolled.

Figure 5. Test beams after installation.

In the rolling operation the only problem arose after certain test beams had been rolled even with the resurfacing mix. Areas immediately surrounding the test beams were void of mix. Hot mix was placed in these areas and the beams were again rolled. After a number of passes these areas appeared filled and flush with the resurfaced pavement.

Although the beams appeared to be flush with the adjoining mix it is possible that they could be raised a small amount. If this is true the applied loading on these beams, from tires, could cause some amount of the asphalt cement to work to the surface. If this occurs, the result would be a decrease in the percentage of AC-20, a loss in stability, and possibly eventual cracking. In addition, bleeding could cause a reduction in skid resistance.

On certain slag beams small cracks were observed but not of a serious enough nature to require remedial action. All other beams were not damaged in any way.

Surface Texture

Several test strips were marked off and sprayed with a solvent, trichlorethane. The strips were one foot wide and three feet long with the center being in the observed wheel path, 39 inches from the shoulder. The solvent was applied in even amounts from ten ounces to fourteen ounces to strips on the newly resurfaced pavement.

As the solvent reacts with the asphalt cement the finer aggregate particles become loose and dislodge with wear from traffic.[5] With finer grades of aggregates missing the surface is coarser and more open. As a coarser surface gives higher skid resistance values, it is anticipated that this treatment will prove successful. Meaningful skid resistance values should be available within several months of application as the fines become dislodged and the surface film of asphalt wears off.

EVALUATION

As mentioned, this report covers only the fabrication and installation of test beams. Initial tests for skid resistance as well as periodic testing will be performed by Research Council personnel. The British portable tester[6] will be used for skid resistance testing on all test beams and textured surfaces.

The tester is not as precise as other devices, such as a skid trailer, and if used on the textured surfaces may show no noticable differences in skid resistance. Therefore, the evaluation of the effects of texture will rely a great deal on visual inspection. A texture would be selected on the basis of fines removed and the depth to which the solvent is absorbed into the mix. If the solvent penetrates too deeply, it could cause eventual cracking or breakage of the pavement.

It is anticipated that the skid resistance values of the beams will have a large enough separation to be detected by the British portable tester.

REFERENCES

1. Dillard, J. H., and G. W. Maupin, Jr. "Use of a Sprinkel Treatment to Provide Skid Resistant Pavements," Proceedings, AAPT, 1971, Ann Arbor, Michigan.

2. Marshall Method of Mix Design, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types, October 1969.

3. Virginia Department of Highways, 1973 Plant Mix Schedules, Richmond, Virginia, 1973.

4. Virginia Department of Highways, Average Daily Traffic Volumes on Interstate, Arterial and Primary Routes, 1970.

5. Virginia Department of Highways, "Section 212 — Bituminous Concrete, "Road and Bridge Specifications, Richmond, Virginia, 1970.

6. Measuring Surface Frictional Properties Using the British Portable Tester, 1973 Annual Book of ASTM Standards, Easton, Maryland, 1973.

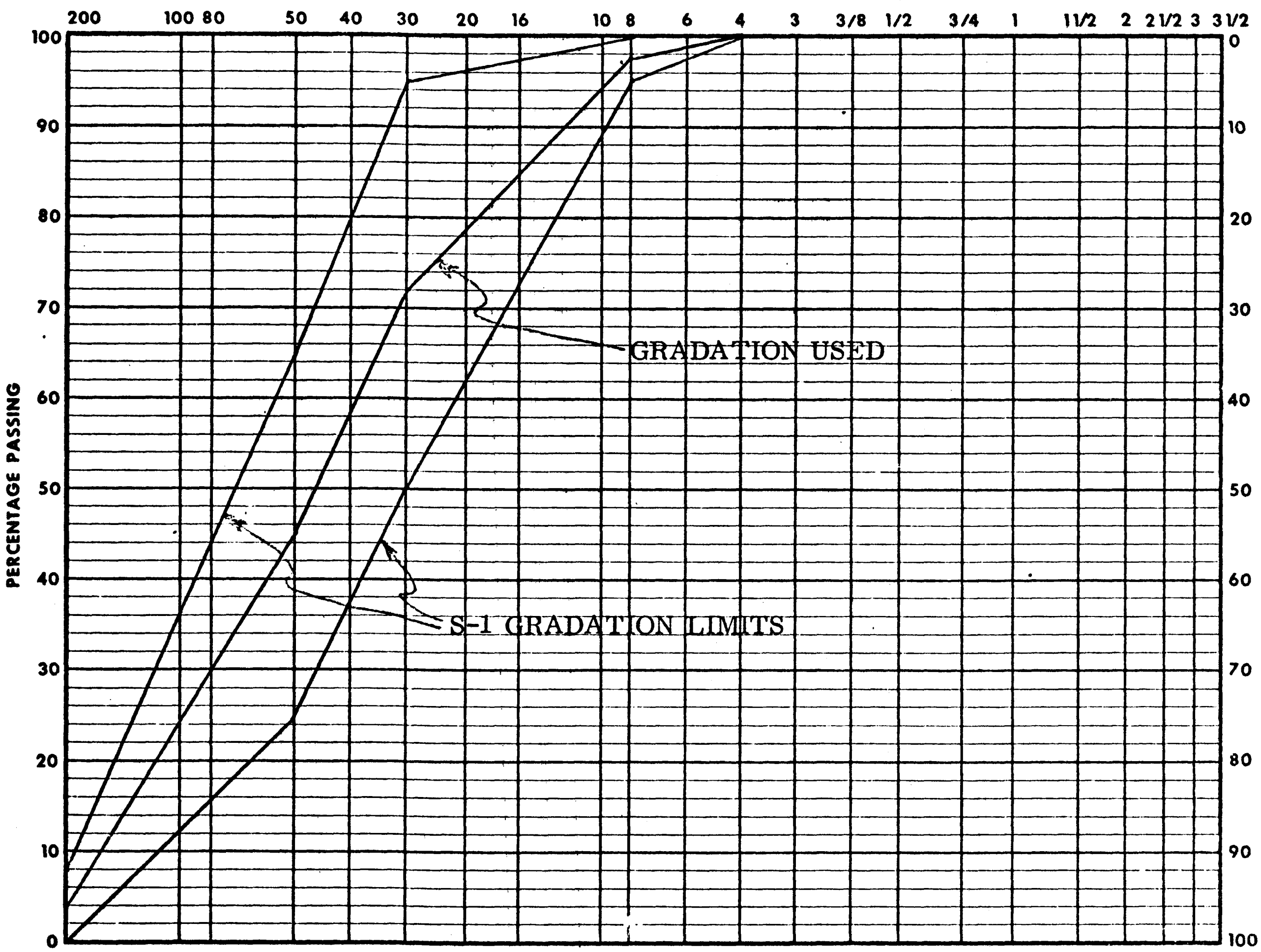
APPENDIX

Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART

Date: ______ File: ______



SAMPLE OF ______ FROM ______ PRODUCER ______

TESTED BY ______ FOR ______ FIN. MOD. ______

MESH	OPEN INCHES	WEIGHT	PERCENT PASS	PERCENT RETAIN	PERCENT CUMUL.	MESH	OPEN INCHES	WEIGHT	PERCENT PASS	PERCENT RETAIN	PERCENT CUMUL.
	3 1/2					6	.132				
	3					8	.0937				
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232				
	3/4					40	.0165				
	1/2					50	.0117				
	3/8					80	.0070				
3	.265					100	.0059				
4	.187					200	.0029				
TOTAL						TOTAL					

Figure A-1. Gradation used in S-1 Mix.

Form No. R-108

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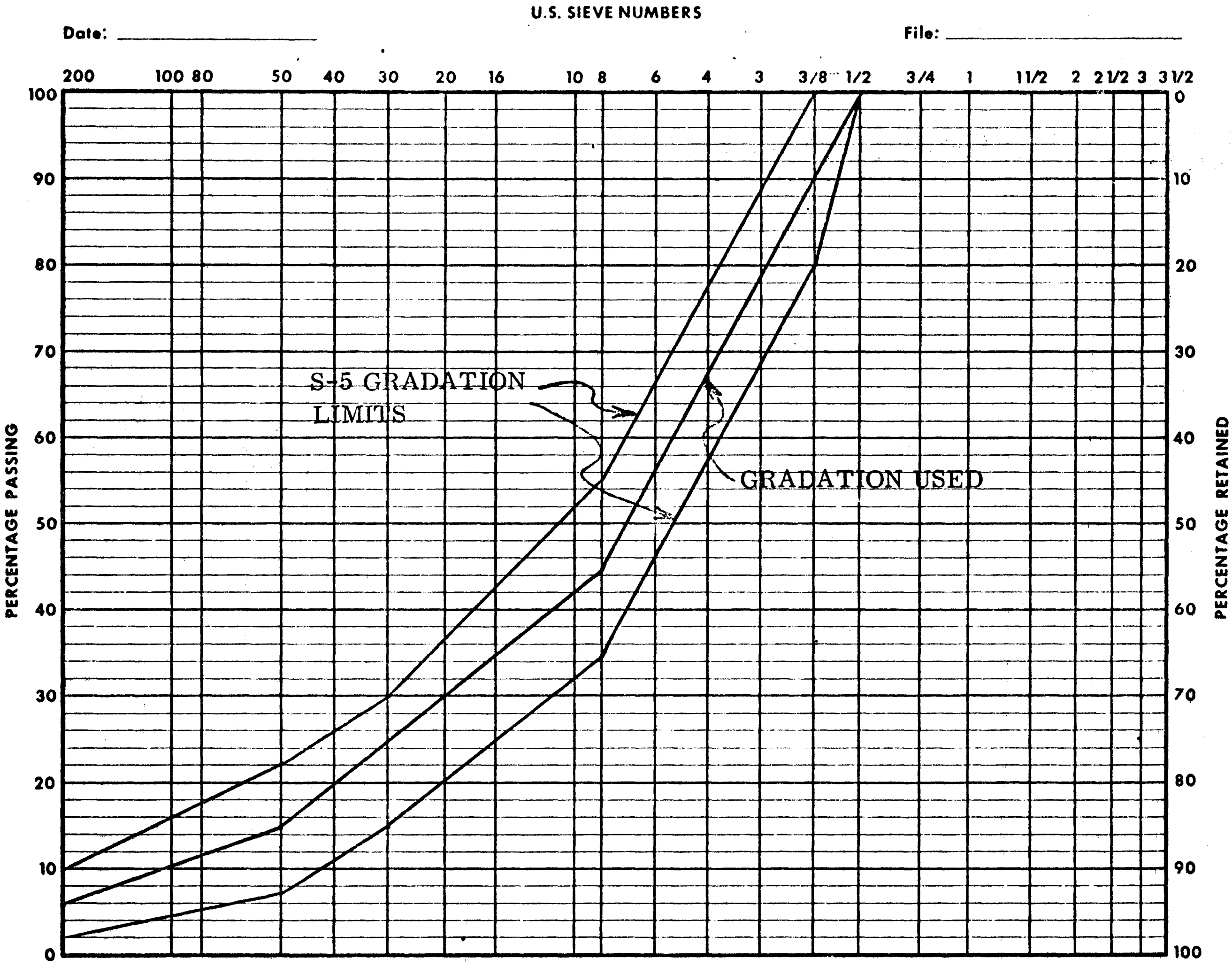
VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART



SAMPLE OF ________ FROM ________ PRODUCER ________

TESTED BY ________ FOR ________ FIN. MOD. ________

MESH	OPEN INCHES	WEIGHT	PERCENT PASS	PERCENT RETAIN	PERCENT CUMUL.	MESH	OPEN INCHES	WEIGHT	PERCENT PASS	PERCENT RETAIN	PERCENT CUMUL.
	3 1/2					6	.132				
	3					8	.0937				
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232				
	3/4					40	.0165				
	1/2					50	.0117				
	3/8					80	.0070				
3	.265					100	.0059				
4	.187					200	.0029				
TOTAL						TOTAL					

Figure A-2. Gradation used in S-5 Mix.