3843

FINAL REPORT

FEASIBILITY OF REDUCING FINES IN S-5 MIXES

by

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Summer Undergraduate Trainee

Virginia Highway & Transportation Research Council
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SUMMARY

The study investigated the feasibility of eliminating aggregate particulates passing the #200 and #100 sieves from a surface mix (S-5) gradation. Feasibility was to be determined on the basis of test mixtures, with particulates deleted, meeting Virginia's specifications.

Two aggregates, greenstone and granite, were used to prepare Marshall specimens for lab tests. For both aggregate types the original S-5 gradation was tested and used as a control. Four variations of this gradation were designed and tested for each aggregate type. These variations excluded portions of the fine particulates to the point of no aggregate passing the #100 sieve.

Test results for each gradation of the two aggregates were compared graphically. A range of acceptable asphalt percentages was calculated for each of the five gradations.

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INTRODUCTION

Federal and state agencies have realized the growing need for control or abatement of all forms of air pollutants. Included in regulations set forth by these agencies are allowable particulate emissions for hot-mix asphalt plants.[1]

A number of means of controlling particulates within specified emission guidelines are very satisfactory.[2] However, the expense involved remains a factor for the plant operator.

One solution is to prevent part or all of the particulates from entering the production system, and is the idea with which this study was concerned.

PURPOSE AND SCOPE

The purpose of this study was to investigate the effects of removing all mineral filler from an asphalt surface mix. The acceptability of this mix design is governed by criteria established by the Virginia Department of Highways and Transportation[3] for S-5 asphalt surface mixes.

To obtain a perspective on how properties of the mix would change, mineral filler was reduced in increments. In addition, material just coarser than mineral filler was reduced.

PROCEDURE

The greenstone and granite aggregates were graded into each sieve size to be used. An appropriate gradation was then produced by combining predetermined amounts of each size.

Five gradations were designed. (See Figures A1-A5 in Appendix.) The first was a median S-5 surface mixture. Using this same basic design, the mineral filler portion (6% passing the #200 sieve) was halved to obtain a second gradation, and then eliminated entirely to get a third.

From this point the fourth and fifth gradations were designed using a median gradation to the #100 sieve. The fourth was made with only 5% passing the #100 sieve and no mineral filler. The fifth gradation, which contained the least amount of fines, had no material passing the #100 sieve.

The Marshall method of mix design, in conjunction with a kneading compactor, was used to produce the test samples. The samples were then tested for voids, density, flow, and stability. These results were plotted and compared to Virginia Department of Highways and Transportation mix design specifications. These specified limits of voids, flow, and stability produced acceptable asphalt percentages for each gradation.

RESULTS

Work by Frank has shown that particles seven microns or less in diameter create dust that causes damage to lungs. (4) A grain-size analysis of the aggregates used revealed that the mineral filler portion of the granite contained 12% finer than seven microns and the greenstone contained over 20% finer. These large percentages of fines illustrate the necessity for controling their possible entry into the atmosphere.

Graphs were prepared to show the effects the reductions in fines had on the properties of the S-5 mix. Figures 1 and 2 present plots of asphalt percent versus properties. A summary of these results is given in Table 1. This summary was prepared by considering a reduction in fines, from gradation one to gradation five, and any constant asphalt percent used.

Table 1

SUMMARY OF EFFECTS FROM FINES REDUCTION
AT CONSTANT ASPHALT PERCENT

Aggregate Properties	Greenstone	Granite
Density	Decrease	Decrease
Stability	Decrease	Decrease
VTM	Increase	Increase
VFA	Decrease	Decrease
VMA	Increase	Increase
Flow	Decrease	Decrease*

*Erratic

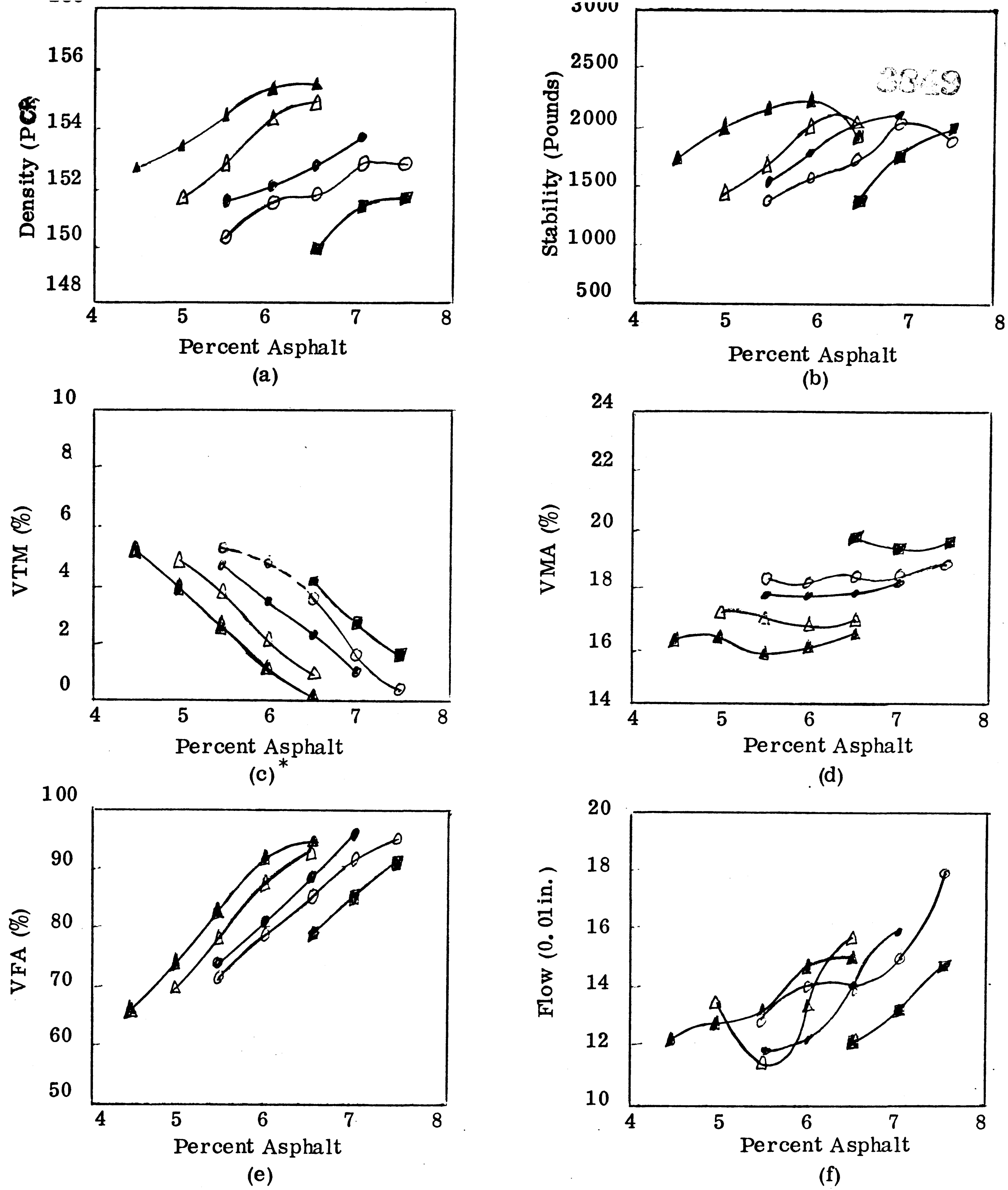

FIGURE 1: GRANITE PROPERTY CHANGES FROM VARIATIONS IN ASPHALT PERCENTAGE ON FIVE GRADATIONS – (a)Density (b)Stability (c)VTM (d)VMA (e)VFA (f)Flow

<u>Legend</u>

- ▲ – Gradation One
- △ – Gradation Two
- ● – Gradation Three
- ○ – Gradation Four
- ■ – Gradation Five

<u>S-5 Specifications</u>

Stability – over 1450 pounds
VTM – 3% to 6%
VMA – over 15%
VFA – 65% to 85%
Flow – 8 to 18

*Probable curve for gradation four; inconsistent VTM at 6% asphalt.

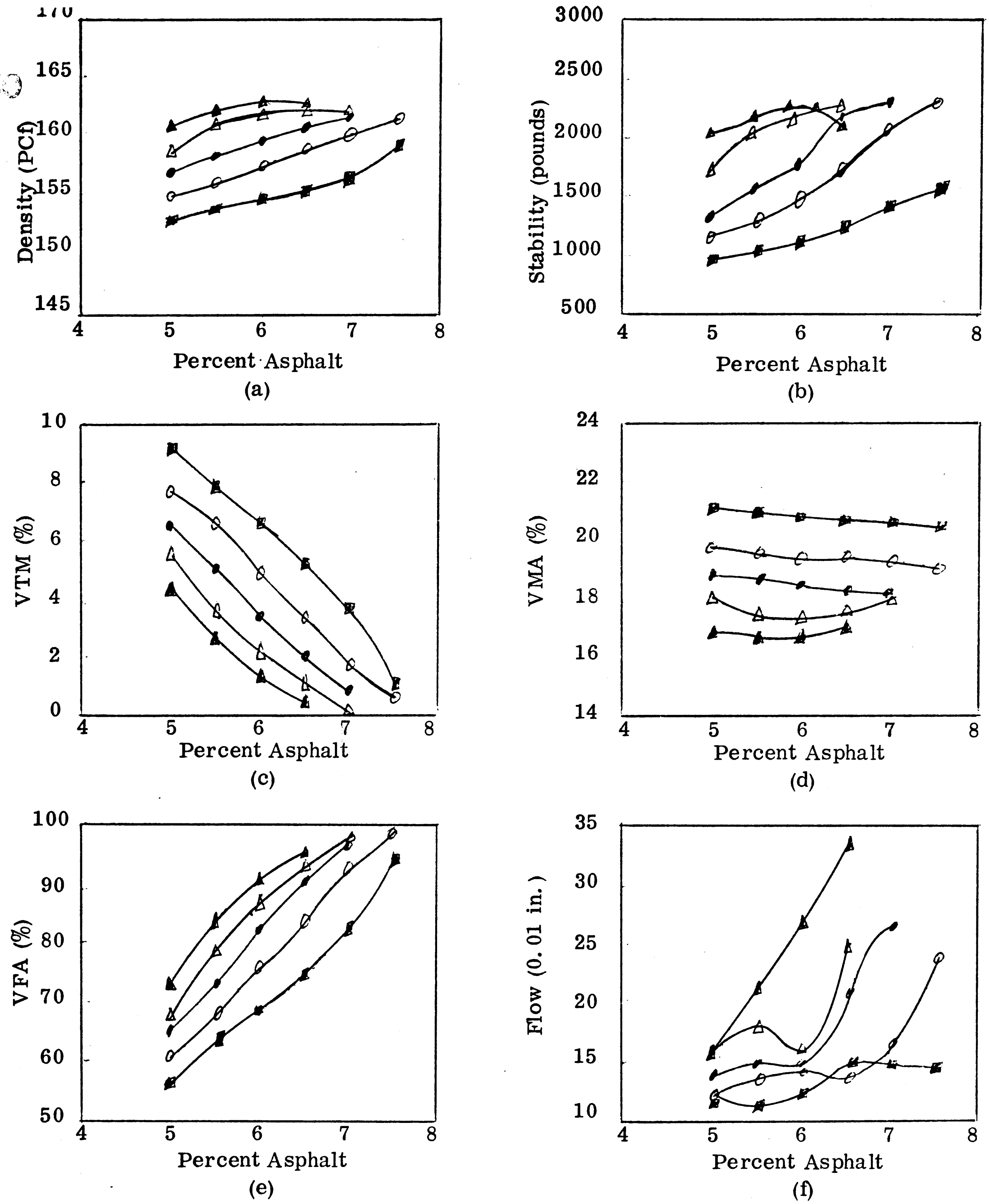

FIGURE 2: GREENSTONE PROPERTY CHANGES FROM VARIATIONS IN ASPHALT PERCENTAGE ON FIVE GRADATIONS - (a)Density (b)Stability (c)VTM (d)VMA (e)VFA (f)Flow

Legend

▲ - Gradation One
Δ - Gradation Two
● - Gradation Three
○ - Gradation Four
■ - Gradation Five

S-5 Specifications

Stability - over 1450 pounds
VTM - 3% to 6%
VMA - over 15%
VFA - 65% to 85%
Flow - 8 to 18

As fines were reduced and the percent asphalt held constant, the following results were obtained.

1. Density — Voidages between the fine and coarse aggregates increased to cause a decrease in density. This decrease in density is apparent as the voids in mineral aggregate (VMA) is seen to increase.

2. Stability — A noticable peak in stability was observed with gradation one for both aggregates. The remaining gradations,with the exception of granite in gradation four, became flat at higher asphalt percentages.

3. Voids — The voids filled with asphalt (VFA) was found to be directly related to the voids total mix (VTM) and VMA. With the removal of fines, the VMA increased and the portion of the mix containing air voids (VTM) also increased. The remaining portion which was filled with asphalt (VFA) resulted in being less on a percentage basis.

4. Flow — With both aggregates the flow tended to increase as the asphalt percent was increased. This trend was not clearly defined and for the granite the results were quite erratic.

If a value for the VTM is specified, corresponding values of other properties can be determined. These determinations are made by comparing properties to a percentage of asphalt. For example, by using Figures 1c or 2 c the intersection of a constant VTM value with any of the five gradations correlates to a percent asphalt. This asphalt percentage can be applied to the same gradation for other properties plotted in Figures 1 or 2. As fines are reduced the asphalt percentage, at constant VTM, increases and each property changes.

With a VTM of 4%, property changes were determined for both aggregates. These changes were plotted against the cumulative percentages of -#100 sieve material present. This scale is directly associated with the fineness modulus of a gradation. Figures 3 and 4 show property changes for the five gradations used.

These graphs summarize the effect of producing the five gradations at a constant air void of 4%. As fines are reduced each property can be studied individually or can be readily compared to other properties. The graphs can also be used to compare sensitivity to removal of fines.

During laboratory procedures of forming and testing Marshall samples it was noted that dissimilarities in the surface textures were slight. Although gradation five samples contained no -#100 sieve material, the surfaces closely resembled those of gradation one samples, which contained the greatest amount of fines. One particular reason for this slight difference could lie in the fact that the fines removed were replaced, for the most part, by asphalt. Also, considering the top size aggregate of 1/2-inch and the size of the fine material which was removed, it is likely that no discernible difference would be observed.

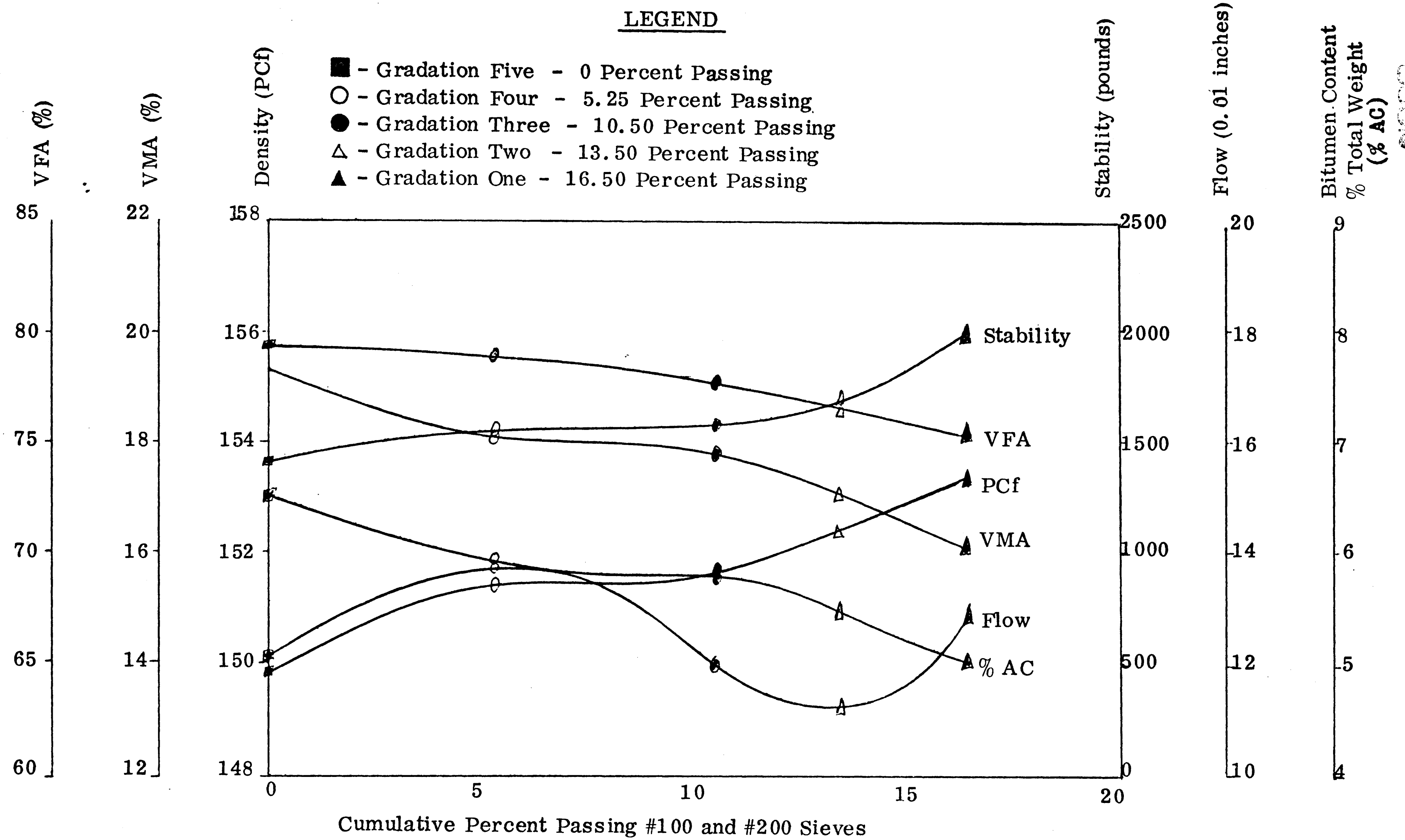

FIGURE 3 - PROPERTY CHANGES OF GRANITE AGGREGATE AT 4% VTM RESULTING FROM THE REDUCTION OF FINES.

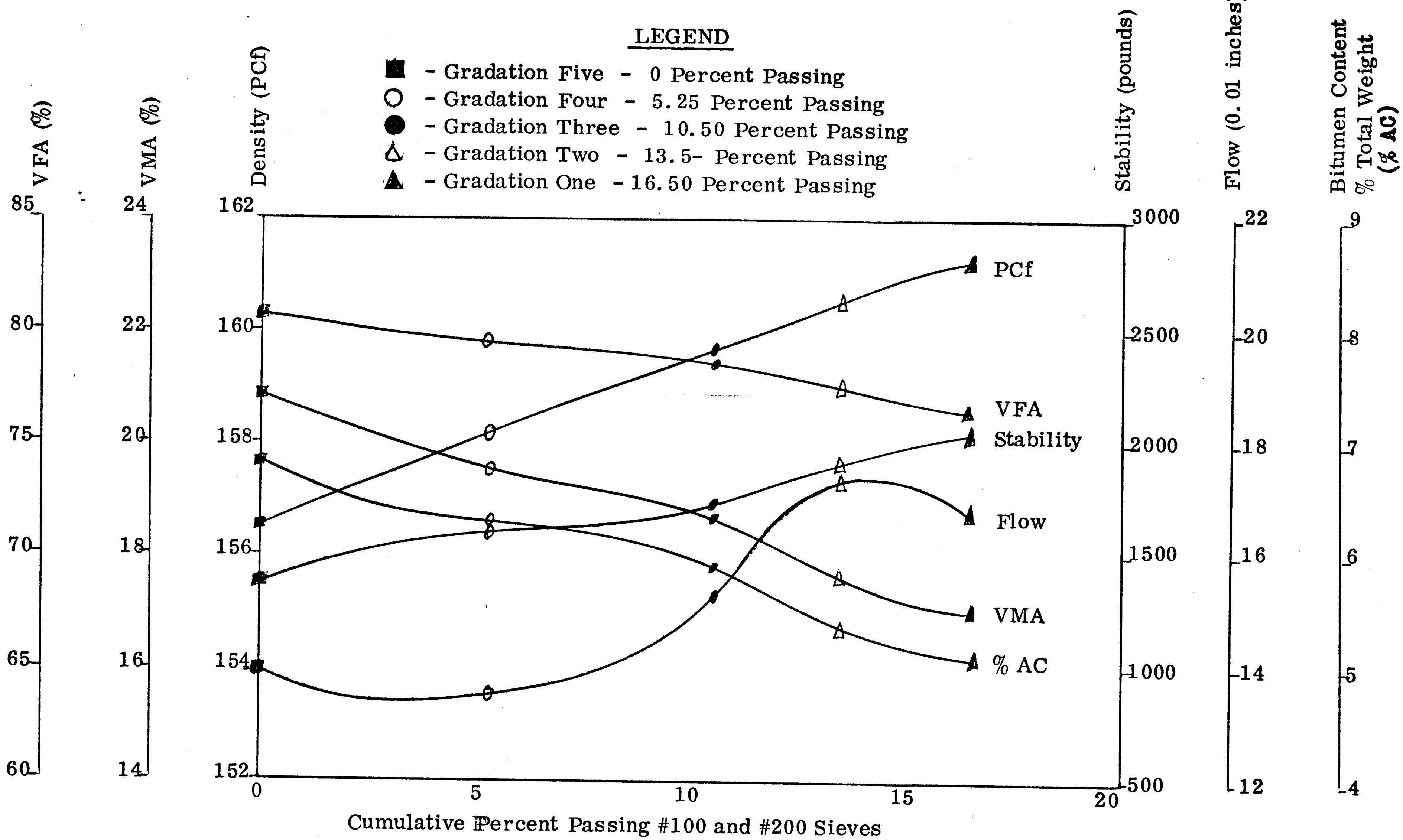

FIGURE 4 - PROPERTY CHANGES OF GREENSTONE AGGREGATE AT 4% VTM RESULTING FROM REDUCTION OF FINES.

DISCUSSION

With the exception of gradation one, no peak densities or stabilities were encountered. Specifications require the calculation of the optimum asphalt percentages on the basis of these peaks and an average VTM of 4%. The asphalt percentages pertaining to peaks in density and stability are usually greater than that for 4% VTM. Therefore, optimum asphalt percentages will be between that for 4% VTM and those for the two peak properties.

For this reason an upper limit on VTM was set at 4%. A lower limit was established by using the specified minimum value of 3% VTM. From this range of VTM's, a range of asphalt percentages corresponded. Table 2 shows these ranges for each aggregate and gradation. Table 2 does not stipulate an optimum, or most suitable, asphalt percent. The resulting range in asphalt percentages in most cases, however, is less than one-half a percent and results in a narrow spectrum.

Table 2

RANGE OF ASPHALT PERCENTAGES FOR 4%-3% VTM

Gradation	Suggested Asphalt Percent	
	Greenstone	Granite
1	5.1 - 5.4	5.0 - 5.4
2	5.4 - 5.7	5.5 - 5.7
3	5.8 - 6.2	5.8 - 6.2
4	6.2 - 6.7	6.3 - 6.5
5	6.8 - 7.2	6.5 - 6.7

With this range of asphalt percentages, it is noted that in most cases all requirements for an acceptable mix design are met. Where the specifications are not met the asphalt percentages border the limits and appear to be tolerable.

These border cases occurred in gradation five with each aggregate. Stabilities were slightly below the specified value of 1,450 pounds. Gradations one and four for greenstone showed high values of flow and VFA, respectively. All the aforementioned values are tolerable enough that no gradation would have to be rejected.

The property graphs (Figures 1 and 2) are useful in studying aggregate sensitivity. The greenstone tended to vary more in density and stability as fines were removed than did the granite. Other properties did not show a great deal of variation.

CONCLUSIONS

This study confirmed that with two Virginia aggregates it was possible to eliminate all mineral filler and produce a satisfactory surface mix design. It further showed that the removal of all material passing the #100 sieve is feasible.

One fact brought out in this study is that any decrease in fines is accompanied by a significant increase in asphalt percent. In certain cases asphalt percentages were found to be somewhat higher than normally expected for a typical S-5 mix. Even with such high asphalt percentages, specifications were met and the mixes were thus acceptable.

REFERENCES

1. Regulations for the Control and Abatement of Air Pollution, State Air Pollution Control Board, Richmond, Virginia, February 3, 1974.

2. Walling, J. C., "Pollution Control Systems for Asphalt Plants," Roads and Streets, May 1971, pp. 114-118.

3. Road and Bridge Specification, Virginia Department of Highways and Transportation, July 1, 1970.

4. Frank, W. G., American Air Filters, Inc., Dust Control Products, Louisville, Ky.

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APPENDIX

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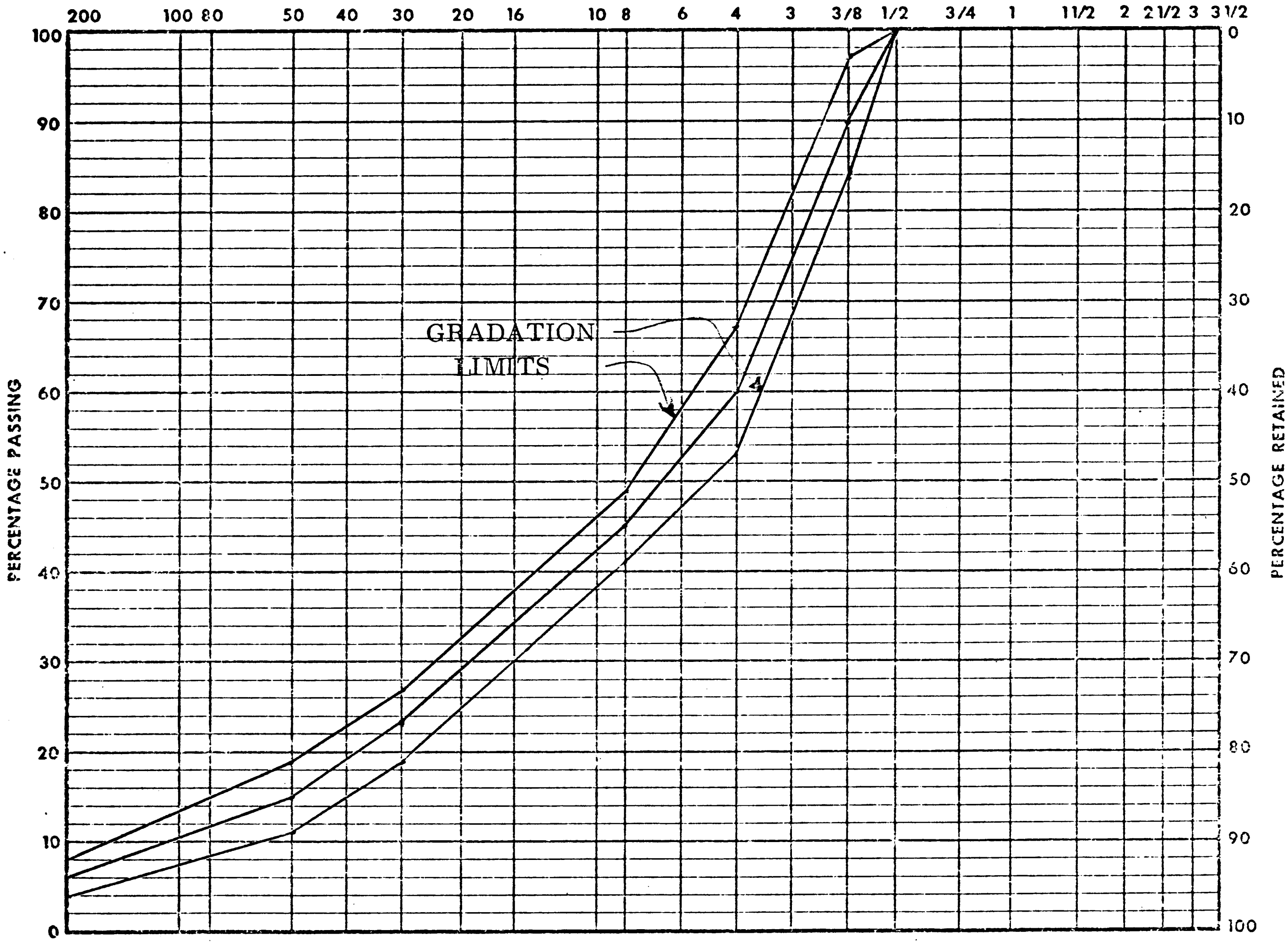
Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART

U.S. SIEVE NUMBERS

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		45		
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232		23		
	3/4					40	.0165				
	1/2		100			50	.0117		15		
	3/8		90			80	.0070				
3	.265					100	.0059		10.5		
4	.187		60			200	.0029		6.0		
TOTAL						TOTAL					

Figure A1. Gradation one

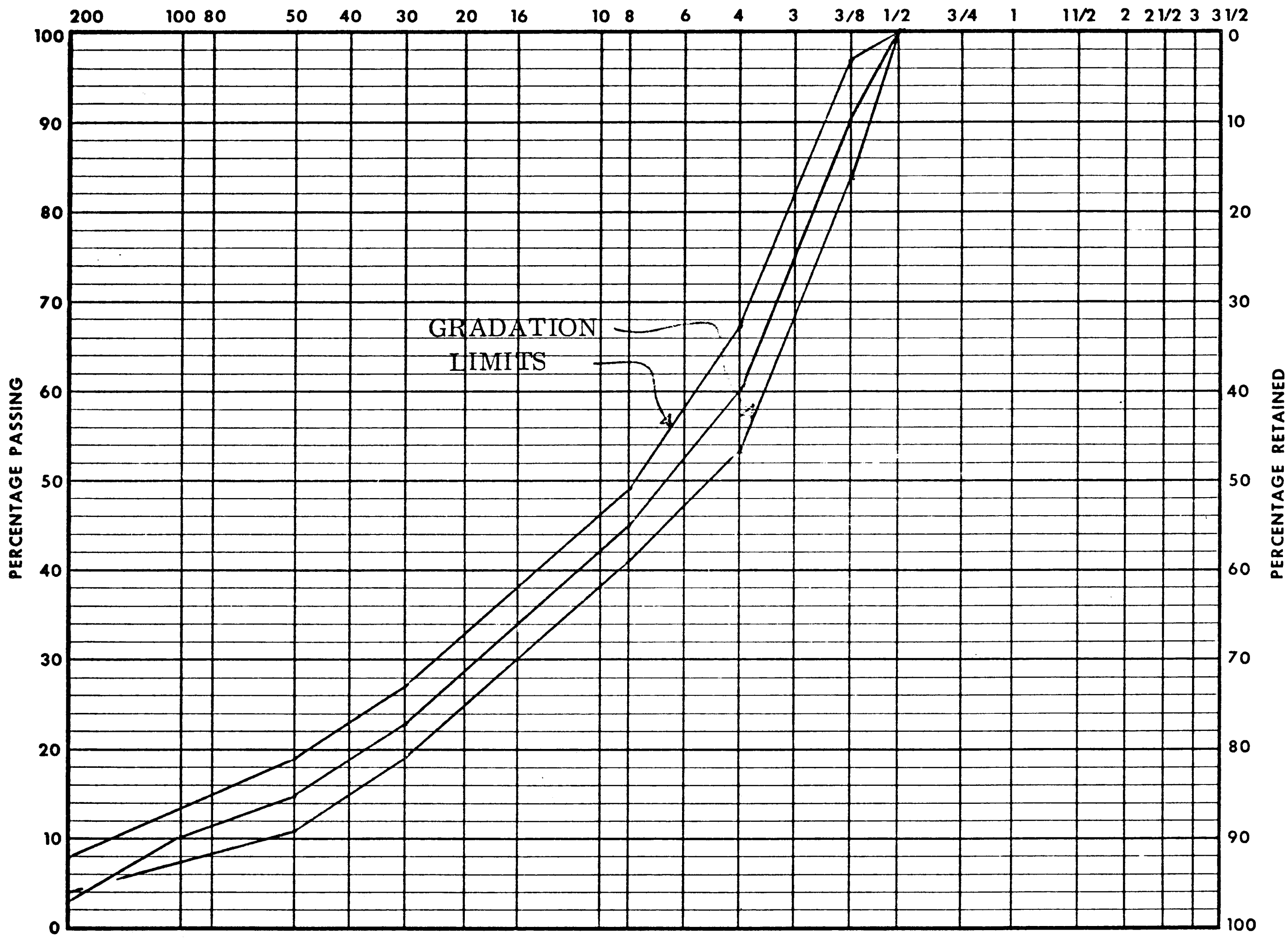
Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART

U.S. SIEVE NUMBERS

Date: ____________________ File: ____________________



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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		45		
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232		23		
	3/4					40	.0165				
	1/2		100			50	.0117		15		
	3/8		90			80	.0070				
3	.265					100	.0059		10.5		
4	.187		60			200	.0029		3.0		
TOTAL						TOTAL					

Figure A2. Gradation two.

Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART

U.S. SIEVE NUMBERS

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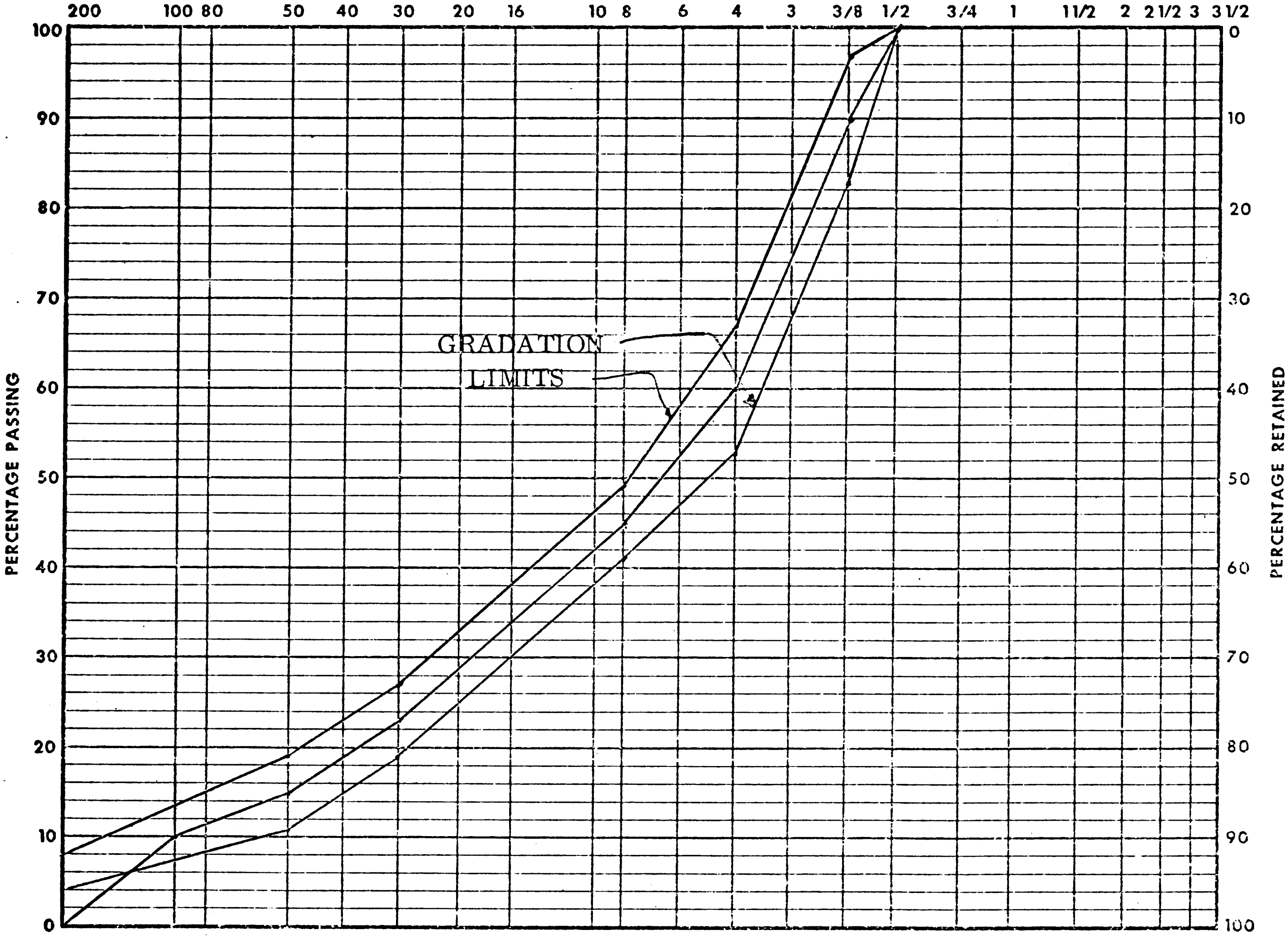

SAMPLE OF ______________________ FROM ______________________ PRODUCER ______________________

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		45		
	2 1/2					10	.0787				
	2					16	.0469				
	11/2					20	.0331				
	1					30	.0232		23		
	3/4					40	.0165				
	1/2		100			50	.0117		15		
	3/8		90			80	.0070				
3	.265					100	.0059		10.5		
4	.187		60			200	.0029		0		
TOTAL						TOTAL					

Figure A3. Gradation three.

Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

GRADATION CHART

U.S. SIEVE NUMBERS

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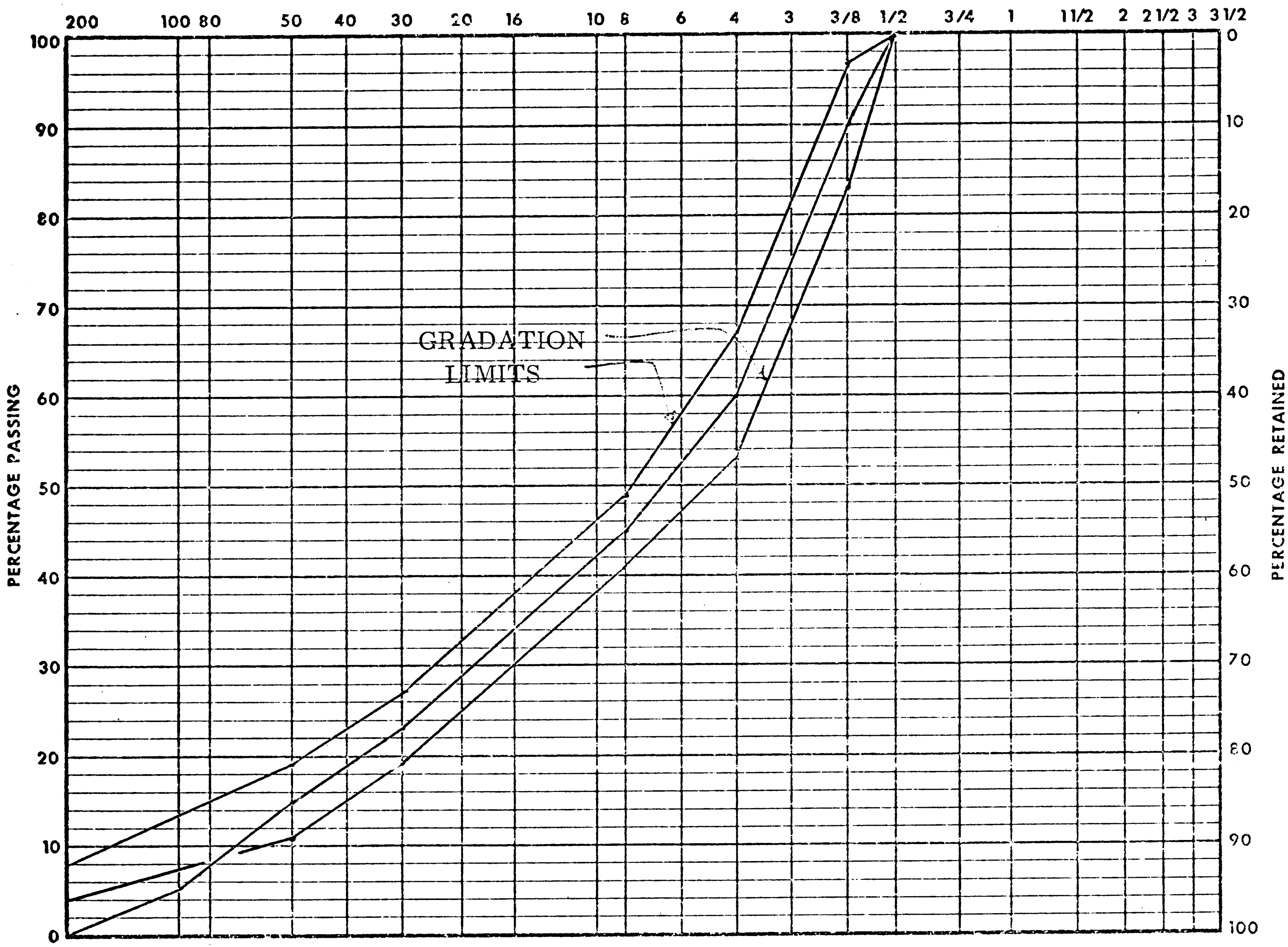

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TESTED BY ______ FOR ______ FIN. MOD. ______

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		45		
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232		23		
	3/4					40	.0165				
	1/2		100			50	.0117		15		
	3/8		90			80	.0070				
3	.265					100	.0059		5.3		
4	.187		60			200	.0029		0		
TOTAL						TOTAL					

Figure A4. Gradation four.

Form No. R-188

VIRGINIA COUNCIL OF HIGHWAY INVESTIGATION AND RESEARCH

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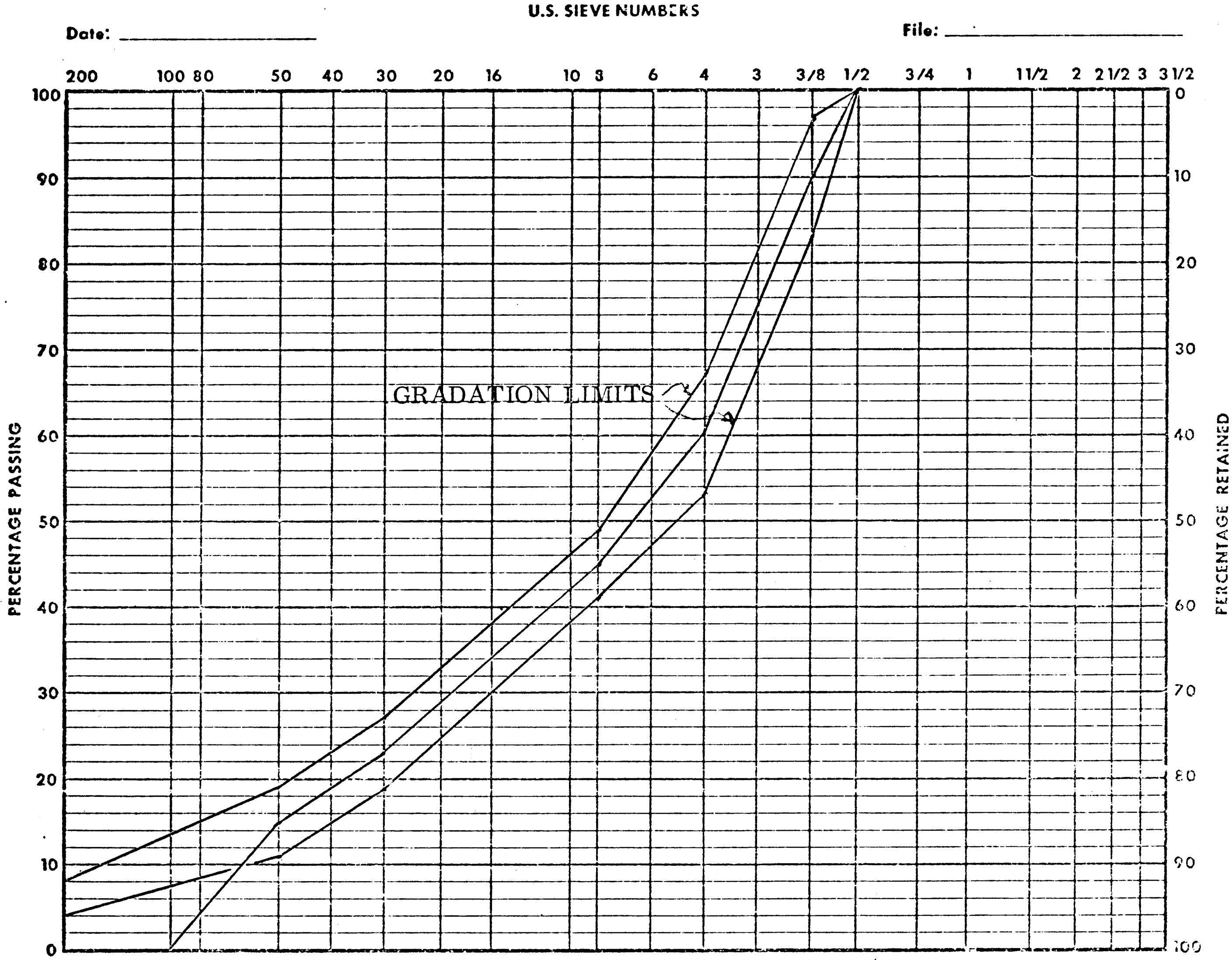
GRADATION CHART

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.
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	3					8	.0937		45		
	2 1/2					10	.0787				
	2					16	.0469				
	1 1/2					20	.0331				
	1					30	.0232		23		
	3/4					40	.0165				
	1/2		100			50	.0117		15		
	3/8		90			80	.0070				
3	.265					100	.0059		0		
4	.187		60			200	.0029				
TOTAL						TOTAL					

Figure A5. Gradation five.