TRANSPORTATION DEPARTMENT

RESEARCH PROJECT NO. 87

EFFECTS OF IDAHO AGGREGATE GRADATION ON ASPHALT PAVING MIX

RESEARCH SECTION

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EFFECTS OF IDAHO AGGREGATE GRADATION ON ASPHALT PAVING MIX

By: William Clark, S.E.T.

and

James Wright, S.E.T.

Reported By: Tri Buu, P.E.
Acting Soils and Foundation Engineer

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IDAHO DEPARTMENT OF TRANSPORTATION

Division of Highways

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ABSTRACT

This study is to investigate the effects of Idaho aggregate gradation on paving mix design. Four Idaho sources of aggregate were chosen for the study. For each source, three different gradations were made and subjected to Hveem test.

It appeared that gradation of each source has its own effect on the asphalt paving mix.

It is found that for Source El-8, gradation does not have much effect on mix design. With Source Bk-117, gradation of 1/2" aggregate should be kept close to the lower limit of the gradation guide, the one that contains more coarse aggregate. Aggregate gradation from Source Ad-56 also should contain more coarse aggregate and this source is good for use in pavement under heavy traffic. Three-quarter aggregate from Source TF-25 also should be kept close to the lower limit of the gradation guide.

II. BACKGROUND ON ASPHALT PAVING MIX DESIGN

Two methods widely used in America for design of asphalt paving mixes are Hveem and Marshall. Idaho has been employing the Hveem method. Generally, asphalt paving mix design is a matter of selecting and proportioning materials to obtain desired properties in finished construction. The overall objective for a preliminary mix design is to determine an economical blend of aggregates and asphalt that yields a mix having:

1) Sufficient asphalt to ensure a durable pavement.

2) Sufficient mix stability to satisfy the demands of traffic without distortion and displacement to the pavement.

3) Sufficient voids in the total compacted mixes to allow for a slight amount of additional compaction under traffic loading without flushing, bleeding, and/or loss of stability, yet low enough to keep out harmful air and moisture.

4) Sufficient aggregate gradation to permit efficient placement of the mix without segregation.

In the process of developing a specific mix design, several trial mixes with aggregate gradation that closes to the middle of the guide and at different asphalt content are often required to find one that meets all the criteria of the design method used. If the trial mixes fail to meet the design criteria, it will be necessary to modify or redesign the mix. Adjustments in the original aggregate gradation may be required to correct the deficiency.

Aggregate plays an important role in asphalt paving mix. Three individual fractions of the total aggregate gradation are often defined as Coarse Aggregate (retained on No. 4 sieve), Fine Aggregate (passing No. 4 sieve), and Mineral Dust (passing No. 200 sieve).

Idaho guide for aggregates used in asphalt paving mixes are shown in Table 1. Asphalt mix design criteria are as follows (Materials Section Procedure No. 6, Item 3, January 1979):

*Air voids:

Gravels: Approximately 5%
Quarries: Approximately 7%

*Stability:

Medium to High Traffic:	Top courses:	$\geq$ 30
	Bases :	$\geq$ 25
Low Traffic (150 ADT or less):	Surfaces:	$\geq$ 25
	Bases :	$\geq$ 20

*Asphalt Film Thickness: Minimum 6 microns

*Void of Mineral Aggregate (VMA) Desirable:
Approximately 15% for 1/2" Gradation Aggregate
Approximately 14% for 3/4" Gradation Aggregate

GUIDE FOR PLANTMIX MOVING AVERAGE GRADATIONS

Sieve Size	Maximum Size Aggregate 3/8" Max. Moving Average	1/2" Max. Moving Average	3/4" Max. Moving Average	1" Max. Moving Average
1-1/2"				100
1"			100	95-100
3/4"		100	95-100 97.5	80-95
1/2"	100	95-100 97.5		
3/8"	95-100	80-95 87.5	65-80 72.5	55-70
No. 4	65-80	55-70 62.5	45-60 52.5	40-55
No. 8	45-60	40-55 47.5	30-45 37.5	25-40
No. 16*	35-50	29-41 35	22-34 28	19-30
No. 30*	25-35	19-31 25	18-26 22	16-24
No. 50*	15-25	13-22 17.5	11-19 15	9-17
No. 200	6-10	4-8 6	3-7 5	2-6

*Note It Will usually be necessary to select only one critical sieve of the No. 16, No. 30, or No. 50 sizes for best control of the aggregate.

TABLE 1

III. INVESTIGATION PROGRAM

Four Idaho aggregates sources were used for this study. They are as follows:

1) Source El-8: Pit run. Alluvial terrace deposits; quartzite, porphyry, granite and conglomerate.

2) Source Bk-117: Slag - by-product - vesicular and glassy.

3) Source Gd-56: Pit run. Melon gravel, vesicular basalt, basalt, vesicular scoria and glassy vesicular basalt.

4) Source Tf-25: Quarry source. Layered dolomite, quartzite, quartz and dolomite.

Three different aggregate gradations were made for each source. One gradation was close to the median of the specification, called Medium Range (MR), one that contains much more coarse aggregates, called Low Range (LR) and one made largely by fine aggregates, called High Range (HR). Their gradations and grading curves plotted on gradation charts (raised to 0.45 power) can be seen in Figure 1 to Figure 4. No special screenings were made to smooth out the grading lines. Generally the crusher run materials were used.

Aggregate at each gradation was mixed with asphalt cement (mostly 120-150 pen.) and subjected to Hveem testing. In the Hveem test, five trial mixes at different asphalt contents, expressed in percent of the total weight of the aggregate, were tested to determine the optimum proportions of each material that yields a mix meeting the design criteria. A detail of Hveem test can be seen in Idaho Test Method T-9.

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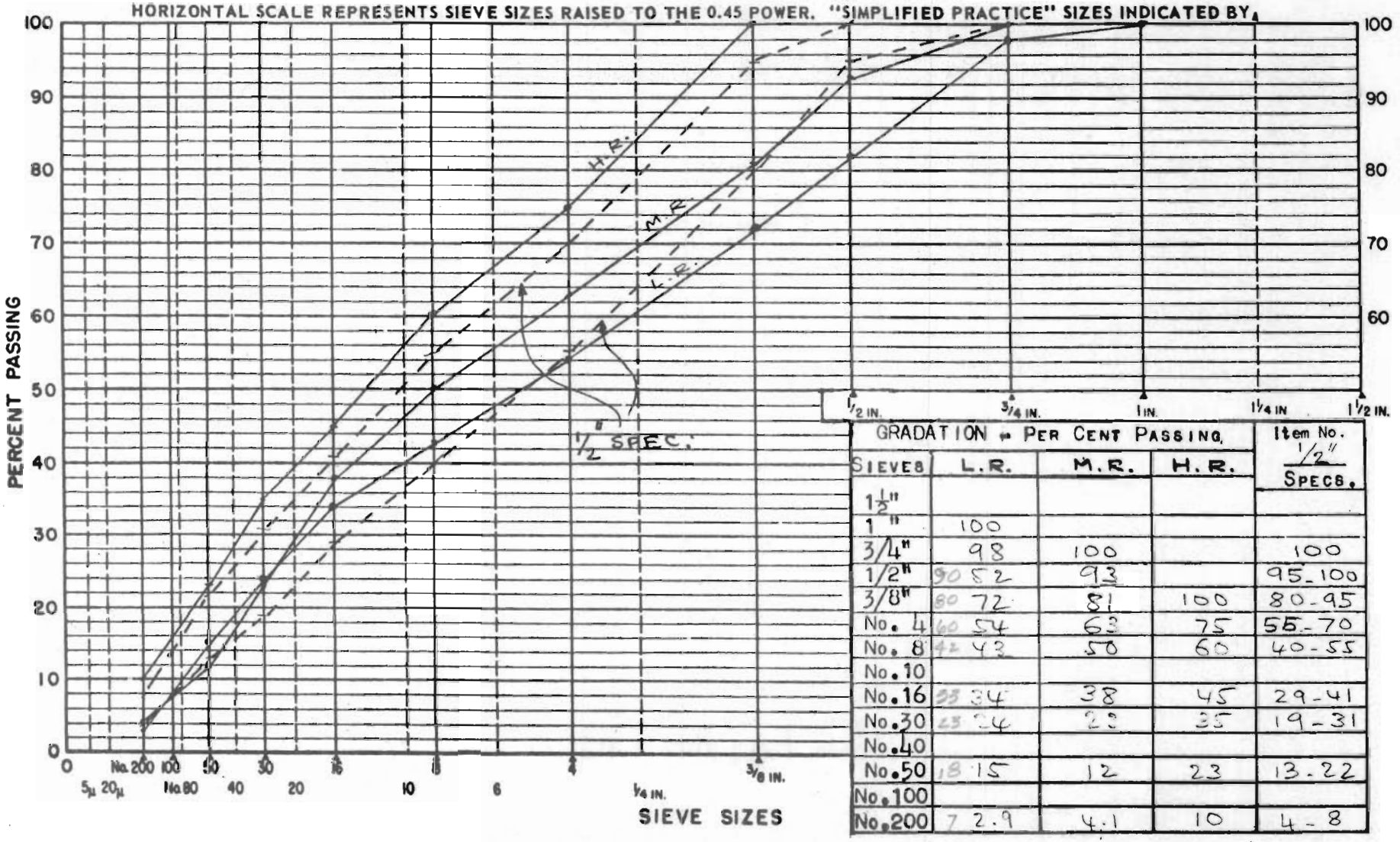
GRADATION CHART

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED BY



GRADATION — PER CENT PASSING				Item No. 1/2" SPECS.
SIEVES	L.R.	M.R.	H.R.	
1 1/2"				
1"	100			
3/4"	98	100		100
1/2"	90 52	93		95-100
3/8"	80 72	81	100	80-95
No. 4	60 54	63	75	55-70
No. 8	42 43	50	60	40-55
No. 10				
No. 16	33 34	38	45	29-41
No. 30	23 24	29	35	19-31
No. 40				
No. 50	18 15	12	23	13-22
No. 100				
No. 200	7 2.9	4.1	10	4-8

PROJECT RESEARCH NO. 87 LAB. NO. 79-A0070

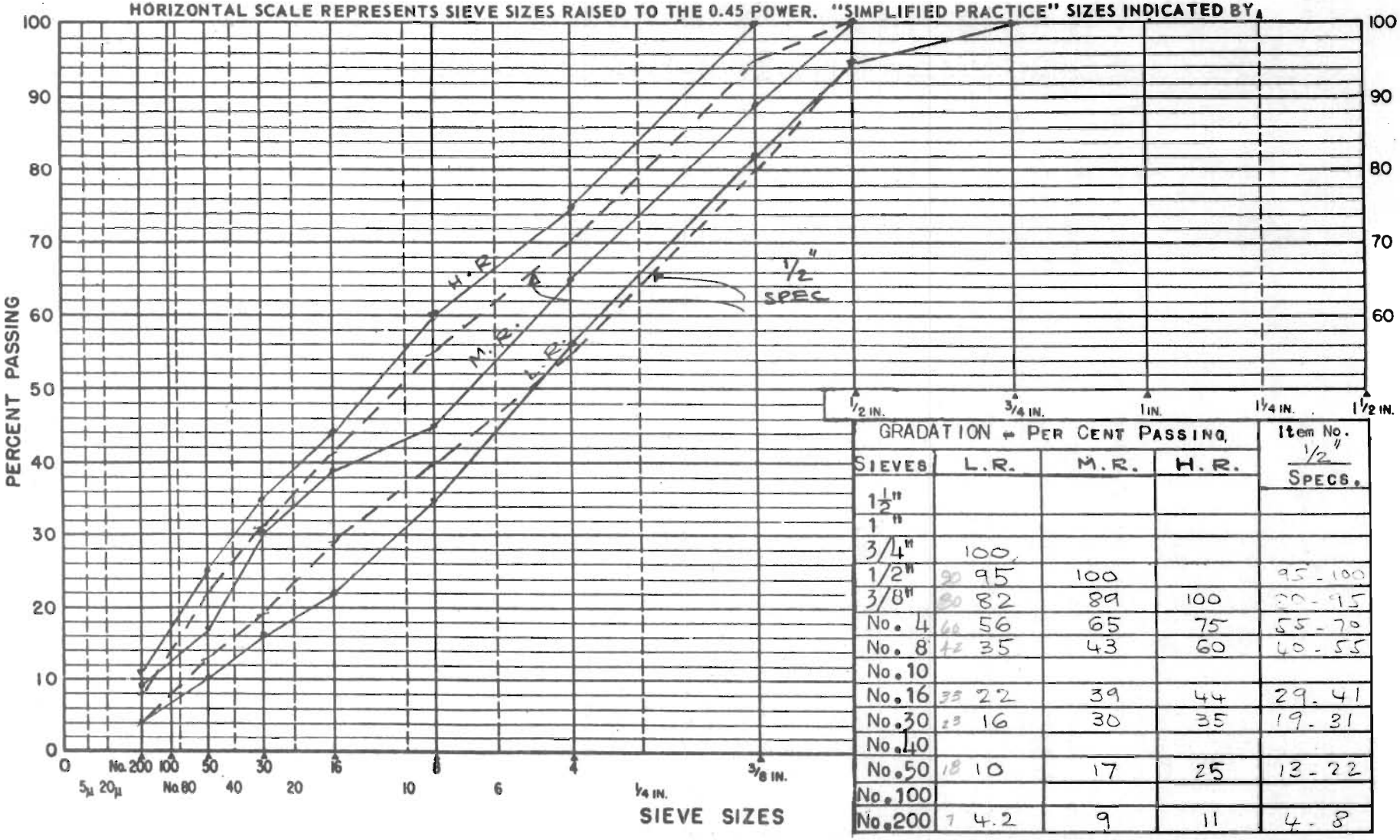
IDENT. NO. PIT. NO. E1-8

FIGURE 1

DH-958 5-78

GRADATION CHART

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED BY ▲



GRADATION — PER CENT PASSING				Item No. 1/2" SPECS.
SIEVES	L.R.	M.R.	H.R.	
1 1/2"				
1"				
3/4"	100			
1/2"	95	100		95 - 100
3/8"	82	89	100	80 - 95
No. 4	56	65	75	55 - 70
No. 8	35	43	60	40 - 55
No. 10				
No. 16	22	39	44	29 - 41
No. 30	16	30	35	19 - 31
No. 40				
No. 50	10	17	25	13 - 22
No. 100				
No. 200	4.2	9	11	4 - 8

PROJECT RESEARCH NO. 87 LAB. NO. 79-A0010

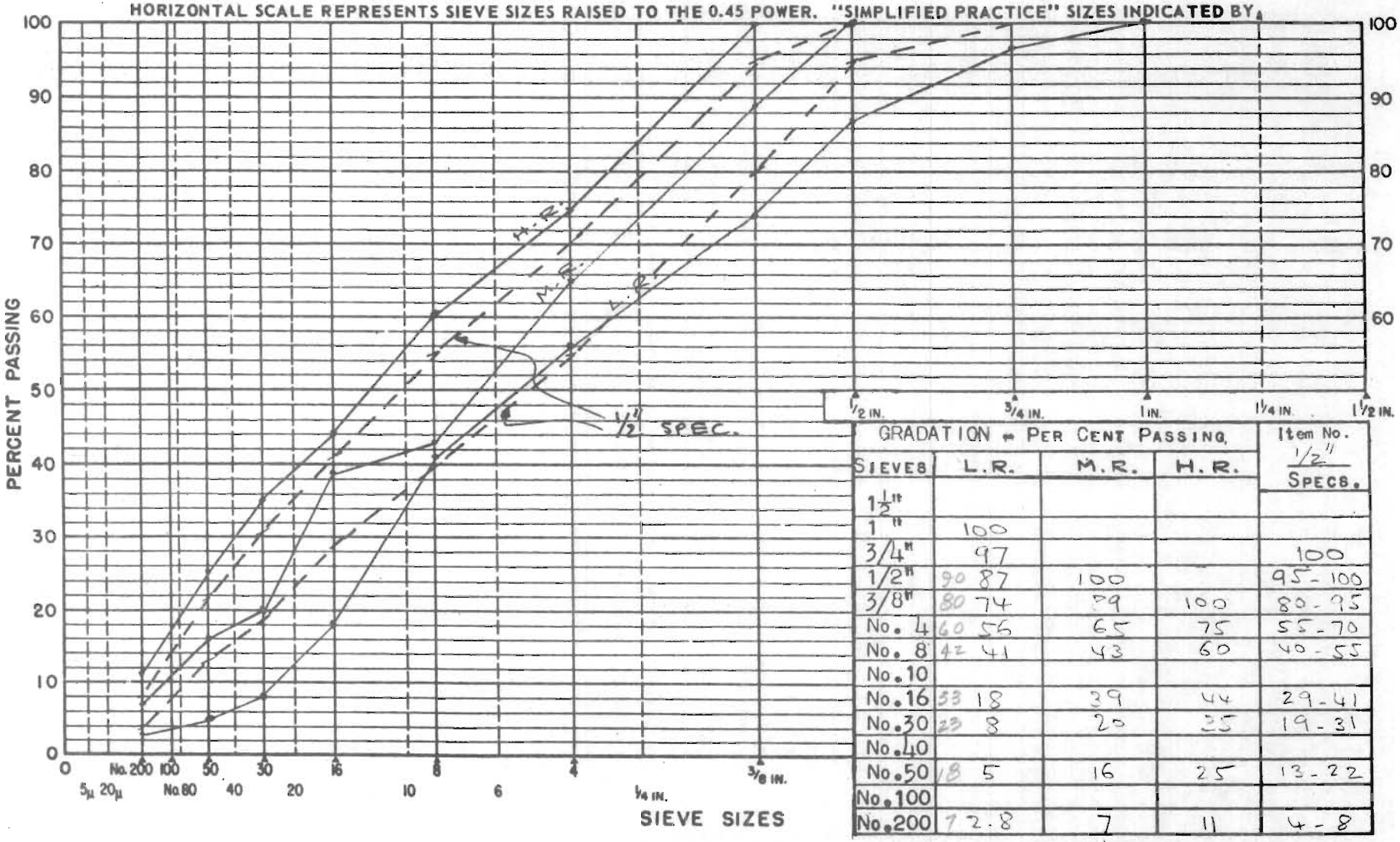
IDENT. NO. _____ PIT. NO. Bk-117

FIGURE 2

DH-958 5-78

GRADATION CHART

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED BY ▲



GRADATION = PER CENT PASSING,				Item No. 1/2"
SIEVES	L.R.	M.R.	H.R.	SPECS.
1 1/2"				
1"	100			
3/4"	97			100
1/2"	90 87	100		95 - 100
3/8"	80 74	89	100	80 - 95
No. 4	60 56	65	75	55 - 70
No. 8	42 41	43	60	40 - 55
No. 10				
No. 16	33 18	39	44	29 - 41
No. 30	23 8	20	35	19 - 31
No. 40				
No. 50	18 5	16	25	13 - 22
No. 100				
No. 200	7 2.8	7	11	4 - 8

PROJECT RESEARCH NO. 87 LAB. NO. 79-A0023

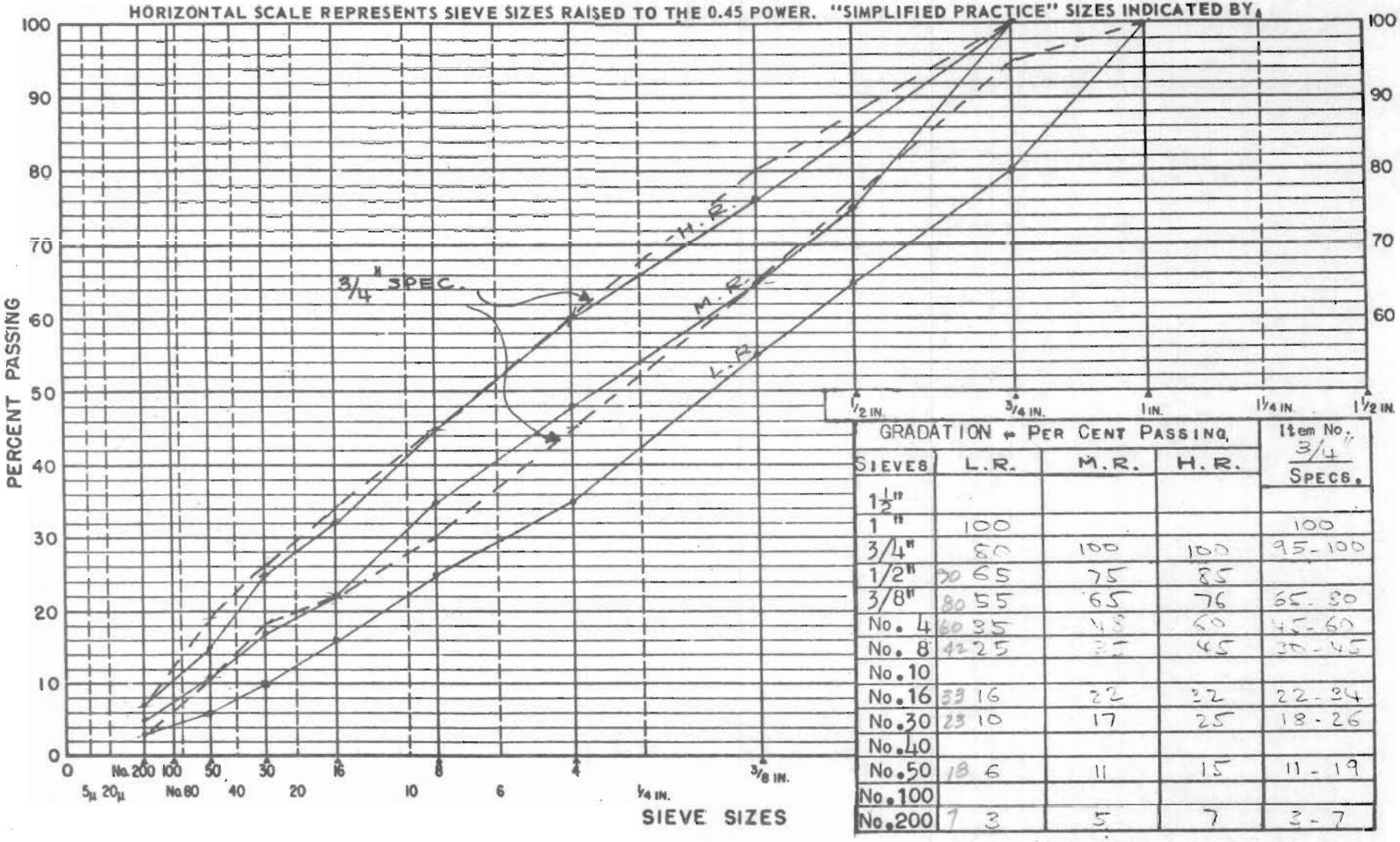
IDENT. No. _____ PIT. No. Gd-56

FIGURE 3

DH-958 5-78

GRADATION CHART

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED BY



GRADATION — PER CENT PASSING				Item No. 3/4"
SIEVES	L.R.	M.R.	H.R.	SPECS.
1 1/2"				
1"	100			100
3/4"	80	100	100	95-100
1/2"	80 65	75	85	
3/8"	80 55	65	76	65-80
No. 4	60 35	45	60	45-60
No. 8	42 25	35	45	30-45
No. 10				
No. 16	33 16	22	32	22-34
No. 30	23 10	17	25	18-26
No. 40				
No. 50	18 6	11	15	11-19
No. 100				
No. 200	7 3	5	7	3-7

PROJECT RESEARCH NO. 87 LAB. NO. 77-A0529

IDENT. NO. _____ PIT. NO. Tf-25

FIGURE 4

IV. TEST RESULTS AND ANALYSES

Results from Hveem tests are shown in Figure 5 to Figure 8. From these results trial mixes that meet the criteria were determined for each aggregate gradation and are illustrated in Table 2 through Table 5 and Figure 5 through Figure 8.

* Source El-8: 1/2" Maximum Size Aggregate.

From Table 2 and Figure 5, the three gradations of aggregate of this source yield almost the same mix design properties. The high range gradation yields an asphalt film thickness a little lower than the recommended 6 microns. All three ranges of aggregate yield a maximum stability of about 26, which will not meet the criteria for asphalt top course for medium to high traffic pavement. This may be caused by the low quality of this source of aggregate. It is noted that while the LR and HR gradation are out of the specification range for 1/2" size aggregate, they fall into the specification range of 3/4" and 3/8", respectively. Probably that is the reason why those three gradations still produce satisfactory mixes.

* Source Bk-117: 1/2" Maximum Size Aggregate.

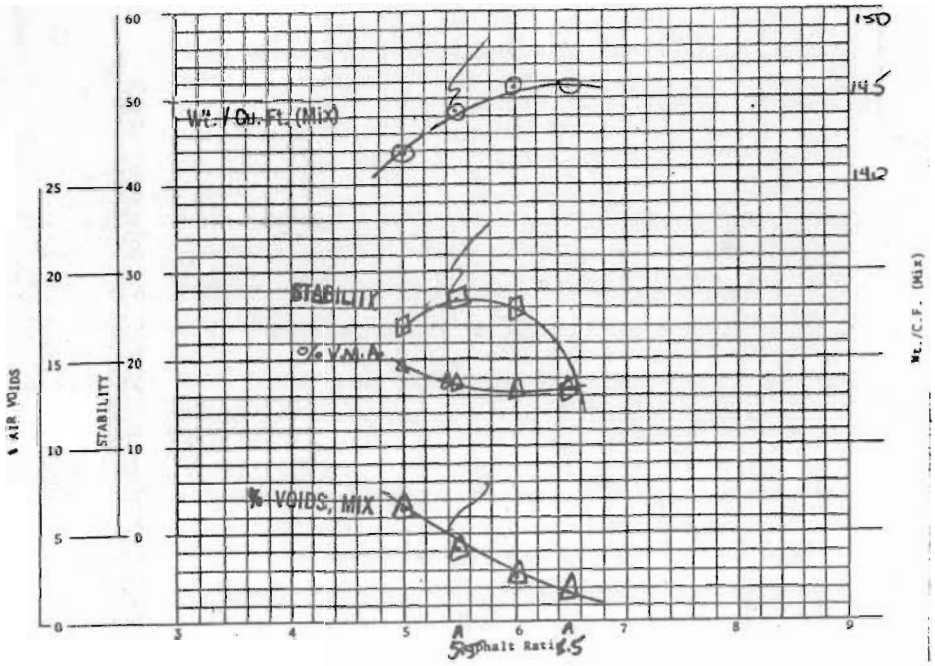
From Table 3 and Figure 6, all three ranges of aggregate gradation yield satisfactory air voids and high densities. Stability is satisfactory with low and middle range but relatively low on high range. MR and HR gradation have asphalt film thickness too low compared to the desirable 6 microns. Increasing the asphalt content will increase the asphalt film thickness but results in air voids becoming too low. A mix with low asphalt film thickness will have a low durability and may lead to brittleness, accelerated oxidation, and high permeability of the pavement. It appears that for this source, the more fine aggregate the mix contains, the lower the stability becomes.

* Source Gd-56: 1/2" Maximum Size Aggregate.

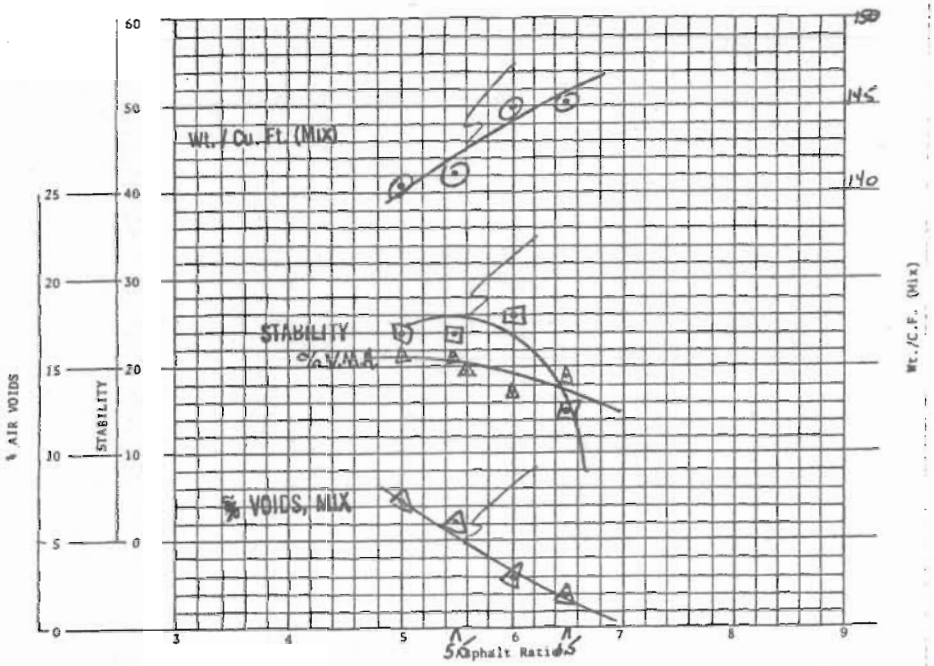
This source tends to yield high air voids as shown in Table 4 and Figure 7. Low range gradation results in high air voids unacceptable for mix design in the normal range of asphalt content. MR and HR gradations produce high densities, high air voids, and satisfactory stabilities. However, both have lower asphalt film thicknesses than desired.

* Source TF-25: 3/4" Maximum Size Aggregate.

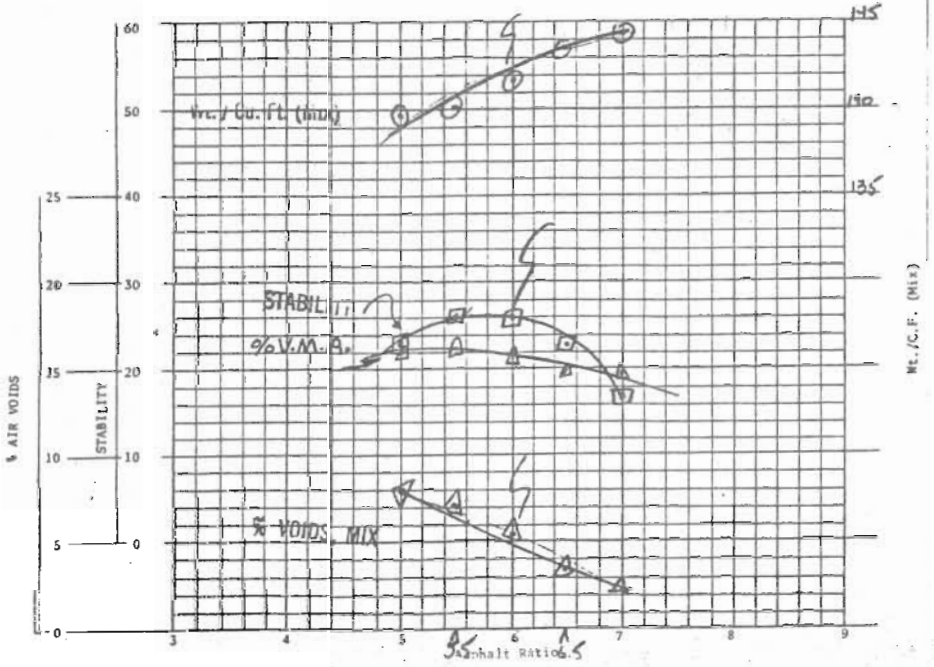
From Table 5 and Figure 8, satisfactory mixes can be produced with the three ranges of gradation. For the HR gradation, stability drops drastically with increasing asphalt content.



LOW RANGE



MIDDLE RANGE



HIGH RANGE

SOURCE E1-8

HVEEM TEST RESULTS

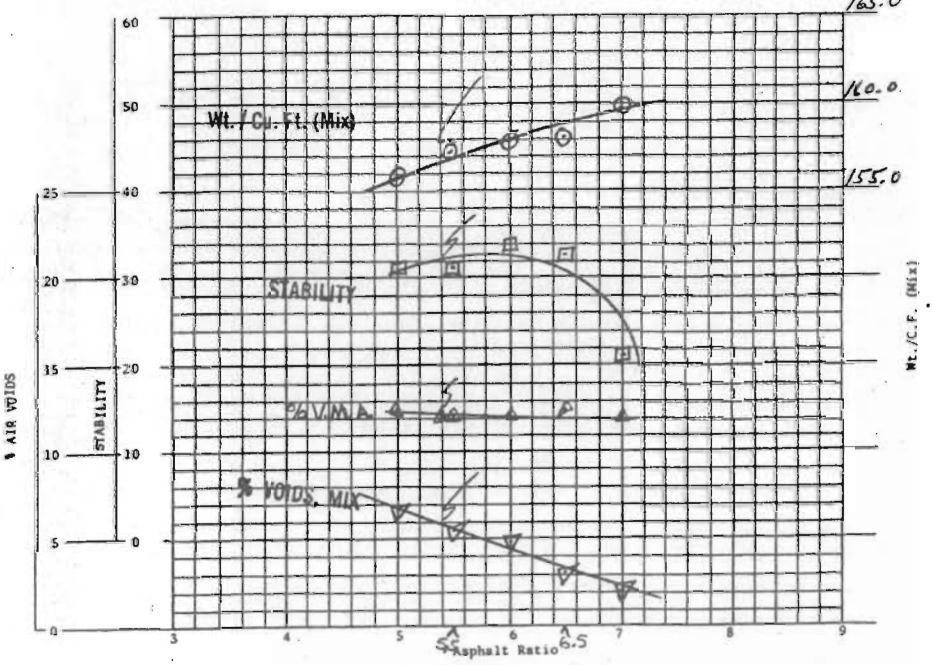
FIGURE 5

AGGREGATE SOURCE: E1-8 MAXIMUM SIZE AGGREGATE: 1/2"

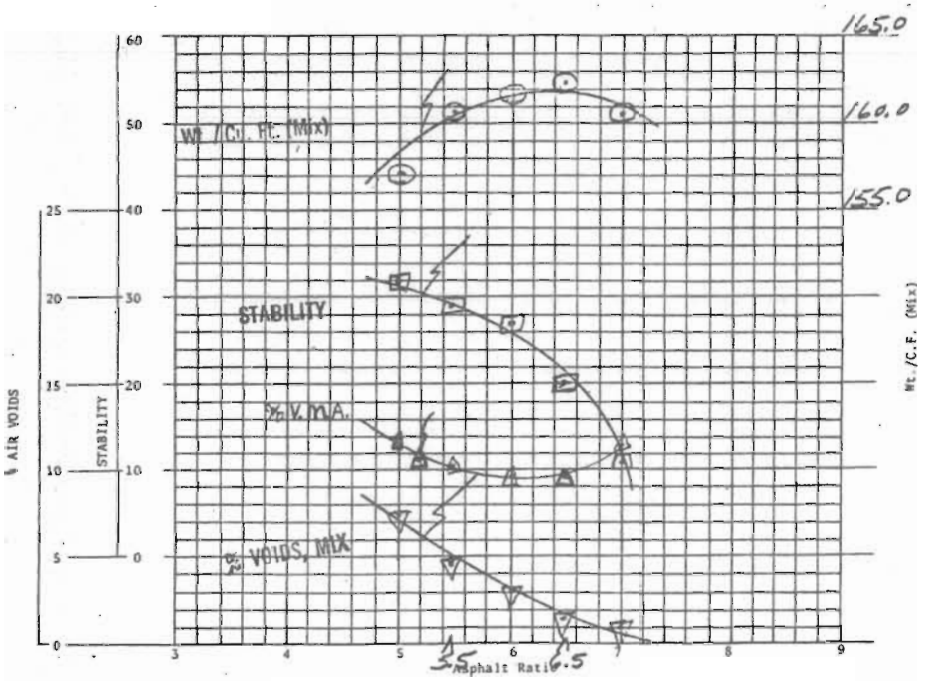
SELECTED MIX DESIGN

GRADATION RANGE	ASPHALT GRADE & BRAND	AGG. SURF. AREA (Ft^2/Lb)	AIR VOIDS (%)	ASPHALT CONTENT (%)	ASPH. FILM THICKNESS (MICRONS)	STABILITY	DENSITY (Lb/Ft^3)	REMARKS
LOW RANGE	120-150 CENEX	25.42	5	5.4	7.8	26	144	Moderate air voids. Low stability. Sharp drop at 6%. Moderate density.
MIDDLE RANGE	120-150 CENEX	25.88	5	5.6	8.5	26	143	Moderate air voids. Low stability. Sharp drop at 6% asphalt. Moderate density.
HIGH RANGE	120-150 CENEX	46.30	5	6.0	5.0	26	142	Moderate air voids. Low stability. Low density. Not enough asphalt film thickness.

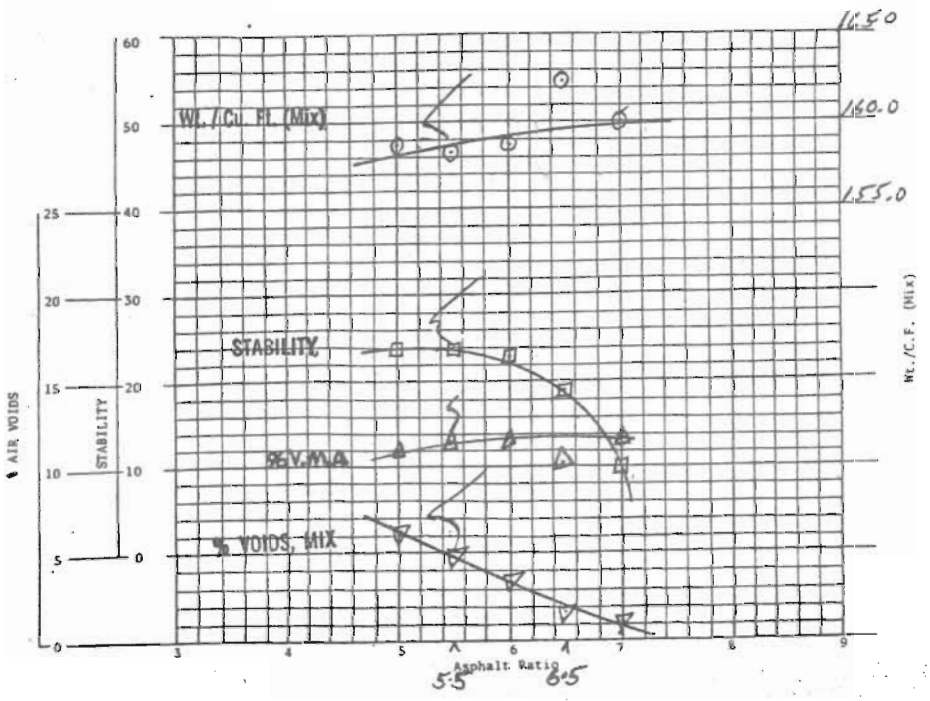
TABLE 2



LOW RANGE



MIDDLE RANGE



HIGH RANGE

SOURCE Bk-117

HVEEM TEST RESULTS

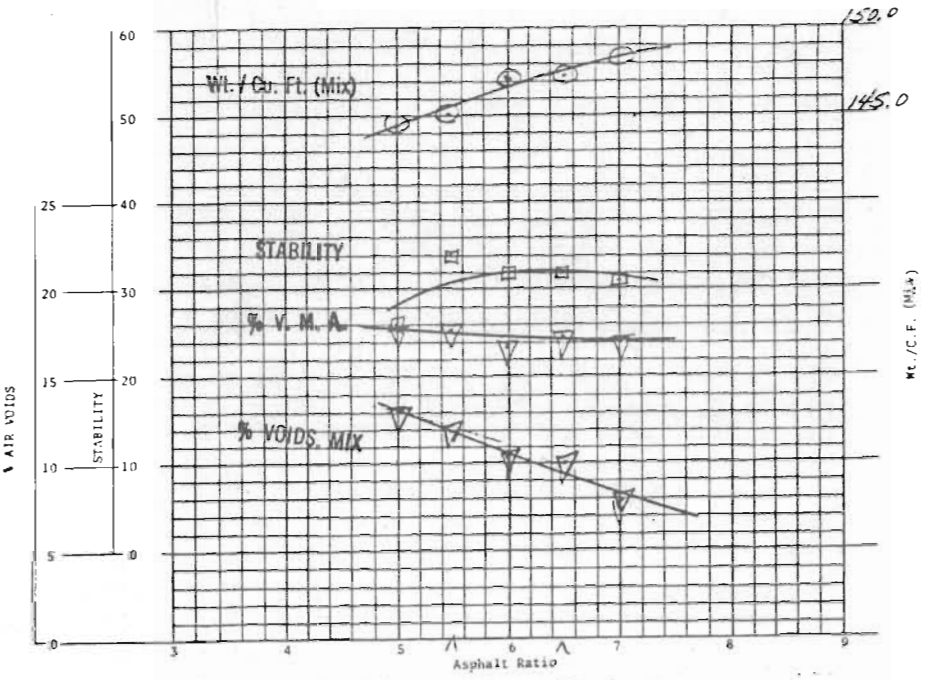
FIGURE 6

AGGREGATE SOURCE: Bk-117 MAXIMUM SIZE AGGREGATE: 1/2"

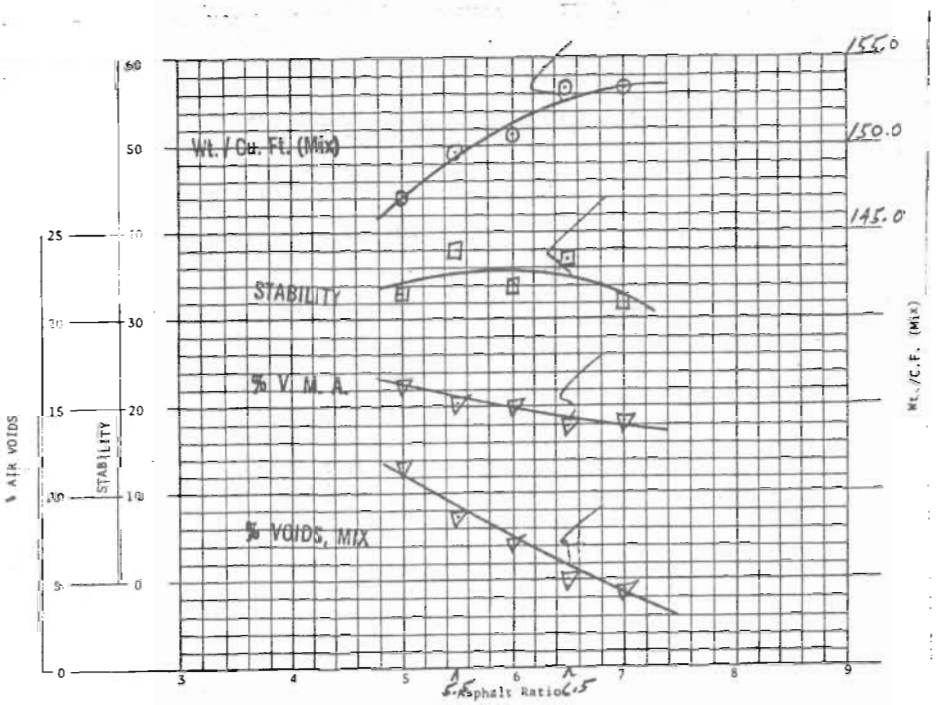
SELECTED MIX DESIGN

GRADATION RANGE	ASPHALT GRADE & BRAND	AGG. SURF. AREA (Ft^2/Lb)	AIR VOIDS (%)	ASPHALT CONTENT (%)	ASPH. FILM THICKNESS (MICRONS)	STABILITY	DENSITY (Lb/Ft^3)	REMARKS
LOW RANGE	120-150 CENEX	22.44	6	5.4	5.8	32	157	Moderate air voids. Moderate stability, sharp drop at 6.5%. High density. Flush at 7.0%.
MIDDLE RANGE	120-150 CENEX	39.04	6	5.2	2.3	30	159	Moderate air voids. Stability drops, with asphalt content. High density. Flush at 7.0%. Not enough asphalt film thickness.
HIGH RANGE	120-150 CENEX	49.02	5	5.5	2.7	24	158	Moderate air voids. Low stability, sharp drop at 6.0%. High density. Not enough asphalt film thickness.

TABLE 3



LOW RANGE

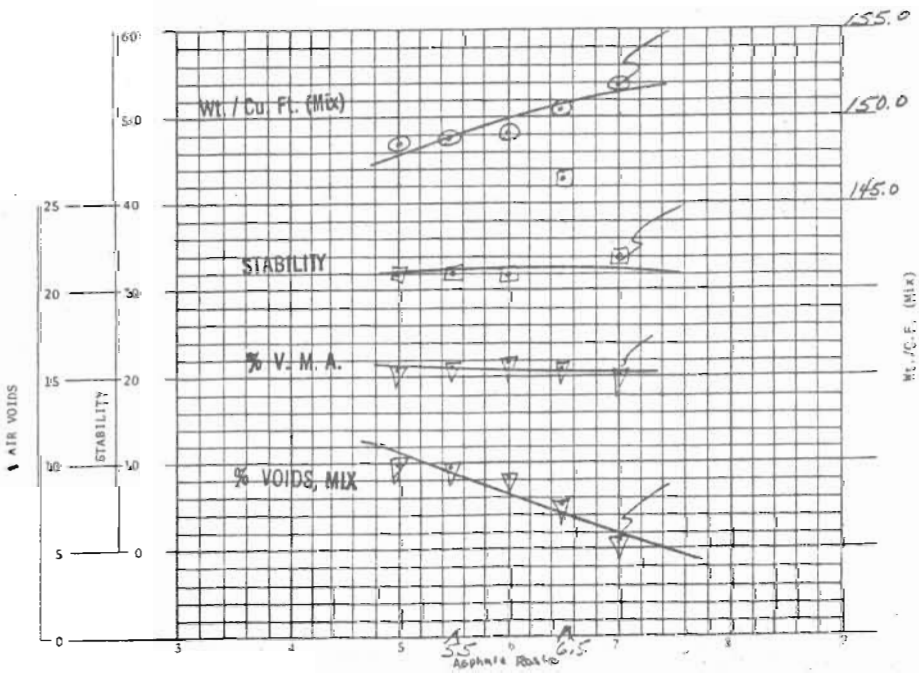


MIDDLE RANGE

SOURCE Gd-56

HVEEN TEST RESULTS

FIGURE 7



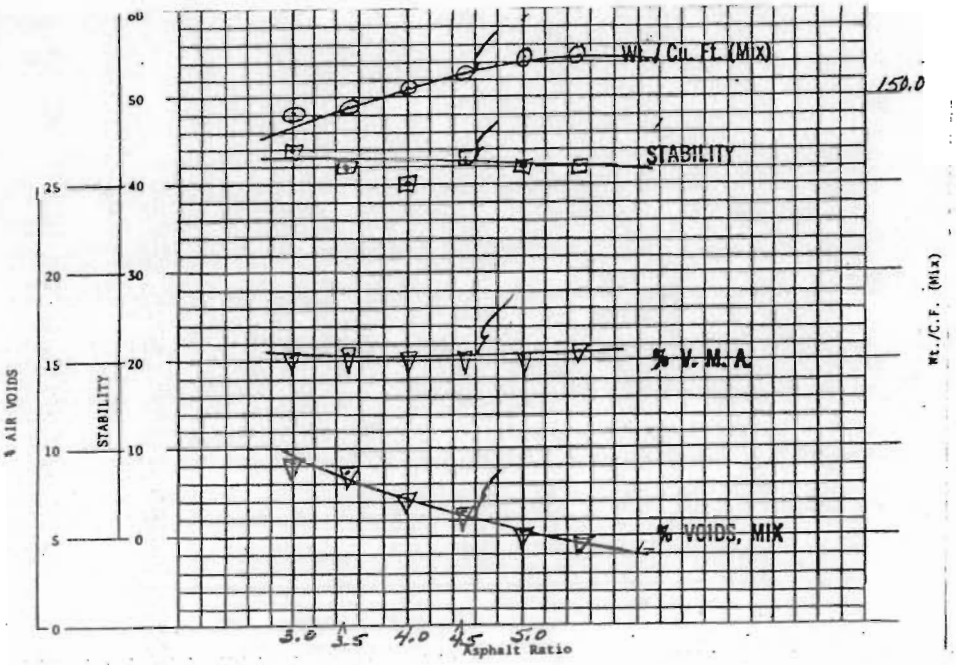
HIGH RANGE

AGGREGATE SOURCE: Gd-56 MAXIMUM SIZE AGGREGATE: 1/2"

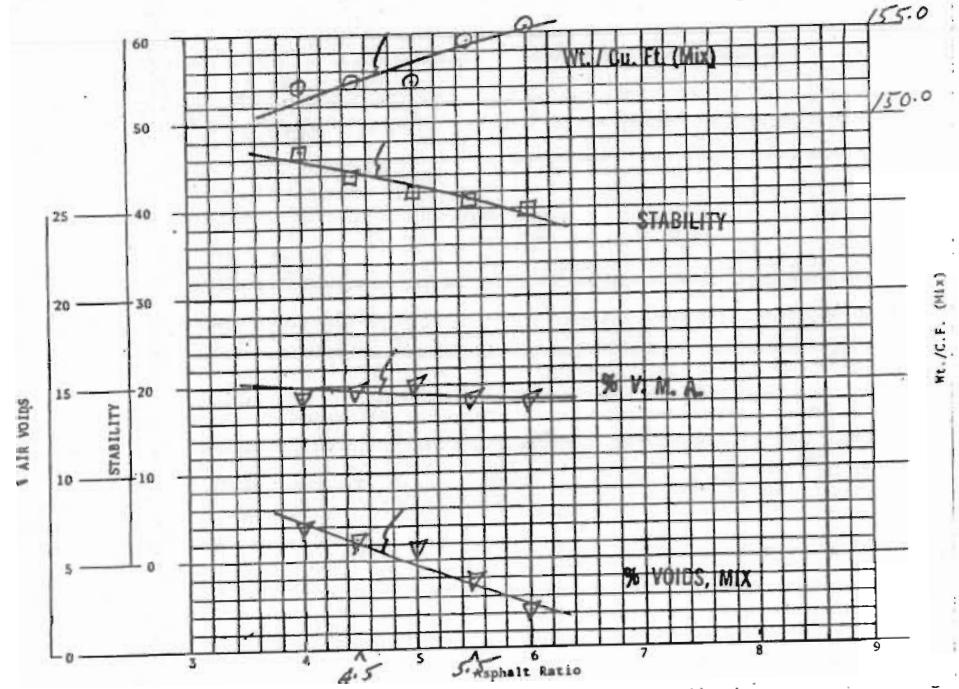
SELECTED MIX DESIGN

GRADATION RANGE	ASPHALT GRADE & BRAND	AGG. SURF. AREA (Ft^2/Lb)	AIR VOIDS (%)	ASPHALT CONTENT (%)	ASPH. FILM THICKNESS (MICRONS)	STABILITY	DENSITY (Lb/Ft^3)	REMARKS
LOW RANGE	120-150 CENEX	15.70	*					* Air voids are too high, insufficient for mix design in an asphalt content range from 5 to 7%.
MIDDLE RANGE	120-150 CENEX	32.94	5	6.5	5.7	35	153	High air voids. Moderate stability. High density. Not enough asphalt film thickness.
HIGH RANGE	120-150 CENEX	49.02	6	7.0	4.1	32	152	High air voids. Moderate stability, flat curve. High density. Not enough asphalt film thickness.

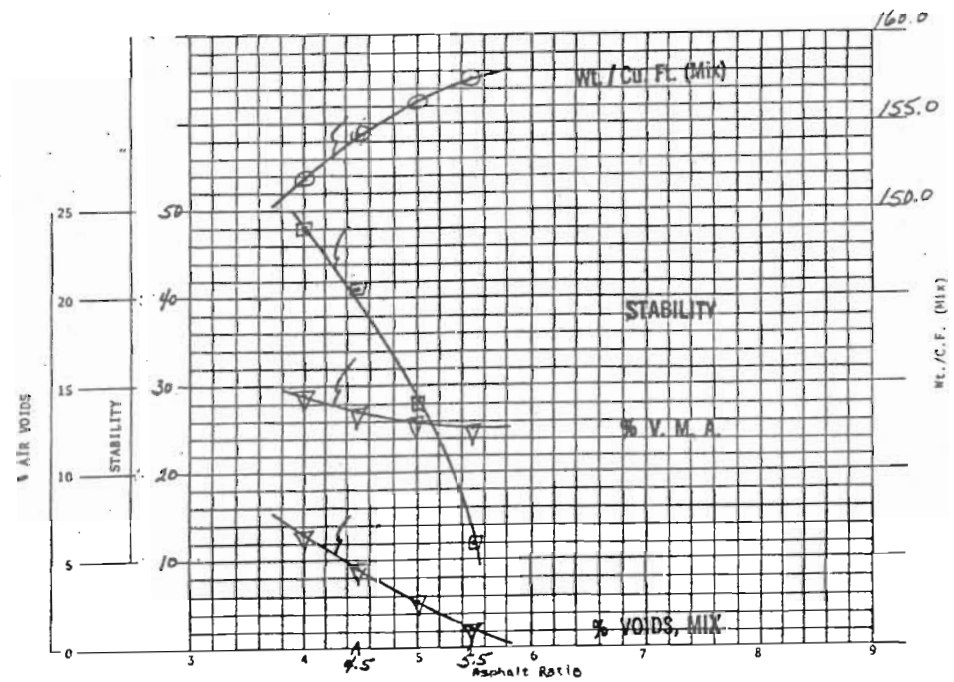
TABLE 4



Low Range



Middle Range



High Range

SOURCE Tf-25

HVEEM TEST RESULTS

FIGURE 8

AGGREGATE SOURCE: Tf-25 MAXIMUM SIZE AGGREGATE: 3/4"

SELECTED MIX DESIGN

GRADATION RANGE	ASPHALT GRADE & BRAND	AGG. SURF. AREA (Ft^2/Lb)	AIR VOIDS (%)	ASPHALT CONTENT (%)	ASPH. FILM THICKNESS (MICRONS)	STABILITY	DENSITY (Lb/Ft^3)	REMARKS
LOW RANGE	170-240 HUSKY	15.98	6	4.6	12.2	42	152	High air voids. High stability, flat curve. Moderate density. Flushing starts at 4.5% asphalt.
MIDDLE RANGE	170-240 HUSKY	24.60	6	4.7	7.8	44	153	Moderate air voids. High stability, moderate flat curve. Moderate density. Flushing at 6.0% asphalt.
HIGH RANGE	170-240 HUSKY	33.36	6	4.3	5.3	44	153	Moderate air voids. High stability, but drops considerably with asphalt. Moderate density. Flushing starts at 5.0% asphalt. Not enough asphalt film thickness.

TABLE 5

V. CONCLUSIONS AND RECOMMENDATIONS

A general trend for the effects of the aggregate gradation on asphalt mix design was not found for the aggregate sources of this study. It appears that each source has its own effect on the mix. Therefore, conclusions and recommendations have been made individually for each source of aggregate.

Source El-8:

The three gradations of this source yield mixes with low stability that will not meet the criteria for top course pavement under medium to high traffic. All produce almost the same mix design. The reason is that when the LR and HR gradation are out of the specification for 1/2" maximum size aggregate, they fall into the specification of 3/4" and 3/8" aggregate size, respectively.

Since this source of aggregate will produce mixes with moderately low stabilities, it should not be used for top course pavements that require a high stability.

Source Bk-117:

The LR gradation of this source yielded a good mix that satisfied all the criteria. MR and HR gradations produce mixes with lower stability and very low asphalt film thickness that may lead to low durability, brittleness, accelerated oxidation, and high permeability.

It is recommended that with Source Bk-117, gradation of 1/2" aggregate should be close to the lower limit of the specification (the one that contain more coarse aggregate).

Source Gd-56:

For this source, LR gradation results in high voids unacceptable for mix design in the normal range of asphalt content. MR and HR gradation produce satisfactory mixes.

The LR gradation, that contains more fine aggregate than the two other gradations is not recommended for asphalt paving mix. This source of aggregate is good for use in pavement under heavy traffic.

Source TF-25:

In this source the two gradations, MR and HR, that are on the extreme sides of the specification for 3/4" aggregate, produce good mixes. The LR gradation that contains much more coarse aggregate and is completely out of the specification, still produces a satisfactory mix. However, for HR gradation, the stability of mix drops rapidly with increase of asphalt content. This is undesirable.

Therefore, it is recommended that for this source, 3/4" size aggregate should be kept close to the lower side of the specifications (the one that contains more coarse aggregate).