Iowa State Highway Commission
Department of Materials

Research Project R-228

EVALUATION OF LIMESTONE FILLER IN GRAVEL MIXTURES OF ASPHALTIC CONCRETE

FOR BETTER HIGHWAYS

IOWA STATE HIGHWAY COMMISSION

DEPARTMENT OF MATERIALS

Report for

Research Project R-228

Evaluation of Limestone Filler in Gravel Mixtures "Asphaltic Concrete"

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by

R. F. Mumm
District Materials Engineer

and

B. H. Ortgies
Bituminous Concrete Engineer

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INTRODUCTION

This study was designed to provide background information on asphaltic concrete mixtures peculiar to northwest Iowa. This background is necessary to provide the basis for future specifications. There were several projects let in 1967 involving 1", 3/4" and 3/8" mixes of Type "B" asphaltic concrete which specified in part, (1) ". . . Not less than 40% of the material passing the No. 200 sieve shall be pulverized limestone or mineral filler, but in no case shall the per cent of pulverized limestone or mineral filler passing the No. 200 sieve be less than 2%. No credit will be allowed for limestone in gravel . . ." Northwest Iowa has no suitable limestone or mineral filler locally available. As a result, this material has to be imported, raising the cost of the mix approximately twenty-five cents per ton. The purpose of this study, therefore, was designed to compare some original job mix samples with alternate mixes from the same local material, but without the addition of pulverized limestone or mineral filler. Since the filler from the crushed gravel does not have the same crushing characteristics or sieve analysis as the pulverized limestone or mineral filler, they could not be compared on an equal percentage basis. Therefore, the alternate mixes were made to conform to the following proposed specification, "No less than 40% of the material passing No. 200 sieve shall be pulverized limestone or mineral filler or a 100% crushed gravel, but in no case shall the per cent of pulverized limestone or mineral filler or a 100% crushed gravel passing the No. 200 sieve be less than 2%."

TESTS AND PROCEDURES (1) (2)

The standard series of tests currently used by the ISHC Materials Laboratory for evaluation of job mixes for regular contract work were used for this study. Marshall stability and flow measurements were made to supplement the standard methods of mix testing. All tests and test procedures followed standards currently provided by A.A.S.H.O. and A.S.T.M. Specimens were compacted by the Marshall mechanical compactor currently used in the laboratory with 50 blows on each side.

MATERIALS (1)

A. 3/4" Pit Run Gravel with 12.5% minimum crushed particles, NW 1/4 1-92-49, Plymouth County.

B. Lime Dust - Weeping Water, Nebraska, 1-10-11 Cass County, Nebraska.

C. 3/4" Crushed Gravel with 100% crushed particles NW 1/4 1-92-49, Plymouth County.

D. -3/8" Crushed Gravel with 100% crushed particles S 1/2 NW 1/4, 15-90-41, Cherokee County.

E. 1" Crushed Gravel with 100% crushed particles S 1/2 NW 1/4, 15-90-41, Cherokee County.

F. -3/8" Pit Run Gravel with no crushed particles S 1/2 NW 1/4, 15-90-41, Cherokee County.

G. Ag. Lime - Fort Dodge Limestone NW 1/4 SW 1/4 24-89N-29W, Webster County.

H. -3/8" Limestone Chips NW 1/4 SW 1/4 24-89N-29W, Webster County.

I. 3/4" Pit Run Gravel with no crushed particles S 1/2 NW 1/4 15-90-41, Cherokee County.

J. 85-100 Penetration Grade Asphalt Cement, Bituminous Matl. & Supply Co., Tama, Iowa.

AGGREGATE GRADATION (1)

The field grading of these aggregates are as follows:

	1"	3/4"	3/8"	#4	#8	#30	#200
A.		100	84	71	61	32	3.0
B.						100	98
C.		100	42	22	14	7.9	3.3
D.			100	71	46	23	8.7
E.	100	86	11	0.8	0.7	0.5	0.3
F.			100	84	70	33	4.7
G.				100	98	78	31.0
H.			100	54	12	6.0	4.2
I.		100	92	78	63	28	4.4

MIX PROPORTIONS (1)

Mixtures were prepared with 4%, 5% and 6% A.C. content as follows:

1.	45% of Material E 10% of Material D 35% of Material F 10% of Material G	Binder Course
1A.	35% of Material E 35% of Material D 30% of Material I	Binder Course
2.	15% of Material D 50% of Material F 15% of Material G 20% of Material H	Surface Course
2A.	40% of Material D 60% of Material F	Surface Course
3.	80% of Material A 17% of Material C 3% of Material B	Base, Binder, or Surface Course
3A.	60% of Material A 15% of Material C 25% of Material D	Base, Binder, or Surface Course

CONCLUSIONS

In applying the findings of this study cognizance must be taken of the fact that this was strictly a laboratory study, very limited in nature; any application or extrapolation of the data to actual situations must be tempered with judgment based on the performance of similar materials and mixtures. The analysis of the laboratory test data resulted in the following conclusions:

1. The alternate mixtures without limestone fines or filler appear to meet all of the other current requirements of the specifications[1] for Type B asphalt concrete as well as the standard specification mixtures.
2. The alternate mixtures appear to have an asphalt demand approximately 1 per cent higher than the standard mixtures.
3. It would appear that the 1 inch binder course mixture (1 and 1A) would be safe for use under all types of traffic volumes and loadings.
4. The characteristics of the 3/8 inch and 3/4 inch mixtures (2, 2A, and 3, 3A) tend to indicate that their usage should be restricted to low and moderate traffic volumes and loadings.
5. The test characteristics of mixtures 1, 1A, 2, and 2A indicate that the mineral aggregate void space is related to the quantity of material passing the No. 50, No. 100 and No. 200 sieves as well as to the compacted density.
6. The findings of this study do not conflict with the results of the studies by Csanyi, et al[3] and Tunnicliff[5] on the effects of fillers in asphaltic concrete.

RECOMMENDATIONS

It is recommended that several experimental primary road projects be let in District 3 utilizing Type B asphaltic concrete mixtures produced under specifications excepting the use of limestone fines or filler if the resulting mixtures meet the standard specification requirements for gradation, voids, and stability.

A study should be initiated to examine more fully the possibility of controlling the mineral aggregate void space required in high type asphaltic concrete mixtures.

DISCUSSION

This portion of the report has been divided into three parts for the sake of clarity and so that the various mixtures may be compared in a direct manner.

Mixtures 1 and 1A, 1" Type B Binder (Refer to Figures 1 & 2 and Table 1)
(1)

Mix number 1 was made up to comply with the standard specifications in the usual manner; mix number 1A was made up to comply with all of the standard specifications except the requirement for limestone filler. This modification involved introducing another material (3/4" pit run gravel) and eliminating the 3/8" pit run gravel and the agricultural lime. The percentages of the constituents were also adjusted. The modified job mix (1A) was comprised, therefore, entirely of local materials; this condition would effect a cost savings and reduce the number of different materials required from four to three.

The gradation curves indicate that mixture number 1A was slightly more densely graded than mixture number 1. Apparently this factor influenced the effect of laboratory compaction; e.g.,lab mix 1A at 6 per cent A.C. had a Marshall density of 2.39 and lab mix No. 1 at 6 per cent had a density of 2.43. Generally an increase is observed in Marshall density on field mix samples; in this case a greater increase would be expected in mix No. 1A. This is due to the fact that the void level of mix No. 1 is already quite low at 5 and 6 per cent A.C. A 3-point (0.03) increase in density would reduce the void level in mix No. 1A to near the level observed in mix No. 1.

The Hveem stability data indicates that mix No. 1 is less stable than mix No. 1A. The Marshall stability and flow data does not corroborate these findings. These mixtures appear to be virtually identical when compared on the basis of Marshall test measurements.

Mixture No. 1 exhibited a higher level of (VMA)* aggregate voids filled (by 5 to 10%) with asphalt than did mix No. 1A. The VMA for the two mixtures differed by 1 to 2 per cent with mix No. 1A being more open. The gradation curves indicate that mix No. 1A was more densely graded than mix No. 1, but the density achieved by laboratory compaction did not close up mix No. 1A as much as mix No. 1. The sag in the gradation curve for mix 1A in the vicinity of the number 50 and 100 mesh sieves tends to indicate that additional void space is available for binder in this mixture. Aggregate combinations providing adequate void space for sufficient binder to assure durability as well as stability are most desirable.

<u>Mixtures 2 and 2A, 3/8" Type B Surface</u> (Refer to Figures 3 & 4 and Table 1)

These mixtures were made up to comply with the requirements outlined previously.(1) Mix No. 2 included limestone fines as required by the specifications and mix No. 2A was made with local gravels.

The density of the 50 blow Marshall specimens was considerably higher for mix No. 2 than for mix No. 2A. This differential varied from 9 to 12 points (0.09 to 0.12). The variations and/or differences observed in the gradations of the two mixtures do not provide a basis for rationalizing the differences in density. The inverse relationship of compacted density to combined aggregate specific gravity also provides no corroboration. Therefore, the only factors left which could influence or cause the observed disparity are particle shape and compactive effort.

To test the supposition that a change in compactive effort would affect the density of mix No. 2A, additional specimens were prepared at 5 per cent A.C. with 75 blow Marshall compaction. An increase in density of 5 points (0.05) was observed. This increase in density reduced the air void level to 10.0%; the 50 blow Marshall specimens tested previously indicated

* VMA - per cent by volume of voids in mineral aggregate

an air void level of 12 1/2 per cent. The moderate increase in density obtained from the additional compactive effort tends to indicate that the substitution of crushed gravel and pit run gravel for limestone chips and agricultural limestone is responsible in part for raising the compaction resistance. This generally speaking is not observed in the field. Gravel mixes generally compact more easily during construction than do mixtures containing a high percentage of crushed limestone.

When the void and stability data are compared for these two mixtures, mix No. 2 exhibited more strength (stability) than mix No. 2A, although the air void percentages become critical at moderate asphalt contents. Due to the fact that these fine, dense graded mixtures are placed in thin lifts (3/4 inch), stability or strength as currently measured may not be a critical matter. The relationship of asphalt content, air voids, and initial compaction may be far more important. If this is true, mix No. 2A which indicates an asphalt demand approximately 1 per cent above mix No. 2 might prove to be more durable under traffic and weathering. Mixtures utilizing higher asphalt contents which result in heavier films of binder are generally preferred over lean mixtures which result in thin films of binder.

Mixtures 3 and 3A, 3/4" Type B, Base or Surface (Refer to Figures 5 & 6 and Table 1)

These mixtures which could be used for wearing surfaces or upper base courses were prepared as outlined previously.[1] Mix No. 3 was prepared with a filler (3%) from Weeping Water, Nebraska; mix No. 3A was made up of local materials.

The differential in density observed in the comparisons between mix Nos. 1 and 1A and Mix. Nos. 2 and 2A is also quite apparent when mix Nos. 3 and 3A are compared. Due to the fact that the factors influencing or causing the differential in density have been discussed previously, additional comments do not appear to be required.

The Hveem and Marshall stability data indicate that these mixes are quite similar. The shape of the stability curves establish a tendency towards erratic behavior not directly related to the asphalt content. Due to the stability levels (Hveem 57 to 70, Marshall 667 to 1217), it would not appear to be advisable to place these mixtures on roads subjected to high volumes of heavy traffic.

The air void levels in mix No. 3A averaged approximately 4 per cent higher than the void levels observed in mix No. 3. Mix No. 3A also exhibited higher VMA percentages and lower VMA filled with A.C. percentages. These test observations may be attributed in part to the lower compacted density obtained for mix No. 3A; other differences and variations such as gradation and particle shape are factors which must be considered even though they cannot be identified quantitatively.

References

1. Iowa State Highway Commission Standard Specifications, 1964, as amended by Supplemental Specifications, Division II.

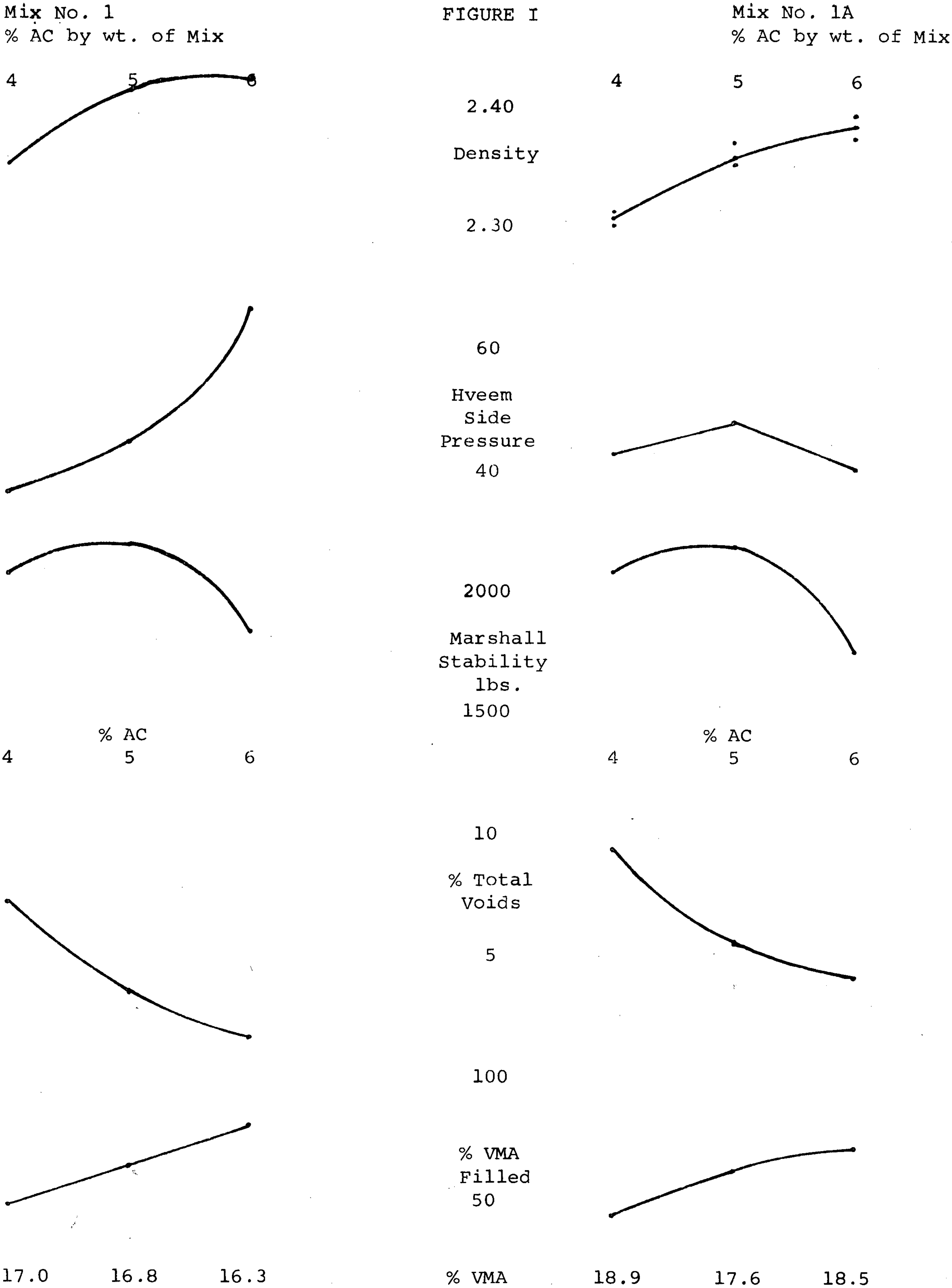
2. The Asphalt Institute Manual Series 2 (MS-2) "Mix Design Methods for Asphalt Concrete ", May 1963.

3. Csanyi, L. H., Cox, Rodney E., and Teagle, Charles R. - "Effect of Fillers on Asphaltic Concrete Mixes" Iowa Highway Research Board Contract Project HR-79, September 25, 1963, Iowa State University.

4. Finn, Fred N., Materials Research and Development, Inc. "Factors Involved in the Design of Asphaltic Pavement Surfaces" Highway Research Board NCHRP Project 39, 1967.

5. Tunnicliff, David G., "Binding Effects of Mineral Filler". Proc. Assn. Asphalt Paving Technologists 1967.

FIGURE I


Mix No. 1
% AC by wt. of Mix
Mix No. 1A
% AC by wt. of Mix
4
5
6
2.40
Density
2.30
60
Hveem
Side
Pressure
40
2000
Marshall
Stability
lbs.
1500
% AC
4
5
6
10
% Total
Voids
5
100
% VMA
Filled
50
17.0
16.8
16.3
% VMA
18.9
17.6
18.5

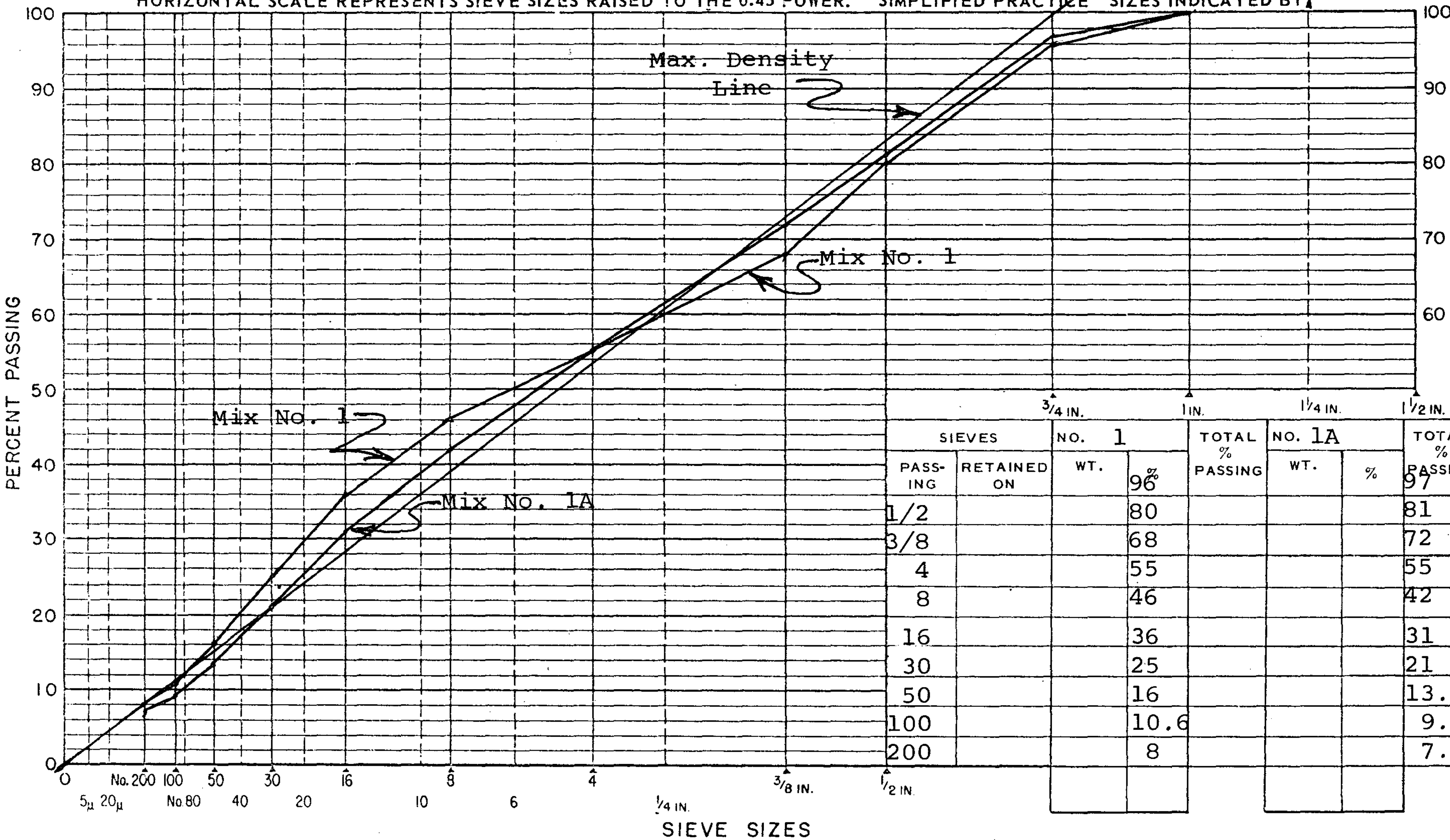
FORM PR-1115
(REV. 10-63)

FIGURE 2

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADATION CHART

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



SIEVES PASSING	SIEVES RETAINED ON	NO. 1 WT.	NO. 1 %	TOTAL % PASSING	NO. 1A WT.	NO. 1A %	TOTAL % PASSING
			96				97
1/2			80				81
3/8			68				72
4			55				55
8			46				42
16			36				31
30			25				21
50			16				13.4
100			10.6				9.2
200			8				7.2

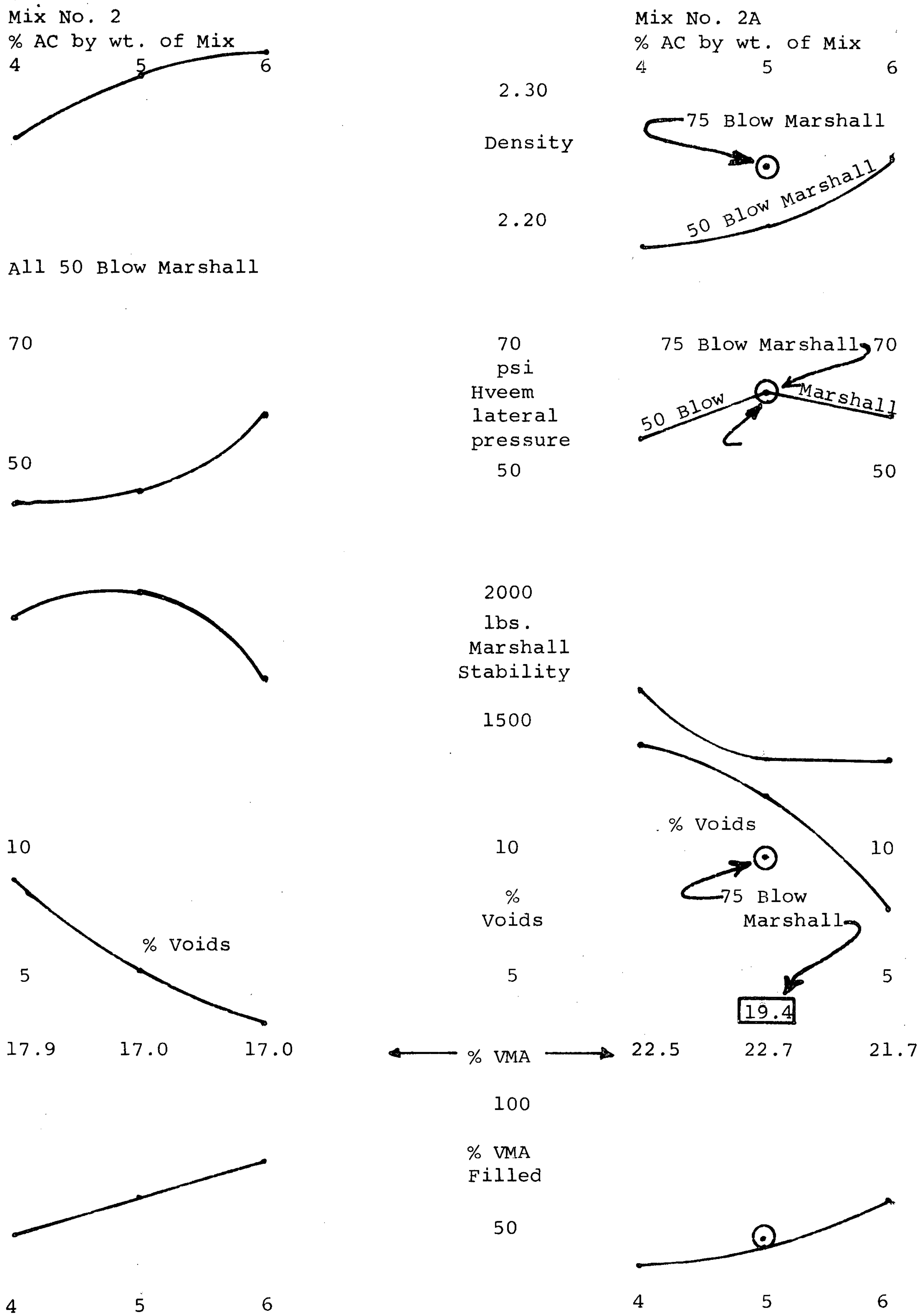
STATE Iowa PROJECT NO. R-228

TYPE, SOURCE, PRODUCER OF AGG.
1" Max. Size Type B binder course

TYPE CONST; LOCATION ON PROJECT
Mix No. 1 90% Gravel, 10% Ag. Lime
Mix No. 1A 100% Gravel
Lab. Mix

SAMPLED FROM	SAMPLED BY	DATE	QUANT. REPRESENTED	SIEVED BY	DATE	SIEVE METHOD	REMARKS
						☐ WET ☐ DRY	Average of 3 extractions

FIGURE 3


Mix No. 2
% AC by wt. of Mix
4
5
6
All 50 Blow Marshall
70
50
10
% Voids
5
17.9
17.0
17.0
4
5
6
2.30
Density
2.20
70
psi
Hveem
lateral
pressure
50
2000
lbs.
Marshall
Stability
1500
10
%
Voids
5
% VMA
100
% VMA
Filled
50
Mix No. 2A
% AC by wt. of Mix
4
5
6
75 Blow Marshall
50 Blow Marshall
75 Blow Marshall
70
50 Blow
Marshall
50
% Voids
10
75 Blow
Marshall
5
19.4
22.5
22.7
21.7
4
5
6

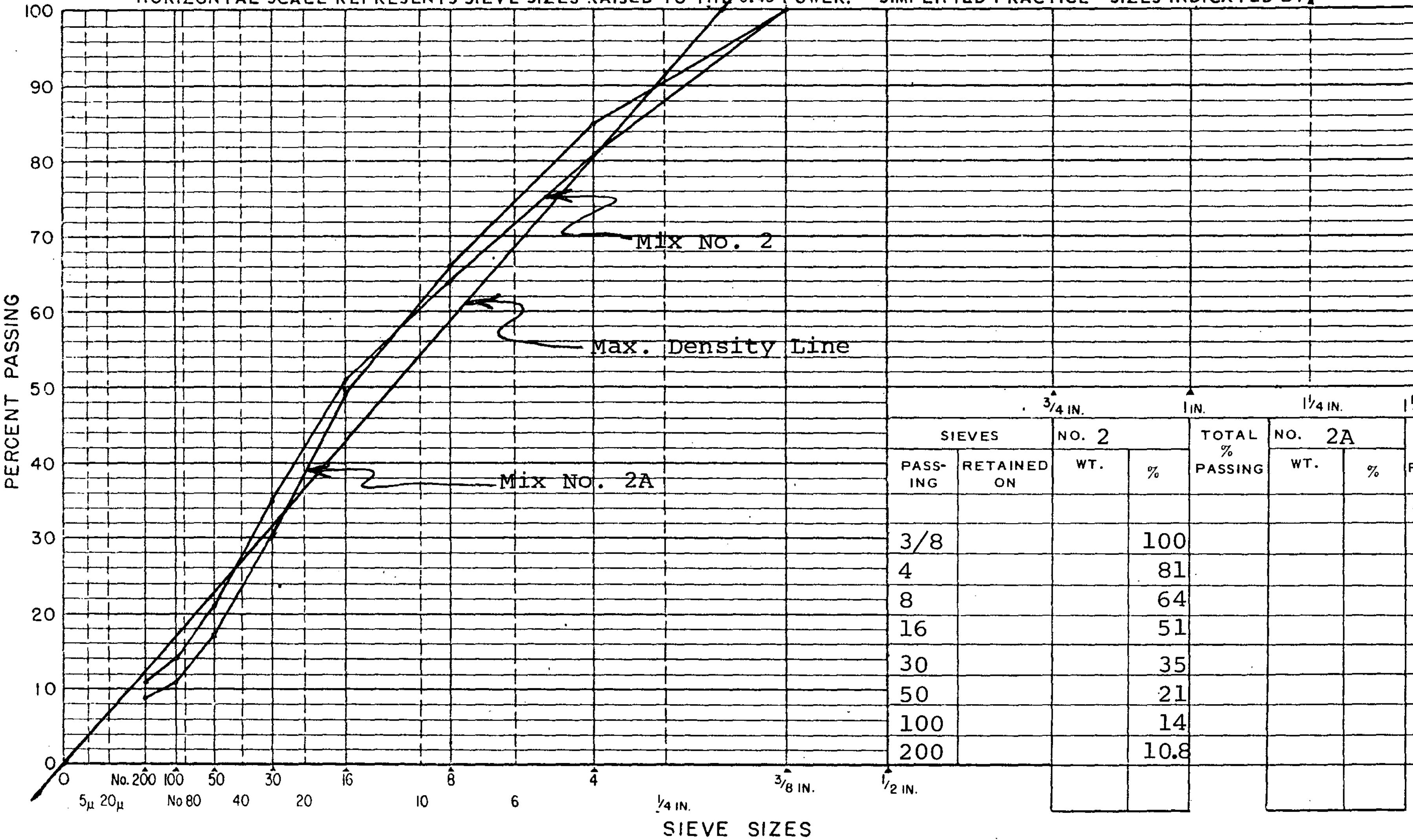
FORM PR-1115
(REV. 10-63)

FIGURE 4

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADATION CHART

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



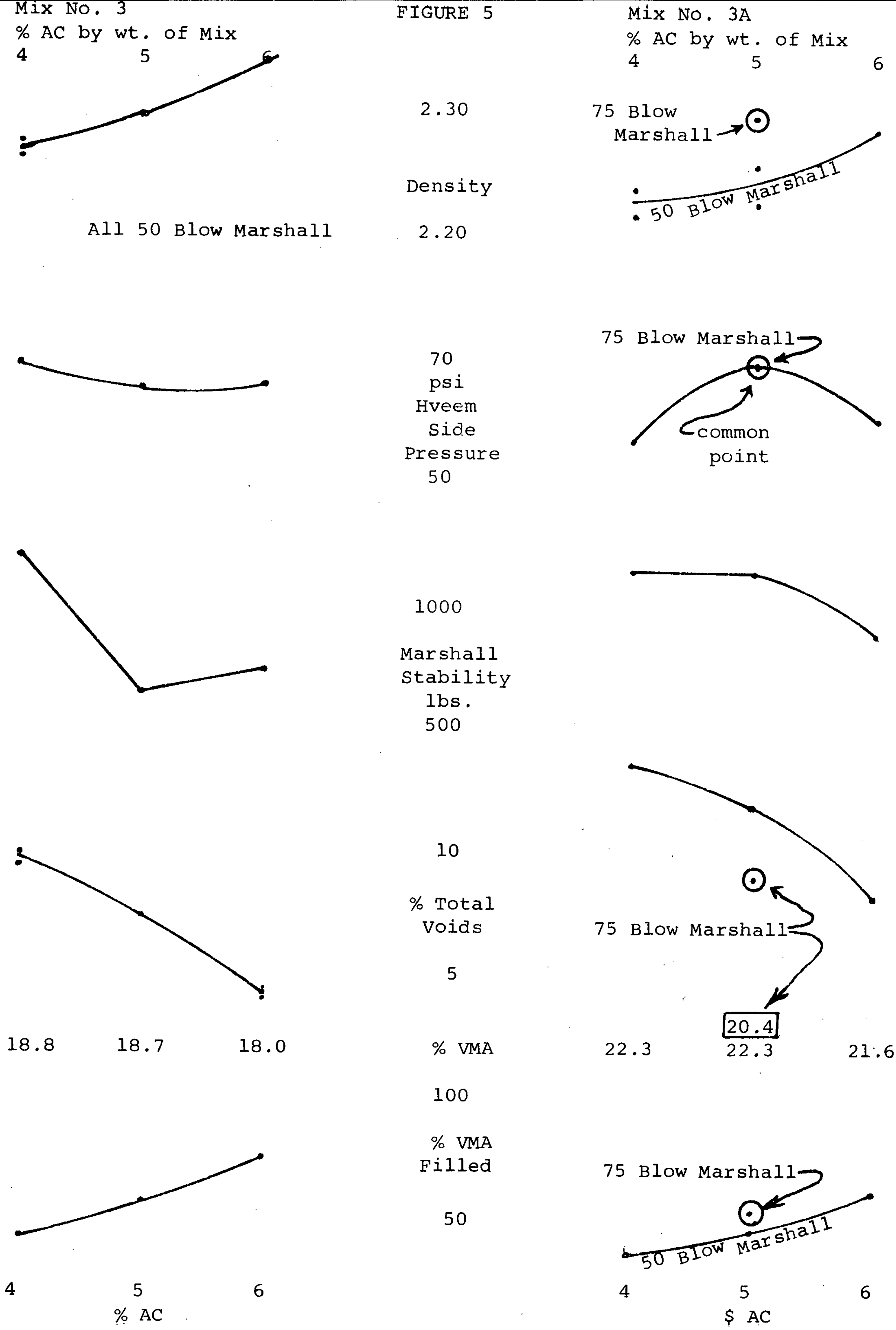
SIEVES PASSING	SIEVES RETAINED ON	NO. 2 WT.	NO. 2 %	TOTAL % PASSING	NO. 2A WT.	NO. 2A %	TOTAL % PASSING
3/8			100				100
4			81				85
8			64				66
16			51				49
30			35				30
50			21				17
100			14				10.6
200			10.8				8.7

STATE Iowa PROJECT NO. R-228	TYPE CONST; LOCATION ON PROJECT
TYPE, SOURCE, PRODUCER OF AGG. 3/8" Max. Size Type B Surface Course	Mix No. 2 65% Gravel, 15% Ag. Lime, 20% L.S., Chips Mix No. 2A 100% Gravel Lab Mix.

SAMPLED FROM	SAMPLED BY	DATE	QUANT. REPRESENTED	SIEVED BY	DATE	SIEVE METHOD	REMARKS
						☐ WET ☐ DRY	Average of 3 Extractions

USCOMM-DC 8372-P63

FIGURE 5


Mix No. 3
% AC by wt. of Mix
4
5
6
All 50 Blow Marshall
Mix No. 3A
% AC by wt. of Mix
4
5
6
75 Blow Marshall
50 Blow Marshall
2.30
Density
2.20
70
psi
Hveem
Side
Pressure
50
75 Blow Marshall
common point
1000
Marshall
Stability
lbs.
500
10
% Total
Voids
5
75 Blow Marshall
18.8
18.7
18.0
% VMA
22.3
20.4
22.3
21.6
100
% VMA
Filled
50
75 Blow Marshall
50 Blow Marshall
4
5
6
% AC
4
5
6
$ AC

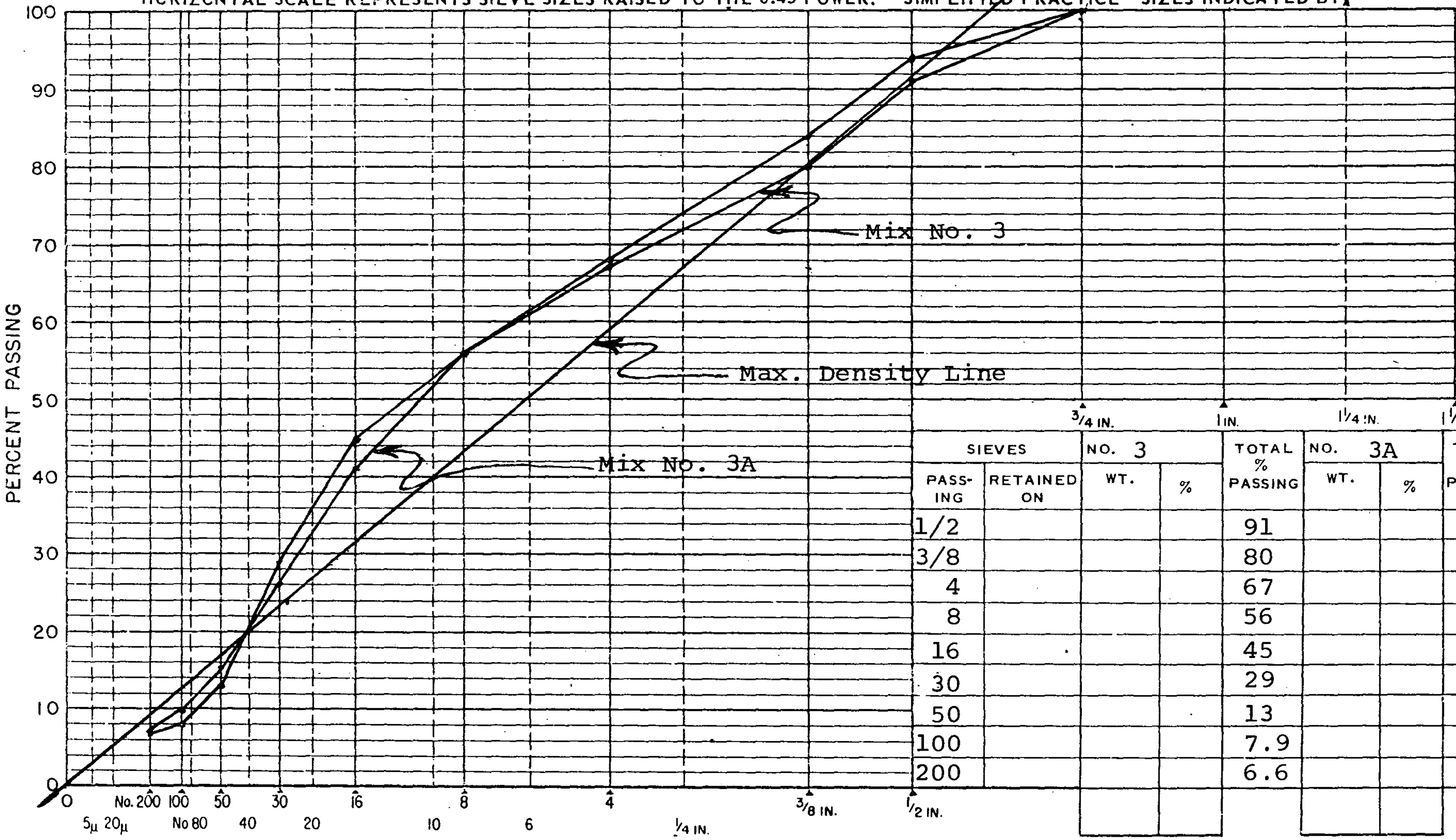
FORM PR-1115
(REV. 10-63)

FIGURE 6

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADATION CHART

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



SIEVES PASSING	SIEVES RETAINED ON	NO. 3 WT.	NO. 3 %	TOTAL % PASSING	NO. 3A WT.	NO. 3A %	TOTAL % PASSING
1/2				91			94
3/8				80			84
4				67			68
8				56			56
16				45			41
30				29			26
50				13			15
100				7.9			9.8
200				6.6			7.5

STATE Iowa PROJECT NO. R-228

TYPE, SOURCE, PRODUCER OF AGG.

3/4" Max. size Type B base or surface

TYPE CONST; LOCATION ON PROJECT

Mix No. 3 97% Gravel, 3% L.S. Filler

Mix No. 3A 100% Gravel

Lab. Mix

SAMPLED FROM	SAMPLED BY	DATE	QUANT. REPRESENTED	SIEVED BY	DATE	SIEVE METHOD	REMARKS
						☐ WET ☐ DRY	Average of 3 extractions

MATERIALS DEPARTMENT
DATA SHEET

TABLE 1

Comparison of Characteristics (2, 3, 4)

Std. and Modified Type B Asphaltic Concrete

Characteristics	1" Binder Mix No.1	1" Binder Mix No.1A	3/8" Surface Mix No.2	3/8" Surface Mix No.2A	3/4" Surface Mix No.3	3/4" Surface Mix No.3A
	Mixtures @ 5% A.C. by Wt. of Mix					
Bitumen lbs. per lb. Dry Aggr.	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526
Hudson $\bar{A}$ (Fineness)	4.6	4.5	5.8	5.7	5.0	5.1
Surface Area S.F. per lb.	35.5	31.2	48.4	39.9	32.9	35.0
Bitumen Index	0.0015	0.0017	0.0011	0.0013	0.0016	0.0015
*% Voids, Mineral Aggr.	15.8	17.9	17.0	22.8	18.7	22.3
*% VMA Filled with A.C.	68.5	64.2	66.5	47.0	59.7	49.0
*% Total Voids in Compacted Mix	4.0	6.4	5.7	11.9	7.6	11.4

Hudson $\bar{A}$ = 1/100 of Summation of 10 Std. Screens (% passing by wt.)

Surface Area in S.F. per lb. computed from established constants

Bitumen Index = Percent A.C. (Aggr. Basis) ÷ 100 x Surf. Area

"A" following Mix No. denotes modified mix without limestone fines or filler

*5% A.C. by wt. mixtures @ 50 blow Marshall compaction