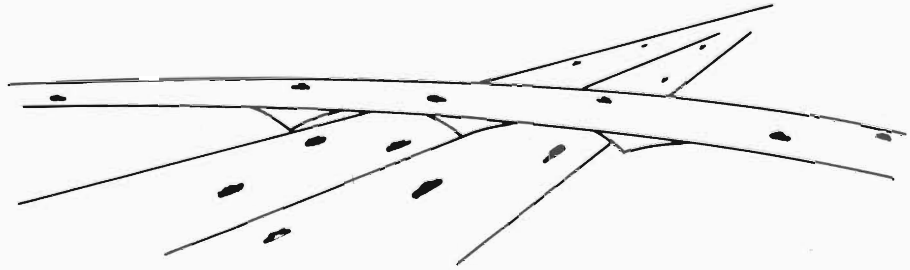

DEPARTMENTAL RESEARCH

Report Number : SS 15.7

GUIDE LINES FOR CONTROLLING A HOT MIX ASPHALTIC CONCRETE DESIGN

TEXAS HIGHWAY DEPARTMENT

GUIDE LINES FOR CONTROLLING

A

HOT MIX ASPHALTIC CONCRETE DESIGN

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PURPOSE

The purpose of this report is to establish some new guide lines which may be followed to develop a satisfactory HMAC design. An accurate method for determining the amount of coarse aggregate required to obtain any desired surface texture and workability, as well as, density, and stability is explained. The principles discussed can be applied to all designs; however, the intent of this report is for aggregates having wide differences in specific gravities.

DISCUSSION

Hot Mix Asphaltic Concrete is normally used to provide a good riding surface, to seal the underlying surface, and to add strength to the existing pavement. Light weight aggregates or nonpolishing aggregates are used to increase the surface skid resistance. All of these design criteria can be obtained with light weight aggregates; however, the amount of coarse aggregate required is difficult to estimate due to the wide differences in the specific gravities of these aggregates.

Our current specifications for HMAC designs were developed by trial and error. These specifications were written for aggregates having essentially the same specific gravities. Since there have been only minor changes during the past twenty-five years, it is only logical to assume that these specifications are meeting the requirements satisfactorily. The intent of this report is not to change current specifications, but make an addition for new materials.

Due to recent developments in synthetic aggregates which have specific gravities ranging from 1.10 to 2.00, new specifications, as well as, design techniques must be developed. Many Design Engineers have already developed a modified specification for synthetic aggregates located in their area. Most of these modified specifications were established by a trial and error method for one particular aggregate source. Each new material requires a new general specification. Unfortunately, many of these modified specifications are needlessly sacrificing one or more of the intended design criteria -- density, stability, or workability.

Some Design Engineers are using a new specification based upon volumetric measurements. The volumetric specification is advantageous since only one general specification can be written for all aggregates. Another type of weight specification which may be used for all aggregates is based upon a ratio of the actual specific gravity and a standard specific gravity. The gradation specifications and pay quantities are adjusted by this ratio.

Regardless of the type of specification, it is recommended that the principles discussed in this report be used in developing any HMAC design. These new principles will eliminate some material and prevent an unworkable design from getting to the plant production stage.

GUIDE LINES

The following procedure gives an accurate method for determining the amount of coarse aggregate required to obtain any desired surface texture and workability. This method utilized the principles already used in designing concrete by the absolute volume method. The amount of coarse aggregate is specified by a coarse aggregate factor. The coarse aggregate factor is expressed in percent of the total amount of dry loose aggregate required to fill a unit volume. A coarse aggregate factor of one hundred means the maximum coarse aggregate that can be used without introducing internal voids. For a normal HMAC design requiring a partially open, dense surface, the coarse aggregate factor will be less than one hundred. To obtain an open, porous surface, this factor may exceed one hundred.

WORKABILITY FACTOR

After the materials have been selected for a HMAC design, check each source for conformation to specifications. Grade each aggregate on the specified sizes, determine the specific gravity, and make a gradation design according to the procedure outlined in Test Method TEX-200F. Determine the unit weight of the combined +10 aggregate and calculate the % solids as outlined in Test Method TEX-400A using an oven dry sample.

All comparison tests are based upon volumetric measurements, so if designing on a weight basis convert to volumetric (See Figure V for calculations). Calculate the workability factor for the design by using the following formula:

$$\text{Workability Factor} = \frac{(\% +10)\ \ (100)}{(\%\ \text{Solids}\ +10\ \text{Material})}$$

Use Table I for estimating the surface texture and placement characteristics. If the design does not meet the desired qualities, make another design using different ratios of aggregates. In some cases, it may be necessary to reject certain materials.

DISCUSSION OF TEST DATA

The information used in this report was obtained from actual field control data and laboratory test data. This information is presented in Figures I, II, III, and IV.

Figures I and II show the effects of varying the workability from 55 to 110 with all other parameters remaining constant. The surface texture and placement characteristics are shown in Figure I. Figure II shows the effects on density, stability, and cohesiometer values. The approximate working range for various types of mixes are indicated.

Three standard HMAC designs using different types of coarse aggregates are shown in Figures III and IV. The volumetric percents of each aggregate in these three designs are the same. As indicated, equal volume percents do not have equivalent workability factors for different types of aggregates. This shows the differences in the external characteristics of each type of aggregate. The total plus ten aggregate in the two light weight designs would have to be reduced to obtain an equivalent workability factor. The weight quantities for each design are presented in Figure V along with the volumetric quantities for all three designs. Three types of gradation specifications are shown: (1) current specification, (2) required weight specification necessary for all types of aggregates, and (3) proposed volumetric specification.

Figure V is a conversion work sheet for use when converting weight percents to volume percents or volume percents to weight percents.

SURFACE TEXTURE

AND

PLACEMENT CHARACTERISTICS

VERSUS

WORKABILITY

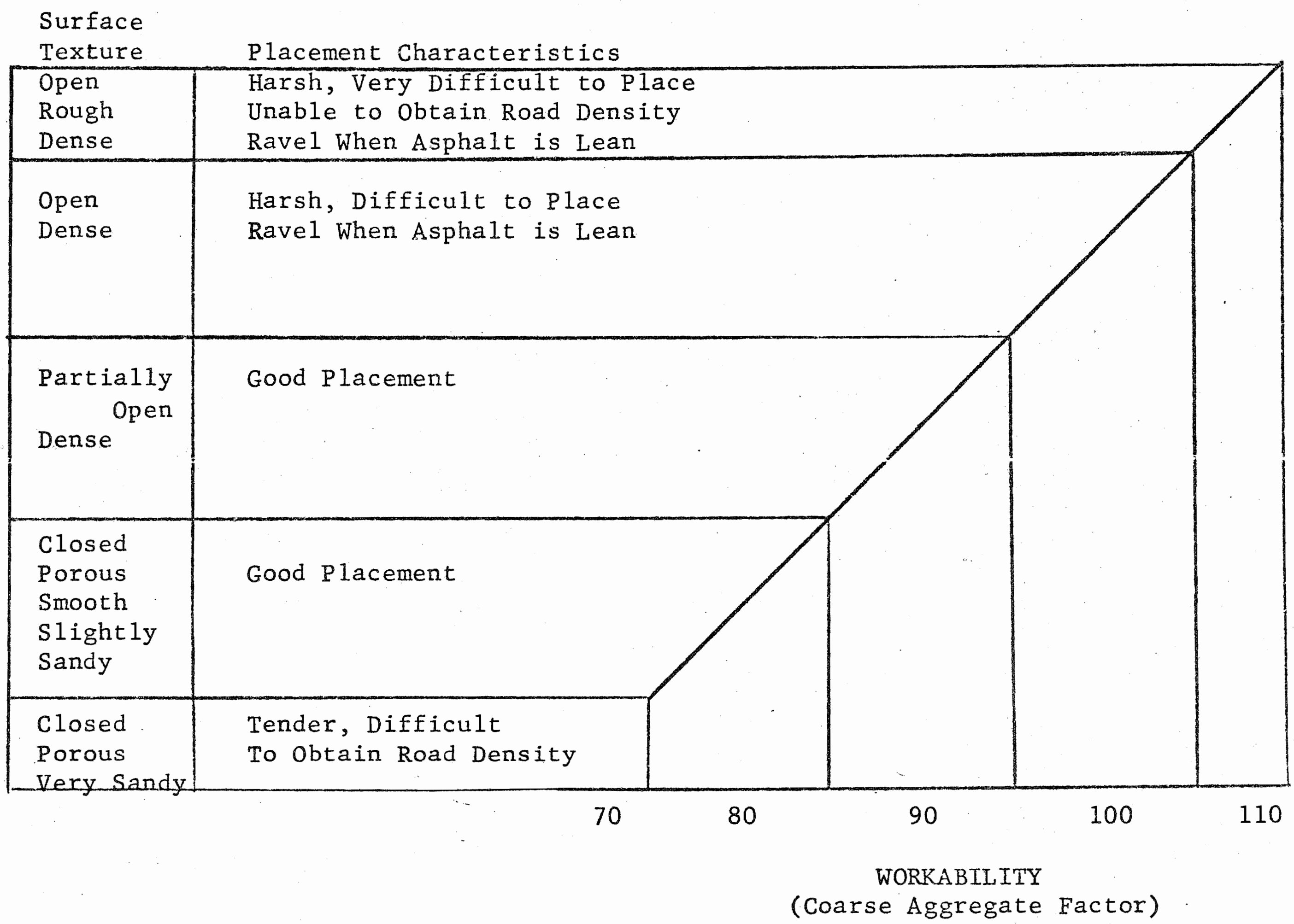

FIGURE I

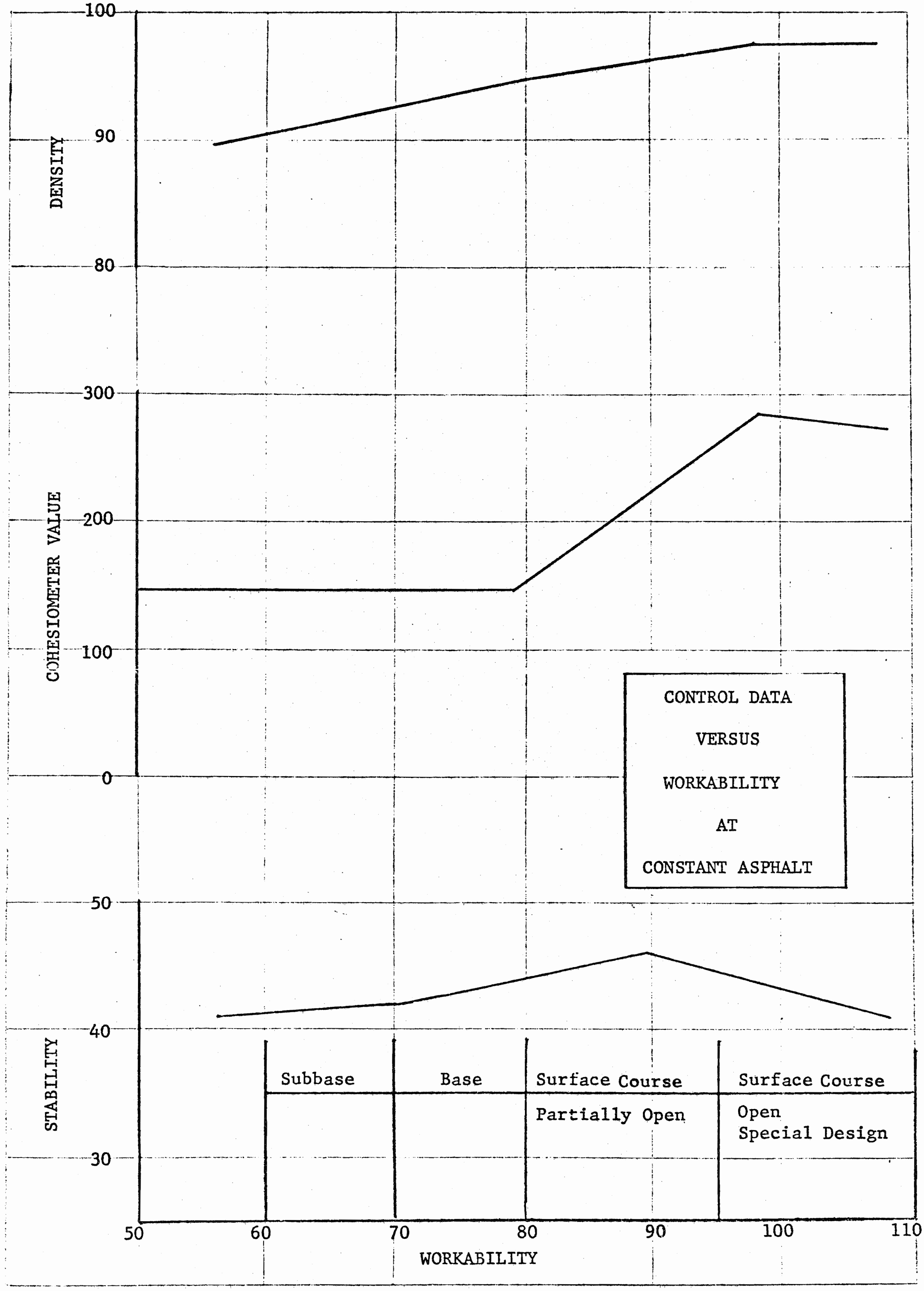
DENSITY
100
90
80
COHESIOMETER VALUE
300
200
100
0
CONTROL DATA
VERSUS
WORKABILITY
AT
CONSTANT ASPHALT
STABILITY
50
40
30
Subbase
Base
Surface Course
Partially Open
Surface Course
Open
Special Design
50
60
70
80
90
100
110
WORKABILITY

FIGURE II

GRADATION REQUIREMENTS FOR AN EQUIVALENT

ITEM 340 TYPE D HMAC VOLUMETRIC DESIGN USING

AGGREGATES WITH VARIOUS SPECIFIC GRAVITIES

% BY WEIGHT				% BY VOLUME
Size	Natural Aggr.	Eastland Lt. Wt.	Dallas Lt. Wt.	All Aggregates
+10	60.0	48.0	40.9	55.6
-10	35.0	45.5	51.7	32.4
**Asphalt	5.0	6.5	7.4	12.0
TOTAL	100.0	100.0	100.0	100.0

** No allowance for absorption.

Aggr.	Sp. Gr.	Unit Wt.	% Solids	Workability	Placement	Surface Texture
Natural Aggr.	2.60	100.0	61.6	90.3	Satisfactory	Partially Open, Der
Eastland Lt. Wt.	1.60	54.7	54.8	101.5	Harsh	Open, Dense
Dallas Lt. Wt.	1.20	38.5	51.4	108.2	Harsh	Rough, Dense

FIGURE III

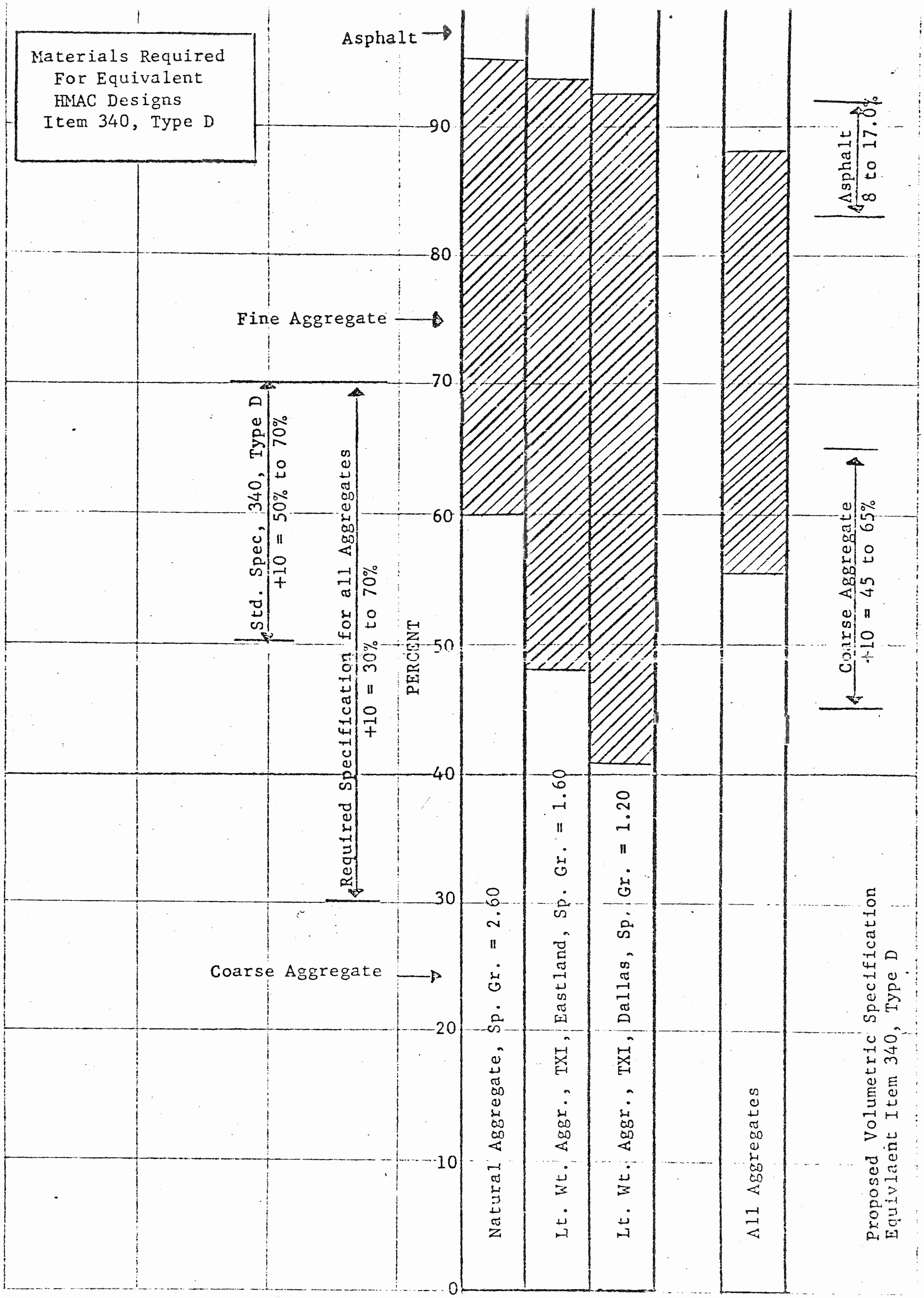
Materials Required
For Equivalent
HMAC Designs
Item 340, Type D
Asphalt
Fine Aggregate
Coarse Aggregate
Std. Spec, 340, Type D
+10 = 50% to 70%
Required Specification for all Aggregates
+10 = 30% to 70%
PERCENT
90
80
70
60
50
40
30
20
10
0
Natural Aggregate, Sp. Gr. = 2.60
Lt. Wt. Aggr., TXI, Eastland, Sp. Gr. = 1.60
Lt. Wt. Aggr., TXI, Dallas, Sp. Gr. = 1.20
All Aggregates
Asphalt
8 to 17.0%
Coarse Aggregate
+10 = 45 to 65%
Proposed Volumetric Specification
Equivlaent Item 340, Type D

FIGURE IV

CONVERSION WORK SHEET

% By Weight To % By Volume

And

% By Volume to % by Weight

Sieve Size	Wt. (gms.)	Wt. (%)	Sp. Gr.	Equiv. (Vol.)	Vol. (%)	Equiv. (Wt.)	Wt. (%)
+10		60.0	2.60	23.077	55.6	144.560	60.0
-10		35.0	2.60	13.462	32.4	84.240	35.0
Asphalt		5.0	1.00	5.000	12.0	12.000	5.0
Total		100.0		41.539	100.0	240.800	100.0

$$\text{Equiv. Vol.} = \frac{\text{\% by Wt.}}{\text{Sp. Gr.}}$$

Equiv. Wt. = (% by Vol.)(Sp. Gr.)

FIGURE V

CONCLUSIONS

The principles presented in this report are based upon actual plant control data and extensive laboratory test data. The results verify the following conclusions:

(1) The workability factor may be used to accurately control the amount of coarse aggregate required in any HMAC design to obtain any desired surface texture and to control the placement characteristics.

(2) Equal volumetric quantities in HMAC designs with different aggregates will not produce an equivalent surface texture or placement characteristics.

(3) The present specifications are not satisfactory for designing or controlling HMAC when using aggregates with varying specific gravities.

(4) Volumetric measurements or weight ratio measurements based upon a standard specific gravity must be adopted in order to write a general specification which may be used to design, to control, and to establish a fair bid practice for HMAC when using aggregates with varying specific gravities.

APPENDIX

HMAC DESIGN (Percent by Weight)
ITEM 3002, TYPE B

Lab. No.	Materials	Producer	Pit	Sp. Gr.
18-71-2559	Lt. Wt. Aggr.	Texas Industries	Dallas Plant	1.228
18-71-2266	Limestone Scrns.	Texas Industries	Bonnsville	2.650
18-71-2147	Concrete Sand	Lone Star	Kleberg	2.674
18-71-2146	Field Sand	Robertson Constr. Co.	Scoggins Pit	2.648
	Asphalt	American Petrofina	Mt. Pleasant	1.030

GRADATION (% by Weight)

Percents	29.0%		11.7%		20.3%		39.0%		100%	
Sieve Sizes	Field Sand		Conc. Sand		Scrns.		Lt. Wt.		Comb.	Mix Design
+ 1/2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2-3/8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3/8-4	0.0	0.0	0.4	0.0	2.0	0.4	56.5	22.0	22.4	20.3
4-10	0.0	0.0	4.1	0.5	25.0	5.1	37.0	14.5	20.1	18.2
+ 10	0.0	0.0	4.5	0.5	27.0	5.5	93.6	36.5	42.5	38.5
10-40	2.8	0.8	29.0	3.4	45.0	9.1	4.9	1.9	15.2	13.8
40-80	59.2	17.2	61.0	7.1	10.0	2.0	0.7	0.3	26.6	24.1
80-200	36.1	10.5	5.0	0.6	7.0	1.4	0.4	0.2	12.7	11.5
-200	1.9	0.5	0.5	0.1	11.0	2.3	0.4	0.1	3.0	2.7
TOTAL	100.0	29.0	100.0	11.7	100.0	20.3	100.0	39.0	100.0	90.6
									Asphalt	9.4

Asphalt Content	Actual Sp. Gr.	Theo. Sp. Gr.	% Density	% Stability	Cohesiometer Values
8.4	1.592	1.697	93.8	51	301
9.1	1.595	1.686	94.6	49	278
9.7	1.609	1.676	96.0	49	331
10.4	1.612	1.667	96.7	52	381

CONVERSION WORKSHEET

Percent by Weight

To

Percent by Volume

Materials	Wt.(%)	Sp. Gr.	Equiv. Vol. Ratio	Vol.(%)
Lt. Wt. Aggr.	39.0	1.228	31.759	58.0
Screenings	20.3	2.650	7.660	14.0
Concrete Sand	11.7	2.674	4.375	8.0
Field Sand	29.0	2.648	10.952	20.0
TOTAL	100.0	--	54.746	100.0
Combined Aggr.	90.6	1.826	49.617	84.5
Asphalt	9.4	1.030	9.126	15.5
TOTAL			58.743	100.0

$$\text{Combined Sp. Gr. (Aggregates)} = \frac{100}{\text{Total Equiv. Vol. Ratios}} = \frac{100}{54.746} = 1.826$$

$$\text{Equivalent Volume Ratio} = \frac{\text{\% by Wt.}}{\text{Sp. Gr.}}$$

$$\text{Percent by Volume} = \frac{\text{Equiv. Vol. Ratio (100)}}{\text{Total Equiv. Volume Ratios}}$$

HMAC DESIGN (Percent by Volume)

Lab. No.	Materials	Producer	Pit	Sp. Gr.
18-71-2441	Lt. Wt. Aggr.	Texas Industries	Dallas Plant	1.228
18-71-2266	Limestone Scrns.	Texas Industries	Boonsville	2.650
18-71-2147	Concrete Sand	Lone Star	Kleberg	2.674
18-71-2146	Field Sand	Robertson Constr. Co.	Scoggins Pit	2.648
	Asphalt (AC-20)	American Petrofina	Mt. Pleasant	1.030

GRADATION (Percent by Volume)

Percents	20.0%		8.0%		14.0%		58.0%		100%	
Sieve Sizes	Field Sand		Conc. Sand		Scrns.		Lt. Wt.		Comb.	Mix Design
+ 1/2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2-3/8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1
3/8-4	0.0	0.0	0.4	0.0	2.0	0.3	63.8	37.0	37.3	31.5
4-10	0.0	0.0	4.1	0.3	25.0	3.5	33.6	19.5	23.3	19.7
+ 10	0.0	0.0	4.5	0.3	27.0	3.8	97.6	56.6	60.7	51.3
10-40	2.8	0.6	29.0	2.3	45.0	6.3	1.5	0.8	10.0	8.4
40-80	59.2	11.8	61.0	4.9	10.0	1.4	0.3	0.2	18.3	15.5
80-200	36.1	7.2	5.0	0.4	7.0	1.0	0.2	0.2	8.8	7.4
-200	1.9	0.4	0.5	0.1	11.0	1.5	0.4	0.2	2.2	1.9
TOTAL	100.0	20.0	100.0	8.0	100.0	14.0	100.0	58.0	100.0	84.5
									Asphalt	15.5

CALCULATIONS

Specific Gravity (+10 Aggregate)

Obtain Individual Weight Percentages from Weight Design Sheet

Materials	%(+10)	Sp. Gr.
Lt. Wt. Aggr.	36.5	1.228
Screenings	5.5	2.650
Concrete Sand	0.5	2.674
Field Sand	0.0	2.648
TOTAL	42.5	

$$\text{Combine Sp. Gr. (+10)} = \frac{42.5}{\frac{36.5}{1.228} + \frac{5.5}{2.650} + \frac{0.5}{7.764}} = 1.329$$

Unit Weight (+10 Aggregate)

Combine the plus ten aggregate in the same ratio as shown above for the combined specific gravity calculations. Determine unit weight on oven dry sample.

Unit Weight (+10 Aggregate) = 45.8 lbs/ft^3

Percent Solid (+10 Aggregate)

$$\%\ \text{Solid} = \frac{45.8\ (100)}{(1.329)(62.4)} = 55.2\%$$

Workability

Total percent plus ten aggregate = 51.3%
(from volumetric design sheet)

$$\text{Workability} = \frac{(\%\ +10)(100)}{\%\ \text{Solid}} = \frac{(51.3)(100)}{55.2} = 92.9\%$$

Placement Characteristic and Surface Texture

From Chart Shown in Figure 1
Placement Characteristics - Good
Surface Texture - Partially Open, Dense