ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ93-368

PROCESSES FOR THE DESIGN OF LARGE STONE MIXTURES: A REVIEW

Final Report

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January 1993

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
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in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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TECHNICAL REPORT DOCUMENTATION PAGE

1. REPORT NO. FHWA-AZ-93-368	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Processes for the Design of Large-Stone Mixtures A Review		5. REPORT DATE January 1993
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR (S) R.A. Jimenez		8. PERFORMING ORGANIZATION REPORT NO. ATTI-92-1
9. PERFORMING ORGANIZATION NAME AND ADDRESS Arizona Transportation and Traffic Institute College of Engineering and Mines, The Univ. of Arizona Tucson, Arizona 85721		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. HPR-PL-1 (43) 368
12. SPONSORING AGENCY NAME AND ADRESS ARIZONA DEPARTMENT OF TRANSPORTATION 206 S. 17TH AVENUE PHOENIX, ARIZONA 85007		13. TYPE OF REPORT & PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. ABSTRACT

The report is concerned with a literature review of the use of large-stone mixtures (LSM). The specific topics of interest were the aggregate gradation, laboratory mixing methods, laboratory making of test specimens, and methods of test. A questionnaire on LSM was sent to all of the states and the responses are listed.

Recommendations for the direction to be taken towards developing a LSM design procedure are presented.

17. KEY WORDS Bituminous mixture, large-stone mixtures, design.	18. DISTRIBUTION STATEMENT Document is available to the U. S. public through the National Technical Information Service, Springfield, Virginia 22161	23. REGISTRANT'S SEAL Registered Professional Engineer (Civil) CERTIFICATE EXPIRES 6 RUDOLF A. JIMENEZ DEC. 31, 19 ARIZONA, U.S.A.

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	18	

ABSTRACT

The report is concerned with a literature review of the use of large-stone paving mixtures (LSM). The specific topics of interest were the aggregate gradation, laboratory mixing methods, laboratory making of test specimens and methods of test.

A questionnaire on LSM was sent to all of the states and the responses are listed.

Recommendations for the direction to be taken towards developing a LSM design procedure are presented.

INTRODUCTION

Presently the greatest volume of asphaltic concrete for highways utilizes aggregate blends with maximum particle size of about 3/4 inch and asphalt content of about five percent. Also the principal occurrence of pavement failures has gone from fatigue cracking to permanent deformation, i.e. rutting. Within the last few years much has been written or said that large-stone (1½ inches) asphaltic concrete mixtures will reduce the incidence of rutting and also be more economical in cost.

This report contains a review of work done with large-stone mixtures (LSM) for road paving as found in the literature and in response to a questionnaire. Its purpose is to present a state-of-the-art of large-stone asphaltic concrete and aimed to provide information for an analysis to recommend a direction to be taken for developing a laboratory procedure for the design of these paving mixtures.

The review of the data presented will include a focus on the areas of:

1. aggregate gradation and particle characteristics,
2. laboratory equipment for mixing relatively large batches of these asphaltic mixtures,
3. laboratory equipment and method for preparing specimens of appropriate size, and
4. laboratory equipment and method for testing specimens.

CHRONOLOGICAL REVIEWS AND COMMENTS

Over the period of time and with different writers the definition of large-stone mixtures has varied. The definition to be used in this report is as follows:

> "An aggregate blend with 100 percent passing a 3-inch sieve, less than 90 percent passing the 1-inch sieve, and 2-5 percent passing the No. 200 sieve." The intent is to have a dense graded specimen without it being scalped on the 1-inch sieve.

1908

Richardson, Clifford, "The Modern Asphalt Pavement," second edition, John Wiley and Sons, 1908.

Very little was presented with reference to LSM. Gradations were defined in terms of filler (-#200), sand (¼" to #200) and stone (+¼"). The breakdown of sizes was principally for the sand fraction. Surface courses were made mainly with sand and filler, but binder courses contained stone. The one-sized stone binder aggregate was improved for stability by "filling the voids in the material with fine stone or grit and the remaining voids, after this addition, with sand or a mineral aggregate corresponding in grading to that of a standard surface mixture".

50 percent retained on the ¼-inch sieve. Photographs of sections cut from sidewalk pavements showed the larger aggregates floating in a mixture of asphalt and fines.

1919

Green, Roy M., "Bituminous Pavement Investigations in Certain Texas Cities - Part I. Bitulithic," Bulletin 22, Texas Engineering Experiment Station, Agricultural and Mechanical College of Texas, 1919.

The author emphasized that performance of bituminous pavements was very much location dependent, especially within the United States. A discussion on the shortcomings of Warren Brothers' "Bituminous Macadam" was given and those criticisms were eliminated with their "Bitulithic" design. Pavement samples from various Texas cities were analyzed. The results showed "ideal" gradations for maximum size of aggregate of 3/4 inch, 1 inch and 1¼ inch. These gradations indicated that sizes above the #10 sieve followed a Fuller Curve and the fine sizes below conformed to the standard sheet asphalt grading for heavy traffic. The 1¼-inch gradation was as follows:

Sieves	P 1¼"-R1	P1"-R 3/4"	P 3/4"-R½"	P½"-R¼"	P¼-R#10	P#10-R#40-	P#40-R#80	P#8-R#200	P#200
Percent	14.3	14.3	14.4	14.4	11.5	5.6	9.0	9.0	4.5

From a study of 36 gradations and comparisons with performance, it was "evident that the most dangerous fault in the various mixtures was that of an incorrect amount of material retained on the 10-mesh sieve".

The amount of design asphalt content was to be determined through a coating-drainage test on the plus 10-mesh material and also on the minus 10-mesh. Bitulithic pavements contained from 3 to 4½ percent asphalt by total weight.

The study indicated the need of a seal coat in order to protect the large aggregate from being shattered and worn and then allowing water to enter the mixture through the large aggregate.

Comment. A plot of the ideal gradations shows a gap from the 10 to 40 mesh sieves and in which approximately 70 percent of the aggregate is retained on the 10-mesh sieve.

The paper defined the Warrenite-Bitulithic pavement as being made of two asphaltic materials. The first layer was a well graded coarse aggregate asphaltic concrete placed about 2 inches deep. While that course was still hot a thin layer of rich fine aggregate asphalt mixture was placed and then the whole mass was compacted by rolling. The first layer contained large-stones graded to give maximum density.

Comment. In later years, the Warrenite-Bitulithic pavement (surface) was placed on "black bases" containing up to 1½-inch aggregate.

1927

Ebberts, A.R., "Variation in Asphaltic Film Thickness on Mineral Aggregates," Proceedings, Sixth Annual Asphalt Paving Conference, The Asphalt Association, 1927.

Asphaltic concrete mixtures containing 1¼-inch aggregate were graded to maximum density following Fuller's curve for maximum density (FMDC). Asphalt content was calculated in a film thickness (Bitumen Index) of a minimum of 0.0005 to 0.0007 inch.

1932

Hubbard, Prevost and Field, F.C., "Adaptation of the Stability Test to Include Coarse Aggregate Asphalt Paving Mixtures," Proceedings, Association of Asphalt Paving Technologists, January 1932.

The Hubbard-Field test was developed in the laboratory of the Asphalt Institute for the design of sheet asphalt paving mixtures. The specimens were 2 inches in diameter and approximately 1 inch in height. The new test could handle mixtures containing aggregates of 1¼". Mixing was done by hand at around 300°F, the mixture was densified using 50-60 blows with two different size hand-tampers. Stability was measured at 140°F by determining the maximum load carried by the specimen when supported by a steel ring having an I.D. of 5 3/4 inches. The 6-inch diameter specimens were made with 2,000 grams of aggregate which would yield a height of approximately 2 1/8 inch. Figure 1 shows the set-up for the Hubbard-Field test. Stability values were in the 3000-3500 pound range.

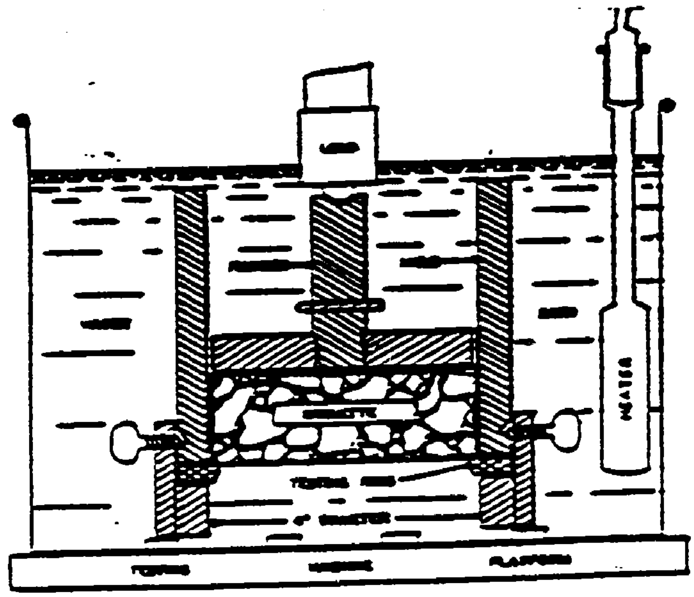

Figure 1. Testing Assembly for Large Size Aggregates

1940

Macatte, W.R., "Asphaltic Mixtures in Bases for Heavy-Duty Streets, Roads, and Airports," Proceedings, American Road Builders' Association, 1940.

The report described the use of asphaltic mixtures in pavements ranging from sidewalks to airfields to railroad beds. Of particular interest were large-stone gradations specified by California and Ohio and one used for the base course at Washington National Airport. The airport gradation was as given below:

Sieve Size	1¼"	5/8"	3/8"	#4	#10	#40	#100	#200
Percent Passing	100	60-85	40-75	35-60	30-45	15-20	2-5	0-5

1957

Chastain, W.E. and Burke, John E., "State Practices in the Use of Bituminous Concrete," Bulletin 160, Highway Research Board, 1957.

The authors reported on responses to a questionnaire that was sent to the states. The portion of the report of main interest to this review for LSM was the listings referring to gradation of aggregates.

1961

Ellison, K.E., "Bituminous Concrete Pavements in Virginia"- Symposium - Asphalt Bound Bases, Proceedings, Association of Asphalt Paving Technologists, 1961.

The portion of that paper relating to this report was an H-3 (1) Base Mix. The specifications called for the following gradation in terms of total percent passing:

Sieve Size	2"	1½"	3/4"	#4	#10	#200	A.C.
Spec-Range	100	90-100	65-80	30-45	20-35	0-5	4.0-7.0
FMDC		100	71	35	23	4.4	

It is to be noted that the specification on gradation follows a Fuller maximum density curve. "The asphalt content is determined on the job when the project is started. In our black base mix (H-3(1)) we put on as much asphalt as the mix will hold". Stability tests were not conducted on the base course mixtures.

1968a

Parker, Charles F., "Large Maximum Sized Aggregate for Bituminous Concrete Bases," internal report to Committee MC-A7 of the Highway Research Board, 1968.

Parker was opposed to the use of aggregates larger than 1 inch because when compared with normal mixtures (sand, ½ inch, 3/4 inch, 1 inch) the 1½" ones had the greatest percentage of gradation specification failures. It was stated that the failure was due to segregation of particles. Additionally, the ratio of a number of sieves for control (7) to number of sieves for design (12) was the smallest for old ASTM specifications (D1663), thus indicating less control of the large aggregate mixtures.

1968b

Kalcheff, I.V., "Some Important Properties of Graded Crushed Aggregate Mixtures for Use as Bases or Subbases," internal report to Committee MC-A7 of the Highway Research Board, 1968.

A 1½-inch maximum sized aggregate meeting the old ASTM D1663 requirement was mixed with asphalt and evaluated for comparisons with stone base material. The gradation followed very closely a maximum density curve as shown in the following tabulation.

Sieve Size	1½"	1"	3/4"	½"	#4	#8	#16	#30	#50	#100	#200
ASTM Gradation	100	80	70	61	38	25	19	14	9	4	3
FMDC	100	82	71	58	35	25	18	12	9	6	4

The mixing procedure was not described but compaction was effected through impact (10 pound weight falling 18 inches) on each of several layers and a final compactive effort of vibration of an 85-pound surcharge for 1 minute. The specimens were 6 inches in diameter and 8 inches in height. The strength properties were evaluated with the triaxial method of the Texas Highway Department.

1970

Khalifa, M.O. and Herrin, M., "The Behavior of Asphaltic Concrete Constructed with Large-Sized Aggregate," Proceedings Association of Asphalt Paving Technologists, 1970.

Aggregate blends of maximum particle sizes of 1½, 2 and 2½ inches were developed to meet old ASTM D1663 requirements. These corresponded to FMDC gradations. The aggregate and asphalt were combined in a Barber-Greene "Mixall" having a pug-mill capacity of 300 pounds. The mixture was placed in two continuous forms of 22 inches wide by 48 inches in length and 8 inches in depth. Compaction of the mixture was effected with a vibro-plate Wacker. Test specimens were 5 5/8-inch diameter by ± 8-inch high cores. The strength test was the triaxial compression using the Texas cell to provide the confining pressure.

1986

Acott, Mike, "The Design of Hot Mix Asphalt for Heavy Duty Pavements," QIP 111/86, National Asphalt Pavement Association, 1986.

The report was a composite of the author's experience and recommendations from a survey of the literature in the field. For the design of large-stone mixtures, guidelines were given with reference to gradation and testing. Gradation requirements were referenced to ASTM D3515 (the replacement to ASTM D1663) and the 0.45 power gradation chart. Compaction and testing of the asphalt-aggregate mixture could be performed using the Marshall method and standard criteria for smaller stone mixtures. The Pennsylvania DOT procedure for fabricating and testing 6-inch diameter samples was mentioned.

1988a

David, Richard L., "Large-stone Mixes: A Historical Insight," IS 103/88, National Asphalt Pavement Association, 1988.

The report presented a background of asphaltic paving mixtures and showed comparative physical characteristics of mixtures classified as (a) mastic, (b) sheet asphalt, (c) Topeka mix, (d) hot mix asphalt, and (e) Bitulithic. A conclusion reached suggested that the "old" Bitulithic type of mixture would serve to reduce the incidence of rutting.

1988b

Acott, Mike, Holt, Dave, and Puzinauskas, Vyt, "Design and Performance Study of a Heavy Duty Large-stone Hot Mix Asphalt Under Concentrated Punching Shear Conditions," IS 105/88, National Asphalt Pavement Association, 1988.

The study was to design a Hot Mix Asphalt that would resist conditions at a railroad yard for trailer loading facility. The large-stone mixture was graded to meet the ASTM D3515 2-inch limits. The mixture was designed using a modified Marshall method in that after mixing with asphalt it was screened through a one-inch sieve. The minus 1" material was compacted with 75 B/F and evaluated the standard way for stability, flow, and voids: Also the total mixture was compacted in a 6-inch mold using a vibratory compaction procedure developed by the FHWA. Density of the 6-inch specimens was lower than those compacted with the 4-inch Marshall method.

1988c

Williams, Ellis G., "Design and Construction of Large-stone HMA Bases in Kentucky," HMAT, Winter 1988, National Asphalt Pavement Association, 1988.

The coal industry in Kentucky imposes tremendous wheel loads on asphalt pavements. A large-stone mixture was developed to withstand the severe loading. The following gradations were used for design of several projects.

Sieve Size	2"	1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
Specs	100	85-100	67-90	56-80	43-71	37-60	22-45	14-35	8-25	6-18	4-13	3-9	2-6
FMDC		100	82	71	58	50	35	25	18	12	9	6	4

The 4-inch Marshall Stability Test was used on the asphaltic mixture by replacing the plus one-inch particles with 3/4 to one-inch aggregate. That procedure was used to compare values obtained from the Pennsylvania DOT Marshall method that used a 6-inch diameter by 3 3/4-inch high specimen. Variations to the usual procedure for field computations were described especially when vibratory compactors were employed.

1989a

Smith, R.P., Humer, R.F., and Webb, A.B., "State DOTs Choose Large Aggregate Asphalt Mixes for Stability and Durability," Asphalt, the Asphalt Institute, 1989-Vol. 2.

The authors present usage of these mixtures in California, Indiana, and Kentucky. Comments are related mainly to the maximum size of aggregate, layer thickness, asphalt content, and compaction of layers.

1989b

__________, "Large Aggregate Asphalt Mixes," TB-5, The Asphalt Institute, 1989.

The Asphalt Institute presented brief descriptions of historical background, mix considerations which included gradation, and construction of these large-stone asphalt courses.

1989c

Acott, Mike, "Large-Stone Mixes- Making a Comeback Across the Country," HMAT, Summer 1989, National Asphalt Pavement Association, 1989.

The author discussed the use of large-stone mixtures in nine states. Of interest was the report that these mixtures will be tested under triaxial conditions of 12-inch diameter by 24-inch high specimens.

1989d

Crawford, Campbell, "The Rocky Road of Mix Design," HMAT, Winter 1989, National Asphalt Pavement Association, 1989.

The article presented a historical review of hot-mix design. It presented Richardson's Pat Test for sheet asphalt, the Warren patent of Bitulithic pavements, the Topeka mixtures, and the rationalized methods of Hubbard-Fields, Hveem, and Marshall. The presentation ends with, "The Marshall procedure is on its way out and its replacement will have to accommodate large-stone mixes".

1990a

Kandhal, Prithi S., "Testing and Evaluation of Large-Stone Mixes Using Marshall Mix Design Procedures," IS-108, National Asphalt Pavement Association, 1990.

Large-stone mixtures were evaluated using a modified Marshall method. Six-inch diameter specimens were formed and tested with compactive effort and breaking head to accommodate the large diameter specimens. Data from Pennsylvania and Kentucky were presented to show comparisons with 4-inch diameter specimens. Appendices present suggested methods of testing. Kentucky's Class K aggregate gradation was given.

1990b

Kandhal, Prithi S., "Design of Large-Stone Asphalt Mixes to Minimize Rutting," preprint of presentation at the 1990 meeting of the Transportation Research Board.

The report was similar to the IS-108 paper (above 1990a) in that development of the 6-inch diameter Marshall test was presented. However, neither report gave suggested gradation limits nor mixing methods.

1990c

Fudaly, T., Massucco, J., and Beatty, T., "Large-Stone Hot Mix Asphalt," FHWA-EP-90-509-007, Federal Highway Administration, 1990.

The report is a "state-of-the-practice" as observed over 8 states. This is an excellent report in that it presented the problems and solutions related to gradation segregation, laboratory mixing, compaction and construction handled by the various states.

Figure 2 presents a boundary of the gradations for dense mixtures used by six of the states covered by the report. The graph shows the band for the upper and lower values found and also the curve for a FMDC for a maximum aggregate size of 1½ inches.

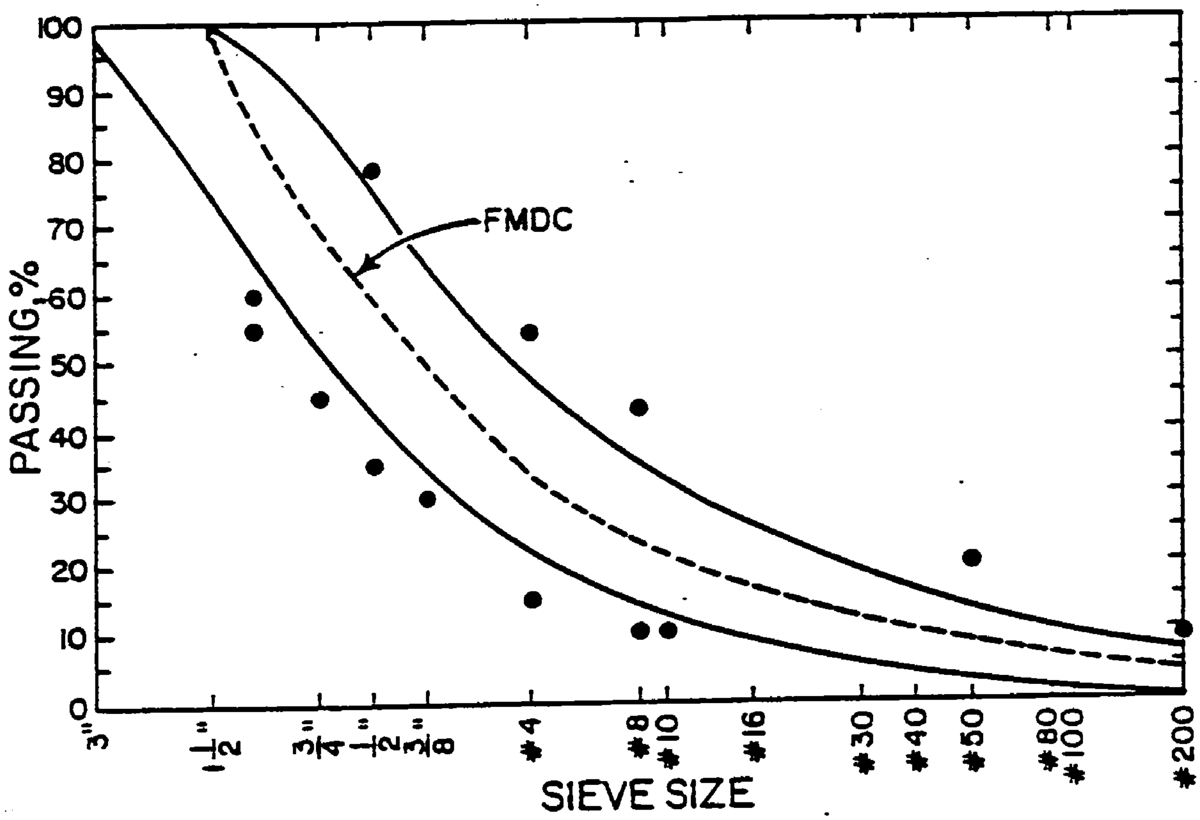

Figure 2. Band of Gradations for Field Large-Stone Mixtures

<u>1991a</u>

Anderson, R.M., Walker, D., Scherocman, J.A., and Epley, E., "Kentucky's Experience with Large Size Aggregate in Bituminous Hot-Mix," preprint of paper presented at the 1991 meeting of the Association of Asphalt Paving Technologists.

The presentation discussed the method of design using a modified Marshall method for large-stone mixtures. Care had to be taken to minimize segregation in the mixtures. The specific mixture of large-stones was referred to as the K Base of Kentucky. Much of the information was previously reported in the National Asphalt Pavement Associations's publications.

QUESTIONNAIRE OF STATE PRACTICE

In early 1991 a questionnaire was developed and mailed to transportation agencies for inquiring as to their use and design of large-stone mixtures. A copy of the questionnaire and a tabulation of the responses received are presented in the appendix. The definition of a large-stone mixture was selected to direct the gradation to a dense one and to minimize the scalping of the plus 1-inch mixture prior to compaction to a 4-inch diameter specimen.

Inspection of the responses received show that most gradation limits and blends can be classified as dense. Several of the blends approach a maximum density curve. The Marshall method was the principal strength test used for the 4-inch diameter specimens and the only method for the 6-inch diameter ones. However, 6-inch diameter specimens were made to obtain a density to be used for control of field compaction.

DISCUSSION OF THE REVIEWS

The discussion to follow will be with reference to the four items of emphasis for developing a design method for large-stone mixtures.

Gradation and Particle Characteristics

The vast majority of the mixtures contained aggregate gradations approaching a maximum density curve. It appears that these came about through the strong influence of ASTM D1663 and D3515. Particular detractors from the maximum density gradation were Green (1919) and Parker (1968). Disadvantages to the use of maximum density gradation were:

(a) Segregation, was much more apparent with maximum particle sizes greater than three-quarter inch.

(b) Large aggregates were more susceptible to breakage under both laboratory and field compaction.

(c) Large-stone mixtures were more susceptible to stripping due to low asphalt content.

Particle characteristics were not given particular attention other than meeting standard crushed-face requirements of the coarse fraction and using field sand (not crushed) to improve compactibility.

Laboratory Mixing of Large-Stone Blends

The review indicated the stone and asphalt were mixed in the laboratory primarily with a Hobart food mixer using a wire whip. An alternative method was to do it by hand with a trowel.

Laboratory Compaction for Large Specimens

The method for compaction most often used was the impact method, that is, the modified Marshall and the drop hammer with a head of less than 6-inch diameter. Static compaction was used but only to obtain a density for field compaction control. There was concern that the compaction procedure would break the large aggregate. There was no mention of using the GTM or the Texas gyratory press for making the 6-inch diameter asphaltic concrete specimens.

The compaction method is a real problem particularly when utilizing a maximum density gradation. There will not be sufficient fines to cushion the large particles under high stresses from dynamic or static forces. To minimize fracture of the large stone under compaction it would be necessary to increase the amount of fines in the gradation (resulting in more asphalt) and utilizing low compaction stresses such as from gyratory or vibratory efforts.

Laboratory Tests for Large-Stone Specimens

The strength tests reported to have been used were the modified Marshall for 6-inch diameter specimens, the standard Marshall (4" diameter) on the portion of the mixture passing the 1-inch sieve, and the standard Hveem on the minus 1 inch mixture. No method was mentioned for durability testing of 6-inch diameter specimens.

RECOMMENDATIONS

The goal of this work has been to provide information for the development of a method for the laboratory design of large-stone asphaltic mixtures. The following comments for achieving this goal are based on the review of the literature and our own experiences concerning asphaltic mixture design and performance in highways. The recommendations to be presented are aimed at the areas discussed previously: gradation, mixing, forming, and testing.

1. Gradation: A band for gradation limits should be developed around a curve having more than 10 percent retained on the 1-inch sieve, yielding a dense gradation and having some minus #200 mesh particles. A maximum density curve is not desired. The disadvantages of such a gradation are (a) segregation, (b) low asphalt content for durability, and (c) susceptibility to aggregate fracture. The promotion of LSM based on resistance to rutting due to stone-to-stone contact leads to high contact stress and to fracture of the stone. Additionally, we have

not seen stone-to-stone contact in cores taken from LSM pavements, nor in photographs of such cores.

2. Mixing: The method of mixing large aggregate blends with asphalt needs to be investigated. The description of the mixers reported in the literature was not sufficient to select an appropriate one at this time. The type to be checked should have planetary action to force counter-flow of the materials while being mixed. The counter-flow mixing pressurizes the asphalt onto the aggregate surface.

3. Forming: The making of the specimens of LSM should be related to the methods of testing. For the design and control of these paving mixtures the methods should be relatively simple and quick to perform. We recommend specimens to be 6 to 8 inches in diameter and approximately 3½ to 4 inches in height. The methods suggested at this time are vibratory kneading (University of Arizona) and gyratory (Texas).

4. Testing. Two test methods are required: one for strength and one for durability. The strength test should evaluate shear strength. The literature has not been of much help in selecting a method except the triaxial compression test which would not meet our criteria of simple and quick to perform. Direct shear is not recommended because the plane of failure is forced. Time and effort will be needed to develop such a strength test. A test for durability can be easily developed by a modification of one of several that is now being used.

   The final recommendation is that ADOT should embark on a research program to develop a laboratory procedure for the design of LSM and to construct pavement with the mixtures for verification of the advantages of LSM and of the design procedure.

APPENDIX

QUESTIONNAIRE ON LARGE STONE MIXTURES (LSM)

Please return by February 15, 1991.

To: Prof. R.A. Jimenez
Civil Engineering Department
University of Arizona
Tucson, Arizona 85721

Identification:

Agency____________________________

Prepared by____________________________

Title____________________________

Date__________________Phone__________________

If you desire that your replies be held in confidence, please check here ☐

1. We are defining LSM as having a gradation of 100% passing the 3"-sieve, <90% passing the 1"-sieve, and 2-5% passing the No. 200-sieve. The binder must be asphaltic.
2. List gradations of aggregates that have been "designed in the laboratory or developed by "experience".

	Lab Designed					Experience		
		1	2	3	4	1	2	3
Total Percent Passing Sieve	3"							
	2 1/2"							
	1 1/2"							
	1"							
	3/4"							
	3/8"							
	#4							
	#8							
	#16							
	#30							
	#50							
	#100							
	#200							
%ASP	BTW							
	BAW							

3. For laboratory mixing of aggregate and asphaltic binder, what was:

   a) Weight of batch __________________(g or lb)
   b) Make of mixer __________________
   c) Capacity of mixing bowl ______________(volumetric)
   d) Type of mixing beater __________________(flex. or rigid)

4. For laboratory compaction of specimens, what was:

   a) Size of specimen diam. _________in. and ht.__________in.
   b) Type of compactor
   c) Compactive effort __________ft-lb./cu.in. or describe in words or reference.

   d) Range of air voids desired based on Rice MTSG_________%

5. For laboratory testing of specimens, what was:
   a) For stability- method and minimum value required.______________
   b) For durability- method and minimum value required.______________

Feel free to comment on the information requested and to add other information you feel would contribute to the objectives of a laboratory design1 method for large stone mixtures.

Be sure that we appreciate the effort you have made in completing the questionnaire.

Thanks

R.A. Jimenez

RAJ/em

TABLE 1. Responses to Questionnaire on Large-Stone Mixutres

	Gradation Percent Passing Sieves															Methods			
Transportation Department	2½	2"	1½	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200	BTW	Type of Mixer	Compaction	Test	Comment
Alaska	- No experience with "large stone" mixtures as defined.																		
Arizona	- No experience with "large stone" mixtures as defined.																		
California	-	100	92	88	74		52	48	40	31	23	16	10	6.8	4.6	Hobart	California	Hveem	Use -1" of mixture
Colorado	.	-	100	-	63-85	46-78	-	22-54	13-43	-	4-22	-		0-8	-	Hobart	California	none	6" Diam.
Connecticut	.		100	88	75		55	42	30	-	16	10		3	4-5	Hobart	Marshall	Marshall	6" Diam.
Delaware	100	-	76	61			41	28	-					3.5	3.2	N/A	N/A	N/A	Experience
Florida	- Gradation system does not meet criteria for "large stone" mixtures as defined.																		
Hawaii	- Our mixes doe not qualify as "large stone" mixtures as defined.																		
Idaho	- Idaho has no laboratory designs for this type of plant mix material.																		
Illinois	- No experience with "large stone" mixtures.																		
Indiana	100	-	45-75	-	20-50	-	10-35	5-25	-	2-15	-	0-7	-	0-4	2.5-3.5	N/A	N/A	N/A	Experimental; No Design
Iowa	- Base mixtures do not meet gradation criteria.																		
Kansas	- No experience with "large stone" mixtures as defined.																		
Kentucky	100	-	80-98	67-90	56-80	-	37-60	22-45	14-35	8-25	6-18	4-13	3-9	2-6	-	Hand	Marshall	Marshall 4000 lb.	6" Diam.
Louisiana	100	-	88	-	52			20	-				1		3.0	Univex	Marshall	N/A	6" Diam.
Maine		100	90-100	-	50-80	-	35-65	25-50	20-40	13-33	-	6-24	4-16	1-8	-	Hveem	Hveem	Hveem	Use -3/4" of Mixture
Maryland	- Use a modified AASHTO T245 for design.																		
Massachusetts	-	100	-	55-80	-	40-65	-	20-45	15-33	-	8-17	4-12	-	0-4	4-5	Plant mix	3,000 psi Compression	For base density control-no test	6" Diam.
Minnesota	- In the early 1980's we did some experimenting with mixtures containing 2" to 3" particles.															Lancaster	FHWA Vibratory	Unconfined Compression	6" Diam

TABLE 1 (continued)

	Gradation Percent Passing Sieves															Methods			
Transportation Department	2½	2"	1½	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200	BTW	Type of Mixer	Compaction	Test	Comment
Mississippi	- No experience with "large stone" mixtures.																		
Missouri	- No experience to date. Plan to use NCAT procedure.																		
Nebraska	- No experience with specified gradation.																		
New Hampshire	-	100	1¼ 95-100	75-95	62-84	50-70	42-60	28-45	#10 18-27	#20 10-18	-	#40 5-13	#80 1-9	0-4	3.8-4.8				
New Jersey	- No experience with "large stone" mixtures.																		
New Mexico	-	-	100	86-98	70-90	60-80	50-70	34-54	#10 22-42	-		#40 8-22	-	3-7	4-6	Hobart	Marshall	Marshall	6" Diam.
New York	100	-	90-100	78-95	-	57-84	¼" 40-72	1/8" 26-57	-	#20 12-16	-	#40 8-25	#80 4-16	2-8	4-6	NOTE:	At the present time we do not require any mix design or laboratory evaluation of this mix.		
North Dakota	-	-	1¼ 100	80-100	-	55-70	-	30-45	-		10-18	-		0-7	-	Hobart	Texas Gyratory	None	4"D x 2½"H
Ohio	100	-	85-100	-	56-80	-	37-60	22-45	14-35	8-25	6-18	4-13	-	2-6	-	Hobart	Marshall	Marshall	6" Diam
Oklahoma	100	95-100	85-100	60-75	-	40-55	-	20-40	#10 13-27	-		#40 5-14	#80 3-10	-	3-6	Hobart	Texas Gyratory	Hveem	Use -1" Mixture
Oregon	100	-	99	79	64		53	35	24	16	10	7	5	4	5.6	California	California, Kneading	Hveem	Use-1" Mixtures
Pennsylvania RESC	100	98	88	75		43		21	17	11	7	5	3	2	2.5				
Pennsylvania SPEC	-	100	95-100	85-95	-	40-65	-	20-47	15-37	10-30	5-24	4-17	3-10	2-5	4-7	Reynolds	Marshall	Marshall	6" Diam.
Rhode Island	-	-	100	74	61		40	29	25	-	12	8	6	4	5.25	Hobart	Static	Air Voids	6" Diam.
South Carolina	- No experience with "large stone" mixtures.																		
South Dakota	-	I-	I100	I97	77	-	53	43	33	24	18	12	8	5.6	14.0	Hobart	Marshall	Marshall	6" Diam.
Texas	- Majority of our LSM do not meet your criteria. Please refer to "Note".																		
Utah	100	-	85-100	67-90	56-80	-	37-60	22-45	14-35	8-25	6-18	4-13	3-9	2-6	-		Marshall	Marshall	6" Diam.
Vermont		-	100	73	62	50		30	20	-				3.0	3.7	By Hand	Marshall	Marshall	6" Diam.
Virginia	- No experience with "large-stone" mixtures.																		

TABLE 1 (continued)

	GRADATION PERCENT PASSING SIEVES															METHODS			
Transportation Department	2½	2"	1½	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200	BTW	Type of Mixer	Compaction	Test	Comment
Washington	- No experience with "large stone" mixtures.																		
West Virginia	100	-	85-100	67-90	56-80	-	35-50	20-40	14-30	8-25	6-18	4-13	3-11	2-6	3-7	By Hand	Marshall	Marshall	6" Diam.
Wisconsin	- No experience with "large stone" mixtures.																		
Wyoming	100	-	-	65±7	-	-	-	30±5	-	-	20±5	-	-	3±2	-	By Hand	N/A	N/A	Base Mix
Port Authority of N.Y & N.J.	-	-	100	86	66	-	49	41	32	25	19	14	9	4.8	3.5	Hobart	Marshall	Marshall	6" Diam.
	-	-	100	87	78	-	45	29	20	15	11	6	4	3	35	Hobart	Marshall	Marshall	6" Diam.
Alberta	- Do not anticipate using larger than 5/8" aggregate.																		
Nova Scotia	-	-	100	96	82	-	69	52	36	28	20	12	6	3.7	5.3	Hand	Marshall	Marshall	4" Diam.