USE OF EXPANDED CLAY AGGREGATE IN BITUMINOUS CONSTRUCTION

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In an effort to find a solution to the shortage of aggregate, for use in highway construction, Louisiana Department of Highways initiated a study.

When this so called investigation was started, we expected to come across materials that were somewhat inferior to those presently in use. Much to our surprise, a number of the aggregates studied yielded very satisfactory results.

In early 1955, we started experimenting with expanded clay aggregate or lightweight aggregate as commonly referred to in Louisiana. Throughout this paper the term lightweight and expanded clay will be used synonymously. Our first objective was to develop a satisfactory hot mixture. The preliminary tests indicated that a very good mixture can be produced and that it would possess abnormally high stability in spite of a high flow. The increase in the stabilities were attributed to the angularity of the particles and the extremely rough surface texture.

The expanded clay aggregate used was manufactured by Big River Industries, Incorporated, under the trade name of "Gravelite". It is produced by calcining a clay, with a very high silica content, to the point of incipient fusion at approximately 1900° Fahrenheit in rotary kilns. The material when dishcarged is red hot, in the form of coarse aggregate which resembles slag in structure. The gradation desired is obtained by crushing and blending.

A test strip was then constructed using this material. The section was laid on the West Approach of the Atchafalaya River Bridge at Krotz Springs, Louisiana, on U. S. Highway 190 which has a daily

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traffic volume of 7300. The lift was 2 inches thick, 200 feet long and covered all four lanes of the old concrete pavement. After 3½ years of heavy traffic service this test section is still as black as the day it was laid and shows no signs of distress. There is some wear but no raveling, pushing or shoving and when compared to the regular gravel section, adjacent to it, is in a much better condition. The three year longitudinal groove measurements show that the lightweight section has an average groove depth of 0.08 inches whereas the regular gravel section has 0.19 inches which is slightly higher than twice as much. Average test properties of this mix are given in Tables I and II. It will be noted in Table II that this mixture had a Marshall stability of 2686 pounds which is approximately twice the values we normally obtain with our regular mixes. Of course the high flow results accompanying this stability can be attributed to the high asphalt content and contributes much toward the flexibility of this type of pavement.

In Table II the results of tests conducted on cores cut three years after construction are also given. The gradation of the extracted aggregate indicates that; there was no crushing under the roller. The stability has increased from 2686 to 3590, or by 33.7% of the original, and the density of the pavement has changed from 90.8% of laboratory compaction to 101.8%, 11% by difference.

It would appear that a mixture with such a high stability would be very susceptible to reflection of cracks at joints. Nevertheless, periodic inspection of this test section indicated that this was not the case. No cracks were reflected for approximately six months and after that only the expansion and the longitudinal joints were visible.

This construction showed that it was uneconomical to use any lightweight aggregate passing a No. 40 mesh sieve. Excessive loss of fines resulted in very adverse working conditions. However, it should be noted that the plant used in this experiment did not have a dust collector. Therefore, we consider this feature a correction to be made in the plant operation. In a further attempt to reduce the cost of this mixture, by reducing the asphalt content, it was decided to conduct laboratory tests using a fine river sand to replace the fine expanded clay aggregate, passing a No. 40 mesh sieve. The results of this study and the tentative specifications prepared are given in the Appendix.

TABLE I

AGGREGATE PROPORTIONS

Bin No. 2 (Fine)	55.0%
Bin No. 1 (Coarse)	41.0%
Filler-Shell Dust	4.0%
Asphalt (85-100 Pen.)	12.0%

TABLE II

TEST PROPERTIES OF THE FINISHED MIXTURE

Specific Gravity	1.644
Theoretical Gravity	1.685
% Theoretical Gravity	97.6
Density - lbs./cu.ft.	102.6
Marshall Stability @140°F-lbs.	2686
Flow 1/100 inch	15

Gradation

U. S. Sieve	Percent Passing: Original	Percent Passing: After 3 years service from cores
1/2 inch	100	99
No. 4	67	67
No. 10	56	54
No. 40	25	24
No. 80	16	16
No. 200	10	10
Asphalt	12.0%	13.0%

Roadway Density

	Original	3 years cores
Specific Gravity	1.493	1.675
% Laboratory Briquette Gravity	90.8	101.8
% Theoretical Gravity	88.6	99.6
Marshall Stability @140°F-lbs.	-	3590
Flow - 1/100 inch	-	13

The mixtures produced by use of the lightweight aggregate naturally weight much less than regular gravel and stone mixes. The weight-volume relations for lightweight mixtures are as follows:

	1000 pounds of mixture will pave: sq. yd. - 1 inch thick	
	Binder Course	Wearing Course
Type A Mix(1)	13.7	13.3
Type B Mix(1)	12.1	11.5
Regular Gravel Mix	9.4	9.7

The preceding values are based on averages obtained from laboratory results.

(1) See "Tentative Specifications" in the appendix.

* * *

The first seal application was made at Grambling, Louisiana on Ruston-Grambling Highway, State Route 150 in Lincoln Parish. The section is 1700 feet long and has a daily traffic volume of 670.

During the application, although the weather was fair and hot, it had been raining for three preceding days and the aggregate was extremely wet. The rate of application of the asphalt and the aggregate and the gradation used in this experiment are given below:

Rate of Application

Asphalt (150-200 Pen.) @350°F	0.275 gal./sq.yd.
Aggregate (M-105)	0.0108 cu.yd./sq.yd.

Gradation

U. S. Sieve	% Passing
3/4 inch	100
5/8 inch	95 - 100
1/2 inch	60 - 90
No. 4	0 - 10

Immediately after the application of the cover material, the rolling was done by use of a 7.5 ton steel wheel roller. No indication of crushing of the lightweight aggregate was noted any more than gravel.

Some of the favorable aspects observed during this experiment are 1) The heat from the asphalt dried the surface of the aggregate and a very good bond was experienced. 2) The cover material did not pick-up under traffic and there was a minimum of waste. 3) After three summers and four winters no bleeding was observed.

Then came several more projects, which I will discuss later, but first I would like to briefly go over the subject of testing of lightweight aggregate.

We had a maintenance project in Baton Rouge District. It was a three application job using lightweight aggregate and asphalt cement. Shortly after the construction started, we were notified by the District Engineer that the first application aggregate, namely C-1, was crushing under the steel wheel roller (Figure 1 and 2). Results of Los Angeles Abrasion Test (Grade A) on the stockpile showed 39.4% loss which meets our maximum requirement of 40. Further study of this material indicated that the Standard Los Angeles Abrasion Test does not give a true indication of abrasive characteristics of the lightweight aggregate. The reason being the considerable difference between the unit weight of this material and gravel or crushed stone. When the standard sample weight is used, the volume of the lightweight aggregate is approximately 44% larger than a regular gravel sample, necessitating either a reduction in the sample weight or an increase in the abrasive change. This situation is very well brought out in Table III. It will be noted that for C-1 size aggregate the standard test weight gives 39.4% loss, whereas a weight corresponding to a volume equal to that of the specified weight of gravel shows 54.1% loss. The same condition is obtained for the C-2 and C-3 sizes. Additionally, Los Angeles Abrasion loss decreases as the aggregate size gets smaller. The same condition also exists in the results

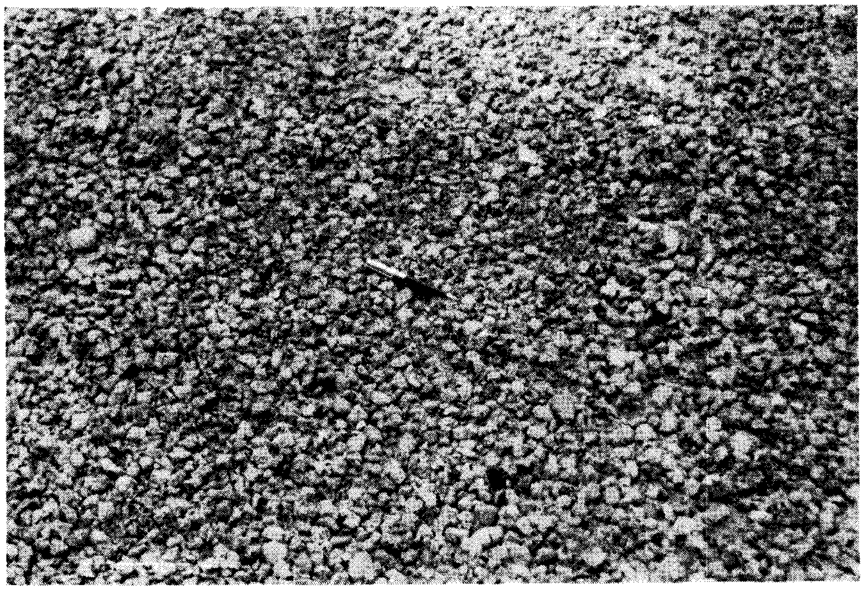


Figure 1
First Application Aggregate, C-1, Immediately After Rolling.

Figure 2
First Application Aggregate After Three Months of Service - no seal used.

obtained from Abrasion tests by volume. Use of a finer material (Table IV) along with a pneumatic tired roller definitely decreased the crushing under roller. However, large particles are not structurally strong enough to support the roller or heavy traffic. Therefore, a modified size similar to that given in Table IV, or even finer, will give satisfactory results. When this aggregate is used in surface treatments, it is advisable to seal the pavement prior to opening to traffic. However, C-2 and C-3 sizes, in my opinion, are structurally strong enough to resist breaking or crushing.

The relationship between size and Abrasion Loss is graphically illustrated in Figure 3 where, the Los Angeles Abrasion Loss is plotted versus the Fineness Modulus of the aggregate as defined by Mr. D. A. Abrams. This illustration shows that as the Fineness Modulus of the aggregate is increased or namely as the average size gets larger the abrasion loss also increases. The rate of increase of loss is higher as the aggregate size gets larger.

TABLE III

LOS ANGELES ABRASION LOSS
STANDARD TEST ASTM DESIGNATION: C 131-55 VS BY VOLUME(2)

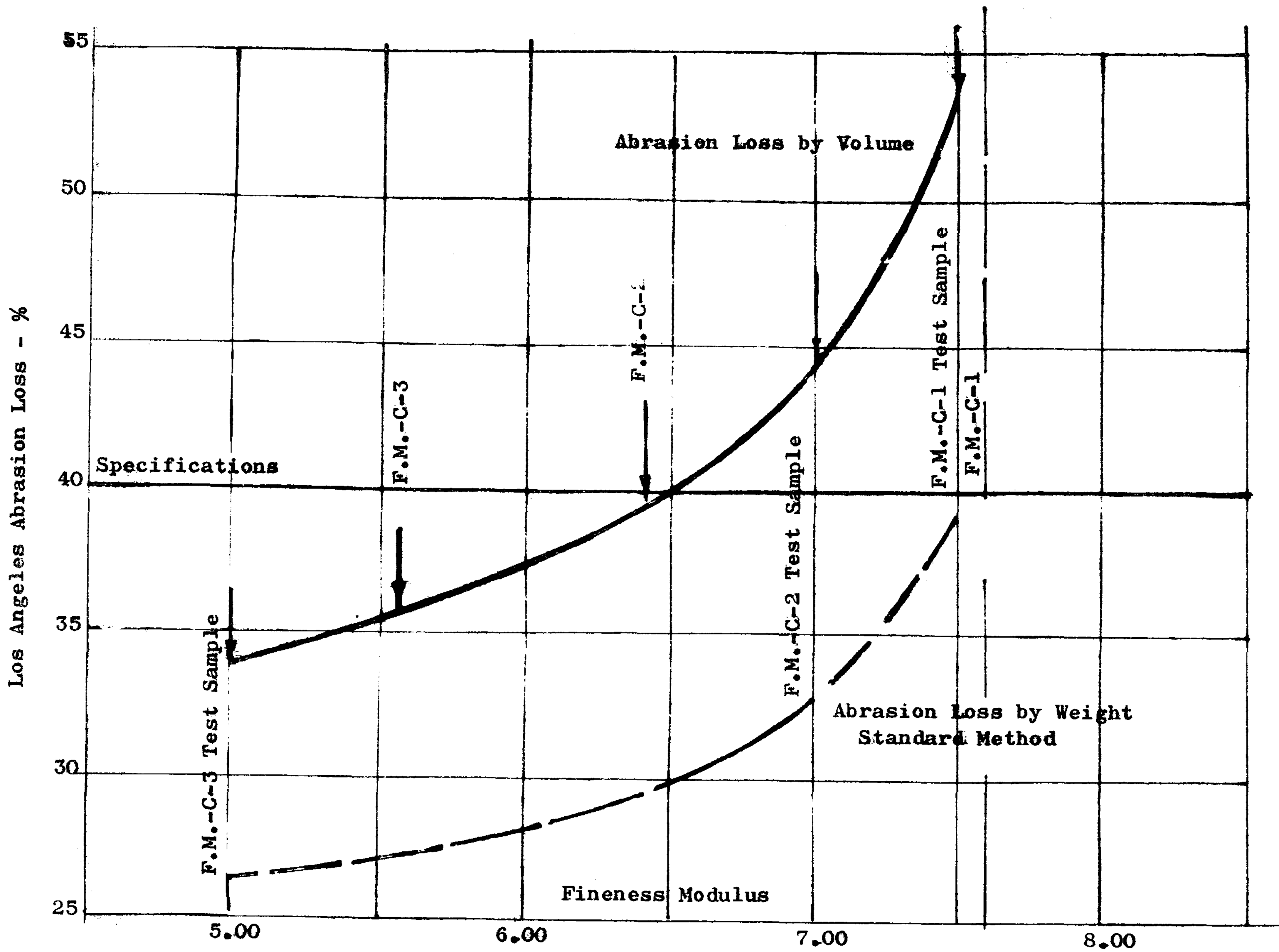
Lab.No.	Type	Standard	By Volume(2)		Fineness Modulus	
					3	4
457413	C-1	39.4	54.1	"Grade A"	7.50	7.62
457415	C-2	32.6	49.4	"Grade B"	7.00	6.39
457819	C-3	26.2	33.6	"Grade D"	5.00	5.60

For gradations of these samples refer to Figure 6.

(2) By volume refers to using a volume approximately equal to that of gravel as called for in ASTM Designation: C 131-55.

(3) Fineness Modulus of prepared test sample.

(4) The actual Fineness Modulus of Aggregate.



LOS ANGELES ABRASION LOSS VERSUS FINENESS MODULUS

Figure 3

TABLE IV

GRADATION OF SAMPLES USED IN LOS ANGELES ABRASION TESTS

U. S. Sieve	Percent Passing			
		Modified		
Aggregate Size	C-1	C-1	C-2	C-3
1-1/2 inch	100.0	100.0		
1 inch	85.2	98.7		
3/4 inch	38.0	86.5	100.0	
5/8 inch	-	35.1	99.2	
1/2 inch	2.8		-	100.0
3/8 inch			-	98.7
No. 4			0.8	33.4
No. 10				1.1
No. 16				0.4

Los Angeles Abrasion Loss - Grade B - 36.7%

The other jobs I mentioned were all in Lafayette District and were constructed by maintenance forces. These consist of single application treatments using 150-200 penetration asphalt cement and the gradation, requirements and application rates given in Table V; and some three application surface treatments using EA-2 Emulsified Asphalt (Figures 4 and 5). The gradations of the aggregate used in one of these jobs are given in Figure 6.

TABLE V

State Route 342

Rate of Application

Asphalt (150-200 Pen.) 0.08-0.11 gals./sq.yd.
Aggregate 0.0035-0.0038 cu. yds./sq.yd.

Gradation

U. S. Sieve	% Passing
1/2 inch	100
3/8 inch	95 - 100
No. 4	30 - 60
No. 10	0 - 15
No. 16	0 - 5

Figure 4
First Application Aggregate During Rolling with EA-2, Emulsified Asphalt.

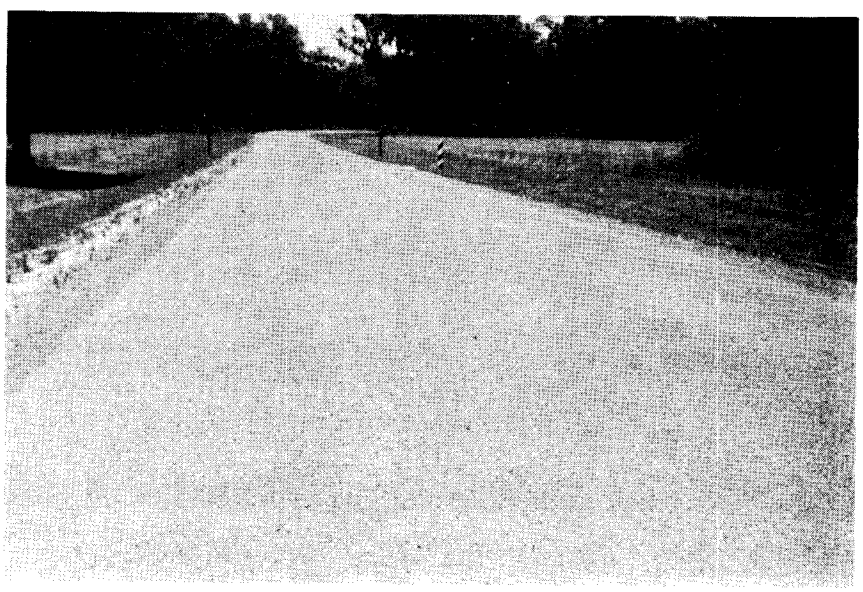


Figure 5
Completed Roadway - Three Course Using EA-2, Emulsified Asphalt.

AGGREGATE CHART

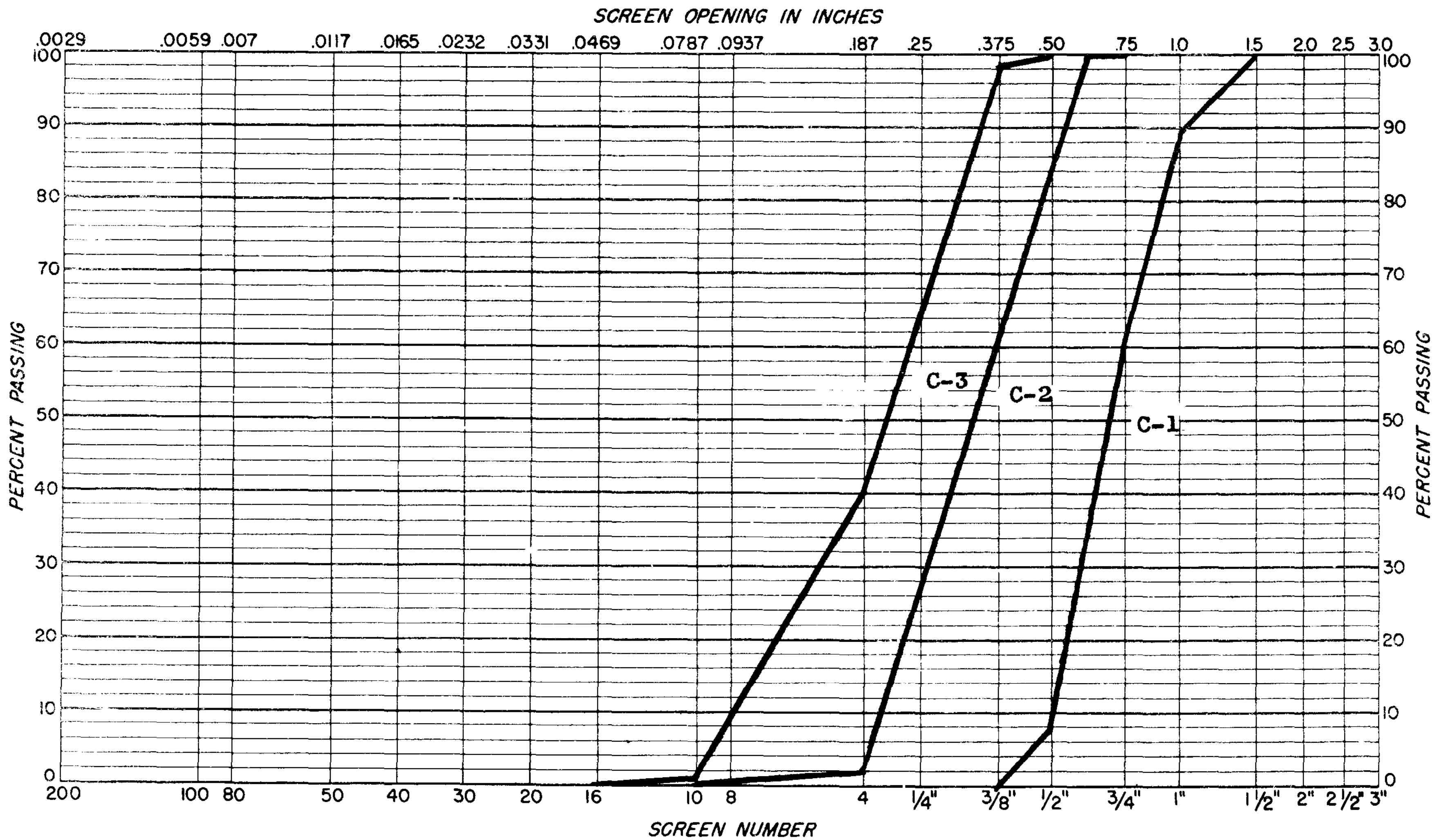


Figure 6

Slight crushing was seen during the application of the first cover material, namely C-1, but no adverse effects were observed.

All of these roads, ranging from one year to four years in age, are in very satisfactory condition and definitely no signs of bleeding are visible. The present indications are that due to the high absorption, extreme angularity and rough surface texture, a very good bond and interlocking is obtained and bleeding is eliminated in this type of construction.

In conclusion, I would like to say that, having been faced with shortage of construction materials, lightweight aggregate has possibilities presently and more so in the future. And our experience, although limited, during these past two years, shows that comparable and possibly better roads can be built by use of this material.

Acknowledgements

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A P P E N D I X

TENTATIVE SPECIFICATIONS FOR LIGHTWEIGHT BITUMINOUS MIXTURES FOR HOT APPLICATION

These tentative specifications have been prepared as a supplement to Part 3, Division II, Section 3 of "Standard Specifications for Roads and Bridges". Changes shall be made wherever the conditions necessitate.

Description

Type A

The mix shall be composed of crushed lightweight aggregate all of which will be retained on a No. 40 mesh sieve, fine sand, mineral filler and bituminous material.

Type B

The mix shall be composed of crushed lightweight aggregate all of which shall be retained on a No. 4 mesh sieve, coarse sand, fine sand, mineral filler and bituminous material.

Composition and Proportioning

The bituminous material and the mineral aggregate shall be combined in such proportions that the mixture shall meet the following requirements by weight:

Type A

	Binder Course	Wearing Course
Aggregate, %	89.0 - 93.0	88.0 - 92.0
Total Bitumen, %	7.0 - 11.0	8.0 - 12.0

Type B

	Binder Course	Wearing Course
Aggregate, %	91.0 - 95.0	90.5 - 94.5
Total Bitumen, %	5.0 - 9.0	5.5 - 9.5

The respective mineral constituents of the mixtures shall be so sized and graded and shall be combined in such proportions that the resulting composite blend will meet the grading specifications indicated below. The percentage of mineral filler shall be determined during the final design of the mixture.

Type A

U. S. Sieve	Binder Course	Wearing Course
1-1/4"	100	100
1"	90 - 100	100
3/4"	75 - 100	100
1/2"	55 - 80	85 - 100
No. 4	30 - 50	60 - 80
No. 10	20 - 40	40 - 65
No. 40	12 - 22	20 - 40
No. 80	8 - 18	12 - 30
No. 200	5 - 10	4 - 15

Type B

1-1/4"	100	100
1"	90 - 100	100
3/4"	75 - 100	100
1/2"	55 - 80	85 - 100
No. 4	40 - 60	60 - 80
No. 10	30 - 50	40 - 65
No. 40	18 - 35	20 - 40
No. 80	8 - 22	12 - 30
No. 200	5 - 10	4 - 15

Physical Properties of the Mixture

Compacted specimens of the finished mixture, either prepared in the mixing plant or in the laboratory, shall conform to the following properties for both types:

Percent Theoretical Gravity	92 - 98
Percent Voids - Total Mix	2 - 8
Marshall Stability @ 140°F	1000 Minimum
Marshall Flow - 1/100"	8 - 18

The lift shall be rolled until a density equal to 97.0% of the laboratory briquette density is obtained.

TABLE VII

GRADATION OF AGGREGATE

Lab. No.	395272	391963	410981	410817	410816
	Gravelite Aggregate			Coarse Sand	Fine Sand
	Coarse	Intermediate	Fine		
1-1/4 inch	100.0				
1 inch	81.3				
3/4 inch	50.0	100.0			
1/2 inch	3.0	93.0	100.0	100.0	
No. 4	1.5	4.3	98.7	95.6	
No. 10			58.3	84.1	100.0
No. 40				29.6	99.8
No. 80				3.1	86.9
No. 200				1.7	32.1

TABLE VIII

SUMMARY OF TEST PROPERTIES

Mix No. 1

<u>Binder Course</u>

Lab. No.		A	B	C
395272	Coarse Lightweight		40.0	
391963	Intermediate Lightweight		25.0	
410981	Fine Lightweight (#4-#40 sieve)		20.0	
410816	Fine Sand		12.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	7.0	8.0	9.0
	Specific Gravity	1.539	1.552	1.550
	% Theoretical Gravity	92.1	93.5	94.0
	Density - Lbs./cu.ft.	96.0	96.8	96.7
	% Voids - Total Mix	7.9	6.5	6.0
	% Voids Filled	57.0	65.0	69.3
	Marshall Stability - lbs.	1395	1825	1480
	Flow 1/100 inch	18	19	19

Gradations of Mixtures

% Passing 1-1/4 inch	100.0
% Passing 1 inch	92.0
% Passing 3/4 inch	80.0
% Passing 1/2 inch	59.0
% Passing No. 4	37.0
% Passing No. 10	27.0
% Passing No. 40	15.0
% Passing No. 80	13.0
% Passing No. 200	6.0

TABLE IX

SUMMARY OF TEST PROPERTIES

Mix No. 2

Binder Course

Lab. No.		A	B	C
395272	Coarse Lightweight		30.0	
391963	Intermediate Lightweight		20.0	
410981	Fine Lightweight (#4-#40 sieve)		25.0	
410816	Fine Sand		22.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	7.0	8.0	9.0
	Specific Gravity	1.590	1.590	1.605
	% Theoretical Gravity	90.4	91.1	92.6
	Density - Lbs./cu.ft.	99.2	99.2	100.2
	% Voids - Total Mix	9.6	8.9	7.4
	% Voids Filled	53.0	58.1	65.5
	Marshall Stability - Lbs.	1970	2325	2855
	Flow 1/100 inch	10	11	13
	Gradations of Mixtures			
	% Passing 1-1/4 inch		100.0	
	% Passing 1 inch		94.0	
	% Passing 3/4 inch		85.0	
	% Passing 1/2 inch		70.0	
	% Passing No. 4		52.0	
	% Passing No. 10		40.0	
	% Passing No. 40		26.0	
	% Passing No. 80		22.0	
	% Passing No. 200		9.0	

TABLE X

SUMMARY OF TEST PROPERTIES

Mix No. 3

Binder Course

Lab. No.		A	B	C
395272	Coarse Lightweight		30.0	
391963	Intermediate Lightweight		20.0	
410817	Coarse Sand		40.0	
410816	Fine Sand		7.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	5.0	6.0	7.0
	Specific Gravity	1.764	1.762	1.779
	% Theoretical Gravity	93.3	94.1	95.8
	Density - Lbs./cu.ft.	110.1	109.9	111.0
	% Voids - Total Mix	6.7	5.9	4.2
	% Voids Filled	56.1	63.5	74.2
	Marshall Stability - Lbs.	615	1015	885
	Flow 1/100 inch	9	10	12
	Gradations of Mixtures			
	% Passing 1-1/4 inch		100.0	
	% Passing 1 inch		94.0	
	% Passing 3/4 inch		85.0	
	% Passing 1/2 inch		70.0	
	% Passing No. 4		50.0	
	% Passing No. 10		44.0	
	% Passing No. 40		22.0	
	% Passing No. 80		10.0	
	% Passing No. 200		5.0	

TABLE XI

SUMMARY OF TEST PROPERTIES

Mix No. 4

Wearing Course

Lab. No.		A	B	C
391963	Intermediate Lightweight		40.0	
410981	Fine Lightweight (#4-#40 sieve)		37.0	
410816	Fine Sand		20.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	8.0	9.0	10.0
	Specific Gravity	1.591	1.601	1.590
	% Theoretical Gravity	89.7	91.0	91.0
	Density - Lbs./cu.ft.	99.3	99.9	99.2
	% Voids - Total Mix	10.3	9.0	9.0
	% Voids Filled	54.8	60.9	63.2
	Marshall Stability - Lbs.	1315	1910	2395
	Flow 1/100 inch	12	13	14
	Gradation of Mixtures			
	% Passing 3/4 inch		100.0	
	% Passing 1/2 inch		97.0	
	% Passing No. 4		62.0	
	% Passing No. 10		45.0	
	% Passing No. 40		24.0	
	% Passing No. 80		21.0	
	% Passing No. 200		8.0	

TABLE XII

SUMMARY OF TEST PROPERTIES

Mix No. 5

Wearing Course

Lab. No.		A	B	C
391963	Intermediate Lightweight		40.0	
410981	Fine Lightweight (#4-#40 sieve)		37.0	
410816	Fine Sand		19.0	
	Filler (Limestone)		4.0	
	Asphalt Cement (85/100) %	10.0	11.0	12.0
	Specific Gravity	1.590	1.607	1.615
	% Theoretical Gravity	91.0	92.7	93.8
	Density - Lbs./cu.ft.	99.2	100.3	100.8
	% Voids - Total Mix	9.0	7.3	6.2
	% Voids Filled	63.2	70.2	75.2
	Marshall Stability - Lbs.	2320	2430	2510
	Flow 1/100 inch	11	13	14

Gradations of Mixtures

% Passing 3/4 inch	100.0
% Passing 1/2 inch	97.0
% Passing No. 4	62.0
% Passing No. 10	45.0
% Passing No. 40	24.0
% Passing No. 80	22.0
% Passing No. 200	9.0

TABLE XIII

SUMMARY OF TEST PROPERTIES

Mix No. 6

Wearing Course

Lab. No.		A	B	C
391963	Intermediate Lightweight		40.0	
410817	Coarse Sand		47.0	
410816	Fine Sand		10.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	5.0	6.0	7.0
	Specific Gravity	1.839	1.868	1.875
	% Theoretical Gravity	92.8	95.2	96.5
	Density - Lbs./cu.ft.	114.8	116.6	117.0
	% Voids - Total Mix	7.2	4.8	3.5
	% Voids Filled	55.4	69.4	78.4
	Marshall Stability - Lbs.	905	1110	1365
	Flow 1/100 inch	7	8	10
	Gradations of Mixtures			
	% Passing 3/4 inch		100.0	
	% Passing 1/2 inch		97.0	
	% Passing No. 4		60.0	
	% Passing No. 10		53.0	
	% Passing No. 40		27.0	
	% Passing No. 80		13.0	
	% Passing No. 200		6.0	

TABLE XIV

SUMMARY OF TEST PROPERTIES

Mix No. 7

Wearing Course

Lab. No.		A	B	C
391963	Intermediate Lightweight		30.0	
410817	Coarse Sand		47.0	
410816	Fine Sand		20.0	
	Filler (Limestone)		3.0	
	Asphalt Cement (85/100) %	5.0	6.0	7.0
	Specific Gravity	1.932	1.947	1.958
	% Theoretical Gravity	92.7	94.5	96.0
	Density - Lbs./cu.ft.	120.6	121.5	122.2
	% Voids - Total Mix	7.3	5.5	4.0
	% Voids Filled	56.2	67.3	76.9
	Marshall Stability - Lbs.	800	1190	1150
	Flow 1/100 inch	7	8	9
	Gradations of Mixtures			
	% Passing 3/4 inch		100.0	
	% Passing 1/2 inch		98.0	
	% Passing No. 4		69.0	
	% Passing No. 10		63.0	
	% Passing No. 40		37.0	
	% Passing No. 80		22.0	
	% Passing No. 200		9.0	