SCORIA - A NATURAL LIGHTWEIGHT AGGREGATE

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3-20-71-033
October 1971

PREFACE

As a result of a continued increase in highway construction and maintenance needs in recent years, greater demands have been placed on our natural resources to supply road-building materials, not only in quantity but in quality. Information about new or potential materials is always a desire of departmental personnel especially when such materials offer a substitute for diminishing or depleted aggregate sources, and even more so, if they provide economic incentives in addition to the required engineering properties.

CONTENTS

I. SUBJECT

Vast deposits of scoria, a vesicular lightweight igneous rock, which occur in neighboring Mexico and New Mexico, provide enormous reserves of potential aggregate materials for highway needs in certain parts of Texas. The presentation of results of several laboratory tests along with general information about the origin and description of five scoria samples is the subject of this report.

II. PURPOSE

The purpose of this report is to make available to departmental personnel the findings of a number of quality tests, recently performed by the Materials and Tests Division, on unofficial scoria samples received from Mexico and New Mexico.

III. SUMMARY AND CONCLUSIONS

Routine physical tests, with regard to the requirements for lightweight aggregates used in surface courses and pavements, have recently been performed by the Materials and Tests Division on a series of extrusive (volcanic) igneous rocks known as scoria resulting in the following:

1. Laboratory findings indicate that the examined scoria samples qualify as lightweight aggregates in terms of unit weights (Max. 55#/cu.ft.).

2. Petrographic observations suggest that a strong relationship exists between the internal structure of scoria (gas voids or bubble density and matrix thickness between voids) and the results of Los Angeles abrasion tests. Three samples, the New Mexico "Black" and both Old

Mexico samples, had a much finer, glassy matrix and thinner internal walls between gas voids than the gray and red scoria from New Mexico. Their wear-loss values by the Los Angeles test ranged from 40.1 to 50.4% compared to a range of 28.0 to 34.2 for the latter two New Mexico samples and the same three had significantly lower unit-weight values.

3. Laboratory tests show that the weighted per cent loss by the freeze-thaw method was greater for the samples with the lower unit weight values.

4. The polish values, as determined by the Accelerated Polish Test (Test Method Tex-438A) measured by the British Portable Tester, for all five scoria samples compared favorably with values obtained on synthetic lightweight aggregates and were very high as compared to conventional aggregates such as river gravels, limestones and sandstones.

5. Both the gray and red scorias from New Mexico appear to meet all the existing specification requirements for lightweight aggregates. The other samples do meet some of the requirements but appear to have too high a loss by the Los Angeles Abrasion Test.

6. Other State Highway Departments have reported satisfactory uses of scoria in some bituminous pavements, although they noted special problems in design and placement. In addition, scoria's high skid-resistance properties were noted.

IV. DISCUSSION

A. Geologic Origin of Scoria

Of the two main classes of igneous rocks, intrusive and extrusive (volcanic), scoria belongs to the latter. It is one of several rock types formed by volcanic activity and is actually a type of lava. As the word igneous implies, these rock types were once molten, however, each type has distinctive features. Scoria is recognized from ordinary lava because of its cellular or vesicular character. The vesicles or bubbles formed when expanding gases were entrapped as the molten material was blown (erupted) from a volcano. Scoria is generally lighter in weight than non-vesicular lava or basalt (trap rock) and slightly heavier than the extremely cellular type-pumice (which commonly floats on water). The texture of scoria can grade from glassy (like obsidian) to micro-granular (like rhyolite) and the size of the bubbles can range from a few microns to several millimeters.

B. Sample-Site Localities

A generalized index map, shown as Figure 1, depicts the areas where the five examined scoria samples were collected. The sites, presently leased for commercial aggregate production, are situated in volcanic areas in Mexico and New Mexico.

Two of the samples (red and black), collected from commercial operations west of Veracruz, Mexico, were submitted by Mr. Keith Maxwell, Sr., of Kemaxco, Inc., in Houston and carry the trade name "Super Lite Aggregate." Reportedly, the material is typical of production

FIGURE 1.

INDEX MAP SHOWING SCORIA LOCALITIES

INCLUDED IN THIS REPORT

the company plans to ship to Houston via bulk carrier vessels (barges).

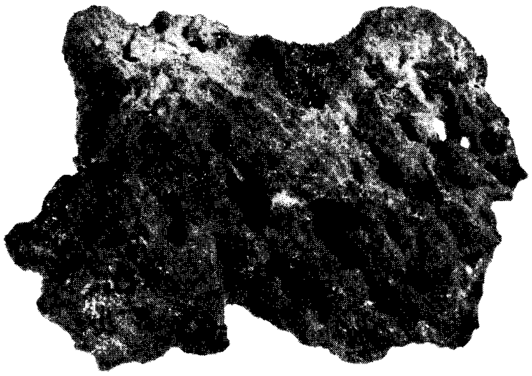
Of the three New Mexico scoria samples, two (black and gray) were taken from sites located about 30 miles west of Las Cruces and south of U.S. 180 (IH-10) near the villages of Akela and Cambray. The third (red) came from an area about 12 miles southwest of Santa Fe off U.S. 85 and SH22. All three of these samples were submitted by John Pirkle of Pirkle-Hoyte Scoria, Inc., Houston and were reported as being typical of production material being considered for shipments into western parts of Texas by rail.

C. Petrographic Analyses

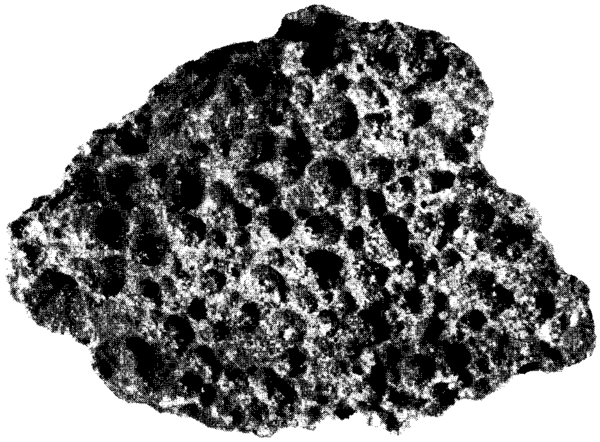
Microscopic examinations of thin-sections ground to 30-35 microns reveal that the scoria samples range in texture from glassy to fine-grained with bubble densities ranging from very high (in the Old Mexico material) to inconspicuous (in certain individual particles of the New Mexico "red" type).

None of the samples were completely void of microcrystals, however, the number and size varied. In addition, the number, size and type of phenocrysts (relatively large included mineral crystals) could somewhat characterize a given sample. Although visible under the microscope, phenocrysts were not observed with the unaided eye in any sample except the New Mexico "red" type. In this latter sample, clear-colored glassy phenocrysts are striking in appearance, measure in size up to 5-6 millimeters, and show some degree of secondary alteration (weathering). Very pronounced brownish-red iron oxides give the

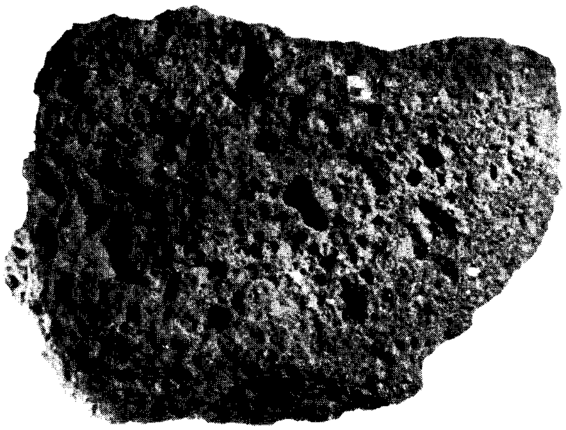
FIGURE 2.



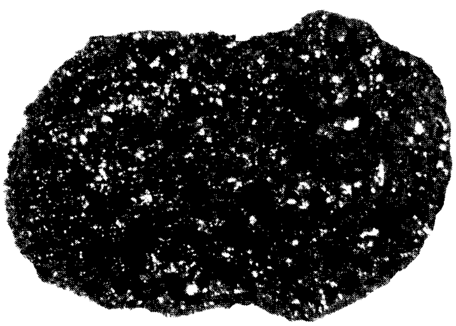
New Mexico "Black"



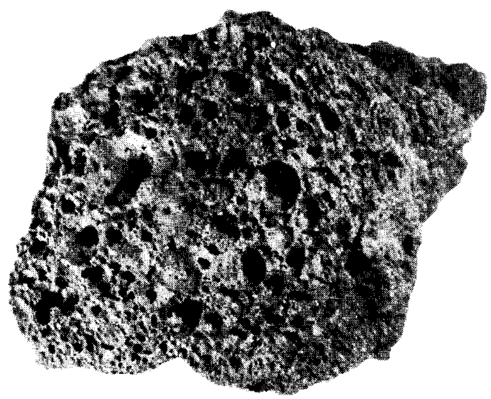
New Mexico "Gray"



New Mexico "Red"



Old Mexico "Black"



Old Mexico "Red"

(All at $3\frac{1}{2}$ times actual size) material its color, which is also prevalent in thin-sections.

The black and gray scoria samples from the Las Cruces area show "flow features" indicating perhaps a less violent eruption and more likely represent material from a fissure-type lava flow rather than a composite volcanic core. At low magnification, these samples appear glassy externally and, likewise, in thin-section the matrix is very fine-grained to glassy with very few phenocrysts. A white precipitate is noticeable as a coating on many of the particles from these New Mexico samples. Although apparently crystalline in form suggesting either a form of calcium carbonate or calcium sulfate (gypsum), acid treatment indicates that it is not a carbonate.

Both the red and black samples from Old Mexico are very vesicular in texture as well as glassy. They also show a much finer-grained matrix and no phenocrysts are visible to the unaided eye and very few can be noted in thin-section. After examining these samples, it becomes apparent that the bubble density is related to bulk unit weight.

The particle shape and texture is illustrated in Figure 2.

D. Physical-Test Results

1. Sieve Analysis: This test method (Tex-401-A) is used for the determination of the particle distribution of aggregate samples. The sieve analysis for the five scoria samples is as follows:

Sieve Size	New Mex-Black % Ret'd	New Mex-Gray % Ret'd	New Mex-Red % Ret'd	Old Mex-Black % Ret'd	Old Mex-Red % Ret'd
3/4"	2.6	0.0	0.0	0.5	0.0
1/2"	78.4	26.4	37.6	41.9	32.0
3/8"	96.3	80.7	78.6	74.8	67.5
#4	98.9	98.9	99.3	97.1	98.1
#10	----	----	----	97.8	99.5
	100.0	100.0	100.0	100.0	100.0

2. Unit Weight: This test method (Tex-404-A) is used for determining the loose weight per cubic foot of both coarse and fine aggregate. The results of the unit weight test performed on the scoria samples are as follows:

	New Mex-Black	New Mex-Gray	New Mex-Red	Old Mex-Black	Old Mex-Red
#/Cu Ft	42.3	53.9	58.7	39.7	41.2

3. Los Angeles Abrasion: This test method (Tex-410-A) is used for testing an aggregate for resistance to abrasion in the Los Angeles testing machine with an abrasive charge. The results of this test as performed on the scoria samples are as follows:

	New Mex-Black	New Mex-Gray	New Mex-Red	Old Mex-Black	Old Mex-Red
% Loss "B" Wear	50.4	28.0	34.2	46.7	40.1

4. <u>Freeze-Thaw:</u> This test method (Tex-432-A) is followed in testing synthetic coarse aggregate to determine their resistance to disintegration by freezing and thawing. It furnishes information helpful in judging the soundness of aggregates subjected to weathering action. The results of the freeze-thaw test on the five scoria samples are as follows:

	New Mex-Black		New Mex-Gray		New Mex-Red	
Size	% Loss	Wt'd % Loss	% Loss	Wt'd % Loss	% Loss	Wt'd % Loss
1/2"	5.5	4.2	3.3	0.9	3.4	1.4
3/8"	7.6	1.4	3.4	1.8	2.8	1.1
#4	0.9	0.2	.0	.0	0.6	0.1
	Total	5.8%		2.7%		2.6%

	Old Mex-Black		Old Mex-Red	
Size	% Loss	Wt'd % Loss	% Loss	Wt'd % Loss
1/2"	6.3	2.6	6.5	2.1
3/8"	7.3	2.4	4.2	1.5
#4	1.7	0.4	0.9	0.3
	Total	5.4%		3.9%

5. <u>Pressure Slaking:</u> This test method (Tex-431-A) is intended to be used to evaluate the amount of dehydration that has occurred in the production of synthetic aggregate and the values obtained on natural scoria are offered for comparison. The result of this test on the scoria materials is as follows:

	New Mex-Black	New Mex-Gray	New Mex-Red	Old Mex-Black	Old Mex-Red
% Loss By Wt.	8.5	3.3	7.1	7.6	4.9

6. Specific Gravity and Absorption: This test method (Tex-433-A) is intended for use in determining the dry bulk specific gravity and absorption of lightweight coarse aggregate. The results of this test on the scoria samples are as follows:

Sample	Dry Bulk Sp. Gr.	Absolute Sp. Gr.	100 min. Sat. Value
New Mex-Black	1.87	2.63	10.4%
New Mex-Gray	1.92	2.73	11.4%
New Mex-Red	1.97	2.87	12.6%
Old Mex-Black	1.46	2.58	7.7%
Old Mex-Red	1.93	2.91	5.1%

7. Accelerated Polish Test: This test method (Tex-438-A) is used for determining a relative measure of the extent to which different types of aggregates in a pavement's wearing surface will polish under traffic. In general, aggregates having low polish values (25-35) are more susceptible to polishing under traffic, thusly, exhibiting low skid-resistance as measured by the skid trailer, whereas, those aggregates with high polish values (45 and above) generally show high skid-resistance. The polish values determined for the five scoria samples are as follows:

	New Mex-Black	New Mex-Gray	New Mex-Red	Old Mex-Black	Old Mex-Red
Polish Value	58	56	62	60	64

Specification requirements governing the use of lightweight aggregates in bituminous surfaces (Items 303, 340) and portland cement concretes (Item 421) are listed in Appendix I.

It should be understood that these five scoria samples are unofficial and that production samples are necessary to fully evaluate the capability and the acceptability of any material submitted.

E. Other Reported Tests and Uses

In June 1970, a sample (Lab #70-3232-A) of red scoria produced by Super Lite Products, Inc., Houston was obtained from a stockpile being routinely examined for a Houston Urban Project (I-610-7(165)797) in Harris County. It was submitted for routine testing under specification Item 423 for use in a concrete bridge slab. The reported test results are as follows:

Sieve Analysis:	Size	% Ret.
	3/4"	1.3
	1/2"	15.7
	3/8"	33.2
	#4	79.4
	#8	89.3

Unit Weight: 48.5 #/Cu. Ft.

Los Angeles Abrasion: 51.0% "C" Wear

Freeze-Thaw: 1.9%

Dry Bulk Specific Gravity: 1.85

100 Min. Saturation Value: 11.5%

Pressure Slaking: 7.1%

Results of other tests conducted by commercial testing laboratories on Red Scoria (Mexico) aggregate for Super Lite Products are as follows:

Portland Cement Concrete

Unit Wt. "Wet" 117.9 #/Cu. Ft.

Unit Wt. Dry 113.9 #/Cu. Ft.

7 Day Compression = 4310 psi

28 Day Compression = 5717 psi

In a letter from the State Highway Department of Oregon to Super Lite Products, Inc., it was noted that volcanic cinders had been used in bituminous surfacing of all types and some had been in use over 10 years. In addition, it was mentioned that because of the vesicular nature of scoria more asphalt had to be used to maintain a given film thickness. Also, that the high inter-particle friction prevented high compaction without degradation. In general, surface treatments and seal coats using scoria had been satisfactory in performance with good riding and non-skid qualities, whereas, scoria in asphaltic concrete had generally been unsatisfactory.

In a similar letter, the State of Nevada Highway Department noted that volcanic scoria had been used for years very satisfactorily in bituminous mixtures. It was noted, however, that 30-40% more asphalt was needed when scoria was used as roadmix aggregate than when gravel aggregates were used. Scoria fines were also reported as used for sanding icy surfaces in winter.

APPENDIX

APPENDIX I

TEST REQUIREMENTS FOR LIGHTWEIGHT AGGREGATES

Item 303. Aggregates for Surface Treatments (Lightweight)
Cellular and granular inorganic material produced by fusing.
Also Special Specifications Item 1989, 2120, etc.

Unit Wt.	= Min. 35#/Cu.Ft. Max. 55#/Cu.Ft. with $\pm$ 4% variation permitted.
L.A. Loss	= Max. 35%
Freeze-Thaw Loss	= Max. 7.0%
Pressure Slaking	= Max. 4.0%

Item 340. Hot Mix Asphaltic Concrete Pavement
Special Provision 340-104 'Synthetic Aggregate'

Unit Wt.	= Min. 35#/Cu.Ft. No Max. with $\pm$ 4% variation permitted
L.A. Loss	= Max. 40%
Pressure Slaking	= Max. 6%

Special Provision 340-113 Cellular and granular inorganic material, etc.

Unit Wt.	= Min. 35#/Cu.Ft. Max. 55#/Cu.Ft. with 6% variation permitted.
L.A. Loss	= Max. 35%

Item 423. Lightweight Concrete for Structures
Lightweight Coarse Aggregate

Gradation	Sieve Size	% Ret'd
	3/4"	0 - 10
	3/8"	45 - 80
	#4	90 - 100
	#8	95 - 100

L.A. Wear	= Max. 35%
Freeze-Thaw Loss	= Max. 7%
Potential Reactivity	= Innocuous
Dry Shrinkage	= Max. 0.07%
Unit Weight	= Max. 55#/Cu.Ft. Max. variation 4%.
Absorption	= 100 min. Saturation Value Max. 15% Max. variation 33%
Pressure Slaking	= Max. 6.0%