FINAL REPORT ON THE USE OF LIGHTWEIGHT AGGREGATE IN FLEXIBLE PAVEMENTS

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ABSTRACT

This final report, the fourth in a series on the subject, summarizes the findings of a study on the use of lightweight aggregate in flexible pavements. The study began in 1963 and was directed initially toward verifying expected performance and safety aspects of lightweight aggregate when compared to precoated limestone used primarily as coverstone for seal coats.

Both laboratory and field studies were carried out to prove that lightweight aggregate is quite suitable as a coverstone for seal coats and surface treatments. Lightweight aggregate was found to cause no "flying" stone problem and thus damage to windshields and headlamps was eliminated where this material was used. Although not a part of the study, it was found that lightweight synthetic aggregate used as coverstone for seal coats produced a surface of high and prolonged skid resistance.

Exploratory research in the laboratory and field with lightweight aggregate in hot-mix asphalt paving mixtures shows great promise for this new source of aggregate. Mixes designed to include as much as fifty percent (by volume) of lightweight aggregate appear entirely suitable for high quality asphalt surface courses.

The mixtures are highly stable, are not water susceptible, and above all, produce a non-skid surface. When proper use is made of local materials for the intermediate and fine sized fraction of the mix, designs containing lightweight aggregate compare favorably in cost with designs made from regular aggregates.

Based on two field trials involving "manufactured" aggregate from three sources, the coefficient of friction as measured wet at 40 mph on a locked wheel trailer is above 0.5. One of the sections with over four million vehicle passages is one year old and the other is over four years old and has in excess of three million vehicle passages over it.

In plant mixes, this new aggregate presents no construction difficulties for which easy adjustment cannot be made. And although asphalt content may at first appear high, it is quite normal when compared on a volume basis with that required by regular aggregates. Asphalt absorption is higher than that for most regular aggregates, but it is non-selective which gives it a definite advantage over absorptive limestones and sandstones, which may absorb the lighter fraction (smaller molecules) of asphalt thus leaving a harder residual binder subject, possibly, to earlier brittle failure.

SUMMARY AND CONCLUSIONS

Summary

This is the fourth and final report to be published on the current study concerned with the use of lightweight aggregate in flexible pavements. Research Report 51-1 on Project 2-14-63-51 was published in August of 1964 (9). Research Report 51-2 was submitted to the sponsor in April of 1966 and subsequently published by the Highway Research Board (10). The third report, Research Report 51-3, was submitted to the sponsors in November of 1966 (11).

Lightweight synthetic aggregate was first introduced experimentally on Texas highways in 1961 when a total of 9.8 miles of pavement was surface treated in the Brownwood District of West Texas. In 1962, two districts placed limited amounts of this material as seal coat coverstone. During the next five construction seasons, more than 1900 miles of primary and secondary roads in ten different districts were surfaced with lightweight aggregate.

Except for a few sections of limited mileage, the aggregate used to date has been from three sources with a major share of the material from a single source.

Experimental sections of plant mixed paving mixtures have been placed in five different districts and have utilized "manufactured" aggregates from four different sources.

As reported in earlier research (9), the laboratory and field evaluations were conducted to determine whether or not lightweight aggregate should be accepted as equal to precoated normal weight material for seal coat coverstone. Data previously presented (9) covered, for all practical purposes, material from only one source; however, during the 1966 and 1967 construction seasons, appreciable quantities of material from two other Texas sources were placed as coverstone for seal coats (11). Additionally the State of Louisiana has placed extensive mileage of seal coats using another of the aggregates included in this study (21).

The following conclusions are based on the laboratory data on lightweight aggregates from seven sources and on laboratory and actual field performance on four of these same materials. All seven lightweight aggregates are tentatively placed in Class I (20) with six of the materials in Group A and one in Group C. This classification is based on Texas Highway Department Grade 4 material (34).

For purposes of clarity, the conclusions will be divided into wo sections, one dealing with applications in seal coat type work nd one on the use of these materials in plant mixed graded aggre- ate asphalt paving mixtures.

overstone Applications

1. The loose unit weight of the lightweight uniform graded aterials under study was in the range 38 to 50 pcf (9).

2. Laboratory design and evaluation of seal coats, preparatory to construction, result in improved over-all economy and service (10).

3. Laboratory studies and field observations showed that all the lightweight material has a strong affinity for the various asphalt cements used in the project. This was a qualitative observation.

4. The steel wheel roller caused degradation of both the crushed limestone and the lightweight synthetic aggregate, particularly in areas of irregular cross section. Numerous quantitative measurements were made in proof of this statement (10).

5. Crushing of the lightweight coverstone during construction is reduced to a negligible amount when the pneumatic roller alone is used to seat the cover material, and it is therefore suggested that only pneumatic rolling of lightweight aggregate be practiced (10).

6. Laboratory induced windshield damage was severe for the crushed limestone and practically insignificant for the lightweight material (9).

7. The Texas and Louisiana modifications of the Los Angeles abrasion test were found to be less severe than the ASTM standard test when used to measure the abrasion resistance of the lightweight materials under study (10).

8. Fifty cycles of rapid freezing and thawing in distilled water caused an appreciable loss (20.9%) for one of the Grade 4 materials and fairly low losses for aggregates from the other sources. For the Grade 3 materials, five of the seven sources yielded losses of less than 10 percent. Only one material of this grading showed excessive loss. Based on the Grade 4 grading, all the materials under study, except one, would be classed as IA (20).

9. Comparative losses for the ASTM standard sulfate soundness test and the 100 cycle rapid freeze-thaw test for one of the light-weight aggregates under study are 1.56 percent for five cycles of the soundness test and 3.07 percent loss for 100 cycles of freeze-thaw.

This particular Class IA material rated highly successful as cover aggregate for seals and surface treatments.

11. Design and construction difficulties have occurred in less than two percent of the mileage placed to date. This is considered an outstanding record for a new material.

12. The volume and type of traffic appears to have no measurable effect on the degradation of any of the lightweight aggregates now in service (10).

13. The lightweight aggregate was favorably accepted by contractors and Texas Highway Department personnel throughout the area in which it was used. Comments are included in the appendix.

14. Lightweight synthetic aggregates meeting the specifications of requirements of the Texas Highway Department (Special Specification Item 1269 (Lightweight) Aggregate for Surface Treatments) are considered equal to precoated limestone for seal coat and surface treatment work. (Specification 1269 is included in the appendix) Extensive field service records attest to this for four of the seven aggregates included in the study. Inadequate use (in flexible pavements) of the materials from the other three sources exists to justify a positive statement about their suitability for this service; however, they do meet the specification requirements of Item 1269 and all except one fall in Class IA (20) of the tentative classification system developed at the Texas Transportation Institute.

Hot Mix Asphalt Paving Mixtures

1. Research findings reveal that economical hot-mix designs can be produced by blending synthetic coarse aggregate (1/2-inch to No. 10) with locally available fine aggregates such as crusher fines and field sand, or both. Where field sand alone is used as the fine material, the coarser gradings produce more economical mixes (11).

Designs meeting the specification requirements of the Texas Highway Department's Item 340, Hot-Mix Asphaltic Concrete Pavement, Class A Type D, were easily obtained with the materials under study. Proof of extended service performance for the various producers' products has not been obtained; however, service records to date are very encouraging.

2. Laboratory compaction degradation was found to be a minor problem even for designs containing 100 percent lightweight aggregate. The Texas gyratory shear compactor was used in the study; so it is not known what results would be obtained with, say, the Marshall

impact hammer or the California kneading compactor. A high Hveem stability is a common characteristic of designs containing aggregate with a rough surface texture, and it is probably for this reason that the hot-mix designs that were investigated produced stabilities in the range of 40 to 50. Large changes in asphalt content have little effect on measured stabilities. This characteristic has economic potential.

3. Asphalt absorption of the synthetic aggregate under study was essentially constant at 2 to 3 percent for the various producers' products when the available asphalt was limited; however, when an unlimited supply of hot asphalt cement was made available to the different materials under study, considerable difference was noted in the absorption capacity. Depending on particle size distribution and source of material, the absorption varied from 2.0 to 15.4 percent by weight. Under plant and field construction conditions, asphalt absorption of the synthetic aggregate fraction would normally be in the range of 2 to 3 percent by weight. Microscopic examinations indicate this absorption to be non-selective. Design asphalt contents of 7 to 10 percent by weight of mix are common. Corrected to a volume basis, these compare favorably with THD Class A, Type D, hot-mix, dense aggregate, designs in use today. For example, a design containing fifty percent lightweight synthetic aggregate (by weight) would require 7 to 8 percent asphalt cement, again, by weight; however, on a volume basis, this would be 4.9 to 5.6 percent asphalt. This is in the same order of asphalt quantity that is used in regular mixes made from natural aggregates.

4. Hot-mix designs examined for water susceptibility included field sands, so the results obtained are not clear, and the method used to make the evaluations is not absolute. However, at reasonable asphalt contents (film thickness of 7-10 microns), most of the designs were acceptable from the viewpoint of water susceptibility.

5. The synthetic aggregates included in this study exhibited negligible expansion pressure and the swell as measured by Test Method Tex-290-F was in the range of 0.004 inch or less, compared to an allowable of 0.03 inch. It is therefore apparent that the qualities measured by these tests are quite high.

6. Air permeability measurements were made on a single design using aggregates from all seven sources. As has been found in the past, a general decrease in air permeability is associated with an increase in asphalt cement; however, a coefficient of determination of 0.43 was obtained when air permeability was related to air voids in the compacted laboratory specimens. Results in the field are likely to be even more variable. Permeability to water instead of air might give more meaningful data and this should be investigated.

General Recommendations

Based on laboratory and field data collected over the past forty-two months and considering only those materials involved in these studies, the following recommendations are presented (9) (10) (11):

1. Considerations should be given to setting a minimum as well as a maximum unit weight for lightweight synthetic aggregate used in seals and surface treatments. This minimum could be a set figure or it could be provisionally based on service records and/or laboratory data from abrasion and rapid freeze-thaw results.

2. The very definite advantages of clean uniform graded materials were emphasized in the study. Improved construction control and extended service would result from further restrictions of range of particle size presently permitted. Grades 1 through 5 permit two percent of the material to pass the No. 10 sieve. Of this minus No. 10 material not more than one half of one percent (based on the total aggregate) should pass the No. 80 sieve.

3. Only pneumatic rolling of lightweight aggregate coverstone is recommended.

4. In the interest of saving testing time, it is suggested that consideration be given to adopting the Louisiana modification of the L. A. abrasion test with washing of the plus No. 5 material* after test as provisional; otherwise, the standard ASTM test should be used.

5. Considering availability of equipment, a rapid freeze-thaw test might be substituted for or made optional to a sulfate soundness test. Fifty cycles and eight percent maximum loss are tentatively suggested for THD Grade 4 material (34).

6. New lightweight materials or lightweight materials produced from unproven sources of raw materials should be subjected to and pass acceptable field service trials before final acceptance and general use.

7. The use of synthetic aggregates in paving systems of all types should be encouraged where these materials meet service requirements. Proof of acceptable service should negate tentative specification requirements. No maximum unit weight restriction should be imposed on materials of this general type unless some definite purpose is served by the restriction, for example, the minimizing of windshield damage in seal coat and surface treatment work.

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*Analysis for wear should be made by use of the No. 5 sieve rather than the No. 4.

8. To establish realistic quality boundaries on the many lightweight aggregates that might be used for seal coats and surface treatments, it would be advisable to evaluate these materials in the laboratory before controlled field serviceability tests are made.

9. General specifications should be prepared which would place the various synthetic aggregates in use categories. Three or four categories would be required. A tentative system has been worked out and is referenced in this report (20).

10. The use of lightweight aggregate is recommended as a pavement surfacing material for good and lasting skid resistance. Properly designed and constructed seal coats involving this material as coverstone have 40 mph wet coefficients of 0.5 to 0.6. Measurements made with ASTM standard tires and a locked wheel on a two wheel trailer reveal no appreciable loss in the coefficient of friction on sections of pavement in service for more than four years. Research carried out by others shows similar results (21).

11. Hot-mix designs involving the use of lightweight aggregate should contain a minimum of fifty percent (by volume) of plus No. 10 mesh lightweight material to realize the primary advantages of this type aggregate. Highly successful designs may contain up to seventy-five percent (by volume) of plus No. 10 lightweight material.

12. Since the lightweight aggregates under study have not been found to be water susceptible and since workability may be a problem in the field, it is recommended that a gap be introduced in the grading to improve workability. Gaps have been used between the No. 10 and the No. 30 sieves and such mixes handle smoothly in the finishing machine.

13. In the event that the delayed release of moisture from this type of aggregate creates a problem during construction the use of silicone such as Dow Corning No. 200 Fluid is recommended in amounts of about 1.5 parts per million in the asphalt cement (35).

14. In fairness to the contractor or asphaltic concrete producer, mixes involving the use of appreciable quantities of lightweight aggregate should be sold on a volume basis. This adjustment is easily accomplished by a linear correction factor based on bulk densities of laboratory specimens molded at optimum asphalt content.

INTRODUCTION

This is the fourth and final report on Study 2-14-63-51. The principal findings of the over-all study are detailed and documented in the three previous reports, namely Research Reports 51-1, 51-2, and 51-3 (9, 10, 11). This final report will therefore summarize the previous findings and where considered advisable, in the light of any new evidence obtained from observations and evaluations made on in-service pavements during 1966 and 1967, modify the earlier recommendations made in previous reports. The reader is urged to read the Research Reports 51-2 and 51-3 for a complete background on the work previously done.

This study which is concerned with the use of lightweight aggregates in asphalt pavements began as a two phase study in 1963 with the major objective of verifying predicted improved construction and service characteristics of lightweight synthetic aggregate.

The primary objective of Phase I of the study was to determine whether or not the several lightweight aggregates presently manufactured in Texas are acceptable as equal to precoated limestone available in the same general market area (9, 10). In order to compare the physical characteristics of the lightweight aggregates under study with the accepted serviceability of precoated stone, it was necessary to design and carry out a rather extensive and intensive series of laboratory evaluations on the lightweight materials. These evaluation measurements then became a necessary part of the primary objectives of Phase I.

Since no study of a construction material is complete without actual field trials, a large number of seal coat and surface treatment jobs built under regular Texas Highway Department Specifications were included for study in the program. Field evaluations on both lightweight aggregate and precoated crushed limestone* seals were included for comparison purposes.

The objective of Phase II of the study was to determine and relate the basic physical characteristics of lightweight aggregates to their uses in hot-mix, hot-laid, asphaltic concrete surfaces for thin overlays and anti-skid pavements. These objectives were an outgrowth of the primary study of lightweight aggregate as coverstone for seals and surface treatments.

This is the final report of the study on a material, which, until rather recently, has been used on a limited scale as a highway surfacing material.

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* Precoating consists essentially of coating the stone in a pugmill with about 1 1/2 percent by weight of a medium curing cutback asphalt to improve adhesion of the stone and thus reduce damage to automotive glass and finish.

At the present time (1967) Texas leads the nation in the number of miles of highways that are surfaced with lightweight "manufactured" aggregate. District-by-district mileage of seals and surface treatments in service as of July, 1967, is shown in Table I. The major portion of the approximately 2000 miles of Texas pavements covered with synthetic aggregate makes use of an expanded shale from a single source; however, minor and successful applications of lightweight aggregate from three other sources have been put into service since the study began in 1963. Current evaluations and data show that all four sources produce highly successful materials for highway surfacing.

Although the aggregates being reported upon have been used primarily as coverstone for seals and surface treatments, lightweight aggregates from four sources have been used in trial sections of plant mixed paving mixtures of the dense type with top sized material of about 1/2-inch.

Also included as a major part of the study were laboratory evaluations of hot-mix designs produced from six lightweight synthetic aggregates currently produced in Texas plus one material from the State of Louisiana.

Condition Survey

In addition to visual and photographic evaluations of hundreds of miles of the seal coats which utilized lightweight synthetic aggregate as coverstone for seals, condition surveys were made using the procedure devised by the South Dakota Department of Highways.*

This system of evaluation was used on twenty-four different sections of pavement in one district of the Texas Highway Department and extended over a period of four years including seal coats up to five years of age.

The South Dakota system of rating seal coats is visual, but the outlined procedure contains photographs which assist the observer in rating a given surface in five distinct areas of considered quality. The five factors which are rated independently are as follows:

1. Chip Retention
2. Skid Resistance
3. Uniformity of Application
4. Cracking
5. Bleeding

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*Procedure for Conducting Surveys of Chip Seal Coats by Physical Research Division, State of South Dakota Department of Highways, Revised January, 1963.

TABLE I

SUMMARY OF LIGHTWEIGHT AGGREGATE
SEALS AND SURFACE TREATMENTS
ON TEXAS HIGHWAYS
July 1967

DISTRICT	1961	1962	1963	1964	1965	1966	1967	TOTAL
1 (Paris)				5.1		96.4	12.2	113.7
2 (Fort Worth)			164.5		15.5		18.5	198.5
3 (Wichita Falls)			10.0	98.0			60.7	168.7
4 (Amarillo)					15.9	1.9	2.4	20.2
8 (Abilene)		0.5		14.0	101.0	131.3		246.8
10 (Tyler)							22.3	22.3
11 (Lufkin)			26.7	4.3	3.8	74.8		109.6
18 (Dallas)			149.4	194.7		109.1		453.2
23 (Brownwood)	9.8	6.5	94.9	29.9	40.3	10.9	42.8	235.1
25 (Childress)			31.2	16.2	68.0	124.5	151.8	391.7
TOTAL	9.8	7.0	476.7	362.2	244.5	548.9	310.7	1959.8

These factors are given numerical ratings between 0-20 with the following general terms as measures of quality:

16-20 Excellent, 11-15 Good, 6-10 Fair and 0-5 Poor.

For the pavements that were rated by this system items "2" and "4" above were omitted since these factors were considered too difficult to evaluate visually or had no bearing on the performance of the coverstone. Separate and reliable skid measurements were made on numerous sections of pavement surfaced with essentially the same materials. The results of these tests rated the surfaces as excellent and as a general statement this would raise the average rating of all sections evaluated by the South Dakota system. Cracking that may be in evidence on a road that has been sealed is very rarely if ever generated by the seal. This left retention, surface uniformity and bleeding to be evaluated. The results of the observation of these factors over a four-year period are listed in Table II. The 1964 ratings represent the combined judgement of three individuals whereas the subsequent data were obtained by two raters. Average ratings by different individuals vary but seldom exceed two units.

The reader will notice from this table that, as indicated in earlier reports (9, 10, 11), the performance of the lightweight synthetic aggregate (Type F) has been rated along with several sections of seal jobs utilizing precoated limestone (Type PB). The general conclusion to be drawn from the data presented is that the lightweight synthetic aggregate is performing very well.

Previous data presented (9, 10) did not involve this rating system, but the conclusions are practically identical. The major advantage to the South Dakota system is that it permits the use of raters who are relatively inexperienced in this type of work. However, it is advisable to have an experienced rater accompany a new rater on several jobs to assure a more consistent evaluation. Sections one half mile in length were used to arrive at a rating.

Figure 1 shows a general view of seal after three years of light traffic. Figure 2 is a close-up of this same surface. This road is identified in Table II as FM 85 and it is to be noted that it rates "Excellent." The edge raveling of this pavement was not considered a fault of the coverstone.

Field Observations

Figure 3 is a general view of the east bound lanes of US 80 at the west city limits of Abilene, Texas. This seal coat with lightweight synthetic aggregate coverstone was placed in 1962 and receives about 10,000 vpd (both directions). The performance of this surface would be rated excellent. Figure 4 is a close-up of this same surface. The photograph was taken in the outside lane and in the wheel path. Stone embedment is estimated at 80 percent in this area.

TABLE II

2051 SUMMARY TO 1967
SEAL COAT CONDITION SURVEY
DISTRICT 18

County	Highway	Aggregate Type Grade	Aggregate Rate Cu.yd/ sq.yd	Asphalt Rate, Gals/ sq.yd	Traffic ADT	Date Placed	Evaluation - Time 1-28-64	6-25-65	7-5-66	6-1-67	Effect Studied **
Collin	S-78	PB-4	1:124	0.230	790	7-23-63	18	17	17	17	R&U
							17	9	14	14	B
Collin	FM 546	PB-4	1:125	0.229	1230	7-24-63	18	18	15	-	R&U
							16	15	13	-	B
Collin	FM2478	PB-4	1:123	0.231	430	7-31-63	17	17	16	15	R&U
							18	17	16	15	B
Denton	FM 423	PB-4	1:124	0.24	690	Summer 1964		14	8	10	R&U
								18	16	13	B
Denton	FM1830	PB-4	1:122	0.232	850	8-2-63	18	17	17	14	R&U
							16	13	15	17	B
Denton	FM 407	PB-4	1:130	0.25	500	Summer 1965			7	7	R&U
										13	B
Denton	FM 407	PB-4	1:125	0.24	600	Summer 1964		17	17	17	R&U
								17	15	16	B
Denton	FM 156	PB-4	1:123	0.230	1210	8-12-73	19	18	18	17	R&U
							19	15	16	15	B
Ellis	FM 55	F-4	1:125	0.271	370	5-29-63	18	19	17	17	R&U
							19	15<	15	13<	B

** R - Retention
U - Uniformity
B - Bleeding

TABLE II (continued)

Ellis	FM 55	F-4	1:125	0.27	370	1966				19	R&U
(reseal)										20	B
Ellis	FM1182	F-4	1:125	0.275	190					10	R&U
										18	B
Ellis	FM1183	F-4	1:125	0.25	260	Summer		17	16	15	R&U
						1964		19	17	-	B
Navarro	FM1838	F-4	1:130	0.275	280	5-27-63	19	19	19	19	R&U
							19	17	17	17	B
Navarro	FM1603	F-4	1:125	0.276	310	5-29-63	19	16	17	17	R&U
							19	14	14	15	B
Navarro	FM1129	PB-4	1:130	0.25	250	6-16-65		20	16	18	R&U
								19	16	15	B
Navarro	FM 85	F-4	1:125	0.25	190	Summer		19	19	16	R&U
						1964		19	19	18	B
Kaufman	FM2451	F-4	1:125	0.25	180	Summer		19	17	19	R&U
						1964		19	20	-	B
Kaufman	FM1390	F-4	1:125	0.272	160	5-31-63	18	17	16	17	R&U
(single on new construction)							19	19	16	17	B
Kaufman	FM 987	F-4	1:125	0.271	870	6-3-63	19	17	15	16	R&U
							17	15	13	7	B
Kaufman	FM 148	PB-4	1:125	0.25	420	Summer		17	18	17	R&U
						1965		18	14	10	B
Dallas	SH 352	F-4	1:127	0.275	1390	6-4-65	20	18	17	17	R&U
							18	19	17	17	
Rockwall	FM 740	F-4	1:127	0.275	370	6-4-63	18	16	15	17	R&U
							14	10	7	9	B
Rockwall	FM 548	F-4	1:127	0.273	420	6-7-63	20	19	17	17	R&U
							20	19	16	17	B

*South Dakota Rating System. Rating scale - 20 = perfect, 10 is considered acceptable.

Figure 1. Expanded shale coverstone after three years of service.

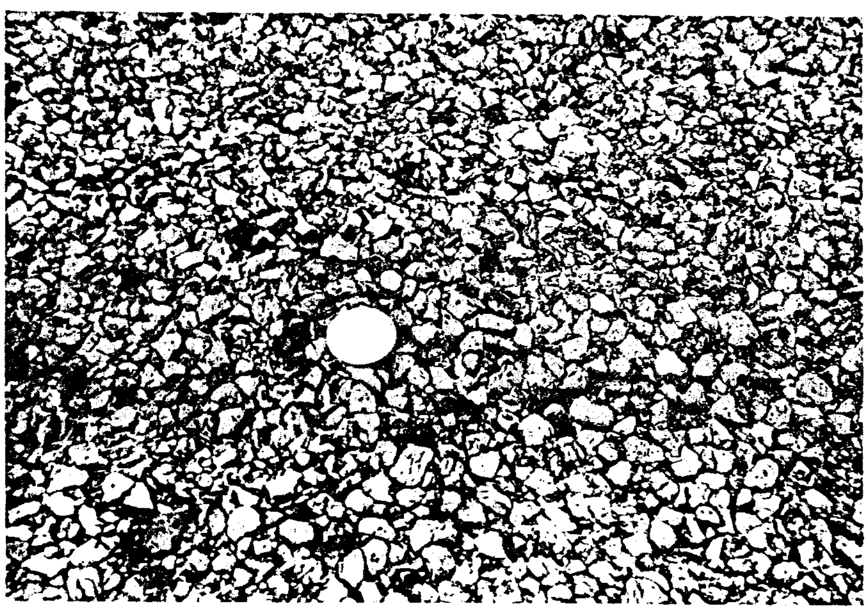

Figure 2. Close-up of surface shown in Figure 1.

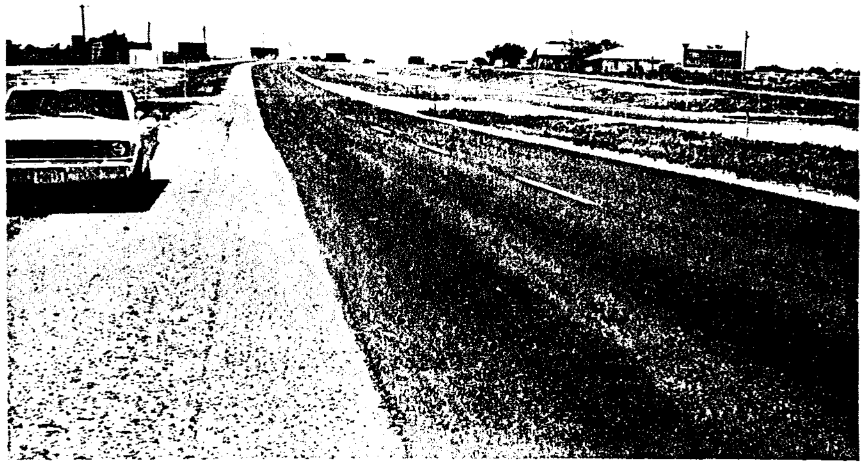

Figure 3. US 80 West of Abilene. Expanded shale coverstone after 5 years of service and 10,000 vpd (both directions).

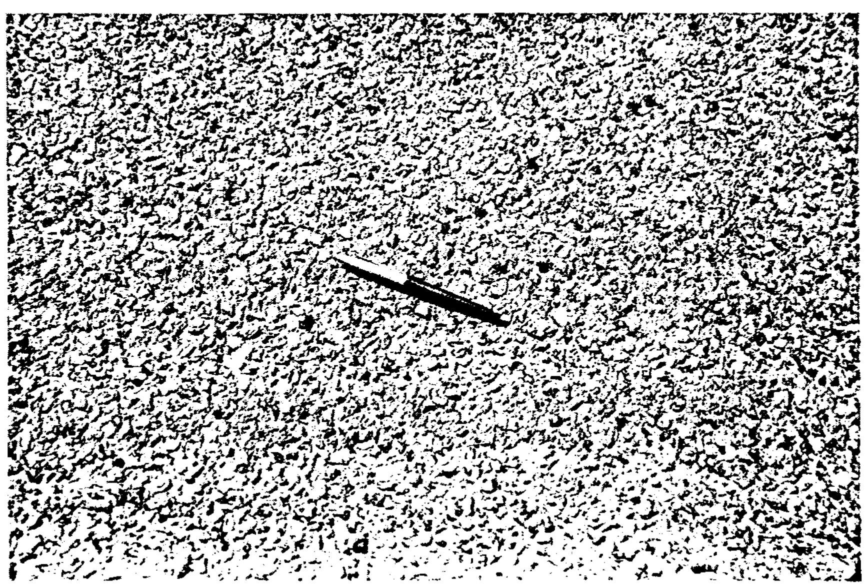

Figure 4. Close-up taken in the wheel path of pavement shown in Figure 3.

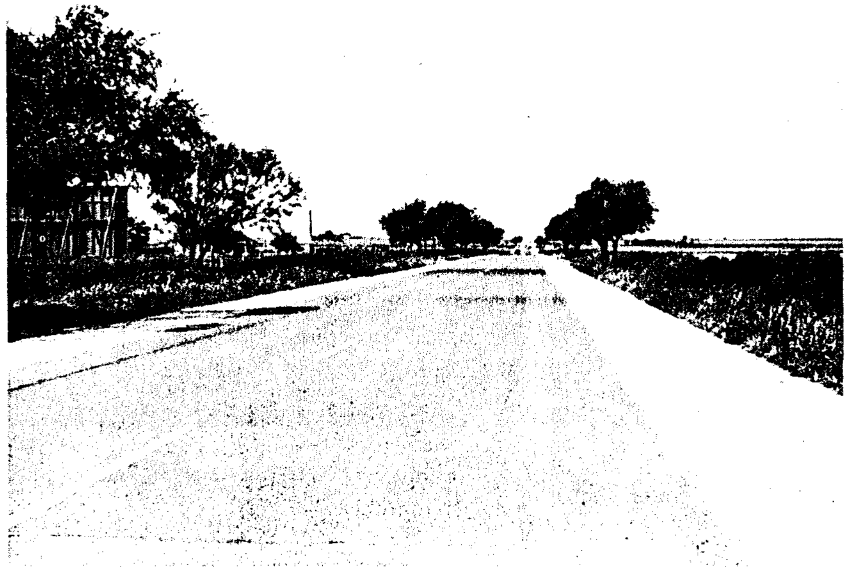

Figure 5. Expanded shale coverstone on traveled roadway. Crushed limestone on shoulder.

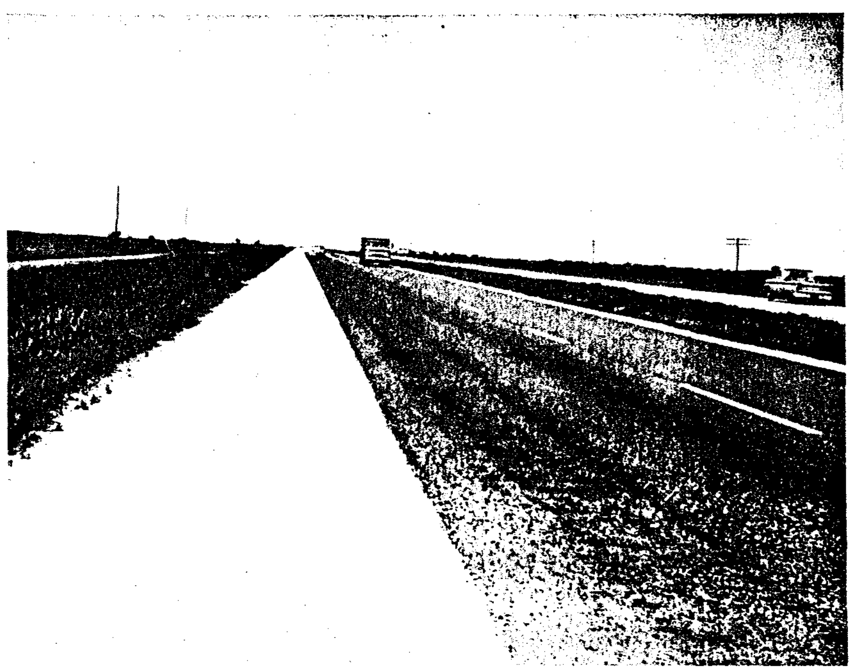

Figure 6. Color contrast of limestone shoulders and expanded shale on traveled roadway.

Skid measurements on this section of pavement revealed a current coefficient above 0.5 measured wet at 40 mph.

Figures 5 and 6 are general views of primary highways in West Texas that carry in excess of 3000 vpd. This is an expanded shale coverstone placed at the rate of 130 square yards per cubic yard. A 135 penetration asphalt cement was used at the rate of 0.28 gallons per square yard. The shoulders were also sealed using crushed limestone as cover material. The color contrast is excellent two years after construction. The permanence of this contrast is also evident in Figure 3, a pavement with five years of service.

Further evidence of the color contrast is shown in Figure 7. This is a close-up of the center stripe in Figure 6. As previously mentioned (10) all the different sources of lightweight aggregates now in service allow excellent bond of the center stripe paint. Based on reports from resident engineers, the average life of the center stripe placed on the particular lightweight aggregate under study is approximately 50 percent greater than that on rounded silicious gravel coverstone.

In the early stages of the introduction of lightweight aggregate some engineers were reluctant to place this material on primary highways subject to high volume heavy traffic and as a result of this many miles of secondary roads such as those shown in Figures 8 and 9 were covered with lightweight aggregate. Such Farm-to-Market roads as these that are not center striped usually carry less than 200 vpd. The pavement in Figure 9 was damaged by construction haul traffic. It is regrettable, from the aesthetics angle, that repairs were not made using cover material matched for color tone.

It is not likely that any study involving as many separate field jobs as this one did, would have only top quality results. The study was, indeed, no exception. An excess of coverstone was used on several jobs. The view in Figure 10 was taken near the shoulder of a pavement approximately one month after construction. Too much coverstone was used, wasted in fact. It is emphasized that any excess stone, be it lightweight or normal weight stone, is undesirable on seals and surface treatments. The loose stone acts as a grinding agent for one thing, creating fines that will infiltrate the binder and possibly cause bleeding. It will act as "roller bearings" to create a skid hazard. If it is "heavy" aggregate, it will be thrown by traffic and cause glass breakage and damage to vehicle finish.

Another fault in an occasional seal coat job is longitudinal striations such as those shown in Figure 11 and 12. The type shown in Figure 11 is often caused by blade application of a plant mixed cold lay material sometime before the seal is placed; whereas the striations in Figure 12 are caused during a sealing operation and could be caused by low temperature of the road and/or binder or possibly by low pressure from the spray bar. The striations in evidence in Figure 12 were not necessarily created when this road was last sealed. The fault could date back several years since it is extremely difficult, if not impossible, to cover such an error with another seal. It should be pointed out that this surface is entirely satisfactory for light traffic on secondary roads, but it will have a limited life, comparatively speaking.

Although somewhat premature with respect to the laboratory work on plant mixed paving materials made from lightweight aggregate, it was possible through the cooperative efforts of the Texas Highway Department, a contractor and an aggregate manufacturer to place a short section of hot-mix on a primary highway in the Dallas, Texas, area.

The experimental section consists of four subsections totaling about 1000 feet on the inside lane of a divided four-lane facility which carries about 24,000 vpd of mixed traffic. A general view of this overlay is shown in Figure 13. A close-up taken at the center line appears in Figure 14. The mix containing the lightweight aggregate occurs as the left lane in these photographs.

In all four subsections fifty percent by weight of the aggregate portion of the mixes was lightweight material falling in the size range of 1/2-inch to No. 10 and classed as Class I (20). One material fell in Group A and the other in Group C. In all cases seven percent by weight of 85-100 penetration asphalt cement was used. Design details of these mixes are given in the Appendix.

The experimental section forms a part of an overlay placed under regular contract on this primary highway.

The coefficient of friction, "f", on both the regular contract section and the experimental section was measured shortly after construction and at age six months. The experimental section had "f " values of 0.53 to 0.57 whereas the control or regularly used mix had "f" values in the range 0.33 to 0.41 for the wet condition at 40 mph.

The value of the coefficient of friction measured on the four subsections was essentially uniform over the six months period. This would appear to indicate that the 50 percent lightweight synthetic aggregate was the major factor which determined the coefficient. Data from seal coat jobs utilizing lightweight synthetic aggregate also show very little change in the skid properties with time (up to five years).

Figure 13. Section to experimental hot-mix utilizing lightweight aggregate for the inside lane. Viewed after 6 months of service. Traffic: 24,000 vpd (both directions).

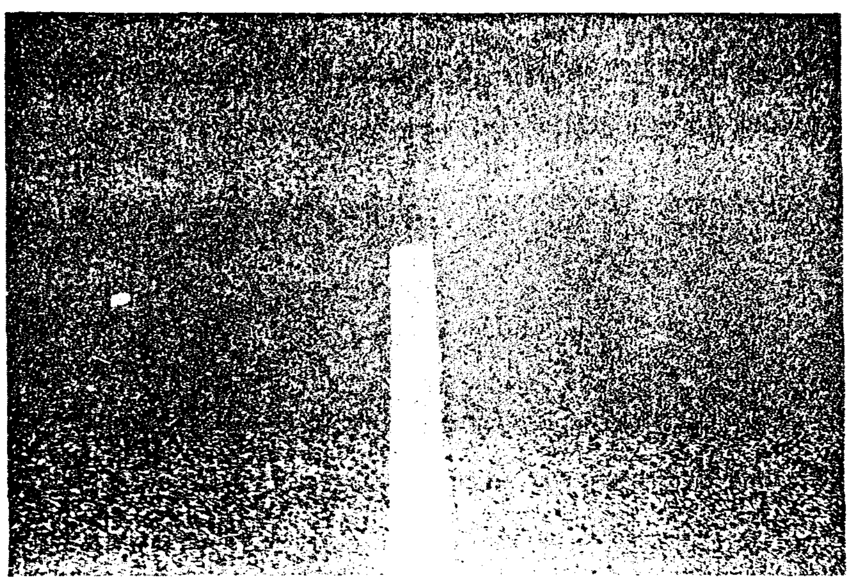

Figure 14. Close-up of pavement shown in Figure 13. Coefficient of friction 0.55 for the wet condition at 40 mph (left of center stripe).

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A P P E N D I X

SPECIAL SPECIFICATION

Item 1269

AGGREGATE FOR SURFACE TREATMENTS

(LIGHTWEIGHT)

1. Description. This item establishes the requirements for lightweight aggregates to be used in the construction of surface treatments.

2. Materials. Aggregates shall be composed predominantly of lightweight cellular and granular inorganic material prepared by expanding, calcining, or sintering products such as clay or shale.

The aggregate shall contain not more than 1 percent of organic matter, impurities or objectionable matter when tested in accordance with Test Method Tex-217-F.

The dry loose unit weight of coarse lightweight aggregates shall not be less than 40 and shall not exceed 60 pounds per cubic foot. If the unit weight of any shipment of lightweight aggregate differs by more than 6 percent from that of the sample submitted for acceptance test, the aggregates in the shipment may be rejected. Tests shall be in accordance with Test Method Tex-404-A, except that the aggregate shall be tested in an oven-dry condition. The percent of wear, as determined by Test Method Tex-410-A (Part II), shall not exceed 35 percent.

The aggregate, when tested in accordance with Test Method Tex-411-A, shall show a loss of not more than 12 percent after five cycles of the sodium sulfate soundness test or 18 percent after five cycles of the magnesium sulfate soundness test.

3. Grades. When tested by Test Method Tex-200-F, the gradation requirements for the several grades of aggregate shall be as follows:

		Percent by Weight
Grade 1:	Retained on 1" sieve	0
	Retained on 7/8" sieve	0-2
	Retained on 5/8" sieve	15-45
	Retained on 3/8" sieve	85-100
	Retained on No. 4 sieve	95-100
	Retained on No. 10 sieve	98-100

Grade 2:	Retained on 7/8" sieve	0
	Retained on 3/4" sieve	0-2
	Retained on 1/2" sieve	20-35
	Retained on No. 4 sieve	85-100
	Retained on No. 10 sieve	98-100
Grade 3:	Retained on 3/4" sieve	0
	Retained on 5/8" sieve	0-2
	Retained on 1/2" sieve	5-20
	Retained on No. 4 sieve	85-100
	Retained on No. 10 sieve	98-100
Grade 4:	Retained on 5/8" sieve	0
	Retained on 1/2" sieve	0-2
	Retained on 3/8" sieve	5-25
	Retained on No. 4 sieve	85-100
	Retained on No. 10 sieve	98-100
Grade 5:	Retained on 1/2" sieve	0
	Retained on 3/8" sieve	0-2
	Retained on No. 4 sieve	40-85
	Retained on No. 10 sieve	98-100
Grade 6:	Retained on 1/2" sieve	0
	Retained on 3/8" sieve	0-2
	Retained on No. 4 sieve	5-40
	Retained on No. 10 sieve	70-100
	Retained on No. 20 sieve	99-100
Grade 7:	Retained on 1/4" sieve	0
	Retained on No. 4 sieve	0-10
	Retained on No. 20 sieve	25-55
Grade 8:	Retained on No. 4 sieve	0
	Retained on No. 10 sieve	0-10
	Retained on No. 20 sieve	10-55

4. Measurement and Payment. Aggregates will be measured and paid for in accordance with the governing specifications for the items of construction in which these materials are used.

ABRASION OF CONVENTIONAL AND LIGHTWEIGHT COARSE AGGREGATE
BY THE USE OF THE LOS ANGELES MACHINE
(Test Method Tex-410-A Rev: November 1963)

Scope

The Test Method covers the procedure for testing conventional and lightweight coarse aggregate for resistance to abrasion in the Los Angeles testing machine with an abrasive charge. The apparatus and procedure used in this test are identical with ASTM Designation:

C 131 with the exceptions noted under Part II of this method.

Part I

ABRASION OF CONVENTIONAL COARSE AGGREGATE

Procedure

Use the apparatus specified to prepare and test the required gradings of aggregate in accordance with the procedure described in ASTM Designation: C 131.

Part II

ABRASION OF LIGHTWEIGHT COARSE AGGREGATE

Procedure

To avoid the excessive volume of materials in the testing machine which will occur when the lightweight aggregate sample is prepared according to ASTM Designation C 131, it is necessary to reduce the weight proportionately to obtain an equal volume of lightweight aggregate comparable to that normally obtained with a conventional aggregate sample.

The abrasive charge must also be reduced in a similar manner.

1. Determine the unit weight (^{U}L) of the lightweight aggregate by Test Method Tex-404-A.

2. Assume an average unit weight of conventional aggregate to be 97.0 lbs. per cu. ft.

3. Reduce the lightweight aggregate sample.

$$\frac{U_L}{97.0} = \frac{X}{C}$$

$$X = \frac{(C)\ (U_L)}{97.0}$$

Where:

U_L = Unit weight of lightweight aggregate sample (lbs. per cu. ft.)

C = Weight of conventional aggregate required for grading in ASTM 131

X = Reduced lightweight aggregate sample charge

4. Reduce the abrasive charge:

$$\frac{U_L}{97.0} = \frac{X_L}{C_L}$$

$$X_1 = \frac{(C)_L\ (U)_L}{97.0}$$

Where:

U_L = Unit weight of lightweight aggregate (lbs. per cu. ft.)

C_L = Weight of abrasive charge required for grading in ASTM 131

X_1 = Reduced abrasive charge for lightweight aggregate

5. Remainder of procedure as set forth in ASTM 131.

NOTE:

It is sometimes impossible to obtain the exact abrasive charge with the steel balls available. In this case, obtain the closest abrasive charge possible to the reduced value and then adjust the weight of the sample in proportion to the new abrasive charge.

Reporting Test Results

Report the test data and type grading and the wear to the nearest 0.1 percent on Form No. 272.

COMMENTS ON THE HANDLING, CONSTRUCTION AND SERVICE OF LIGHTWEIGHT AGGREGATE COMPARED TO PRECOAT

The following comments represent a cross section of those received in interviews with THD personnel and contractors who used these materials in Districts 2, 8, 18, 23 and 25.

I. State and District Personnel

A. Within its area of competitive haul, the Type F expanded shale aggregate is an important alternate to other materials because of reduction in windshield breakage alone. The material is dark in color which reduced glare and it appears to have a natural affinity for asphalt. The material is not degraded appreciably under normal surface rolling.

B. The hard freeze during the winter of 1963 did not damage the lightweight. It performs as well as precoat and has less flying particles immediately after construction. Lightweight dusts a little but the grading is good and it is a valuable material for seal coat and surface treatment work.

C. After two years of service we are still pleased with the performance of Type F aggregate. The color contrast produced by the lightweight is maintained throughout the life of the surface whereas precoat fades out in a few months.

D. Of all the stone available for seal coat and surface treatment I prefer the overall characteristics of precoated rock asphalt with lightweight running a close second. The contractor's men prefer the handling ease afforded by lightweight aggregate and it bonds well to the asphalt.

E. We had one job, a double surface treatment, (lightweight) that bled severely but this was in the early trial stages and was caused by a fault in design. We have had some trouble with variation in amount of oil used on our precoated material. However, both materials do a good job when properly designed and constructed.

F. High speed traffic on new surfaces of lightweight does not create flying stone hazard. Loose stone is thrown but is carried only a short way from the vehicle wheel. It is not necessary to sweep loose stone back on a new surface made with lightweight. Initial adhesion is good with both precoat and lightweight.

G. Where lightweight is used, the reduced gross loads of equipment during construction can minimize damage to shoulders on low-traffic roads.

H. Retention of lightweight aggregate is as good as that of precoated aggregate when placed under identical conditions. Lightweight aggregate is naturally dust free and has an inherent affinity for asphalt. This material has produced excellent results on high-traffic roads when placed under favorable weather conditions.

II. Resident Engineer and Contractor Personnel

A. Some dusting was experienced on one surface one to four days after construction. (This lightweight aggregate seal was rolled with steel and pneumatic rollers). At speeds up to 60 mph some stone was thrown by traffic. Stones were airborne for a distance of 20 to 40 feet. No windshield damage was observed or reported on this lightweight aggregate section.

B. Lightweight aggregate adheres well to the asphalt. The grading is uniform and the material is clean when delivered. Due to its lightweight and good bond, it can be broomed effectively with a blade broom.

C. In-place crushing (of lightweight) helps key in the coverstone. A nonglare surface is produced.

D. The material (lightweight) is easy to handle and easy on equipment. Job progress is more rapid and laborers handling the hand touch-up work find their job easier.

E. Without special modification of hauling equipment, overloading is eliminated and this extends equipment life.

Summarizing these observations on Type F and Type PB aggregate we find:

A. Retention is comparable for like designs and service conditions.

B. Bleeding, where observed, was about the same and could not, for either material, be definitely attributed to any characteristic of the materials involved.

C. Serious raveling was encountered on one precoat job and this was attributed to improper design. Minor raveling was observed on several other sections but there was no great difference in degree of raveling for the two materials. As a general rule where minor raveling occurred this took place between the wheel paths possibility indicating the need for a slight increase in asphalt application rate.

D. Degradation during construction rolling was comparable except where the Type F material was rolled excessively with steel flat wheel rollers.

E. General appearance of the two types of material is good. Type PB material used for contrast purposes often fades or loses color within a few months.

F. Contractors prefer the lightweight material due to ease of handling and increased production rate of finished road surface. Wear and tear on equipment is reduced materially.

G. No broken windshields attributable to either material were reported from any of the sections under observation.

H. Some Engineers and Maintenance Personnel indicated a preference for the Type F material. No one contacted objected to its use and all were satisfied with its performance.

Design Details of Hot-Mix Sections Containing Lightweight Synthetic Aggregate

The proportions of aggregate used in these designs are as follows:

Design No. 1

50 percent Lightweight "A"
30 percent Concrete Sand
20 percent Field Sand

Design No. 2

50 percent Lightweight "A"
50 percent Field Sand

Design No. 3

50 percent Lightweight "B"
30 percent Concrete Sand
20 percent Field Sand

Design No. 4

50 percent Lightweight "B"
50 percent Field Sand

The asphalt content was 7.0 percent (total mix basis) of 85-100 penetration asphalt cement. The Hveem stabilities of these mixes ranged in the mid forties and the cohesionmeter values were in the range 100 to 125. Voids in the laboratory compacted specimens were in the range of 4-6 percent. The unit weight of the finished mix in the field was such as to require about 70 pounds per square yard per inch of thickness.

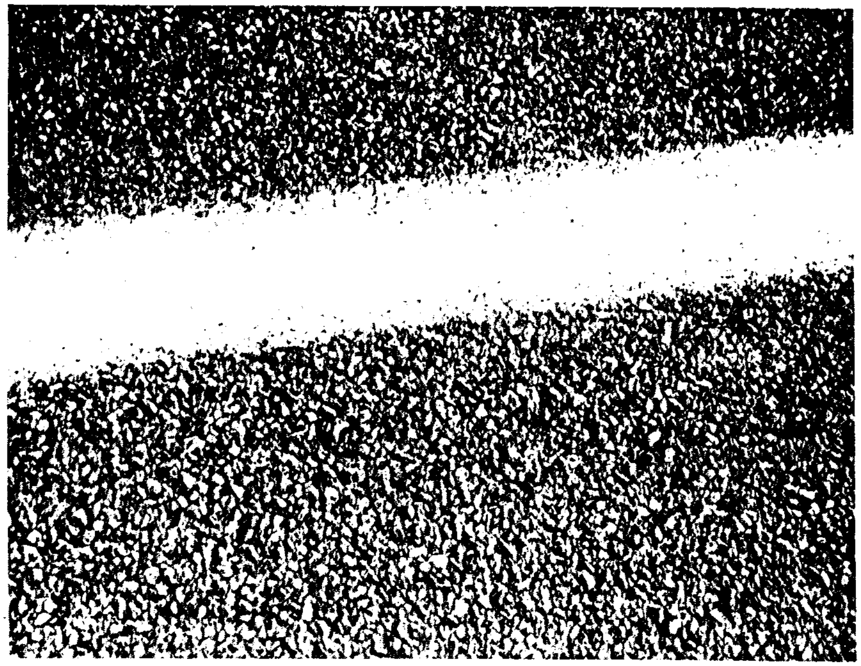

Figure 7. Note contrast of white center stripe and expanded shale lightweight synthetic aggregate.

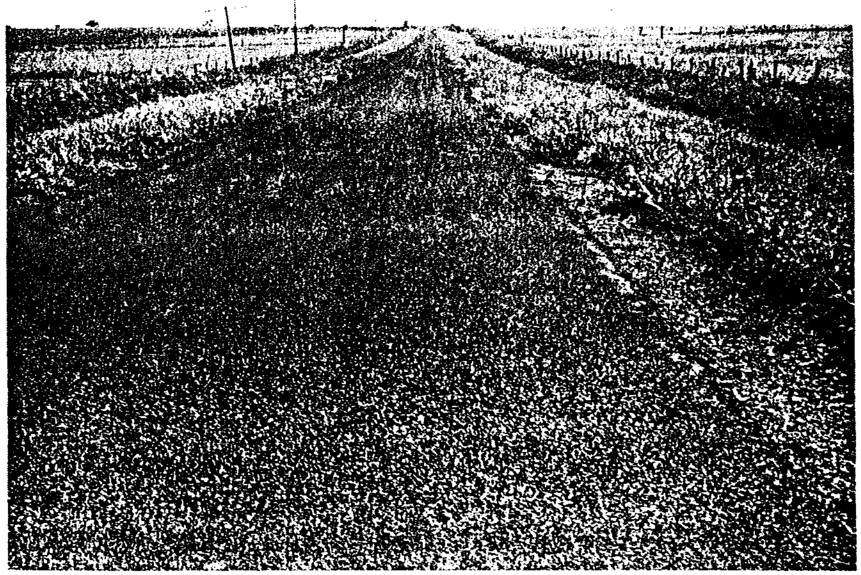

Figure 8. Low traffic volume facility utilizes lightweight synthetic aggregate as coverstone.

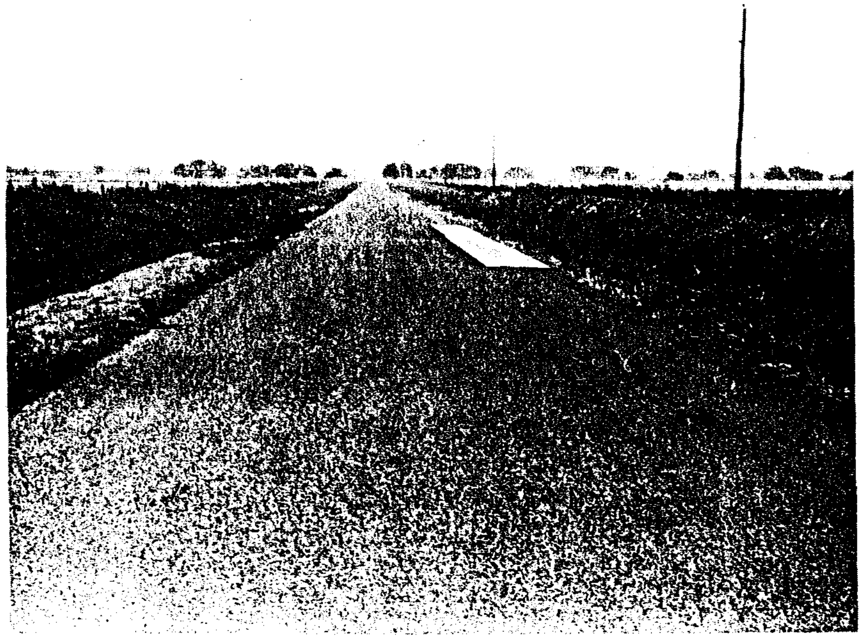

Figure 9. Skin patches made using aggregate of the same color and texture would improve the appearance of this road.

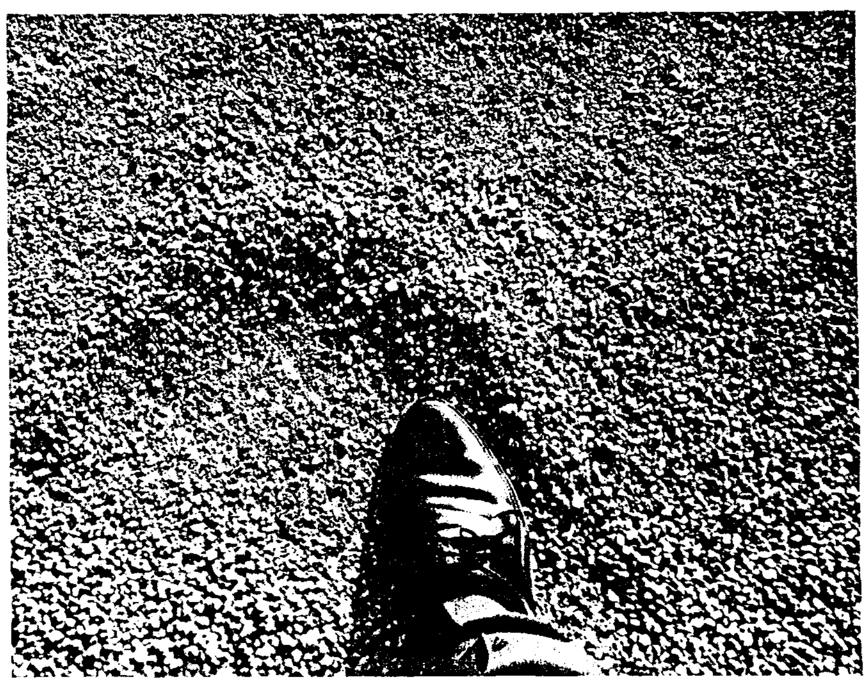

Figure 10. Excess coverstone should be avoided.

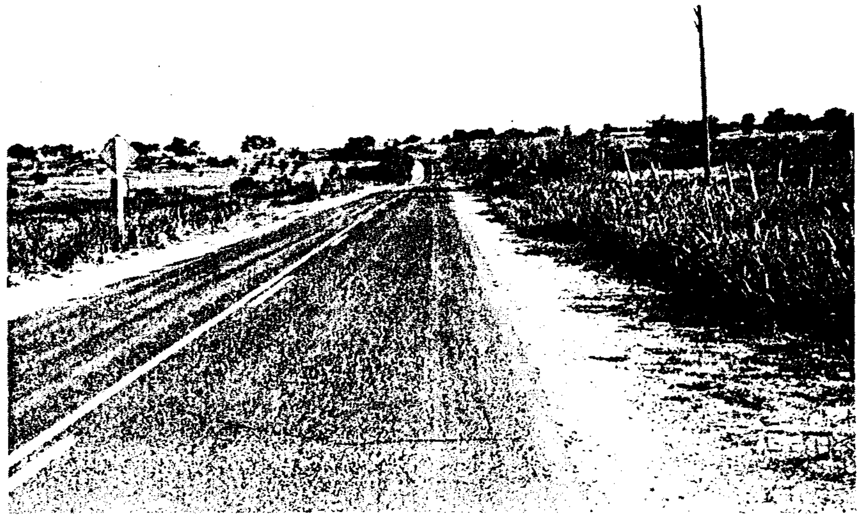

Figure 11. Previous construction operations may be cause of longitudinal striations.

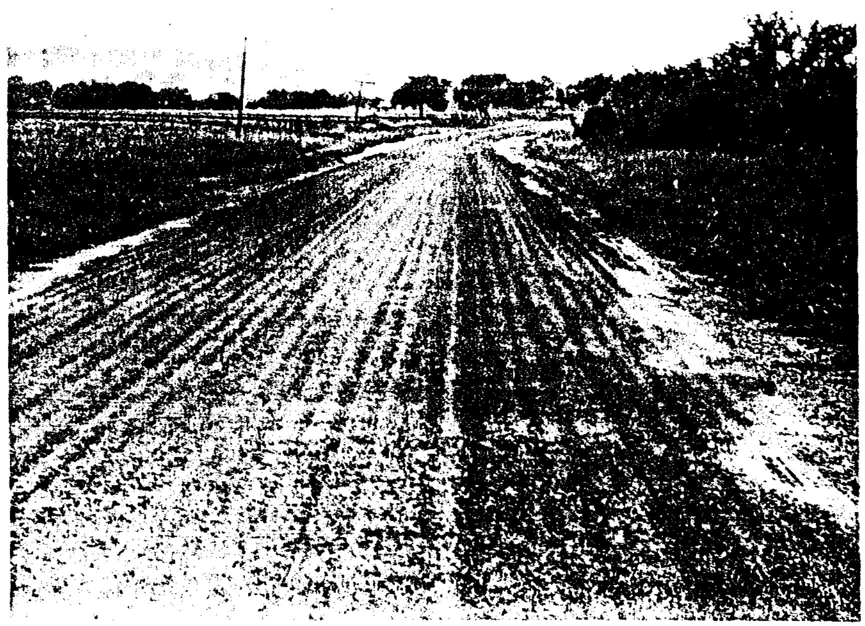

Figure 12. Striations possibly caused by poor performance of distribution and/or bad weather conditions.