TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
SYNTHETIC AGGREGATE SEAL COATS	May 1974
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Jon A. Epps, Bob M. Gallaway and Mark R. Brown	Research Report No. 83-2F
9. Performing Organization Name and Address	**10. Work Unit No.**
Texas Transportation Institute Texas A&M University College Station, Texas 77843	11. Contract or Grant No. Study 2-6-71-83
12. Sponsoring Agency Name and Address	**13. Type of Report and Period Covered**
Texas Highway Department 11th & Brazos Austin, Texas 78701	Final Report - Sept. 1970 May 1974
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with DOT, FHWA.
Research Study Title: "Synthetic Aggregates for Seal Coats."

16. Abstract

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17. Key Words	18. Distribution Statement
Seal Coat, Synthetic Aggregate, Construction Practices, Performance, Design	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	133	

Form DOT F 1700.7 (8-69)

SYNTHETIC AGGREGATE SEAL COATS

by

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Research Report 83-2F

Synthetic Aggregates for Seal Coats

Research Study No. 2-6-71-83

Sponsored by

The Texas Highway Department

In Cooperation with the

U. S. Department of Transportation

Federal Highway Administration

May 1974

TEXAS TRANSPORTATION INSTITUTE

Texas A&M University

College Station, Texas

PREFACE

This is the second report issued under Research Study 2-6-71-83, "Synthetic Aggregates for Seal Coats--An Exploratory Study." This report presents a review of current Texas Highway Department design and construction practices, a definition of the problems associated with the use of synthetic aggregate for seal coats, the results of field trial sections utilizing four synthetic aggregates and various aggregate and asphalt quantities, and a synthetic aggregate seal coat design method.

DISCLAIMER

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Texas Highway Department personnel in the district offices visited as well as representatives from the following divisions of D-6, D-8, D-9 and D-18 for their time and efforts expended on defining the current design and construction practices utilized in Texas, for their evaluation of certain problems associated with the use of synthetic aggregate as coverstone for seal coats and for their efforts during construction and evaluation of trial field sections.

ABSTRACT

Personal visits, questionnaires and a review of available literature were utilized to identify current synthetic aggregate seal coat design and construction practices used by the Texas Highway Department. Problems associated with the performance of seal coats involving synthetic aggregates for coverstone are defined. Trial field sections have been constructed. Aggregate gradation, aggregate moisture content, quantity of aggregate, quantity of asphalt, skid numbers, surface texture and environmental data were obtained. Based on a collection of the above information a synthetic aggregate seal coat design method has been suggested and construction guidelines developed.

KEY WORDS

SEAL COAT, SYNTHETIC AGGREGATE, CONSTRUCTION PRACTICES, PERFORMANCE, DESIGN

SUMMARY

Information collected from personal visits to Texas Highway Department district offices, field observations, detailed questionnaires and the construction of field trial sections indicate that many problems associated with poor performance of synthetic aggregate seal coats can be traced, in large measure, to moisture present in the aggregate, degradation of the aggregate during construction and in the first week of service and rainfall during or within a 24 hour period after construction.

Certain design and construction techniques can be utilized to reduce some of these problems and thus increase the probability of constructing a satisfactory surface. These items are summarized below:

1. Avoid construction if rainfall is likely during construction or within 24-hours thereafter.

2. Control traffic speed or preferably detour traffic around the freshly sealed surface if rainfall is likely and construction must proceed.

3. Limit lightweight aggregate usage to conditions such that a sufficient bond will be established between the aggregate and asphalt prior to allowing high speed traffic on the facility. Traffic control during and for a short period after construction should be practiced to allow development of adequate bond between the asphalt and stone.

4. The use of steel wheel rollers should be avoided.

5. Aggregate quantities utilized should be at a minimum. Excess aggregate on the roadway which is not removed by brooming will degrade under traffic and is a factor in dislodging loosely attached material.

6. The use of maximum asphalt quantities to provide deeper embedment together with the use of harder asphalts is advised.

7. The use of aggregate seal coats on high traffic volume roads and in certain urban areas where traffic turning movements are expected should be discouraged until sufficient information has been developed to insure the successful use of such material under these conditions.

8. For an aggregate of fixed quality, a reduction in the average particle size improves the resistance to degradation during construction and early service life. Dislodgement of the aggregate is also minimized.

9. A seal coat design method is presented to establish asphalt and aggregate quantities.

10. The freeze-thaw test requirement for synthetic aggregates utilized on seal coats should be re-evaluated, as the currently specified values appear too restrictive.

IMPLEMENTATION STATEMENT

Information summarized in this report indicates that alteration of certain construction techniques and design methods will offer a better opportunity for synthetic aggregate seal coats to be placed successfully. Many of the suggested construction practices are currently in use on a limited basis throughout the state. Increased awareness and conformity to these practices should increase the probability of success of the construction projects involving lightweight aggregates.

Information collected during the study affords the opportunity to more accurately define the limits under which these improved construction and design practices need to be implemented.

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INTRODUCTION

The highway engineer is providing a safer driving environment for the public by constructing skid resistant roadway surfaces. Often, seal coats utilizing synthetic aggregate as coverstone are used for such surfaces. However, difficulties associated with materials, design, and construction are being experienced. For example, the cover aggregate does not "stick" properly or the aggregate degrades during handling and on the job site and/or during construction operations. Compounding the problem, different sources of synthetic aggregates behave differently; thus, standard design and construction techniques in current practice may require certain adjustment to optimize the opportunity for success.

Recognizing this need and realizing that synthetic aggregate seal coats will become one of the more important construction and maintenance methods to provide skid resistant surfaces, the Texas Highway Department initiated a study at the Texas Transportation Institute. The objective of the study was to develop design and construction guidelines for synthetic aggregate seal coats to include material quality controls which will improve the performance of seal coats using synthetic aggregate. This exploratory study emphasized close cooperation between Texas Transportation Institute and Texas Highway Department personnel including the following Texas Highway Department Division contact representatives: Robert G. Keyser of the Construction Division, Irl E. Larrimore, Jr., of the Maintenance Operations Division, William E. Elmore of the Materials and Test Division, and T. R. Kennedy of the Highway Design Division.

Since field experience dates to 1961, an important element of the research effort involved information gathering from field personnel. This information was obtained by questionnaires as well as personal visits to those districts which have placed large mileages of synthetic aggregate seal coats. Districts visited included Districts 2 (Fort Worth), 3 (Wichita Falls), 5 (Lubbock), 7 (San Angelo), 8 (Abilene), 9 (Waco), 11 (Lufkin), 17 (Bryan), 18 (Dallas), 23 (Brownwood), and 25 (Childress). Results from these district visits, questionnaires submitted to selected districts, visits with Texas Highway Department Austin office personnel and the literature [1-8] resulted in Texas Transportation Institute Research Report 83-1, "Synthetic Aggregate Seal Coats - Current Texas Highway Department Practices" [9].

A summary of existing construction practices and a definition of the problems associated with placing synthetic aggregate seal coats led to the development of a research plan to place field trial sections containing the following variables:

1. Environment
2. Asphalt type and quantity
3. Aggregate type and quantity
4. Traffic volume
5. Aggregate moisture content

Periodic field evaluations have been made on these sections.

Results of the field trial sections and a review of pertinent information on state practices and construction difficulties is presented below together with a suggested seal coat design method.

TEXAS HIGHWAY DEPARTMENT EXPERIENCE

Synthetic aggregates have been used as coverstone in Texas since 1961 when a 9.8-mile double surface treatment section was placed in District 23 (Brownwood). In 1962 District 8 (Abilene) placed a seal coat section 1000 feet in length on Interstate 20 west of Abilene, while District 23 placed an additional 6.5 miles of double surface treatment. From 1962 to 1972 between 300 and 500 miles of synthetic seal coat were placed annually.

Thus approximately 4,000 miles of synthetic aggregate seal coats, or approximately 5 percent of the total state highway system, has been laid as of January 1973. It would not be unreasonable to estimate that 8 to 10 percent of pavements in Texas will be surfaces with mixtures containing synthetic aggregates by the end of 1975.

Twenty-one of the state's 25 districts have placed synthetic aggregate seal coats; Districts 5 (Lubbock), 8 (Abilene), 17 (Bryan), 18 (Dallas), 23 (Brownwood) and 25 (Childress) have placed over 200 miles of synthetic aggregate seal coats.

Synthetic aggregate producers in Texas are shown on Table 1. Seal coat aggregates from Ranger, Clodine, Dallas and Eastland are the most widely used sources and were utilized in the field trial sections that are reported in a later section of this report. It is anticipated that the new (1973) synthetic aggregate producer near Streetman, Texas, will become a major supplier of seal coat rock for East and North Central Texas.

TABLE 1

SYNTHETIC AGGREGATE PRODUCERS IN TEXAS

Producer	Location of Plant	Brand Name
Featherlite	Converse	Featherlite
Featherlite	Ranger	Featherlite
Texas Industries	Clodine	Haydite
Texas Industries	Dallas	Haydite
Texas Industries	Eastland	Haydite
Waco Aggregate Co.	Waco	Eaglelite
Bay Prairie Aggregate Corp.	Lane City	BPAC
Trotti and Thompson	Beaumont	
Superrock Corp.	Streetman	Superrock

Design Methods and Materials

Design - The most commonly used design method for seal coats in Texas is a modification of the Kearby Method [10, 11]. Experience together with field alterations of design quantities are the predominant methods of establishing asphalt and aggregate quantities. A proposed design method is included in this report in a later section.

Asphalts - Asphalt cements utilized include AC-5 and AC-10 as described by the Texas Highway Department specifications [12]. These asphalts typically have penetrations in the range 85 to 150. Emulsions of the high viscosity rapid setting type have been used in certain districts. Districts 9 (Waco) and 14 (Austin) have utilized emulsion on heavily traveled roads. Additives such as silicone and rubber have been used on a limited basis in both asphalt cements and emulsified asphalts. District 5 (Lubbock) has placed seal coats with "rubberized" asphalts since 1972.

The quantity of asphalt utilized for these seal coats varies from district to district, but an application rate of 0.30 gallons per square yard is a representative average value for Grade 4 aggregate [9, 13, 14]. Differences in condition of the pavement upon which the seal is to be placed, traffic volume, aggregate gradations, and asphalt characteristics are in part responsible for the variations in asphalt quantities utilized.

Aggregates - Gradation of aggregates utilized has varied. Texas Highway Department Grades 3, 4, and 5 have all been used; however, Grade 4 aggregate is now used almost exclusively. Modifications of certain grades have been used on a limited basis.

Aggregate application rates as reported by the various districts ranged from 90:1 to 140.1*. An average value of about 115:1** was indicated for a Grade 4 aggregate.

Construction Practices - Self-propelled, pressurized asphalt distribution equipment is utilized. Strapping of the asphalt distributor before and after each asphalt shot is the usual method of determining the quantity of asphalt.

Distribution of Rock and Asphalt - Distribution of aggregates is usually performed by self-propelled equipment. For some limited operations, tailgate and distribution boxes attached to dump trucks have been utilized. Aggregate quantities are usually controlled by staking rocklands and establishing a fixed setting on the spreader box for a certain speed while spreading a known amount of aggregate.

Rolling - A summary of district rolling operations can be found in reference 9. Pneumatic tired rollers with 30 to 45 psi tire pressures have been used extensively; however, a light steel wheel roller is utilized in one district to seat the aggregate. Crushing of the aggregate may result if heavy steel wheel rollers are utilized or multiple passes of light steel wheel rollers are utilized. Since pneumatic rollers are effective for seating the aggregate and cause minimal crushing, they are recommended. Therefore, steel rollers are not advised.

Removal of excess aggregate by brooming is practiced in some districts; however, about half of the districts visited did not practice this operation.

Traffic Control - Control of traffic speed for a prescribed period of time after construction is not the usual state practice; however, some districts

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*Ratio of the area the material will cover on the roadway surface measured in square yards per cubic yard of aggregate.

**Laboratory tests indicate an idealized value of about 140:1. Quantities greater than 130:1 are considered detrimental to good design and wasteful of material for the currently used Grade 4.

follow this policy. Traffic is kept off of the newly sealed surface until rolling is complete. Under certain conditions traffic has been kept off the seal for a number of hours to allow for proper asphalt-aggregate adhesion.

Problems Associated with Synthetic Aggregate Seal Coats. Each material utilized on highway construction has its own associated problems. Synthetic aggregates are not different is this respect. The introduction of a new material requires time. Synthetic aggregates have been used in seal coats on Texas highways for more than ten years and still all problems associated with design, construction, and the material have not been solved, primarily because inexperienced users continue to enter this field.

Questionnaires circulated to collect data regarding existing districts' practices were also used to identify problems associated with synthetic aggregate seal coats. Several districts were asked to select typical projects from each of the last four years of construction. Emphasis was given to selecting problem construction contracts. Results of these questionnaires together with information obtained on personal visits indicate that projects experiencing poor performance were often associated with one or more of the following: moisture, crushing during construction, or degradation under traffic. These results are discussed in detail below.

Moisture - Rainfall during and/or shortly after construction of seal coats has long been a problem with natural aggregates. Ample evidence exists which indicates that this problem may exist to an even greater extent with synthetic aggregates of the high absorption capacity type. Precautions are always taken to stop construction during rainfall; however, a small percent of seal coat construction may be subjected to the rainfall during construction. Subsequent loss of some coverstone usually results.

Rainfall after construction can be tolerated provided a strong bond has been established between the asphalt and the aggregate and between the old pavement surface and the applied asphalt before traffic is allowed on the surface; thus, the length of time between the end of construction and the beginning of rain is important. Rainfall within 48 hours after construction has been reported to be detrimental under certain conditions; whereas, under certain other conditions rainfall occurring within 2 hours has not been detrimental.

To establish the limit of time delay between construction and rainfall, the engineer must also consider the magnitude of bond tenacity necessary for the given traffic conditions. Certainly, increased traffic volumes will necessitate a greater bond tenacity to provide good performance. Traffic speed and tire pressure will also input to the time delay requirements.

Moisture present in the aggregate during construction is often detrimental as mentioned above. Synthetic aggregates with their relatively large capacity to absorb or store water, present an even more difficult problem than most natural aggregates. Rainfall on synthetic aggregate stockpiles prior to construction can be detrimental if construction is not performed on warm, low-humidity days. An example of the problems associated with the use of wet aggregate is illustrated by the following situation. On some projects raveling of aggregates placed during the early part of the construction day was traced in part to moist aggregates not establishing a sufficient bond with the asphalt in the time frame of the construction operation. As the temperature increased and humidity dropped during the day, the aggregates dried sufficiently to allow the establishment of the required bond to prevent aggregate loss. A construction time frame adjustment would appear in order to assist in rectifying the problem.

A comparison among physical properties of synthetic aggregates and a precoated aggregate is shown in Table 2. This comparison illustrates the relatively high absorption capacity of synthetic aggregates. Figures 1 and 2 illustrate the rate of absorption for various synthetic aggregates, thereby illustrating the field-observed problems of wet stockpiles of aggregate. As noted in these data, certain synthetic aggregates can be expected to absorb a larger quantity of water than others, and, furthermore, the rate of absorption is higher for some types of aggregates than for others. Field behavior under wet conditions is believed to be related in part to both the capacity of the aggregate to hold water as well as the rate at which the aggregate will take up water during periods of rainfall.

Degradation - Degradation or the manufacture of fines during transporting, handling, construction and in-service has been observed to be a problem under certain conditions. This degradation often leads to "dusting" and poor adhesion between asphalt and aggregate and consequently loss of stone, which loss may result in a flushed pavement.

Experience gained in several districts indicates that degradation may occur in transit from the aggregate manufacturing plant to the roadside stockpiles. The extent of this degradation is such that the fine side of the gradation specifications are sometimes not met; this occurrence in minimal.

General performance trends experienced by construction and maintenance personnel suggest that aggregates A and D experience only minimal degradation under construction and traffic, while aggregates B and H have, under certain conditions, experienced excessive degradation. On the other hand, aggregates A, B, D and H have all been placed successfully and have rendered good service.

TABLE 2

AGGREGATE PHYSICAL PROPERTIES*

Aggregate Identification*	Specific Gravity Bulk	Specific Gravity Absolute**	Unit Weight lbs/ft^3 (loose)	Absorption Capacity, Percent	Porosity	100-Minute Saturation Percent	14-day Absorption Percent	Los Angeles Abrasion***	Freeze Thaw Resistance***
A	1.57	2.21	52.4	12.8	28.9	14.0	9.20	27.6	2.3
B	1.23	2.04	37.7	28.1	39.6	60.4	24.88	26.3	37.7
D	1.49	2.09	48.1	15.6	26.7	14.2	9.61	27.0	2.6
H	1.81	2.30	43.4	13.8	21.3	24.6	9.04	33.2	30.0
M	2.43	2.62	84.0	1.9	7.3	—	2.85	—	—
Number of Tests	3	3	2	2	3	3	3	—	—

* Aggregates A, B, D, and H are lightweight aggregates. Aggregate M is a precoated aggregate.

** Values determined as described in Reference (24). Determined from pressure pycnometer.

*** Values obtained from previously published work at the Texas Transportation Institute (2, 7, 8, 25).
Loss Angeles Abrasion based on ASTM Grading BC.
Freeze-thaw based on 50 cycles Grade 4.

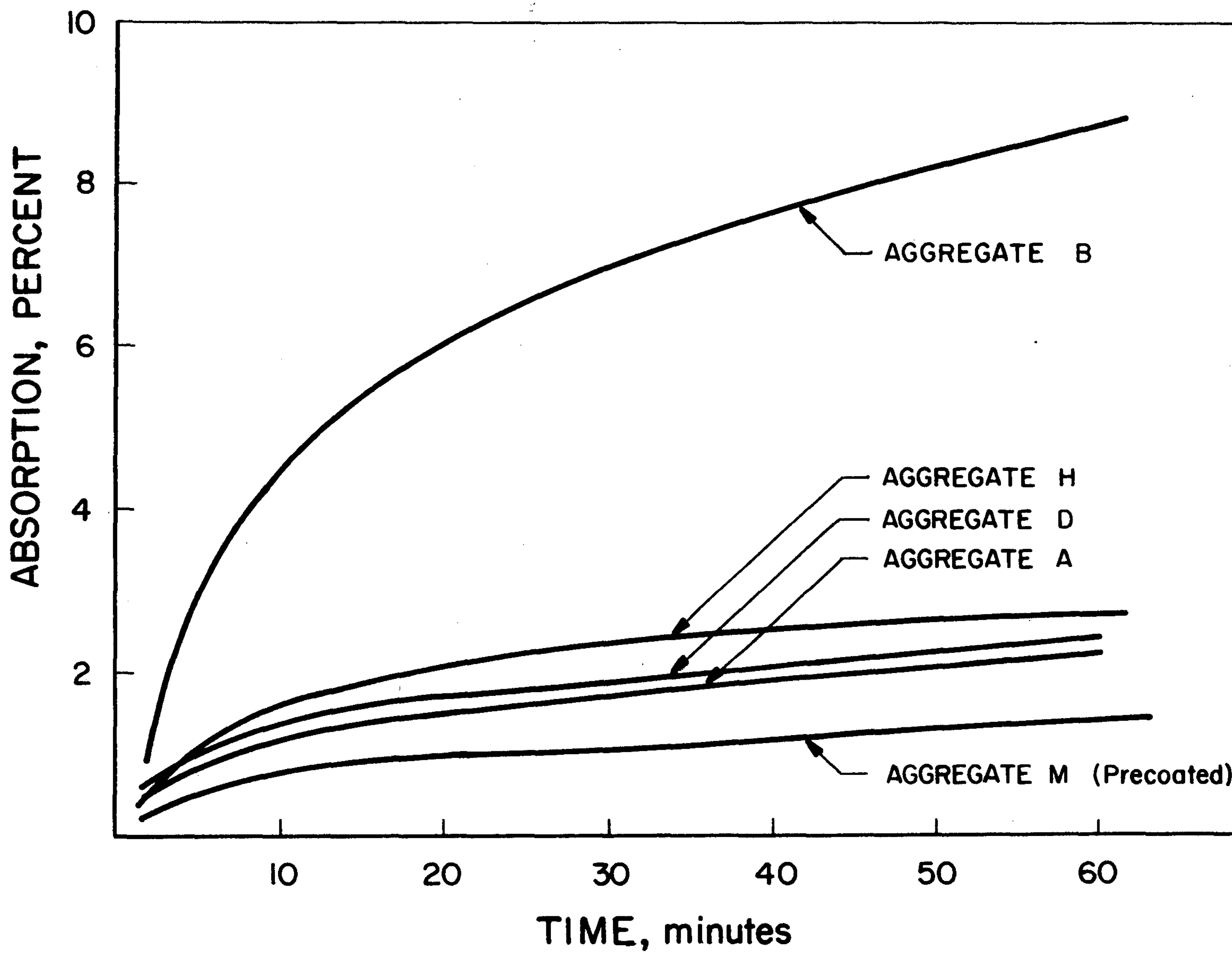

Figure 1. Typical absorption curves.

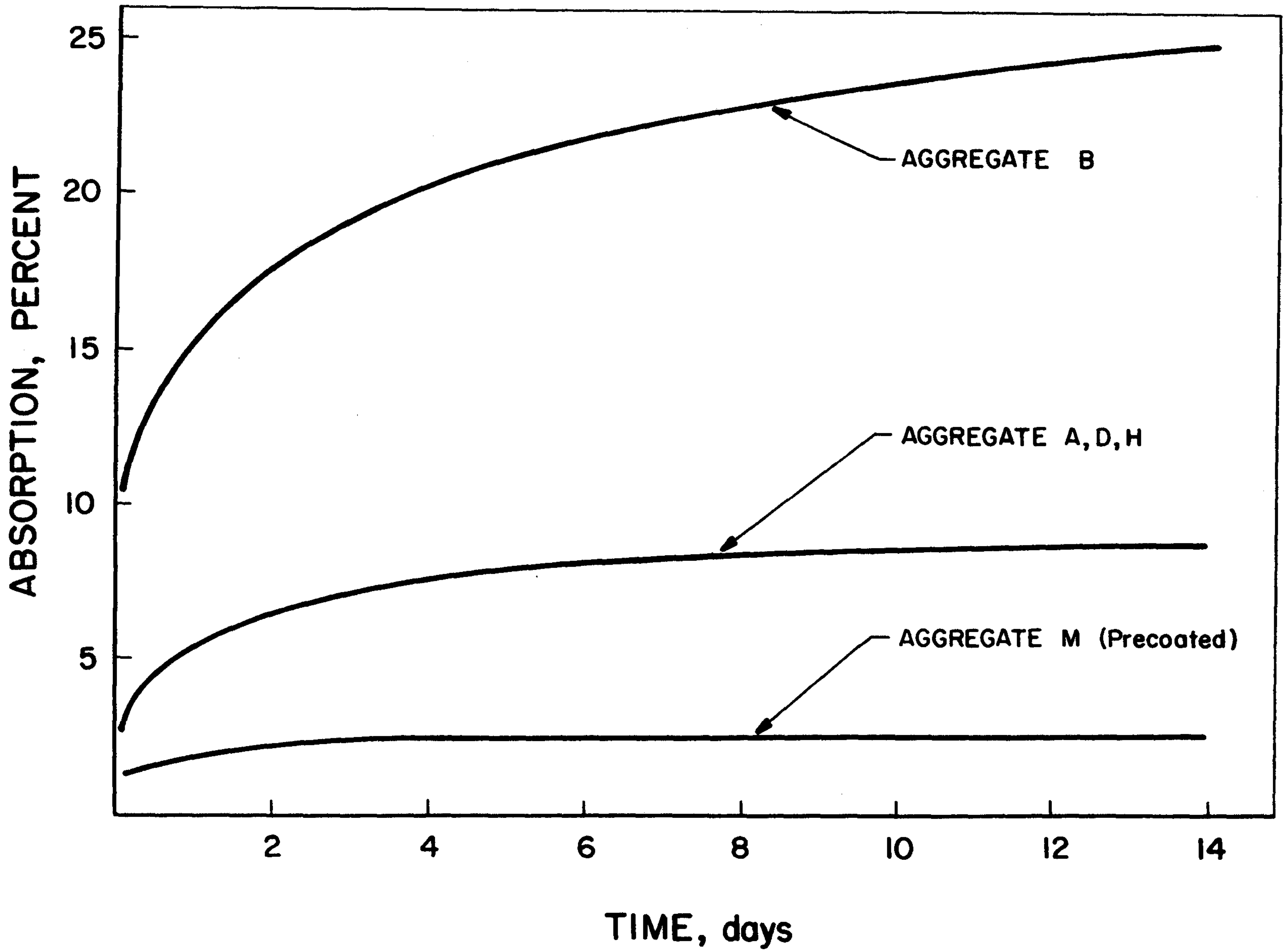

Figure 2. Typical absorption curves.

In service degradation of the cover aggregate is aggravated by stacking of the aggregate, (caused by exceeding 130:1 aggregate application rates for Grade 4 material) by excessive percentages of heavy trucks or high tire pressure vehicles, and by high traffic volumes. For general design considerations, it is probable that a general relationship between aggregate type and traffic volume can be established. An example of one type of development is illustrated in Figure 3. Hopefully these traffic volumes can be refined as additional field data become available and as definitive laboratory information is developed (15).

The number of projects experiencing substantial aggregate degradation has been reduced in the past two to three years. This observed behavior is in part related to the following items:

1. Manufacturing quality control of synthetic aggregates has improved.

2. The aggregate physical properties for seal coat aggregates have been more accurately defined through field experience. Manuafacturers have altered their processes somewhat to meet these needs.

3. Grade 4 gradations have been utilized predominantly during the past two to three years, whereas Grade 3 (a coarser gradation) has been utilized on a limited basis in prior years. Excessive degradation was experienced when grade 3 aggregates were utilized under certain conditions.

4. Construction techniques such as brooming of excess aggregate and utilizing only pneumatic wheel compaction equipment have reduced degradation.

5. Coverstone application rates have been reduced in some districts. Minimal cover rates are most important.

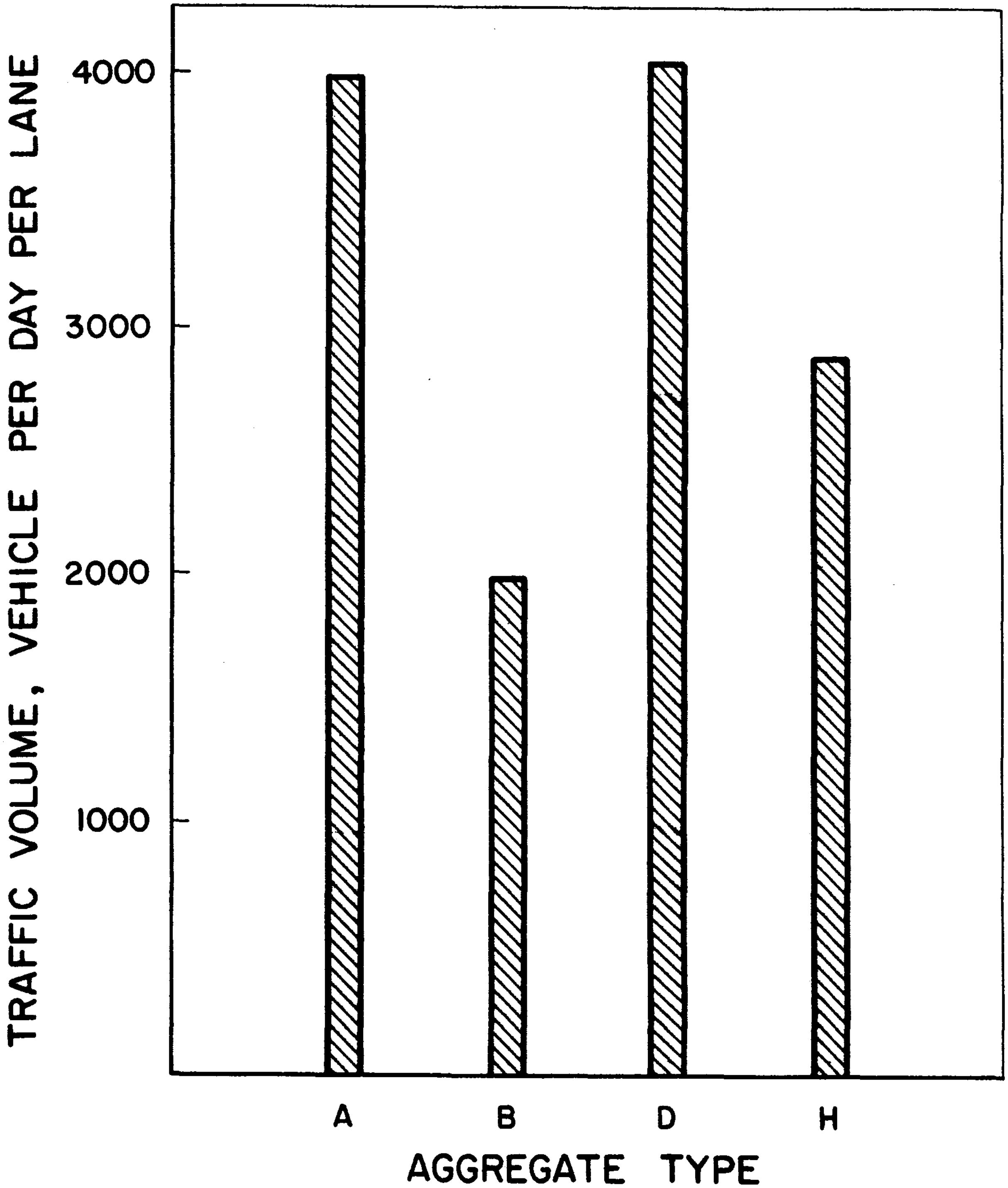

Figure 3. Suggested traffic volumes at which synthetic aggregate should be utilized to provide a reasonable degree of success.

Other Factors - Factors in addition to moisture and degradation have been suggested as possible causes of poor performance of synthetic aggregate seal coats. For example, asphalts with undesirable properties, contamination of aggregates during shipment, and failure to meet designated aggregate grading specifications. These problems appear to be minor relative to those caused by moisture and degradation.

Benefits of Synthetic Aggregate Seal Coats - Increased use of synthetic aggregates for coverstone in seal coat operations in Texas is predicated by field acceptance which is based on field performance. Not only do seal coats perform the normally expected functions of seal coats such as sealing the bituminous mat against the entrance of air and water and reducing the brittleness of the underlying layer of bituminous material; but, when lightweight aggregates are used they provide a very skid-resistant surface, provide good color contrast which improves visibility in daylight and at night, provide a surface on which paint striping maintenance is reduced, and practically eliminate glass damage caused by "flying" stones.

Skid Resistance - High initial skid resistance and prolonged skid resistance can be obtained with synthetic aggregate seal coats under moderate traffic. Typical skid numbers (SN_{40}) for synthetic aggregate pavements are shown in Table 3. Figure 4 illustrates the measured skid number as a function of traffic and age under high traffic. In general, the skid numbers as measured by the Texas Highway Department skid trailer are above 50 (measured at 40 mph) for almost all synthetic aggregate seal coats. However, under heavy traffic a decrease in skid number may be expected due to excessive abrasion, loss of coverstone or bleeding.

Delineation - Delineation of travel lane is important for night driving, especially during periods of limited visibility. Synthetic aggregate seal

TABLE 3

COEFFICIENT OF FRICTION FOR SYNTHETIC AGGREGATE SURFACES

State	Type of Facility	Age After Construction	Average Daily Traffic	Skid Number (SN_{40})	Measuring Device	Reference
Alabama	Surface Treatment	0	---	65		
		4 mo.	---	65	Decelerometer Method	Eiland (3)
Louisiana	Hot-Mix Overlay	0	---	40-55*	Two Locked-Wheel Skid Trailer (ASTM E-274-69)	Arena (4)
		4 mo.	---	44-58*		
		8 mo.	---	45-63*		
		12 mo.	---	50-64*		
Virginia	Hot-Mix Overlay	2 years	---	45-54**	Stopping Distance Vehicle	Dillard(5)
Wyoming	Seal Coat	4 years	965	63***	Bureau of Public Roads Skid Trailer (ASTM E-274-69)	Mills (6)
Texas	Seal Coat FM 416	5 years	100	63	Locked Wheel Texas Skid Trailer (ASTM E-274-69)	
Texas	Seal Coat FM 2452	5 years	300	65	Texas Skid Trailer (ASTM E-274-69)	
Texas	Seal Coat	1 year	18,200	52	Texas Skid Trailer (ASTM E-274-69)	
Texas	Hot-Mix Overlay Open-graded	1 year	700	55	Texas Skid Trailer (ASTM E-274-69)	
Texas	Hot-Mix Overlay Open-graded	1 year	700	58	Texas Skid Trailer (ASTM E-274-69)	

*Range of eight test sections.
** Range of three test sections.
*** Scoria - a natural lightweight material although described as burned shale by the author.

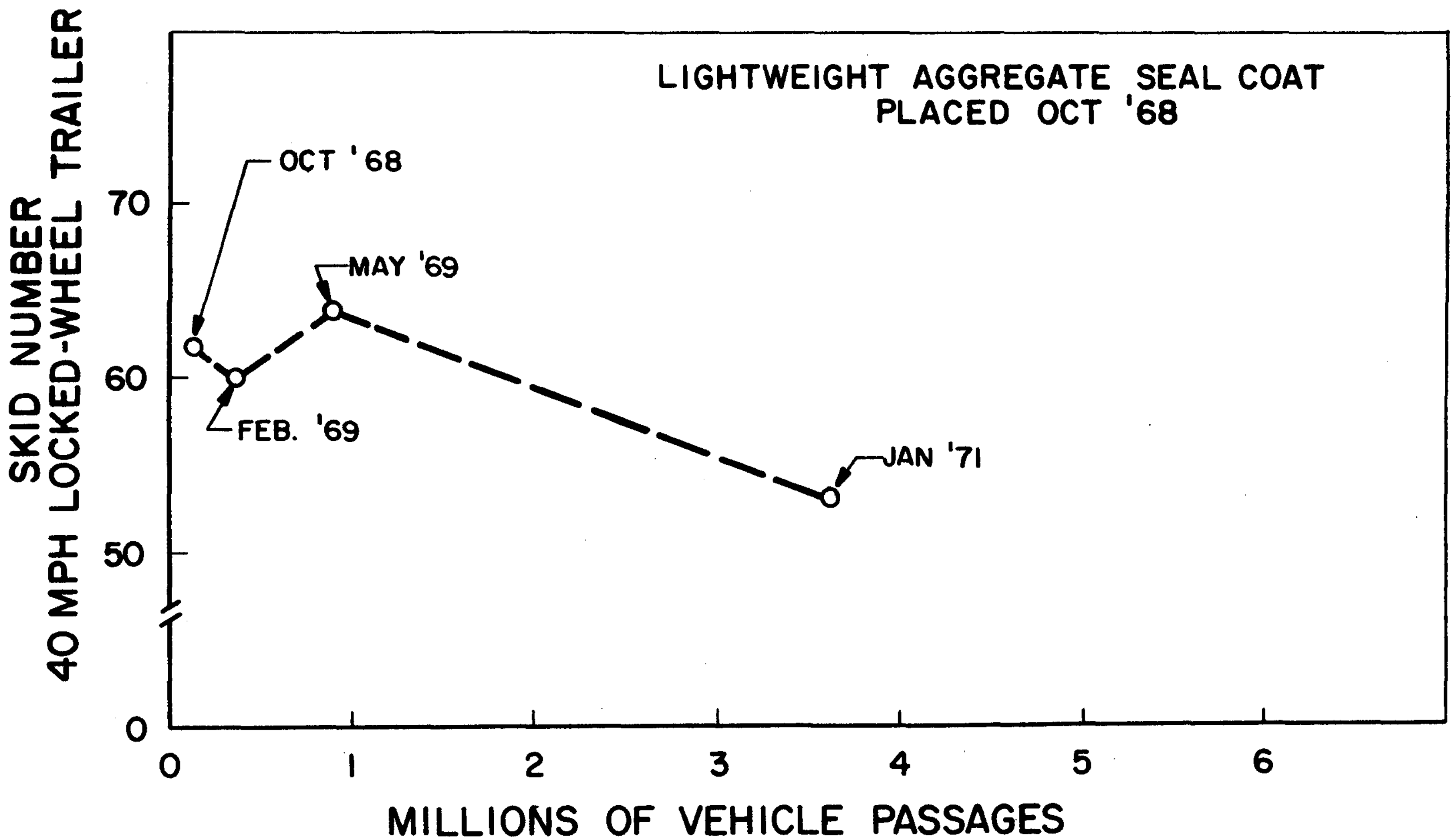

Figure 4. Lightweight aggregate seal coat
(IH-35, Waco, Texas).

coats and especially those constructed with aggregates from sources A or D produce an initial and long lasting dark color which contrasts with lighter colored shoulders. Other types of seal coat aggregates provide initial color contrast of limited duration. Contrast between the white or yellow painted traffic marking and the darker surfaces with synthetic aggregate seal coats is also of benefit to the driver.

Evidence exists which indicates that traffic paint adheres to and provides a longer lasting traffic stripe on synthetic aggregate seal coats as opposed to natural aggregate seal coats.

Flying Stone Damage - Glass and paint damage due to flying stones is a problem which exists on the highway under certain conditions (2, 7, 8). Definitive evidence exists which proves that windshield damage and paint damage is significantly reduced or eliminated by the use of synthetic aggregates.

The advantages of utilizing synthetic aggregates has led to its acceptance in many districts. Reduction of windshield damage and the high friction obtained are recognized as the primary advantages resulting from the use of synthetic aggregates.

TRIAL FIELD SECTIONS

Based upon the experience gained from field visits, questionnaires and a review of the literature (references 1 to 23), field trial sections were designed to contain the following variables:

1. Environment (4 locations).
2. Traffic (6 levels).
3. Asphalt Type (3 types).
4. Asphalt quantity (3 levels).

5. Aggregate type (aggregates A, B, D, and H).

6. Aggregate quantity (3 levels).

7. Aggregate moisture content (3 levels).

8. Simulated rainfall (3 levels).

These variables, together with traffic control, compaction technique and removal of excess aggregate, control to a large degree the performance of synthetic aggregate seal coats.

Environment - Six sites (two sites in each of two locations and one each in the remaining two) information on the effect of environment on performance of synthetic aggregate seal coats. More definitive information on the location of the six sites is given on Table 4.

The test site located on State Highway 6 (SH6) near Dublin was constructed by District 2 (Fort Worth) personnel and was selected to represent a relatively cool, moist climate typical of the rolling plains of Texas. This test site will be subjected to approximately 55 "freeze-thaw" cycles annually as determined by air temperature (24). Such "freeze-thaw" cycles should not be confused with true freeze-thaw cycles as per Test Method Tex-432-A. The test site contains the code 2-SH6 for District 2 State Highway 6 in this report.

The test sites placed on United States Highway 62 (US62) and Farm-to-Market Road 1730 (FM1730) near Lubbock were constructed by District 5 (Lubbock) personnel and were selected to represent a relatively cold, dry climate typical of the high plains area of Texas. These test sites will be subjected to approximately 85 "freeze-thaw" cycles annually and will be referred to as test sites 5-US62 and 5-FM1730.

The test sites located on US59 and SH103 near Lufkin were constructed by District 11 (Lufkin) personnel and were selected to represent a relatively

TABLE 4

LOCATION OF FIELD TRIAL SECTION

TRIAL SECTION DESIGNATION	DISTRICT	COUNTY	HIGHWAY	CONTROL AND SECTION NO.	NUMBER OF LANE AND WIDTH	GENERAL LOCATIONS
2-SH6	2(Ft. Worth)	ERATH	SH6	257-6	2-11 ft. lanes	Dublin city limit to 4 miles west of Dublin
5-US62	5(Lubbock)	LUBBOCK	US62	380-1	2-12 ft. south bound lanes of 2 lane divided highway	Lubbock city limit to 3 miles south west of Lubbock
5-FM1730	5(Lubbock)	LUBBOCK	FM1730	1344-2	2-10 ft. lanes	Loop 289 south to FM1585
11-US59	11(Lufkin)	ANGELINA	US59	176-3	2-12 ft. south bound lanes of 4 lane divided high-way	Diboll south to Neches River
11-SH103	11(Lufkin)	ANGELINA	SH103	336-5	2-13 ft. lanes	FM 1475 east to Angelina River
14-SH95	14(Austin)	BASTROP	SH95	322-1	2-12 ft. lanes	Elgin city limit to 4 miles south of Elgin

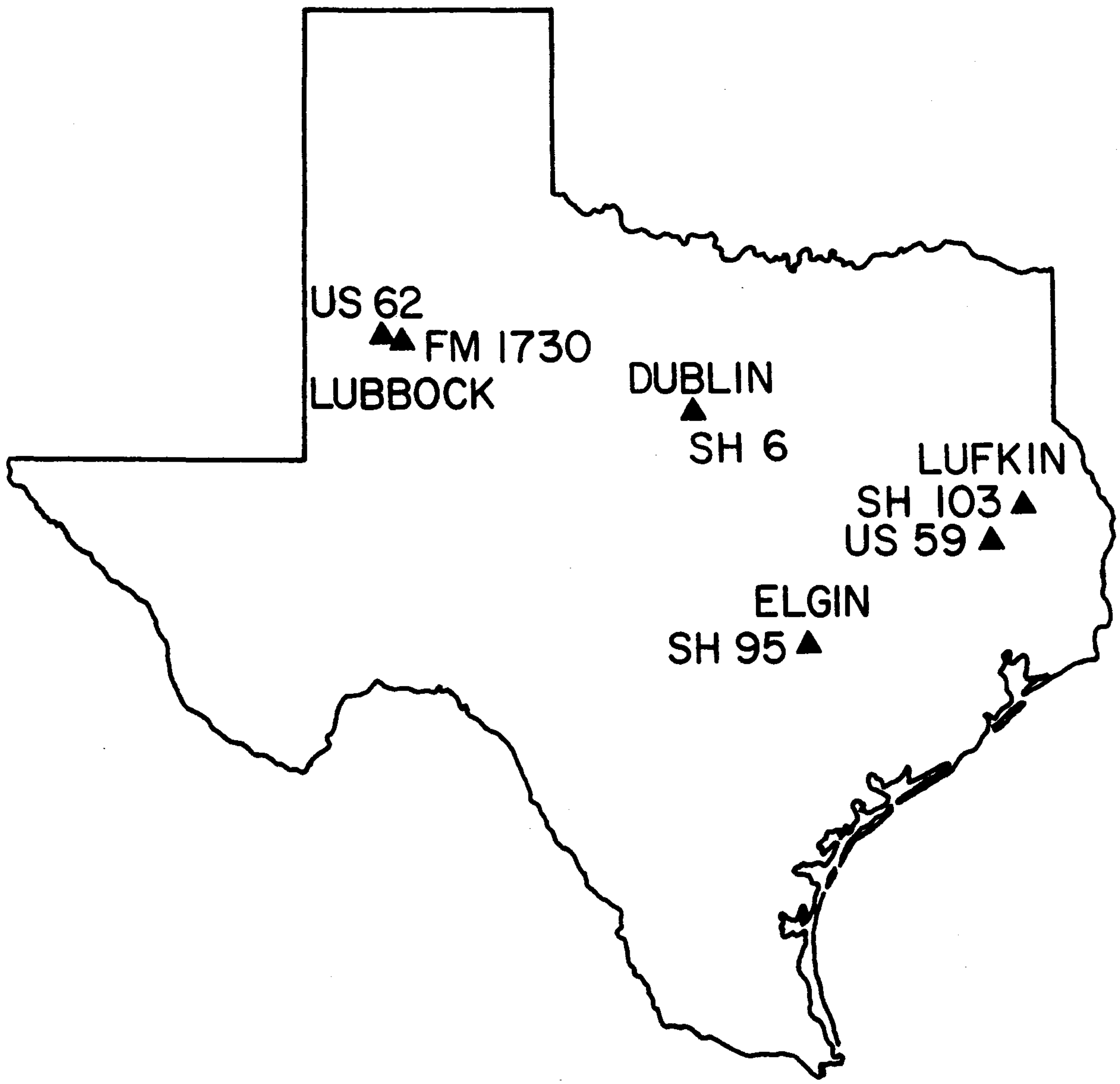

FIG. 5. LOCATION OF TRIAL FIELD SECTIONS

mild, wet climate typical of east Texas. These test sites will be subjected to approximately 20 "freeze-thaw" cycles annually and will be referred to as test sites 11-US59 and 11-SH103.

The test site placed on SH95 near Elgin and constructed by District 14 (Austin) personnel was selected to represent a relatively mild, moist climate typical of the upper coastal plain of Texas. This test site will be subjected to approximately 25 "freeze-thaw" cycles annually and will be referred to as test site 14-SH95.

Values representing mean annual precipitation, mean annual temperature, mean length of warm season and physiographic province of the United States for each of these test sites are given in Table 5 (25). In addition to the data given on Table 5, it should be realized that the sites near Lubbock (5-US62 and 5-FM1730) and Dublin (2-SH6) are subjected to lower temperatures and to more rapid rates of temperature drops. Definitive data are not available to illustrate the number of days that ice could be expected to form in the seal coat aggregate, hence the term "freeze-thaw".

Traffic

Traffic volumes as determined by the Texas Highway Department for each test site are given on Table 6. These volumes are two directional counts and range from 1400 to 8,500 vehicles per day. Sites 5-US62 and 11-US59 are four-lane divided facilities. Estimated traffic volumes in terms of vehicles per day per lane are as follows:

Test Site Number	Vehicles per Day per Lane
2-SH6	775
5-US62	1,750
5-FM1730	750
11-US59	2,275
11-SH103	925
14-SH95	700

TABLE 5

GENERAL ENVIRONMENTAL CONDITION AT TEST SITES

TEST SITE LOCATION	MEAN ANNUAL TOTAL PRECIPITATION, INCHES	MEAN ANNUAL TEMPERATURE, °F	MEAN LENGTH OF WARM SEASON, * DAYS	MEAN AVERAGE AIR FREEZE-THAW CYCLES	PHYSIOGRAPHIC PROVICES OF THE UNITED STATES
2-SH6 (Dublin)	31.7	63.7	230	55	Central Lowlands
5-US62 5-FM1730 (Lubbock)	18.1	59.7	210	85	Great Plains
11-US59 11-SH103 (Lufkin)	48.1	67.1	245	20	Coastal Plains
14-SH95 (Elgin)	32.6	68.3	275	25	Coastal Plains

after references (24, 25)

*Number of days between the mean dates of last 32°F freezing in spring and first 32°F freeze in Fall.

TABLE 6: TRAFFIC VOLUME AND PAVEMENT CONDITION PRIOR TO SYNTHETIC AGGREGATE SEAL COAT

TRIAL SECTION DESIGNATION	TRAFFIC VOLUME, Upd	SKID NUMBER SN_{40}	SURFACE TEXTURE, INCHES (1)	WASHINGTON PAVEMENT EVALUATION SCORE, G_D (2)	SERVICEABLITY INDEX (3)	GENERAL CONDITION OF PAVEMENT
2-SH6	1,525	31	0.0522	86	3.3	Localized cracking, slight rutting in localized areas, no transverse or longitudinal cracks of significance
5-US62	5,000	36 (TL) 44 (PL)	0.035 (TL) 0.073 (PL)	78 (TL)	4.0 (TL)	Extensive alligator cracking in localized areas where pack roadside drainage exists, moderate rutting in localized areas, raveling in wheel path at few locations
5-FM1730	1,500	30	0.019	66	3.2	Narrow pavement with localized rutting in outside wheel path, some alligator cracking in north end of project, transverse cracking with some longitudinal cracking present in certain area
11-US59	8,500	29	.037 (TL) .040 (PL)	81	—	Longitudinal and transverse reflection cracking from overlaid portland cement concrete pavement, some cracks spalled
11-SH103	1,850	36	.037	95	—	Some localized rutting with alligator cracking, surfaced shoulder distressed in some areas
14-SH95	1,400	0.33	0.048	88	3.2	Minor amounts of cracking, flushing evident in where paths in many areas, strip seal patches utilized over entire length of job

(1) Measured by putty impression test in inner and outer wheel paths.
(2) Rating system developed by Washington State Highway Department (33).
(3) Measured with Mays Ride Meter at 50 m.p.h.

TL - Travel Lane
PL - Passing Lane

Asphalt

Asphalt Type - Asphalt cements and emulsified asphalts were utilized on these projects. Properties of these materials as determined by the Texas Highway Department are shown in Table 7 and 8 for asphalt cement and emulsified asphalts, respectively. No attempt was made in this project to use a single asphalt cement or emulsion for all projects but rather the type of asphalt was selected by the District performing the construction.

Emulsified asphalts were utilized in Districts 2, 11 and 14. District 14 utilized both cationic and anionic emulsions.

Asphalt Quantity - The amount of asphalt utilized on the trial sections was determined by the District responsible for construction. These quantities were established by experience or by a modified Kearby Method. The design quantity was then altered plus or minus 15 percent on those sections which were placed to study the effect of asphalt quantity on performance. Design asphalt quantities are shown on Table 9 for those sections constructed in District 2, Table 10 for District 5, Tables 11 and 12 for District 11 and Table 13 for District 14.

The difference in asphalt quantity between test sites is due in part to the gradation of the aggregate and the asphalt surface demand of the roadway upon which the seal coat was placed. Test sites 5-US62, 11-US59, 11-SH103 were designed specifically to study the effect of asphalt quantity on field performance.

Aggregate

Aggregate Type - Synthetic aggregates A, B, D and H were utilized in this study at all six test sites. The physical properties typical of these aggregates are shown in Table 2. Detailed test results on those aggregates utilized in the trial field section and determined by the Texas Highway Department

TABLE 7: ASPHALT CEMENT PROPERTIES

PROPERTY	TEST SITE			
	2-SH6	5-US62 5-FM1730	11-US59 11-SH103	14-SH95
ASPHALT TYPE	AC-10	AC-5	AC-10	AC-5
ASPHALT REFINERY CODE	9	1	6	6
Viscosity, 140°F, Stokes	937	476	999	498
Viscosity, 275°F, Stokes	3.3	1.8	2.5	1.8
Penetration, 77°F, 100g, 5 sec.	118	135	94	181
Flash Point C.O.C., °F	600+	540	600+	600+
Solubility, percent	99.7+	99.7+	99.7+	99.7+
Tests on Residue after the film oven test				
Viscosity, 140°F, Stokes	2432	1141	1763	934
Ductility, 77°F, cms	141+	141+	141+	141+
Spot Test	Neg.	Neg.	Neg.	Neg.

TABLE 8: EMULSIFIED ASPHALT PROPERTIES

PROPERTY	TEST SITE			
	2-SH6	11-US59 11-SH103	14-US95	
ASPHALT TYPE	EA-HVRS	EA-HVRS	EA-HVRS	EA-CRS-2
ASPHALT REFINERY CODE	22	23	22	23
Viscosity, Furol, 122°F, sec.	116	251	169	167
Residue by Distillation by Weight, percent	69.0	69.0	66.0	69.0
Oil Portion of distillate, percent	Trace	Trace	Trace	Trace
Sieve Test, percent	0.05	0.05	0.05	0.05
Demulsibility 35 cc of N/50 $CaCl_2$, percent	79.0	73.0	81.0	83.0*
Settlement, 5 days, percent	1.6	1.6	1.7	1.6
Penetration of Residue, 77°F	120	—	118	152
Solubility of Residue in $CaCl_4$, percent	99.8+	99.8+	99.8+	99.8+
Ductility of Residue, 77°F, cm	100+	100+	100+	100+

*this test performed with 35 ml 0.8 percent sodium dioctyl sulfosuccinate

TABLE 9

DISTRICT 2 - TRIAL FIELD SECTIONS (2-SH6)

Aggregate Source	Aggregate Spread Rate	Type of Asphalt / Aggregate Moisture Condition: Asphalt Cement 0.29 gal/yd^2			Anionic Emulsion 0.37 to 0.42 gal/yd^2		
		Dry	Moist	Wet	Dry	Moist	Wet
Clodine	160:1	X	X	X	X	X	X
	180:1	X	X	X	X	X	X
	200:1	X	X	X	X	X	X
Dallas	110:1	X	X	X	X	X	X
	125:1	X	X	X	X	X	X
Eastland	155:1	X	X	X	X	X	X
Ranger	150:1	X	X	X	X	X	X
	165:1	X	X	X	X	X	X
	180:1	X	X	X	X	X	X

TABLE 10

DISTRICT 5 - TRIAL FIELD SECTIONS (5-US62 and 5-FM1730)

		US62			FM1730
Aggregate Source	Aggregate Spread Rate	Asphalt Quantity gal/yd^2			
		0.27 (0.29)*	0.32 (0.34)	0.37 (0.39)	0.34
Clodine	120:1	X	X	X	X
	135:1	X	X	X	X
	140:1	X	X	X	X
Dallas	120:1		X		X
	135:1		X		X
	140:1		X		X
Eastland	120:1		X		X
	135:1		X		X
	140:1		X		X
Ranger	120:1	X	X	X	X
	135:1	X	X	X	X
	140:1	X	X	X	X

* 0.27 refers to asphalt quantity in passing lane.
(0.29) refers to asphalt quantity in travel lane.

TABLE 11

DISTRICT 11 - TRIAL FIELD SECTIONS (11-US59)

Aggregate Source	Aggregate Spread Rate	Asphalt Quantity gal/yd^2			Emulsion Quantity gal/yd^2
		0.19	0.22	0.25	0.33
Clodine	120:1	X	X	X	X
	140:1	X	X	X	X
	150:1	X	X	X	X
Dallas	120:1		X		X
	140:1		X		X
	150:1		X		X
Eastland	120:1		X		X
	140:1		X		X
	150:1		X		X
Range	120:1	X	X	X	X
	140:1	X	X	X	X
	150:1	X	X	X	X

TABLE 12

DISTRICT 11 - TRIAL FIELD SECTIONS (11-SH103)

Aggregate Source	Aggregate Spread Rate	Asphalt Quantity gal/yd^2			Emulsion Quantity gal/yd^2		
		0.19	0.22	0.25	0.28	0.33	0.38
Clodine	120:1		X			X	
	140:1		X			X	
	150:1		X			X	
Dallas	120:1		X			X	
	140:1	X	X	X	X	X	X
	150:1		X			X	
Eastland	120:1		X			X	
	140:1	X	X	X	X	X	X
	150:1		X			X	
Ranger	120:1		X			X	
	140:1		X			X	
	150:1		X			X	

TABLE 13

DISTRICT 14 - TRIAL FIELD SECTION (14-SH95)

Aggregate Source	Aggregate Spread Rate / Type of Asphalt / Delay to Simulated Rainfall	Asphalt Cement (0.36)			Anionic Emulsion 0.34 gal/yd^2 Cationic Emulsion 0.38 gal/yd^2		
		None	0 hours	24 hours	None	0 hours	24 hours
Clodine	105:1	X	X	X	X	X	X
	120:1	X	X	X	X	X	X
	135:1	X	X	X	X	X	X
Dallas	105:1	X	X	X	X	X	X
	120:1	X	X	X	X	X	X
	135:1	X	X	X	X	X	X
Eastland	120:1	X	X	X	X	X	X
Range	105:1	X	X	X	X	X	X
	120:1	X	X	X	X	X	X
	135:1	X	X	X	X	X	X
Precoat	120:1	X	X	X	X	X	X

X Indicates test section.

TABLE 14: Aggregate Properties - District 2 Trial Section

Test Method & Size	Aggregate			
	A	B	D	H
Tex-200-F, Sieve Analysis (% By Wt.)				
Ret. 5/8"	0	0	0	0
Ret. 1/2"	0.5	1.7	0	0
Ret. 3/8"	23.9	50.4	38.5	6.9
Ret. 1/4"	81.9	82.1	97.6	59.7
Ret. No. 4	92.4	90.3	99.1	90.0
Ret. No. 10	98.6	98.3	99.6	99.2
Tex-404-A, Unit Weight (lbs./ft^3)				
Standard-As Received	49.99	40.64	50.25	50.05
Tex-431-A, Pressure Slaking Standard Method				
3/4"-No. 10(Loss, % By Wt.)	1.9	3.5	1.5	2.4
Tex-432-A, Freeze & Thaw Test (% By Wt.)				
Total Weighted Loss	7.5	39.4	8.4	13.5
Tex-410-A, Los Angeles Abrasion Test (% By Wt.)				
L. A. Abrasion Value-Type "C"	19.8	20.2	20.5	25.3

TABLE 15: Aggregate Properties - District 5 Trial Section

Test Method & Size	Aggregate			
	A	B	D	H
Tex-200-F, Sieve Analysis (% By Wt.)				
Ret. 5/8"	0	0	0	0
Ret. 1/2"	0.1	1.2	0	0
Ret. 3/8"	34.0	38.4	33.4	30.0
Ret. 1/4"	87.0	95.1	95.7	82.0
Ret. No. 4	96.0	97.5	98.3	96.0
Ret. No. 10	99.0	99.4	99.0	99.0
Tex-404-A, Unit Weight ($lbs./ft^3$)				
Standard-As Received	48.83	37.25	51.83	45.42
Tex-431-A, Pressure Slaking Standard Method				
3/4"-No. 10(Loss, % By Wt.)	1.6	3.6	1.4	3.0
Tex-432-A, Freeze & Thaw Test (% By Wt.)				
Total Weighted Loss	4.5	61.0	6.8	12.3
Tex-410-A, Los Angeles Abrasion Test (% By Wt.)				
L. A. Abrasion Value-Type "C"	19.4	21.0	19.7	23.

TABLE 16: Aggregate Properties - District 11 Trial Section

Test Method & Size	Aggregate			
	A	B	D	H
Tex-200-F, Sieve Analysis (% By Wt.)				
Ret. 5/8"	0	0	0	0
Ret. 1/2"	0.6	0	0	0
Ret. 3/8"	33.4	25.7	35.1	11.4
Ret. 1/4"	87.6	61.1	92.8	63.5
Ret. No. 4	92.3	79.0	95.5	88.8
Ret. No. 10	96.3	97.0	97.7	97.2
Tex-404-A, Unit Weight ($lbs./ft^3$)				
Standard-As Received	46.75	42.76	53.81	48.09
Tex-431-A, Pressure Slaking Standard Method				
3/4"-No. 10 (Loss, % By Wt.)	3.0	3.3	1.3	3.5
Tex-432-A, Freeze & Thaw Test (% By Wt.)				
Total Weighted Loss	3.5	40.6	7.6	12.6
Tex-410-A, Loss Angeles Abrasion Test (% By Wt.)				
L. A. Abrasion Value-Type "C"	20.7	21.7	20.7	25.4

TABLE 17: Aggregate Properties - District 14 Trial Sections

Test Method & Size	Aggregate					
	A*	A**	B	D	H*	H**
Tex-200-F, Sieve Analysis (% By Wt.)						
Ret. 5/8"	0	0	0	0	0	0
Ret. 1/2"	0	0.2	0.8	0	0	0
Ret. 3/8"	46.6	22.9	55.5	52.8	8.7	14.5
Ret. 1/4"	92.7	80.2	92.6	97.0	59.4	70.1
Ret. No. 4	97.7	94.5	96.5	97.9	86.2	94.2
Ret. No. 10	99.0	98.8	99.1	98.7	97.4	98.9
Tex-404-A, Unit Weight (lbs./ft^3)						
Standard-As Received	52.63	50.09	36.54	49.49	56.60	46.87
Tex-431-A, Pressure Slaking Standard Method						
3/4"-No. 10 (Loss, % by Wt.)	2.4	2.1	1.8	1.8	2.9	3.5
Tex-432-A, Freeze & Thaw Test (% By Wt.)						
Total Weighted Loss	5.5	5.3	44.5	18.9	12.1	17.3
Tex-410-A Los Angeles Abrasion Test (% By Wt.)						
L. A. Abrasion Value-Type "C"	22.2	19.6	20.8	20.8	26.0	25.6

*placed in 1971
**placed in 1972

including gradation, unit weight, pressure slaking, freeze-thaw resistance and Los Angeles Abrasion for Districts 2, 5, 11 and 14 are shown in Tables 14, 15, 16 and 17 respectively. Average gradation of the aggregates utilized at the various test sites is given in Table 18. These gradations were obtained from aggregate collected as it dropped on the roadway.

Considerable variation in the gradation for any one aggregate exists among the test sites. Based on these gradations, which represent average values of several tests, 75 percent of these aggregates would be rejected if strict compliance to gradation specification were required. This relatively large percentage is due in part to the utilization of aggregate B which is currently not produced for seal coats in Texas. Other noted variations are related to plant control, sampling and testing technique and possible degradation during shipping and construction operations.

Aggregate degradation associated with materials handling operations during shipping and construction has been considered important. Table 19 and 20 present gradation results for aggregate obtained at various points in the materials handling sequence. Data scatter is evident from a review of this information and may mask the true picture. For example, 10 to 15 percentage point increase in material retained on the 3/8-inch sieve is evident from the data collected for the District 5 trial sections (Table 19) between the point of shipment and the stockpile while an approximate 5 percentage point increase is noted for the District 2 trial sections (Table 20). Significant differences on the No. 4 and No. 10 sieves cannot be established based on these data. Perhaps the single most important factor evident from these data is the importance of aggregate sampling and testing to establish a representative gradation. Stockpile segregation can be a major problem.

TABLE 18: Average Aggregate Gradation

SIEVE SIZE (AGGREGATE TYPE / SITE NUMBER)	ACCUMULATIVE PERCENT RETAINED																								SPECIFICATION*
	A						B						D						H						
	2-SH6	5-US62	5-FM1730	11-US59	11-SH103	14-SH95	2-SH6	5-US62	5-FM1730	11-US59	11-SH103	14-SH95	2-SH6	5-US62	5-FM1730	11-US59	11-SH103	14-SH95	2-SH6	5-1730	5-US59	11-US59	11-SH103	14-SH95	
5/8	0	0	0	0	0	0	.2	.5	0.1	.1	.2	0	0	0	0	.1	.1	0	0	0	0	0	0	0	0
1/2	1.2	1.7	1.5	1.4	1.2	1.4	3.0	5.6	5.1	4.2	2.9	.8	.3	.9	.6	.4	.7	.3	.2	1.1	1.2	1.6	.1	.1	0-5
3/8	24.4	32.2	31.4	38.8	38.5	31.6	49.6	60.1	48.8	34.4	43.2	34.0	25.9	50.0	31.4	37.7	36.9	43.2	9.2	22.1	19.3	24.3	13.1	16.9	20-40
No. 4	93.1	91.6	95.4	96.0	95.6	92.9	93.3	93.2	90.7	83.9	89.4	83.9	96.6	97.4	96.9	98.0	94.1	96.5	87.1	91.3	91.0	92.8	86.3	90.2	95-100
No. 10	98.9	97.9	99.1	98.2	98.1	97.9	98.1	97.8	97.0	97.8	96.5	95.1	99.0	98.3	98.7	98.9	97.7	97.8	97.0	98.0	98.2	98.0	93.9	97.4	98-100

* Texas Highway Department Specification Item 303, "Aggregate for Surface Treatments (Lightweight), Grade 4

TABLE 19: Gradation of Aggregate B Sampled at Various Locations during Transportation to and Construction at District 5 Trial 56 Field Sections

SAMPLE LOCATION	Accumulative Percent Retained				
	Sieve Size				
	5/ in.	1/2 in.	3/ in.	No. 4	No. 10
Rail Cars After Loading	0	5.2	45.5	93.1	93.0
	0	0	30.8	89.8	98.1
	0	0.2	36.8	92.2	97.8
	0	2.1	40.0	95.7	99.0
	0	2.2	34.1	84.6	92.7
Average	0	1.9	37.4	91.1	97.1
Stockpile Sampled And Tested By District 5, THD	0	2	67	93	100
	0	1	45	91	98
	0	5	45	91	97
	0	7	41	86	96
Average	0	3.8	49.5	91.5	97.8
Stockpile Sampled and Tested By TTI	0	1.9	54.1	95.1	98.9
	0	2.6	54.7	95.2	99.0
Average	0	2.3	54.4	95.1	98.9
Stockpile Sampled and Tested by Div. 9, THD	0	1.2	78.4	97.5	99.4
Roadway Sampled And Tested By TTI*	0	5.1	48.8	90.7	97.0
	0.5	5-6	60.0	93.2	97.8

*represent average values of materials placed on 5-US62 and 5-FM1730.

TABLE 20: Gradation of Aggregate B Sampled at Various Location during Transportation to and Construction at the District 2 Trial Field Site

SAMPLE LOCATION	Accumulation Percent Retained				
	Sieve Size				
	5/8 in.	1/2 in.	3/8 in.	No. 4	No. 10
Trucks After Loading	0	3.8	41.2	91.5	97.4
	0	2.0	51.6	99.4	99.7
	0	2.2	53.8	97.9	99.4
	0	2.5	38.3	93.9	99.0
	0	.2	40.1	80.0	98.9
Average	0	2.1	45.0	92.5	98.9
Stockpile Sampled and Tested By Division 9, THD	0	1.7	50.4	90.3	98.3
Roadway Sampled and Tested By TTI*	0.2	3.0	49.6	93.3	98.1

*represents average of 13 tests made during construction.

In addition to gradation several of the aggregates utilized in this study possessed freeze-thaw test values in excess of the 7 percent allowed by the Texas Highway Department (12). Aggregate from source B and H exceeded these limiting values based on samples obtained at all trial section sites. Field evaluation of these materials during the next five years may result in alteration of this specification.

Aggregate Quantity - The amount of aggregate utilized on the trial sections was determined by the Districts responsible for construction with consultation in some cases with D-18 perconnel. The design quantity was then altered plus or minus about 15 percent on those sections selected to study the effect of aggregate quantity on performance. Quantities of aggregate utilized are shown in Tables 10, 11, 12 and 13. A suggested design procedure to establish asphalt and aggregate quantities is proposed in a later section of this report in order that comparison between field suggested quantities and quantities based on field experience can be compared.

Construction

Construction was performed by Texas Highway Department maintenance crews in the respective districts. Self-propelled asphalt distributors and aggregate spreader were utilized in all cases. Rolling was accomplished with pneumatic tired rollers. Traffic control varied among projects.

Construction dates were as follows:

District 14 - October 22 and 26, 1971 and July 24, 25 and 26, 1972

District 2 - August 1 and 2, 1972

District 11 - August 8, 9, 10 and 21, 1972

District 5 - August 22, 23 and 24, 1972

Results of these trial sections will be discussed in a chronological order.

DISTRICT 14 TRIAL FIELD SECTIONS

Trial field sections were placed on State Highway 95 south of Elgin, Texas, on the 22 and 26 of October 1971 and July 24, 25 and 26 of 1972. They layout of these test sections is shown on Table 21. As noted the main variables investigated were asphalt type, aggregate quantity, aggregate type and simulated rainfall (Table 13).

Codes for identification of these test sections have been established and are illustrated below:

```
┌→district number
│
│     ┌→aggregate quantity (ratio of square yards to cubic yards)
│     │
│     │      ┌──────────→asphalt quantity (gallons per square yard)
│     │      │
│     │      │      ┌─────────────────→simulated rainfall (None, 24 hrs)
│     │      │      │
14-M(135)C-(0.35)E(N)
   /     /         │
  /     /          └→type of asphalt (Asphalt cement, Emulsion)
 /     └→SOURCE OF AGGREGATE
└→traffic level (Light, Medium and Heavy)
```

This code will be used throughout this report.

Tests conducted prior, during and after the construction of this project include: environmental data, surface texture, asphalt quantities, aggregate quantities, aggregate gradation, skid resistance, surface texture and visual performance rating. The results of these tests are discussed below.

<u>Construction Sequence</u>

Construction was performed on October 22 and October 26, 1971, utilizing anionic emulsion. The sections containing the Clodine, Dallas and Eastland aggregates were constructed on October 22 while those sections containing the Ranger and Precoated aggregates were constructed on October 26. Those sections placed utilizing asphalt cement and cationic emulsion were placed on July 24, 25 and 26, 1972

The construction sequence as shown on Table 21 indicates that sections containing a single aggregate type were constructed continuously with the southbound lanes placed before the northbound lanes.

Delays between the asphalt shot and the aggregate placement as shown on Table 21 ranged from about 30 minutes during the cooler and high humidity environmental condition to about 5 to 6 minutes during the warmer and dry parts of the day. These long delays were necessary as the coverstone should be applied after the emulsion is partially broken.

A pilot car was utilized together with signing to control traffic. Thus the traffic speed was controlled until the days' construction was complete.

Construction Equipment

Texas Highway Department District 14 maintenance equipment and crews were utilized for placement of the trial sections. A self-propelled spreader, 4-cubic yard dump trucks and pneumatic tired rolling equipment were utilized (Figure 6). Excess aggregate was removed from the pavement by brooming one day after construction.

Environmental Data

Temperature and humidity readings were made periodically during the construction operations for all projects. Average humidity conditions for the months of October, November and December of 1971 as a function of the time of day are shown in Table 22 and for July, August and September of 1972 on Table 23 (26). The humidity, temperature and rainfall data shown in Table 22 and Figures 7 and 8 are important in that they control to a certain degree the rate the emulsion breaks or loses its water which in turn controls the viscosity of the emulsion and thus the bond tenacity.

TABLE 21: Field Construction Data - 14 SH 95

(1) Roadway stations
(2) Determined from spreader box measurements
(3) Determined from roadway samples

Section Number	Lane	Location(1) From	To	Type of Asphalt	Amount of Asphalt gal/yd² Design	THD	TTI	Type of Aggregate	Quantity of Aggregate Design	TTI(2)	TTI(3)	Time Date of Construction	Asphalt Shot At	Rock Land Placed At	Aggregate Moisture Content Percent	Aggregate Gradation Accumulative Percent Retained 1/2 Inch	3/8 Inch	No. 4	No. 10	Visual Evaluation 10/27/71	5/15/72	9/11/72	6/4/73
14-M(105)C-(0.34)E(N)	SBL	116+36	119+51	AE	0.34	0.35	--	H	105	--	80	10/22/71	9:47	10:20	14.8	0	16.8	88.6	98.0	33.5	30.8		28.2
14-M(120)C-(0.34)E(N)	SBL	119+51	123+11	AE	0.34	0.35	0.37	H	120	130	100	"	9:49	10:25	14.5	0	14.1	88.3	98.2	34.8	29.5		29.2
14-M(135)C-(0.34)E(N)	SBL	123+11	127+16	AE	0.34	0.35	0.39	H	135	140	105	"	9:50	10:40	15.5	0	16.0	90.0	97.8	34.4	29.2		28.8
14-M(105)C-(0.34)E(N)	NBL	116+36	119+51	AE	0.34	0.34	0.37	H	105	105	65	"	12:45	1:05	15.4								
14-M(120)C-(0.34)E(N)	NBL	119+51	123+11	AE	0.34	0.34	0.31	H	120	115	105	"	12:43	1:00	14.2								
14-M(135)C-(0.34)E(N)	NBL	123+11	127+16	AE	0.34	0.34	--	H	135	135	120	"	12:40	12.55	17.7								
14-M(105)C-(0.34)E(24)	SBL	127+16	133+46	AE	0.34	0.34	--	H	105	105	55	"	10.52	11:12	--	0	13.9	87.5	97.3	30.7	31.4		28.6
14-M(120)C-(0.34)E(24)	SBL	133+46	140+66	AE	0.34	0.34	0.39	H	120	1	110	"	10:55	11:20	16.6	0	15.6	88.1	96.4	33.4	30.6		30.4
14-M(135)C-(0.34)E(24)	SBL	140+66	148+76	AE	0.34	0.34	0.36	H	135	130	125	"	11:00	11:35	18.7	0	18.5	91.2	98.1	34.1	31.2		27.0
14-M(105)C-(0.34)E(24)	NBL	127+16	133+46	AE	0.34	0.34	0.36	H	105	110	100	"	12:05	12:24	17.7	0	18.5	92.8	98.5				
14-M(120)C-(0.34)E(24)	NBL	133+46	140+66	AE	0.34	0.34	0.34	H	120	105	65	"	12:00	12:20	13.2	0	19.0	92.6	98.3				
14-M(135)C-(0.34)E(24)	NBL	140+66	148+76	AE	0.34	0.34	0.35	H	135	110	105	"	11:56	12:15	--	0	17.6	91.4	97.8				
14-M(105)D-(0.37)E(N)	SBL	148+76	151+91	AE	0.37	0.36	--	B	105	115	100	"	1:35	1:44	16.7	1.1	36.4	89.4	96.3	31.6	28.2		24.8
14-M(120)D-(0.37)E(N)	SBL	151+91	155+51	AE	0.37	0.36	0.34	B	120	120	95	"	1:37	1:46	14.5	2.3	39.0	92.5	98.4	31.7	27.5		24.4
14-M(135)D-(0.37)E(N)	SBL	155+51	159+56	AE	0.37	0.36	0.33	B	135	140	110	"	1:39	1:49	--	0	36.2	87.5	96.2	33.5	30.2		24.6
14-M(105)D-(0.37)E(N)	NBL	148+76	151+91	AE	0.37	0.36	--	B	105	110	70	"	3:00	3:10	17.7								
14-M(120)D-(0.37)E(N)	NBL	151+91	155+51	AE	0.37	0.36	0.38	B	120	120	120	"	2:58	3:08	24.4								
14-M(135)D-(0.37)E(N)	NBL	155+51	159+56	AE	0.37	0.36	0.33	B	135	130	80	"	2:57	3:06	18.7								
14-M(105)D-(0.37)E(24)	SBL	159+56	165+86	AE	0.37	0.36	0.37	B	105	110	100	"	1:40	1:52	18.3	1.2	40.4	91.6	97.2	31.4	29.9		27.0
14-M(120)D-(0.37)E(24)	SBL	165+86	173+06	AE	0.37	0.37	0.32	B	120	110	95	"	2:00	2:05	17.8	1.6	36.9	91.1	98.4	31.6	30.0		28.0
14-M(135)D-(0.37)E(24)	SBL	173+06	181+16	AE	0.37	0.37	0.40	B	135	135	100	"	2:05	2:12	17.8	.8	37.2	88.3	96.6	34.1	31.9		29.2
14-M(105)D-(0.37)E(24)	NBL	159+56	165+86	AE	0.37	0.36	0.37	B	105	115	100	"	2:55	3:00	17.1	3.1	41.9	86.3	94.2				
14-M(120)D-(0.37)E(24)	NBL	165+86	173+06	AE	0.37	0.37	0.38	B	120	120	90	"	2:40	2:43	17.0	1.3	35.6	88.6	97.1				
14-M(135)D-(0.37)E(24)	NBL	173+06	181+16	AE	0.37	0.37	0.43	B	135	135	140	"	2:35	2:40	9.8	1.6	41.4	93.2	98.9				
14-M(120)E-(0.39)E(N)	SBL	181+16	184+76	AE	0.39	0.40	--	D	120	110	140	"	3:30	3:39	6.7	.5	46.4	96.1	97.9	34.1	35.5		32.8
14-M(120)E-(0.39)E(24)	SBL	184+76	191+96	AE	0.39	0.40	0.39	D	120	130	—	"	3:35	3:42	--	0	31.7	93.8	96.8				
14-M(120)E-(0.39)E(N)	NBL	181+16	184+76	AE	0.39	0.40	—	D	120	125	115	"	3:57	4:05	5.7	0	47.7	96.1	97.8				
14-M(120)E-(0.39)E(24)	NBL	184+76	191+96	AE	0.39	0.39	0.40	D	120	125	100	10/22/71	3:52	4.02	7.9	0	40.5	97.7	98.6				
14-M(105)R-(0.37)E(N)	SBL	191+96	195+16	AE	0.37	0.38	0.36	A	105	110	110	10/26/71	11:02	11:18	9.5	2.1	36.2	95.5	98.7	28.8	31.9		30.0
14-M(120)R-(0.37)E(N)	SBL	195+16	198+71	AE	0.37	0.38	0.40	A	120	110	120	"	11:04	11:20	7.8	2.8	34.8	93.8	98.2	30.6	32.0		31.0
14-M(135)R-(0.49)E(N)	SBL	198+71	202+16	AE	0.49	0.47	0.50	A	135	135	--	"	11:31	11:47	10.3	2.1	39.8	96.3	99.1	31.0	33.0		32.4
14-M(105)R-(0.37)E(N)	NBL	191+96	195+16	AE	0.37	0.38	0.40	A	105	110	90	"	1:35	1:41	11.1								
14-M(120)R-(0.37)E(N)	NBL	195+16	198+71	AE	0.37	0.38	0.31	A	120	120	85	"	1:32	1:39	11.7								
14-M(135)R-(0.49)E(N)	NBL	198+71	202+16	AE	0.49	0.47	0.49	A	135	135	105	"	1:10	1:21	9.2								
14-M(105)R-(0.49)E(24)	SBL	202+16	209+16	AE	0.49	0.47	0.47	A	105	105	100	"	11:35	11:50	9.6	2.2	34.2	95.1	98.5	30.4	32.9		32.8
14-M(120)R-(0.49)E(24)	SBL	209+16	216+26	AE	0.49	0.47	0.45	A	120	110	120	"	12:06	12:22	8.2	2.2	35.1	95.5	98.6	29.8			
14-M(135)R-(0.49)E(24)	SBL	216+26	224+36	AE	0.49	0.49	0.54	A	135	135	150	"	12:12	12:29	8.2	2.3	38.4	95.8	98.6	30.4			
14-M(105)R-(0.49)E(24)	NBL	202+16	209+16	AE	0.49	0.47	0.46	A	105	105	95	"	1:06	1:19	9.5	1.9	28.8	93.0	97.9				
14-M(120)R-(0.49)E(24)	NBL	209+16	216+26	AE	0.49	0.47	0.48	A	120	110	80	"	12:40	12:59	9.4	2.4	37.5	95.5	98.7				
14-M(135)R-(0.49)E(24)	NBL	216+26	224+36	AE	0.49	0.49	0.44	A	135	130	120	"	12:35	12:53	8.7	3.8	44.7	97.0	98.9				
14-M(120)PB-(0.49)E(N)	SBL	224+36	227+96	AE	0.49	0.49	0.49	M	120	120	90	"	2:00	2:06	.8	0	31.1	97.5	99.4	35.7	35.8		35.2
14-M(120)PB-(0.49)E(N)	SBL	227+96	235+16	AE	0.49	0.49	0.51	M	120	120	90	"	2:05	2:16	1.1	.3	29.3	96.3	99.2				
14-M(120)PB-(0.49)E(N)	NBL	224+36	227+96	AE	0.49	0.50	0.52	M	120	120	80	"	2:21	2:30	1.1	.3	36.6	97.5	99.5				
14-M(120)PB-(0.49)E(N)	NBL	227+96	235+16	AE	0.49	0.50	0.47	M	120	120	70	10/26/71	2:17	2:25	1.5	.2	32.3	97.4	99.4				
14-M(105)C-(0.36)AC(N)	SBL	235+16	238+31	AC	0.36	0.35		H	105	95		7/24/72	9:52	10:00								31.5	34.0
14-M(120)C-(0.36)AC(N)	SBL	238+31	241+91	AC	0.36	0.35	0.34	H	120	185	85	"	9:52	10:02	18.3	0.6	17.3	88.6	96.9			31.9	33.6
14-M(135)C-(0.36)AC(N)	SBL	241+91	245+96	AC	0.36	0.35		H	135	115		"	9:56	10:04								28.9	33.4
14-M(105)C-(0.36)AC(N)	NBL	235+16	238+31	AC	0.36	0.37		H	105	105		"	11:20	11:25									
14-M(120)C-(0.36)AC(N)	NBL	238+31	241+91	AC	0.36	0.37	0.38	H	120	120	75	"	11:18	11:22	18.6	0	26.8	92.6	98.6				
14-M(135)C-(0.36)AC(N)	NBL	241+91	245+96	AC	0.36	0.37		H	135	145		"	1:17	11:20									
14-M(105)C-(0.36)AC(R)	SBL	245+96	249+11	AC	0.36	0.35	0.37	H	105	100	145	"	9:57	10:06	19.6	0	20.2	88.0	95.9			31.5	34.2
14-M(100)C-(0.36)AC(R)	SBL	249+11	252+71	AC	0.36	0.35		H	120	110		"	9:58	10:08								32.1	34.1
14-M(135)C-(0.36)AC(R)	SBL	252+71	256+76	AC	0.36	0.35		H	135	130		"	10:00	10:09								29.9	34.2
14-M(105)C-(0.36)AC(R)	NBL	245+96	249+11	AC	0.36	0.37		H	105	100		"	11:16	11:16									
14-M(120)C-(0.36)AC(R)	NBL	249+11	252+71	AC	0.36	0.37		H	120	120		"	11:15	11:15									
14-M(135)C-(0.36)AC(R)	NBL	252+71	256+76	AC	0.36	0.37		H	135	140		"	11:13	11:13									
14-M(105)C-(0.36)AC(24)	SBL	256+76	259+91	AC	0.36	0.37	0.20	H	105	95	65	"	10:45	10:46	19.1	0	21.1	90.9	97.4			31.8	
14-M(120)C-(0.36)AC(24)	SBL	259+91	263+51	AC	0.36	0.37	0.24	H	120	110	110	"	10:47	10:48	19.4	0	21.0	89.4	96.9			30.3	
14-M(135)C-(0.36)AC(24)	SBL	263+51	267+56	AC	0.36	0.37	0.39	H	135	155	65	"	10:44	10:51	17.7							29.9	

TABLE 21 (Cont'd)

Section Number	Lane	Location (1) From	Location (1) To	Type of Asphalt	Amount of Asphalt gal/yd^2 Design	Amount of Asphalt THD	Amount of Asphalt TTI	Type of Aggregate	Quantity of Aggregate Design	Quantity of Aggregate TTI(2)	TTI(3)	Date of Construction	Time Asphalt Shot At	Time Rock Land Placed At	Aggregate Moisture Content Percent	Aggregate Gradation Accumulative Percent Retained 1/2 inch	3/8 inch	No. 4	No. 10	Visual Evaluation 10/27/71	5/15/72	9/11/72	6/4/73
14-M(105)C-(0.36)AC(24)	NBL	256+76	259+91	AC	0.36	0.37		H	105	90		"	11:03	11:08									
14-M(120)C-(0.36)AC(24)	NBL	259+91	263+51	AC	0.36	0.37	0.37	H	120	115		"	11:02	11:06									
14-M(135)C-(0.36)AC(24)	NBL	263+51	267+56	AC	0.36	0.37	0.34	H	135	135	100	"	11:00	11:04	18.9	0	24.7	90.3	96.4				
14-M(105)C-(0.39)AC(N)	SBL	267+56	270+71	AC	0.39	0.38		H	105			"	11:51	11:22								28.5	
14-M(120)C-(0.39)AC(N)	SBL	270+71	274+31	AC	0.39	0.38	0.35	H	120		115	"	11:53	11:54	22.8	1.1	38.2	92.1	98.2			27.8	
14-M(135)C-(0.39)AC(N)	SBL	274+31	278+36	AC	0.39	0.38	0.26	H	135		120	"	11:55	11:56	23.6	0.3	33.3	87.3	96.8			27.8	
14-M(105)C-(0.39)AC(N)	NBL	267+56	270+71	AC	0.39	0.39		H	105			"	1:04	1:07									
14-M(120)C-(0.39)AC(N)	NBL	270+71	274+31	AC	0.39	0.39		H	120		105	"	1:02	1:05	26.0	0.3	26.2	79.8	94.9				
14-M(135)C-(0.39)AC(N)	NBL	274+31	278+36	AC	0.39	0.39	0.30	H	135		155	"	1:01	1:03	24.5	1.3	34.1	90.2	93.2				
14-M(105)C-(0.39)AC(N)	SBL	278+36	281+51	AC	0.39	0.38		H	105			"	11:55	11:58								29.1	31.2
14-M(120)C-(0.39)AC(N)	SBL	281+51	285+11	AC	0.39	0.39		H	120		115	"	12:13	12:15	27.6	1.3	45.5	88.0	97.4			27.5	30.0
14-M(135)C-(0.39)AC(N)	SBL	285+11	289+16	AC	0.39	0.39		H	135			"	12:14	12:15								26.5	30.8
14-M(105)C-(0.39)AC(N)	SBL	278+36	281+51	AC	0.39	0.39		H	105			"	1:00	1:01									
14-M(120)C-(0.39)AC(N)	NBL	281+51	285+11	AC	0.39	0.39		H	120			"	12:45	12:48									
14-M(135)C-(0.39)AC(N)	NBL	285+11	289+16	AC	0.39	0.39	0.53	H	135		120	"	12:44	12:46	23.4	1.2	31.3	73.5	89.3				
14-M(105)D-(0.39)AC(24)	SBL	289+16	292+31	AC	0.39	0.39		B	105			"	12:15	12:20								27.9	31.0
14-M(120)D-(0.39)AC(24)	SBL	292+31	295+91	AC	0.39	0.39	0.36	B	120			"	12:17	12:22	10.2	0.4	32.1	83.0	93.3			30.0	31.0
14-M(135)D-(0.39)AC(24)	SBL	295+91	299+96	AC	0.39	0.39		B	135			"	12:20	12:26								28.8	31.0
14-M(105)D-(0.39)AC(24)	NBL	289+16	292+31	AC	0.39	0.39		B	105			"	12:43	12:45									
14-M(120)D-(0.39)AC(24)	NBL	292+31	295+91	AC	0.39	0.39		B	120		70	"	12:40	12:41	21.8	0.2	31.1	67.4	97.5				
14-M(135)D-(0.39)AC(24)	NBL	245+91	299+96	AC	0.39	0.39		B	135			"	12:37	12:38									
14-M(130)E-(0.41)AC(N)	SBL	299+96	303+56	AC	0.41	0.40		D	120			"	1:25	1:27								39.0	38.4
14-M(120)E-(0.41)AC(R)	SBL	303+56	307+16	AC	0.41	0.40	0.39	D	120		95	"	1:29	1:30	14.6	0.3	42.3	96.0	97.5				
14-M(120)E-(0.41)AC(24)	SBL	307+16	310+76	AC	0.41	0.40		D	120			"	1:33	1:34									
14-M(120)E-(0.41)AC(N)	NBL	299+96	303+56	AC	0.41	0.44		D	120	115		"	1:45	1:46									
14-M(120)E-(0.41)AC(R)	NBL	303+56	307+76	AC	0.41	0.44	0.43	D	120	120	85	"	1:46	1:48	12.9	0.3	43.7	97.1	98.2				
14-M(120)E-(0.41)AC(24)	NBL	307+16	310+76	AC	0.41	0.44		D	120	120		"	1:48	1:50									
14-M(105)R-(0.39)AC(N)	SBL	310+76	313+91	AC	0.39	0.40		A	105			"	2:05	2:08								34.8	36.0
14-M(120)R-(0.39)AC(N)	SBL	313+91	317+51	AC	0.39	0.40		A	120			"	2:06	2:09								32.4	35.6
14-M(135)R-(0.39)AC(N)	SBL	317+51	321+56	AC	0.39	0.40	0.38	A	135	160	80	"	2:08	2:10	15.2	0.9	29.8	92.9	98.2			29.5	32.5
14-M(105)R-(0.39)AC(N)	NBL	310+76	313+91	AC	0.39	0.39		A	105	140		"	3:13	3:15									
14-M(120)R-(0.39)AC(N)	NBL	313+91	317+51	AC	0.39	0.39		A	120	120		"	3:11	3:13									
14-M(135)R-(0.39)AC(N)	NBL	317+51	321+56	AC	0.39	0.39	0.45	A	135	100	100	"	3:10	3:12	6.9	1.2	31.5	89.5	96.8				
14-M(105)R-(0.39)AC(N)	SBL	321+56	324+71	AC	0.39	0.40		A	105	115		"	2:10	2:12								31.1	34.2
14-M(120)R-(0.39)AC(R)	SBL	324+71	328+31	AC	0.39	0.38		A	120	120		"	2:27	2:28								32.9	34.2
14-M(135)R-(0.39)AC(R)	SBL	328+31	332+36	AC	0.39	0.38		A	135	145		"	2:29	2:30								30.9	34.2
14-M(105)R-(0.39)AC(R)	NBL	321+56	324+71	AC	0.39	0.39		A	105	100		"	3:08	3:10									
14-M(120)R-(0.39)AC(R)	NBL	324+71	328+31	AC	0.39	0.39		A	120	125		"	2:50	2:51									
14-M(135)R-(0.39)AC(R)	NBL	228+31	332+36	AC	0.39	0.39		A	135	120		"	2:46	2:48									
14-M(105)R-(0.39)AC(24)	SBL	332+36	335+51	AC	0.39	0.38	0.36	A	105	100		"	2:30	2:31	12.4	1.8	42.0	92.3	97.5			32.0	
14-M(120)R-(0.39)AC(24)	SBL	335+15	339+11	AC	0.39	0.38		A	120	125		"	2:31	2:33								32.5	
14-M(135)R-(0.39)AC(24)	SBL	339+11	343+16	AC	0.39	0.38	0.36	A	135	100	75	"	2:32	2:35	9.3	1.5	30.4	89.1	96.9			29.1	
14-M(105)R-(0.39)AC(24)	NBL	332+36	335+51	AC	0.39	0.39	0.42	A	105	100	60	"	2:45	2:47	6.3	0.83	26.5	84.3	95.9				
14-M(120)R-(0.39)AC(24)	NBL	335+51	339+11	AC	0.39	0.39		A	120	120		"	2:44	2:45									
14-M(135)R-(0.39)AC(24)	NBL	339+11	343+16	AC	0.39	0.39		A	135	140		"	2:42	2:43									
14-M(120)PB-(0.39)AC(N)	SBL	343+16	346+76	AC	0.39	0.40		M	120	90		"	3:25	3:27								31.6	32.6
14-M(120)PB-(0.39)AC(R)	SBL	346+76	350+36	AC	0.39	0.40	0.39	M	120	120	95	"	3:27	3:30	1.8	0.4	38.6	98.1	99.5				
14-M(120)DB-(.39)AC(24)	SBL	350+36	353+96	AC	0.39	0.40	0.42	M	120	135		"	3:29	3:35	2.6	0.2	34.6	96.0	99.5				
14-M(120)DB-(.39)AC(N)	NBL	343+16	346+76	AC	0.39	0.39		M	120	130		"	3:38	3:45									
14-M(120)DB-(.39)AC(R)	NBL	346+76	350+36	AC	0.39	0.39	0.24	M	120	130		"	3:41	3:46									
14-M(120)PB-(.39)AC(24)	NBL	350+36	353+96	AC	0.39	0.39	0.26	M	120	125		"	3:44	3:47									
14-M(110)C-(.38)CE	SBL	353+36	367+16	CE	0.38	0.38	0.40	H	110		90	7/25/72	9:28	9:30	11.2	0	13.3	90.5	97.8			31.8	34.3
14-M(125)C-(.38)CE	SBL	367+16	385+91	CE	0.38	0.38	0.50	H	125	135	120	"	9:49	9:50	10.4	0.4	18.3	90.2	96.95			32.1	35.5
14-M(140)C-(.38)CE	SBL	385+91	406+91	CE	0.38	0.38	0.39	H	140		125	"	9:55	9:56	10.1	0	18.3	92.7	98.1			32.7	32.8
14-M(110)C-(.38)CE	NBL	353+36	367+16	CE	0.38	0.39	0.48	H	110	110	50	"	12:29	12:30	8.0	0	9.8	88.1	97.5				
14-M(125)C-(.38)CE	NBL	367+16	385+91	CE	0.38	0.38	0.45	H	125	125	75	"	11:16	11:17	8.0	0.5	10.3	90.4	97.6				
14-M(140)C-(.38)CE	NBL	385+91	406+91	CE	0.38	0.38	0.41	H	140	140	100	"	10:46	10:47	9.6	0	19.6	93.2	98.0				
14-M(110)R-(.46)CE	SBL	406+91	420+11	CE	0.46	0.45	0.51	A	110	115	75	"	12:49	12:50	6.1	1.9	28.0	91.95	98.5			32.0	[illegible]
14-M(125)R-(.46)CE	SBL	420+11	438+86	CE	0.46	0.45	0.46	A	125	130	70	"	1:11	1:12	12.7	1.2	38.2	93.7	96.6			31.3	[illegible]
14-M(140)R-(.46)CE	SBL	438+86	459+86	CE	0.46	0.43	0.40	A	140		150	7/26/72	8:35	8:36	10.1	1.6	32.2	96.2	98.7			34.8	[illegible]
14-M(110)R-(.46)CE	NBL	406+91	420+11	CE	0.46	0.44	0.48	A	110	120		7/25/72	2:03	2:05		0.6	22.4	91.1	96.9				
14-M(125)R-(.46)CE	NBL	420+11	438+86	CE	0.46	0.46	0.51	A	125	120	105	7/25/72	1:36	1:38	8.9	1.6	37.95	92.6	97.7				
14-M(140)R-(.46)CE	NBL	438+86	459+86	CE	0.46	0.44	0.43	A	140			7/26/72	9:08	9:09		2.8	31.1	94.7	98.8				

TABLE 22: Average Monthly Temperature Relative Humidity at Austin, Texas - 1971

MONTH	TIME OF DAY	TEMPERATURE OF		AVERAGE MONTHLY RELATIVE HUMIDITY PERCENT
		MAX.	MIN.	
October	12:01 a.m. 6:00 a.m. 12:01 p.m. 6:00 p.m.	81.3	63.1	86 90 63 64
November	12:01 a.m. 6:00 a.m. 12:01 p.m. 6:00 p.m.	70.6	50.3	77 86 57 58
December	12:01 a.m. 6:00 a.m. 12:01 p.m. 6:00 p.m.	65.2	47.6	80 86 71 73

TABLE 23: Average Monthly Temperature and Relative Humidity - 1972

LOCATION	MONTH	TEMPERATURE OF		RELATIVE HUMIDITY PERCENT			
		MAX.	MIN.	12:01 a.m.	6:00 a.m.	12:01 p.m.	6:00 p.m.
ABILENE	July	91.8	69.7	67	82	55	46
	Aug.	89.3	68.4	74	81	62	55
	Sept.	85.2	65.4	75	83	65	58
AUSTIN	July	91.7	72.9	79	88	53	53
	Aug.	92.9	73.3	77	87	54	52
	Sept.	92.1	72.7	76	85	53	52
FT. WORTH	July	94.0	72.2	72	89	51	44
	Aug.	95.8	73.5	69	84	49	47
	Sept.	90.4	71.1	79	93	63	57
LUBBOCK	July	86.7	66.3	69	79	60	47
	Aug.	84.5	64.2	77	88	61	55
	Sept.	81.3	60.6	83	89	62	55
HOUSTON	July	90.2	70.3	94	97	62	72
	Aug.	90.5	70.0	95	98	62	69
	Sept.	89.4	69.8	98	99	66	77

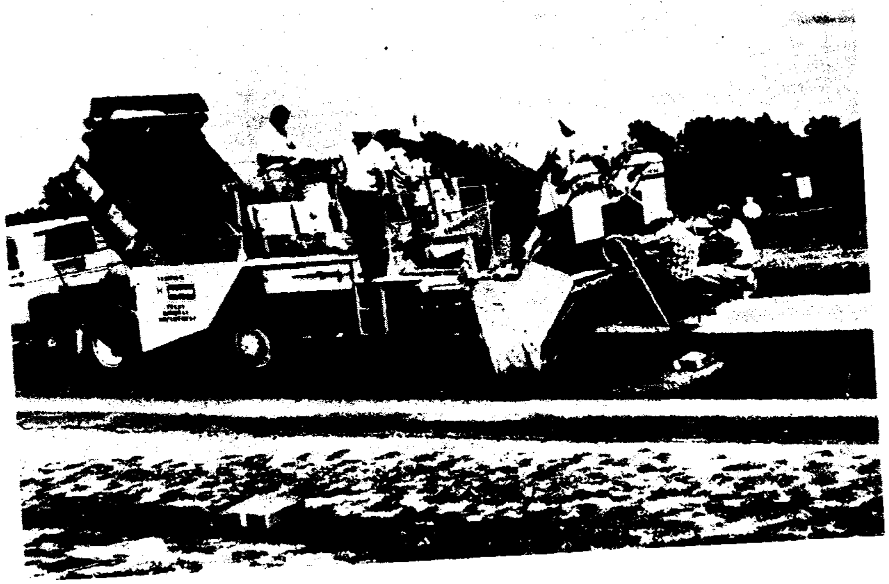

Figure 6. Typical seal coat operation on trial field sections.

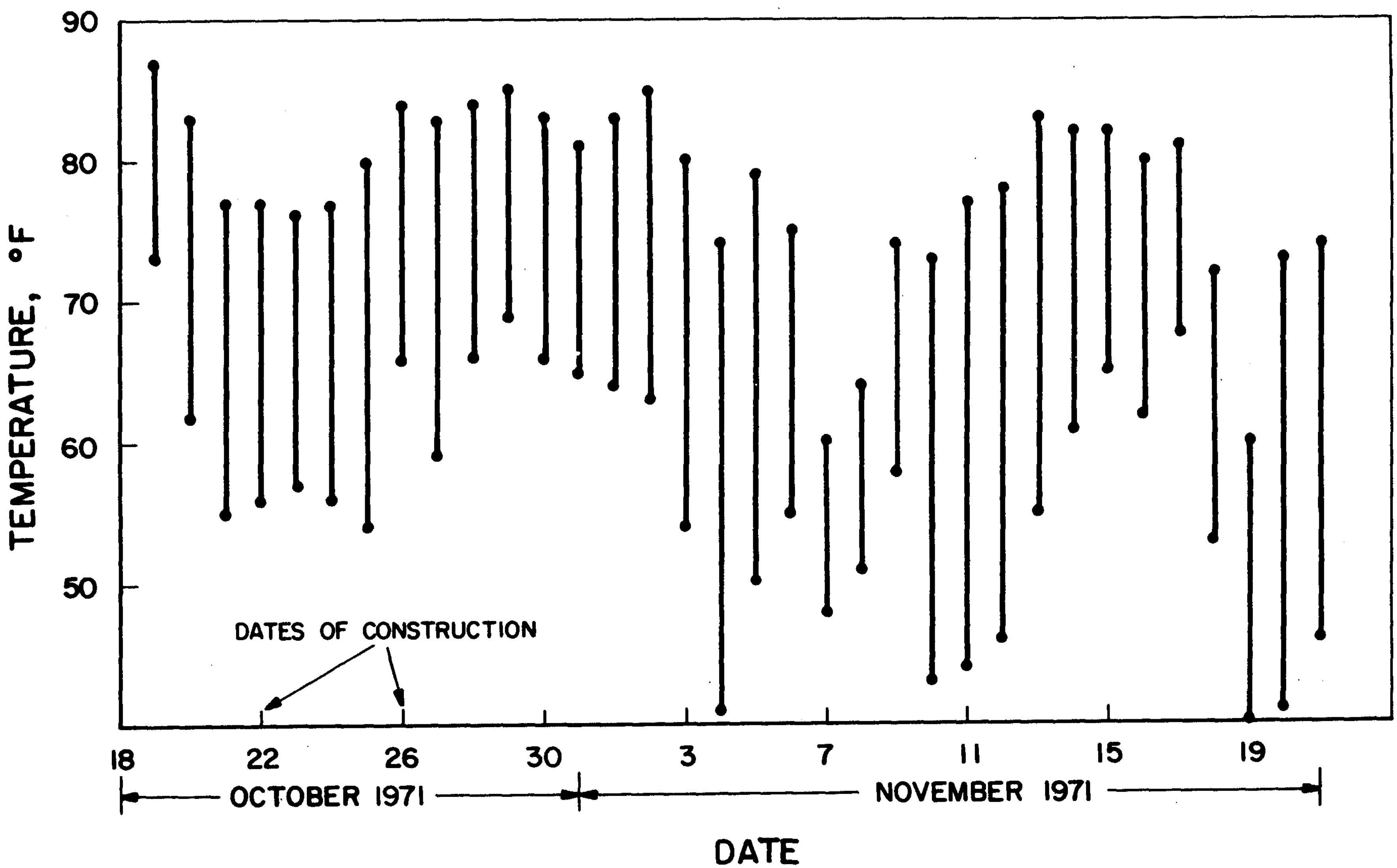

Figure 7. Daily maximum and minimum temperatures -- Elgin, Texas.

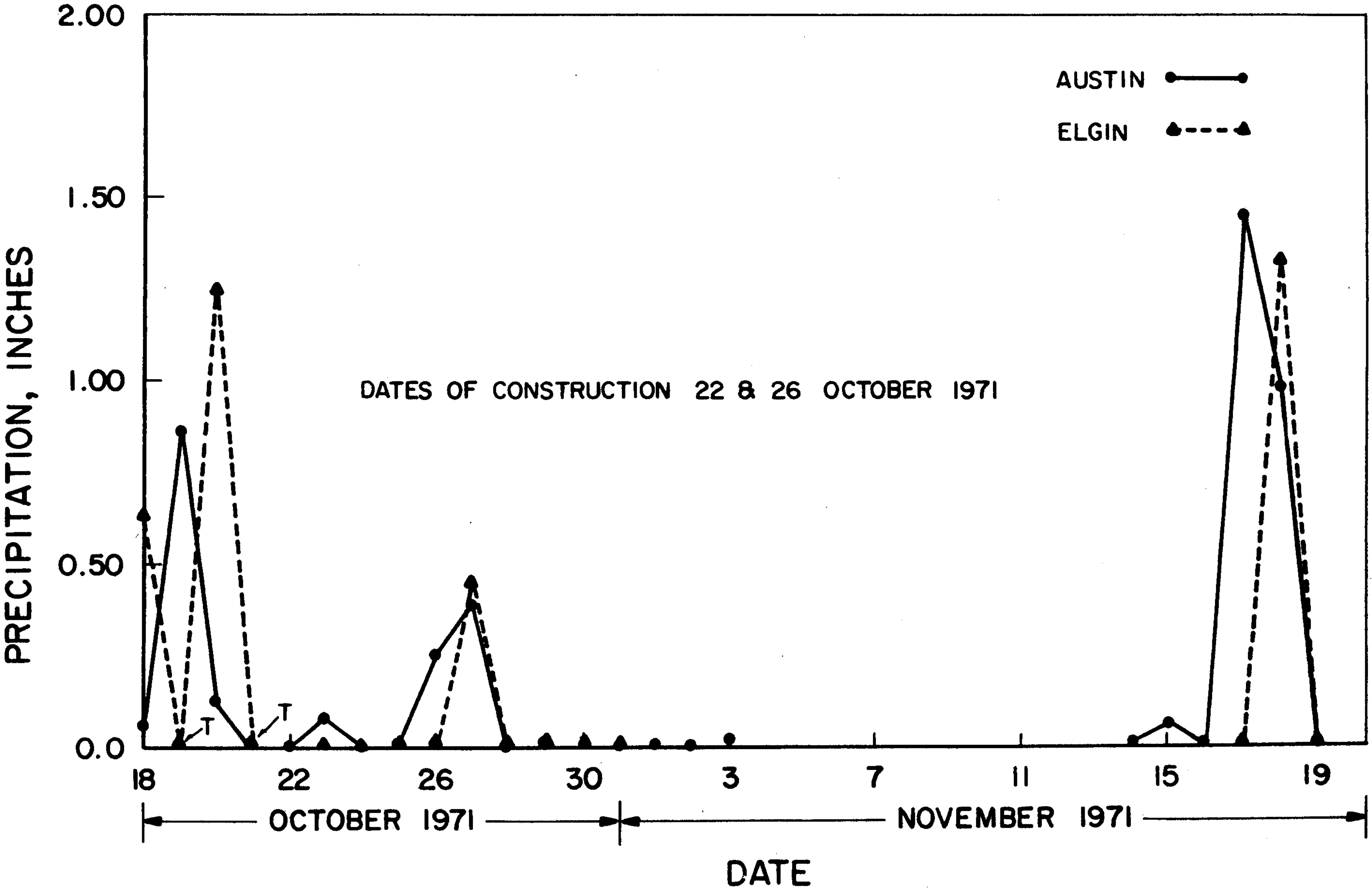

Figure 8. Daily precipitation -- Elgin and Austin, Texas.

Construction was delayed on October 22 due to the low air and associated ground temperature. The first emulsion was shot at 9:47 a.m. The emulsion did not break sufficiently until 10:15 a.m. at which time the coverstone was applied. Construction records indicate that an air temperature of 65°F and 90 percent relative humidity existed during the period of early morning anionic emulsion asphalt shots of August 22, 1971. Five to ten minute delays between asphalt and aggregate applications were common by 1:00 p.m. with air temperatures of 75°F and relative humidity of 65 percent. No pavement temperature measurements were made. The construction was initiated under marginal environmental conditions. A light rain fell in the general area on the 23 of October, but local residents did not note precipitation at the construction site.

Construction began on October 26 at 11:02 a.m. The initial asphalt shot was delayed due to the relatively low temperatures, high humidity and overcast skies (70°F, 90 percent relative humidity). The temperature and relative humidity at the time of the first asphalt shot were 75°F and 78 percent, respectively. A 15-minute delay was experienced under these conditions. About 0.40 inches of rain fell on the test site during the night and next day. Initial precipitation commenced about 10 hours after construction was completed. These environmental conditions can be considered marginal for emulsion seal coat construction.

Simulated rainfall was applied with a water truck to selected sections. Approximately 0.50 inches of water was applied to those sections placed in October 22, 1971 on the 23 of October 1971. Rainfall during the night of October 26 and the morning of October 27 negated the necessity of simulated rainfall for selected sections placed on 26 October 1971. Based on this experience, simulated rainfall was not utilized on any sections placed in 1972.

Asphalt Quantities

Asphalt quantities were obtained from two sources. Texas Highway Department personnel following their normal construction operations strapped the asphalt distributor before and after each shot. Metal pans were placed on the roadway as shown in Figure 9 by Texas Transportation Institute personnel. Emulsion sprayed into these pans was dried to a constant weight and the quantity of emulsion calculated based on data that indicated that 70 percent residual asphalt existed in the emulsion. A summary and comparison of these data are contained in Table 21. A review of these data indicates that the quantities of asphalt as determined from strapping the distributor and from pans placed on the pavement agree within plus or minus 0.03 gallons per square yard for the vast majority of the measurements made. Since 0.03 gallons per square yard is an accepted variation for asphalt distribution transverse and normal to the direction of travel, additional detail testing to determine field asphalt application may not be warranted.

Asphalt quantities were varied along the length of the roadway to account for aggregate gradation and road surface demand. Asphalt quantities placed are shown in Table 21 for the various sections.

Aggregate Properties and Quantities

Aggregate Properties - Physical properties of the aggregates used in this project are shown in Tables 2 and 17. Reference to detailed testing procedures and comparison values for synthetic aggregates can be found in references 27 and 28.

Aggregate Gradation - Aggregate gradations as obtained from the stockpile and averaged from samples obtained as the aggregate was spread on the

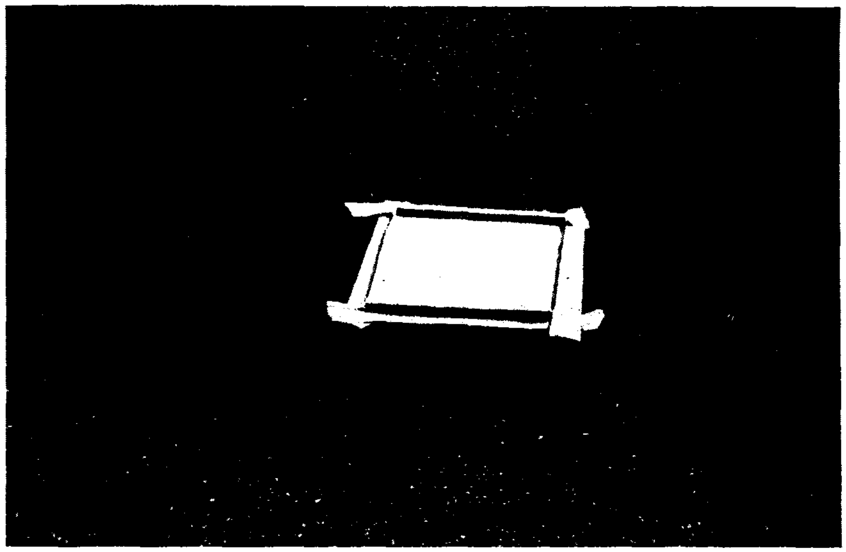

Figure 9. Metal pans for determining asphalt quantity.

Figure 10. Sampling aggregate from roadway.

road (Figure 10) are given in Table 24. Aggregate degradation due to handling during the construction operation is not evident from these data as variations in sieve analysis due to segregation in the stockpile and sample size has made a positive conclusion unwise.

Detailed results of the sieve analysis perofrmed on samples taken from the roadway during construction are given in Table 21.

Moisture Content - The presence of moisture in the aggregate during construction is extremely important as discussed previously. Thus moisture samples were obtained as the aggregate was spread on the roadway. Results of these tests are shown in Table 21 in detail and summarized by aggregate type in Table 25. Aggregate stockpiles were covered with polyethylene sheets; however, relatively high moisture contents were noted in the aggregates. Sources of this moisture include the manufacturing process (some plants cool the aggregate in a water spray), rainfall during storage at the manufacturing site or during transportation to the job site.

Visual observations of the covered stockpiles indicated a higher moisture content at the top of the stockpile than at the bottom. This is probably due to water vapor which rises from the ground and aggregate condensing on the underside of the polyethylene sheets. Thus, to prevent the buildup of moisture, vents at the top of the covered stockpile may be necessary to allow water vapor to escape rather than condensing.

A comparison of moisture content between the stockpile and the samples obtained on the roadway was made for two aggregates (Table 25). In both cases the moisture content decreased slightly.

TABLE 24: Aggregate Gradations - 14SH95

AGGREGATE IDENTIFICATION	SAMPLED AT	ACCUMULATIVE PERCENT RETAINED				
		3/4 inch	1/2 inch	3/8 inch	No. 4	No. 10
A	Stockpile Roadway	0 0	4 2.9	33 36.6	94 95.3	99 98.6
B	Stockpile Roadway	0 0	2 1.4	33 38.4	90 89.8	98 97.0
D	Stockpile Roadway	0 0	2 0.1	59 40.1	98 95.9	99 97.8
H	Stockpile Roadway	0 0	0 0	25 16.6	92 90.1	98 97.8
M	Stockpile Roadway	0 0	0 0.2	36 32.3	97 97.4	100 99.4
Specification Item 1989		0	0-5	20-40	95-100	98-100

TABLE 25: Aggregate Moisture Content - 14SH95

AGGREGATE PRODUCER	ROAD SAMPLES MOISTURE CONTENT, percent			STOCKPILE-SAMPLES MOISTURE CONTENT, percent		
	No. of Samples	Range	Average	No. of Samples	Range	Average
A	17	7.8-11.7	9.3	3	8.4-14.4	10.2
B	13	14.5-24.4	17.8			
D	7	5.7-13.0	9.1			
H	12	13.2-18.7	15.8			
M	6	0.8-1.5	1.2	2	2.3-3.3	2.8

Aggregate quantities obtained from use of the boxes placed on the roadway resulted in spread quantities (expressed in square yards per cubic yard) that were on the average 20 percent below the design quantity. (Basis: pounds per square yard). Closer agreement was obtained between design quantities and quantities determined from measurements made by striking off the aggregates in the truck than by measurements made by the spreader box procedure. Less than 5 percent variation resulted. Therefore it appears as if field control of the order of 5 to 10 square yards per cubic yard can be maintained.

The prime reason for this observed variation between design and measured quantities when boxes were used was the inability of the box to catch and retain all of the aggregate as it is spread on the roadway. However, moisture content and gradations can be reliably obtained from this sampling technique.

Skid Resistance

Skid measurements were made on the trial sections before and after the seal coats were placed. The Texas Highway Department locked wheel skid trailer which was utilized for these measurements. All measurements were made at 40 miles per hour (Tables 26 and 27). As noted in Table 26 a significant increase in skid number is apparent between the old and new surfaces. Table 27 illustrates the limited variation in skid number with aggregate application rate. The values obtained for the synthetic aggregate seal coats are typical of those obtained on other in-service pavements in Texas. The precoated limestone, although it has a high initial skid number, can be expected to drop substantially, while the synthetic aggregate seal coats should maintain their high initial values.

TABLE 26: Skid Resistance Measurements

AGGREGATE TYPE	SN_{40}			
	NUMBER OF MEASUREMENT	AVERAGE	STANDARD DEVIATION	RANGE
A	11	65	1	61-66
B	10	66	3	60-73
D	7	64	2	60-66
H	10	72	3	64-75
M	9	58	3	53-65
Before Construction (Limestone seal coat)	17	33	5	24-41

TABLE 27: Skid Numbers on 14SH95 Test Sections

AGGREGATE TYPE	AGGREGATE QUANTITY sq. yds/cu. yds.	SKID NUMBER, (SN_{40})
A	150 165 180	58 57 58
B	110 125	61 62
D	155	57
H	160 180 200	64 60 63

Surface Texture

Surface texture measurements were made before and after placement of the seal coats by using the putty impression method (29). Results of this test are shown in Table 28. A typical value of texture for portland cement concrete pavements is 0.02 inches, asphalt concrete 0.02 inches, plant mix seal 0.06 inches and seal coats 0.08 inches (29). Additional measurements on these trial field sections should produce data that will indicate a decrease in surface texture with time and traffic.

Variations in texture depth exists in the test sections. The seals placed with Eastland and Ranger have similar texture depths, while the Clodine and Dallas materials have nearly identical textures. The reasons for this observed grouping is not evident from the gradations as the Dallas aggregate possesses a gradation similar to that of the Ranger and Eastland aggregates. However, visual examination indicated that degradation of the Dallas aggregate caused by construction and limited traffic was more pronounced than that occurring in the other aggregates.

A primary benefit of providing macrotexture surface to highway surfaces is to reduce the potential of hydroplaning. However, the reduction in hydroplaning may be balanced with the increased noise level often created when macrotexture is maximized.

Traffic

The Texas Highway Department Planning and Survey Division performed an hourly traffic count from Tuesday, September 14, to Tuesday, September 21, 1971. The results of this count indicate the average daily traffic count is 1400 vehicles per day with approximately 10 percent commercial vehicles using the roadway during the daylight hours. The 1970 Texas Highway Traffic Map indicates that the roadway carries 1220 vehicles per day.

TABLE 28: Surface Texture Measurements - 14SH95

Aggregate Type	Surface Texture, inches*	
	November 1971	March 1972
Clodine	0.105	——
Dallas	0.118	0.085
Eastland	0.136	0.122
Ranger	0.141	0.108
Precoated Limestone	0.136	0.102
Before Seal Coat	0.048	

Seal Coat Placed 22 October 1971

*represents average of a minimum of six measurements

The traffic in the southbound lanes is equivalent to the traffic in the northbound lanes in terms of amount as well as percent of commercial vehicles.

Roughness and Rating of Roadway

A Mays Ride Meter was utilized to measure road roughness before and after construction. An average Serviceability Index of 3.2 was measured before construction while 3.3 was measured after construction. Slight improvements have been noted in smoothness after seal coats based on data collected as part of Study 2-18-71-151.

Visual examinations conducted by personnel from the Texas Highway Department and Texas Transportation Institute are reported in Table 20*. Details of the method of examination and results will be discussed later in the report.

DISTRICT 2 TRIAL FIELD SECTION

Trial field sections were placed on SH6 west of Dublin, Texas on August 1 and 2, 1974. The layout of these test sections is shown in Tables 9 and 29. As noted the main variables investigated were aggregate quantity, aggregate type, aggregate moisture content and asphalt type.

Construction Sequence

All sections utilizing asphalt cement were placed on 1 August 1972, while the anionic emulsion sections were placed on 2 August 1972.

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*Rating team consisted of:

John Nixon, Engineer of Research, Planning and Research, Texas Highway Department
Irl Larrimore, Senior Field Engineer, Maintenance Operations, Texas Highway Department
Arthur J. Hill, Materials and Tests Bituminous Engineer, Materials and Tests, Texas Highway Department
W. W. Scott, Jr., Instructor, Texas A&M University
Jon A. Epps, Associate Research Engineer, Texas Transportation Institute

TABLE 29: Trial Field Section - 2 SH 6

Section Number	Lane	Location From	Location To	Type of Asphalt	Amount of Asphalt gal/yd² Design	Amount of Asphalt gal/yd² FHD	Amount of Asphalt gal/yd² TTI	Type of Aggregate	Quantity of Aggregate Design	Quantity of Aggregate TTI(2)	Quantity of Aggregate TTI(3)	Aggregate Moisture Content Percent	Aggregate Gradation, Accumalative Percent Retained: 1/2 inch	3/8 inch	No. 4	No. 10	Time: Date of Construction	Time: Asphalt Shot At	Rockland Placed At	Visual Evaluation 10/27/72	Visual Evaluation 6/19/72
2-M(160)C-(.29)AC(D)	EBL	40+55	45+78	AC	0.29	0.37		H	160		270	7.2	0.2	9.2	90.4	98.3	8-1-72	10:05	10:06	30.4	30.4
2-M(180)C-(.29)AC(D)	EBL	45+78	51+67	AC	0.29	0.37		H	180	105							"	10:07	10:10	27.8	29.8
2-M(200)C-(.29)AC(D)	EBL	51+67	58+21	AC	0.29	0.37		H	200	205							"	10:10	10:17	27.4	29.4
2-M(160)C-(.29)AC(D)	WBL	40+55	45+78	AC	0.29	0.31		H	160	185							"	3:50	3:57		
2-M(180)C-(.29)AC(D)	WBL	45+78	51+67	AC	0.29	0.29		H	180	175	210	5.9	0.2	5.3	81.8	95.0	"	3:27	3:44		
2-M(200)C-(.29)AC(D)	WBL	51+67	58+21	AC	0.29	0.29		H	200	170							"	3:25	3:36		
2-M(110)D-(.29)AC(D)	EBL	58+21	61+81	AC	0.29	0.29		B	110	170							"	10:28	10:29	31.0	30.0
2-M(125)D-(.29)AC(D)	EBL	61+81	65+90	AC	0.29	0.29	.24	B	125	140	150	16.7	3.2	34.4	89.9	98.0	"	10:31	10:32		
2-M(110)D-(.29)AC(D)	WBL	58+21	61+81	AC	0.29	0.29		B	110	110							"	3:24	3:34		
2-M(125)D-(.29)AC(D)	WBL	61+81	65+90	AC	0.29	0.29	.13	B	125	125	125	16.2	3.5	44.1	91.8	98.4	"	3.23	3:29		
2-M(155)E-(.29)AC(D)	EBL	65+90	70+97	AC	0.29	0.29		D	155		110	7.8	0.8	29.3	98.0	99.4	"	10:34	10:36	34.4	35.6
2-M(155)E-(.29)AC(D)	WBL	65+90	70+97	AC	0.29	0.29		D	155	155	140	7.2	0.2	31.6	98.7	99.5	"	3:22	3:24		
2-M(150)R-(.29)AC(D)	EBL	70+97	75+88	AC	0.29	0.29		A	150								"	10:48	10:49	33.4	33.0
2-M(165)R-(.29)AC(D)	EBL	75+88	81+28	AC	0.29	0.29	.25	A	165	155	150	8.8	2.03	27.2	93.6	99.5	"	10:50	10:53		
2-M(180)R-(.29)AC(D)	EBL	81+28	87+17	AC	0.29	0.29		A	180	175							"	10:52	10:58	30.0	32.2
2-M(150)R-(.29)AC(D)	WBL	70+97	75+88	AC	0.29	0.29		A	150	135							"	3:21	3:22		
2-M(165)R-(.29)AC(D)	WBL	75+88	81+28	AC	0.29	0.27	.23	A	165	180	145	5.8	0.6	13.8	89.8	99.1	"	2:50	2:58		
2-M(180)R-(.29)AC(D)	WBL	81+28	87+17	AC	0.29	0.29		A	180	185	195	9.2	0.1	14.3	90.6	98.8	"	2:48	2:55		
2-M(160)C-(.29)AC(M)	EBL	87+17	92+40	AC	0.29	0.29		H	160	160							"	10:54	11:03	31.6	31.8
2-M(180)C-(.29)AC(M)	EBL	92+40	98+29	AC	0.29	0.30		H	180	160							"	10:57	11:11	30.8	---
2-M(200)C-(.29)AC(M)	EBL	98+29	104+83	AC	0.29	0.30		H	200	200	120	10.2					"	11:00	11:13	30.8	---
2-M(160)C-(.29)AC(M)	WBL	87+17	92+40	AC	0.29	0.27		H	160	160	100	14.8	0	9.2	86.7	94.5	"	2:46	2:50		
2-M(180)C-(.29)AC(M)	WBL	92+40	98+29	AC	0.29	0.27		H	180	175							"	2:45	2:47		
2-M(200)C-(.29)AC(M)	WBL	98+29	104+83	AC	0.29	0.27		H	200	160			2.1	29.2	89.2	97.1	"	2:44	2:45		
2-M(110)D-(.29)AC(M)	EBL	104+83	108+43	AC	0.29	0.29		B	110	125							"	11.23	11:24	26.2	30.8
2-M(125)D-(.29)AC(M)	EBL	108+43	112+52	AC	0.29	0.29	.25	B	125	130	120	23.7	4.2	55.5	92.8	98.0	"	11:24	11:29		
2-M(110)D-(.29)AC(M)	WBL	104+83	108+43	AC	0.29	0.28		B	110	155							"	2:11	2:21		
2-M(125)D-(.29)AC(M)	WBL	108+43	112+52	AC	0.29	0.28	.27	B	125	90	170	23.9	3.0	50.8	91.2	97.0	"	2:10	2:20		
2-M(155)E-(.29)AC(M)	EBL	112+52	117+59	AC	0.29	0.29		D	155								"	11:26	11:32	35.4	34.6
2-M(155)E-(.29)AC(M)	WBL	112+52	117+59	AC	0.29	0.28		D	155	165	170	11.7	0.6	30.7	98.4	99.4	"	2:09	2:15		
2-M(150)R-(.29)AC(M)	EBL	117+59	122+50	AC	0.29	0.29	.29	A	150		120	9.8	2.3	31.8	92.6	97.8	"	11:27	11:37	35.8	33.8
2-M(165)R-(.29)AC(M)	EBL	122+50	127+90	AC	0.29	0.29		A	165								"	11:28	11:40	34.4	---
2-M(180)R-(.29)AC(M)	EBL	127+90	133+79	AC	0.29	0.29		A	180								"	11:30	11:45	32.6	---
2-M(150)R-(.29)AC(M)	WBL	117+59	122+50	AC	0.29	0.28		A	150	140							"	2:08	2:11		
2-M(165)R-(.29)AC(M)	WBL	122+50	127+90	AC	0.29	0.28	.25	A	165	165	130	11.8	1.6	23.9	92.8	99.1	"	2:07	2:09		
2-M(180)R-(.29)AC(M)	WBL	127+90	133+79	AC	0.29	0.28		A	180	190							"	2:06	2:06		
2-M(160)C-(.29)AC(W)	EBL	133+79	139+02	AC	0.29	0.28		H	160								"	12:25	12:27	28.6	30.2
2-M(180)C-(.29)AC(W)	EBL	139+02	144+91	AC	0.29	0.28		H	180		260	17.5	0	11.5	87.8	98.0	"	12:28	12:35		
2-M(200)C-(.29)AC(W)	EBL	144+91	151+45	AC	0.29	0.28		H	200								"	12:31	12:43	30.2	---
2-M(160)C-(.29)AC(W)	WBL	133+79	139+02	AC	0.29	0.28		H	160	155							"	1:50	1:57		
2-M(180)C-(.29)AC(W)	WBL	139+02	144+91	AC	0.29	0.28	.27	H	180								"	1:48	1:55		
2-M(200)C-(.29)AC(W)	WBL	144+91	151+45	AC	0.29	0.28		H	200	150							"	1:46	1:53		
2-M(110)D-(.29)AC(W)	EBL	151+45	155+05	AC	0.29	0.28		B	110		155	19.2	3.8	58.1	95.4	98.5	"	12:34	12:46	30.3	31.4
2-M(125)D-(.29)AC(W)	EBL	155+05	159+14	AC	0.29	0.28		B	125								"	12:37	12:48		
2-M(110)D-(.29)AC(W)	WBL	151+45	155+05	AC	0.29	0.28	.25	B	110	160	135	17.6	4.4	63.5	95.6	98.0	"	1:44	1:46		
2-M(125)D-(.29)AC(W)	WBL	155+05	159+14	AC	0.29	0.28		B	125	125							"	1:42	1:44		
2-M(155)E-(.29)AC(W)	EBL	159+14	164+21	AC	0.29	0.28		D	155	135	155	13.5	0.1	2.2	87.2	98.0	"	12:40	12:50	34.6	35.2
2-M(155)E-(.29)AC(W)	WBL	159+14	164+21	AC	0.29	0.28		D	155	160	125	11.5	0.4	28.0	96.8	98.7	"	1:40	1:40		
2-M(150)R-(.29)AC(W)	EBL	164+21	169+12	AC	0.29	0.27		A	150	140							"	12:53	12:55	33.6	---
2-M(165)R-(.29)AC(W)	ELL	169+12	174+52	AC	0.29	0.27	.26	A	165	260	195	14.6	1.4	27.5	95.4	99.1	"	12:55	12:59	33.2	---
2-M(180)R-(.29)AC(W)	EBL	174+52	180+41	AC	0.29	0.27		A	180	180							"	12:57	1:02	32.6	32.4
2-M(150)R-(.29)AC(W)	WBL	164+21	169+12	AC	0.29	0.32		A	150	140							"	1:25	1:28		
2-M(165)R-(.29)AC(W)	WBL	169+12	174+52	AC	0.29	0.32	.24	A	165	200	150	13.7	1.9	34.0	96.7	99.5	"	1:22	1:26		
2-M(180)R-(.29)AC(W)	WBL	174+52	180+41	AC	0.29	0.32		A	180								"	1:20	1:22		
2-M(110)D-(.37)E(D)	EBL	180+41	180+01	AE	0.37	0.37	.33	B	110		100	16.4	2.7	50.1	96.3	99.4	8-2-72	8:31	8:31	30.2	32.4
2-M(125)D-(.37)E(D)	EBL	184+01	188+10	AE	0.37	0.37		B	125	130							"	8:34	8:35		

TABLE 29 (Cont'd)

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd² DESIGN	AMOUNT OF ASPHALT gal/yd² THD	AMOUNT OF ASPHALT gal/yd² TTI	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	QUANTITY OF AGGREGATE TTI(2)	QUANTITY OF AGGREGATE TTI(3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION ACCUMULATIVE PERCENT RETAINED 1/2 inch	3/8 inch	No. 4	No. 10	TIME DATE OF CONSTRUCTION	ASPHALT SHOT AT	ROCKLAND PLACED AT	VISUAL EVALUATION 10/5/72	VISUAL EVALUATION 6/6/73
2-M(110)D-(.37)E(D)	WBL	180+41	184+01	AE	0.37	0.40	.38	B	110				2.0	51.1	92.1	97.2	"	1:48	1:52		
2-M(125)D-(.37)E(D)	WBL	184+01	188+10	AE	0.37	0.40		B	125	125							"	1:46	1:50		
2-M(155)E-(.37)E(D)	EBL	188+41	193+17	AE	0.37	0.37		D	155	205	140	7.0	0	26.1	98.5	99.4	"	8:36	8:38	33.6	35.6
2-M(155)E-(.37)E(D)	WBL	188+41	193+17	AE	0.37	0.40		D	155	150	130	11.5	0.3	25.7	97.2	99.0	"	1:44	1:46		
2-M(150)R-(.37)E(D)	EBL	193+17	198+08	AE	0.37	0.37		A	150								"	8:38	8:41	35.0	35.6
2-M(165)R-(.37)E(D)	EBL	198+08	203+48	AE	0.37	0.37		A	165	170	145	6.5	0.7	22.5	93.5	99.1	"	8:40	8:43	35.0	35.0
2-M(180)R-(.42)E(D)	EBL	203+48	209+37	AE	0.42	0.42		A	180								"	9:30	9:31	33.2	32.8
2-M(150)R-(.37)E(D)	WBL	193+17	198+08	AE	0.37	0.40	.39	A	150	150	95	6.4	1.1	21.6	90.5	98.1	"	1:42	1:44		
2-M(165)R-(.37)E(D)	WBL	198+08	203+48	AE	0.37	0.40		A	165	160							"	1:41	1:41		
2-M(180)R-(.42)E(D)	WBL	203+48	209+37	AE	0.42	0.41		A	180	240							"	1:22	1:32		
2-M(110)D-(.42)E(M)	EBL	209+37	212+97	AE	0.42	0.42		B	110								"	9:32	9:36	29.2	30.4
2-M(125)D-(.40)E(M)	EBL	212+97	217+06	AE	0.40	0.42	.49	B	125	130	145	25.9	2.9	56.0	94.8	98.6	".	9:35	9:40		
2-M(110)D-(.42)E(M)	WBL	209+37	212+97	AE	0.42	0.41		B	110	130							"	1:21	1:27		
2-M(125)D-(.40)E(M)	WBL	212+97	217+06	AE	0.40	0.41	.36	B	125	130	115	22.9	2.5	48.2	91.1	97.4	"	1:20	1:25		
2-M(155)D-(.40)E(M)	EBL	217+06	222+13	AE	0.40	0.42		B	155	155	85	12.1	0	31.6	97.5	98.9	"	9:37	9:43	33.0	34.25
2-M(155)D-(.40)E(M)	WBL	217+06	222+13	AE	0.40	0.41		B	155	155	90	13.7	0.5	25.7	97.0	98.7	"	1:18	1:20		
2-M(150)R-(.40)E(M)	EBL	222+13	227+04	AE	0.40	0.42		A	150	150							"	9:40	9:46	35.2	33.25
2-M(165)R-(.40)E(M)	EBL	227+04	232+44	AE	0.40	0.40	.49	A	165	160			1.3	30.0	91.8	98.3	"	9:54	9:54	33.4	---
2-M(180)R-(.40)E(M)	EBL	232+04	238+33	AE	0.40	0.40		A	180	190							"	9:56	9:58	33.3	---
2-M(150)R-(.40)E(M)	WBL	222+13	227+04	AE	0.40	0.41		A	150	150							"	1:17	1:18		
2-M(165)R-(.40)E(M)	WBL	227+04	232+44	AE	0.40	0.40	.44	A	165	165	220						"	1:00	1:05		
2-M(180)R-(.40)E(M)	WBL	232+44	238+33	AE	0.40	0.40		A	180	185							"	12:58	1:03		
2-M(160)C-(.40)E(W)	EBL	238+33	243+56	AE	0.40	0.40		H	160	170			0.1	6.9	85.5	97.7	"	9:58	10:01	31.2	---
2-M(180)C-(.40)E(W)	EBL	243+56	249+45	AE	0.40	0.40	.42	H	180	165	120	16.0					"	10:00	10:05	31.4	---
2-M(200)C-(.40)E(W)	EBL	249+45	255+99	AE	0.40	0.40		H	200	185							"	11:00	11:00	30.8	31.0
2-M(160)C-(.40)E(W)	WBL	238+33	243+56	AE	0.40	0.40	.35	H	160	175	140	22.5					"	12:56	12:57		
2-M(180)C-(.40)E(W)	WBL	243+56	249+45	AE	0.40	0.40		H	180	180							"	12:54	12:55		
2-M(200)C-(.40)E(W)	WBL	249+45	255+99	AE	0.40	0.41		H	200	185							"	12:38	12:45		
2-M(110)D-(.40)E(W)	EBL	255+99	259+59	AE	0.40	0.40		B	110	120							"	11:01	11:05	30.4	34.0
2-M(125)D-(.40)E(W)	EBL	259+59	263+68	AE	0.40	0.40	.48	B	125	125	125	27.4	2.3	49.2	95.5	98.9	"	11:02	11:06		
2-M(110)D-(.40)E(W)	WBL	255+99	259+59	AE	0.40	0.41		B	110	105							"	12:36	12:40		
2-M(125)D-(.40)E(W)	WBL	259+59	263+68	AE	0.40	0.41	.35	B	125	140	130	29.2	2.3	54.2	97.6	99.2	"	12:34	12:37		
2-M(155)E-(.40)E(W)	EBL	263+68	268+75	AE	0.40	0.40		D	155	155	110	13.8	0	26.7	98.2	99.3	"	11:04	11:10	34.8	35.6
2-M(155)E-(.40)E(W)	WBL	263+68	268+75	AE	0.40	0.41		D	155	165	130	17.3	0	21.7	94.7	98.1	"	12:32	12:34		
2-M(150)R-(.40)E(W)	EBL	268+75	273+66	AE	0.40	0.40		A	150	145							"	11:06	11:14	35.2	36.0
2-M(165)R-(.40)E(W)	EBL	273+66	279+06	AE	0.40	0.40		A	165	150							"	11:24	11:24	35.0	---
2-M(180)R-(.40)E(W)	EBL	279+06	284+95	AE	0.40	0.40		A	180		215	15.4	0.7	19.0	95.5	99.3	"	11:27	11:27		
2-M(150)R-(.40)E(W)	WBL	268+75	273+66	AE	0.40	0.41		A	150	165							"	12:30	12:31		
2-M(165)R-(.40)E(W)	WBL	273+66	279+06	AE	0.40	0.44		A	165	145	135	14.9	0.8	27.7	94.8	99.2	"	11:40	11:41		
2-M(180)R-(.40)E(W)	WBL	279+06	284+95	AE	0.40	0.44		A	180								"	11:35	11:38		
			280+0				.48														

TABLE 30: Temperature Extremes and Precipitation - 2SH6

DATE	TEMPERATURE, °F MAXIMUM	MINIMUM	PRECIPITATION, INCHES
29 July	98	74	---
30 July	101	68	---
31 July	96	67	---
1 August	97	69	---
2 August	96	68	---
3 "	96	69	---
4 "	90	68	0.10
5 "	92	68	0.10
6 "	97	68	---
7 "	100	71	---
8 "	99	72	---
9 "	100	68	0.15
10 "	90	68	1.05
11 "	90	68	0.60
12 "	85	68	0.52

Construction dates - 1 and 2 August

Delays between the asphalt shot and aggregate placement as shown in Table 29 were generally less than two minutes for both the asphalt cement sections and the anionic emulsion sections. Adequate adhesion between the aggregate and asphalt was achieved with these delays and under these environmental conditions.

Construction Equipment

Texas Highway Department District 2 maintenance equipment and crews were utilized for placement of the trial sections. A self-propelled spreader box, 4-cubic yard dump trucks and pneumatic-tired rolling equipment were utilized. Excess aggregate was not removed from the pavement after construction. Traffic was controlled during construction with a pilot car. After placement of the final seal load, uncontrolled traffic was allowed to use the facility. This occurred at 4:00 p.m. on August 1 and 2:00 p.m. on August 2.

Environmental Data

Average humidity and temperatures for the months of July, August and September of 1972 are shown in Table 23. Temperature extremes and precipitation for the period immediately prior and after construction recorded at Dublin at the east end of the project site are given in Table 30.

Asphalt and Aggregate Quantities

Asphalt and aggregate quantities determined during construction of the project are shown in Table 29. While properties are shown in Tables 2 and 15, average gradations are shown in Table 18 and moisture contents in Tables 29 and 30.

Skid Resistance

Skid measurements were made on the trial sections before and after the seal coats were placed. As noted in Table 31, a significant increase in

TABLE 31: Skid Resistance Data -2SH6

AGGREGATE TYPE	MOISTURE CONDITION	AGGREGATE QUANTITY*	NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION	RANGE
A	Dry	150 165 180	4 4 4	0.58 0.57 0.58	0.02 0.01 0.04	0.56-0.60 0.55-0.58 0.54-0.65
	Moist	150 165 180	4 4 4	0.59 0.57 0.58	0.02 0.01 0.02	0.57-0.61 0.55-0.59 0.55-0.61
	Wet	150 165 180	4 4 4	0.58 0.58 0.58	0.01 0.02 0.02	0.56-0.60 0.57-0.61 0.55-0.60
B	Dry	110 125	5 4	0.60 0.63	0.06 0.02	0.48-0.65 0.62-0.65
	Moist	110 125	4 4	0.61 0.62	0.03 0.02	0.56-0.64 0.60-0.64
	Wet	110 125	4 3	0.61 0.62	0.01 ----	0.60-0.63 0.61-0.64
D	Dry	155	4	0.58	0.01	0.56-0.60
	Moist	155	4	0.56	0.03	0.53-0.60
	Wet	155	4	0.56	0.01	0.54-0.57
H	Dry	160 180 200	5 4 4	0.62 0.63 0.63	0.01 0.02 0.04	0.60-0.64 0.61-0.66 0.58-0.66
	Moist	160 180 200	4 4 4	0.65 0.59 0.62	0.02 0.05 0.02	0.62-0.66 0.53-0.64 0.58-0.64
	Wet	160 180 200	4 4 4	0.65 0.57 0.63	0.03 0.04 0.02	0.63-0.69 0.52-0.62 0.60-0.64
Before Construction			10	.31	.04	0.27-0.40

*moisture condition at time of placement skid number is apparent between the old and new surface. Little difference exists between aggregate types. These skid data were obtained 7 days after construction.

Surface Texture

Surface texture measurements were made before and after placement of seal coats by using the putty impression method (29). Results of tests conducted before construction on 2SH6 are shown in Table 32. Surface texture variation across the lane is not evident from these data.

Table 33 shows surface texture measurements performed three months after construction on the various trial sections.

DISTRICT 11 TRIAL FIELD SECTIONS

Trial field sections were placed on U. S. Highway 59 and State Highway 103 near Lufkin, Texas, on the 8, 9, 10 and 21 of August 1972. The layout of these test sections is shown in Tables 34 and 35. As noted, the main variables investigated were aggregate quantity, aggregate type, asphalt quantity and traffic volume. These sections investigated the same variables as the sections in District 5 (Lubbock) but were placed in a different climate.

Construction Sequence

Construction was performed on US59 on August 8 and 10, 1972 and August 9, 10 and 21 on SH103.

The trial sections on US 59 which are located south of Diboll, Texas were placed on the passing lane first while traffic was directed to the travel lane. Emulsion was utilized the first day of construction. The last aggregate was placed at 11:16 a.m. Traffic control was maintained by

TABLE 32: Surface Texture Measurements - 2SH6 Before Construction

WHEEL PATH	SURFACE TEXTURE, INCHES		
	NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION
All	16	0.052	0.019
Outer	7	0.054	0.022
Inner	7	0.052	0.021
Between	2	0.049	---
Inner & Outer	14	0.052	0.019

TABLE 33: Surface Texture Measurements - 2SH6 After Construction

AGGREGATE TYPE	NUMBER OF READINGS	AVERAGE	STANDARD DEVIATION	RANGE
A	9	0.128	0.021	0.104-0.170
B	6	0.095	0.016	0.080-0.115
D	3	0.123	0.011	0.115-0.135
H	9	0.090	0.013	0.070-0.101

TABLE 34: 11 US 59 Layout of Test Section

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd² DESIGN	THD	TTI	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	(TTI(2)	TTI(3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION ACCUMULATIVE % RETAINED 1/2 Inch	3/8 Inch	No. 4	No. 10	TIME DATE OF CONSTRUCTION	ASPHALT SHOT AT	ROCK LAND PLACED AT	VISUAL EVALUATION 10/5/72	[illegible]
11-H(120)C-(.25)AC	TL	568+23	572+73	AC	.25	.29		H	120								8/10/72	7:50	7:51		
11-H(140)C-(.25)AC	TL	572+73	577+98	AC	.25	.29	.21	H	140	140	150	7.7	0.4	17.6	93.7	98.9	"	7:52	7:53		
11-H(150)C-(.25)AC	TL	577+98	583+61	AC	.25	.29		H	150	175							"	7:53	7:55		
11-H(120)C-(.25)AC	PL	568+23	572+73	AC	.25	.24		H	120	95							"	10:23	10:24		
11-H(140)C-(.25)AC	PL	572+73	577+98	AC	.25	.24	.23	H	140	115	100	8.3	0	12.9	89.1	96.8	"	10:22	10:22		
11-H(150)C-(.25)AC	PL	577+98	583+61	AC	.25	.24		H	150	150							"	10:19	10:20		
11-H(120)C-(.22)AC	TL	583+61	588+11	AC	.22	.23		H	120	125							"	8:06	8:07		
11-H(140)C-(.22)AC	TL	588+11	593+36	AC	.22	.23	.21	H	140	150			0.5	18.5	93.7	97.9	"	8:00	8:10		
11-H(150)C-(.22)AC	TL	593+36	598+99	AC	.22	.23		H	150	140							"	8:10	8:12		
11-H(120)C-(.22)AC	PL	583+61	588+11	AC	.22	.22		H	120	120	95	7.7					"	10:14	10:16		
11-H(140)C-(.22)AC	PL	588+11	593+36	AC	.22	.22	.20	H	140	140			0.7	19.5	97.1	99.2	"	10:12	10:14		
11-H(150)C-(.22)AC	PL	593+36	598+99	AC	.22	.22		H	150	170							"	10:10	10:11		
11-H(120)C-(.19)AC	TL	598+99	603+49	AC	.19	.21		H	120	120							"	8:21	8:22		
11-H(140)C-(.19)AC	TL	603+49	608+74	AC	.19	.21	.20	H	140	140			1.1	18.7	93.6	97.9	"	8:23	8:24		
11-H(150)C-(.19)AC	TL	608+74	614+37	AC	.19	.21		H	150	150							"	8:25	8:29		
11-H(120)C-(.19)AC	PL	598+99	603+49	AC	.19	.20		H	120	120							"	10:00	10:03		
11-H(140)C-(.19)AC	PL	603+49	608+74	AC	.19	.20	.18	H	140	125	105	8.0	0.3	16.9	92.0	98.9	"	9:58	10:01		
11-H(150)C-(19)AC	PL	608+74	614+37	AC	.19	.20		H	150	150							"	9:57	9:58		
11-H(120)D-(.22)AC	TL	614+37	618+87	AC	.22	.22		B	120								"	8:40	8:41		
11-H(140)D-(.22)AC	TL	618+87	624+12	AC	.22	.22	.19	B	140	140	155	28.2	1.2	22.8	74.9	97.3	"	8:42	8:43		
11-H(150)D-(.22)AC	TL	624+12	629+75	AC	.22	.22		B	150	150			1.6	35.3	86.8	98.3	"	8:44	8:46		
11-H(120)D-(.22)AC	PL	614+37	618+87	AC	.22	.24		B	120	90							"	10:46	10:48		
11-H(140)D-(.22)AC	PL	618+87	624+12	AC	.22	.24		B	140	140	115	20.8	0.9	56.3	93.3	98.1	"	10:45	10:46		
11-H(150)D-(.22)AC	PL	624+12	629+75	AC	.22	.24		B	150	175			1.2	43.3	90.8	97.6	"	10:43	10:44		
11-H(120)E-(.22)AC	TL	629+75	634+25	AC	.22	.22		D	120	120							"	8:53	8:54		
11-H(140)E-(.22)AC	TL	634+25	639+50	AC	.22	.22	.19	D	140	140			0.3	33.6	98.1	99.0	"	8:55	8:56		
11-H(150)E-(.22)AC	TL	639+50	645+13	AC	.22	.22		D	150	155	165	11.6	0.9	34.8	98.0	99.0	"	8:56	8:58		
11-H(120)E-(.22)AC	PL	629+75	634+25	AC	.22	.22		D	120	140							"	10:34	10:36		
11-H(140)E-(.22)AC	PL	634+25	639+50	AC	.22	.22		D	140	120			0.8	37.9	97.7	98.6	"	10:32	10:34		
11-H(150)E-(.22)AC	PL	639+50	645+13	AC	.22	.22		D	150	150			0.3	43.0	98.6	99.3	"	10:31	10:32		
11-H(120)R-(.25)AC	TL	645+13	649+63	AC	.25	.22		A	120								"	9:07	9:08		
11-H(140)R-(.25)AC	TL	649+63	654+88	AC	.25	.22	.21	A	140	130	100	8.1	1.3	37.3	96.2	98.3	"	9:09	9:10		
11-H(150)R-(.25)AC	TL	654+88	660+151	AC	.25	.22		A	150	150							"	9:10	9:12		
11-H(120)R-(.25)AC	PL	645+13	649+63	AC	.25	.26		A	120	120							"				
11-H(140)R-(.25)AC	PL	649+63	654+88	AC	.25	.26	.23	A	140	170	95	13.3	1.3	41.5	95.3	98.4	"				
11-H(150)R-(.25)AC	PL	654+188	660+51	AC	.25	.26		A	150	135							"				
11-H(120)R-(.22)AC	TL	660+51	665+51	AC	.22	.20	.21	A	120	120	110	11.5	1.7	40.2	97.2	98.5	8/10/72	9:17	9:18		
11-H(140)R-(.22)AC	TL	665+51	670+26	AC	.22	.20		A	140	125							"	9:19	9:20		
11-H(150)R-(.22)AC	TL	670+26	675+89	AC	.22	.20		A	150	145							"	9:21	9:22		
11-H(120)R-(.22)AC	PL	660+151	665+51	AC	.22	.21	.17	A	120	110	105	13.4	0.7	38.3	93.0	96.7	"				
11-H(140)R-(.22)AC	PL	665+51	670+26	AC	.22	.21		A	140	140							"				
11-H(150)R-(.22)AC	PL	670+26	675+89	AC	.22	.21		A	150	150							"				
11-H(120)R-(.19)AC	TL	675+89	680+39	AC	.19	.22		A	120	175							"	9:30	9:31		
11-H(140)R-(.19)AC	TL	680+39	685+64	AC	.19	.22	.20	A	140	125			1.1	34.7	96.2	98.2	"	9:33	9:33		
11-H(150)R-(.19)AC	TL	685+64	691+27	AC	.19	.22		A	150	195							"	9:36	9:36		
11-H(120)R-(.19)AC	PL	675+89	680+39	AC	.19	.21		A	120	115							"				
11-H(140)R-(.19)AC	PL	680+39	685+74	AC	.19	.21	.19	A	140	140			0.9	40.1	97.0	98.0	"				
11-H(150)R-(.19)AC	PL	685+64	691+27	AC	.19	.21		A	150	150							"				
11-H(120)C-(.33) E	TL	691+27	700+27	AE	.33	.31	.35	H	120	140	135	7.1	11.5	11.5	93.7	98.8	8/8/72	10:20	10:22	29.83	20.[illegible]
11-H(140)C-(.33) E	TL	700+27	710+77	AE	.33	.33		H	140	160	130	6.7	0	11.8	93.3	98.4	"	10:25	10:27	30.2	[illegible]
11-H(150)C-(.33) E	TL	710+77	716+40	AE	.33	.31		H	150	135							"	10:37	10:37		
11-H(120)C-(.33) E	PL	691+27	700+27	AE	.33	.33	.41	H	120		100	6.3	0	9.5	90.7	97.3	"	8:26	8:29	[illegible]	[illegible]
11-H(140)C-(.33) E	PL	700+27	710+40	AE	.33	.33		H	140	140	130	7.1	0	11.1	92.6	99.0	"	8:36	8:34	[illegible]	[illegible]
11-H(150)C-(.33) E	PL	710+77	716+40	AE	.33	.33		H	150	155							"	8:45	8:42		
11-H(120)D-(.33) E	TL	716+40	726+53	AE	.33	.34		B	120	95	110	24.5	0.3	19.2	75.3	97.5	"	10:33	10:44	[illegible]	[illegible]
11-H(140)D-(.33) E	TL	726+53	731+78	AE	.33	.34	.30	B	140	145							"	10:40	10:47	[illegible]	[illegible]
11-H(150)D-(.33) E	TL	731+78	737+41	AE	.33	.34		B	150	150	135	25.1	1.9	36.3	82.7	97.8	"	10:43	10:49		
11-H(120)D-(.33) E	PL	716+40	726+53	AE	.33	.32	.34	B	120		105	22.9	25.2	31.2	84.4	98.3	"	8:45	8:55	[illegible]	[illegible]
11-H(140)D-(.33) E	PL	726+53	731+78	AE	.33	.32		B	140	175							"	8:48	9:00	[illegible]	[illegible]
11-H(150)D-(.33) E	PL	731+78	737+41	AE	.33	.32		B	150	165	180	23.5	2.1	31.0	82.7	97.3	"	8:52	9:03		

TABLE 34 (Cont'd)

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd² DESIGN	AMOUNT OF ASPHALT gal/yd² THD	AMOUNT OF ASPHALT gal/yd² TTI	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	QUANTITY OF AGGREGATE TTI(2)	QUANTITY OF AGGREGATE TTI(3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION, ACCUMULATIVE PERCENT RETAINED 1/2 inch	3/8 inch	No. 4	No. 10	TIME: DATE OF CONSTRUCTION	TIME: ASPHALT SHOT AT	TIME: ROCKLAND PLACED AT	VISUAL EVALUATION 10/5/72	VISUAL EVALUATION 6/6/73
11-H(120)E-(.33) E	TL	737+41	741+91	AE	.33	.34		D	120	110							"	10:57	10:57	34.16	34.0
11-H(140)E-(.33) E	TL	741+91	745+62	AE	.33	.34	.27	D	140	140	135	11.8	0	39.7	98.6	.99.3	"	10:59	11:00	32.66	30.71
11-H(150)E-(.33) E	TL	745+67	752+79	AE	.33	.34		D	150	185	135	11.8					"	11:00	11:02		
11-H(120)E-(.33) E	PL	737+41	741+91	AE	.33	.32		D	120	160							"	9:09	9:11	35.66	36.43
11-H(140)E-(.33) E	PL	741+91	745+62	AE	.33	.32	.27	D	140	155	140	11.3	0.8	41.7	98.2	99.3	"	9:11	9:13	35.16	35.73
11-H(150)E-(.33) E	PL	745+67	752+75	AE	.33	.32		D	150	90	110	10.2					"	9:15	9:18		
11-H(120)R-(.33) E	TL	752+79	761+79	AE	.33	.35	.26	A	120	105	110	11.6	0.7	36.5	97.0	98.7	"	11:13	11:13	33.5	30.71
11-H(120)R-(.33) E	PL	752+79	761+79	AE	.33	.32	.41	A	120	105	125	11.6	0.9	37.9	96.9	98.4	"	9:25	9:26	34.5	35.57

TABLE 35: 11 SH 103 Layout of Test Section

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd² DESIGN	AMOUNT OF ASPHALT THD	AMOUNT OF ASPHALT TTI	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	QUANTITY OF AGGREGATE TTI(2)	QUANTITY OF AGGREGATE TTI(3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION ACCUMALATIVE PERCENT RETAINED 1/2 inch	3/8 inch	No. 4	No. 10	DATE OF CONSTRUCTION	TIME ASPHALT SHOT AT	TIME ROCKLAND PLACED AT	VISUAL EVALUATION 10/5/72	VISUAL EVALUATION 6/6/73
11-M(120)C-(0.22)AC	EBL	307+50	316+50	AC	0.22	0.21		H	120	120							8-10-72	12:55	12:56		
11-M(140)C-(0.22)AC	EBL	316+50	327+00	AC	0.22	0.21		H	140	145	85	8.8	0	5.5	63.1	71.4	"	12:59	1:00		
11-M(150)C-(0.22)AC	EBL	327+00	338+26	AC	0.22	0.21		H	150	145	110	10.6	0	15.9	92.2	98.9	"	1:02	1:07		
11-M(120)C-(0.22)AC	WBL	307+50	316+60	AC	0.22	0.21		H	120								"				
11-M(140)C-(0.22)AC	WBL	316+50	327+00	AC	0.22	0.21		H	140								"				
11-M(140)C-(0.22)AC	WBL	327+00	338+26	AC	0.22	0.21		H	140								"				
11-M(140)D-(0.22)AC	EBL	338+26	348+76	AC	0.22	0.25		B	140	140	135	22.7	4.5	51.3	92.8	98.3	"	1:16	1:17		
11-M(140)D-(0.22)AC	WBL	338+26	348+76	AC	0.22	0.25		B	140								"				
11-M(120)D-(0.22)AC	EBL	348+76	357+76	AC	0.22	0.21		B	120	145	125	19.9	3.6	47.5	91.9	97.5	"	1:23	1:24		
11-M(140)D-(0.22)AC	EBL	357+76	368+26	AC	0.22	0.21		B	140	140							"	1:27	1:28		
11-M(150)D-(0.22)AC	EBL	368+26	379+52	AC	0.22	0.21		B	150	140			0.2	28.1	97.2	98.7	"	1:30	1:35		
11-M(120)D-(0.22)AC	WBL	348+76	357+76	AC	0.22	0.21		B	120								"				
11-N(140)D-(0.22)AC	WBL	357+76	368+26	AC	0.22	0.21		B	140								"				
11-M(150)D-(0.22)AC	WBL	368+26	379+52	AC	0.22	0.21		B	150								"				
11-M(140)D-(0.19)AC	EBL	379+52	390+02	AC	0.19	0.21		B	140	140							"	1:42	1:42		
11-M(140)D-(0.19)AC	WBL	379+52	390+02	AC	0.19	0.21		B	140								"				
11-M(140)E-(0.25)AC	EBL	390+02	400+52	AC	0.25	0.27		D	140	120	90	12.9					"	1:49	1:50		
11-M(140)E-(0.25)AC	WBL	390+02	400+52	AC	0.25	0.27		D	140								"				
11-M(120)E-(0.22)AC	EBL	400+52	409+52	AC	0.22	0.21		D	120	185	125	15.2					"	1:59	1:59		
11-M(140)E-(0.22)AC	EBL	409+52	420+02	AC	0.22	0.21		D	140	135							"	2:03	2:04		
11-M(150)E-(0.22)AC	EBL	420+02	431+28	AC	0.22	0.21		D	150	140							"	2:07	2:12		
11-M(120)E-(0.22)AC	WBL	400+52	409+52	AC	0.22	0.21		D	120				0.1	31.3	97.3	98.8	"				
11-M(140)E-(0.22)AC	WBL	409+52	420+02	AC	0.22	0.21		D	140								"				
11-M(150)E-(0.22)AC	WBL	420+02	431+28	AC	0.22	0.21		D	150								"				
11-M(150)C-( )CE	EBL	431+28	442+54	CE				H	150		170	17.7					8-21-72				
11-M(150)C-( )CE	WBL	431+28	442+54	CE			.30	H	150		145	18.0					"				
11-M(150)E-( )CE	EBL	442+52	453+80	CE			.29	D	150		210	14.7					"				
11-M(150)E-( )CE	WBL	442+52	453+80	CE			.34	D	150		170	13.7					"				
11-M(150)D-( )CE	EBL	453+80	461+28	CE			.29	B	150		190	30.5					"				
11-M(150)D-( )CE	WBL	435+80	461+28	CE			.28	B	150		210	20.1					"				
11-M(120)C-(0.33)AE	EBL	461+28	470+28	AE	0.33	0.31	.27	H	120	150	110	10.7	0.1	12.7	90.6	98.7	8-9-72	8:12	8:13	31.0	31.33
11-M(140)C-(0.33)AE	EBL	470+78	480+78	AE	0.33	0.31		H	140	150	125	10.4	0	15.2	90.8	98.4	"	8:15	8:17		
11-M(150)C-(0.33)AE	EBL	480+78	492+04	AE	0.33	0.33		H	150	155							"	8:27	8:27		
11-M(120)C-(0.33)AE	WBL	461+28	470+28	AE	0.33	0.31	.32	H	120	170	135	9.9	0	17.0	93.7	99.0	"	2:33	2:37		
11-M(140)C-(0.33)AE	WBL	470+78	480+78	AE	0.33	0.31		H	140	150			0	12.4	87.1	97.1	"	2:28	2:28		
11-M(150)C-(0.33)AE	WBL	480+78	492+04	AE	0.33	0.33		H	150	155							"	2:17	2:18		
11-M(140)D-(0.38)AE	EBL	492+04	502+54	AE	0.38	0.38	.31	H	140	185	150	21.2	3.9	48.0	92.0	97.6	"	8:38	8:39	29.8	TL-29.17 PL-29.67
11-M(140)D-(0.38)AE	WBL	492+04	502+54	AE	0.38	0.38	.32	H	140	135	110	19.3	3.8	49.4	88.9	96.3	"	1:13	1:15		
11-M(120)D-(0.33)AE	EBL	502+54	511+54	AE	0.33	0.35		B	120	125							"	8:52	8:52	31.4	29.83
11-M(140)D-(0.33)AE	EBL	511+54	522+04	AE	0.33	0.35	.32	B	140	140	105	22.3	1.3	33.6	74.7	91.9	"	8:56	9:58		
11-M(150)D-(0.33)AE	EBL	522+04	533+30	AE	0.33	0.36		B	150	155							"	9:06	9:06		
11-M(120)D-(0.33)AE	WBL	502+54	511+54	AE	0.33	0.35		B	120	135							"	1:03	1:08		
11-M(140)D-(0.33)AE	WBL	511+54	522+04	AE	0.33	0.35	.30	B	140	135	115	17.8	2.6	44.4	88.4	96.7	"	12:58	1:01		
11-M(150)D-(0.33)AE	WBL	522+04	533+30	AE	0.33	0.36		B	150	160							"	12:47	12:48		
11-M(140)D-(0.38)AE	EBL	533+30	543+80	AE	0.33	0.29		B	140	130	105	17.9	1.8	42.7	88.7	96.4	"	9:14	9:14	31.2	30.00
11-M(140)D-(0.38)AE	WBL	533+30	543+80	AE	0.33	0.29	.31	B	140	130	115	25.9	1.5	39.3	86.3	95.6	"	12:34	12:34		
11-M(140)E-(0.33)AE	EBL	543+80	554+30	AE	0.33	0.39	.32	D	140	135	120	15.7	0.7	36.4	98.0	99.0	"	9:25	9:26	34.8	34.20
11-M(140)E-(0.33)AE	WBL	543+80	554+30	AE	0.33	0.39	.33	D	140	135	100	13.5	0.5	41.6	97.2	98.3	"	11:44	11:45		
11-M(120)E-(0.33)AE	EBL	554+30	563+30	AE	0.33	0.31		D	120	115							"	9:34	9:35	34.2	36.00
11-M(140)E-(0.33)AE	EBL	563+30	573+80	AE	0.33	0.31	.26	D	140	145	90	14.8	0.3	30.4	94.1	97.4	"	9:36	9:39		
11-M(150)E-(0.33)AE	EBL	573+80	585+06	AE	0.33	0.33		D	150	155							"	9:50	9:51		
11-M(120)E-(0.33)AE	WBL	554+30	563+30	AE	0.33	0.31		D	120	120							"	11:36	11:40		
11-M(140)E-(0.33)AE	WBL	563+30	573+80	AE	0.33	0.31	.31	D	140	140	105	13.8	0.3	36.9	97.2	98.6	"	11:31	11:32		
11-M(150)E-(0.33)AE	WBL	573+80	585+06	AE	0.33	0.33		D	150	155							"	11:17	11:18		

TABLE 35 (Cont'd)

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd² DESIGN	AMOUNT OF ASPHALT gal/yd² THD	AMOUNT OF ASPHALT gal/yd² TTI	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	QUANTITY OF AGGREGATE TTI(2)	QUANTITY OF AGGREGATE TTI(3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION ACCUMULATIVE PERCENT RETAINED 1/2 inch	3/8 inch	No. 4	No. 10	TIME DATE OF CONSTRUCTION	TIME ASPHALT SHOT AT	TIME ROCKLAND PLACED AT	VISUAL EVALUATION 10/5/72	VISUAL EVALUATION 6/6/73
11-M(140)E-(0.28)AE	EBL	585+06	595+56	AE	0.28	0.32		D	140	125	90	13.7	0.4	28.3	92.6	96.4	"	9:59	9:59	34.2	35.14
11-M(140)E-(0.28)AE	WBL	585+06	595+56	AE	0.28	0.32	.25	D	140	135	110	15.4	0.3	41.4	97.0	98.3	"	11:10	11:11		
11-M(120)R-(0.33)AE	EBL	595+56	604+56	AE	0.33	0.33	.31	A	120	130	115	12.0	1.3	40.6	96.1	98.5	"	10:11	10:12	33.3	35.72
11-M(140)R-(0.33)AE	EBL	604+56	615+06	AE	0.33	0.33		A	140	155	85	13.1	2.1	33.1	93.4	97.7	"	10:20	10:22		
11-M(120)R-(0.33)AE	WBL	595+56	604+56	AE	0.33	0.33	.26	A	120	120	110	15.3	1.2	40.0	96.7	98.5	"	10:46	10:50		
11-M(140)R-(0.33)AE	WBL	604+56	615+06	AE	0.33	0.33		A	140	135	130	11.0	1.9	47.5	97.7	98.9	"	10:42	10:43		
11-M(150)D-( )CE	EBL	615+06	624+47	CE		0.20		B	150		215	26.8					8-21-72			34.2	
11-M(150)D-( )CE	WBL	615+06	624+47	CE		0.34		B	150		205	22.1					"				
11-M(150)R-( )CE	EBL	624+47	641+36	CE		0.33		A	150		185	14.3					"				
11-M(150)R-( )CE	WBL	624+47	641+36	CE		0.33		A	150		215	16.4					"				

signing until 4:00 p.m. Asphalt cement was utilized on August 10. The final asphalt shot occurred at 11:17 a.m., and uncontrolled traffic was turned on the facility. Rainfall occurred between 2:00 and 3:00 p.m. resulting in loss of aggregate from all sections placed on US59 on August 10. Visual examination of the sections indicated that aggregates B and H degraded excessively; however, some fine aggregate remained in the wheelpath. Aggregates A and D showed considerably less degradation although the aggregate and asphalt was completely removed from the wheelpath. These trial sections were removed by a blade and replaced with an open-graded plant mix friction course.

Trial sections utilizing the emulsions as the binder were placed on SH103 on 9 August. The last asphalt shot occurred at 2:33 p.m. and uncontrolled traffic was allowed to use the facility at 4:00 p.m. Aggregate was spread immediately behind the asphalt distribution and prior to the emulsion breaking as indicated by a color change from brown to black on several rock lands. No adverse effects were noted on these sections. At 1:13 p.m. on 9 August the emulsion was shot. Due to a breakdown in the aggregate loader, aggregate was placed at 2:11 p.m. No adverse effects have been noted in this section.

Trial sections placed with asphalt cement on SH103 on 10 August experienced rain as did those on US59. Construction began at 12:55 p.m. on SH103 and terminated at 2:14 p.m. a few minutes prior to rainfall. Uncontrolled traffic was allowed on the facility at 3:15 p.m. The remaining asphalt cement section were not placed; however, on August 21 additional sections utilizing cationic emulsion were placed as described in Table 34.

Visual evaluation of the asphalt cement sections on SH103 subjected to traffic and rainfall indicated that all of the asphalt and aggregate was not removed from the wheelpath as occurred on US59. Aggregates A and D performed better than Aggregates B and H.

Construction Equipment

Texas Highway Department District 11 maintenance equipment and crews were utilized for placement of the trial sections. A self-propelled spreader box, 5-cubic yard dump trucks and pneumatic-tired rolling equipment were utilized. Excess aggregate was not removed from the pavement after construction.

Environmental Data

Average humidity and temperature for the months of July, August and September of 1972 are shown in Table 23. Temperature extremes and precipitation for the period immediately prior and after construction recorded at the Lufkin airport which is 10 miles north of 11US59 project and 10 miles west of 11SH103 project are given in Table 36. Rainfall was recorded at the airport during the afternoon of August 10. These showers were associated with the loss of aggregate on both projects.

Asphalt and Aggregate Quantity

Asphalt and aggregate quantities determined during construction of the projects are shown in Tables 34 and 35. Properties of the aggregates utilized on this project are shown in Tables 2 and 15. Average gradations are shown in Table 18 and moisture contents in Tables 34 and 35.

Skid Resistance

Skid measurements were made on the trial section location prior to construction. A skid number of 36 was reported for SH103 and 29 for US59. No measurements have been made after construction of the sections.

TABLE 36: Temperature Extremes and Precipitation - 11US59 & 11SH103

DATE	TEMPERATURE, °F MAXIMUM	MINIMUM	PRECIPITATION, INCHES
5 August	96	71	---
6 August	98	67	---
7 "	97	67	---
8 "	92	72	---
9 "	95	75	---
10 "	93	71	0.05
11 "	91	71	T
12 "	91	73	0.68
13 "	90	73	0.32
14 "	88	70	1.34
15 "	92	68	0.21
16 "	90	72	---
17 "	90	74	0.03

Construction Dates - 8, 9, 10 August

Surface Texture

Surface texture measurements were made before placement of seal coats by using the putty impression method (29). Results of these tests are shown on Table 37. No measurements have been made after construction of the sections.

DISTRICT 5 TRIAL FIELD SECTIONS

Trial field sections were placed on U. S. Highway 62 (also US82) and FM1730 south of Lubbock, Texas on the 22, 23 and 24 of August 1972. The layout of these test sections is shown in Tables 38 and 39. As noted, the main variables investigated were aggregate quantity, aggregate type, asphalt quantity and traffic volume. These sections investigated the same variables as the sections in District 11 (Lufkin) but were placed in a different climate.

Construction Sequence

Construction was performed on US62 August 22 and 23, 1972 and August 23 and 24 on FM1730. The trial sections on US62 were placed on the passing lane first while traffic was directed to the travel lane.

The final rock land was placed at 3:07 on the passing lane with lane opened to traffic at 3:15 p.m. on 22 August 1972. Both lanes were opened to uncontrolled traffic at 6:00 p.m. on 22 August 1972.

Delays between the asphalt shot and the aggregate placement as shown on Tables 38 and 39 were less than one minute for the first rock land and from 7 to 10 minutes for the last rock land of an asphalt shot. Adequate adhesion between the aggregate and asphalt was achieved with these delays and under these environmental conditions.

TABLE 37: Surface Texture Measurements - 11US59 and 11SH103

PROJECT DESIGNATION	LANE	LOCATION	SURFACE TEXTURE, INCHES		
			NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION
11US59	Travel	Wheel Path	2	0.037	
	Passing	Wheel Path	5	0.040	0.006
		Between Wheel Path	1	0.036	
11SH103	East Bound	Wheel Path	6	0.039	0.004
	West Bound	Wheel Path	6	0.036	0.004

TABLE 38: Trial Field Section - 5 US 62

SECTION NUMBER	LANE	LOCATION FROM	LOCATION TO	TYPE OF ASPHALT	AMOUNT OF ASPHALT GAL/YD² DESIGN	AMOUNT OF ASPHALT GAL/YD² THD	AMOUNT OF ASPHALT GAL/YD² [illegible]	TYPE OF AGGREGATE	QUANTITY OF AGGREGATE DESIGN	QUANTITY OF AGGREGATE [illegible](2)	QUANTITY OF AGGREGATE [illegible](3)	AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION, ACCUMULATIVE PERCENT RETAINED 1/2 inch	3/8 inch	No. 4	No. 10	TIME: DATE OF CONSTRUCTION	ASPHALT SHOT AT	ROCKLAND PLACED AT	VISUAL EVALUATION 9/21/72	5/22/73
5-H(120)C-(0.37)AC	TL	330+00	333+60	AC	0.37	0.46		H	[illegible]	[illegible]							8-22-72	3:37	3:37	25.41	23.33
5-H(135)C-(0.37)AC	TL	333+60	341+70	AC	0.37	0.46	.39	H	[illegible]	---							"	3:40	3:42	24.08	25.67
5-H(140)C-(0.37)AC	TL	341+70	345+90	AC	0.37	0.46		H	[illegible]	[illegible]	80	13.7	2.0	29.4	93.0	98.4	"	3:43	3:50	29.30	25.67
5-H(120)C-(0.39)AC	PL	330+00	333+60	AC	0.39	0.39		H	120	105							"	10:30	10:33	31.66	31.00
5-H(135)C-(0.39)AC	PL	333+60	341+70	AC	0.39	0.39	.40	H	135	[illegible]							"	10:34	10:35	31.41	30.50
5-H(140)C-(0.39)AC	PL	341+70	345+90	AC	0.39	0.39		H	140	[illegible]			1.0	18.3	91.5	98.[illegible]	"	10:36	10:42	33.00	30.50
5-H(120)C-(0.32)AC	TL	345+90	353+10	AC	0.32	0.37	.36	H	120	120	130	17.3					"	4:13	4:14	30.83	27.30
5-H(135)C-(0.32)AC	TL	353+10	361+20	AC	0.32	0.37		H	135	135			.9	25.6	93.9	98.7	"	4:16	4:17	30.16	30.00
5-H(140)C-(0.32)AC	TL	361+20	369+60	AC	0.32	0.37		H	140	145							"	4:21	4:28		
5-H(120)C-(0.34)AC	PL	345+90	353+10	AC	0.34	0.37	.37	H	120	95							"	10:54	10:55	32.33	31.00
5-H(135)C-(0.34)AC	PL	353+10	361+20	AC	0.34	0.37		H	135	185			1.6	26.4	92.9	98.1	"	10:56	10:59	30.16	30.33
5-H(140)C-(0.34)AC	PL	361+20	369+60	AC	0.34	0.37		H	140	165							"	11:48	11:48		
5-H(120)C-(0.27)AC	TL	369+60	373+20	AC	0.27	0.30		H	120	115							"	4:51	4:52	31.33	29.00
5-H(135)C-(0.27)AC	TL	373+20	381+30	AC	0.27	0.30	.28	H	135	135							"	4:54	4:55	32.33	28.33
5-H(140)C-(0.27)AC	TL	381+30	389+70	AC	0.27	0.30		H	140	140	165	22.1	0.4	17.7	88.8	97.1	"	4:56	5:08		
5-H(120)C-(0.29)AC	PL	369+60	373+20	AC	0.29	0.35		H	120	110							"	11:55	11:55	31.66	32.33
5-H(135)C-(0.29)AC	PL	373+20	381+30	AC	0.29	0.35	.37	H	135	135							"	11:57	11:58	32.83	33.00
5-H(140)C-(0.29)AC	PL	381+30	389+70	AC	0.29	0.35		H	140	120	140	18.3	.5	14.9	87.7	97.6	"	12:00	12:06		
5-H(120)D-(0.32)AC	TL	389+70	396+90	AC	0.32	0.37	.33	B	120	145							"	5:26	5:27	22.33	22.33
5-H(135)D-(0.32)AC	TL	396+90	405+00	AC	0.32	0.37		B	135	170	195	43.5	4.6	60.7	95.8	98.7	"	5:29	5:30	25.33	25.67
5-H(140)D-().32)AC	TL	405+00	413+50	AC	0.32	0.37		B	140	140	255	37.9	4.2	69.8	94.4	97.3	"	5:33	5:44		
5-H(120)B-(0.34)AC	PL	389+70	396+90	AC	0.34	0.35		B	120	105							"	12:40	12:40	25.66	25.67
5-H(135)D-(0.34)AC	PL	396+90	405+00	AC	0.34	0.35	.52	B	135	155							"	12:44	12:45	28.83	30.33
5-H(140)D-(0.34)AC	PL	405+00	413+50	AC	0.34	0.35		B	140	185	165	35.6	7.9	49.8	89.4	97.6	"	12:47	12:56		
5-H(120)E-(0.32)AC	TL	413+50	420+60	AC	0.32	0.32		D	120	120	170	7.9	0.6	46.8	98.7	99.2	8-23-72	9:40	9:41	34.83	34.33
5-H(135)E-(0.32)AC	TL	420+60	428+70	AC	0.32	0.32		D	135	135							"	9:44	9:44	35.08	36.67
5-H(140)E-(0.32)AC	TL	428+70	437+10	AC	0.32	0.32		D	140	135			0.8	37.6	98.4	99.1	"	9:48	9:58		
5-H(120)E-(0.34)AC	PL	413+50	420+60	AC	0.34	0.35		D	120	100							"	1:16	1:17	35.33	34.67
5-H(135)E-(0.34)AC	PL	420+60	428+70	AC	0.34	0.35	.19	D	135	135	130	7.8	0.8	57.6	95.2	96.9	"	1:22	1:22	34.25	35.33
5-H(140)E-(0.34)AC	PL	428+70	437+10	AC	0.34	0.35		D	140	145	120	8.4	.9	52.2	98.1	98.7	"	1:24	1:33		
5-H(120)R-(0.37)AC	TL	437+10	440+70	AC	0.37	0.38		A	120	125			2.3	42.4	96.7	98.3	"	10:22	10:22	34.41	34.00
5-H(135)R-(0.37)AC	TL	440+70	448+80	AC	0.37	0.38	.35	A	135	135	135	7.7	.9	23.7	89.6	97.5	"	10:24	10:24		32.67
5-H(140)R-(0.37)AC	TL	448+80	453+00	AC	0.37	0.38		A	140	145							"	10:28	10:28		
5-H(120)R-(0.39)AC	PL	437+10	440+70	AC	0.39	0.39		A	120	110			1.7	37.7	95.9	98.8	"	1:55	1:56	35.6	33.33
5-H(135)R-(0.39)AC	PL	440+70	448+80	AC	0.39	0.39		A	135	135	110	6.7	1.9	26.0	88.3	97.3	"	1:57	2:00		34.67
5-H(140)R-(0.39)AC	PL	448+80	453+00	AC	0.39	0.39		A	140	145							"	2:00	2:02		
5-H(120)R-(0.32)AC	TL	453+00	456+60	AC	0.32	0.23		A	120	115							"	10:35	10:38	35.33	33.33
5-H(135)R-(0.32)AC	TL	456+60	460+65	AC	0.32	0.23		A	135	135	125	6.0	1.7	23.7	87.7	97.2	"	10:37	10:44		33.67
5-H(140)R-(0.32)AC	TL	460+65	464+85	AC	0.32	0.23		A	140	130							"	10:39	10:44		
5-H(120)R-(0.34)AC	PL	453+00	456+60	AC	0.34	0.37		A	120	115			1.3	24.5	85.3	96.3	"			35.50	35.30
5-H(135)R-(0.34)AC	PL	456+60	460+65	AC	0.34	0.37	.37	A	135	150	140	6.0					"				34.30
5-H(140)R-(0.34)AC	PL	460+65	464+85	AC	0.34	0.37		A	140	155							"				
5-H(120)R-(0.27)AC	TL	464+85	468+45	AC	0.27	0.28		A	120	115							"	11:07	11:07	34.20	34.30
5-H(135)R-(0.27)AC	TL	468+45	476+55	AC	0.27	0.28	.38	A	135	115							"	11:09	11:09		33.30
5-H(140)R-(0.27)AC	TL	476+55	480+75	AC	0.27	0.28		A	140	175	180	8.0	1.9	43.3	94.0	98.6	"				
5-H(120)R-(0.29)AC	PL	464+85	488+45	AC	0.29	0.36		A	120	110							"			35.0	34.33
5-H(135)R-(0.29)AC	PL	468+45	476+55	AC	0.29	0.36		A	135	175							"				35.67
5-H(140)R-(0.29)AC	PL	476+55	480+75	AC	0.29	0.36		A	140	150	165	2.1	2.1	36.2	95.1	99.1	"				

TABLE 39: Trial Field Section - 5 FM 1730

SECTION NUMBER	LANE	LOCATION		TYPE OF ASPHALT	AMOUNT OF ASPHALT gal/yd^2			TYPE OF AGGREGATE	QUANTITY OF AGGREGATE			AGGREGATE MOISTURE CONTENT PERCENT	AGGREGATE GRADATION ACCUMALATIVE PERCENT RETAINED				TIME DATE OF CONSTRUCTION	TIME ASPHALT SHOT AT	TIME ROCKLAND PLACED AT	VISUAL EVALUATION	
		FROM	TO		DESIGN	THD	TTI		DESIGN	TTI(2)	TTI(3)		1/2 inch	3/8 inch	No. 4	No. 10				9/21/72	5/22/73
5-M(120)C-(0.34)AC	SBL	110+10	128+38	AC	0.34	0.38		H	120	110	150	14.6	0.9	18.3	87.3	95.7	8-23-72	1:00	1:01	29.1	26.67
5-M(135)C-(0.34)AC	SBL	128+38	142+96	AC	0.34	0.34		H	135	140	195	12.2	0.7	23.1	93.1	98.9	"	1:23	1:24	29.4	31.67
5-M(140)C-(0.34)AC	SBL	142+96	163+12	AC	0.34	0.31		H	140	150	200	10.7	1.4	18.3	91.0	99.2	"	2:05	2:06		
5-M(120)C-(0.34)AC	NBL	111+10	128+38	AC	0.34	0.28		H	120								8-24-72				
5-M(135)C-(0.34)AC	NBL	128+38	142+96	AC	0.34	0.29		H	135	115	100	10.5	1.8	19.5	91.2	98.4	"	2:16	2:16		
5-M(140)C-(0.34)AC	NBL	142+96	163+12	AC	0.34	0.36		H	140	145	110	9.3	1.1	17.4	92.6	98.6	"	1:41	1:43		
5-M(120)D-(0.34)AC	SBL	163+12	180+40	AC	0.34	0.33		B	120	135	160	39.5	3.5	49.6	85.8	94.5	8-23-72	2:34	2:35	28.8	31.33
5-M(135)D-(0.34)AC	SBL	180+40	194+98	AC	0.34	0.34		B	135	115	185	34.3	3.1	47.9	90.9	96.6	"	2:50	2:51	30.3	31.67
5-M(140)D-(0.34)AC	SBL	194+98	215+14	AC	0.34	0.35		B	140	130	150	39.5	5.0	53.2	92.8	98.1	"	3:24	3:25		
5-M(120)D-(0.34)AC	NBL	163+12	180+40	AC	0.34	0.39		B	120	125	90	23.6	3.7	47.7	90.9	97.4	8-24-72	1:26	1:27		
5-M(135)D-(0.34)AC	NBL	180+40	194+98	AC	0.34	0.34		B	135	135	120	27.6	8.5	51.0	91.4	97.4	"	12:37	12:37		
5-M(140)D-(0.34)AC	NBL	194+98	215+14	AC	0.34	0.33		B	140	145	190	33.1	7.0	43.7	92.6	98.1	"	12:21	12:24		
5-M(120)E-(0.34)AC	SBL	215+14	232+42	AC	0.34	0.30		D	120	130	130	11.3	1.0	38.8	98.7	99.2	8-23-72	3:56	4:09	35.7	35.67
5-M(135)E-(0.34)AC	SBL	232+42	247+00	AC	0.34	0.35		D	135	135	200	12.6	0.7	24.8	94.7	98.3	"	4:20	4:29	31.9	34.33
5-M(140)E-(0.34)AC	SBL	247+00	267+16	AC	0.34	0.39		D	140	130	190	9.2	0.2	28.2	97.3	98.7	"	5:09	5:18		
5-M(120)E-(0.34)AC	NBL	215+14	232+42	AC	0.34	0.31		D	120	115	150	12.5	0.6	35.9	97.2	98.5	8-24-72	12:05	12:05		
5-M(135)E-(0.34)AC	NBL	232+42	247+00	AC	0.34	0.25		D	135	135	235	19.3	0.3	31.9	97.3	98.3	"	10:51	10:52		
5-M(140)E-(0.34)AC	NBL	247+00	267+16	AC	0.34	0.28		D	140	160	180	11.3	0.5	35.4	98.7	99.4	"	10:34	10:35		
5-M(120)R-(0.34)AC	SBL	267+16	284+44	AC	0.34	0.30		A	120	140							8-23-72	5:33	5:36	35.4	36.00
5-M(135)R-(0.34)AC	SBL	284+44	299+02	AC	0.34	0.33		A	135	135							"	6:18	6:19	33.6	34.00
5-M(140)R-(0.34)AC	SBL	299+02	319+18	AC	0.34	0.32		A	140	145	180	5.0	1.1	28.9	95.4	99.4	"	6:28	6:39		
5-M(120)R-(0.34)AC	NBL	267+16	284+44	AC	0.34	0.35		A	120	125	170	9.0	2.8	35.9	97.0	99.3	8-24-72	10:11	10:15		
5-M(135)R-(0.34)AC	NBL	284+44	299+02	AC	0.34	0.29		A	135	130	200	12.9	0.9	28.8	94.2	98.8	"	9:22	9:23		
5-M(140)R-(0.34)AC	NBL	299+02	319+18	AC	0.34	0.35		A	140	135		18.0	1.3	32.0	95.1	98.8	"	9:00	9:03		

Construction Equipment

Texas Highway Department District 5 maintenance equipment and crews were utilized for placement of the trial sections. A self-propelled spreader box, 4-cubic yard dump trucks and pneumatic-tired rolling equipment were utilized. Excess aggregate was not removed from the pavement after construction.

Environmental Data

Average humidity and temperatures for the months of July, August and September of 1972 are shown in Table 23. Temperature extremes and precipitation for the period immediately prior and after construction recorded at the Lubbock airport which is 10 miles from the project site are given in Table 40. Rainfall was recorded at the airport on the night of the 22nd, but only a trace of precipitation was noted at the project site. A cool wind from 15 to 20 miles per hour was present during construction on August 24.

Asphalt and Aggregate Quantities

Asphalt and aggregate quantities determined during construction of the project are shown in Tables 38 and 39. Asphalt pickup on the aggregate spreader box tires was noted on several sections of 5FM1730 constructed in the afternoon of August 23. Excessive asphalt together with the relatively small size of aggregate B utilized on these sections appeared to create the problem.

Asphalt and aggregate properties utilized on this project are shown in Tables 2 and 15. Average gradations are shown in Table 18 and moisture contents in Tables 38 and 39.

Skid Resistance

Skid measurements were made on the trial sections before and after

TABLE 40: Temperature Extremes and Precipitation - 5US62

DATE	TEMPERATURE, °F MAXIMUM	MINIMUM	PRECIPITATION, INCHES
20 August 72	88	65	---
21 August 72	92	67	0.18
22 " "	81	62	0.23
23 " "	85	64	Trace
24 " "	94	66	---
25 " "	74	62	0.18
26 " "	72	64	0.94
27 " "	73	63	2.72
28 " "	84	63	---
29 " "	85	64	---
30 " "	89	67	---
31 August 72	91	66	Trace

Construction dates - 22, 23, 24 August

the seal coats were placed. As noted in Tables 41 and 42, a significant increase in skid number is apparent between the old and new surfaces.

Surface Texture

Surface texture measurements were made before and after placement of seal coats by using the putty impression method (29). Results of tests conducted before construction on 5US62 are shown in Table 43. These data indicate the variations in surface texture, and thus to a certain degree the asphalt demand between passing and travel lane and also across any given lane. The variation across the travel lane is particularly evident from these data. Table 44 shows surface texture data taken before construction on 5FM1730. These data show similar relationships to those evident from the more heavily traveled US62 roadway.

Surface texture measurements performed after construction on the various trial sections are shown in Table 45. Coefficients of variation of the order of 40 are not unusual as evident from these data.

SEAL COAT DESIGN METHODS

Methods utilized for the design of asphalt quantity and aggregate spread rate for seal coats and surface treatments have been adequately summarized by the Asphalt Institute (21). Three types of methods are recognized in this publication and are referred to as design methods for one-sized aggregate, design method for graded aggregate and design method for multiple surface treatments. These methods are based on references 10, 11, 16, 17, 18, 19, 20, 21, 22, 23 and 30. The design method for graded aggregate is based on work performed by Lovering (14) while the crack for multiple surface treatments is based on studies by Kearby (10) and Benson and Gallaway (11).

TABLE 41: Skid Resistance Data - 5US62

		SN_{40}			
AGGREGATE TYPE	LANE	NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION	RANGE
A	Travel	9	57	2	53-59
	Passing	9	58	2	57-60
B	Travel	3	38	4	35-42
	Passing	3	54	6	48-59
D	Travel	3	50	4	45-53
	Passing	3	58	1	58-59
H	Travel	9	58	10	42-67
	Passing	9	66	3	62-71
Before Construction	Travel	14	36	7	21-42
	Passing	14	44	8	29-55

TABLE 42: Skid Resistance Data - 5FM1730

AGGREGATE TYPE	LANE	SN_{40} NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION	RANGE
A		6	51	5	42-56
B		6	55	3	49-58
D		6	51	3	46-54
H		6	53	4	54-61
Before Construction	South Bound	20	28	2	25-33
	North Bound	20	32	8	21-48

TABLE 43: Surface Texture Measurements - 5US62 Before Construction

		SURFACE TEXTURE, INCHES		
LANE	WHEEL PATH	NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION
TRAVEL	All	10	0.040	0.013
	Outer	4	0.034	0.007
	Inner	3	0.038	0.006
	Between	3	0.055	0.024
	Inner & Outer	7	0.035	0.006
PASSING	All	10	0.075	0.021
	Outer	3	0.087	0.016
	Inner	3	0.059	0.018
	Between	4	0.078	0.022
	Inner & Outer	6	0.073	0.022

TABLE 44: Surface Texture Measurements - 5FM1730 Before Construction

LANE	WHEEL PATH	SURFACE TEXTURE, INCHES NUMBER OF MEASUREMENTS	AVERAGE	STANDARD DEVIATION
SOUTH BOUND	All	11	0.023	0.012
	Outer	5	0.016	0.011
	Inner	5	0.026	0.010
	Between	1	0.043	---
NORTH BOUND	All	9	0.026	0.018
	Outer	2	0.010	---
	Inner	4	0.018	0.009
	Between	3	0.046	0.013
NORTH & SOUTH BOUND	Inner & Outer	16	0.019	0.011
	Between	4	0.045	0.010

TABLE 45: Surface Texture Measurements - 5US62 and 5FM1730 After Construction

		SURFACE TEXTURE, INCHES			
HIGHWAY	AGGREGATE TYPE	NUMBER OF READINGS	AVERAGE	STANDARD DEVIATION	RANGE
5US62	A	2	0.067	---	0.025-0.109
	B	4	0.056	0.024	0.031-0.071
	D	2	0.038	---	----
	H	12	0.059	0.020	0.031-0.105
5FM1730	A	6	0.022	0.020	0.001-0.043
	B	2	0.013	---	----
	D	5	0.027	0.009	0.017-0.039
	H	7	0.028	0.015	0.016-0.060

Based on a review of Texas Highway Department practices presented above the Kearby method also referred to as the "board" method appears to be the most popular method utilized in the state. The Asphalt Institute (21) further suggests that this method be utilized for final design quantities when the aggregate has been selected and available for design.

Comparison of Design Methods

Asphalt and aggregate design quantities for Texas Highway Department Grade 4 lightweight aggregate (12) as determined by Hansen's method as described in reference 21 and by the Modified Benson and Gallaway method as described in reference 31 are shown in Table 46. The fine, medium and coarse portions of the gradation bands were utilized for this determination. In general the aggregate rates determined by the modified Kearby method are in agreement with proven field experience gained as a part of this research project and Texas Highway Department field experience. Thus, those aggregate quantities determined by Hanson's method are greater than required. The asphalt quantities resulting from both methods are lower than those generally utilized for synthetic aggregate seal coats in Texas. Thus, adjustments should be made in these design methods for prediction of asphalt quantities.

Aggregates utilized for construction of trial sections on project 14SH95 were sampled and design aggregate and asphalt quantities were determined by four methods as shown in Table 47. Hanson's and Lovering's design calculations were performed according to the procedure given in reference 21, while the modified Kearby method was performed according to the procedure given in reference 21. The fourth method is a modification of the Kearby method as prepared by J. W. Livingston of District 19 (Atlanta) of the Texas Highway Department. Of the methods investigated, the modified Kearby method appeared

TABLE 46: Design Asphalt and Aggregate Quantities for Texas Highway Department Grade 4 Light Weight Aggregates

		HANSON'S METHOD*		MODIFIED KEARBY METHOD**	
AGGREGATE IDENTIFICATION	GRADING	AGGREGATE SQ. YDS/CU. YDS.	**ASPHALT** GAL/SQ. YDS.	AGGREGATE SQ. YDS/CU. YDS.	**ASPHALT** GAL/SQ. YDS.
A	Fine	105	0.21	105	0.22
	Medium	95	0.23	---	----
	Coarse	85	0.25	130	0.26
B	Fine	100	0.21	145	0.21
	Medium	90	0.23	---	----
	Coarse	80	0.24	120	0.26
D	Fine	110	0.20	140	0.19
	Medium	100	0.21	---	----
	Coarse	90	0.23	125	0.22
H	Fine	70	0.22	140	0.22
	Medium	65	0.24	---	----
	Coarse	60	0.26	135	0.23

*Quantities determined for traffic volumes between 500 and 1000 vehicles per day, a slightly porous, slightly oxidized surface and no aggregate waste.

** Quantities determined for moderate traffic, a slightly porous, slightly oxidized surface, and no aggregate waste.

TABLE 47: Design Asphalt and Aggregate Quantities for Aggregates Used on 14SH95 Project

AGGREGATE IDENTIFICATION	HANSON'S METHOD(1)		LOVERINGS METHOD(2)		MODIFIED KEARBY METHOD(3)		TEXAS HIGHWAY DEPT.(4) DIST. 19 METHOD	
	AGGREGATE SQ. YDS/CU. YDS.	ASPHALT GAL/SQ. YDS.	AGGREGATE SQ. YDS/CU. YDS.	ASPHALT GAL/SQ. YDS.	AGGREGATE SQ. YDS/CU. YDS.	ASPHALT GAL/SQ. YDS.	AGGREGATE SQ. YDS/CU. YDS.	ASPHALT GAL/SQ. YDS.
A	95	0.23	110	0.33	145	0.20	110	0.30
B	70	0.28	110	0.33	140	0.23	95	0.32
D	80	0.26	110	0.33	115	0.27	110	0.36
H	60	0.27	125	0.29	110	0.35	120	0.45
M	85	0.26	120	0.31	140	0.20	110	0.17

(1) Quantities determined for 500-1000 vehicles per day, a slightly porous, slightly oxidized surface and no aggregate waste.

(2) Quantities determined for 500-1000 vehicles per day, a slight porous, slightly oxidized surface and no aggregate waste.

(3) Quantities determined for moderate traffic, a slightly porous, slightly oxidized surface and no aggregate waste.

(4) Method developed by district 19, Atlanta based on Kearby Method.

to be the best prediction of aggregate quantity while the Lovering and Texas Highway Department method was the best prediction of the asphalt quantity. Inaccuracies in determination of aggregate bulk specific gravity can in part be responsible for the unusually high aggregate quantities predicted by Hanson's error.

Development of Design Method

In order to more accurately predict the quantities of aggregate and asphalt required for a particular synthetic aggregate seal coat project a modification of the existing Kearby method has been developed. This method involves spreading aggregate one stone thick on a board of a known area. From a knowledge of the loose unit weight of the material and the weight of aggregate per unit of surface area, aggregate quantities may be determined.

Asphalt quantities are determined by calculation of an average aggregate mat thickness, selecting an appropriate percent embedment and calculating the amount of asphalt to fill this volume between the aggregate to the selected embedment depth assuming that the rocks in one stone layer will be the same as the rocks in the loose mass of aggregate. Furthermore, it is assumed that the aggregate is non-absorptive. The relationship between average mat thickness and percent embedment is shown on Figure 11. The original curve suggested by Kearby (10) together with the Benson and Gallaway modification (11) and the suggested curve for use with synthetic aggregates are shown for comparison purposes. Details of the method together with sample calculations are shown in Appendix A.

EVALUATION OF TRIAL SECTIONS

Evaluation of the performance of the trial field sections was determined by skid resistance measurements, surface texture measurements and visual

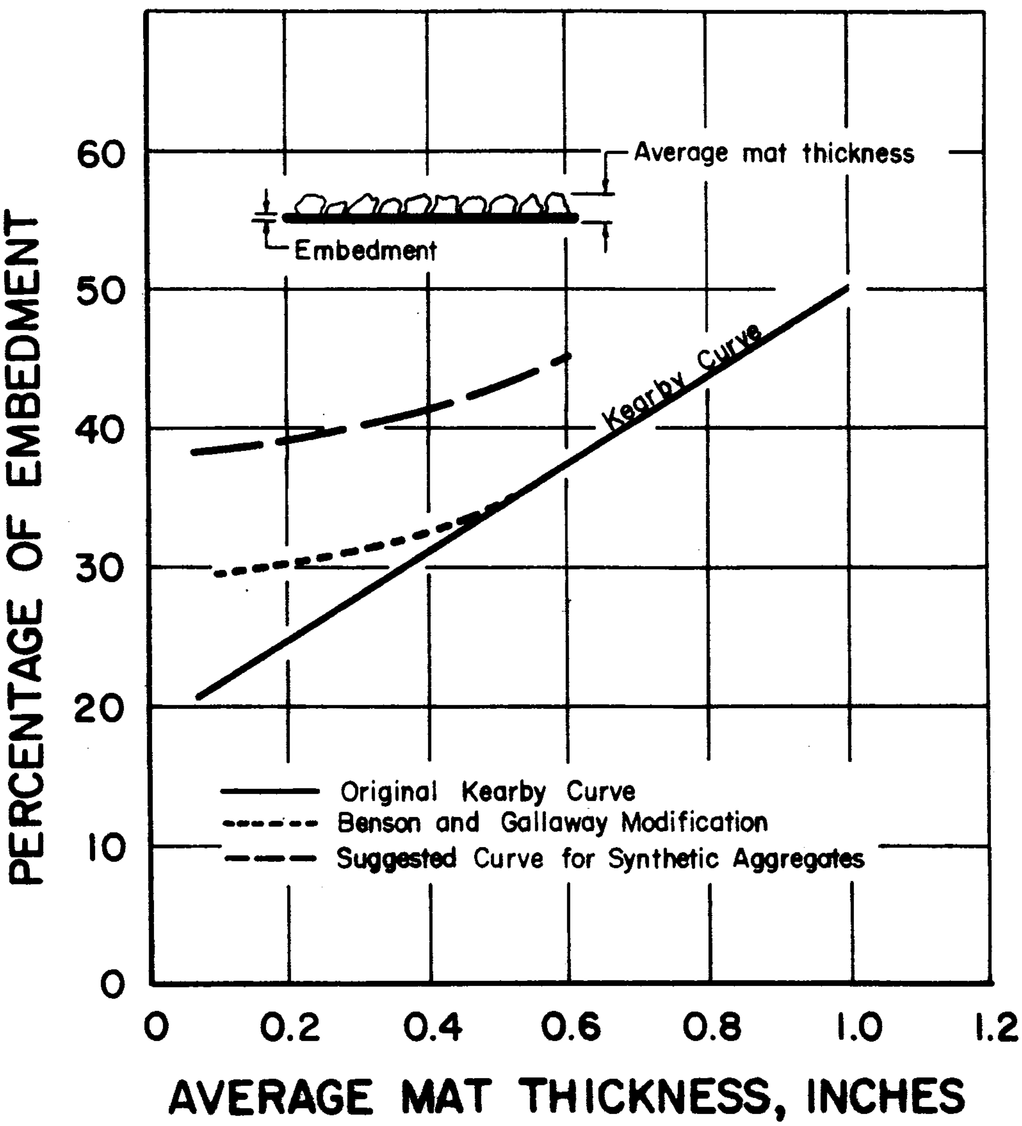

Figure 11. Relation of percent embedment to mat thickness for determining quantity of asphalt.

evaluation. Skid resistance and surface texture measurements are reported above. The visual evaluation method utilized in this study was based on a review of the literature (22, 33, 34).

The form selected for use in evaluating the trial sections and randomly selected roadway sections is shown on Figure 12. The major sections of the form are job identification, materials and design and evaluation. A total of 40 points are possible in the evaluation section. Ten points for each of the following categories discussed below.

1. Visual inspection - A measure of the raters' overall impression of the sections as seen from the drivers' view. Detailed inspection is not a part of this category.

2. Aggregate Degradation - The degree of aggregate crushing occurring during the construction and by traffic using the facility. This evaluation is made relative to the gradation of the aggregate as it exists in the stockpile.

3. Aggregate Retention - The amount of aggregate retained on the roadway.

4. Bleeding - The amount of fat or flushed spots in the roadway. This could result from excessive asphalt, too little asphalt and subsequent loss of aggregate, or loss of aggregate due to environmental problems.

Visual evaluation of the trial sections was performed by a rating team composed of representatives of the Texas Highway Department and the Texas Transportation Institute. Irl Larrimore (Texas Highway Department) and Jon Epps (Texas Transportation Institute) and a District representative were present for all information reported in Tables 20, 28, 33, 34, 37 and 38 for the various trial sections. John Nixon, Arthur Hill, and Robert

A. JOB IDENTIFICATION

District No. ________ Highway No. ________ County ________

Control No. ________ Section No. ________ Job No. ________

________ miles N S E W of ________ (nearest town);

Mile Post ________ to Mile Post ________

Trial Field Section No. ________ Date Sealed ________

B. MATERIALS AND DESIGN

Aggregate Source ________ Aggregate Quantity ________

Asphalt Source ________ Asphalt Quantity ________
(gal./sq. yd.)

Length of Section Evaluated ________ miles

C EVALUATION

1. VISUAL INSPECTION

0	2	4	6	8	10
Very Poor	Poor	Fair	Good	Very Good	

2. AGGREGATE DEGRADATION

0	2	4	6	8	10
Excessive	Heavy	Moderate	Slight		None

3. AGGREGATE RETENTION

0	2	4	6	8	10
Entire Aggregate Loss	Aggregate Loss In Wheel Path		Some Aggregate Loss In Wheel Path	Slight Aggregate Loss	

4. BLEEDING

0	2	4	6	8	10
Excessive and Extensive Bleeding	Bleeding in Wheel Path		Slight Bleeding in Wheel Path		Slight Discolor-ation in Wheel Path

TOTAL SCORE ________

COMMENTS:

Figure 12. Seal coat evaluation.

Keyser of the Planning and Research Division, Materials and Test Division and Construction Division of the Texas Highway Department were present on a majority of the evaluations. Polling of the evaluators was performed individually.

Fifty seal coated roadway sections were evaluated in Districts 5, 8, 14, 23 and 25 with the visual examination form described above. The results of these evaluations form a basis for comparing the results obtained on the field trial sections. The sections evaluated were on high and low traffic volume roads and were constructed with both synthetic and natural aggregates at various times. Average values for these sections are shown in Table 48 with a total score of 30 being a representative average for the fifty sites investigated.

Evaluation scores of the field trial sections are shown in Tables 21, 29, 34, 35, 38 and 39. All field trial sections have been evaluated a minimum of two times--immediately after construction and after one winter of service. A third evaluation will be made during the fall of 1974. With few exceptions both lanes of the field trial sections were evaluated as one. With few exceptions all sections placed had evaulation scores above thirty. Scores below thirty were most commonly associated with Aggregate B. Stations 330+00 to 345+90 on US62 near Lubbock had excess asphalt and thus a resulting low score. In general, adequate performance was obtained on all sections with the exception of those placed on US59 south of Lufkin which has been previously discussed. Performance trends over a period of time to study the effects of traffic and the environment will be developed as parts of other research projects. Particular attention should be paid to freeze-thaw damage and the effects of traffic on skid resistance, aggregate degradation and surface texture.

Aggregate degradation was scored individually during the evaluation and discussed in general after the evaluation. The consensus of those who evaluated the trial sections indicated that Aggregate B showed the most degradation followed by Aggregate H. Aggregates A and D showed considerable less degradation.

DISCUSSION OF RESULTS

A large amount of field data has been collected on this project. These data together with data to be collected in the future may lead to the improvement of seal coat design and construction practices together with revised material specifications. The results of the data gathered to date and presented above are discussed below.

Construction Procedures

Equipment - Self-propelled pressurized asphalt distributors and self-propelled aggregate spreaders are commonly used for construction of seal coats. Self-propelled pneumatic tired compaction equipment is commonly utilized.

Traffic Control - Traffic control is effected by a number of methods depending upon district preference, volume of traffic and highway geometrics. The use of pilot cars appears to be the most effective method of traffic control on two-lane roadways without shoulders. The use of signing and traffic cones for four-lane and two-lane roads with shoulders appears satisfactory except for control of traffic speed. Positive speed control should be required.

Traffic control should be maintained until adequate bond is achieved between the aggregate and the asphalt. The time necessary for this to occur is dependent upon the environmental conditions, the moisture content of the aggregate, the type of asphalt and the amount of traffic. If traffic is allowed to use the facility and aggregate loss is evident, traffic should be removed or its speed controlled until a satisfactory bond is achieved. This procedure is absolutely necessary should rain occur immediately after placement of seal coats.

Timing - Time delays between the asphalt shot and the placement of aggregate on sections utilizing asphalt cements ranged from one minute for placement of the first rock land after application of asphalt to as high as 8 to 12 minutes at the end of the asphalt shot. During cool weather the length of asphalt shots should be reduced to promote good adhesion between the asphalt and aggregate.

The use of anionic emulsion on cool and humid days will result in considerable construction delay and possible loss of the emulsion by run-off. On hot days anionic emulsions were covered with aggregate prior to breaking with satisfactory results. Cationic emulsions were utilized during warm weather and covered immediately with aggregate without encountering difficulty.

Asphalt Distribution - Design asphalt quantities were, with few exceptions, placed successfully on the trial sections. Transverse and longitudinal distribution variation are normally not determined during Texas Highway Department construction operations. Transverse spread rates should not be allowed to vary more than 15 percent for asphalt emulsions and no more than 10 percent for asphalt cement while longitudinal spread rates should not vary more than 10 percent regardless of the type of material (21). Examination of the data collected suggests that for the most part variations within the suggested limits were achieved. A large amount of data scatter is evident when comparing asphalt in pans. Some of these variations are due to poor handling of the pans between the time of construction and weighing the pans at the laboratory.

Aggregates

Aggregate Distribution - Aggregate distribution rates were difficult to control as the rate was changing at each rockland on a number of projects. Control was attempted by changing the hopper opening while maintaining a constant speed of the spreader box. Each aggregate required different settings to obtain a like aggregate rate. A change in one notch of the box opening control normally changed the quantity of aggregate by 10 to 15 percent. Data collected by measuring the amount of aggregate in the hopper at the start and end of a rockland and knowing the amount of rock in the truck and the length of land agree reasonably well with the design quantities. A review of the data collected from boxes placed on the roadway suggest that poor aggregate distribution is achieved; however, satisfactory performance is evident. A 15 percent variation in aggregate spread quantity is not unlikely on seal coat projects.

Degradation - Aggregate degradation was one of the principal factors studied during the project. A 10 to 15 percentage point increase in material retained on the 3/8-inch sieve is evident while smaller changes are evident on the No. 4 and No. 10 sieves. Aggregate sampling and testing variations appear to contribute to the data scatter indicated in these two tables. Claims of degradation during shipping and handling are contradicted by these data.

Visual examination during and after construction indicate that Aggregates B and H are more susceptible to crushing than Aggregates A and D. However, adequate trial section and in-service pavements have been constructed with all types of aggregate.

Moisture Content - Rainfall prior, during and immediately after construction was indicated to be a major contributor to seal coat failure. Moisture contents of aggregates placed on projects in the study are shown in Table 49. Aggregates A and D have similar moisture contents and similar water absorption curves as shown in Figures 1 and 2. On the average Aggregate H has a slightly higher moisture content than Aggregates A and D. Aggregate B has moisture contents in excess of thirty percent on one project and above twenty percent on all but one project. This aggregate also absorbs moisture at a relatively fast rate (Figures 1 and 2). Waterproof covers are advised for dry stockpiles.

Gradation - Detailed information on aggregate gradation including variation of grading as the aggregate fell on the pavement and collected in boxes is shown in Tables 50 to 55. Examination of data gathered on percent retained on the 3/8-inch sieve indicates that a standard deviation of 5 to 6 is not unusual with two projects reporting in excess of 10. Specifications indicate a range of 20 to 40 percent retained on the 3/8-inch sieve. Thus, if the aggregate supplier is to be 95 percent certain of meeting the gradation specification, he must produce the aggregate near the middle of the gradation band with allowance for degradation during shipment. Proper stockpile sampling will doubtless yield entirely different results.

Performance

Skid Resistance - Skid numbers measured at 40 mph with the self-watering THD trailer are above 55 for all sections reported. Values above 60

TABLE 48: Results of the Visual Examination of Selected Roadway Sections in Texas

INSPECTION CATEGORY	THD DISTRICT DESIGNATION				
	14	23	8	5	25
Visual	7.3	6.4	7.0	7.5	7.1
Aggregate Degradation	8.3	8.0	7.8	7.7	7.7
Aggregate Retention	7.3	7.0	8.3	8.3	8.0
Bleeding	8.8	6.9	6.9	7.0	7.2
TOTAL SCORE	31.7	28.3	30.0	30.5	30.0

TABLE 49: Aggregate Moisture Contents

Aggregate Type	Project: 2 - SH6				5 - US62				5 - FM1730				11 - US59				11 - SH103				14-SH95*				14-SH95**			
	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
A	10.6	3.6	34.2	11	7.1	1.0	14.9	6	11.2	5.5	49.4	4	11.5	1.9	16.6	6	13.7	2.0	14.9	6	9.3	1.1	12.5	17	10.4	2.8	27.4	22
B	20.6	5.3	25.8	14	39.0	4.0	10.4	3	32.9	6.4	19.4	6	24.2	2.5	10.2	6	20.5	3.7	18.0	12	17.8	2.4	13.3	13	21.8	-	-	1
D	11.3	3.4	30.6	9	8.0	.3	4.0	3	12.7	3.5	27.2	6	11.3	.7	5.9	5	14.3	.9	6.6	10	9.1	2.6	28.9	7	12.9	-	-	2
H	13.4	6.0	44.4	7	17.8	3.4	19.4	4	11.5	2.0	17.9	5	7.4	.7	9.2	8	10.1	.8	7.7	5	15.9	1.7	10.6	12	15.4	6.2	40.5	25

* placed 1971
** placed 1972

$\bar{X}$ = mean or average valve
σ = standard deviation
C_v = coefficient of variation percent
N = number of reading

TABLE 50: Gradation of Aggregate Utilized on Project 2-SH6

	ACCUMULATIVE PERCENT RETAINED															
	TYPE OF AGGREGATE															
	A				B				D				H			
SIEVE SIZE	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0			12	0.2			13	0			11	0			6
1/2-inch	1.2	0.7	55.0	12	3.0	0.8	3.8	13	0.3			11	0.2			6
3/8-inch	24.4	6.5	27.0	12	49.6	9.4	19.0	13	25.9	6.9	27.0	11	9.2	2.9	31.0	6
No. 4	93.1	2.2	2.4	12	93.3	2.7	2.9	13	96.6	3.3	3.4	11	87.1	3.2	3.7	6
No. 10	98.9	0.6	0.6	12	98.1	0.8	0.8	13	99.0	0.5	0.5	11	97.0	1.8	1.8	6

TABLE 51: Gradation of Aggregate Utilized on Project 5-US62

	ACCUMULATIVE PERCENT RETAINED															
	TYPE OF AGGREGATE															
	A				B				D				H			
SIEVE SIZE	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0			8	0.5			3	0			5	0			6
1/2-inch	1.7	.4	24.6	8	5.6			3	0.9	0.1	14.9	5	1.1	0.6	57.6	6
3/8-inch	32.2	8.6	26.7	8	60.1			3	50.0	8.1	16.2	5	22.1	5.8	26.4	6
No. 4	91.6	4.3	4.7	8	93.2			3	97.4	1.5	1.5	5	91.3	6.4	6.9	6
No. 10	97.9	1.0	1.0	8	97.8			3	98.3	1.0	1.1	5	98.0	.7	.7	6

TABLE 52: Gradation of Aggregate Utilized on Project 5-FM1730

SIEVE SIZE	ACCUMULATIVE PERCENT RETAINED — TYPE OF AGGREGATE															
	A				B				D				H			
	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0			4	0.1			6	0			7	0		0.0	5
1/2-inch	1.5	0.8	56.0	4	5.1	2.2	42.0	6	0.6	0.4	67.0	7	1.2	0.4	38.4	5
3/8-inch	31.4	3.4	11.0	4	48.8	3.3	6.7	6	31.4	5.6	18.0	7	19.3	2.2	11.6	5
No. 4	95.4	1.2	1.2	4	90.7	2.6	2.8	6	96.9	1.8	1.8	7	91.0	2.3	2.5	5
No. 10	99.1	0.6	0.6	4	97.0	1.3	1.4	6	98.7	0.5	0.5	7	98.1	1.9	2.0	5

TABLE 53: Gradation of Aggregate Utilized on Project 11-SH59

Sieve Size	ACCUMULATIVE PERCENT RETAINED															
	TYPE OF AGGREGATE															
	A				B				D				H			
	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0.0			8	0.1			8	0.1			8	0.1			18
1/2-inch	1.4	0.4	27.6	8	4.1	8.5	20.4	8	0.4	0.4	89.3	8	1.6			18
3/8-inch	38.3	2.9	7.4	8	34.4	11.7	33.9	8	37.7	3.7	9.7	8	24.3	12.3	50.6	18
No. 4	96.0	1.4	1.4	8	83.9	6.6	7.8	8	97.9	.6	0.7	8	92.8	3.1	3.3	18
No. 10	98.2	0.6	0.6	8	97.8	0.4	0.4	8	98.9	0.5	0.5	8	98.0	1.0	1.0	18

TABLE 54: Gradation of Aggregate Utilized on Project 11-SH103

SIEVE SIZE	ACCUMULATIVE PERCENT RETAINED															
	TYPE OF AGGREGATE															
	A				B				D				H			
	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0.0			6	0.2			7	0.1			7	0			6
1/2-inch	1.2	0.7	0.6	6	2.9	1.6	60	7	0.7	0.6	88	7	0			6
3/8-inch	38.5	6.8	17.6	6	43.2	8.8	20	7	36.9	4.8	13	7	13.1	4.1	32	6
No. 4	95.6	2.1	2.2	6	89.4	7.1	7.9	7	94.1	4.7	5	7	86.2	11.6	13	6
No. 10	98.1	0.9	0.9	6	96.5	2.6	2.7		97.7	1.3	1.3	7	93.9	11.1	1.2	6

TABLE 55: Gradation of Aggregate Utilized on Project 14-SH95

SIEVE SIZE	ACCUMULATIVE PERCENT RETAINED															
	TYPE OF AGGREGATE															
	A				B				D				H			
	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N	$\bar{X}$	σ	C_v	N
5/8-inch	0			21	0.0			8	0			2	0			
1/2-inch	1.4	.8	59.0	21	0.8	.5	67.0	8	.3			2	0.10			
3/8-inch	31.6	5.6	18.0	21	34.0	5.7	17.0	8	43.2			2	16.9	5.9	35.0	24
No. 4	92.9	2.9	3.1	21	88.9	5.9	7.1	8	96.5			2	90.2	2.0	2.3	24
No. 10	97.9	1.0	1.0	21	95.1	3.0	3.2	8	97.8			2	97.4	0.9	0.9	24

predominate. The skid numbers appear to be reasonably independent of aggregate quantity and asphalt quantity within the variation investigated on the project. It should, however, be pointed out that the pavements have been subjected to a relatively few number of vehicle passes. Surface texture measurements were performed on all projects with the majority of values between 0.04 to 0.10 inches as measured by the putty impression method. These values are in agreement with other seal coats measured in Texas and reported in reference 29. Measurements after additional traffic will most likely show a reduction in texture values.

Visual Examination - Visual examination after construction indicated that all sections performed satisfactorily within the variation studied in this project except those placed on US59 near Lufkin which were subjected to heavy traffic and rainfall within a few hours of placement. Thus, these data indicate that asphalt quantities can vary plus or minus 15 percent from the design over a 15 to 20 percent range and aggregate quantities can vary plus 10 percent and minus 20 percent from design with satisfactory performance. The authors recommend that design procedures be followed and close supervision of construction be maintained.

Seal Coat Design - A modification of the Kearby design method has been suggested for use in designing seal coats (Appendix A). The design asphalt and aggregate quantities are in accordance with quantities considered near optimum for the field trial sections.

SUMMARY

Information collected from personal visits to Texas Highway Department district offices, field observations, detailed questionnaires and the construction of field trial sections indicate that many problems associated with poor performance of synthetic aggregate seal coats can be traced, in large measure, to moisture present in the aggregate, degradation of the aggregate during construction and in the first week of service and rainfall during or within a 24-hour period after construction.

Certain design and construction techniques are recommended to reduce some of these problems and thus increase the probability of constructing a satisfactory surface. These items are summarized below.

1. Avoid construction if rainfall is likely during construction or within 24 hours thereafter.

2. Control traffic speed or preferably detour traffic around the freshly sealed surface if rainfall is likely and construction must proceed.

3. Limit lightweight aggregate usage to conditions such that a sufficient bond will be established between the aggregate and asphalt prior to allowing high speed traffic on the facility. Traffic control during and for a short period after construction should be practiced to allow development of adequate bond between the asphalt and stone.

4. Use pneumatic rollers.

5. Use a minimum of aggregate cover material. Excess aggregate on the roadway which is not removed by brooming will degrade under traffic and is a factor in dislodging loosely attached material.

6. Use maximum asphalt quantities to provide deeper embedment. The use of harder asphalts is advised.

7. Avoid the use of aggregate seal coats on high traffic volume roads and in certain urban areas where traffic turning movements are expected.

Sufficient information has not been developed to insure the successful use of such material under these conditions.

8. Reduce the average particle size to improve the resistance to degradation during construction and early service life. Dislodgement of the aggregate is also minimized.

9. Follow the seal coat design method presented to establish asphalt and aggregate quantities.

10. Re-evaluate the freeze-thaw test requirement for synthetic aggregates utilized on seal coats, as the currently specified values appear too restrictive.

11. Claims of degradation of lightweight aggregate during transporting and handling are not verified by data taken during this study. However, aggregate sampling does present a definite problem. Care must be exercised to assure the selection of representative samples, particularly for grading analysis.

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APPENDIX A

SYNTHETIC AGGREGATE SEAL COAT DESIGN METHOD

The design method described below is based on field experience gained by representatives of the Texas Highway Department and the Texas Transportation Institute on synthetic aggregate seal coats since 1961. The method is based on Kearby's original research as modified by Benson and Gallaway. Modification on the original design method includes changes in the relationship between mat thickness and percent of embedment and correction for traffic volume and existing surface condition.

LABORATORY TESTS

Dry Loose Unit Weight

The dry loose unit weight determination shall be made in accordance with Tex-404A, except that the aggregate shall be tested in an oven-dry condition.

Bulk Specific Gravity

The bulk specific gravity should be determined by the method given in reference 32 as altered and contained in Appendix B.

Board Test

Place a sufficient quantity of aggregate on a board of known area such that full coverage one stone in depth is obtained. One-half square yard areas are convenient laboratory size. The weight of the aggregates applied in this area is obtained and converted to the units lbs. per square yard. Good lighting is recommended and care should be taken to place the aggregate only one stone in depth.

CALCULATIONS

The quantity of aggregate expressed in terms of square yards of road surface per cubic yard of aggregate and the quantity of asphalt in gallons per square yard can be found as described below.

Aggregate Quantity

$$S = \frac{27W}{Q}$$

Asphalt Quantity

$$A = 5.61E \left(1 - \frac{W}{62.4G}\right)(T) + V$$

where:

S = quantity of aggregate required, sq. yds. per cu. yd.

W = dry loose unit weight, lbs. per cu. ft.

Q = aggregate quantity determined from board test, lbs. per sq. yd.

A = asphalt quantity, gals./sq. yd.

E = embedment depth obtained from Figure A-1 as follows:

$E = ed$

where e = percent embedment (Figure A-1)

d = average mat depth, inches

$$= \frac{1.33Q}{W}$$

G = dry bulk specific gravity of aggregate

T = traffic correction factor obtained from Table A-1

V = correction for surface condition obtained from Table A-2

Note: Asphalt quantities calculated by these methods are for asphalt cement. Appropriate corrections should be made where utilizing cutback and emulsion.

SAMPLE CALCULATION

Given:

(W) Dry loose unit weight of aggregate = 52.4 lbs/cu. ft.

(G) Dry bulk specific gravity of aggregate = 1.57

(Q) Quantity of aggregate (board test) = 9.7 lbs/sq. yd.

Traffic = 700 vehicles per day per lane

Roadway Surface Condition = slightly pocked, porous, oxidized

Quantity of Aggregate

$$S = \frac{27W}{Q} = \frac{27(52.4)}{9.7} = 146 \text{ sq. yds./cu. yd.}$$

(square yards of roadway surface per 1 cubic yard of aggregate)

Quantity of Asphalt

$$A = 5.61E\left(1 - \frac{W}{62.4G}\right)(T) + V$$

$$d = \frac{1.33Q}{W} = \frac{1.33(9.7)}{52.4} = .246 \text{ inches}$$

e = 40 percent from Figure A-1

$E = ed = .40(.246) = 0.0985$ inches

T = 1.05 from Table A-1

V = +0.03 from Table A-2

$$A = 5.61\ (0.0985)\left(1 - \frac{52.4}{62.4(1.57)}\right)(1.05) + 0.03$$

A = 0.30 gallons of asphalt per square yard of roadway surface

If an emulsion with 30 percent water was to be utilized the quantity of emulsion would be

$$\frac{0.30}{.70} = 0.43 \text{ gallons of emulsion per square yard of roadway surface.}$$

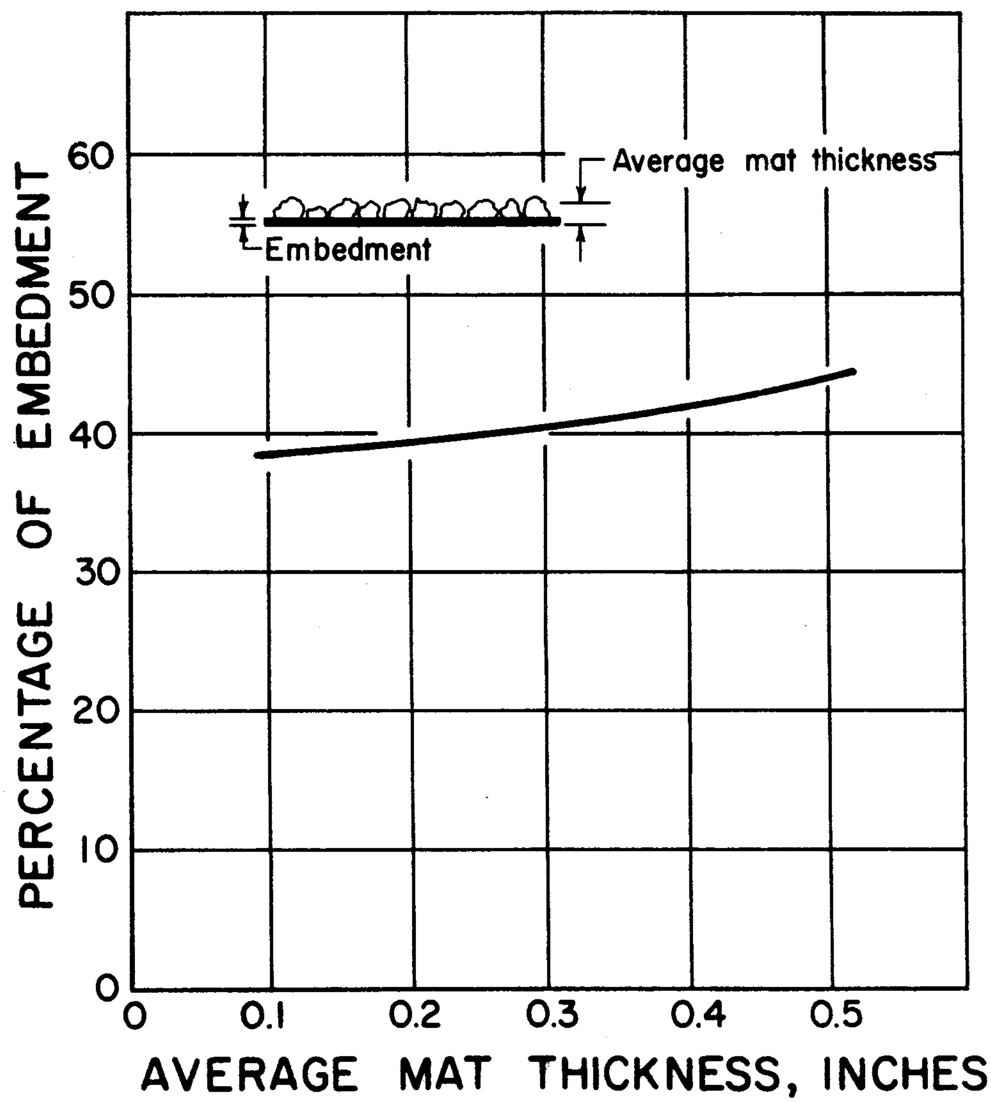

Figure A-1. Relation of percent embedment to average mat thickness for determining quantity of asphalt for lightweight aggregate seals.

Table A-1: ASPHALT APPLICATION RATE - CORRECTION DUE TO TRAFFIC

	Traffic - Vehicles Per Day Per Lane				
	over 1,000	500 to 1,000	250 to 500	100 to 250	Under 100
Traffic Factor (T)	1.00	1.05	1.10	1.15	1.20

Table A-2: ASPHALT APPLICATION RATE CORRECTION DUE TO EXISTING PAVEMENT SURFACE CONDITION

Description of Existing Surface	Asphalt Quantity Correction gal/sq. yd.
Flushed asphalt surface	-0.06
Smooth, nonporous surface	-0.03
Slightly porous, slightly oxidized surface	0.00
Slightly pocked, porous, oxidized surface	+0.03
Badly pocked, porous, oxidized surface	+0.06

APPENDIX B

TEST METHOD FOR DRY BULK SPECIFIC GRAVITY OF SYNTHETIC COARSE AGGREGATE

Scope. This method of test is intended for use in determining dry bulk specific gravity of lightweight coarse aggregate.

Apparatus. The apparatus shall consist of the following:

(a) Balance--A balance having a capacity of 3 kilograms or more and a sensitivity of 0.1 gram or less.

(b) Container--A glass small mouth quart Mason jar fitted with a pycnometer cap.

Sample. A sample of sufficient size to yield approximately 400 grams after being oven dried shall be selected, by the method of quartering, from the aggregate to be tested.

Procedure.

(a) The test shall be conducted at a temperature of 72 ± 5°F.

(b) The sample shall be dried in an oven at a temperature of 105°C for a minimum of 24 hours. The sample shall then be allowed to cool to room temperature in a desiccator.

(c) The weight of the pycnometer jar and cap shall be determined to the nearest 0.1 gram.

(d) The weight of the pycnometer completely filled with distilled water shall be obtained to the nearest 0.1 gram. Match marks shall be used on the jar and cap to insure that the same volume is obtained throughout the test.

(e) The dry sample shall be placed in the pycnometer and the total weight determined to the nearest 0.1 gram.

(f) The jar shall be filled with distilled water. The top shall then be placed on the jar with the match mark coinciding and water added to fill the jar and top completely. The pycnometer with sample and water shall then be weighed to the nearest 0.1 gram. With a little practice, the first weighing can be accomplished two minutes after the water is first introduced into the container. Weighings shall then be made at intervals of 4, 6, 8, 10, 20, 30, 60, 90, and 120 minutes from the beginning of the test, taking care to agitate the sample by rolling and shaking the jar and then add water as required to return the water level to the reference level before each weighing is made.

Calculations. A curve with time (to at least 10 minutes) as the abscissa and weight of pycnometer plus sample plus water as the ordinate shall be plotted on rectangular coordinate paper. This curve shall be extended back to include zero time and the weight of pycnometer plus sample plus initial water read from the curve. The dry bulk specific gravity shall be calculated by dividing the oven dry weight of the sample by the bulk volume of the sample determined at zero time.