SYNTHETIC AGGREGATE SEAL COATS--CURRENT TEXAS HIGHWAY DEPARTMENT PRACTICES

by

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Synthetic Aggregates for Seal Coats

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PREFACE

This is the first 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 together with a definition of the problems associated with the use of synthetic aggregate for seal coats.

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 and for their evaluation of certain problems associated with the use of synthetic aggregate as coverstone for seal coats.

ABSTRACT

Personal visits, questionnaires and a review of available literature were utilized to identify current synthetic aggregate seal coat design and construction practices utilized by the Texas Highway Department. Problems associated with the performance of seal coats utilizing synthetic aggregates for coverstone are defined. Poor performance associated with wet aggregates and degradation of aggregates is mainly responsible for poor results observed in the field. Suggested solutions to these problems are presented including: control of aggregate quantities, rolling practices, design for traffic density, traffic control, and construction timing relative to existing environmental conditions.

KEY WORDS

SEAL COAT, SYNTHETIC AGGREGATE, CONSTRUCTION PRACTICES, PERFORMANCE

SUMMARY

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

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 after construction.

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 possibility of using maximum asphalt quantities to provide deeper embedment together with the use of harder asphalts should be considered.

7. The use of synthetic 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 justify the 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.

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. Most of the suggested construction practices are utilized on a limited basis throughout the state. Increased awareness and conformity to these practices should increase the probability of success of the construction project.

Additional information to be collected during the remainder of this project will afford the opportunity to more accurately define the limits under which these improved construction and design practices need to be practiced.

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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.

Historical Review of Synthetic Aggregate Production in Texas

Two lightweight aggregate plants began production shortly after restricting patents expired in April of 1946. These plants were located at Eastland and Strawn and were owned by Texas Lightweight Aggregate Company and Featherlite, respectively. During 1947 two additional plants were under construction at Converse and Stafford. The Converse plant was owned by a group of Austin businessmen who later sold to Featherlite, while the plant located at Stafford became part of the Texas Industries system. A plant located at Rosenberg commenced production in 1949; however, this privately owned plant was acquired by Texas Industries and their operations at Rosenberg and Stafford were combined at the Stafford plant (1).

In 1954 Texas Industries constructed their Dallas Haydite plant, Barrett Industries built a small plant in San Antonio and a plant was built at Ranger. Featherlite subsequently purchased the Ranger plant and combined their Strawn and Ranger production facilities at Ranger. Other plants have been built at Waco and at a location between Corpus Christi and Robstown (1) but were not utilized for extended periods of time. The newest lightweight aggregate plant is located at Streetman, Texas and it will be in full production shortly.

In the past few years plants have become operational at Beaumont and near Wharton. Several groups are currently interested in locating plants in East Texas and West Texas. Thus, additional aggregate supplies should be available to meet the demands expected in the future.

Synthetic aggregate producers currently in operation and supplying aggregates for use in seal coats and hot mix asphalt concrete mixtures are shown in Table 1. Plants located at Clodine, Dallas, Eastland, and Ranger have supplied the majority of synthetic aggregates utilized in seal coats.

Codes will be utilized to identify the aggregates in this report. These codes are based on the code developed in a previous Texas Transportation Institute Report (2). Those aggregates utilized in this study are coded A, B, D, H and K and are further described in Table 15.

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	Eagleite
Bay Prairie Aggregate Corp.	Lane City	BPAC
Trotti and Thompson	Beaumont	
Superock, Inc.	Streetman	Superock

Synthetic Aggregate Seal Coats

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 1967 between 300 and 500 miles of synthetic seal coat were placed annually (Table 2).

In May of 1971 a questionnaire was sent to all District Engineers requesting the mileage of synthetic aggregate seal coats placed in their district. Replies from this questionnaire were used as a basis for field visits and subsequent location of trial sections. A summary of the data obtained from these questionnaires can be found in Tables 3 and 4. As noted on these tables, nearly 3,300 miles of synthetic aggregate seal coats are located in 21 of the State's 25 districts. Over 200 miles of synthetic aggregate seal coat have been placed in each of the following districts: 5 (Lubbock), 8 (Abilene), 17 (Bryan), 18 (Dallas), 23 (Brownwood), and 25 (Childress).

Table 4 contains a summary of the sources of aggregates used for synthetic aggregate seal coats in Texas. The material from source A has been utilized on more than 1800 miles of road.

Over 400 miles of synthetic aggregate seal coats were placed during the summer of 1971 in the following districts: 5 (Lubbock), 8 (Abilene), 9 (Waco), 13 (Yoakum), 17 (Bryan), 23 (Brownwood) and 25 (Childress). Thus, a total of approximately 3600 miles of synthetic aggregate seal coats or approximately 5 percent of the total state highway system as of January

TABLE 2

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

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

1972 has a synthetic aggregate seal coat surface. It would not be unreasonable to estimate that 8 to 10 percent of pavement in Texas will be surfaced with mixtures containing synthetic aggregates by the end of the construction season in 1975.

Increased use of synthetic aggregates for coverstone in seal coat operations 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 high 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.

High initial skid resistance and prolonged skid resistance can be obtained with synthetic aggregate seal coats under moderate traffic. Typical skid numbers (coefficients of friction) for synthetic aggregate pavements are shown in Table 5. Figure 1 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. A typical curve illustrating the pavement friction versus traffic for a synthetic aggregate hot mix is shown in Figure 2. Comparison of these two curves indicates that from a skid resistance standpoint under high volumes of traffic, hot mix overlays should prove more beneficial than seal coats.

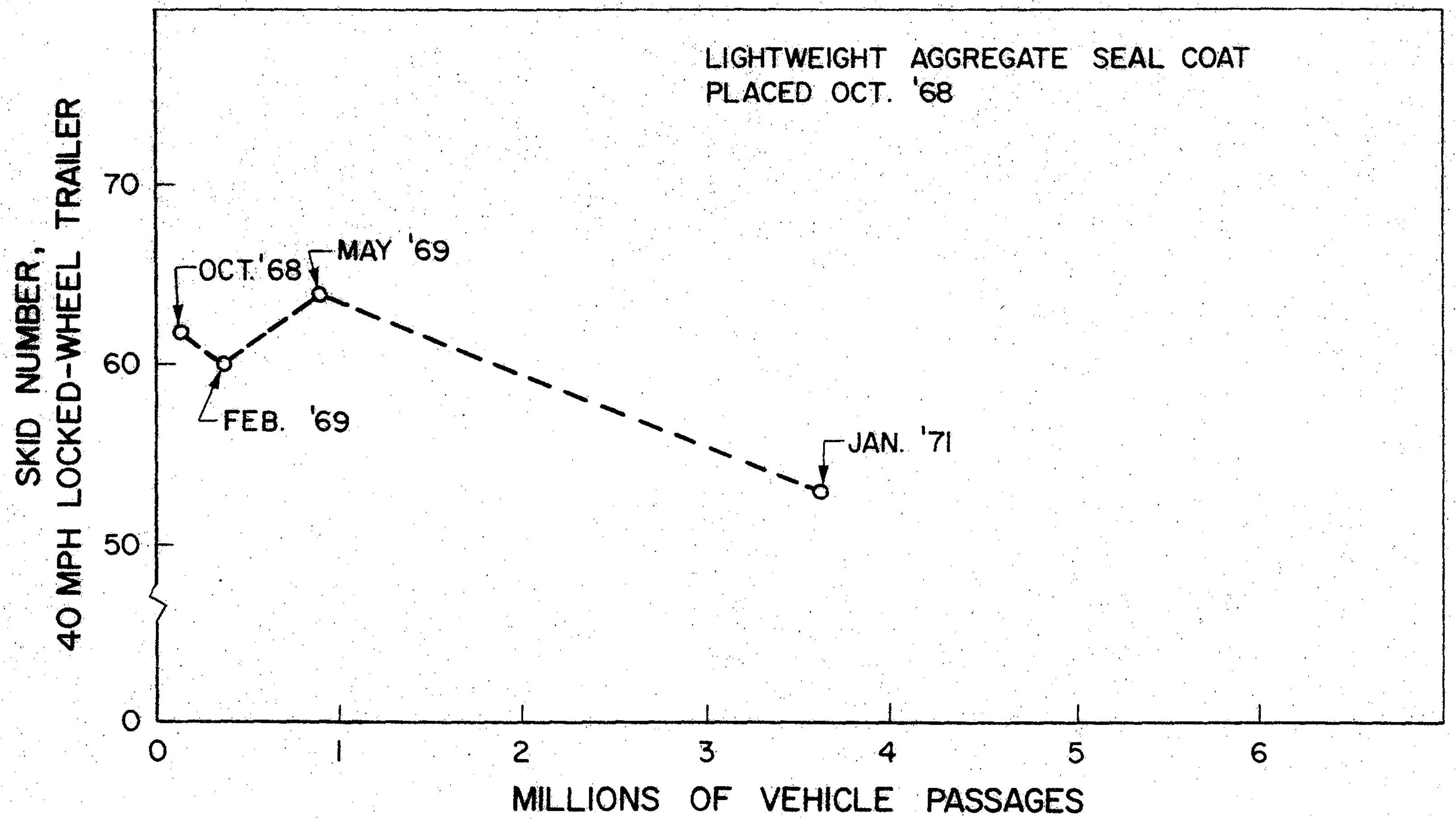

Figure 1. Lightweight Aggregate seal coat
(IH-35, Waco, Texas).

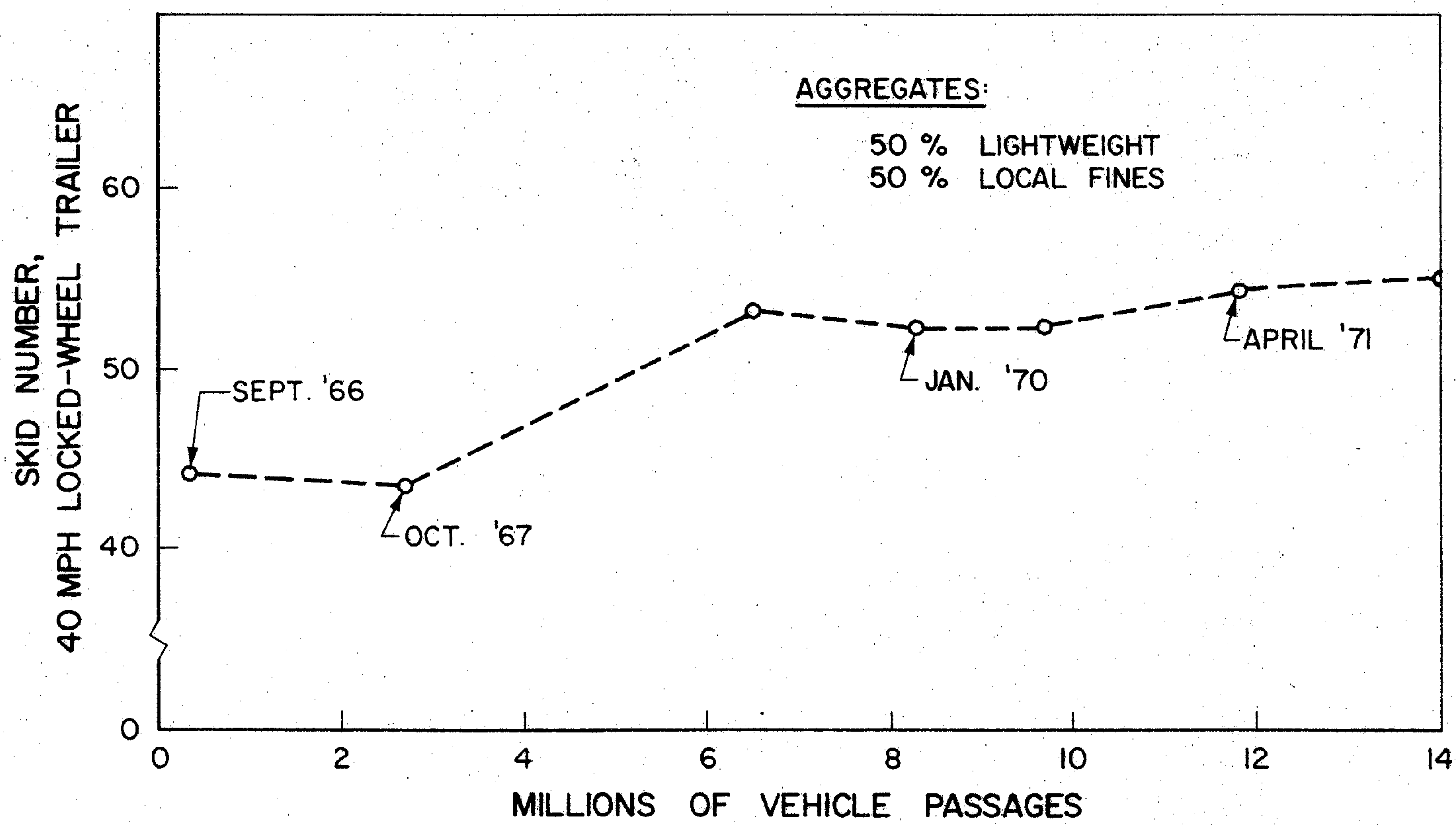

Figure 2. Texas experimental section--lightweight aggregate hot mix pavement (IH-20 Dallas).

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

Glass and paint damage due to flying stones is a problem which exists on the highway under certain conditions (7, 8). Definitive evidence exists which proves that windshield damage and paint damage is significantly reduced or eliminated by the use of synthetic aggregates (Figure 3).

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. However, certain difficulties have been experienced with design, construction and materials specifications during synthetic aggregate seal coat construction. Reasons for these difficulties are briefly outlined in Figure 4 and will be more fully discussed later in the report in terms of materials properties and field experience.

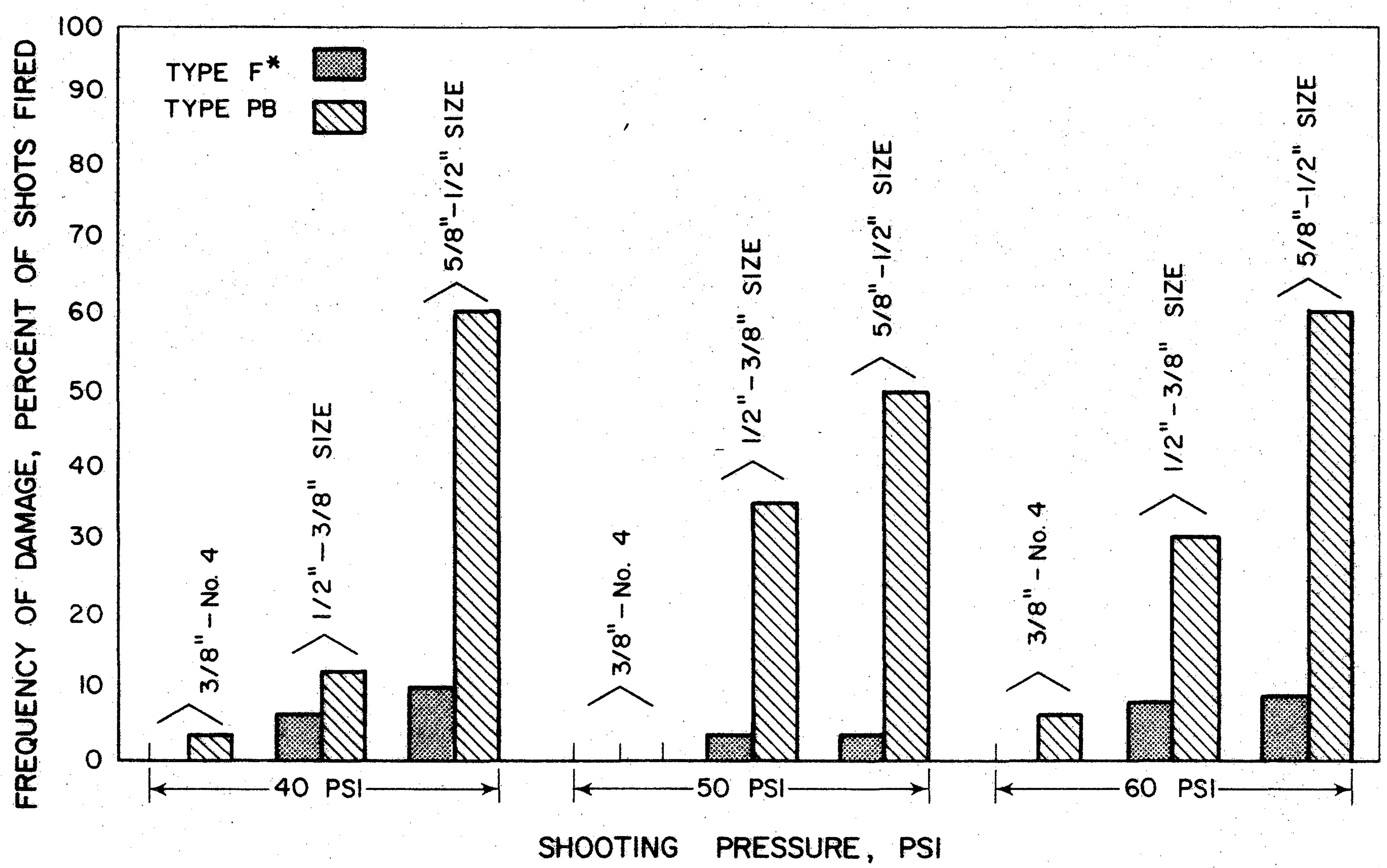

Figure 3. Comparative damage to windshields for Type F* aggregate and Type PB aggregate shot at different pressures.

*after Gallaway (7)

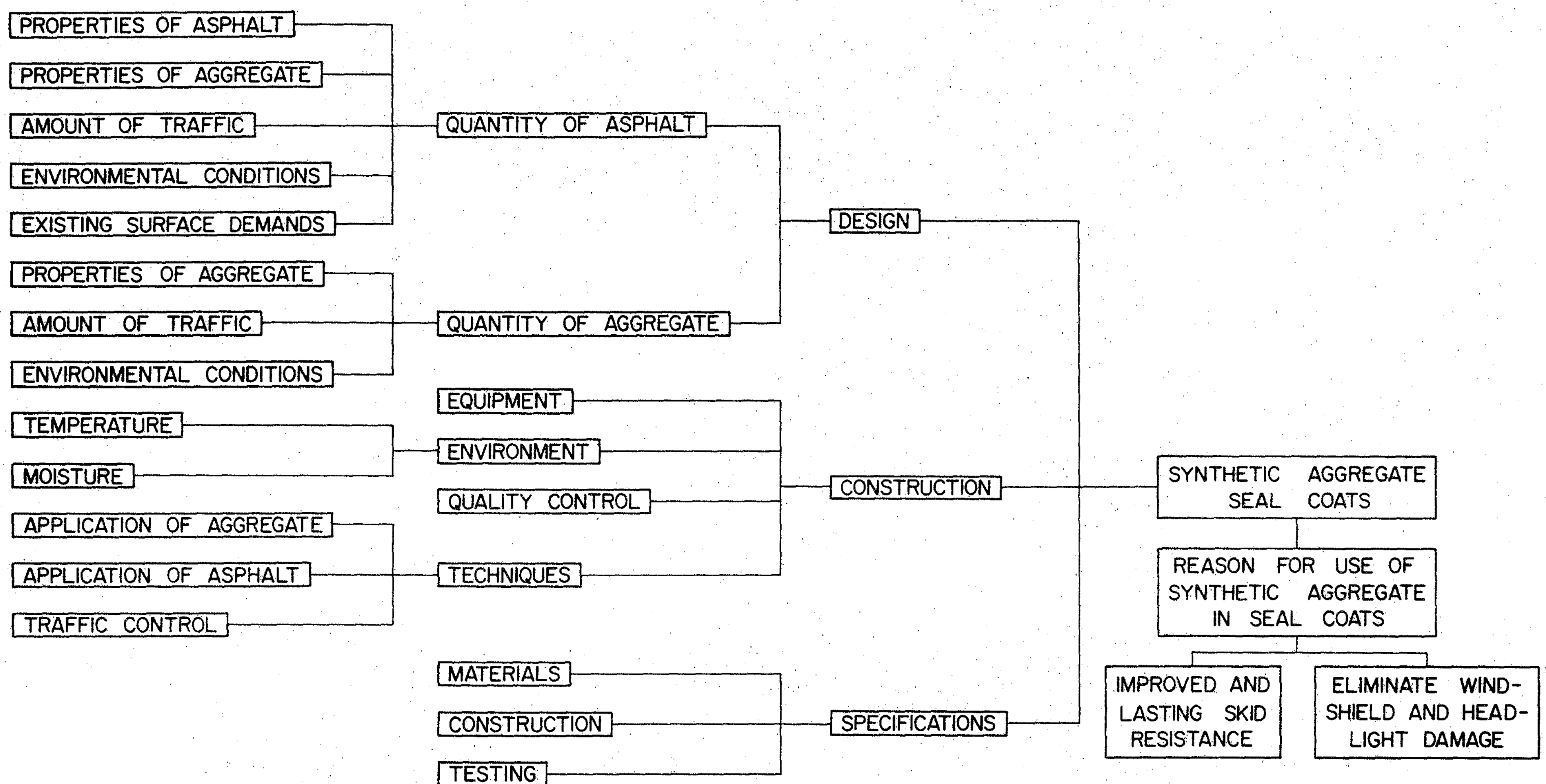

Figure 4. Factors associated with design, construction and specifications of synthetic aggregate seal coats.

EXPERIENCE WITH SYNTHETIC AGGREGATE SEAL COATS

Since the first use of synthetic aggregates as coverstone in Texas in 1961, certain design, construction and material difficulties have been encountered. These difficulties were not unexpected as the utilization of new specialized materials is often accompanied by certain problems. As designers, specification writers and construction crews became more familiar with the performance of these specialized materials under a variety of conditions, many of these difficulties have been reduced.

In an attempt to more accurately define the factors affecting the performance of synthetic aggregate seal coats, several cooperative meetings have been held between Texas Highway Department personnel and the researchers. Results of two such meetings held in October 1968 and January 1969 (10) together with results of Texas Highway Department-Texas Transportation Institute Research Project Number 2-14-63-51 on the "Use of Lightweight Aggregates" (2, 7, 8, 11) served as excellent background data for the present study.

Realizing that additional detailed information would be necessary to successfully accomplish the objectives of this study, visits were made to twelve Texas Highway Department District Offices by Texas Transportation Institute and Texas Highway Department central office personnel. These meetings together with questionnaires were used to define current district synthetic aggregate seal coat practices and to define problems associated with the use of these special materials.

TABLE 3

SUMMARY OF LIGHTWEIGHT SEAL COAT QUESTIONNAIRE*

District Number	District Headquarters	Aggregate Source	MILES PLACED by aggregate type to May 1971	Total
1	Paris	A	15.2	100.6
		B	85.4	
2	Ft. Worth	A	183	204
		B	21	
3	Wichita Falls	A	83	167.5
		B	14.5	
		D	70	
4	Amarillo	A	56	64
		D	8	
5	Lubbock	A	325.4	
		H	6.1	398.5
		D	67	
6	Odessa			None
7	San Angelo	A	36	49
		B	13	
8	Abilene	A	232	301
		D	69	
9	Waco	A	58	58
10	Tyler	A	43	58.4
		D	15.4	
11	Lufkin	A	89	120
		H	31	
12	Houston	H	25.44	25
13	Yoakum	J	33	33
14	Austin	A	37.7	
		D	7.0	53.9
		H	9.2	

TABLE 3 (Continued)

District Number	District Headquarters	Aggregate Source	MILES PLACED by aggregate type to May 1971	Total
15	San Antonio			None
16	Corpus Christi			None
17	Bryan	A	64	441
		D	377	
		H		
18	Dallas	A	108	406
		D	45	
		B	253	
19	Atlanta	A	4.7	10.6
			5.9	
20	Beaumont	A	3.8	5.6
		H	1.8	
21	Pharr	A	2.0	2
22	Del Rio			None
23	Brownwood	A	208	208
24	El Paso			None
25	Childress	A	275	557
		D	282	

* Survey taken May, 1971, indicates response of District Engineers.

TABLE 4

SUMMARY OF LIGHTWEIGHT SEAL COAT QUESTIONNAIRE*

Aggregate Sources		Mileage in Place
A		1823.8
B		379.8
D		676.4
H		350.5
J		33.0
	Total	3263.5

* Survey taken May, 1971, indicates response of District Engineers.

TABLE 5

COEFFICIENT OF FRICTION FOR SYNTHETIC AGGREGATE SURFACES

State	Type of Facility	Age After Construction	Average Daily Traffic	Coefficient of Friction	Measuring Device	Reference
Alabama	Surface Treatment	0	---	0.65	Decelerometer Method	Eiland (3)
		4 mo.	---	0.65		
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	0.63***	Bureau of Public Roads Skid Trailer (ASTM E-274-69)	Mills (6)
Texas	Seal Coat FM 416	5 years	100	0.63	Locked Wheel Texas Skid Trailer (ASTM E-274-69)	
Texas	Seal Coat FM 2452	5 years	300	0.65	Texas Skid Trailer (ASTM E-274-69)	
Texas	Seal Coat	1 year	18,200	0.52	Texas Skid Trailer (ASTM E-274-69)	
Texas	Hot-Mix Overlay Open-graded	1 year	700	0.55	Texas Skid Trailer (ASTM E-274-69)	
Texas	Hot-Mix Overlay Open-graded	1 year	700	0.58	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.

Current District Construction and Design Practices

Districts visited included Districts 2 (Ft. 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 visits and questionnaires submitted by certain of these districts are summarized in Tables 6 to 12.

As shown in Tables 6 and 7 the most commonly used design method for seal coats is a modification of the Kearby Method (12). Experience, together with field alterations of design quantities, are the predominant methods of establishing asphalt and aggregate quantities.

Asphalt cements utilized include AC-5 and AC-10 as described by the Texas Highway Department specifications (Tables 6 and 7). 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. Additional use of "rubberized" asphalt cements is expected in District 5 (Lubbock) during the 1972 construction season.

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. 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.

Gradation of aggregates utilized has varied. Texas Highway Department Grades 3, 4, and 5 have been utilized; however, Grade 4 aggregate now is

TABLE 6

SUMMARY OF PERSONAL FIELD VISITS--APRIL, MAY, 1971

Design Method	Asphalt Type & Application Rates	Aggregate Grading & Application Rates	Aggregate Problems	Type of Rolling	Traffic Control	Broom After Compaction	Additives in Asphalt	Miscellaneous
Not used Field control exercised 5 (Lubbock)	0.35 gal/yd = special precoat 0.32 gal.yd = lightweight 0.30 if bleeding AC-5 OA 175,230 (Maint.)	Use modified Gr.4 1:120 Other 1:140 (lwt.)	Aggregate degrades during transportation	pneumatic	Allow traffic after rolling	No brooming	Polymerized asphalt good results rubber - 1961	Some problems with aggregates
Kearby Method plus experience 8 (Abilene)	AC-5 cool weather AC-10 hot weather emulsion (maintenance) 0.35 gal/yd^2 = regular 0.31 Interstate	Gr.4 1:90 Gr.5 1:100 Higher temperature use higher aggregate spread rate 1:115 morning 1:125 evening	Moisture retention Dust problems Transport contamination	pneumatic roller only	Excess aggregate removed before allowing traffic	Sweep off excess	Silicone DC-200 Rubber wl emulsion increase asphalt cost 10c/gallon	April-Oct. 1 seal coat season Heated aggregate used (.50-.75 p/cy) -use plenty asphalt to insure crack seal
Kearby Method for aggregate quantity & Hanson Method -none used for asphalt quantity 23 (Brownwood)	AC-5, HVRS in future	Grade 4 Lightweight 1:115 1:125	Wet stockpile Excessive tire wear on one FM	pneumatic			Rubber but not recent	Should have spec to vary distribution across travel lane
Experience 7 (San Angelo)	Cosden asphalt 0.28 gal/yd^2 main roads 0.40-0.42 - FM	Grade 4 1:105	Difficult to meet grading specifications	Steel wheel & pneumatic rollers used	6'	Broom off excess	Some rubber asphalt	Tire pressure may be important--like triple courses--
Experience 11 (Lufkin)	AC-5 or AC-10 MC or RC2 primer + Gr.5 then Agg. seal for FM emulsions 0.2-0.25-Gr.4 adjust for road conditions RC-5 for surface course of two course seal	1:140 maintenance 1:120 new constr.	Utilized excessive aggregate on certain projects Gr.3 requires more asphalt. Problems with aggregates. Excess dust. Wet stockpile	pneumatic	Hold speed to 30 mph with tickets			Emulsions will be used
Kearby Method but don't use results specifically (experience) 18 (Dallas)	AC-10 0.25-0.27 gal/yd^2 RC-5 & RC-2 Maint. no emulsions	1:125 Gr.4	Water in stockpile	AM pneumatic	All traffic soon as asphalt covered up			April 1- Oct. 1 Construction season
No set design procedure 25 (Childress)	AC-5 0.30 gal/sq.yd.	Ranger 1:110 Gr.4	Dust not a problem	Steel wheel 1 pass pneumatic		No brooming		Equal performance Gravel strips easier than lightweight
Kearby Method 3 (Wichita Falls)	AC-5 .28 gal/sq.yd.for synthetics .34 gal.yd^2 for hard rock 1:120-1:130 compared-no difference noted	1:130 most common 1:120 design 1:90 hard rock some crushing lightweight Gr.4	Some crushing moisture & temperature a problem rain up to 2 days after placing has created problems	pneumatic	Traffic off until rolling finished	No brooming	No emulsions or rubber	May 15-Oct.Const. Don't vary across roadway -some bleeding from below
Design based on judgement 2 (Jacksboro)	AC-10, AC-5	Gr.4	No wet aggregate problems	pneumatic	Traffic off until after first compaction			May 1- Oct.1. Const. season
Experience 2 (Fort Worth)	AC-5, AC-10, 135 pen .28 gal/sq.yd	1:115 Gr.4	Wet stockpile	pneumatic	No special traffic control	Broom off in morning when asphalt is cold		May 1- Oct.1 Const.seal btwn.overlays
Kearby Method originally but now use experience 9 (Waco)	HVRS 0.35 gal/yd^2 135 0.40-0.42 emulsion or AC -02 diff.outside lane	Gr.4 1:120	No problems wet aggregate in morning Some dust-not as much as limestone Difficult to sample	Light pneumatic	Keep traffic off 3-5 hours	Broom off excess next day	No rubber	Rain & cold weather give trouble Skid no. once a year Shoot emulsions at high pressure Elliptical nozzles
Modified Kearby Method 17 (Bryan)	Emulsion		Dusting and some degradation with aggregate H	pneumatic	No attempt to reduce speed	No brooming		Special end nozzle lightweight & emulsion better than precoat and AC

TABLE 7

MATERIAL QUANTITIES
LIGHTWEIGHT SEAL COAT CONSTRUCTION

Section Designation	Quantity Determination	Asphalt Quantity gal/sq. yd.	Aggregate Spread Quantity cu. yd./ sq. yd.	Asphalt Type	Producer
5-7-1	Experience	0.320	1:110	AC-5	01
5-7-2	Experience	0.339	1:110	AC-5	01
5-7-3	Experience	0.299	1:117	EA-HVRS	01
5-7-4	Experience	0.351	1:110	AC-5	01
5-9-1	Experience	0.348	1:110	AC-5	01
5-9-2	Experience	0.350	1:110	AC-5	01
7-9-1		0.30 outside 0.28 inside	1:105	AC-10	01
9-9-1	Experience & test section	0.40	1:125	EA-HVRS	22
9-8-1	Experience & District Design Procedure	0.382	1:120	EA-HVRS	22
9-7-1	Experience & Kearby	0.278	1:131	AC-10	03
9-11-1	Experience & District Design Procedure	0.425	1:120	EA-HVRS	22
17-8-1	Experience	0.25	1:130	AC-10	18
17-9-1	District Design Procedure	0.31	1:116	AC-10	06
17-11-1	District Design Procedure	0.414	1:119	EA-HVRS	22
18-9-1	Experience	0.28	1:125	AC-10	01
18-9-2	Experience	0.29	1:125	AC-10	17
18-8-1	Experience	0.30	1:125	AC-10	03
19-6-1	Experience	0.25	1:130	AC-10	03

TABLE 7 (Continued)

Section Designation	Quantity Determination	Asphalt Quantity gal/sq. yd.	Aggregate Spread Quantity cu. yd./ sq. yd.	Asphalt Type	Producer
23-11-1	Experience	0.30	1:117	AC-5	01
23-7-1	Experience	0.28	1:115	AC-10	07
23-5-1	Experience	0.35	1:115	OA-135	07
23-3-1	Experience	0.26	1:100	OA-135	07
25-10-1	Experience	0.30	16 lbs/sq. yd.	AC-5	01

used almost exclusively. Modifications of certain grades have been used on a limited basis. A summary of the various gradations and gradation limits that have been utilized are shown in Table 8 and 13.

Aggregate application rates as reported by the various districts ranged from 1:90 to 1:140*. An average value of about 1:115** was indicated for a Grade 4 aggregate (Tables 6 and 7).

A summary of district rolling operations can be found in Tables 9 and 10. Pneumatic tired rollers have been used extensively; however, a light steel wheel roller was utilized in one district to seat the rock in the asphalt. Crushing of the aggregate may result if heavy steel wheel rollers are utilized or multiple passes of light steel wheel rollers are utilized. Thus for normal operations, steel wheel rollers are not recommended.

Removal of excess aggregate by brooming is utilized in some districts; however, about half of the districts visited avoid this operation.

Control of traffic speed for a prescribed period of time after construction is not the usual state practice; however, some districts follow this policy. Traffic is usually kept off of the newly sealed surface until rolling is complete.

Types of aggregate spreading equipment and asphalt distribution equipment utilized by several districts is given in Table 10. Control of aggregate and asphalt quantities is usually controlled by staking rock lands and establishing a fixed setting on the spreader box for a certain speed while spreading a known amount of aggregate. Strapping of the asphalt distributor

*Ratio of loose cubic yards of material to the area the material will cover on the roadway surface measured in square yards.

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

TABLE 8

AGGREGATE DATA
LIGHTWEIGHT SEAL COAT CONSTRUCTION

Section Designation	Aggregate Code	THD Type & Grade of Aggregate	Unit Weight (loose, dry) pounds/cubic foot	Sieve Analysis, Percent Retained				
				5/8 inch	1/2 inch	3/8 inch	No. 4	No. 10
5-7-1	H	TyF, Gr. Sp.	49.98 45.04	 0				
5-7-2	A	TyF, Gr. Sp.	50.0	0	0	40.7	93.8	98.9
5-7-3	A	TyF, Gr. 4	50.0	0	0	33	99	99
5-7-4	A	TyF, Gr. Sp.						
5-9-1	A	TyF, Gr. Sp.	46.65					
5-9-2	A	TyF, Gr. Sp.	46.65					
7-9-1	D	TyF, Gr. 4		0	0 0	5.9 3.6	64.0 69.6	98.6 98.6
9-9-1	A	TyF, Gr. 5	49.01	0	1.3	21.7	95.3	98.3
9-8-1	A	TyF, Gr. 4	49.77 50.27	0	0.6	19.0	92.5	98.6
9-7-1	G	TyF, Gr. 4	42.6		0	13.2 20.0	85.9 90.2	99.3 97.1
9-11-1	A	TyF, Gr. 4	48.41	0	0.7	32.3	98.1	99.4
17-8-1	H	TyF, Gr. 5						
17-9-1	H	TyF, Gr. 4 Med.	47.34			25	96	99
17-11-1	A	TyF, Gr. 4	52.39	0	1	33	98	99
18-9-1	B	TyF, Gr. 4	38.02	0	0.5	39.2	98.9	99.7
18-9-2	B	TyF, Gr. 4	38.02	0	0.5	39.2	98.9	99.7
18-8-1	D	TyF, Gr. 4	50.54	0	0	15.9	89.2	97.1
19-6-1	A	TyF, Gr. 4	49.2	0	0	17.3	88.8	98.5
23-11-1	A	TyF, Gr. 4 med.	47.6 52.2	0	1.5	28	96	99.7
23-7-1	A	TyF, Gr. 4	50	0	0	25	92	99

TABLE 8 (Continued)

Section Designation	Aggregate Code	THD Type & Grade	Unit Weight (loose, dry) pounds/cubic foot	Sieve Analysis, Percent Retained 5/8 inch	1/2 inch	3/8 inch	No. 4	No. 10
23-5-1	A	TyF, Gr. 4	51.7	0	0	13.2	90.0	98.8
23-3-1	A	TyF, Gr. 4		0	0	17	90	98.5
25-10-1	A	TyF, Gr. 4		0	1	29	96	100

TABLE 9

ROLLING OPERATIONS
LIGHTWEIGHT SEAL COAT CONSTRUCTION

Section	Roller Type	Roller Weight (tons)	Tire Pressure (psi)	Number of Passes	Problems with rolling operation
5-7-1	Pneumatic	4.5		12-16	None
5-7-2	Pneumatic	4.5		12-16	None
5-7-3	Pneumatic	4-5		10-12	None
5-7-4	Pneumatic	4.75 & 8.75		12-16	None
5-9-1	Pneumatic	5 & 10		12-16	None
5-9-2	Pneumatic	5 & 10		12-16	None
7-9-1	Light Pneumatic				
9-9-1	Pneumatic		50	6	
9-8-1	Pneumatic		50	6	
9-7-1	Pneumatic				None
9-11-1	Pneumatic		50	6	At 92-95° rock turns over, no buildup though
17-8-1	Pneumatic			5	
17-9-1	Pneumatic	5		5	
17-11-1	Pneumatic			5	
18-9-1	Light Pneumatic	4.25-5.5	45-50	3.1 hrs/mi.	
18-9-2	Light Pneumatic			4.7 hrs/mi.	
18-8-1	Light Pneumatic	4.25-5.5	45-50	5.2 hrs/mi.	None
19-6-1	Light Pneumatic	4.25-5.5	95-50	4.4hrs/mi.	
23-11-1	Light Pneumatic			2000 sy/hr	None
23-7-1	Flat wheel Pneumatic				
23-5-1	Light Pneumatic				

TABLE 9. (Continued)

Section	Roller Type	Roller Weight (tons)	Tire Pressure (psi)	Number of Passes	Problems with rolling operation
23-3-1	Flat wheel Light Pneumatic			1 or 2	
25-10-1	Flat wheel Med. Pneumatic			1 4	 None

TABLE 10

CONSTRUCTION DATA
LIGHTWEIGHT SEAL COAT CONSTRUCTION

Section	Aggregate Spreading Equipment	Aggregate Quantity Control	Asphalt Distribution Equipment	Asphalt Quantity Control	Spray Nozzle Overlap	Spraying Pressure	Asphalt Spraying Temperature °F	Problems Spraying & Spreading
5-7-1	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	1 Triple	Unknown	350	None
5-7-2	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	Triple	Unknown	350	None
5-7-3	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	Triple	Unknown	140	None
5-7-4	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	Triple	Unknown	340	None
5-9-1	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	Triple	Unknown	340	None
5-9-2	Flaherty Spreadmaster	Experience & Visual	Etnyre Pressure Distributor	As directed by Engineer	Triple	Unknown	340	None
7-9-1								
9-9-1	Flaherty Power Spreader	Staking rock lands	Etnyre Model B-TR	Gallons per measured land	Double	12 psi/ft. bar	160	
9-8-1	Flaherty Power Spreader	Staking rock lands	Etnyre Model FK 400	Gallons per measured land	Double	15 psi/ft. bar	145	
9-7-1	Flaherty Self-propelled	Calibrate Spreader box-strike-off trucks	Etnyre	Manufacturer's charts	Double	10 psi/ft. bar	350	Spreader exhaust displaces aggregate
9-11-1	Flaherty Power Spreader	Calibrate Spreader box-strike-off trucks	Etnyre Model B-TR	Strapping	Double	12 psi/ft. bar	150-155	
17-8-1	Flaherty Self-propelled	Land distance & measured volumes	Etnyre	Tachometer & Pressure Pump			350	None
17-9-1	Falherty Self-propelled (Model K)	Land distance & measured volumes	Etnyre Model B-TR	Tachometer & Pressure Pump	Double		350	None

TABLE 10 (Continued)

Section	Aggregate Spreading Equipment	Aggregate Quantity Control	Asphalt Distribution Equipment	Asphalt Quantity Control	Spray Nozzle Overlap	Spraying Pressure	Asphalt Spraying Temperature °F	Problems Spraying & Spreading
17-11-1	Flaherty Self-propelled	Land Distance & measured volumes	Etnyre	Tachometer & Pressure Pump	Double		160	None
18-9-1	Falherty Self-propelled (Model K)	Calibrated box opening & speed	Etnyre FX 400 style D	Orifice size, temperature, spray pressure, distributor speed	Triple		320-340	Delay on asphalt arrival
18-9-2	Etnyre Spreader	Calibrated box opening & speed	Etnyre		Triple		340	
18-8-1	Flaherty Spread Master (K)	Calibrated box opening & speed	Etnyre FX 400 Style D	Orifice size, temperature, spray pressure, distributor speed	Triple		350	28 foot road 3 passes, spreader
19-6-1	Flaherty Spread Master (R)	Calibrated box opening & speed	Etnyre FX 400 Style D	Orifice size, temperature, spray pressure, distributor speed	Triple		320-375	Time loss at intersection
23-11-1	Self-propelled	Lands spread rate	Etnyre	Gallons/area	Triple & Quadruple		350	None
23-7-1	Self-propelled	Lands Spread rate	Etnyre FX 400	Gallons/area	Triple & Quadruple	Higher than manufacturer recommends	350	None
23-5-1	Self-propelled	Lands spread rate	Etnyre FX 700	Gallons/area	Triple		340	Spreader box down one hour
23-3-1	Self-propelled	Lands Spread rate	Etnyre FX 400 Style D	Gallons/area	Triple	Higher than recommended	370	None
25-10-1	Self-propelled	Rock lands	Etnyre single	Strap	Triple	20 psi	325	None

TABLE 11

SECTION DATA

LIGHTWEIGHT SEAL COAT CONSTRUCTION

Saction	Vehicles per Day	Percent Trucks	Number of Lanes	Number hours after spraying traffic or road again	Traffic Speed Control
5-7-1	15,370		4 & 6	1	None
5-7-2	5800-9080		2 & 4	1	None
5-7-3	4400		4	24-28	None
5-7-4	1790		2	1	None
5-9-1	2150		2	1	None
5-9-2	2450		4	1	None
7-9-1	3000-4700		4(divided)		----
9-9-1	15,000	13	4	1½-5	None
9-8-1	14,000	17	4	5	None
9-7-1	530-660		2	1	None
9-11-1	10,000	13	4	2-5	None
17-8-1	6100		2	1	2 hours speed control
17-9-1	280-1310		2	1	None
17-11-1	3700		2 & 4	2	None
18-9-1	266		2	Soon as cover-stone spread	None
18-9-2	610		2	Soon as cover-stone spread	None
18-8-1	247		2	Soon as cover-stone spread	None
19-6-1	1388		2	Soon as cover-stone spread	None
23-11-1	300	7	2	¼	None
23-7-1	1000	9	2	¼	None
23-5-1	100	10	2	¼	None
23-3-1	1000	9	2	¼	None
25-10-1	1740	10	2	2	None

TABLE 12

LIGHTWEIGHT SEAL COAT PERFORMANCE

Control Number	Date	Overall Performance	Loss of Coverstone Percent Surface Area	Bleeding Percent Surface Area	Crushing of Aggregate	Cause of Distress
5-7-1	1967	Poor	---	Slick surface	Extensive	Aggregate Under-fired
5-7-2	1967	Good	1.0	None	Small amount or inter-section	---
5-7-3	1967	Poor	---	----	---	Emulsion did not stick
5-7-4	1967	Good	Very little	None	Small amount or inter-section	---
5-9-1	1969	Excellent	None	None	---	---
5-9-2	1969	Good for 30 hrs. then poor	85-90	90	---	Contaminated asphalt
7-9-1	1969	Poor	Large amount	---	Some dust cloud	Possibly wet stockpile
9-9-1	1969	Good	---	---	None	Rain on emulsion flushing around aggregate
9-8-1	1968	Good	---	---	None	Rained 2 hours after shooting reshot with no problems
9-7-1	1967	Good	Negligible	Negligible	None	None
9-11-1	1971	Good	<10	None	None	None
17-8-1	1968	Poor	75	50	Some	Excessive dust from aggregate crushing
17-9-1	1969	Good	---	---	Small amount	Dusty-some aggregate doesn't stick
17-11-1	1971	Good	5	25	None	High traffic & turning causes bleeding in city area
18-9-1	1969	Good	Negligible except in curve wheel paths	Negligible except in curve wheel paths	Some but no damage	Traffic allowed before aggregate bonded to asphalt-loss of coverstone
18-9-2	1969	Poor	70-80	Excessive	Negligible	Rain after aggregate spread-no bond
18-8-1	1968	Good	Negligible	<1.0	Some but no damage to roadway	---
18-6-1	1966	Good	Negligible	Negligible	Negligible	---
23-11-1	1971	Excellent	None	None	Slight	---
23-7-1	1967	Excellent	None	None	Slight	None
23-5-1	1965	Excellent	---	---	---	---
23-3-1	1963	Excellent	None	None	Slight	None
25-10-1	1970	Poor	30	25	None	Rain during construction operations

TABLE 13

SYNTHETIC AGGREGATE COVERSTONE GRADING SPECIFICATIONS

Sieve Size	1972 THD Specifications (1)			1965 THD Specifications (2)			District 5	District 8
	Grade 3	Grade 4	Grade 5	Grade 3	Grade 4	Grade 5	Grade 4 Special	Special (3)
3/4 inch	0			0				
5/8 inch	0-5	0		0-2	0		0	
1/2 inch	30-50	0-5	0	5-20	0-2	0	0-2	0
3/8 inch	85-100	20-40	0-2		5-25	0-2	30-60	20-4
No. 4	95-100	95-100	60-80	85-100	85-100	40-85	90-100	90-100
No. 10	98-100	98-100	98-100	98-100	98-100	98-100	98-100	

(1) First published as THD Special Specification Item 1989 in 1969.
(2) First published about 1965 as THD Special Specification Item 1269.
(3) This gradation has been utilized on limited projects.

before and after each asphalt shot is the usual method of determining the quantity of asphalt. Representative asphalt spraying temperatures, spraying pressure, and nozzle overlap are also given in Table 10.

Problems Associated with Synthetic Aggregate Seal Coats

Each material utilized on highway construction has its own associated problems. Synthetic aggregates are no different in this respect. The introduction of a new material requires time. The fact that synthetic aggregates have been used in seal coats on a limited basis for about ten years indicates that all problems associated with design, construction, and the material have not been solved. Another primary factor is the limited availability of this material.

Questionnaires utilized 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. These data are summarized in Tables 11 and 12. Environmental data obtained from U. S. Weather Bureau Data recorded near the job site (13) and taken during the construction period are also summarized in Table 14. 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, or degradation. 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 (Tables 6 and 12). Precautions are always taken to stop construction during

TABLE 14

Section	Construction Dates	Maximum Air Temperature	Minimum Air Temperature	Precipitation During Construction	Precipitation Before Construction Date	Precipitation Before Construction Amount	Precipitation After Construction Date	Precipitation After Construction Amount	Average Humidity 12 a.m.
5-7-1	8-14	89	61	T	8-12	0.02	8-18	T	46
	8-15	90	62	0.14					
	8-16	71	62	0.07					
	8-17	80	61	0.00					
5-7-2	8-18	90	56	T	8-15	0.14			46
	8-19	87	60	0.00	8-16	0.07			
	8-20	89	63	0.00					
	8-21	88	62	0.06					
5-7-3	3-13	84	45	0.00					40
	3-14	81	47	0.00					
5-7-4	7-29	100	69	0.50					47
	7-30	93	69	0.00					
	7-31	97	72	0.00					
5-9-1	6-26	95	70	0.00					38
	6-27	96	60	0.00					
	6-28	101	67	0.00					
	6-29	98	69	0.00					
	6-30	97	70	0.00					
5-9-2	6-10	81	58	0.00	6-8	.07			38
	6-11	89	59	0.00					
	6-12	87	50	0.00					
	6-13	83	51	1.25					
	6-14	65	48	0.62					
	6-15	63	47	0.00					
	6-16	68	45	0.11					
	6-17	75	53	T 0.00					
	6-18	82	59	0.00					
	6-19	82	57	0.00					
	6-20	92	59	0.04					
7-9-1	9-17	86	67	0.04					59
	9-18	73	65	1.91					
9-9-1	9-16	99	73	2.20	9-15	T			94-48
	9-19	89	71	0.00	9-22	0.02			84-48
	9-20	90	70	2.00	9-15	0.42			90-52
	9-24	85	65	0.00					97-39
	9-25	90	65	0.00					97-44
9-8-1	9-4	95	73	0.34	9-3	0.07			91-50
	9-6	88	65	0.00	9-5	T			84-45
	9-9	90	66	0.00					79-31
	9-10	87	62	0.00					78-27
	9-11	86	56	0.00					80-28
	9-12	87	57	0.00					78-31
	9-13	85	61	0.00					81-40
	9-14	74	66	1.28					87-62
	9-15	86	69	0.64					90-61
	9-16	96	72	0.00					88-54
	9-17	79	67	0.85					81-44
	9-18	86	56	0.00					83-26
	9-19	88	62	0.00					75-39
	9-20	92	71	0.03					87-52
	9-21	87	74	0.06					88-63
	9-22	90	72	0.00					88-52
	9-23	90	74	0.00					91-51
	9-24			1.24					
9-7-1	5-25	87	65	0.00	5-20	.85	5-29	1.35	62
				0.00	5-21	T			
9-11-1	6-17	99	74	0.00	6-15	T	6-27	.17	79-29
	6-18	97	75	0.00	6-19	0.02			87-34
	6-24	99	72	0.00	6-20	T			
	6-25	96	72	0.00	6-21	0.5-2.0			
	6-26	95	74		6-22	.03			
17-8-1	9-	*95	*75	0.00					
17-9-1	6-9	90	69	0.00	6-3	1.86			
	6-10	90	70	0.00	6-4	1.09			
17-11-1	8-20								
	8-21								
	8-22								
	8-23								
	8-24								
	8-25								
	8-26								
	8-27								
19-9-1	7-3	101	77	0.00					
	7-7	98	78	0.00					
19-9-2	5-30	92	72	T	5-28	.09			59
	6-2	80	58	0.00	6-1	.02			50
19-8-1	7-16	91	71	0.00	7-13	.54	7-20	0.33	55
	7-17	91	71	0.00	7-14	1.52			
19-6-1	7-27	97	78	0.00	7-23	0.05			57
	7-28	98	79	0.00	7-25	.07			
23-11-1	5-27	97	62	0.00	5-25	0.34			38
	5-28	90	64	0.00					
23-7-1	7-14	88	63	0.42	7-13	T	7-18	0.04	50
	7-17	91	66	0.00			7-19	0.10	
							7-20	0.63	
							7-21	0.10	
23-5-1	8-9	94	70	0.04	8-7	1.15			39
	8-10	96	67	0.00					
23-3-1	7-29								
	7-30								
25-10-1	5-26	88	58	1.0	5-24	0.74	5-28	0.89	51

*Monthly averages

rainfall; however, a very small percent of seal coat construction is subjected to the rainfall during construction. Subsequent loss of some coverstone usually results. This loss of coverstone is more likely under high traffic volumes.

Rainfall after construction can sometimes 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. High traffic volumes will increase the probability of failure.

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. Figure 5 has been prepared to illustrate this observed behavior. If a dry aggregate is utilized during construction, a certain degree of bond between the asphalt and aggregate is established as the aggregate falls into the asphalt. As the asphalt cools (less than two minutes are required to reach an equilibrium temperature) and aggregate seating is effected, the bond increases. After a certain length of time the bond between the asphalt and aggregate is of such strength that water will not displace the asphalt from the aggregate surface. Thus, rainfall will not create raveling. Certain types of aggregate-asphalt combinations produce a stronger bond than others as depicted by a comparison between Case A and Case B in Figure 5.

The typical case involving wet aggregate and the associated poor bond that can be established between the asphalt and the aggregate is shown as Case C in Figure 5. A significantly longer period of time is required to provide a bond of necessary tenacity to prevent raveling due to subsequent rainfall. The shape of the Case C Curve is controlled by the following

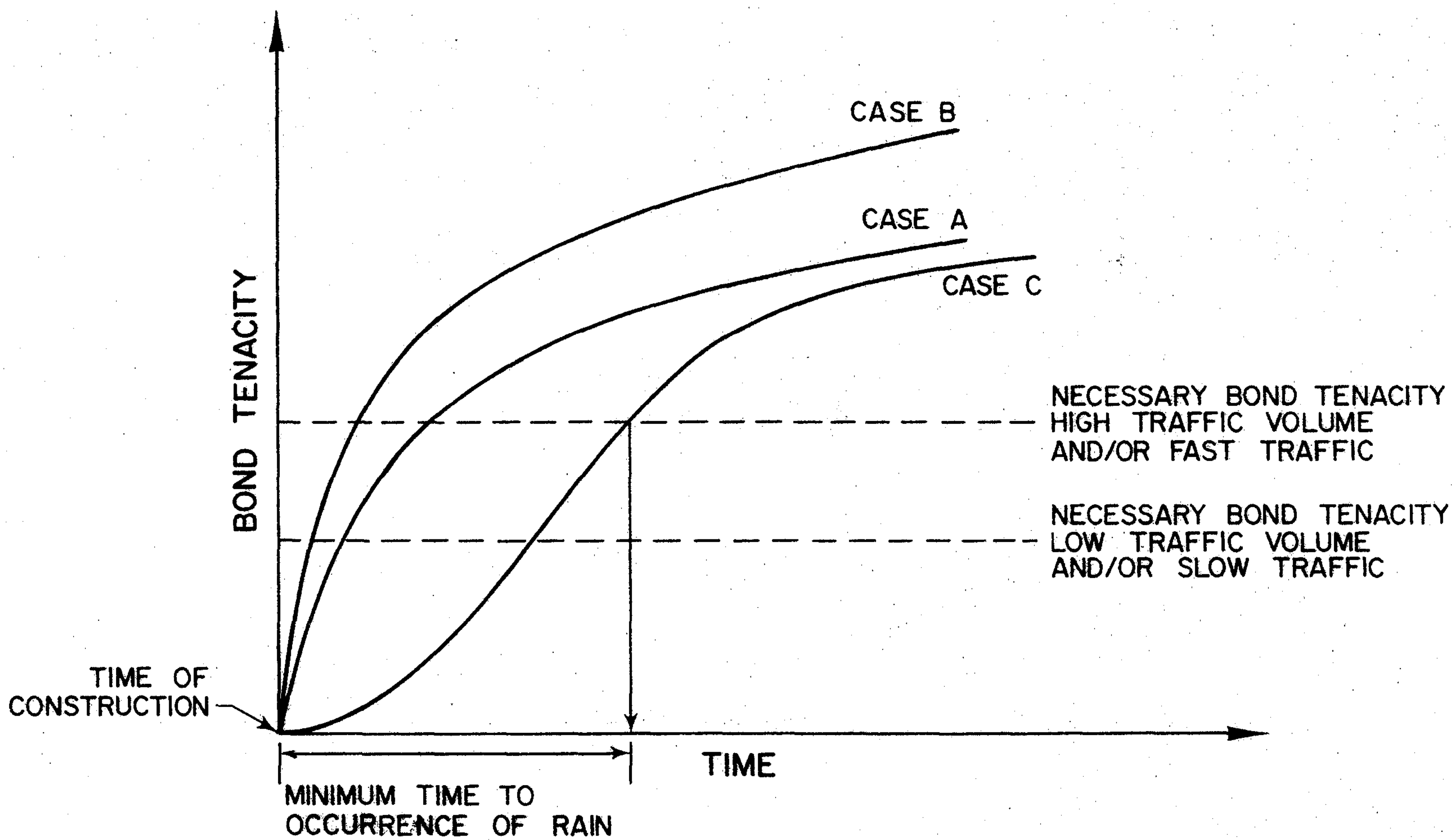

Figure 5. Time required to establish necessary bond tenacity prior to rainfall.

factors: temperature, humidity, and absorption properties of the aggregate.

To establish the required 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 control the requirements to a certain degree (Figure 5).

Moisture present in the aggregate during construction is often detrimental as illustrated 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 precoated aggregates is shown in Table 15. This comparison illustrates the relatively high absorption capacity of synthetic aggregates. Figure

TABLE 15

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**
H	1.81	2.30	43.4	13.8	21.3	24.6	9.04	33.2	30.0
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
A	1.57	2.21	52.4	12.8	28.9	14.0	9.20	27.6	2.3
K	2.43	2.62	84.0	1.93	7.3	476	2.85		
Number of Tests	3	3	2	2	3	3	3		

*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.

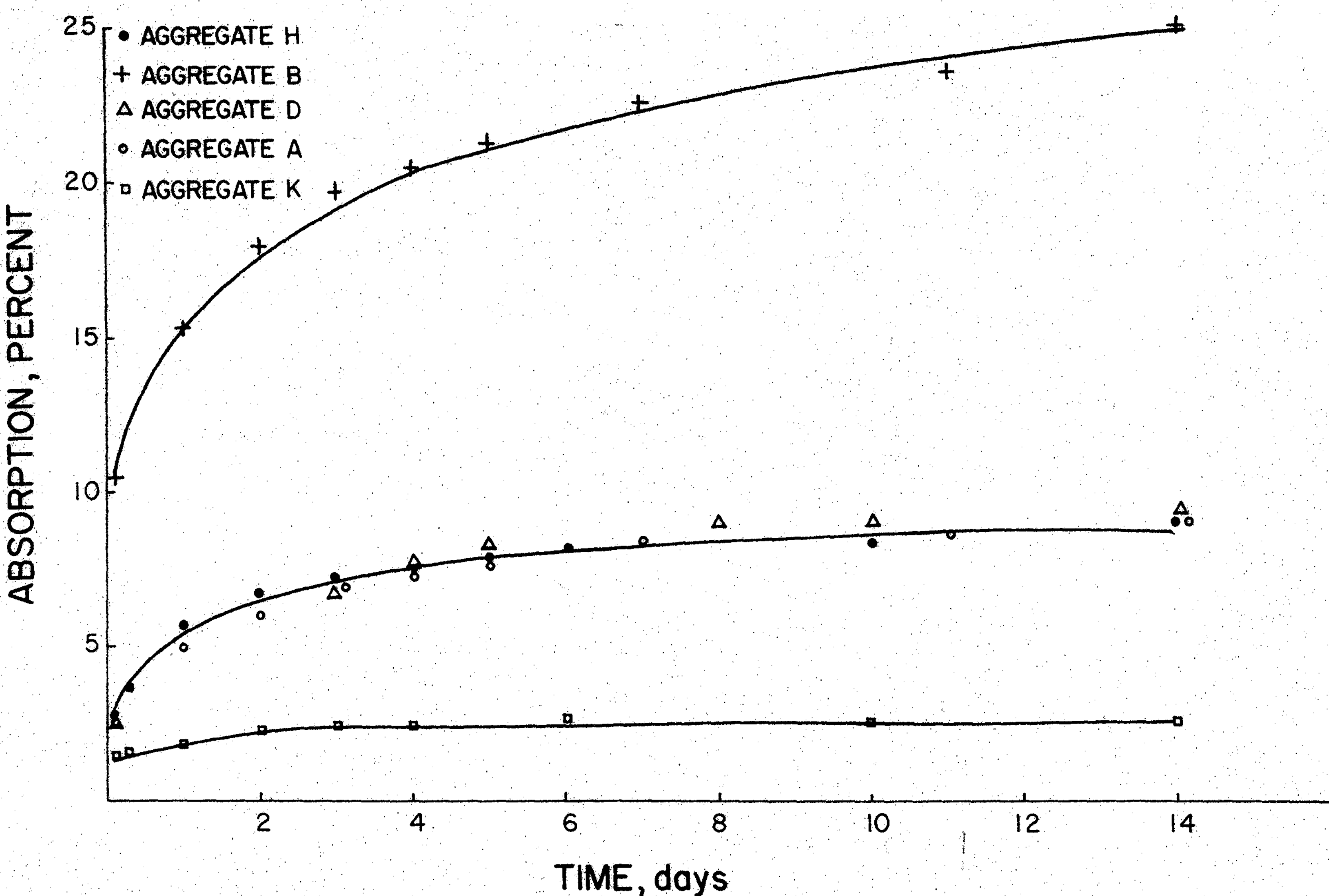

Figure 6. Typical absorption curves.

6 illustrates the rate of absorption for various synthetic aggregates thereby illustrating the field observed problems of wet aggregates in the stockpile. 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 other types. 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 resulting 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.

The degree of aggregate degradation during construction and traffic for typical synthetic aggregate seal coat and precoated limestone projects is shown in Figures 7 and 8, respectively (7). Additional field data on lightweight aggregate seals are shown in Figure 9. The effect of rolling on aggregate degradation is shown in Figure 9 together with an alternative representation of the identical degradation data in bargraph form in Figure 10. These data indicate that certain construction precautions as well as material selection judgement should be exercised with synthetic aggregates to minimize aggregate degradation.

General performance trends experienced by construction and maintenance personnel suggest that aggregates A and D experience only minimal degradation

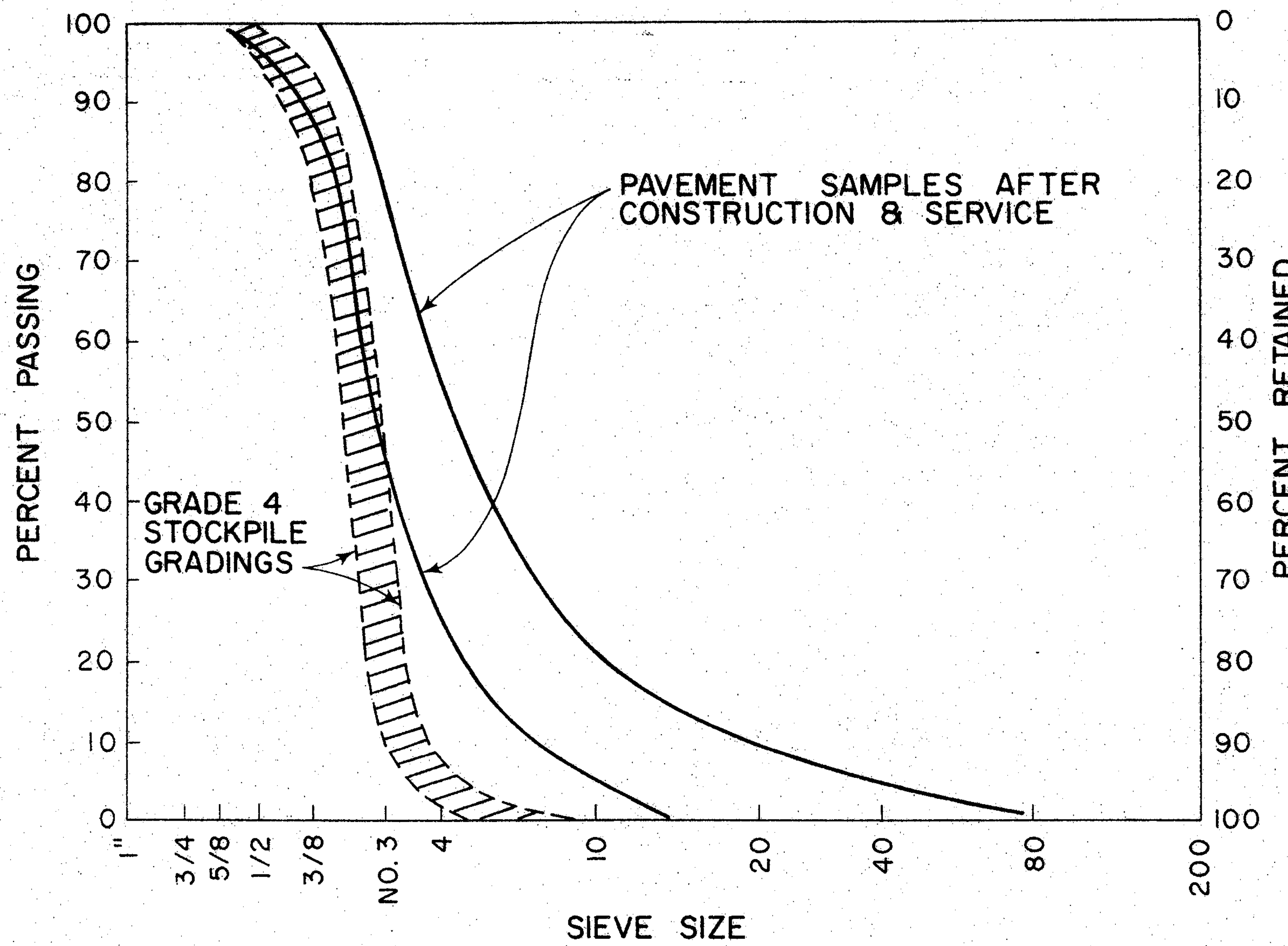

Figure 7. Comparative degradation of lightweight aggregate due to construction and service (after Gallaway (7)).

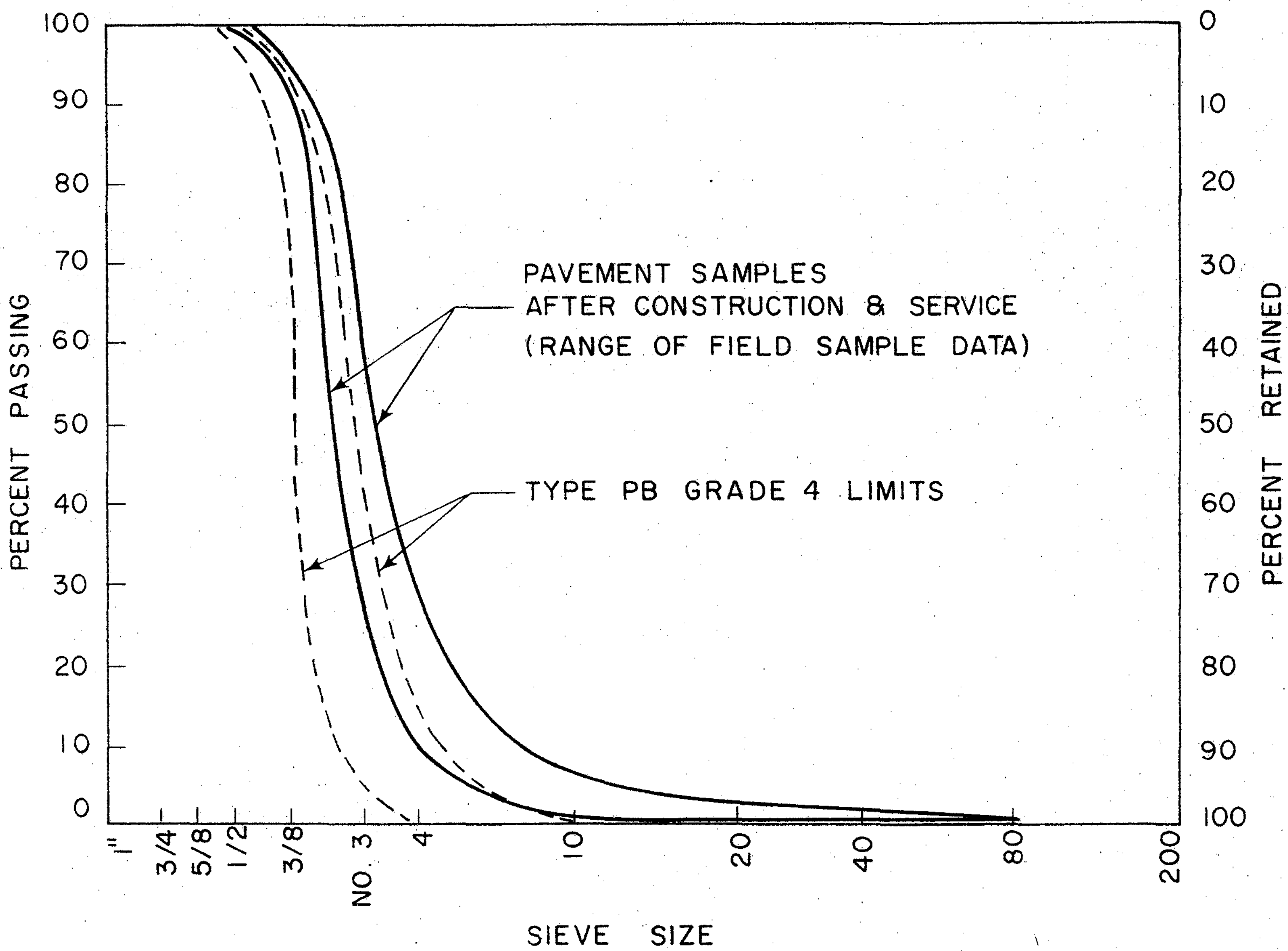

Figure 8. Comparative degradation of precoated limestone due to construction and service (after Gallaway (7)).

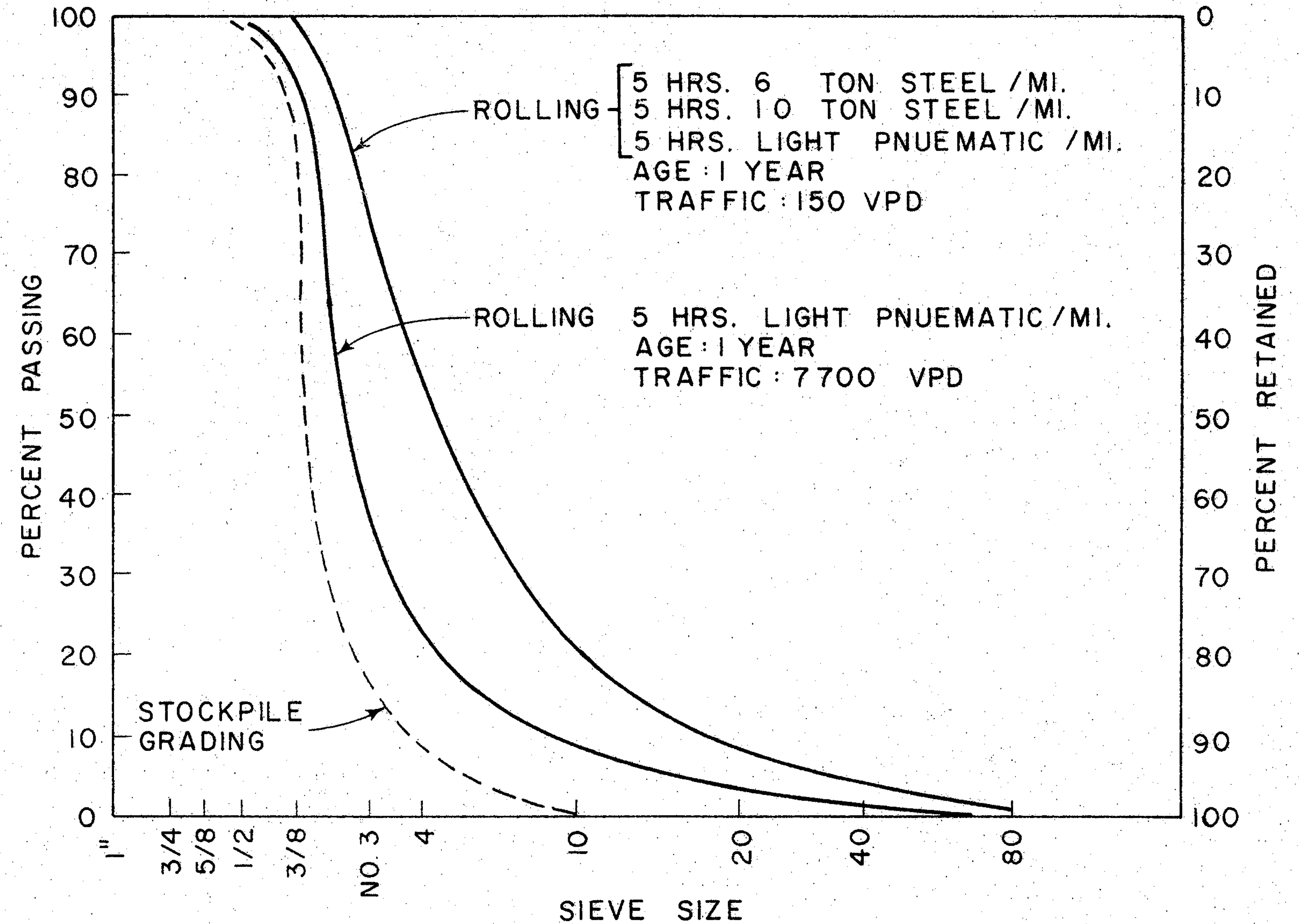

Figure 9. Degradation of Type F aggregate due to construction and service (after Gallaway (7)).

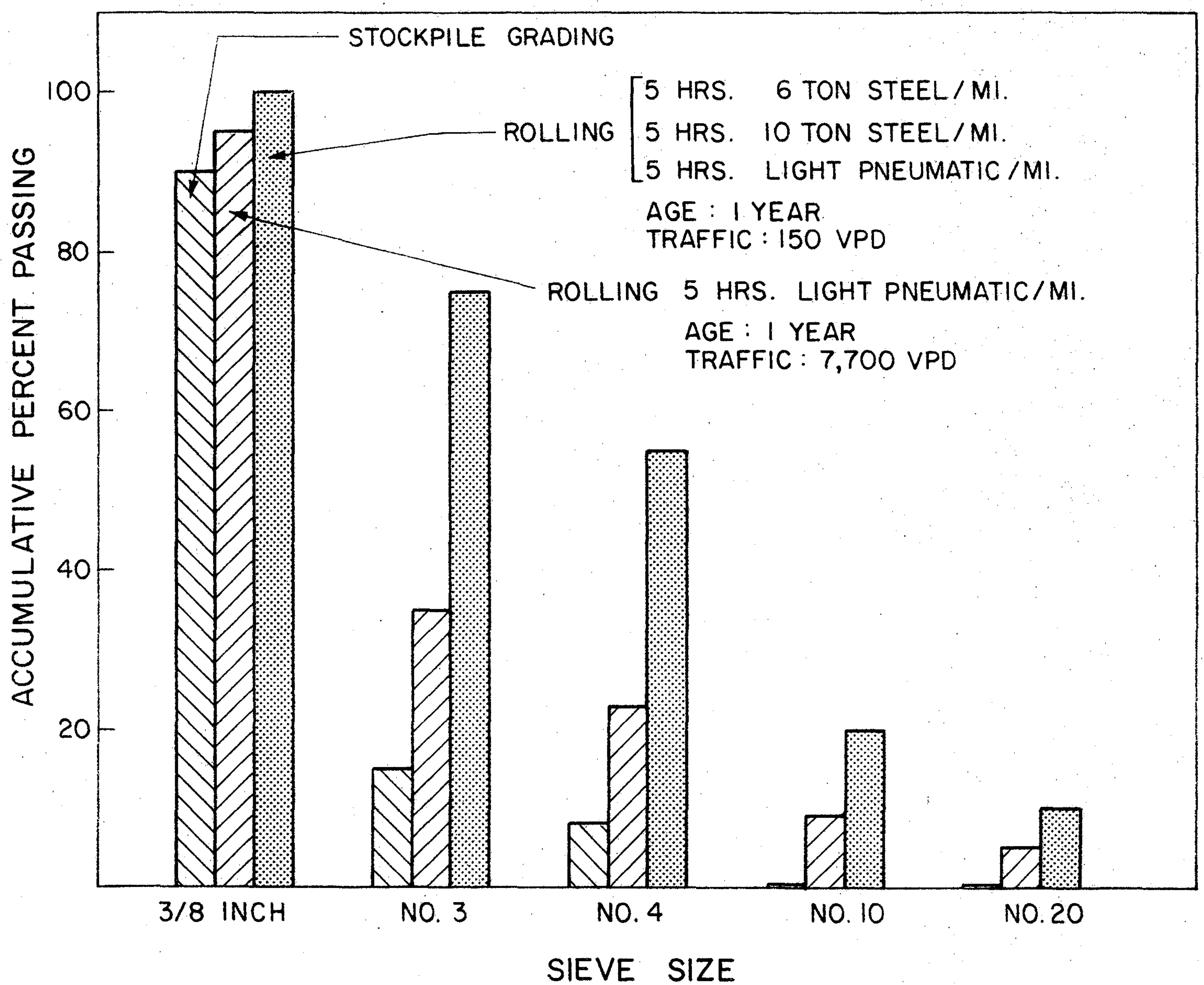

Figure 10. Degradation of Type F aggregate due to construction and service. (after Gallaway (7)).

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.

Degradation under traffic is aggravated by stacking of the aggregate, (caused by exceeding 1:130 aggregate application rates for Grade 4 material) excessive percentages of heavy trucks or high tire pressure vehicles, and high traffic volumes. For general design consideration, it is hopeful that a general relationship between aggregate type and traffic volume can be established. An example of one type of development is illustrated in Figure 11. Hopefully these traffic volumes can be refined as additional field data become available.

The amount of projects experiencing a substantial aggregate degradation has 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. Manufacturers 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.

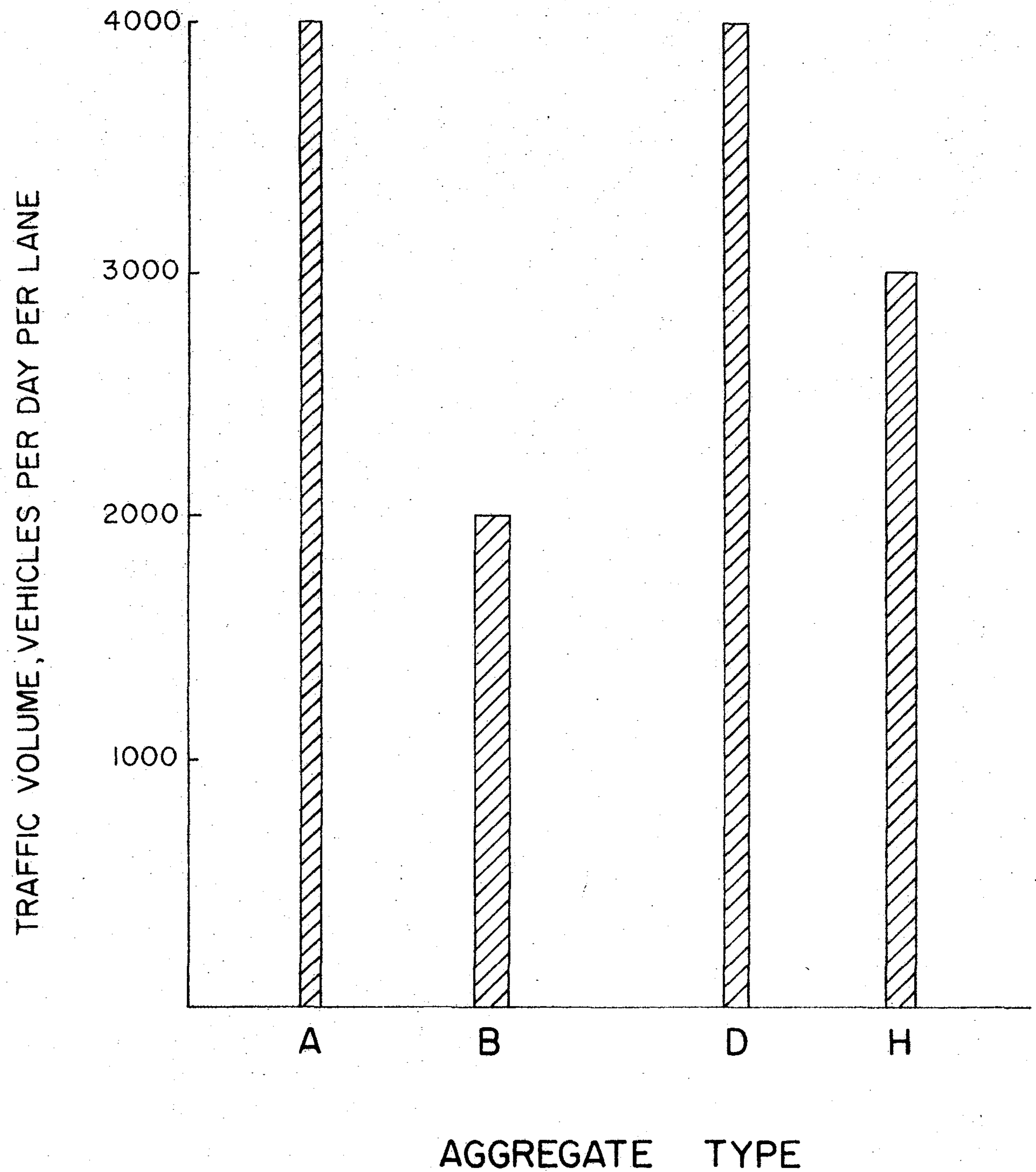

Figure 11. Suggested traffic values at which synthetic aggregate should be utilized to provide a reasonable degree of success.

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.

METHODS OF IMPROVING PERFORMANCE

As illustrated above, many problems associated with poor synthetic aggregate seal coat performance can be traced to the following:

1. Use of excessively wet aggregates during construction under environmental conditions that do not allow an adequate bond to be established between the asphalt and the aggregate for the traffic conditions imposed upon the project.

2. Rainfall after construction thus preventing a satisfactory asphalt-aggregate bond resulting in stripping or displacement of the asphalt from the aggregate surface by water.

3. Degradation of the aggregate during transportation thus causing dust and a resulting poor bond between the asphalt and aggregate.

4. Degradation during construction or immediately after construction creating a bleeding pavement.

Methods for solving the above mentioned problems have been suggested by various individuals and are presented below.

Use of Wet Aggregates

The utilization of wet or moist aggregates can be accomplished provided sufficient time is allowed for the proper bond to be established. If traffic is not allowed on the newly sealed surface and/or if the speed of traffic on the new surface is controlled until adequate bond is established, an acceptable job will quite likely result.

A successful project can also be accomplished by delaying construction until the air temperature and humidity conditions are such that the aggregate will dry on the roadway in a reasonable length of time. This may require that construction cannot commence until late morning.

Moisture in the stockpiled aggregate may result from moisture used in the manufacturing process to cool the aggregate, from rainfall during transportation to the job site, and from rainfall on the stockpile. Covered transportation vehicles and covered stockpiles may reduce aggregate moisture contents such that delays to wet aggregates can be minimized.*

Rainfall After Construction

It is impossible to prevent rainfall, thus the engineer must control his construction operation such that rainfall problem will be minimized. By maintaining contact with local weather forecasting services equipped with radar to define areas of rainfall, the engineer could minimize the possibility of hinderance from rain falling during or immediately after construction.

Control of traffic either by the use of a pilot car or flagman can prevent a possible failure if rainfall has occurred or is likely to occur. If possible, traffic should be removed from the newly sealed surface or the speed controlled on this surface to prevent a possible failure.

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*Covered stockpiles may be beneficial when the aggregate is delivered dry and rainfall is likely prior to construction.

Degradation During Transportation

Degradation during transportation may possibly be reduced by altering manufacturing operations; however, this may be an expensive alternative. More rigid adherence to the new specification may force the manufacturers to solve this aggregate dusting problem.

Precoating of the aggregate offers yet another solution. Again this will increase the cost of the aggregates. Fortunately, under the majority of circumstances degradation and the resulting dust has not been a serious problem.

Degradation During Construction

Degradation of the aggregate during construction and immediately after construction can be reduced to a large degree by altered construction techniques. The use of steel wheel rollers should be eliminated on seal coats utilizing synthetic aggregates as coverstone. Excessive rolling with heavy, high tire pressure, pneumatic tired rollers may also cause degradation, especially if excessive aggregate is spread on the roadway.

Aggregate quantities should be controlled to provide only the necessary amount of aggregate on the roadway. Excessive aggregate will offer the opportunity for rolling equipment and traffic to rub aggregate against aggregate thus creating degradation. Suggested quantities of aggregates and asphalt based on field experience and current design methods are given in Table 16 for the various aggregate types and traffic volumes (12, 13, 14, 15, 16, 17). A correction term for asphalt content bases on surface demand and traffic volume is given in Table 17 and Figure 12 (19, 26).

TABLE 16

SUGGESTED QUANTITIES OF AGGREGATES AND ASPHALT FOR SELECTED SYNTHETIC AGGREGATES

Aggregate Designation	Aggregate quantities, square yard per cubic yard — Aggregate Gradation		Unadjusted** Asphalt Quantity, gallons per square yard — Aggregate Gradation	
	fine*	coarse*	fine*	coarse*
A	153	129	0.22	0.26
B	144	122	0.21	0.26
D	139	124	0.19	0.22
H	142	137	0.22	0.23

*Gradations are the fine and coarse side of THD Grade 4 specifications.

** Adjusted rates as determined by considering field pavement surface and traffic volumes as shown in Table 17 and Figure 12 must be considered.

TABLE 17

ASPHALT QUANTITY CORRECTION FOR PAVEMENT SURFACE CONDITION

Surface Condition	Asphalt Correction, Gallons per square yard
Flushed asphalt surface	-0.03
Smooth, nonporous surface	0.00
Slightly porous, slightly oxidized surface	+0.03
Slightly pocked, porous, oxidized surface	+0.06
Badly pocked, porous, oxidized surface	+0.09

after the Asphalt Institute (19)

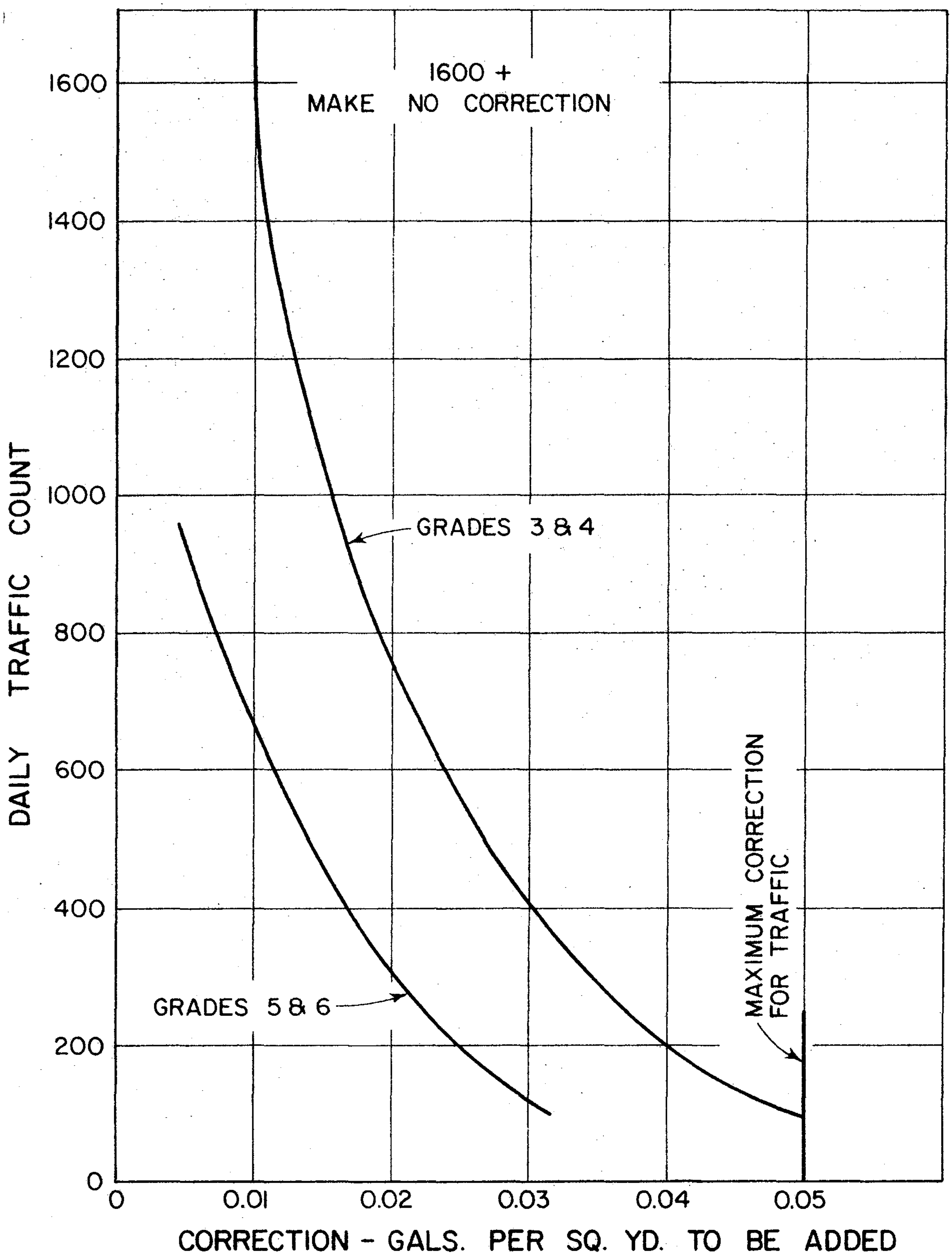

Figure 12. Seal coat asphalt application rate correction due to traffic.

ADDITIONAL STUDY

Additional study will be conducted as part of this project to qualify under what conditions synthetic aggregate seal coats can be utilized. Two major items will be developed: installation of trial field sections and a seal coat rating system. These are briefly discussed below.

Field Trial Sections

Based upon the experience gained from field visits, questionnaires and a review of the literature (references 1 to 19), field trial sections were designed to contain the following variables:

1. Environment.
2. Asphalt type (asphalt cement and emulsion).
3. Traffic (900 to 7,000 vehicles per day).
4. Asphalt quantity (3 levels).
5. Aggregate quantity (3 levels).
6. Aggregate moisture content (3 levels).
7. Simulated rainfall (3 levels).
8. Aggregate type (aggregates A, B, D, and H).

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. Certainly a more extensive field program should be considered to more accurately define the tolerable limits of these variables. A summary of the field trial sections to be placed in the summer of 1972 is included in Tables 16 to 21.

Part of the field trial sections scheduled for District 14 (Austin) has been completed. That portion of the section utilizing the emulsified

TABLE 18

DISTRICT 2 - TRIAL FIELD SECTIONS*

Aggregate Source		Aggregate Spread Rate	Design Asphalt Cement			Design Emulsion		
			Aggregate Moisture Content					
			Dry	Moist	Wet	Dry	Moist	Wet
Clodine	1	1:(117%) Design	X	X	X	X	X	X
	2	1: Design	X	X	X	X	X	X
	3	1:(83%) Design	X	X	X	X	X	X
Dallas	1	1:(117%) Design						
	2	1: Design	X	X	X	X	X	X
	3	1:(83%) Design	X	X	X	X	X	X
Eastland	1	1:(117%) Design						
	2	1: Design	X	X	X	X	X	X
	3	1:(83%) Design						
Ranger	1	1:(117%) Design	X	X	X	X	X	X
	2	1: Design	X	X	X	X	X	X
	3	1:(83%) Design	X	X	X	X	X	X

* Location
Erath County
SH 6 Control 257-6
From Dublin West 40 Mile
Length = 21,120 ft.
2 Lane 22'
1650 vpd.

TABLE 19

DISTRICT 5 - TRIAL FIELD SECTIONS

Aggregate Source		Aggregate Spread Rate	Asphalt Quantity			
			(115%) Design*	Design*	(85%) Design*	Design**
	1	1:(117%) Design	(1)X	(2)X	(1)X	(4)X
Clodine	2	1: Design	(2)X	(2)X	(2)X	(4)X
	3	1: (83%) Design	(1)X	(2)X	(2)X	(4)X
	1	1:(117%) Design		(2)X		(4)X
Dallas	2	1: Design		(2)X		(4)X
	3	1:(83%) Design		(2)X		(4)X
	1	1:(117%) Design		(2)X		(4)X
Eastland	2	1: Design		(2)X		(4)X
	3	1:(83%) Design		(2)X		(4)X
	1	1:(117%) Design	(1)X	(2)X	(1)X	(4)X
Ranger	2	1: Design	(2)X	(2)X	(2)X	(4)X
	3	1:(83%) Design	(1)X	(2)X	(2)X	(4)X

( )X indicates number of rock lands in test section

* Location
Lubbock County
US 62 Control 380-1
From Lubbock City Limits to 3 miles SW
Length = 15,000 ft. - 2.840 miles
4 Lane divides traffic
South Bound Lanes 24'
4310 vpd.

** Location
Lubbock County
FM 1730 Control 1344
Loop 289 to FM 1585
Length 20,823 ft. - 3.943 mi.
2 Lane 20'
930 to 1570 vpd.

TABLE 20

DISTRICT 11 - TRIAL FIELD SECTIONS*

Aggregate Source		Aggregate Spread Rate	US 59 7000 vpd (4 lanes) 24'			
			Asphalt Quantity			Emulsion Quantity
			(115%) Design	Design	(85%) Design	Design
Clodine	1	1:(117%)Design	(1)X	(2)X	(1)X	(2)X
	2	1:Design	(1)X	(2)X	(1)X	(2)X
	3	1:(83%)Design	(1)X	(2)X	(1)X	(2)X
Dallas	1	1:(117%)Design		(2)X		(2)X
	2	1:Design		(2)X		(2)X
	3	1:(83%)Design		(2)X		(2)X
Eastland	1	1:(117%)Design		(2)X		(2)X
	2	1:Design		(2)X		(2)X
	3	1:(83%)Design		(2)X		(2)X
Ranger	1	1:(117%)Design	(1)X	(2)X	(1)X	(2)X
	2	1:Design	(1)X	(2)X	(1)X	(2)X
	3	1:(83%)Design	(1)X	(2)X	(1)X	(2)X

( )X Indicates number of rock lands in test section

*Location
Angelina County
US 59 Control 176-3
From Diboll to Neches River
Length: 21,120 ft - 4.0 miles
4 Lane Divides
South bound lanes 24'
7000 vpd.

TABLE 21

DISTRICT 11 - TRIAL FIELD SECTIONS

SH 103 1900-2500 vpd 26'

Aggregate Source		Aggregate Spread Rate	Asphalt Quantity			Emulsion Quantity		
			(115%) Design	Design	(85%) Design	(115%) Design	Design	(85%) Design
	1	1:(117%) Design		(2)X			(2)X	
Clodine	2	1: Design		(2)X			(2)X	
	3	1:(83%) Design		(2)X			(2)X	
	1	1:(117%) Design		(2)X			(2)X	
Dallas	2	1: Design	(2)X	(2)X	(2)X	(2)X	(2)X	(2)X
	3	1:(83%) Design		(2)X			(2)X	
	1	1:(117%) Design		(2)X			(2)X	
Eastland	2	1: Design	(2)X	(2)X	(2)X	(2)X	(2)X	(2)X
	3	1:(83%) Design		(2)X			(2)X	
	1	1:(117%) Design		(2)X			(2)X	
Ranger	2	1: Design		(2)X			(2)X	
	3	1:(83%) Design		(2)X			(2)X	

( )X indicates number of rock lands in test section.

Angelina County
Sh 103 Control 336-5
From FM 1475 to Angelina River
Length: 21,120 ft - 4.0 Miles
2 Lane 26' 1900-2500 vpd
1900 to 2500 vpd.

TABLE 22

DISTRICT 14 - TRIAL FIELD SECTIONS*

Aggregate Source		Aggregate Spread Rate	St. 95 1220 vpd 28'					
			Design Asphalt Cement			Design Emulsion		
			None	0 hours	24 hours	None	0 hours	24 hours
Clodine	1	1:(117%)Design	X	X	X	X	X	X
	2	1:Design	X	X	X	X	X	X
	3	1:(83%)Design	X	X	X	X	X	X
Dallas	1	1:(117%)Design	X	X	X	X	X	X
	2	1:Design	X	X	X	X	X	X
	3	1:(83%)Design	X	X	X	X	X	X
Eastland	1	1:(117%)Design						
	2	1:Design	X	X	X	X	X	X
	3	1:(83%)Design						
Ranger	1	1:(117%)Design	X	X	X	X	X	X
	2	1:Design	X	X	X	X	X	X
	3	1:(83%)Design	X	X	X	X	X	X
Precoat	2	1:Design	X	X	X	X	X	X

X Indicates test section.

*Location
Bastrop County
SH 95 Control 322-1
From near S. city limits of Elgin to 4 miles south
Length: 21,120 ft. = 4.00 miles
2-Lane 28'
1220 vpd.

asphalt was placed in order to establish the necessary construction and testing techniques for the remaining field trial sections. Results from this field trial will be a part of the final report of this study.

Seal Coat Rating System

A method to evaluate the performance of seal coats is being developed as a part of this study. This method is based on work performed by South Dakota Highway Department (22), Washington State Highway Department (23), University of Minnesota (24), and Texas A&M University (2). As data are collected on Texas highways and on the trial field sections, a more realistic appraisal of the performance of synthetic aggregate seal coats in Texas will be possible.

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