Performance of Bituminous Surface Treatments in Alaska

FINAL REPORT

by

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16. Abstract

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Most of the failures studied can be attributed to improper construction techniques such as low asphalt content, dirty aggregate, construction during poor climate conditions or poor base. Other factors which were found to contribute to poor performance include construction after August 20, the use of "C" and "E" chip combinations and the use of unsound aggregate.

No significant differences in performance could be shown between RC-800 and CRS-2 or between pre-1974 and post-1974 asphalt cements.

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TABLE OF CONTENTS

Abstract . . . . p. 1
Introduction . . . . p. 2
Background . . . . p. 3
Methodology . . . . p. 4
Performance Variables . . . . p. 5
Aggregate Loss . . . . p. 7
Aggregate . . . . p. 7
Relationship Between Asphalt Content
and Aggregate Loss . . . . p. 23
Proper Distributor Operation . . . . p. 26
RC-800 Vs. CRS-2 . . . . p. 31
Pre & Post 1974 BST Performance . . . . p. 38
Seasonal Factors . . . . p. 42
Traffic Control . . . . p. 47
Probable Causes of High Aggregate Loss
on a Case by Case Basis . . . . p. 48
Embedment Depth . . . . p. 52
Design of Bituminous Surface Treatments . . . . p. 54
Summary and Conclusions . . . . p. 56
Implementation and Recommendations . . . . p. 58
Research Needs . . . . p. 59
Acknowledgements . . . . p. 60
References . . . . p. 61
Appendix A . . . . p. A-1
Appendix B . . . . p. B-1
Appendix C . . . . p. C-1
Appendix D . . . . p. D-1

LIST OF FIGURES

Figure 1 . . Distribution of Aggregate Loss . . . . p. 8
Figure 2 . . Ideal Aggregate-Asphalt Combination . . . . p. 9
Figure 3 . . Problems Associated With Non-Uniform Aggregate Size . . . . p. 9
Figure 4 . . Results of Non-Uniform Aggregate in a Two-Layer BST . . . . p. 11
Figure 5 . . "B" Chip Gradation . . . . p. 12
Figure 6 . . "C" Chip Gradation . . . . p. 13
Figure 7 . . "E" Chip Gradation . . . . p. 14
Figure 8 . . Gradations . . . . p. 16
Figure 9 . . Comparison of Aggregate Meshing for Various Chip Sizes . . . . p. 17
Figure 10 . . Comparison of Chip Size Combinations . . . . p. 18
Figure 11 . . Comparison of Original Asphalt Content and Extracted Asphalt Content . . . . . . p. 24
Figure 12 . . Proper Nozzle Angle Setting . . . . p. 27
Figure 13 . . Spray Bar Height Setting . . . . p. 27
Figure 14 . . Distribution of Asphalt Content . . . . . . p. 29
Figure 15 . . Comparison of RC-800 and CRS-2 . . . . p. 32
Figure 16 . . Pliancy of CRS-2 and RC-800 BST's . . . . . . p. 33
Figure 17 . . Asphalt Contents of BST's Studied . . . . . p. 34
Figure 18 . . CRS-2 Vs. RC-800 . . . . p. 35
Figure 19 . . Viscosity -- RC-800 Vs. CRS-2 . . . . p. 36
Figure 20 . . Aggregate Loss Before and After 1974 . . . . p. 39
Figure 21 . . Percent Asphalt Pre & Post 1974 . . . . p. 41
Figure 22 . . Distribution of BST's Placed by Month . . . p. 43
Figure 23 . . Quartile Plot of % Aggregate Loss by Month Placed . . . . p. 44
Figure 24 . . Comparison of Aggregate Loss Before and After August 20 . . . . p. 46
Figure 25 . . Summary of Data . . . . p. 49
Figure 26 . . Probable Causes of Failure . . . . p. 51
Figure 27 . . Percent Aggregate Embedded . . . . p. 53
Figure 28 . . Percentage Aggregate Loss (Surface) . . . . p. 53

LIST OF TABLES

Table 1 . . . Gradations, 3/4" - 1/2" Chip Size . . . . . . p. 19
Table 2 . . . Gradations, 1/2" - 3/8" Chip Size . . . . . . p. 20
Table 3 . . . Gradations, 1/2" - 3/8" Chip Size . . . . . . p. 21
Table 4 . . . Suggested Grading Specifications
for Surface Treatments . . . . p. 22
Table 5 . . . Variation in Asphalt Content
Within the Project . . . . p. 30

ABSTRACT

A detailed investigation of Bituminous Surface Treatments (BST's) has been completed which determines the probable causes of a number of failures. Results of a two-year study have isolated many of the causes of these failures and offer recommendations to improve the performance of BST's.

Most of the failures studied can be attributed to improper construction techniques such as low asphalt content, dirty aggregate, construction during poor climate conditions or poor base. Other factors which were found to contribute to poor performance include construction after August 20, the use of "C" and "E" chip combinations and the use of unsound aggregate.

No significant differences in performance could be shown between RC-800 and CRS-2 or between pre-1974 and post-1974 asphalt cements.

INTRODUCTION

The State of Alaska has approximately 45 roadway projects representing approximately 200 miles which are surfaced with bituminous surface treatments (BST) at the present time. Many of these have given excellent service while many others have failed immediately or shortly after construction or deteriorated rapidly thereafter, causing BST's to fall into disfavor with project designers.

It was the intent of this study to isolate the most frequent causes of failures as well as those factors common to success. Using this information, specifications are proposed herein to improve the success ratio for BST's. To this end, 97 roadway sections about 500 feet in length were selected from 26 projects throughout the Interior and Southcentral regions where BST's are used most heavily. These sections were studied to determine what factors influenced their performance.

For the purposes of this study the transportation Research Board Committee Specification MC-A3 definition for a surface treatment will be used. A surface treatment is defined as:

> One or more applications of liquid asphalt and cover aggregate on a prepared base of consolidated gravel, stone, macadam, earth or stabilized soil. (1)

Because this was not a controlled experiment no mathematical models were developed. Only trends can be shown. The approach taken was to attempt to verify commonly held beliefs of project personnel and recommendations from the literature.

BACKGROUND

Because surface treatments represent a less expensive alternative to plant mixed asphalts, they are desirable for low traffic volumes or where permafrost-related roadway settlements are expected to result in a short surface life. However, the large number of failures has greatly reduced the economic attractiveness of BST's.

Most of Alaska's highway system is subjected to extremely severe climatic conditions where air temperatures range from 100°F to -70°F. Much of the system experiences 5,000 degree days of freezing and 3,000 degree days of thawing. Because of a short construction season of approximately 120 days, placement of roadway surfacing is typically done in August or September when the weather may have become marginal. Proper curing, therefore, may be inadequate before freezing conditions prevail. These conditions are suspected to have a particularly adverse affect on surface treatments.

A common contention is that the asphalt properties have changed since the 1974 Arab oil embargo. At the same time, the use of emulsified asphalts increased and the use of cutback asphalts has been gradually reduced until they are no longer easily available in Alaska. The effects of these changes will be explored.

METHODOLOGY

A total of 97 roadway sections 0.1 miles in length from 26 projects were chosen at random from the Interior and Southcentral regions of the State. These sections were evaluated in the field for performance and present condition. Among the performance variables considered were ravelling, flushing, fatigue cracking, thermal cracking, rut depth and wear. The roadway was rated using the Manual for Condition Rating of Flexible Pavements prepared by the Ontario Ministry of Transportation and Communications (2). A complete description of the evaluation procedure is given in Appendix A.

Four cores taken randomly from each section were visually inspected for aggregate chip loss, embedment depth, flexibility and stripping. Lab tests were run to determine the asphalt content, percentage of volatiles, and penetration.

Construction records were searched for information on gradation, spread rates, oil types, oil source, properties of the oil, additives, application temperatures, weather conditions, and dates of application.

These data were then entered into the University of Alaska Honeywell computer and analyzed using the Statistical Package for the Social Scientists (SPSS) developed by Kansas University.

PERFORMANCE VARIABLES

As with all studies of this type, an attempt was made to determine the cause and effect relationships. To do so, a roadway surface condition survey was made to determine what deficiencies were evident. These distress manifestations were used as dependent variables and can be divided into three major headings: surface defects, surface deformation and cracking. Definition and methods of measurement of each of these variables are found in Appendix A.

Surface defects include surface aggregate loss, ravelling and flushing. Surface aggregate loss proved to be the major problem in the State. Some flushing was initially reported but, upon closer examination, it was found that the reported flushing was actually areas where the cover aggregate had been plucked from the surface leaving the exposed asphalt behind. Aggregate loss will therefore be the major surface defect discussed.

Surface deformation includes washboarding, shoving, rutting and distortion. No correlation could be found between surface deformation and construction variables. This is no surprise since a BST is a thin section and any surface deformations, except shoving, would be primarily a function of the underlying soils. Shoving has not generally been a problem. For this reason no further mention of these variables will be made except that these data might be useful in studying the base course at some future date.

Cracking includes longitudinal and transverse cracking, alligator cracking, random or map cracking, and slippage cracking. There were few cracks that could be attributed to the BST itself. Except in a few of the older pavements (10-12 years of age), few fatigue cracks were recorded. Visual observations have shown that BST's are able to follow differential settlement quite well and still maintain their integrity.

In general, no correlation could be found between the properties of the BST and cracking. It is felt that most of the cracking is related to the underlying soils.

An attempt was made to correlate patching to construction variables, since pothole patching represents final failure of the surface. However, no correlation could be found. This may be partially due to a weak base rather than the surface treatment.

Because only surface aggregate loss was found to have significant correlation with construction and materials variables, it will be discussed in quite some detail.

AGGREGATE LOSS

Loss of surface aggregate is a major problem in Alaska. As evidenced in Figure 1, 40 percent of the sections studied had greater than 20 percent aggregate loss. Project diaries have stated repeatedly that 25 percent of the aggregate is swept off during brooming. Aggregate loss was determined by visual examination of the cores. The percentage of aggregate removed from the surface of the core was estimated by noting the indentations in the asphalt cement. These indentations indicated where aggregate particles had been lost. Note that this method of estimating only gives an indication of those particles which should have been held in place. No information other than that available from project diaries was available to determine the total loss of chips.

The most commonly listed causes of aggregate loss are:

1. poor aggregate
2. too little asphalt binder
3. faulty distributor operation
4. traffic wear before the asphalt hardens

These causes are discussed under separate titles.

AGGREGATE

In general, any hard aggregate can be used for surface treatments with a few limitations. The aggregate ideally should be cubical or pyramidal in shape with all particles uniform in size as shown in Figure 2. The Asphalt Institute recommends that 60 to 70 percent of the particles passing the specified nominal size must be retained on the sieve having an opening of 70 percent of that size and that the smallest particle should be no more than one-half the largest size (3).

If there are excessive differences in aggregate particle size, many of the smaller particles will be covered with asphalt while the larger particles are easily dislodged as shown in Figure 3. In the case of a two layer surface, the problem is compounded as shown in Figure 4. If the larger particles of the second course fall on top of the larger

Figure 1

DISTRIBUTION OF AGGREGATE LOSS

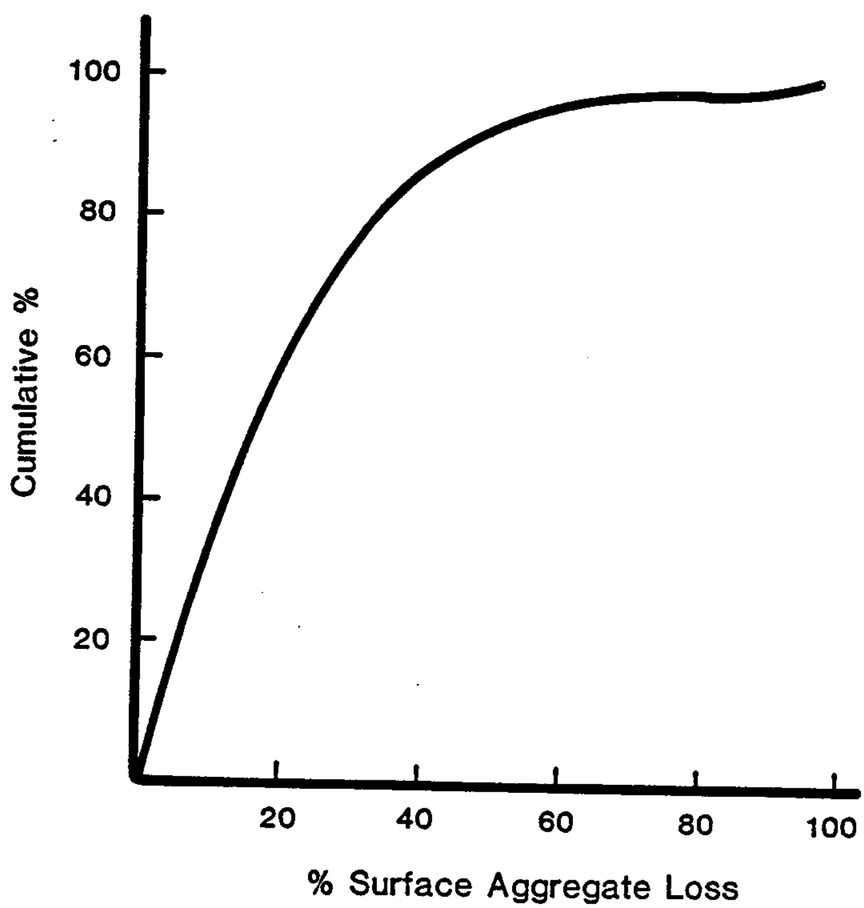


FIGURE 2

IDEAL AGGREGATE-ASPHALT COMBINATION

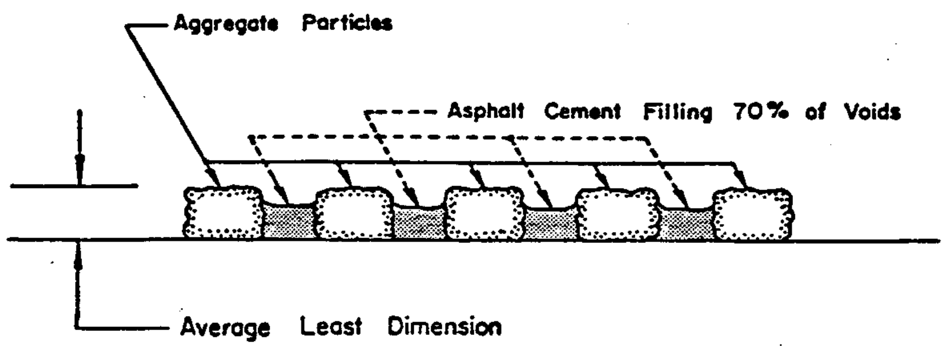
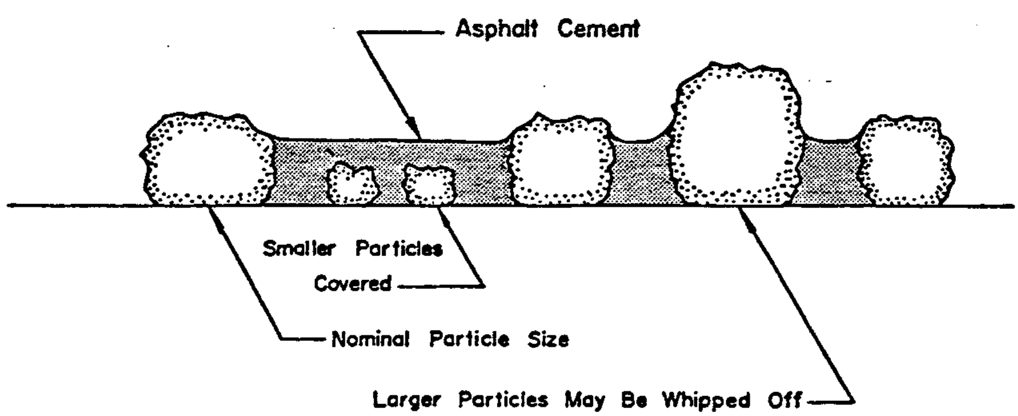


FIGURE 3

PROBLEMS ASSOCIATED WITH NON-UNIFORM AGGREGATE SIZE



particles of the first course, the particles will be lost immediately. Conversely, if small particles fall of top of small particles, then the surface will appear slick. Many of the particles never become properly seated and are consequently swept off by traffic.

Figures 5, 6, and 7 show the current Alaska specification bands for "B", "C", and "E" chips. As can be seen by comparison of the figures, it is possible that 70 percent of the particles be retained on the sieve having only 40 percent of the nominal particle size for "B" chips, 30 percent for "C" chips and 65 percent for "E" chips. The contractors are tending to crush on the finer side of the specification band as indicated by the "crushing band" as determined from project records which would be the worse gradation.

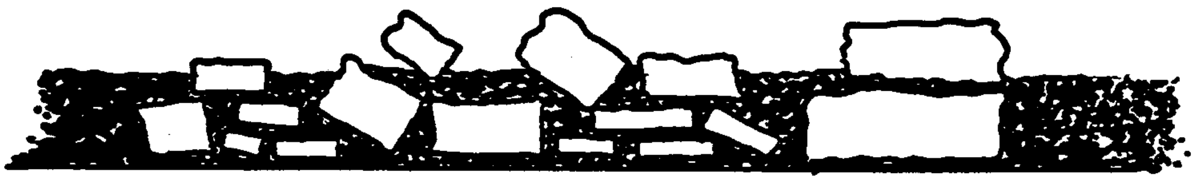
On any multiple surface treatment, the largest aggregate should be placed first. Each succeeding layer should contain aggregate approximately one-half the size of the preceding course. It is essential that each succeeding layer nest with the previously placed layer such that a compact mass with a dense, tight surface is formed (4). If, for example, "B" and "C" chips are used, the median of the chip size for "B" chips is 0.56 inches in the middle of the specification band and the median size for "C" chips is 0.35 inches. The size ratio is then 0.63, which though not exactly 0.50, may be acceptable.

However, the use of "C" and "E" chips as a two-layer treatment may not be too advisable. The median size for "E" chips is 0.28 inches in the middle of the specification band. Thus the size ratio is 0.80 which is far from the 0.50 criteria. In fact, if the contractor chooses to crush the "C" chips on the fine side of the band and "E" chips on the coarse side of the band, the ratio would be nearly 1.0 as shown in Figure 8. Theoretically the ideal combination would be "B" and "E" chips which have a median size ratio of 0.50. At worst the ratio would be 0.36 as shown in Figure 8.

In order to ascertain how well the aggregate actually meshed, the cores were visually examined closely. The cores were rated from poor to

FIGURE 4

RESULTS OF NON-UNIFORM AGGREGATE IN A TWO-LAYERED BST



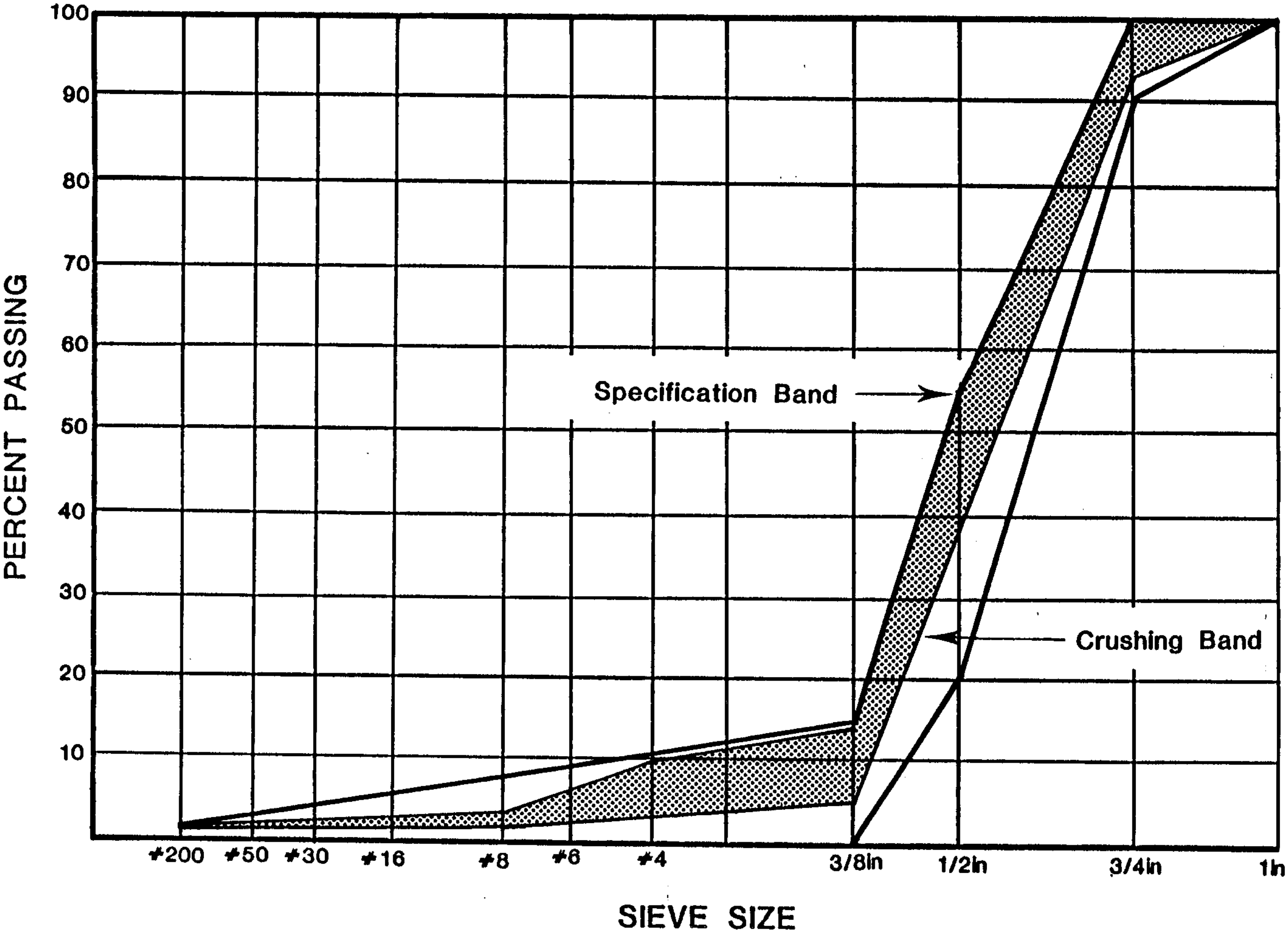


FIGURE 5 "B" CHIP GRADATION

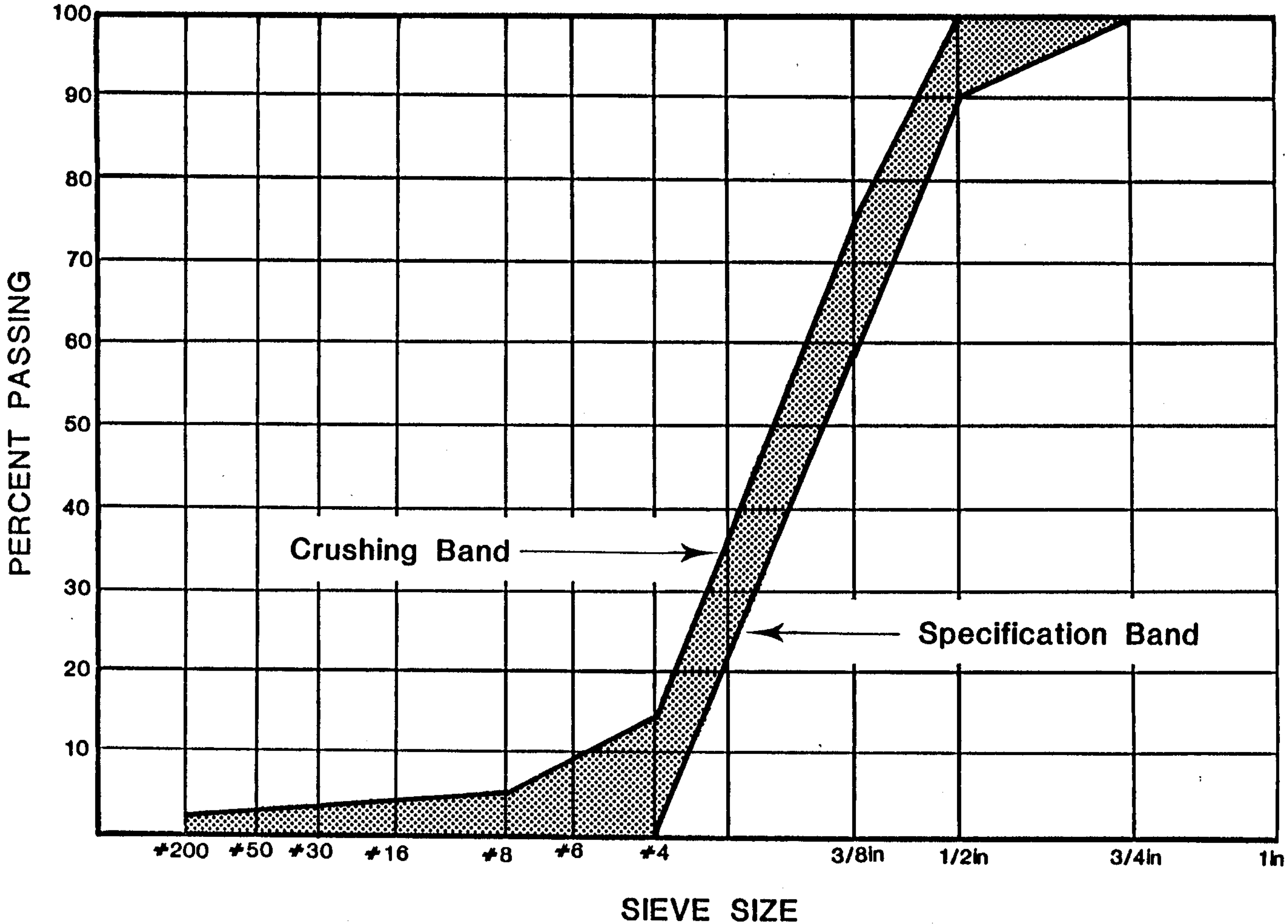


FIGURE 6 "C" CHIP GRADATION

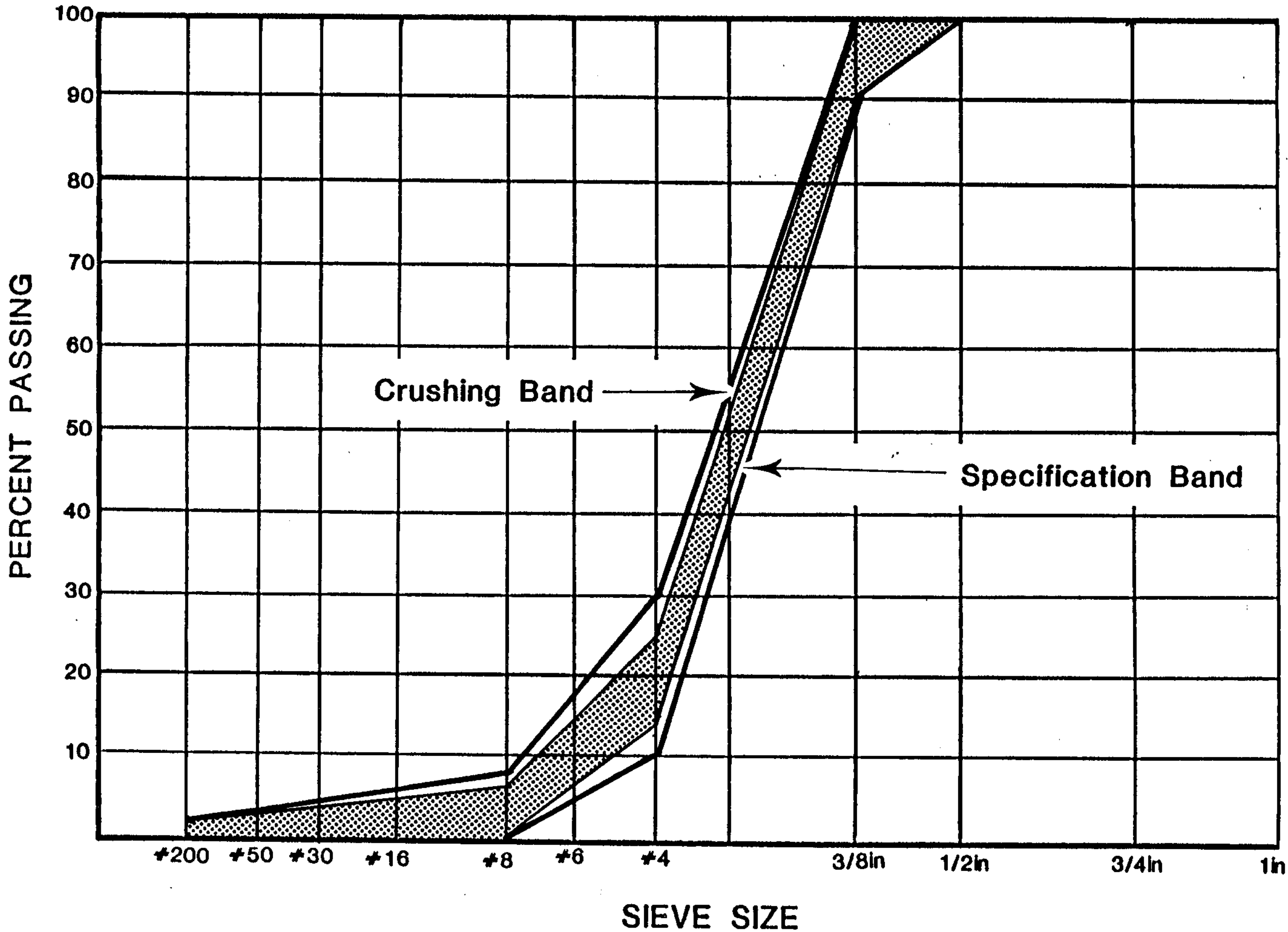


FIGURE 7 "E" CHIP GRADATION

excellent according to how well the particles fit together to form a dense surface. Figure 9 summarizes those observations. As might be expected, the "C" and "E" chip combination showed the worst aggregate meshing. Suprisingly, the "B" and "C" combination proved to be the best. However, the proof is in the amount of surface aggregate loss.

Figure 10 shows that the "C" and "E" chip combination again is the most likely to lose surface aggregate, while the other two combinations are not too different. It should be noted that 57 percent of the sections studied used the "C" and "E" combination.

It is imperative that the aggregate be free of dust since a dust coating will not allow the asphalt to properly adhere to the aggregate surface. At least two of the eleven projects which showed excessive chip loss had excessive dust. A minor dust problem can be improved by slightly moistening the aggregate. However, excessive moisture will cause the asphalt not to adhere to the chips.

Tables 1, 2 and 3 compare the gradation specifications for several states. While Alaska does not differ greatly on the + 3/8 inch size fraction, it does not have the #4 specification for "B" chips common to most specifications. This requirement limits the fine aggregate to less than 5%. Also note that most of the other specifications limit the -200 size fraction to 1%. This is to help insure there is no dust coating. These added restrictions should help reduce chip loss.

In summary, only clean, sound aggregate should be used. The commonly used "C" and "E" chip combination should be strongly discouraged in favor of the "B" and "E" or the "B" and "C" chip combination. And finally, the specification band should be "tightened" to insure a more uniform gradation. The specifications shown in Table 4 are suggested as a starting point.

FIGURE 8 GRADATIONS

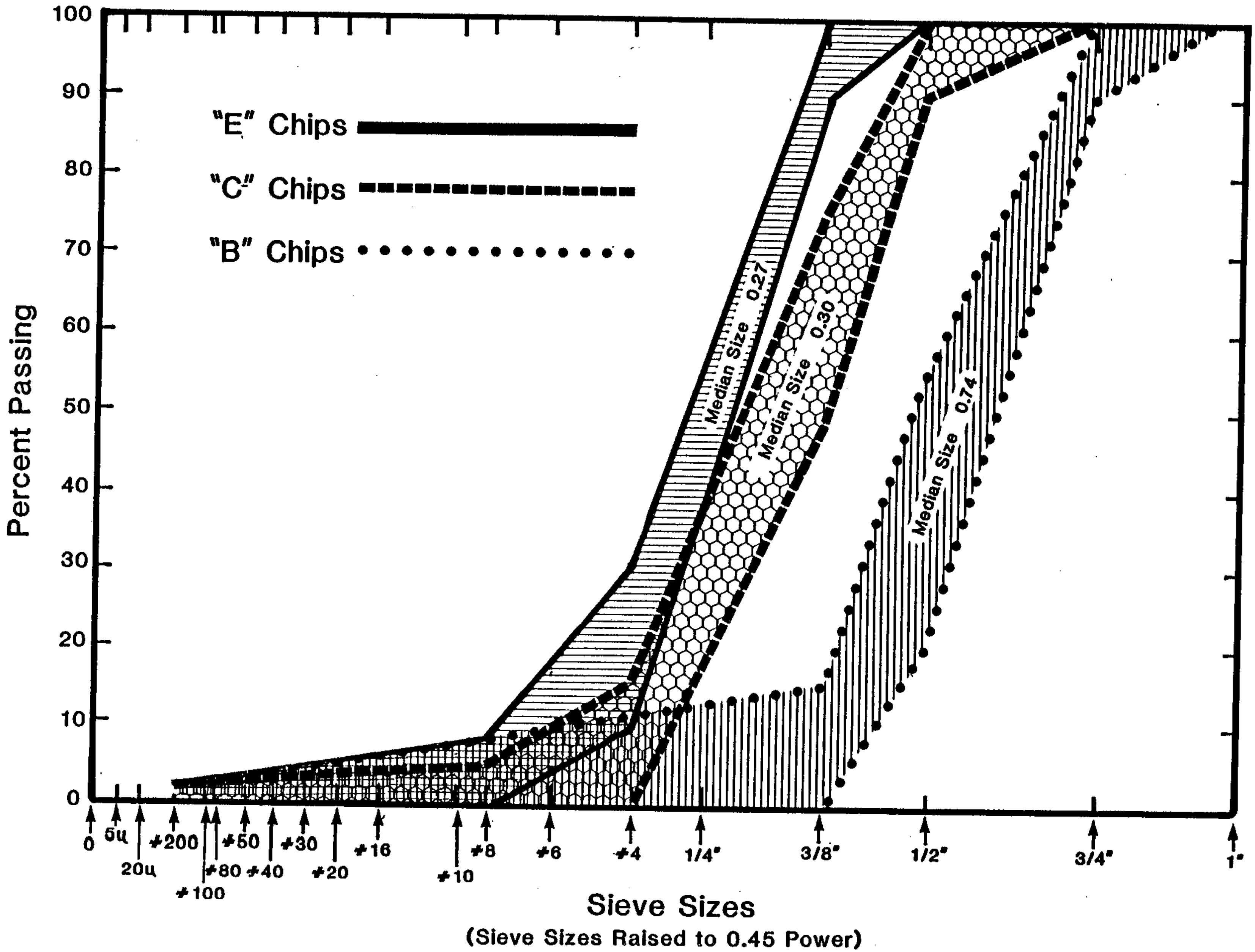


Figure 9

COMPARISON OF AGGREGATE MESHING FOR VARIOUS CHIP SIZES

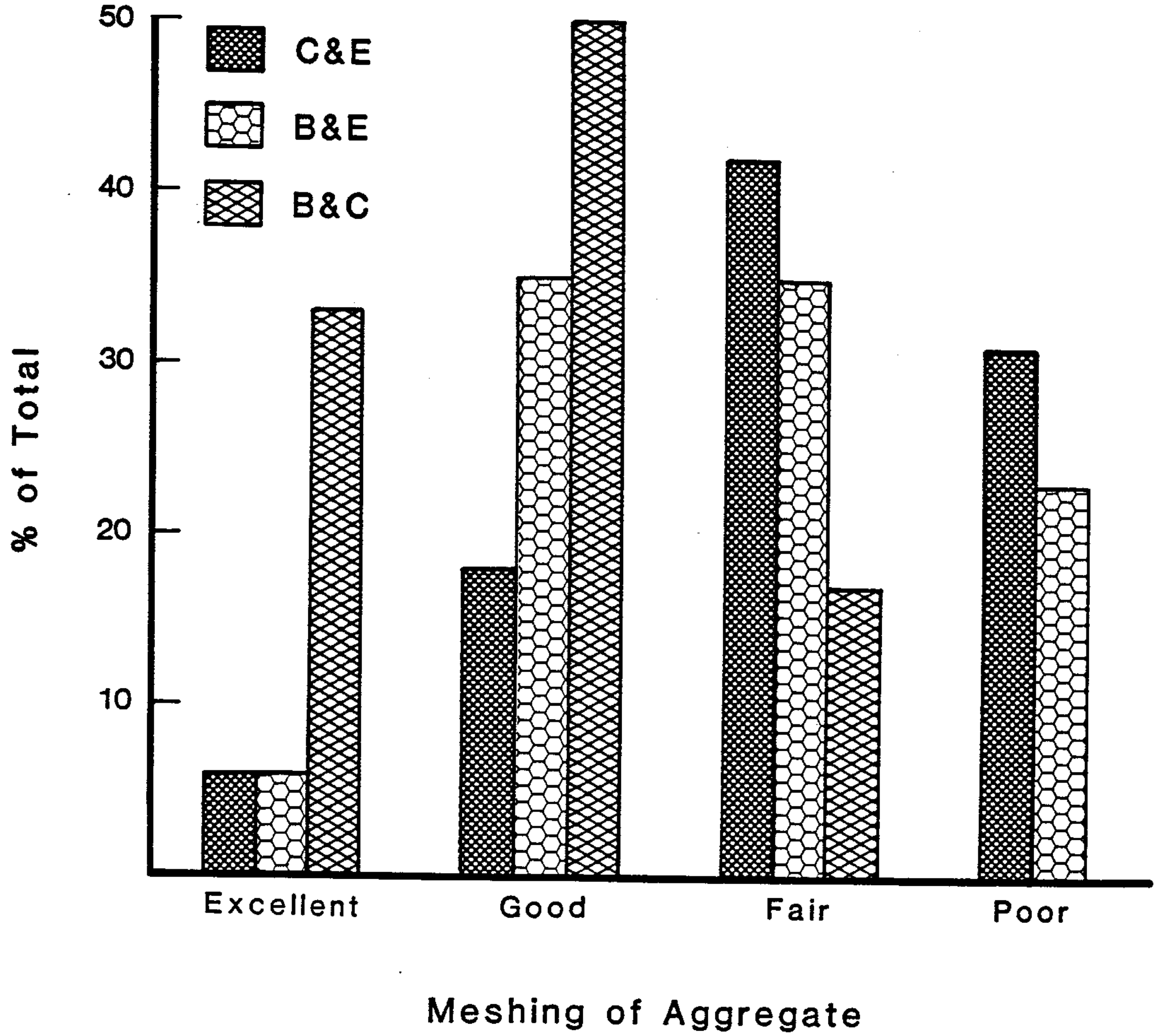


Figure 10

COMPARISON OF CHIP SIZE COMBINATIONS

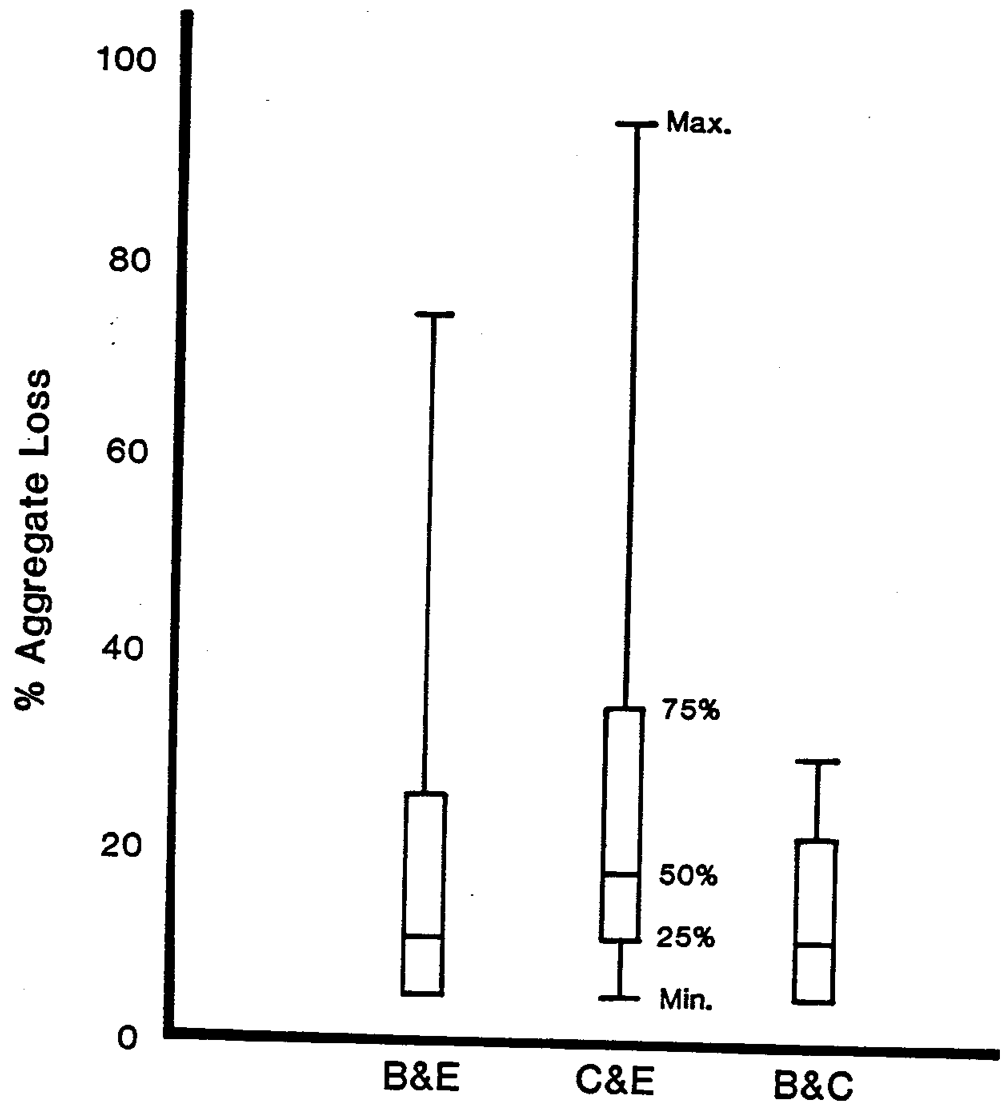


TABLE 1

GRADATIONS

3/4" - 1/2" Chip Size

Sieve	Alaska ("B" Chips)	Pennsylvania	Oklahoma	Texas	Asphalt Institute
1"	100	100		100	100
3/4"	90-100	90-100	100	95-100	90-100
5/8"	---	---		0-15	---
1/2"	20-55	20-55	25-60	---	20-55
3/8"	0-15	0-10	0-15	0-5	0-15
#4	---	0-5	0-5	---	0-5
#8	---	---	---	0-1	---
#10	---	---	---		---
#16	---	---	---		---
#200	0-2	0-1	0-2	0-1	0-0.5

TABLE 2

GRADATIONS

1/2" - 3/8" Chip Size

Sieve	Alaska ("C" Chips)	Illinois	Oklahoma	Texas	Asphalt Institute
1"	---	---	---	---	
3/4"	100	---	100	---	100
5/8"	---	100	---	100	---
1/2"	90-100	80-100	90-100	95-100	90-100
3/8"	40-75	25-65	0-25	0-15	40-70
1/4"	---	---	---	0-5	
#4	0-5	0-6	0-5	---	0-15
#8	---	---	---	0-1	0-5
#10	---	---	---	---	---
#16	---	---	---	---	---
#200	0-2	---	0-2	0-1	0-0.5

TABLE 3

GRADATIONS

1/2" - 3/8" Chip Size

Sieve	Alaska ("E" Chips)	Pennsylvania	Illinois	Oklahoma	Texas	Asphalt Institute
1"						
3/4"						
5/8"						
1/2"	100	100	100	100	100	100
3/8"	90-100	75-100	94-100	90-100	95-100	85-100
1/4"	---	---	---	---	0-15	---
#4	10-30	10-30	15-45	0-25	---	10-30
#8	0-8	0-10	---	0-5	---	0-10
#10	---	---	---	---	---	---
#16	---	---	---	---	0-1	0-5
#200	0-2	0-1	0-4	0-2	0-1	0-0.5

TABLE 4

SUGGESTED GRADING SPECIFICATIONS

FOR SURFACE TREATMENTS

Sieve Size	GRADING B	GRADING C	GRADING E
		% Passing	
1"	100		
3/4"	90-100	100	
1/2"	20-55	90-100	100
3/8"	0-15	40-70	90-100
#4	0-5	0-15	10-30
#8		0-5	0-8
#200	0-1	0-1	0-1

RELATIONSHIP BETWEEN ASPHALT CONTENT AND AGGREGATE LOSS

The relationship between aggregate loss and asphalt content can easily become confusing. Past experience has established that too little asphalt binder will result in excessive aggregate. Unfortunately, good data is lacking which shows the change in asphalt content with time. Any information derived from current asphalt content must therefore be hypothesized.

As chips are lost, the asphalt content may be expected to increase provided no asphalt adheres to the aggregate. For example, if a surface treatment is placed at six percent by weight of the dry aggregate, the asphalt content would increase to 7.5 percent if 20 percent cover aggregate is lost.

But, the aggregate may very likely remove some of the binder when it is plucked. If a 3/4 inch cubical particle embedded to 50 percent of its depth is removed, the film thickness of asphalt would need to be 0.043 inches thick to remove ten percent particle weight in asphalt. This film thickness is entirely reasonable.

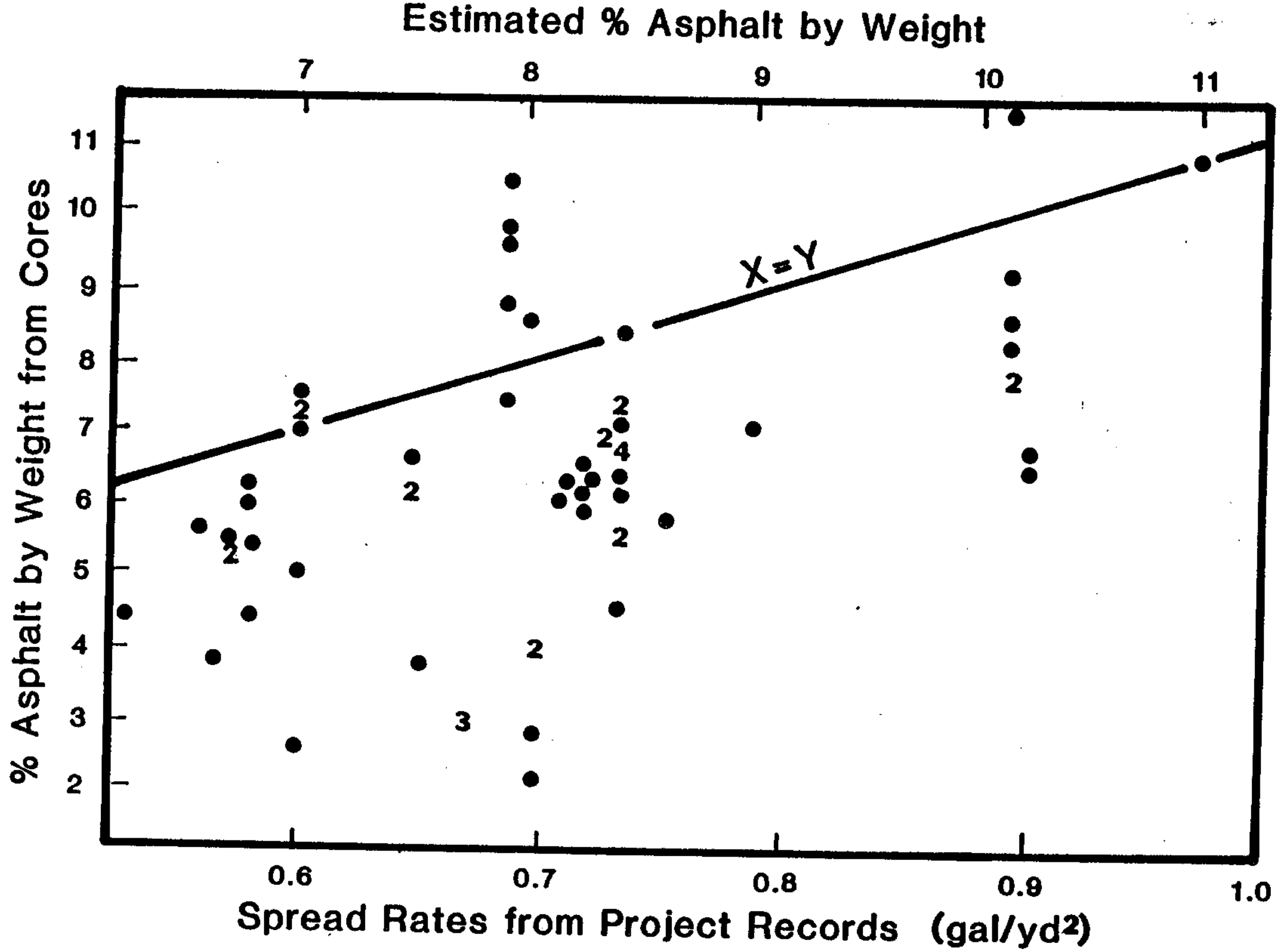
A third explanation for differences in the asphalt content as specified in the project records and the asphalt content from the cores is variance in spread rate due to the distributor.

In order to ascertain which of these mechanisms prevailed, the asphalt contents were plotted in Figure 11. To estimate the initial asphalt content, the following assumptions were made:

1. 60 lb/yd^2 total aggregate spread was used
2. ten percent of the aggregate was broomed off
3. 25 percent of the weight of the asphalt was removed as volatiles

Note that in Figure 11 most of the points fall below the "x = y" line indicating that the aggregate is taking some asphalt with it when removed. The exact amount of asphalt removed cannot be determined. However, it is reasonable to expect that the average film thickness would be the same for all roadway sections. This assumption allows the

Figure 11 COMPARISON OF ORIGINAL ASPHALT CONTENT AND EXTRACTED ASPHALT CONTENT



use of oil content from the cores as a useful independent variable.

No significant correlation could be found between project asphalt spread rates, recovered asphalt content and aggregate loss. This only implies that additional factors strongly affect aggregate loss. Among these are climate, traffic and dust coating.

PROPER DISTRIBUTOR OPERATION

Review of the literature indicates that the spread of asphalt is the most critical operation in constructing a good surface treatment. Considerable care must be taken to insure uniform application of the asphalt which requires that the asphalt distributor be in good condition and that the spraybar be properly adjusted. Frequent checks of the nozzles should be made to keep them clean and functioning properly. Particular attention should be paid on a daily basis to the spraybar height, nozzle size and the nozzle angle. The nozzle angle should be set according to the manufacturers specifications. Never set the end nozzles at 90^{o} with respect to the spraybar.

The spraybar height should be selected and maintained throughout the application to assure uniformity of spread. Figures 12 and 13 show the proper height and alignment for spraybar. As can be seen in Figure 15, streaking will occur if the spraybar is too high or too low. When the spraybar is at the correct height, the transverse spread will be uniform providing the distributor is in good condition. The Asphalt Institute recommends that the transverse spread be allowed to vary no more than 15 percent for emulsions and no more than ten percent for other asphalts, cement and cutback asphalts. (4)

The longitudinal spread should vary no more than 10%. The distributor's longitudinal spread rate should be checked carefully and all gauges calibrated for each project. Do not rely on the calibration from another project.

To explore the uniformity of the asphalt spread, the asphalt content of the cores was determined using the Abson Recovery technique. The cores were carefully cleaned of any particles thought to be from the prime base to insure only the surface treatment was being tested. The asphalt content was determined as a percentage of the weight of the aggregate.

Figure 14 shows that a uniform spread of asphalt is not always being obtained in Alaska. Although the most common total spread rate of 0.70

FIGURE 12

PROPER NOZZLE ANGLE SETTING

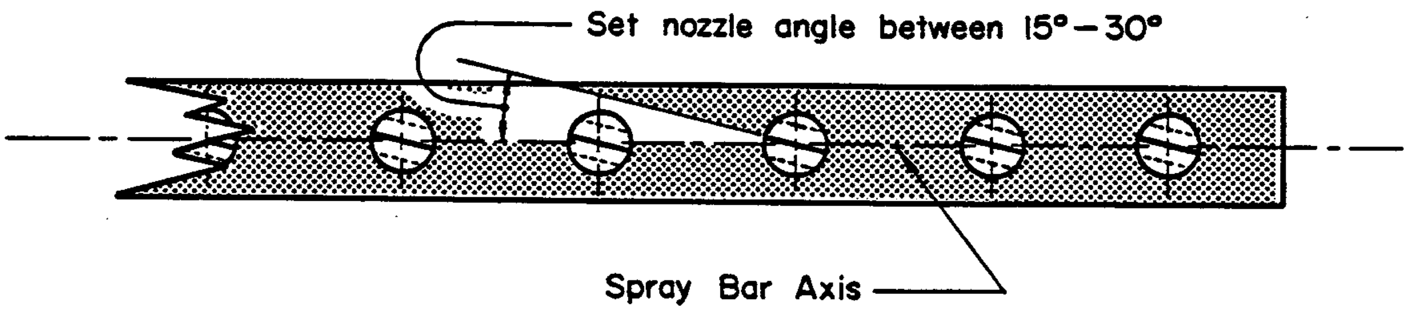
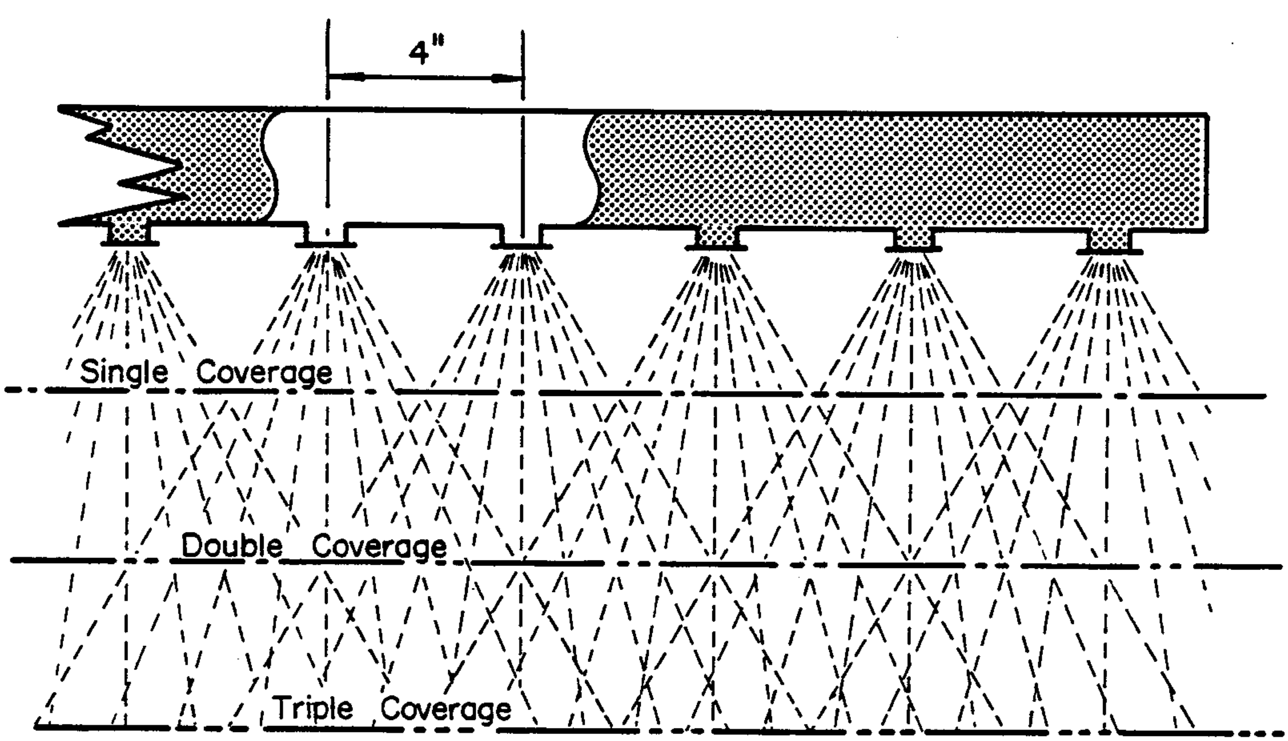


FIGURE 13

SPRAY BAR HEIGHT SETTING



Spray bar height must be set exactly for proper coverage.

gal/yd^2 (6-6.5 percent by wt) is specified, the percentage asphalt content by weight varies from 1.8 percent to 11.4 percent. Table 5 further supports this contention. The average variation of asphalt content within the project averages 18 percent when Yankovich-Miller Hill Road is treated as an outlier.

Interviews with project engineers revealed a common complaint that the operators were not familiar with their equipment. Another common complaint is that on short jobs, the project is completed before the application rates are properly adjusted. It is therefore suggested that the distributor be calibrated off the roadway. This includes adjusting pressures and speed, checking for transverse uniformity, and general inspection of the distributor. This will also provide a chance for both the inspector and operator to become thoroughly familiar with the distributor. The roadway should not be a training ground.

Figure 14

DISTRIBUTION OF ASPHALT CONTENT FROM CORES

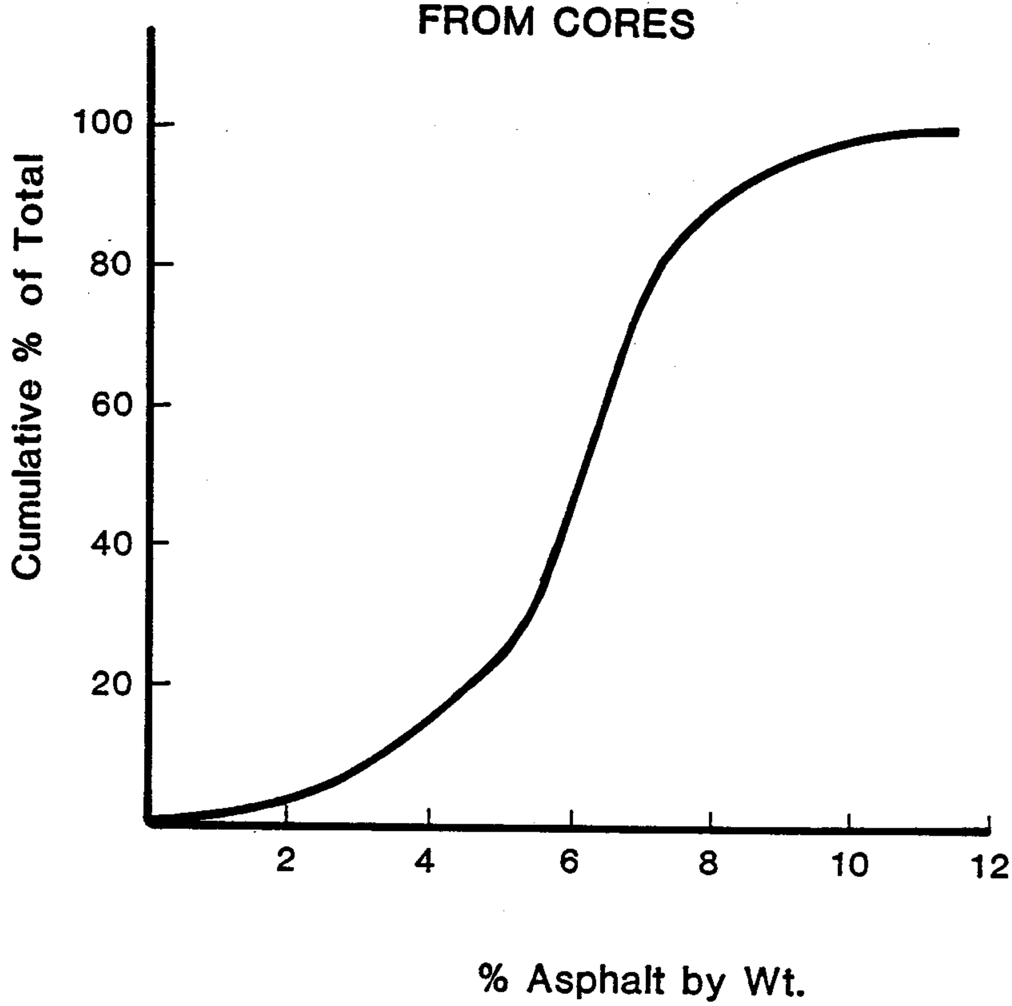


TABLE 5

Variation in Asphalt Content Within the Project

Project	Average Asphalt Content (% by weight)	Standard Deviation	% Variation (2s/ave) x 100	Asphalt Type
Goldstream Rd. Mi. 5-11	6.6	0.36	11	RC-800
Yankovich-Miller Hill	2.2	0.66	60	RC-800
Ballaine Rd.	5.4	0.78	14	RC-800
Old Nenana Hwy.	6.3	0.26	8	CRS-2
McGrath Rd.	3.2	0.47	29	RC-800
Nelson Rd.	5.7	0	0	RC-800
Chena Hot Springs Rd.	9.3	1.13	24	CRS-2
Harding Lake Rd.	5.2	.35	13	RC-800
Jack Warren Rd.	6.7	.90	19	CRS-2
Canyon-Shaw	6.1	0.53	17	RC-800
Richardson Hwy. Mi. 52-65	8.9	1.34	30	CRS-2
Edgerton Hwy. Mi. 0-18	6.4	0.98	31	—
Glenn Hwy.	6.3	0.93	30	CRS-2
Tok Cut-Off Mi. 3-18	6.4	0.40	13	—
Tok Cut-Off Mi. 24-30	4.0	0.31	16	—

RC-800 VS. CRS-2

There have been a number of accusations that many of the noted BST failures are directly related to the use of CRS-2 in recent years. For this reason, considerable effort was made to verify this accusation.

According to the local asphalt cement suppliers, the base asphalt for the RC-800 is a harder asphalt than that for CRS-2. However, the base crude is the same. Figure 14 shows that the ability to retain aggregate is exactly the same for both CRS-2 and RC-800, as is the distribution of the embedment depth.

In Figure 16, the pliability of CRS-2 is shown to be considerably higher for CRS-2 than RC-800. There are two probable reasons for this:

1. The CRS-2 projects have higher asphalt contents.
2. The difference in viscosity in the two oils.

To explore the first possibility, the asphalt was extracted and recovered from the cores brought in from the field. Figure 17 shows that projects using CRS-2 consistently tend to have a higher residual oil content. This could have a significant effect on the pliancy of the cores taken. The asphalt content was then plotted against pliancy for each of the oils in Figure 18. The pliancy tends to increase for both oils as the asphalt content rises. It is interesting to note the asphalt content was found to be higher with CRS-2 for the same pliancy. Even taking this into account, the difference in pliancy can be at least partially due to the higher asphalt content on projects using CRS-2.

It was also found that RC-800 tended to have a higher absolute viscosity than CRS-2 as shown in Figure 19. This difference is probably because RC-800 starts with 80-90 pen asphalt where CRS-2 starts with 120-150 penn asphalt. The RC-800 had a much wider distribution. It is very difficult to establish why this occurs, but it is probably due to the difference in the volatiles used. Judging by the wide spread in values, the RC-800 is probably more susceptible to aging than CRS-2, although this could not be shown directly from the data.

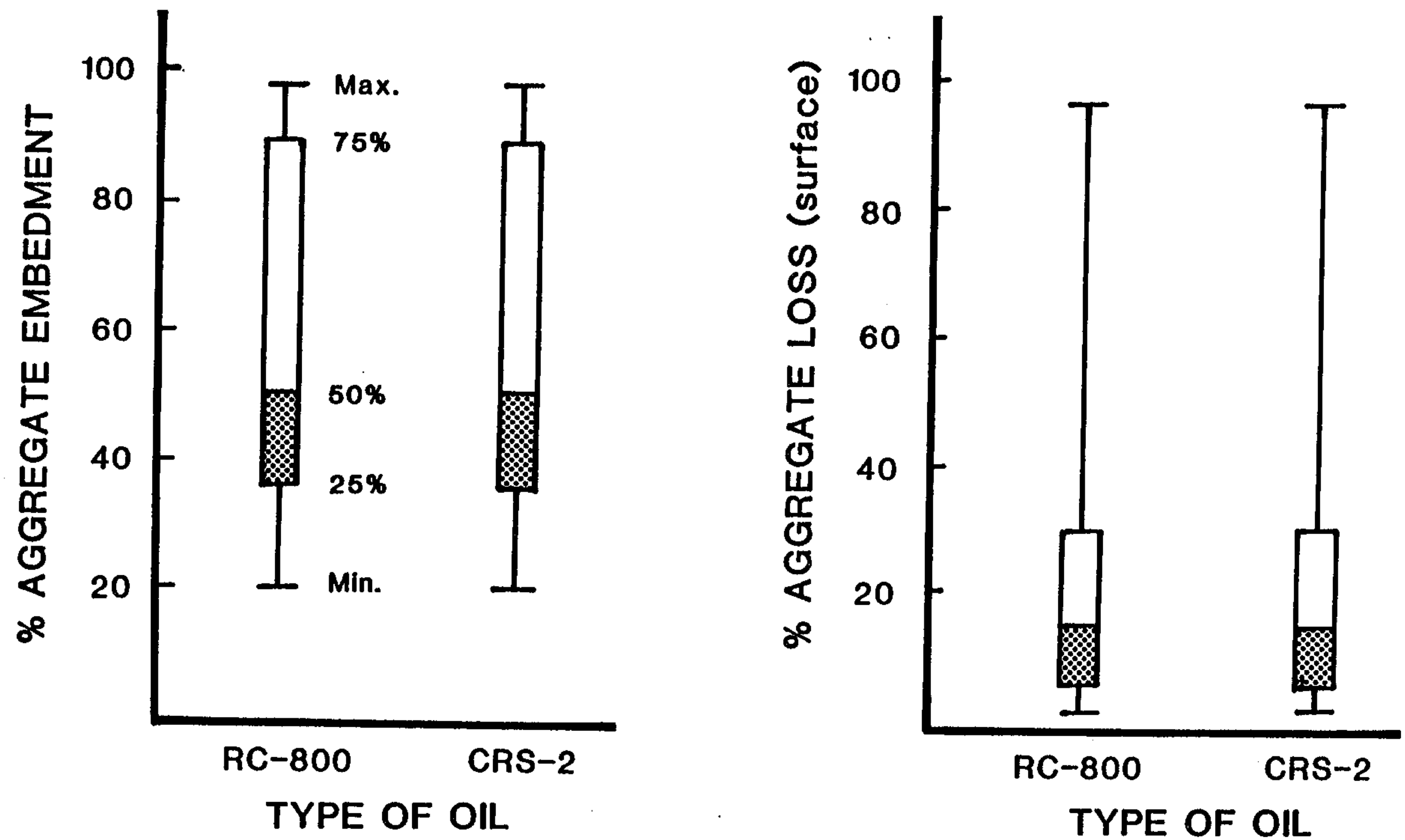


FIGURE 15 COMPARISON OF RC-800 & CRS-2

Figure 16

PLIANCY OF CRS-2 & RC-800 BST's

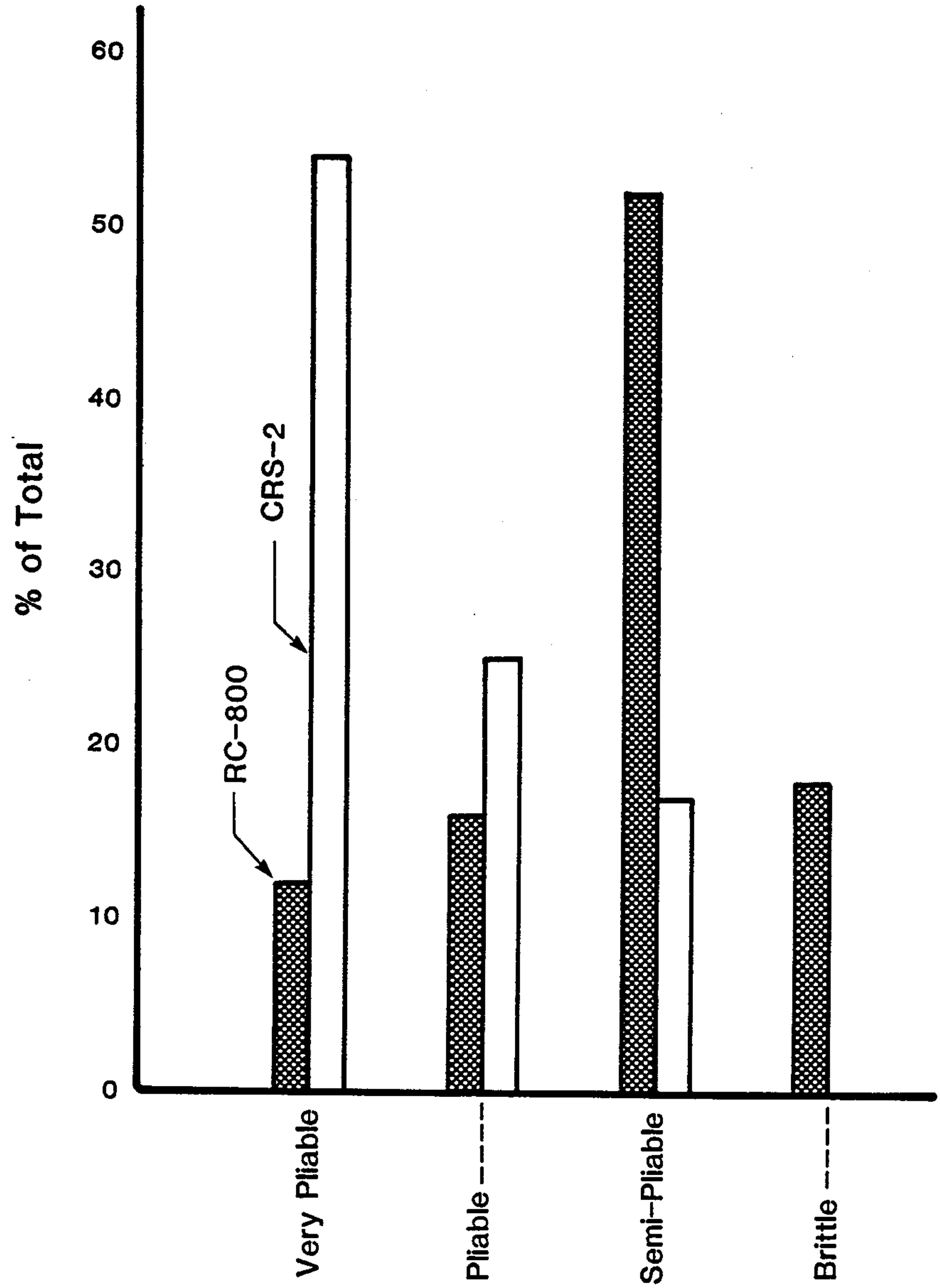


Figure 17

ASPHALT CONTENTS OF BST'S STUDIED

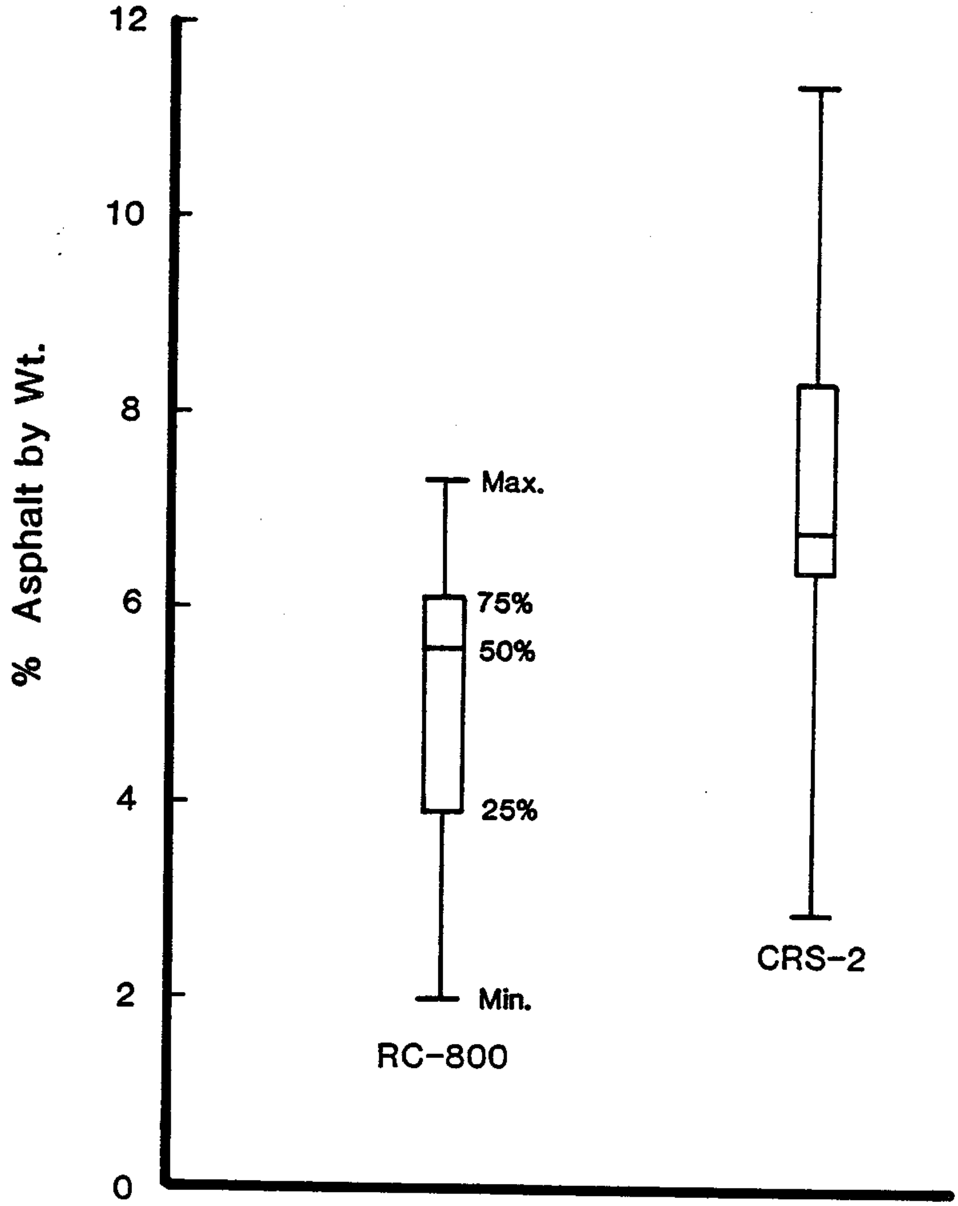
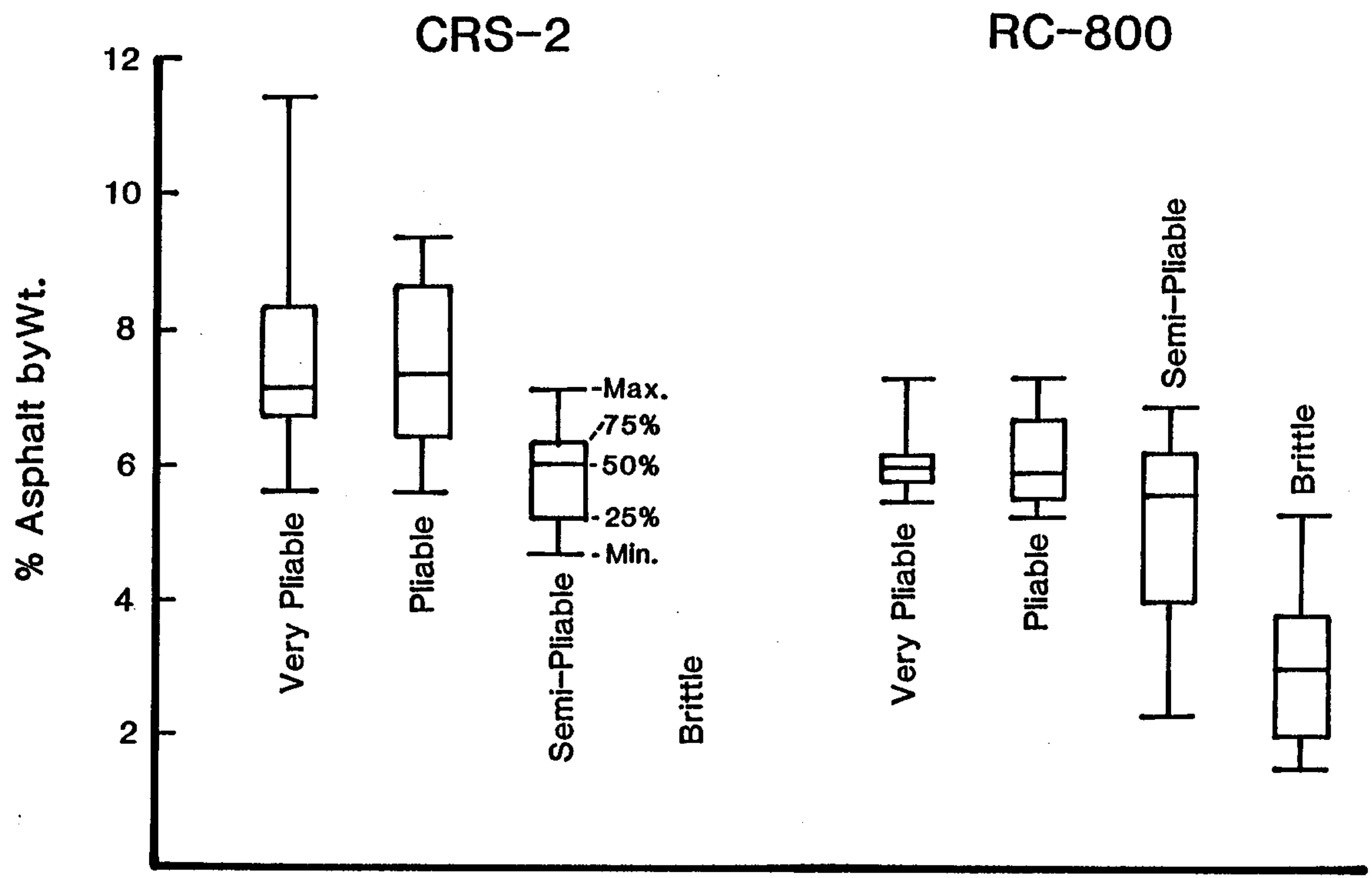
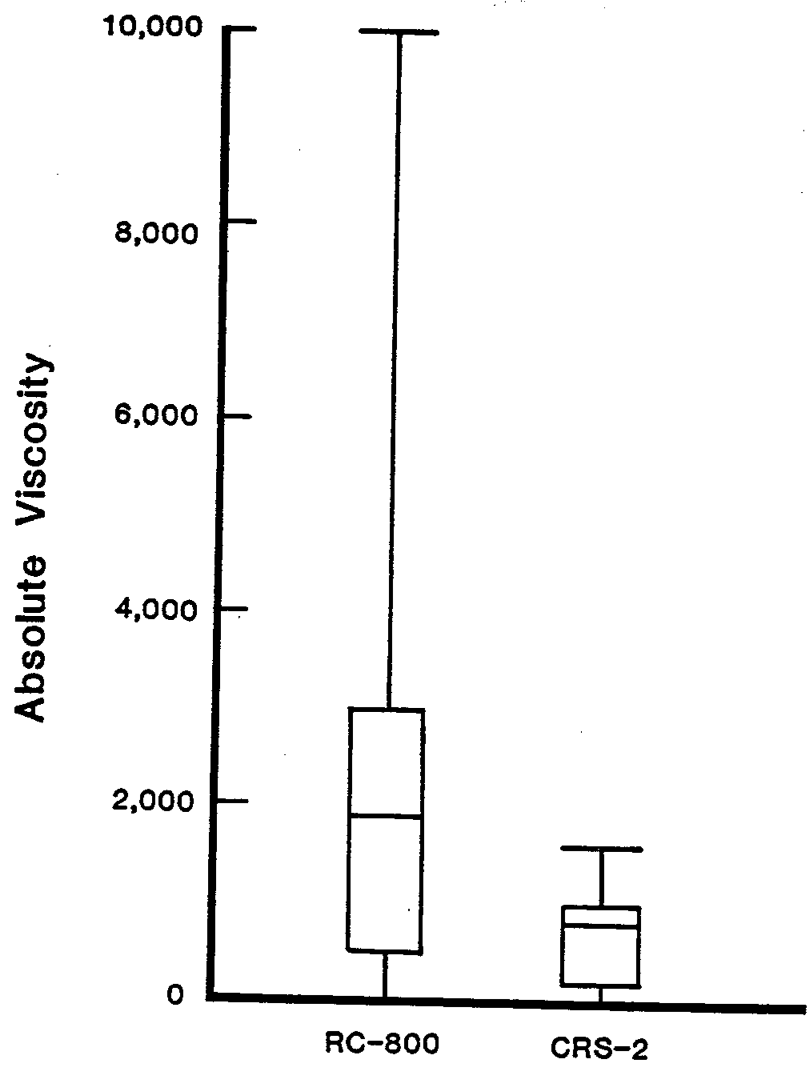


Figure 18



CRS-2
RC-800
% Asphalt byWt.
12
10
8
6
4
2
Very Pliable
Pliable
Semi-Pliable
Brittle
-Max.
75%
50%
25%
Min.
Very Pliable
Pliable
Semi-Pliable
Brittle

Figure 19



In summary, the higher pliability of surfaces constructed using CRS-2 is probably due to higher asphalt contents and to the softer base asphalt used. As long as the surface does not move on the base, rut or ravel, a softer asphalt is beneficial since it tends to heal cracks.

PRE & POST 1974 BST PERFORMANCE

Claims have been and continue to be made that the performance of BST's constructed after 1974 have performed worse than those constructed prior to that year. While the oil industry has claimed no change in the asphalt cement properties, most of the project engineers claim a loss of "stickiness" in the oil.

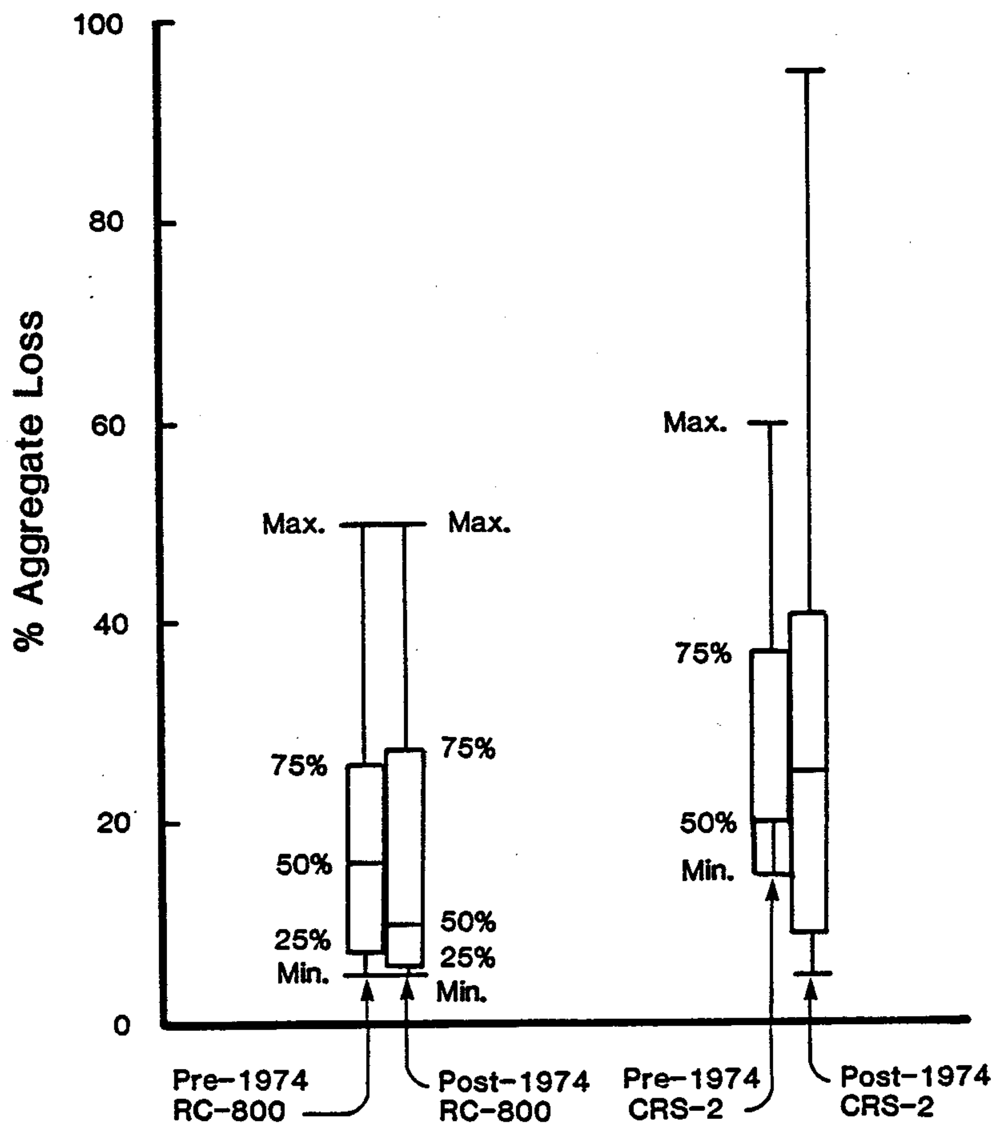
The October 1973 Arab-Israeli war and the consequent oil embargo caused a shift in the base stock crude oil supply throughout the world. However, the State's major asphalt crude sources for cutback and emulsified grades for Anchorage and Interior Alaska had consistently supplied crude from Cook Inlet - Swanson River field between 1968 and 1978 and was therefore unaffected by the oil embargo. Southeast Alaska has been supplied almost exclusively from the Richmond Beach refinery in Washington which has used various crude sources. In 1980 the crude source for asphalts shifted to Prudhoe Bay. However, none of the sections studied were built after 1979.

One measure of the tenacity of an asphalt cement is its ability to retain the aggregate. Figure 20 shows the surface aggregate loss for RC-800 and CRS-2 before and after 1974. The ability of the RC-800 to hold aggregate appears to have increased after 1974 while the CRS-2 tended to lose a larger percentage of aggregate. One possible explanation of why the RC-800 pavements showed more aggregate loss prior to 1974 is that the older pavements have had more time to wear. The question remains concerning why the emulsified asphalts have tended to lose more aggregate after 1974. Since one of the causes of aggregate loss is a lack of bonding, this avenue must be explored before any conclusion can be drawn.

Figure 21 shows the change in oil content after 1974. Interestingly, the asphalt content tended to increase after 1974 on projects using RC-800 which may at least partially explain the drop in aggregate loss. Another possible explanation of the increased oil content may be due to aging. However, the asphalt content on projects after 1974 using CRS-2

Figure 20

AGGREGATE LOSS BEFORE & AFTER 1974



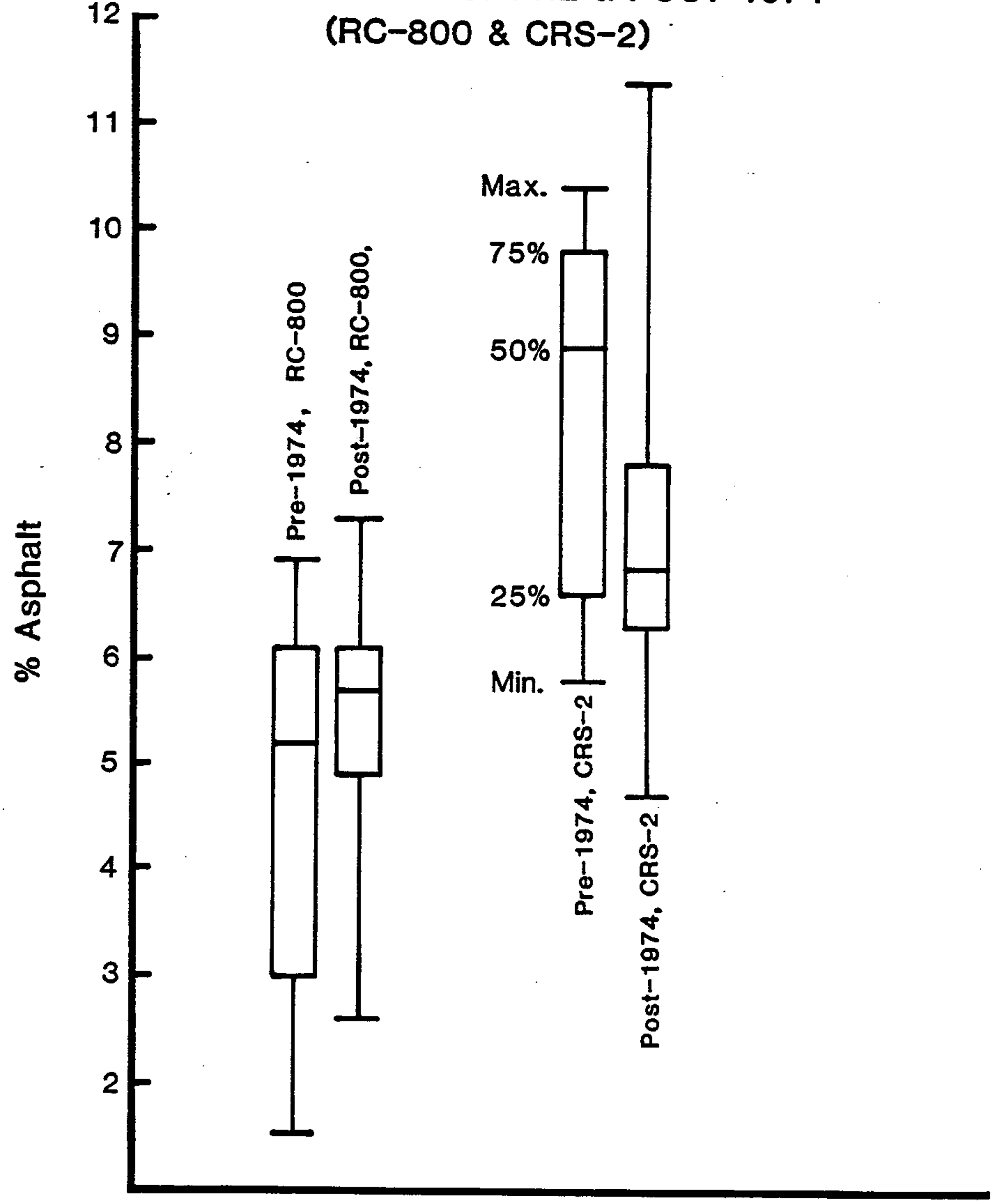
decreased. This again may explain the increased aggregate loss on those projects.

It should be noted that the 1974 oil embargo caused a shift towards an increased use of emulsified asphalts. While the base crude may be the same, emulsion asphalts require more care during construction than cutback asphalts. This is especially true in cool weather.

In conclusion, the only significant change in the asphalt cements that can be derived under this study is the shift towards use of emulsion asphalts.

Figure 21

PERCENT ASPHALT PRE & POST 1974
(RC-800 & CRS-2)



SEASONAL FACTORS

The weather plays an important role in the success or failure of any BST. Unfortunately, it is the one factor which cannot be controlled. The literature describes the ideal weather for constructing a BST as "hot and dry" during and several weeks after construction (5). Ideally the air temperature should be above 80°F and certainly above 40°F. No rain should be expected within two or three weeks after construction.

The conditions described thus far are almost non-existent in Alaska. However, Alaska has had successful surface treatments in the past, even though the construction season is very short with every day between break-up and freeze-up being fully utilized.

Typically, the embankment construction and roadway preparation takes until August or September when the projects are finally surfaced. By mid-August frost can be expected in Interior Alaska. As a result, many BST's are constructed under less than ideal conditions. The effects of the seasonal factor must therefore be explored.

Figure 22 shows that the vast majority of surface treatments are placed in August. Figure 23 shows that the probability of surface aggregate loss tended to be higher for projects constructed in August than in June or July. However, the median aggregate loss was similar to that of July. To explore this further, the construction season was broken into two parts: before and after August 20. August 20 was chosen because it is when the mean daily temperature low falls below 40°F in the Interior of the State. Those surface treatments that were laid after August 20 tended to have significantly higher aggregate loss than those laid before, as well as a greater variability of loss as shown in Figure 24.

Of the 12 projects which had aggregate loss of 20 percent or greater, six were placed after August 20. A review of the weather records revealed that all of these experienced minimum temperatures below 40°F. The failure on Ballaine Road was attributed entirely to cold weather. Of these five, three were considered to be undercured or overly pliable. In

Figure 22

DISTRIBUTION OF BST's PLACED BY MONTH

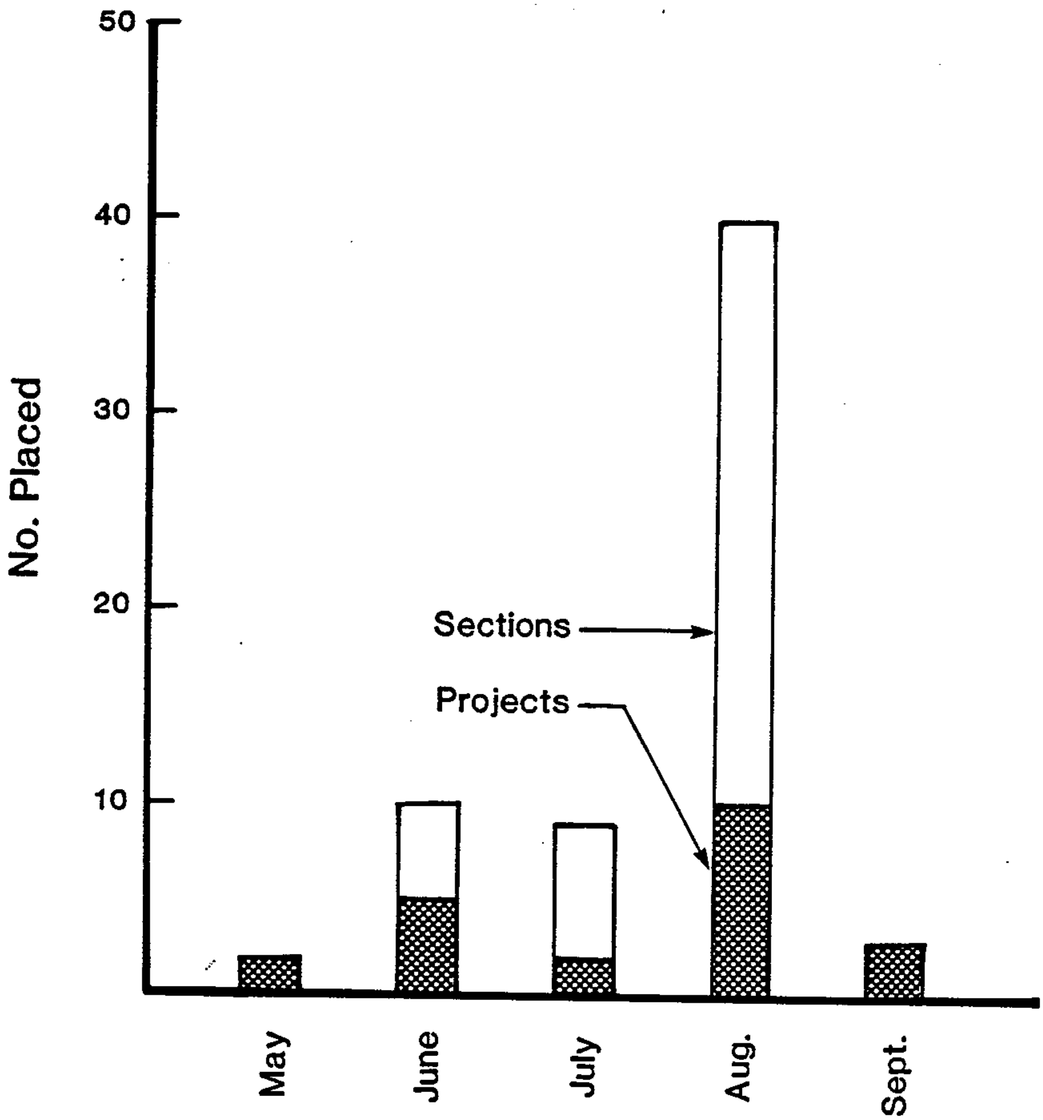
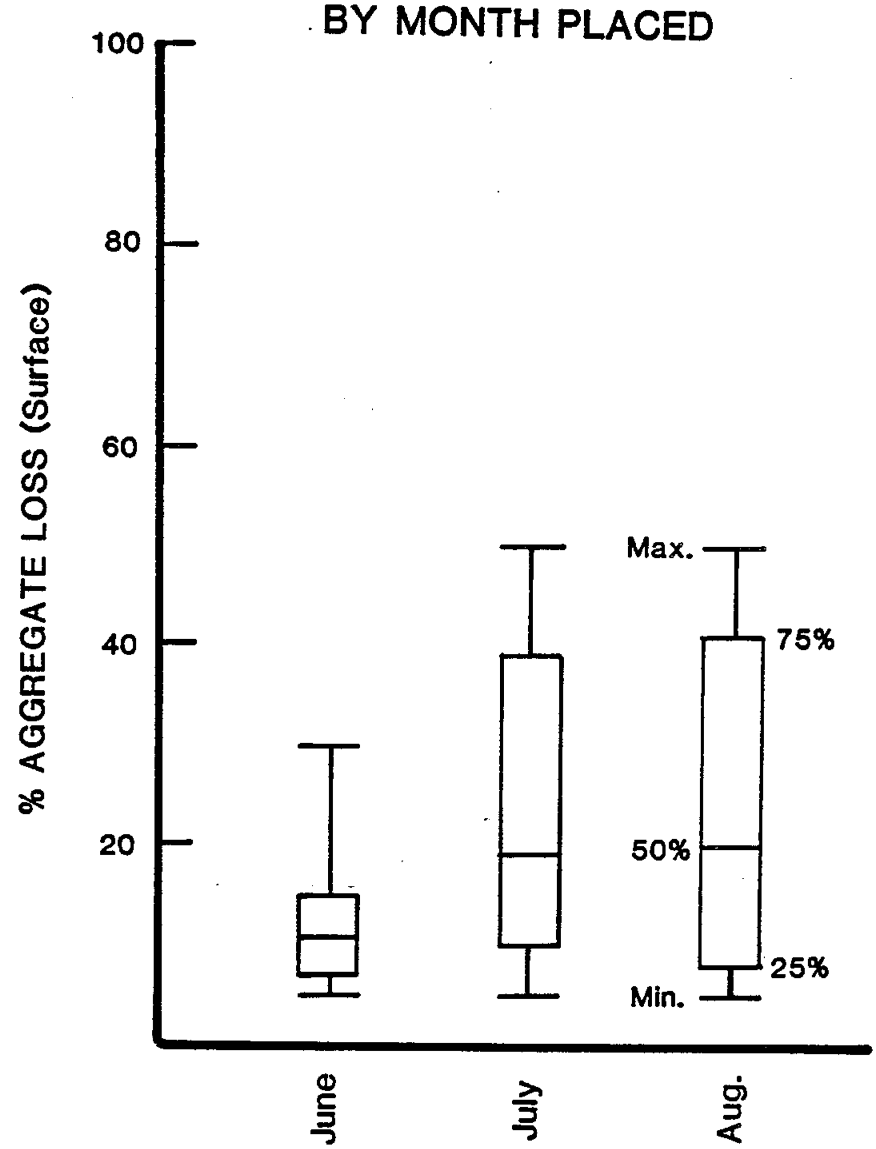


Figure 23

QUARTILE PLOT OF % AGGREGATE LOSS BY MONTH PLACED

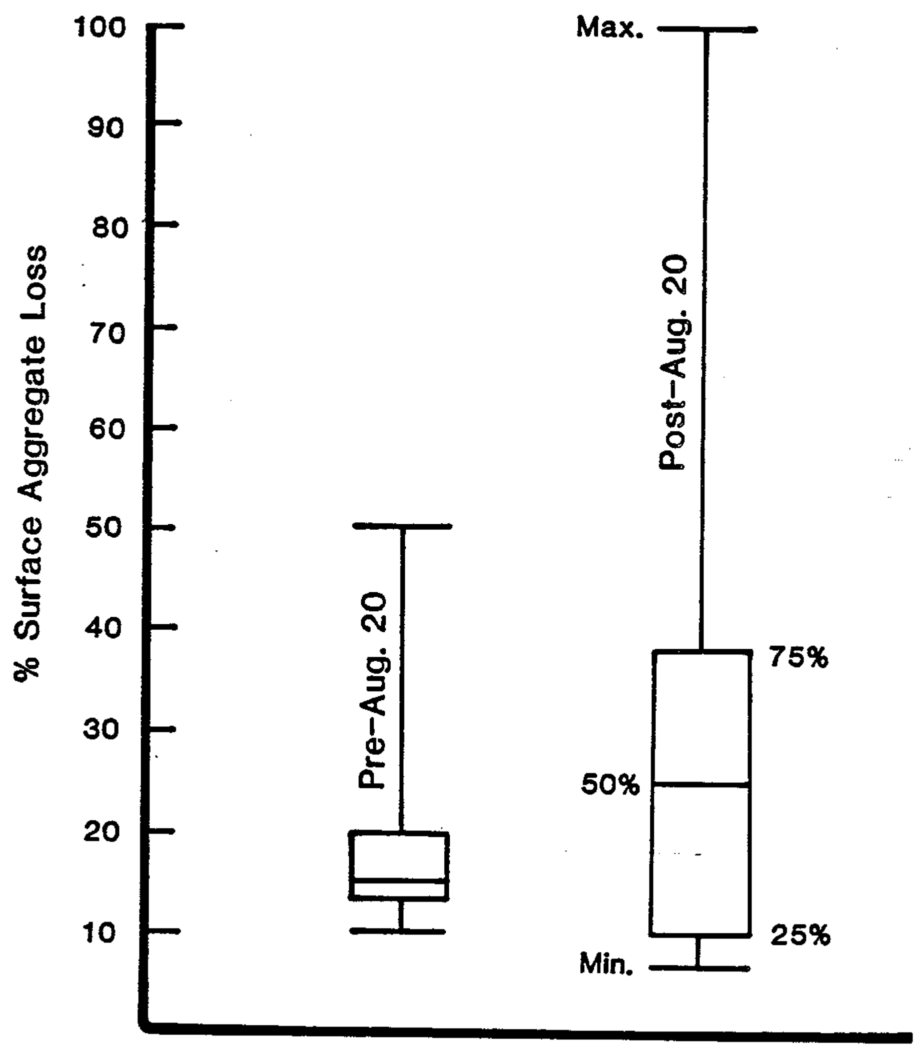


fact, two had appearances of having just been placed.

It is therefore recommended that no BST's be constructed after August 20 in Interior Alaska or when the average daily minimum is below 40°F unless unusually warm weather will follow.

Figure 24

COMPARISON OF AGGREGATE LOSS
BEFORE AND AFTER AUGUST 20



TRAFFIC CONTROL

Traffic control is an often neglected facet in the construction of a surface treatment. Its importance cannot be overstated because the lack of traffic control can easily destroy the best of jobs.

Current Alaska specifications state that the roadway shall be open to traffic at all times. However, traffic must be routed through the project in such a manner as to minimize damage to work already accomplished while causing the least inconvenience to the traveling public. It should be remembered that high speed traffic can cause considerable damage. Therefore, traffic speeds must be maintained at less than 25 mph until the cover is set. Because turning movements and skids produce damage which is difficult to remove, traffic must be handled in such a manner as to avoid these moves. Traffic control must extend to all construction equipment as well.

In order to understand the problems with traffic control in Alaska, project personnel were questioned. Of the 23 projects studied, 13 used a pilot car and two used a flagman to control traffic. Three projects were on closed roads and one project had no traffic control. There was no available information on seven projects. When asked if traffic control was a problem, five engineers said yes.

Current specifications require a pilot car be used at a speed not to exceed 15 miles per hour for a period of 2 to 24 hours, as directed. It is up to the project engineer to insure the traffic is controlled until such time as the surface will not be damaged.

PROBABLE CAUSES OF HIGH AGGREGATE LOSS ON A CASE BY CASE BASIS

To this point, only tendencies have been discussed. It is the intent here to review those projects which have shown exceptionally poor performance and determine the probable cause. Figure 25 is a summary of the data which has been found to be related to aggregate loss. For the purposes of this discussion, only those projects which had greater than or equal to 20 percent aggregate loss will be considered as poor.

These projects are shown in Figure 26. From this the following statements can be made:

1. Of the 12 projects considered poor, rain was considered to be at least part of the reason for failure in two projects.
2. Dusty aggregate was observed in two of the projects.
3. The BST was constructed after August 20 in six of the 12 projects.
4. Degradable aggregate was observed in two projects.
5. Low asphalt content contributed to the failure of at least two projects.
6. A weak base contributed to the failure of one project.

Of the 12 projects, insufficient records were available to ascertain the probable cause of high aggregate loss for two of the projects.

The probable cause could not be readily identified for three of the projects. However, on Geist Road most of the aggregate was lost in the first summer. Since then, it has performed well under high traffic loadings.

It can therefore be said that at least 70 percent of the projects which had high aggregate loss were directly attributable to poor construction practices. It is recommended that construction personnel be trained in how to properly construct a BST.

FIGURE 25

SUMMARY OF DATA

Section No.	Project Name	Construction Date	Air Temp. °F	Sky	Asphalt Type	Supplier	% Asphalt by Wt. Ave.	% Asphalt by Wt. Std. Dev.	% Aggregate Loss Ave.	% Aggregate Loss Std. Dev.	% Embedment Depth Ave.	% Embedment Depth Std. Dev.	% -200	Median Aggregate Size B	Median Aggregate Size C	Median Aggregate Size E	Remarks
005	Geist Road	6/05-6/09/76	79	PC	CRS-2	Chevron	5.8		20		98		1		0.37	0.30	High aggregate loss early
010	Wolf Run	5/20-5/24/78	50-60	PC	RC-800	Chevron	5.6		10		98		4		0.34	0.26	
015	Steese-Farmers Loop	7/27-8/02/78	70	Clear	RC-800	Chevron	3.9		50		95		1		0.35	0.27	
020-045	Goldstream Rd. mi. 5-11	8/10-8/17/76	65		RC-800		6.6	.36	29	7	32	5	1		0.35	0.29	1) Dusty aggregate 2) Rollers unable to keep up 3) Chips broke down; used one steel roller & one rubber tire roller
050-060	Yankovich-Miller Hill Rd.	9/06-9/09/69			RC-800	Chevron	2.2	.66	7	3	70		1	0.68	0.39		
065-075	Ballaine Rd.	9/27-9/30/78 6/07-6/09/79	32-51	PC	CRS-2	Chevron & Union	5.4	.78	7	3	40	10	1	0.52		0.29	E chips replaced in June after being lost in September
080-095	Old Nenana Hwy.	6/10-6/14/76	65	PC	CRS-2	Chevron	6.3	.26	18	10	40	17	2		0.35	0.29	
100-105	Nordale Rd.	8/27-8/30/75	55	PC	CRS-2	Chevron	8.7		20		98		1		0.34	0.28	Oil did not set
110	5th Avenue North Pole	6/22-6/27/79	55-60	Cldy	RC-800	Chevron & Union	3.9		15		90		1	0.55		0.28	
115	8th Avenue North Pole	6/23-6/27/79	46-71	Showers	RC-800	Chevron & Union	2.6		15		60		1	0.55		0.28	
120-130	McGrath Rd.	9/10-9/14/68			RC-800		3.2	.47	27	3	50	0		0.55	0.35		
135-140	Dale Rd.	8/17-8/20/72	64	Clear	RC-800	Chevron	4.0	0.0	13	4	50	14	1		0.39	0.29	

150	Lawrence Rd.	6/24-6/25/71	80	Clear	RC-800	Union	2.6		15		50				0.37	0.28	
155	Dyke Rd.	6/24-6/25/71	80	Clear	RC-800	Union	3.8		10		50		1		0.37	0.28	
170-180	Nelson Rd.	5/25-5/31/78	65	PC	RC-800	Chevron	5.7	0.0	18	7.6	43	12	0		0.34	0.29	
185-205	Chena Hot Springs Rd.	8/27-9/10/74	65	PC	CRS-2	Chevron	9.3	1.13	33	21	32	5	1		0.34	0.29	1) Probable excess moisture in base 2) Showers during chipping 3) Heavy rain on stockpile before chipping 4) No prime
210-225	Harding Lake Rd.	7/06-8/05/72	63-68	PC	RC-800	Chevron	5.2	.35	16	5	40	22	0		0.38	0.28	
230	Harding Lake Park Rd.	8/27-8/30/76	55-60		RC-800	Chevron	6.1		10		30		1		0.33	0.29	
235-240	Cantwell Cutoff	8/23-8/24/76	58-66	PC	RC-800	Chevron	7.3	0.0	45	4	40	0					
245-315	Jack Warren Rd.	8/15-9/13/75	56-60	PC	CRS-2	Chevron	6.7	.90	38	24	92	15	1		0.36	0.29	1) heavy dust 2) oil did not set
320-345	Richardson Hwy. Canyon-Shaw	8/16-8/25/76	67-71	Cldy	RC-800	Chevron & Union	6.1	.53	9	4	86	10	1		0.36	0.24	
360-390	Richardson Hwy. mi. 52-65	8/31-9/24/78	44-68	Cldy Rain	CRS-2	Chevron	8.9	1.34	29	24	89	20	1	0.56		0.29	1) highly degradable aggregate 2) weak base
400-440	Edgerton Hwy. mi. 0-18						6.4	.98	17	33	55	18					1) no construction records
445-485	Glenn Hwy.	8/02-8/07/78	73-77	PC	CRS-2	Chevron	6.3	.4	23	19	51	24	1	0.56		0.29	
490-520	Tok Cutoff mi. 3-18				RC-800	Chevron	6.1	.40	27	18	68	26	2	0.55		0.28	1) no construction records
525-555	Tok Cutoff mi. 24-30						4.0	.31	18	19	60	17					1) no construction records

FIGURE 26

Probable Causes of Failure

Project Name	Rain	Dusty Aggregate	Placed After August 20	Degradable Aggregate	Low Oil Content	Weak Base	Average % Aggregate Loss	Pliancy of Cores
Geist Rd.							20	Semi-pliable
Steese Farmers	X						50	Semi-pliable
Goldstream Mi. 5-11		X		X			29	Semi-pliable
Nordale Rd.			8/27				20	Pliable
McGrath Rd.			9/10		X		27	Brittle
Chena Hot Springs	X						33	Pliable
Cantwell Cutoff			8/23				45	Very Pliable
Jack Warren Road		X	8/15-9/13				38	Semi-pliable
Richardson Hwy. Mi. 52-65	X		8/31-9/24	X		X	29	Very Pliable
Glenn Hwy.							23	Very Pliable
Tok Cutoff Mi. 3-18 (no records)							27	Semi-pliable
Ballaine Rd.*			9/27-9/30				*	Semi-pliable

* Replaced "E" chips in spring.

EMBEDMENT DEPTH

During analysis of the data it was noted that embedment depth did not correlate with either percent asphalt or percent aggregate loss, as shown in Figures 27 and 28. This caused considerable concern until it was realized that high embedment depth results when the surface aggregate is removed and the base aggregate remains. This was confirmed by visiting several of the projects near Fairbanks which had high aggregate loss and high embedment depth. Consequently, embedment depth data may be in question in this study. It is suggested that, in future studies, care be taken to distinguish between embedment of both the surface aggregate and the aggregate in the first course.

Figure 27

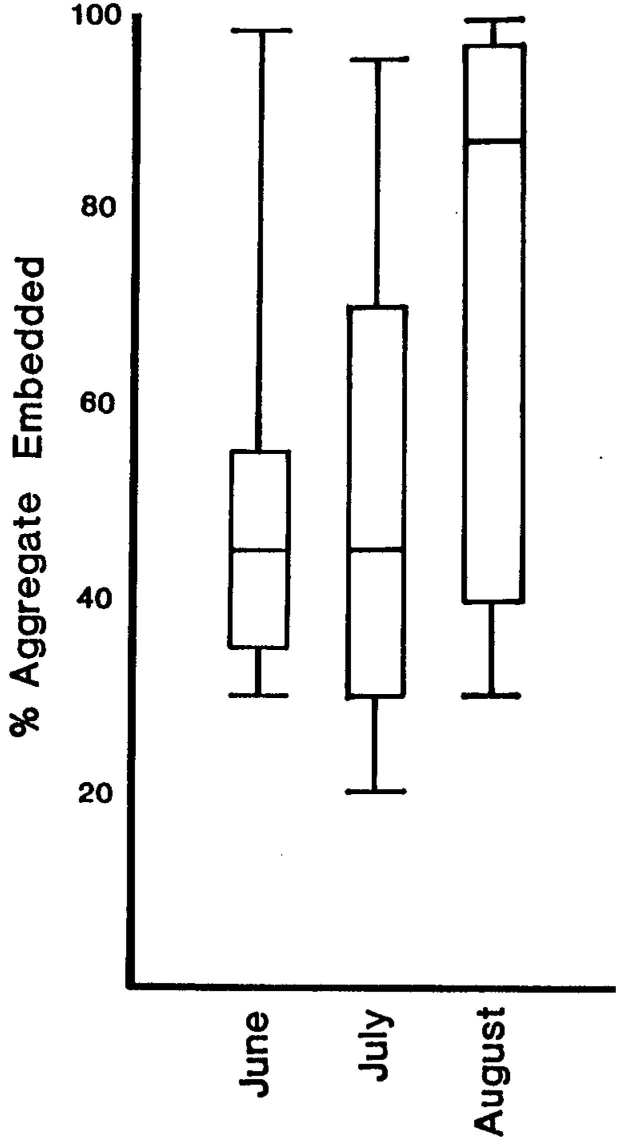
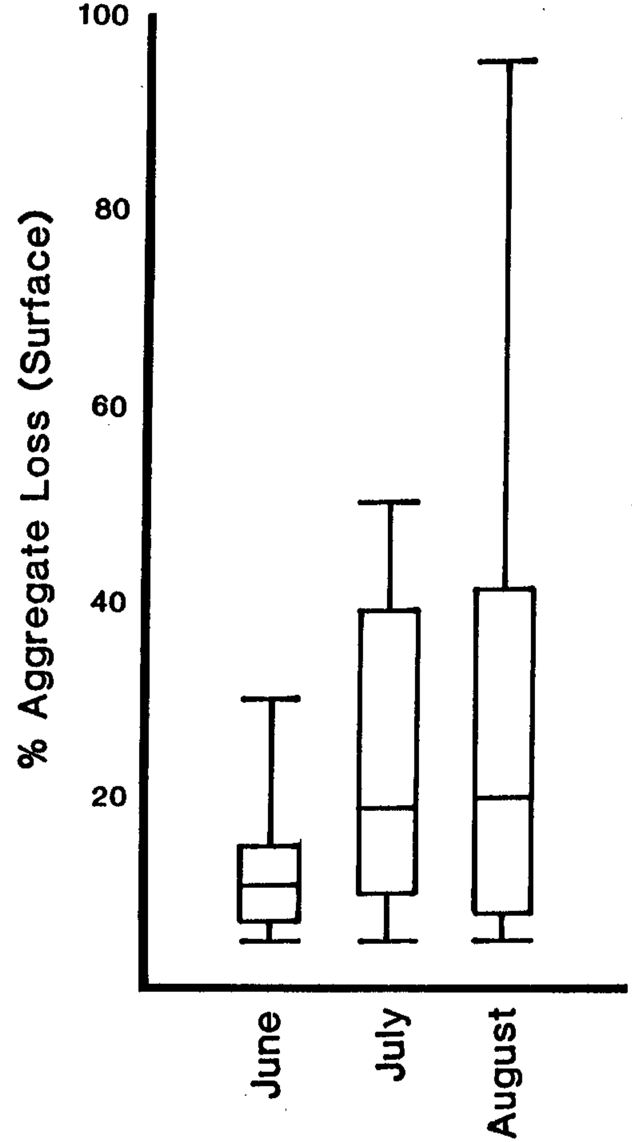


Figure 28



DESIGN OF BITUMINOUS SURFACE TREATMENTS

The current practice in Alaska is to specify a standard spread rate for asphalt and aggregate irregardless of the aggregate used. Although construction personnel are given some latitude, they are given no guidance for starting points except for plan quantities. While this may not be too serious on large projects, the ideal spread rates may never be found on smaller projects.

Several methods of designing surface treatments are currently available. Most of these will work once they are adjusted to local conditions.

Because aggregate characteristics vary to some extent, even when obtained from the same source, the design of surface treatments must be done in two separate stages: the "design phase" and the "construction stage." The design method should be the same for both phases even though the input variables may change.

The concepts in the design of a surface treatment are simple. The objective is to produce a dense pavement one stone thick with enough binder to hold it in place but not so much as to cause bleeding. This is generally accomplished by determining the volume of voids remaining when the particles are oriented on their longest side. Once the void space is determined, it is relatively simple to compute the required asphalt.

One of the most popular design methods for designing surface treatments was developed by the Country Roads Board of Victoria, Australia and subsequently modified by N.W. McLeod. The principles are relatively simple (6):

1. The voids are approximately 50 percent when one-size cover aggregate is dropped on an asphalt film.
2. Rolling rearranges the particles into a denser state, reducing the voids to about 30 percent.
3. Traffic further arranges the particles into their densest state, reducing voids to about 20 percent.

4. The thickness of the surface treatment is determined from the overall average least dimension (ALD) of the aggregate particles.
5. The asphalt binder should fill approximately 70 percent of the void space when the surface is in its densest state.

The entire method will not be reproduced here. A detailed description of the method can be found in FHWA-1P-79-1, A Basic Asphalt Emulsion Manual or the Asphalt Institute's MS-19 of the same title. The method has found wide acceptance. It is suggested that the method be adopted in Alaska in order to account for particle shape, surface conditions, etc.

SUMMARY AND CONCLUSIONS

Aggregate loss has proven to be the major problem in the State of Alaska on BST's. Fatigue cracking, rutting, shoving, and bleeding have not generally been a problem. The primary causes of high aggregate loss in Alaska were found to be:

1. low asphalt content
2. dusty aggregate
3. an inability of "C" and "E" chips to properly nest together
4. cool air temperatures
5. rain immediately before or after construction
6. a weak base
7. use of unsound aggregate

If these seven deficiencies are corrected, the success ratios for BST's are expected to improve by 70 percent.

It was found that the ability of RC-800 and CRS-2 to retain aggregate were identical. However, CRS-2 tended to be less susceptible to age hardening and brittleness. The viscosity ranges for CRS-2 were much tighter than for RC-800.

The base crude for cutback and emulsified asphalt in Alaska has remained the same as before 1974 until 1980 when the source was changed from Cook Inlet to Prudhoe Bay. It is therefore unlikely that the properties of the asphalt had changed until 1980. All projects studied were constructed before 1980.

BST's constructed after August 20 were found to have significantly higher aggregate loss than those constructed prior to August 20. This date was chosen for analysis because it is the date on which the average daily low temperature falls below $40^{\circ}F$. Emulsion asphalts generally cease to cure at about $40^{\circ}F$.

Uniform asphalt distribution has not generally been achieved. It has been shown that the spread rate varies as much as 1.3 percent by weight. The percent variation was found to be as much as 30 percent.

In general, it has been found that the majority of failures can be linked directly to deviation from good construction practice for BST's.

IMPLEMENTATION AND RECOMMENDATIONS

It is suggested that the following recommendations be implemented as soon as possible.

1. The use of the "C" and "E" chip combination be discontinued in favor of the "B" and "C" or the "B" and "E" chip combinations.
2. The construction of surface treatments should be limited to June 1 through August 20 except when weather conditions meet the suggested specifications in Appendix B.
3. The gradation should be changed to that shown in Figure 14 in order to insure a reasonably clean and uniform aggregate.
4. The starting aggregate and asphalt spread rates should be determined by the method described by McLeod in the Asphalt Institutes MS-19.
5. The spread rates should be adjusted by the method described in Appendix C.
6. Personnel should be trained to properly construct surface treatments.

RESEARCH NEEDS

This project has indicated the need for additional research in the following areas:

1. The effects of new crude sources not explored under this study should be evaluated.
2. Several emulsifying agents should be tested to determine which agent gives the most desirable qualities in emulsified asphalts.
3. The optimum spread rates to insure aggregate retention should be found in order to "tune" the BST design method to Alaska.
4. Additional specifications need to be developed for aggregate and construction methods to insure good performance.

ACKNOWLEDGEMENTS

The Alaska Department of Transportation and Public Facilities fully acknowledges the technical suggestions and funding assistance provided by the Federal Highway Administration under the Highway Planning and Research Program.

Recognition is extended to Carol Pederson and Tom Chang, Materials Technicians for Alaska's Statewide Research Section, and Dean Day, student at the University of Alaska, for the testing and field evaluations they performed. The Interior Region Materials Section personnel are thanked for their support.

A special thanks is extended to Nick Merrill, from Interior Region Design and Construction, for his participation in preparation and evaluation of data. His experience proved most valuable to the success of the project.

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APPENDIX A

PERFORMANCE RATING PROCEDURE

The method for condition ratings used in this study are described completely in the Manual for Condition Rating of Flexible Pavements published by the Ontario Ministry of Transportation and Communications.

The form shown in Figure A-1 was used to record the data. In order to reduce ambiguity, the following definitions were used:

coarse aggregate loss: Loss of aggregate larger than 1/4 inch from the surface of a pavement through traffic action.

ravelling: Progressive loss of aggregate from a pavement surface.

flushing or bleeding: Free asphalt binder on the surface of a pavement due to upward migration of the binder. Usually most prevalent in the wheel path during hot weather.

rippling or washboarding: Regular closely spaced undulations.

shoving: Horizontal displacement of the asphalt material due to traffic action.

rutting: Longitudinal deformation of the surface in the wheel paths resulting from repeated traffic loadings.

distortion: Any deviation of a pavement surface from its original shape other than rippling, shoving or rutting due to frost heaving, slope failure, settlement or any other phenomenon.

longitudinal wheel-track cracking: Any crack falling within the wheel path and approximately parallel to the center line of the roadway.

longitudinal mid-lane crack: A crack parallel to the center line of the roadway and located at or near the middle of the travel lane.

center line crack: A crack along or near the center line of the pavement.

meandering crack: Long crack which wanders from edge to edge of the pavement.

pavement edge crack: Cracks parallel to the center line which are within 12 inches of the pavement edge.

transverse crack: A crack which is approximately at right angles to the center line.

full transverse cracks: Cracks approximately at right angles to the center line which extend completely across the pavement.

random or block cracking: Interconnected random cracking which form a series of large polygons.

alligator cracking: Interconnected cracks forming a series of small polygons resembling the skin of an alligator.

slippage crack: A crack which outlines the edge of a fill settlement usually in the form of a large crescent.

Miscellaneous crack: Any crack not specifically described above.

A more complete description of these distress manifestations is given in the Ontario manual.

ROUTE NO.: ______________________ ROUTE NAME: ______________________

CDS MILE: ______________________ ROUTE MILE: ______________________

DATE: ______________________ CREW: ______________________

WEATHER: ____

PAVEMENT DISTRESS MANIFESTATIONS			SEVERITY OF PAVEMENT DISTRESS					DENSITY OF PAVEMENT DISTRESS (AREA)					CHARACTERISTICS OF PAVEMENT DISTRESS				
													PAVEMENT EDGE CRACK			ALLIGATOR CRACKING	
			VERY SLIGHT	SLIGHT	MODERATE	SEVERE	VERY SEVERE	FEW <10%	INTERMITTENT 10–20 %	FREQUENT 20–50 %	EXTENSIVE 50–80 %	THROUGHOUT 80–100 %	PROGRESSIVE (> 12" FROM EDGE)	NON-PROGRESSIVE (< 12" FROM EDGE)	TRANSVERSE CRACK SPACING FT.	ALLIGATOR BLOCK SIZE IN.	DISTORTION OF ALLIGATOR AREAS IN.
SURFACE DEFECTS	COARSE AGGREGATE LOSS																
	RAVELLING																
	FLUSHING																
SURFACE DEFORMATION	RIPPLING																
	SHOVING																
	WHEEL TRACK RUTTING																
	DISTORTION																
CRACKING	LONGITUDINAL WHEEL TRACK	SINGLE															
		MULTIPLE															
		ALLIGATOR															
	MIDLANE	SINGLE															
		MULTIPLE															
	CENTER LINE	SINGLE															
		MULTIPLE															
		ALLIGATOR															
	MEANDER	SINGLE															
		MULTIPLE															
	PAVEMENT EDGE	SINGLE															
		MULTIPLE															
		ALLIGATOR															
	TRANSVERSE	PARTIAL															
		HALF															
		FULL															
		MULTIPLE															
		ALLIGATOR															
	RANDOM																
	SLIPPAGE																
MAINTENANCE PATCHING																	
ADDITIONAL REMARKS																	

Figure A-1

CONDITION RATING FORM

APPENDIX B

SUGGESTED SPECIFICATIONS

SECTION 402

TACK COAT

402-1.01 DESCRIPTION. This work shall consist of furnishing and placing asphalt on a prepared surface in accordance with these specifications.

402-2.01 ASPHALT MATERIAL. The type and grade of asphalt material shall be as shown in the bid schedule.

The asphalt material shall conform to the applicable requirements of Section 702, and will be conditionally accepted at the source.

CONSTRUCTION REQUIREMENTS

402-3.01 EQUIPMENT. The Contractor shall provide equipment for heating and applying the asphalt material. This equipment shall conform to the following requirements:

The distributor shall be so designed, equipped, maintained and operated that asphalt material at even heat may be applied uniformly on variable widths of surface up to 15 feet at readily determined and controlled rates from 0.05 to 0.50 gallons per square yard, with uniform pressure, and with an allowable variation from any specified rate not to exceed 0.02 gallons per square yard. Distributor equipment shall include a tachometer, pressure guages, a calibrated tank, and a thermometer for measuring temperatures of tank contents. Distributors shall be equipped with a power unit for the pump, and full circulation spray bars adjustable laterally and vertically.

402-3.02 PREPARATION OF SURFACE TO BE TREATED. The existing surface shall be patched and cleaned and shall be free of irregularities to provide reasonably smooth and uniform surface to receive the treatment. Unstable corrugated areas shall be removed and replaced with suitable patching materials. Payment for the patching will be made at the contract unit price for the various items used unless a reconditioning item is included in the contract. The edges of existing pavements, which are to be adjacent to new pavement, shall be cleaned to permit the adhesion of asphalt materials.

402-3.03 APPLICATION OF ASPHALT MATERIAL. The tack coat shall be uniformly applied with a pressure distributor in such manner as to offer the least inconvenience to traffic and to permit one-way traffic without pickup or tracking of the asphalt material.

Tack coat shall not be applied unless the air temperature is 40°F as measured in the shade away from heat sources, or a surface which is coated with free water.

Application of tack coat shall be limited to that amount which can be covered by one day's paving operation.

Emulsified asphalt for tack shall be diluted with an equal amount of water and mixed. The quality and temperature of the water shall be such that asphalt will not separate from the emulsion before application.

Asphalt material shall be applied at a rate that will result in a residual covering of 0.025 to 0.04 gallons of asphalt per square yard.

402-4.01 METHOD OF MEASUREMENT. The asphalt material for tack coat will be measured by the ton in accordance with Section 109, including water.

402-5.01 BASIS OF PAYMENT. The accepted quantities of tack coat will be paid for at the contract unit price per ton for asphalt material, complete in place, or by lump sum.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
402(1)	CSS 1 Asphalt for Tack Coat	Ton
402(2)	CSS 1 Aphalt for Tack Coat	Lump Sum

SECTION 403

PRIME COAT

403-1.01 DESCRIPTION. This work shall consist of preparing and treating a previously prepared roadbed with asphalt material, and blotter material, if required, in accordance with these specifications and in reasonably close conformance with the lines shown on the plans.

403-2.01 ASPHALT MATERIAL. The type and grade of asphalt material shall be as shown in the bid schedule.

The asphalt material shall meet the applicable requirements of Section 702, and will be conditionally accepted at the source.

403-2.02 BLOTTER MATERIAL. Blotter material shall be suitable clean sand.

CONSTRUCTION REQUIREMENTS

403-3.01 WEATHER LIMITATIONS. Asphalt material shall not be applied on a wet surface, when the temperature is below 45°F, or when weather conditions would prevent the proper penetration of the prime coat.

403-3.02 EQUIPMENT. The Contractor shall provide equipment for heating and applying the asphalt material and for applying blotter material. The distributor equipment shall conform to the requirements set forth in Section 402-3.01 of these specifications.

In addition, one self-propelled aggregate spreader of approved design and a rotary power broom shall be provided by the Contractor.

403-3.03 PREPARATION OF SURFACE. The surface to be primed shall be shaped to the required grade and section, shall be free from all ruts, corrugations, segregated material or other irregularities and shall be uniformly compacted. Non-specification materials shall be removed from the surface immediately prior to application of the asphalt material.

Delays in priming will necessitate reprocessing or reshaping to provide a smooth compacted surface.

403-3.04 APPLICATION OF ASPHALT MATERIAL. Asphalt material shall be applied to the width of the section to be primed by means of a pressure distributor in a uniform, continuous spread. When traffic is maintained, not more than 1/2 of the width of the section shall be treated in one application. Care shall be taken that the application of asphalt material at the junctions of spreads is not in excess of the specified amount. Excess asphalt material shall be squeegeed from the surface. Skipped areas or deficiencies shall be corrected. Building paper shall be placed over the end of the previous applications and the joining application shall start on the building paper. Building paper used shall be removed and satisfactorily disposed of.

When traffic is maintained, one-way traffic shall be permitted on the untreated portion of the roadbed. As soon as the asphalt material has been absorbed by the surface and will not pick up, traffic may be transferred to the treated portion and the remaining width of the section primed.

The quantities, rate of application, temperature and areas to be treated shall be approved before application of the prime coat.

403-3.05 APPLICATION OF BLOTTER MATERIAL. If, after the application of the prime coat, the asphalt material fails to penetrate and dry, and traffic must be routed over the primed surface, or rain is imminent, blotter material shall be applied as directed.

Only with written approval shall blotter material be applied sooner than 4 hours after application of the asphalt material.

403-4.01 METHOD OF MEASUREMENT. Asphalt material will be measured by the ton in accordance with Section 109, Measurement and Payment. Blotter material will not be measured for payment but will be considered incidental.

403-5.01 BASIS OF PAYMENT. The accepted quantity of prime coat as determined above shall be paid for at the contract price per unit of measurement complete in place.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
403(1)	RC___ Liquid Asphalt for Prime Coat	Ton
403(2)	MC___ Liquid Asphalt for Prime Coat	Ton

SECTION 404

SEAL COAT

404-1.01 DESCRIPTION. This work shall consist of an application of asphalt material with or without cover coat material, applied as hereinafter specified, or as directed.

404-2.01 ASPHALT MATERIAL. The type and grade of asphalt material shall be as shown in the bid schedule.

The asphalt material shall conform to the applicable requirements of Section 702 and will be conditionally accepted at the source.

404-2.02 COVER COAT MATERIAL. Cover coat material shall conform to the requirements of Section 703-2.05 for the size specified. The material may be accepted in the stockpile at the source. Washing of the aggregate may be required. At the time of spreading, the aggregate may be surface dry or slightly damp.

CONSTRUCTION REQUIREMENTS

404-3.02 EQUIPMENT. The following equipment or its equivalent shall be required:

1. Equipment for heating and applying asphalt material. This equipment shall conform to the requirements of Section 402-3.01 and as further specified herein.

2. A rotary power broom or power vacuum sweeper.

3. A minimum of two self-propelled pneumatic tired rollers having gross loads adjustable to apply 200 to 350 pounds per inch of rolling width as directed. Tire pressure or contact pressure may be specified for pneumatic tire rollers. Pneumatic tire rollers shall be operated at a maximum speed of 5 miles per hour.

4. One self-propelled aggregate spreader of approved design supported by at least 4 wheels equipped with pneumatic tires on two axles.

404-3.03 PREPARATION OF SURFACE. Seal coating operations shall not be started until the surface is thoroughly compacted.

Asphalt material shall not be applied until the surface has been cleaned as required, and the section to be sealed has been approved.

404-3.04 APPLYING ASPHALT MATERIAL. Asphalt material shall be applied by means of a pressure distributor in a uniform, continuous spread over the section to be treated and within the temperature range specified. The quantity of asphalt material to be used per square yard shall be as directed. If the texture of the surface is such that asphalt material penetrates the surface, a preliminary application of 0.05 to 0.10 gallon per square yard of surface may be required. A strip of building paper, at least 3 feet in width and with a length equal to that of the spray bar of the distributor plus one foot shall be used at the beginning of each spread. The used paper shall be removed and disposed of in a satisfactory manner. The distributor shall be moving forward at proper application speed at the time the spray bar is opened. Any skipped areas or deficiencies shall be corrected. Junctions of spreads shall be carefully made to prevent an excess of asphalt material.

The distributor shall be operated in such a manner that missing or overlapping shall be avoided. If the Contractor is unable to obtain satisfactory application due to unsuitable or poorly regulated distributory equipment, or to incompetent operators, he shall immediately repair or replace equipment or furnish competent operators.

The rate of application specified in the contract may be adjusted with the approval of the Engineer when necessary to result in satisfactory imbedment and retention of the cover aggregate.

Spreading asphaltic material shall be discontinued early enough in the day to permit the termination of traffic control prior to darkness. Asphaltic material shall be applied to only one designated traffic lane at a time and the entire width of the designated lane shall be covered in one operation.

The length of spread of asphalt material shall not be in excess of that which trucks loaded with cover coat material can immediately cover.

The spread of asphalt material shall not be more than 6 inches wider than the width covered by the cover coat material from the spreading device. Under no circumstances shall operations proceed in such manner that asphalt material will be allowed to chill, set up, dry, or otherwise impair retention of the cover coat.

The distributor, when not spreading, shall be parked so that the spray bar or mechanism will not drip asphalt materials on the surface of the traveled way.

404-3.05 APPLICATION OF COVER COAT MATERIAL. Immediately following the application of the asphalt material, cover coat material shall be spread in quantities as designated. Spreading shall be accomplished in such a manner that the tires of the trucks or aggregate spreader at no time contact the uncovered and newly applied asphalt material.

The cover coat material shall be moistened with water as directed. Moistening shall be done the day before the aggregate is to be used.

When applying asphalt material without a cover coat, rolling of the asphalt material shall begin immediately upon application and continue until there is no evidence of kneading action. The Contractor shall provide at least one complete roller coverage of the road surface.

Immediately after the cover coat material is spread, any deficient areas shall be covered by additional material. Pneumatic tire rolling for the full width of the aggregates, shall begin immediately and shall be continued until 3 complete coverages are obtained. Pneumatic tire rolling shall be completed within one hour of the time the asphalt material and cover coat materials are applied. Vibratory rollers shall not be used for rolling cover coat material.

After the application of the cover coat material, the surface where specified shall be lightly broomed or otherwise maintained as directed for a period of

4 days or as directed. Maintenance of the surface shall include the distribution of cover coat material over the surface to absorb any free asphalt material and cover any area deficient in cover coat material. The maintenance shall be conducted so as not to displace imbedded material. Excess material shall be swept from the entire surface by means of rotary brooms at the time directed.

TRAFFIC LIMITATIONS. Traffic will not be permitted on the seal coat until rolling is completed. Traffic on seal coats shall be controlled by pilot cars at a speed not to exceed 15 miles per hour for a period of 2 to 24 hours, as directed.

404-4.01 METHOD OF MEASUREMENT. Asphalt material and cover coat material will be measured by the ton in accordance with Section 109, Measurement and Payment. When water is added to cationic emulsion, the quantity of emulsion to be paid for will be determined prior to the addition of the water.

404-5.01 BASIS OF PAYMENT. The accepted quantities of seal coat will be paid for at the contract price per ton for asphalt material and per ton for cover coat material complete in place.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
404(1)	___ Asphalt for Seal Coat	Ton
404(2)	Cover Coat Material Grading ___	Ton

SECTION 405

SURFACE TREATMENT

405-1.01 DESCRIPTION. This work shall consist of the construction of a single or multiple course asphalt surface treatment in accordance with these specifications and in reasonable conformance with the lines shown on the plans.

405-2.02 ASPHALT MATERIALS. The types and grades of asphalt material will be as shown in the bid schedule.

The asphalt material shall conform to the applicable requirements of Section 702. The asphalt material will be conditionally accepted at the source.

405-2.02 AGGREGATES. Aggregates and blotter material shall conform to the requirements of Section 703-2.05 and 403-2.02 respectively for the sizes specified. The material may be accepted in stockpile at the source.

CONSTRUCTION REQUIREMENTS

405-3.01 PRIME COAT. A curing period may be required between the application of the prime coat and the next application of asphalt material, as directed.

During the period between the application of the prime coat and the surface treatment, the primed surface shall be kept in repair. All holes, ravels and areas deficient in prime shall be patched and repaired with asphalt treated materials, by penetration methods or other approved procedures.

405-3.02 SURFACE TREATMENT. Each surface treatment course shall be applied in accordance with the requirements of Section 404 and the following modifications thereto:

This work shall be done between June 1 and August 20. Asphalt surface treatments shall be applied only when the temperature of the air is above 60°F in the shade. No work shall be started if local conditions indicates rain is imminent.

This work may be done between May 1 and June 1 and between August 20 and September 15 providing the air temperature of the three consecutive days immediately preceeding the day of application has been: (1) above 60°F in the shade each day, (2) a minimum of 40°F, and (3) the temperature of the air in the shade at the time of application is above 60°F.

Surface treatments may be constructed between 40°F and 60°F provided the aggregate is heated to 155°F or greater at the time of application.

When using emulsion grade asphalts, no work shall begin if the air temperature is expected to fall below 32°F within 24 hours after the completion of the work.

405-3.03 OPENING TO TRAFFIC. Unless otherwise specified, the highway shall be kept open to traffic at all times. As soon as the final layer is rolled, controlled traffic in accordance with Section 404-3.05, may be permitted thereon.

405-4.01 METHOD OF MEASUREMENT. Asphalt material and cover coat material will be measured by the ton in accordance with Section 109. When water is added to cationic emulsion, the quantity of emulsion to be paid for shall be determined prior to the addition of the water.

405-5.01 BASIS OF PAYMENT. The accepted quantities determined as provided above, shall be paid for at the contract price per unit of measurement for each of the pay items listed below, complete in place.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
405(1)	___ Asphalt for Surface Treatment	Ton
405(2)	Grading ___, Cover Coat Material for Asphalt Surface Treatment	Ton

When more than one grade of cover coat material is specified, letter suffixes shall be included within the parentheses of the pay item number in order to differentiate between the different gradings.

APPENDIX C

The following method of adjusting spread rates is suggested.

To adjust the aggregate spread rates:

1. Determine the current spread rate in the normal manner.

$$\text{spread rate (lbs/yd}^2\text{)} = \frac{\text{wt. of aggregate}}{\text{(width x length of spread)}}$$

2. Immediately after rolling is completed mark off a 6 ft. x 6 ft. square (4 sq. yd.) on the surface.
3. Using a broom and dust pan sweep up the loose aggregate and weigh.
4. Determine the <u>excess</u> aggregate per square yard by the equation:

$$\text{excess} = \frac{\text{wt. of aggregate}}{4\ \text{yd}^2}$$

5. Reduce the spread rate by 80 percent of the excess.

To adjust the asphalt spread rate:

1. Visually inspect the swept surface for adequate embedment depth. The embedment depth should be 85 percent for RC-800 and 99 percent for CRS-2. This will give a 70 percent embedment depth when the volatiles have evaporated.
2. Increase or decrease asphalt spread rate as necessary.

APPENDIX D

STEPS TO A GOOD SURFACE TREATMENT

(A LITERATURE SUMMARY)

by

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July 1980

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STEPS TO A GOOD SURFACE TREATMENT

(A LITERATURE SUMMARY)

To the layman, a surface treatment is "squirting some oil on the road and throwing some chips on it." Unfortunately, this attitude exists to some extent among those who specify surface treatments. According to the Transportation Research Board Committee Specification MC-A3, a surface treatment is defined as:

> "One or more applications of liquid asphalt and cover aggregate on a prepared base of consolidated gravel, stone, macadam, earth or stabilized soil." (1)

There are three basic steps to a good surface treatment:

1. Proper application
2. Proper design techniques
3. Good construction techniques

Proper Application:

A common mistake is the treating of gravel roads which are structurally weak. Because surface treatments have no structural strength, these projects are doomed to failure. A surface treatment is exactly what its name implies -- a treatment to the surface to improve its wearing and ride quality. If the foundation is weak, strengthen it. If any surface defects exist, correct them. If any doubt exists, run springtime deflection tests or investigate the pavement structure with test holes.

Proper Design Techniques:

As stated in the definition, a surface treatment is comprised of two components; asphalt cement and aggregate. By obtaining the optimum combination of these two elements, a good long lasting surface treatment is possible.

The selection of the proper grade of asphalt for surface treatments should consider the environment, the aggregate and equipment which will be used. According to the Asphalt Institute, the correct grade of asphalt for a surface treatment should:

1. When applied, be fluid enough to spray properly and cover the surface uniformly
2. After application, retain the proper consistency to wet the applied aggregate
3. Cure and develop adhesion quickly
4. After rolling and curing, hold the aggregate tightly to the road surface to prevent dislodgment by traffic
5. When applied in the right amount, not bleed or strip with changing weather conditions

After the surface treatment has been subjected to traffic, the aggregate particles will seek their densest state. This can result only when the particles have oriented themselves on their flattest side. Ideally, the asphalt should fill approximately 70% of the void between the particles as shown in Figure 1. Less than 50% voids filled result in aggregate loss while 100% cause flushing.

Because the aggregate particles tend to rest on their longest side, it becomes intuitively obvious that the asphalt application rate should be based on the average least dimension (ALD) as shown in Figure 1. The embedment depth is then based on the ALD.

In general, the larger aggregate size results in a better surface treatment because the control of the asphalt spread becomes less critical. However, larger stone increases tire noise which may not be desirable. A trade-off must be made.

The cover aggregate should be as uniform as possible. It is suggested that 60 to 70% of the particles passing the specified nominal size must be retained on the sieve having an opening of 70% of that size and that the smallest size particle should be no more than one-half the largest size. Referring to Figure 2, it can be seen that if there is excessive differences in aggregate particle size, many of the smaller particles will be covered with asphalt while the larger particles will be whipped off by traffic. The same condition may occur if many of the particles are elongated. The ideal shape of the aggregate particles is therefore cubical or pyramidal with all particles uniform in size.

In summary, four things must be remembered in the design of a surface treatment:

1. A good foundation is a necessity
2. The asphalt cement must be selected for the use
3. The aggregate should be of a uniform size and cubical or pyramidal shape
4. The embedment depth and asphalt spread are based on the average least dimension.

Good Construction Techniques:

Perhaps the single most important factor in the construction of a good surface treatment is the recognition of a really good treatment by everyone on the project. What should be seen is aggregate without any evidence of flushing, bleeding or ravelling. Figure 3 shows the common problems, their causes and cures. Familiarity with this chart will aid considerably in getting a good, long lasting job.

Construction of a surface treatment can be broken into four steps:

1. Foundation preparation
2. Spreading of asphalt cement
3. Spreading of aggregate
4. Compaction

FIGURE 1

IDEAL AGGREGATE-ASPHALT COMBINATION

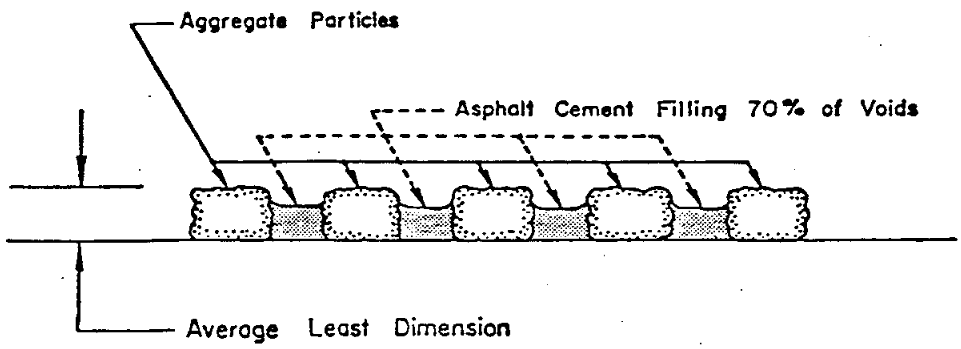
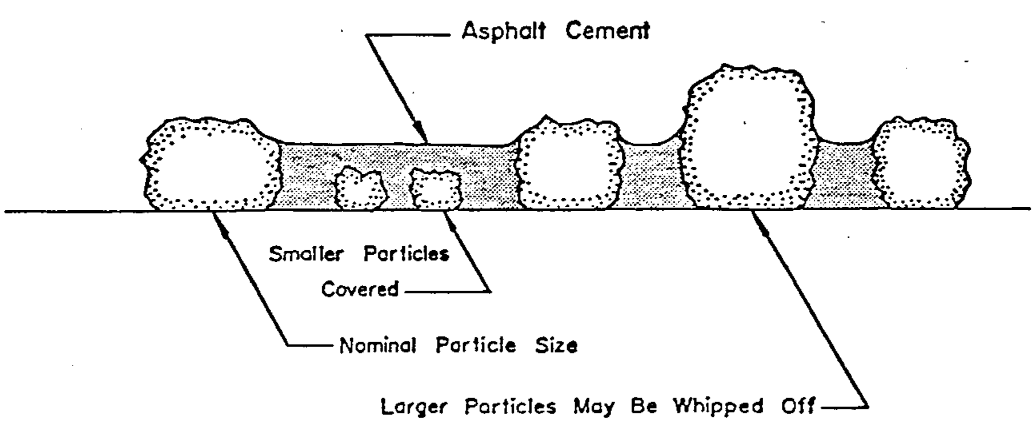


FIGURE 2

PROBLEMS ASSOCIATED WITH NON-UNIFORM AGGREGATE SIZE



Preparation of the foundation is often neglected or improperly completed. As was stated earlier,. a weak foundation will always result in rapid failure of any surface treatment.

The asphalt spread is the most critical part of the operation. Considerable care should be taken to insure uniform application of the asphalt cement. This requires that the asphalt distributor be in good condition and that the spraybar be properly adjusted. Particular attention should be paid daily to the spraybar height, nozzle size and angle. Frequent checks of the nozzles should be made to keep them clean and functioning properly. The nozzle angle should be set according to the manufacturer's specifications.

A common practice is to set the end nozzles at 90° with respect to the spraybar.

> "This practice should not be permitted as it will produce a fat streak on the edge and rob the adjacent spray fan of the lap from this nozzle. A curtain on the end of the bar or a special end nozzle with all nozzles set at the same angle will provide more uniform coverage and make a better edge." (2)

The spraybar height should be selected and maintained throughout the application to assure uniformity of spread. Streaking will occur if the spraybar is too high or too low. When the spraybar is the correct height, the transverse spread will be uniform. Figures 4 and 5 show the proper height and alignment of the spraybar. The Asphalt Institute recommends that the transverse spread should be allowed to vary no more than 15% for asphalt emulsions and no more than 10% for other asphalt cements and cutback asphalts. (2) The distributor should be inspected at regular intervals to assure this uniformity.

The longitudinal spread should vary no more than 10%. The distributor's longitudinal spread rate should be checked and all guages calibrated for each project. Do not rely on the calibration from another project. If the distributor is used, taken to another project and brought back, check it out.

It is suggested that anyone responsible for the asphalt distribution read the section on the Asphalt Distributor in MS-13 Asphalt Surface Treatments, published by the Asphalt Institute, and also any manufacturer's literature supplied with the distributor to be used on the project.

It is also recommended that building paper should be used at the beginning and end of each shot to prevent overlap and dripping at the construction joint. If two layers of surface treatment are used, the top shot of asphalt should be made in the reverse direction of the bottom shot. (3)

Because the asphalt will reach the road surface temperature in one minute or less after application, the aggregate should be spread immediately after the asphalt. The distance between the asphalt distri-

FIGURE 4

PROPER NOZZLE ANGLE SETTING

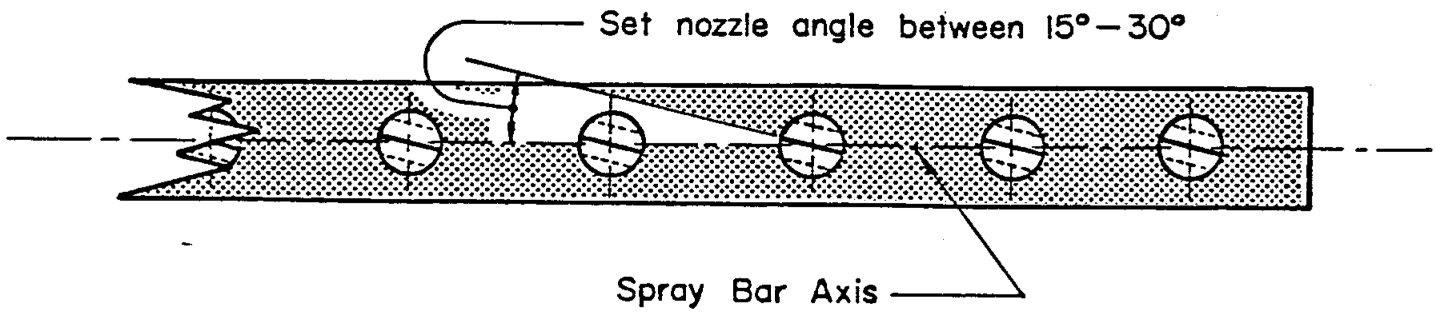
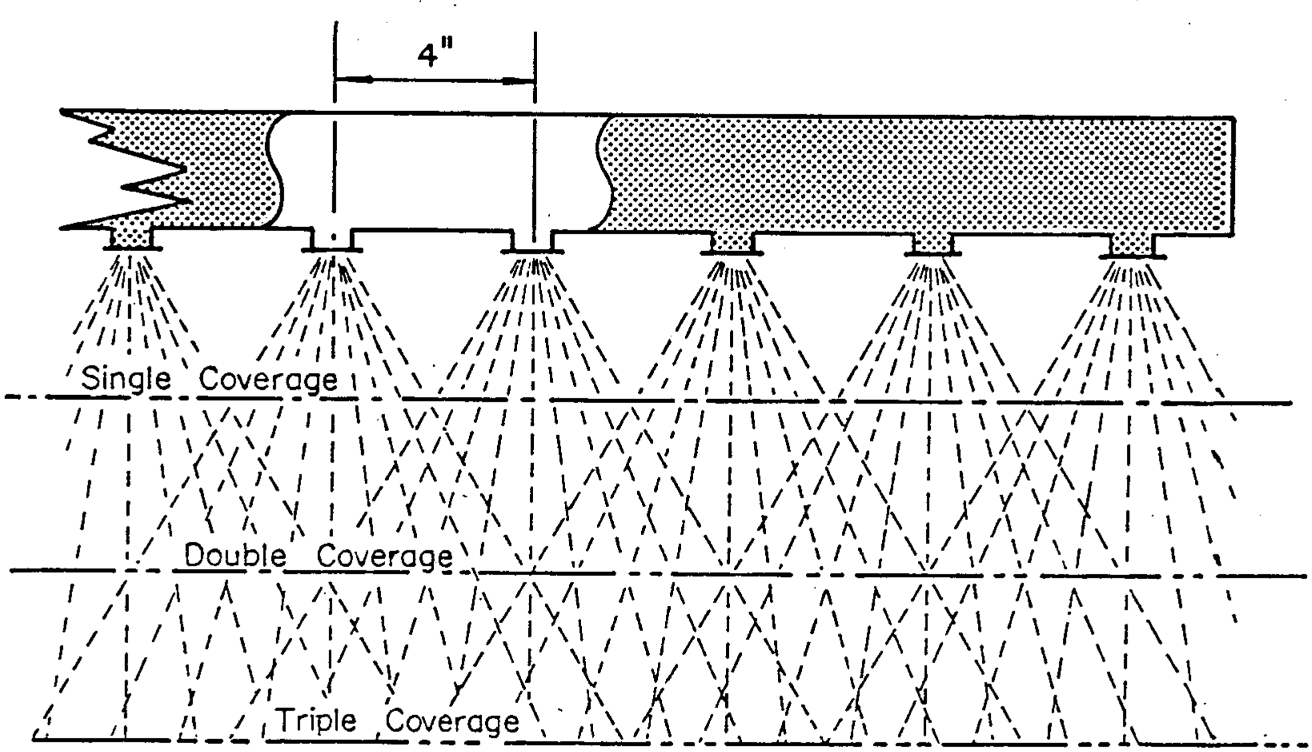


FIGURE 5

SPRAY BAR HEIGHT SETTING



Spray bar height must be set exactly for proper coverage.

butor and aggregate spreader and roller should be such that the roller makes its first full coverage within 30 seconds. A sufficient number of trucks should be on the job to assure a continuous supply of aggregate to the spreader. If, for any reason, there should be a break in the supply, the distributor should be stopped at a point where the aggregate will cover it and a construction joint made. This requires that the echelon be kept closed.

The aggregate spreader should also be inspected before the operation begins. The spreader should be able to distribute the aggregate particles uniformly over the surface and at a rate which will minimize aggregate loss. Aggregate quantities should be measured from a pan placed under the spreading operation or from pavement samples to determine compliance with specifications. (3) Truck weights should continue to be recorded in order to allow field personnel control of the operation.

The aggregate must be well-drained and dust free for good adhesion; but, in some instances damp or dusty gravel must be used. Clean, damp aggregate causes no problem when used in warm, dry weather. When used with asphalt emulsions, damp aggregate is desirable; however, a satisfactory surface treatment will seldom result when aggregate having free water is used. There is some evidence that when dusty aggregates must be used, dampening will improve the results.

Another means of solving the dust problem is precoating the aggregate. The process begins by running the aggregate through a mixing plant dryer and cooling the aggregate to 200°F. It is then mixed in the pugmill with about 1% MC-70 to coat each particle. This small amount of asphalt does not alter the free-flowing characteristics of the aggregate.

Rollers are used to seat the aggregate particles into the asphalt. Because steel-wheeled rollers bridge over the smaller particles and small depressions while crushing softer particles, these rollers should not be used on surface treatments. The resilient tires on the self-propelled smooth-tread pneumatic rollers force the particles firmly into place without crushing them. It is suggested that two rollers be used to provide proper coverage.

Traffic control is an often neglected facet of the construction of surface treatments. Its importance cannot be overstated because the lack of traffic control can easily destroy the best of jobs. Traffic speeds must be maintained at less than 25 mph until the final cover is set. Sharp turns should be avoided. Traffic control also extends to all construction equipment. Traffic control becomes even more important should it rain before the treatment has cured.

An important factor in constructing a good surface treatment is the weather. Whenever possible, surface treatments should only be started when the weather is expected to be hot and dry during and for several days after placement. Never start with a wet surface or if it looks like rain is imminent. The minimum ground temperature should be 50°F; however, 80°F is a more desirable temperature. Whenever construction must proceed in unfavorable weather, stricter construction control becomes a must.

In summary, the following construction guidelines are recommended:

1. Assure all equipment is in good working condition and properly adjusted
2. Spread aggregate immediately after the application of the asphalt
3. Start and stop on building paper to prevent overlapping and dripping
4. Use only pneumatic rollers
5. Control traffic including construction vehicles until the final coat has set-up
6. Never start on a wet surface or if rain is likely
7. The minimum ground temperature should be 50°F
8. Familiarize each person on the job with exactly what a good treatment looks like as well as the causes and cures of problems which might occur

TABLE 1

ASPHALT, PERCENT BY WEIGHT AND BY VOLUME,

FOR VARIOUS SURFACE USES

PRINCIPAL USES OF SURFACE TREATMENT	ASPHALT % BY WEIGHT	ASPHALT % BY VOLUME
Parking Areas and Seldom Used Areas	9.4	22
Small Volumes of Traffic	8.2	20
Medium Volumes of Traffic	7.6	19
Large Volumes of Traffic	7.0	18
Very Heavy Traffic	6.5	17

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