EVALUATION OF QUESTIONNAIRE FOR 1981-1983 PROJECTS ON ASPHALT AGING IN HOT MIX PLANTS

by

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ABSTRACT

As a measure of the aging of asphalt concrete mixes in the mixing and placement process, a formula was developed to determine the percentage of expected change in asphalt viscosity at the time of paving (Lund and Wilson, 1984). A value of 30 or higher was used in 1983-84 for acceptance on paving projects. At the conclusion of this study, a follow-up survey was made of all projects. Two major areas of interest were covered in the follow-up questionnaire: 1) the characteristics of the asphalt mix and pavement at the time of placement, and 2) the characteristics of the pavement at the time of receiving the questionnaire (March, 1984).

The responses to the questionnaire, even though they are subjective, appear to identify and confirm relationships between the "C" value and asphalt mix problems. The strongest correlation appears to be more with problems at the time of construction than with long term pavement performance problems. Using statistical tests, the significant problems that were identified during construction were tenderness, shoving and rutting, segregation and the mix being too cold. The long term significant problems developing after construction were stripping and cracking.

When the individual characteristics were evaluated, the great majority had the significance level peak at the less than 40 "C" value. This is, a greater percentage of the samples that are below 40 have some problems in the field.

In early 1985, the Oregon Highway Department raised the minimum acceptable "C" value to 40. Mix with a value less than 40 is to be removed, or at the discretion of the Engineer, it may be left in place and a reduction in a Composite Pay Factor calculated (OSHD Spec. 403.39).

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INTRODUCTION

Background

Asphalt concrete pavement tenderness, due to inadequate aging or unexpected soft consistency of the asphalt, has caused problems such as rutting, surface flushing, stripping, ravelling and segregation in Oregon highways over the past ten years. In order to identify the causes of the pavement tenderness, data were gathered from various construction projects throughout the state. As a measure of the aging in the mixing and placement process the following formula was developed to determine the percentage of the expected change in asphalt viscosity at the time of paving (Lund and Wilson, 1984):

$$C = \frac{R - A}{B - A} \times 100 \%$$

where, A = absolute viscosity of the original asphalt, B = absolute viscosity of the asphalt residue after rolling thin film oven aging, and R = absolute viscosity of the asphalt recovered from the mixture. Based on field observations of paving projects prior to the 1984 report, no paving problems (tenderness) were experienced when "C" values were above 50 precent, some problems were experienced when "C" values were from 30 to 50 percent, and pavement problems were always experienced when "C" values were less than 30 percent. A value of 30 or higher was then used in 1983-84 for acceptance on paving projects (OSHD Specification (403.39).

Starting in 1981 and continuing through the summer of 1983, data were collected from 29 different projects in Oregon. A total of 111 samples were collected for "C" value from these projects. For each project, the contractor, mixing plant type, dust collection system, asphalt concrete mix class, asphalt cement supplier and grade, and burner fuel type were recorded. These variables were correlated against the "C" value of the various paving mix samples.

Results from the study indicated that the selection of burner fuel type is critical in producing a satisfactory mix. Some lower grade fuels (reclaimed oils), due to poor combustion, cause contamination of the mix by softening the asphalt. Low temperature in the mixing or aggregate drying process, especially in drum mixer plant burners, is detrimental to the mix. This produces poor combustion of burner fuel and less aging. The overall operation and construction of asphalt plants, burner fuel type, mixing temperature and the use of bag house dust collectors, has a significant influence on the tenderness of the produced mix (Lund and Wilson, 1984).

Purpose of This Study

At the conclusion of the 1983-84 study and report, a follow-up survey was made on all of the projects covered in this study. A questionnaire was developed for this purpose, a copy of which is included in the Appendix. This questionnaire was sent to Highway Division project managers for completion. The information requested covered two major areas of interest: 1) the characteristics of the asphalt mix and pavement at the time of placement, and 2) the characteristics of the pavement at the time of receiving the questionnaire (March 1984).

A total of 80 questionnaires were mailed out and 73 were returned. The completed questionnaires covered 133 individual samples for which "C" values had been calculated, and were from 34 different projects. The number of samples per project varied from one to eleven, with the majority of projects having only one or two samples. For projects with multiple samples, the "C" values were averaged for use in the calculations. Some of the questionnaires were only partially complete due to lack of information; thus in subsequent calculations for this report less than 73 questionnaires are used.

DATA ANALYSIS

Referring to the sample questionnaire in the Appendix, the data were analyzed in four different catagories as follows: 1) whether or not there were problems during construction (item I), 2) whether there were problems after construction (item II), 3) an overall rating (good, fair or poor), and 4) a detailed analysis of individual items under the first two categories (I and II). These reponses were subjective, since no specific guidlines were given for completion of the questionnaire.

Problems During Construction

The average "C" value and standard deviation for each of the responses under item I were determined. The "yes" and "no" value results were then compared for significance using the Student-t test. The results of these analysis is shown in Figure 1 with the data tabulated in the Appendix. The significance level is shown opposite each bar graph, indicating the level at which the "yes" and "no" data differ. The higher the percentage of the significance level, the greater the difference. Thus, tenderness,

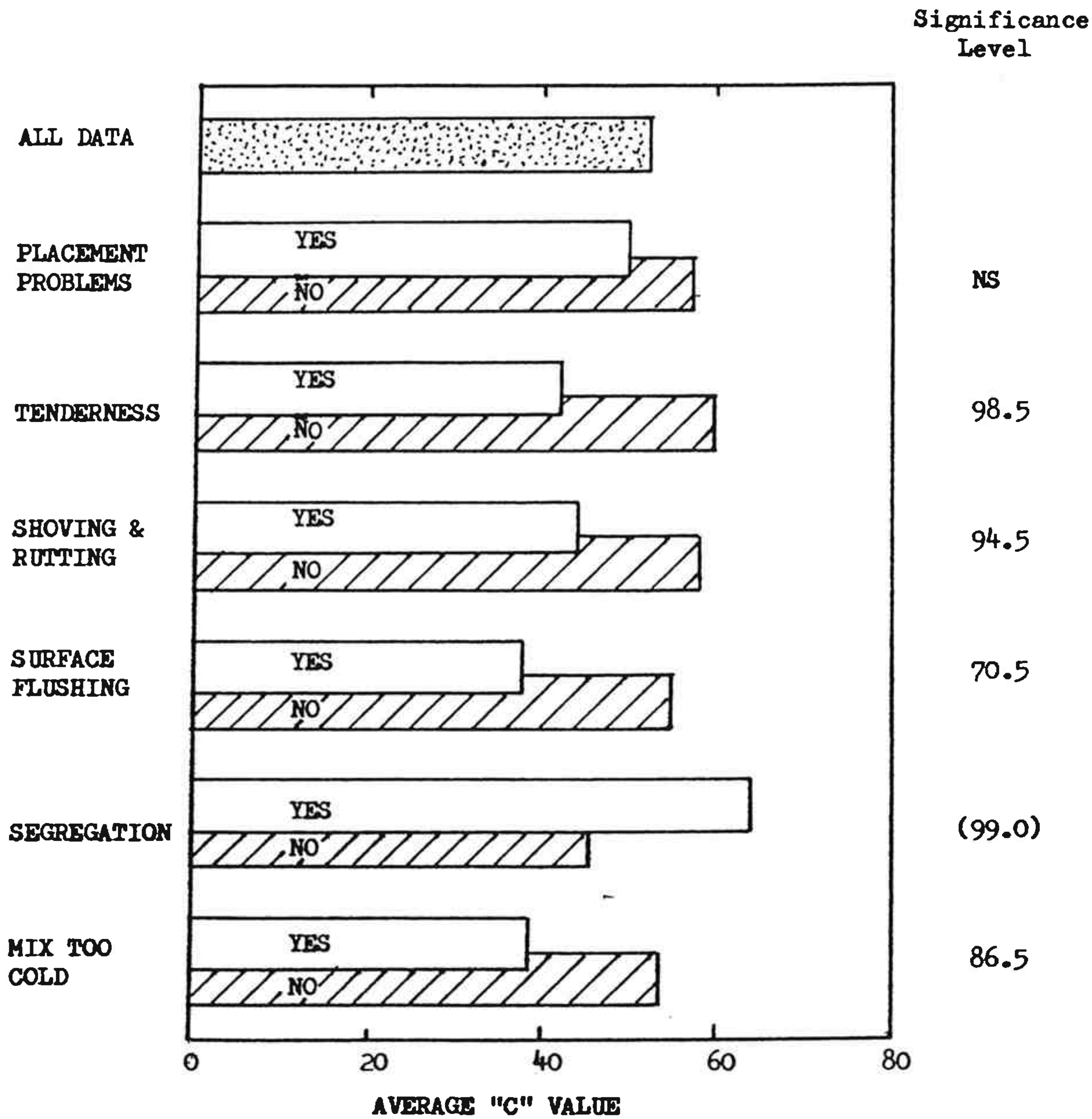

FIGURE 1. Problems during construction.

NS = not significant

shoving and rutting, and segregation appear to be strongly influenced by the "C" value of the mix. Note that the segregation results are opposite of the other two; that is, those project with segregation problems had higher average "C" values than those with no segregation problems.

Stripping (item E), ravelling (item F) and mix too hot (item H) are not shown due to lack of a significant number of "yes" responses. The average "C" value for all of the responses under item I is shown at the top of Figure 1.

The data from item I was also grouped according to the range of the "C" values. Based on the initial work, "C" values between 30 and 50 appeared to be in a critical transition range. For this reason, the percentage of "C" values <30, <40 and <50 were investigated. These grouping are shown graphically in Figure 2 and the detailed data listed in the Appendix. As can be seen the differences between the "yes" and "no" responses are somewhat significant for values less than 30 and 40. As was expected, those projects that had a problem during construction (items A through H) also had the higher percentage of "C" values below the indicated limits of 30, 40 or 50. The Chi-squared test was used for this analysis.

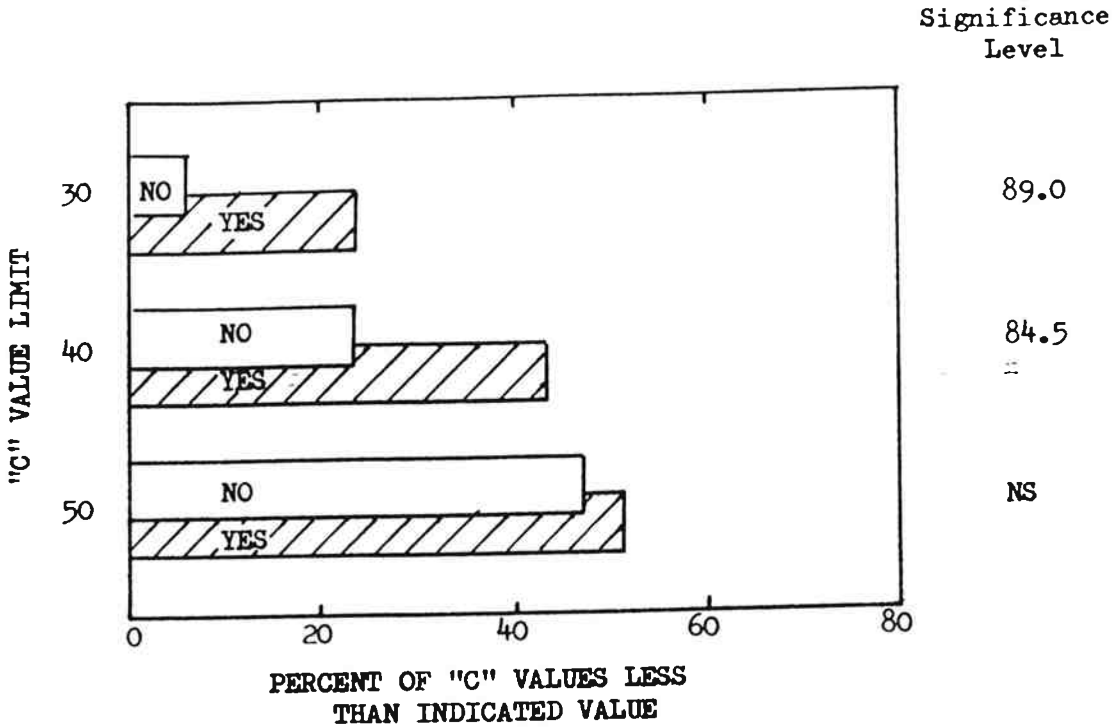

FIGURE 2. Any problems during construction.

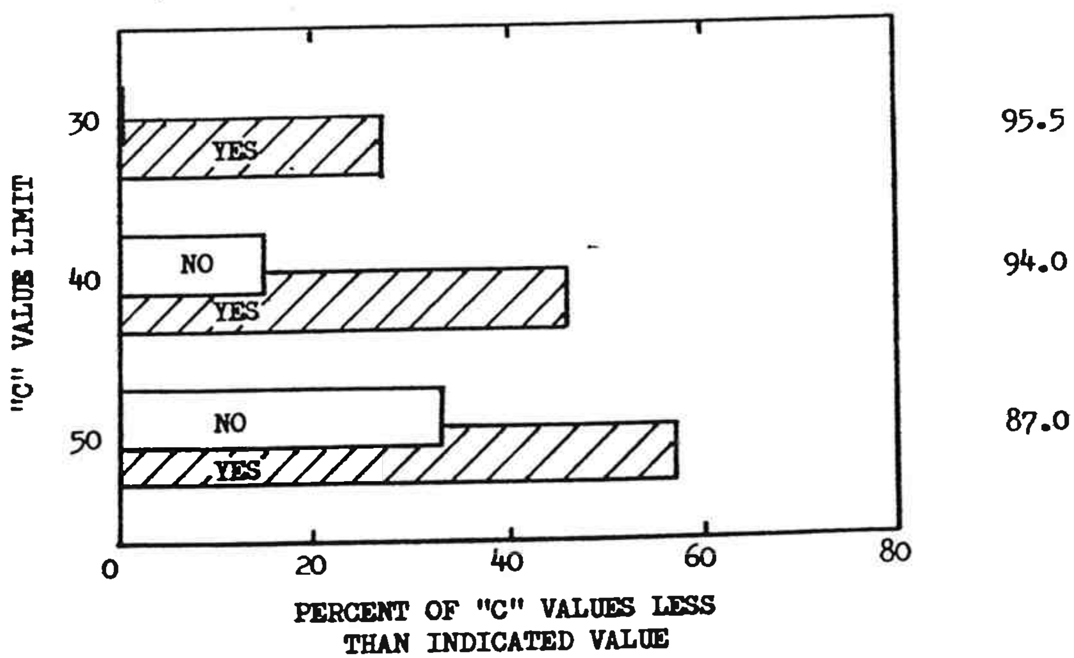

FIGURE 4. Any problems after construction.

NS = not significant

Problems After Construction

The average "C" value and standard deviation for each of the responses under item II were also determined. The "yes" and "no" value results were then compared for significance using the Student-t test. The results of these analysis is shown in Figure 3 with the data tabulated in the Appendix. As can be seen from the figure, the only statistically important items are stripping and cracking, both being highly significant.

The data were also grouped according to "C" value ranges of 30, 40 and 50. These results are shown in Figure 4. The differences at the <30 and <40 levels are highly significant, whereas the difference at the <50 level is only slightly significant. This follows the same general trend as the results shown in Figure 2 for problems during construction.

Overall Rating

The questionnaire had three items where the project manager could rate the overall project performance as to the paving operation, mixing operation and the pavement performance with time. Categories of "good", "fair" and "poor" could be checked Since very few of the "poor" category

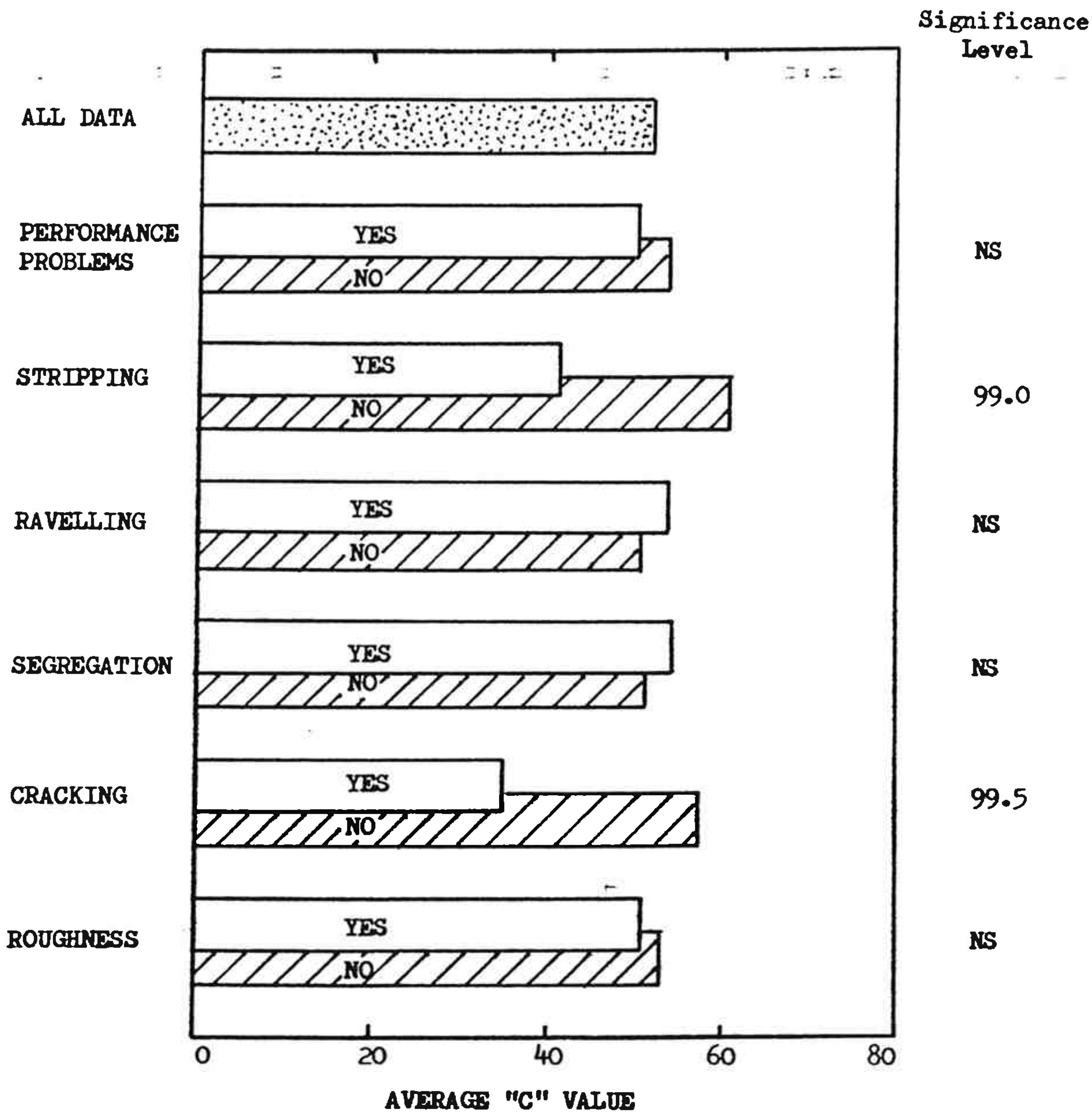

FIGURE 3. Problems after construction.

NS = not significant

were checked, they were grouped with the "fair" values in the analysis. The three performance items were then compared for average "C" value, which is shown graphically in Figure 5. Only the paving operation appear to show a significant difference between the "good" and "fair + poor" groupings, and only weakly significant at that.

The paving operation results were then looked at in more detail. The data were grouped in the <30, <40 and <50 categories. As can be seen in Figure 6, the difference between the two groupings is highly significant for the <30 and <40 categories. The significance peaks at the <40 level.

<u>Individual Characteristics</u>

Individual characteristics under items I and II were then analyzed using the <30, <40 and <50 groupings and tested for significance with the Chi-squared distribution. Figures 7 through 11 illustrate the results for characteristics during construction. All of these items have a large difference between the "yes" and "no" responses, peaking in significance in all but one case at the <40 value. Again, it should be noted that the segregation problem has results opposite of the others.

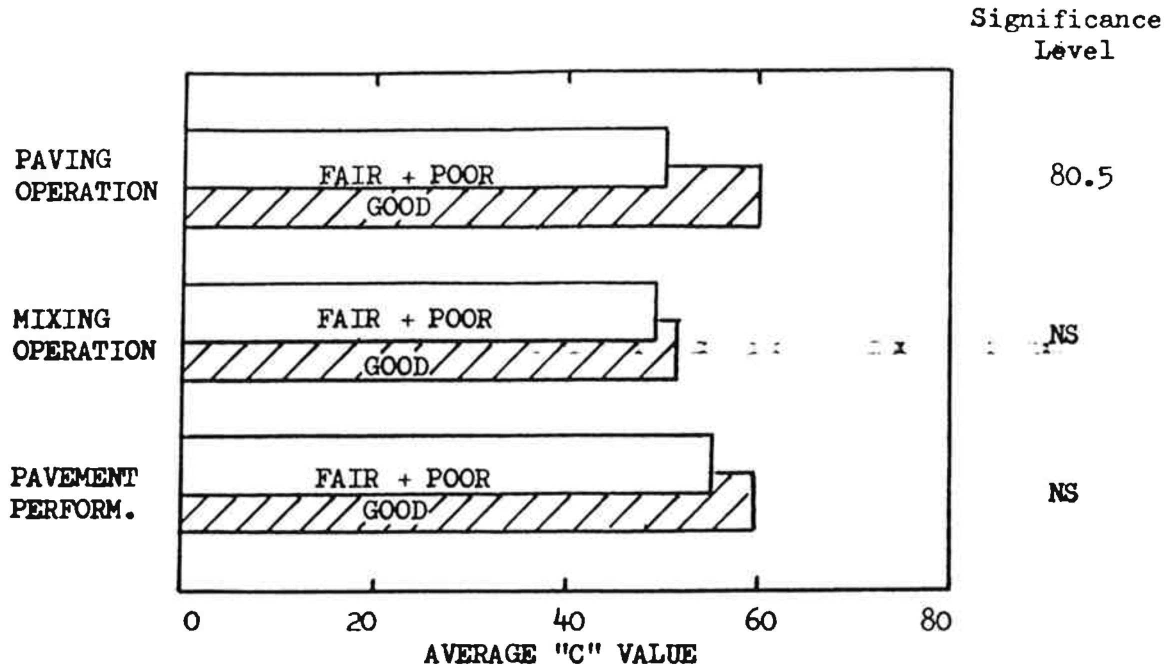

FIGURE 5. Overall rating.

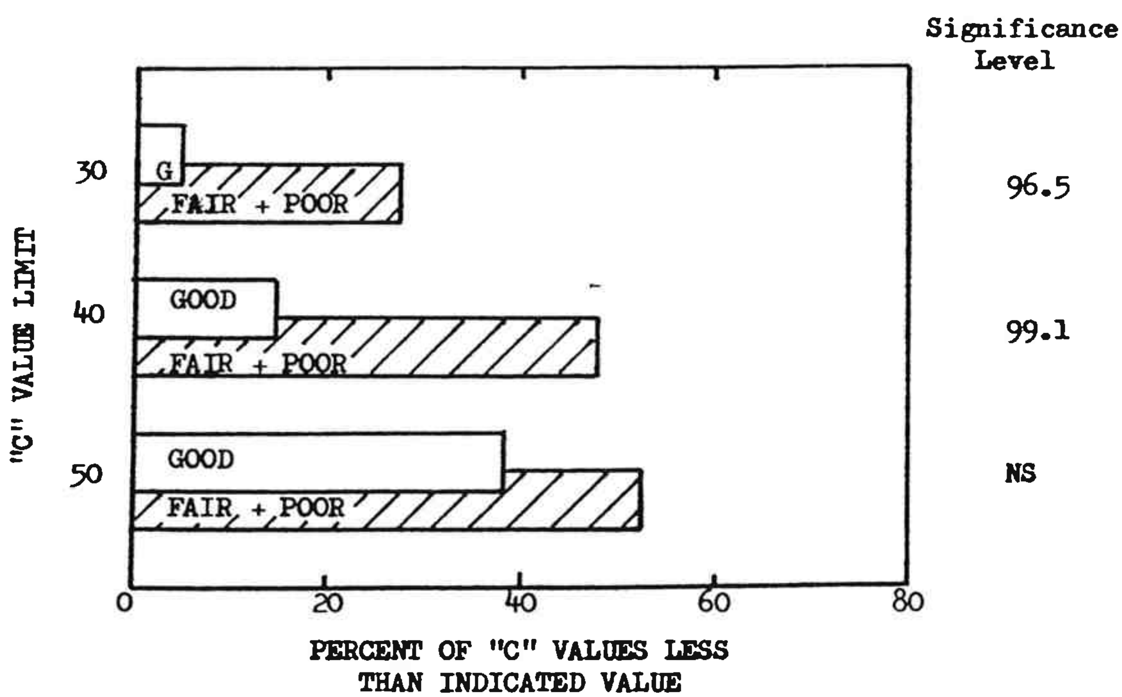

FIGURE 6. Paving operation.

NS = not significant

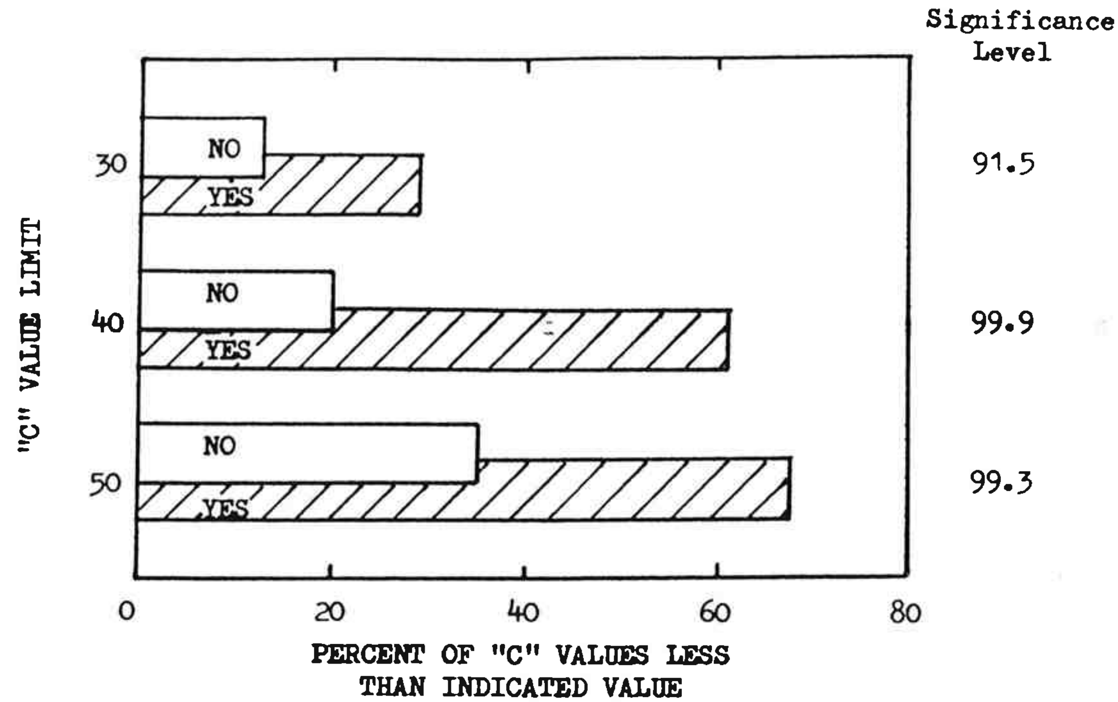

FIGURE 7. Tenderness at time of paving.

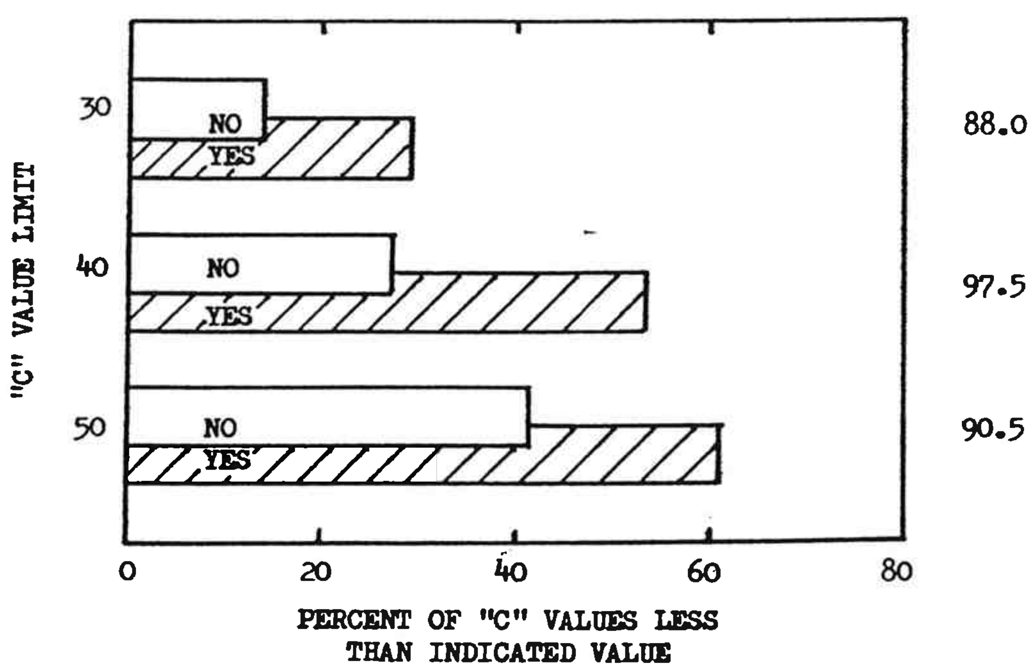

FIGURE 8. Shoving and rutting at time of paving.

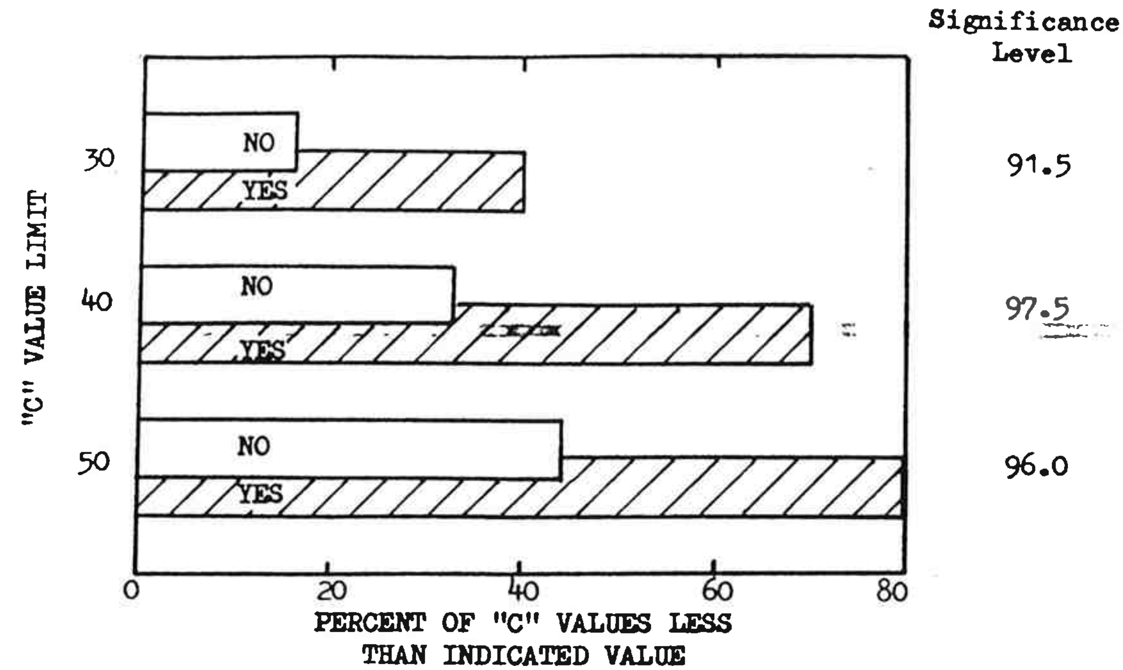

FIGURE 9. Surface flushing at time of paving.

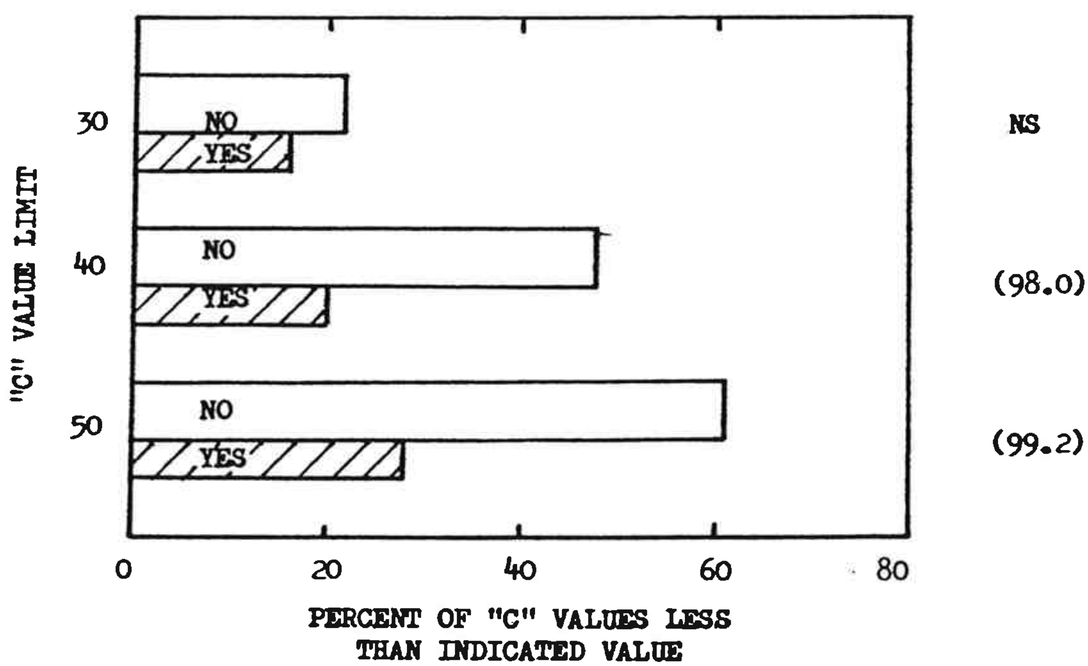

FIGURE 10. Segregation at time of paving.

NS = not significant

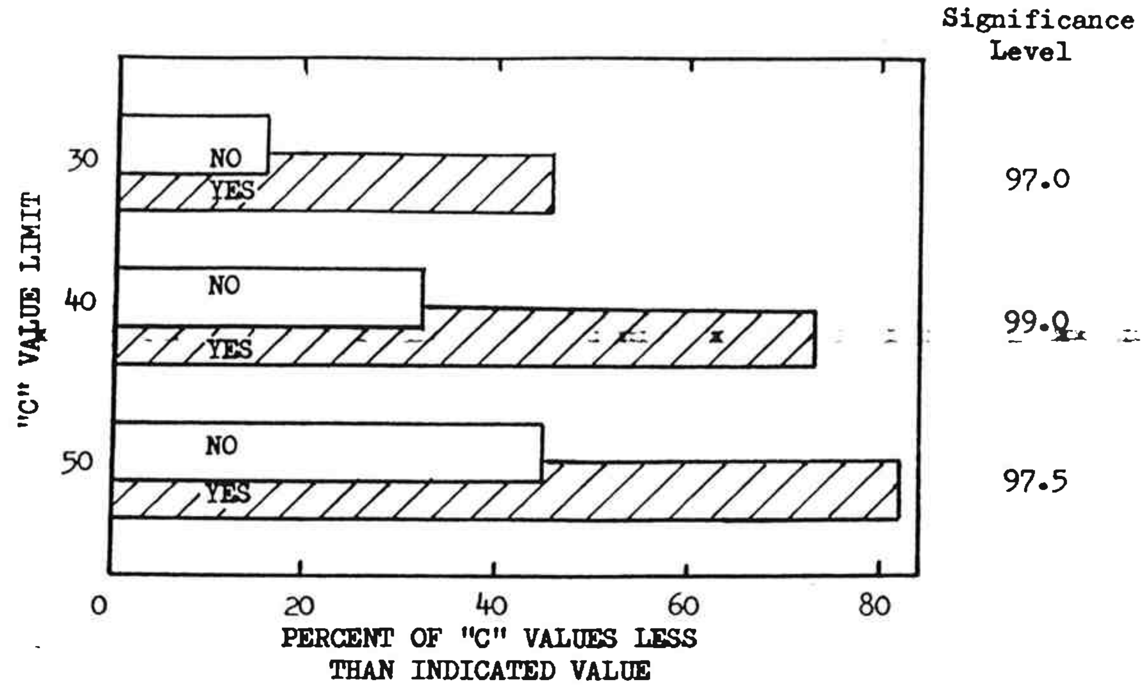

FIGURE 11. Mix too cold at time of paving.

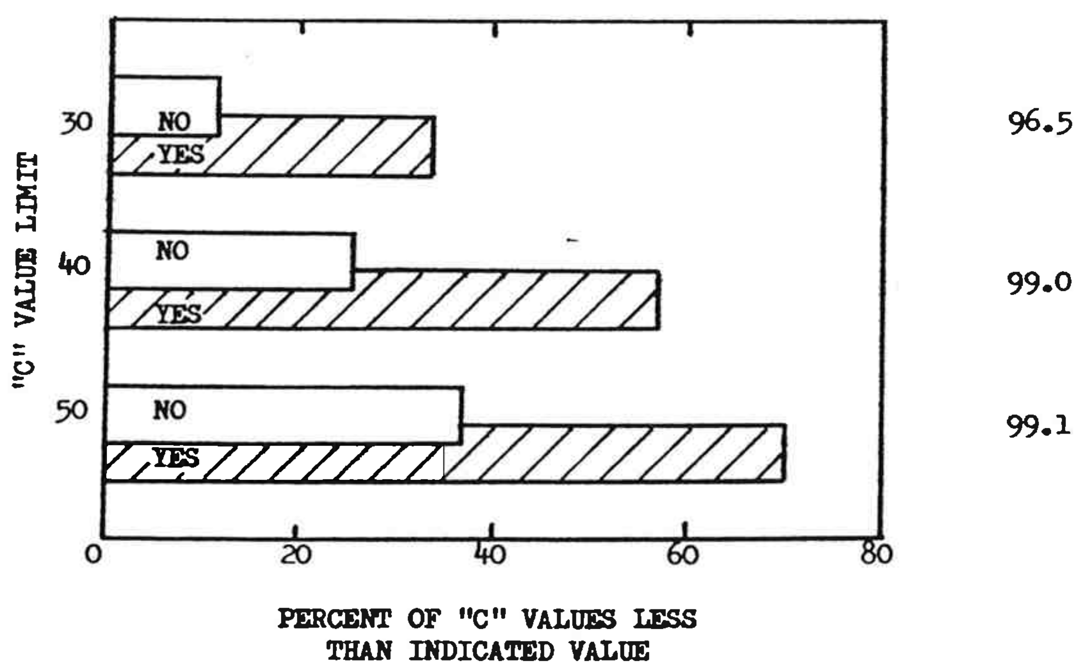

FIGURE 12. Stripping after construction.

Figures 12 through 14 illustrate characteristics after construction. Again almost all of the comparisons are highly signficant, peaking at the <40 level. Note that the ravelling problem has results opposite of the others, that is, the "no" responses have a higher percentage of "C" values less than the indicated level.

DISCUSSION AND CONCLUSIONS

Discussion

The responses to the questionnaire, even though they are subjective, appear to identify and confirm relationships between the "C" value and asphalt mix problems. The strongest correlation appears to be more with problems at the time of construction than with long term pavement performance problems. However, there are significant long term problems that were identified.

In the analysis of the data, the Student-t test was used to compare data where mean and standard deviation of "C" values were available. When comparing the number of items that either do or do not fall into a certain category, as in the case of the <30, <40 or <50 "C" values, a 2 x 2 contingency table tested against the Chi-squared distribution was used. It is important to note that the statistical tests do not indicate why there is a difference between two

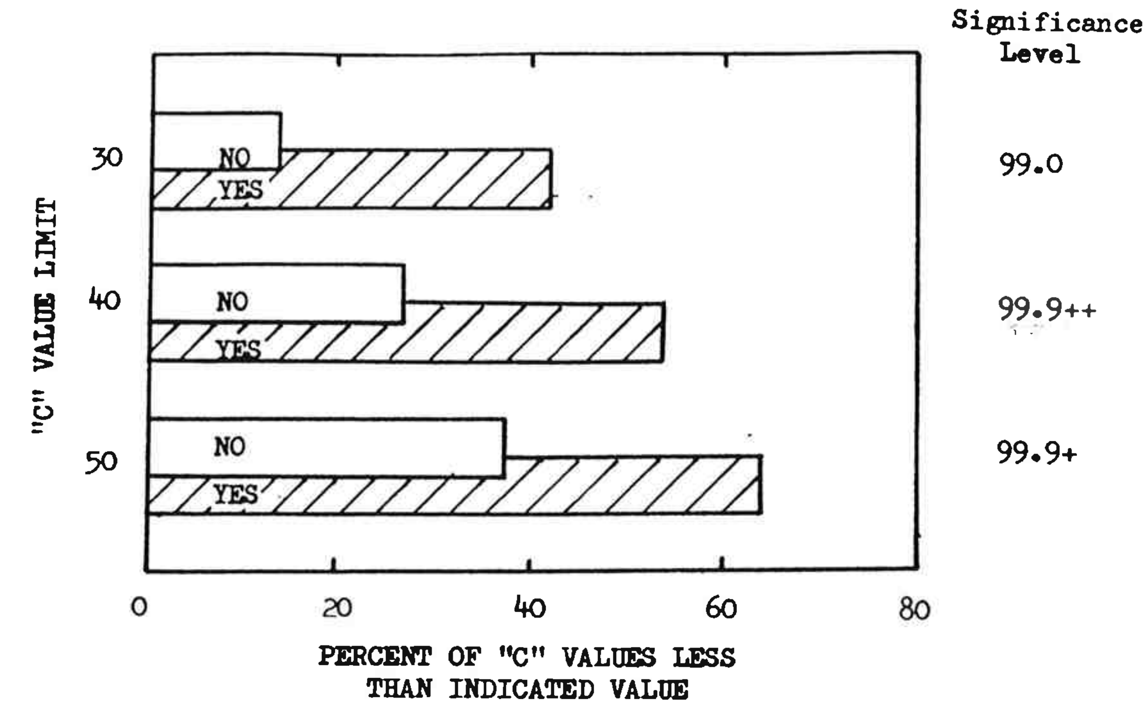

FIGURE 13. Cracking after construction.

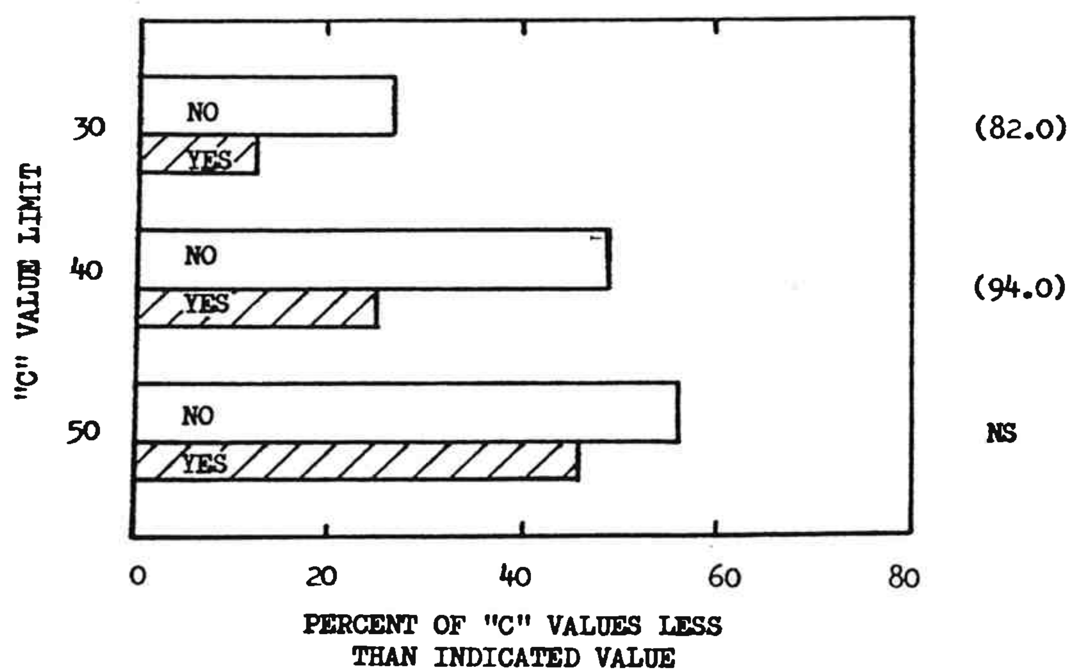

FIGURE 14. Ravelling after construction.

NS = not significant

comparisons, only that there is a difference and the significance level. Generally a significance level above 90 or 95 percent is considered adequate for most engineering comparisons.

The significant problems of tenderness, shoving and rutting and mix too cold (see Figure 1) support the conclusions of the previous study (Lund and Wilson, 1984). The results of the segration problem are more difficult to understand. This can best be explained in that the stiffer (less tender) and viscous mixes are more difficult to blend. The stripping and cracking problems identified by the after construction data (see Figure 3) are related to the tenderness problem. Tenderness tends to prevent adequate compaction, thus producing less dense pavements. Less dense pavements have a greater tendency to strip and crack.

When evaluating the individual characteristics at the <30, <40 and <50 "C" value level, the great majority have the significant level peak at the <40 value. That is, a greater percentage of the samples that are below 40 have some problem in the field as compared to those samples which have "C" values above 40.

Conclusions

The use of the "C" value to predict tenderness and related problems in asphaltic mixes and pavements appears to be reasonable. This field study as a follow-up to the original 1981-83 evaluation does verify the conclusions of that report. The 30 to 50 "C" value range still appears to be a critical area. The value of 30 was original established as the minimum acceptable, however it appears from this study that the value should be raised to 40, as this level has a higher significance with pavement problems.

Since 1983, at least two state highway departments, Nevada and Montana, have adopted the use of the "C" value. Both use the minimum acceptable value of 30. In discussion with materials personnel at these two highway departments, Nevada felt that the 30 value was too lenient and should be raised (Pradere, 1985). The Montana Highway Department has since dropped the use of the "C" value specification due to a problem with one contractor. They now specify the type of burner fuel that can be used instead (Wagner, 1985).

In early 1985, the Oregon Highway Department raised the minimum acceptable "C" value to 40. Mix with a value less than 40 is to be removed, or at the discretion of the Engineer it may be left in place and a reduction in a

Composite Pay Factor calculated (OSHD Specification 403.39). This specification is reproduced in the Appendix.

ACKNOWLEDGMENTS

The data were provided by the Oregon State Highway Division. In particular, the assistance of the project managers is greatly appreciated.

DISCLAIMER

The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those held by Oregon Department of Transportation or Oregon Institute of Technology.

REFERENCES

1. Lund, John W. and James E. Wilson, 1984. Evaluation of Asphalt Aging in Hot Mix Plants, Proceeding of the Association of Asphalt Paving Technologists, Vol. 53, pp. 1-18, Scottsdale, AZ.

2. Pradere, Peter, Materials Engineer, Nevada Department of Highways, Carson City, June, 1985 (personal conversation).

3 Wagner, Richard, Materials Engineer, Montana Department of Highways, Helena, June, 1985 (personal conversation).

ASPHALT AGING PROJECT ("C" VALUE - BURNER FUEL STUDY)

Project # ______________ Project name ______________________________

Project manager __________________ Paving Contractor ____________________

Sample # ______________ Date taken ________________

I. Characteristics of asphalt mix and pavment at time of placement (approximately where sample was taken):

	yes	no	unknown
A. tenderness (soft consistency)	☐	☐	☐
B. shoving and rutting during rolling	☐	☐	☐
C. Surface flushing	☐	☐	☐
D. segregation	☐	☐	☐
E. stripping	☐	☐	☐
F. ravelling	☐	☐	☐
G. mix too cold	☐	☐	☐
H. mix too hot	☐	☐	☐

Any other mixing or placement difficulties: ____________________________

____

____

	good	fair	poor
How would you rate the overall paving operation:	☐	☐	☐
How would you rate the overall mixing operation:	☐	☐	☐

II. Characteristics of the pavement today (enter date: ______________) (approximately where sample was taken):

	yes	no	unknown
A. rutting and shoving	☐	☐	☐
B. surface flushing	☐	☐	☐
C. stripping	☐	☐	☐
D. ravelling	☐	☐	☐
E. segregation	☐	☐	☐
F. cracking	☐	☐	☐
G. roughness	☐	☐	☐

Any other pavement problems: ______________________________

____

____

How would you rate the overall pavment performance to date: good ☐ fair ☐ poor ☐

Please write any other comments below:

Please return this form to: James Wilson, Materials Section, Salem.

APPENDIX 1

STATISTICAL DATA

Item	N	Ave.	S.D.	%<30	%<40	%<50
All Data I	71	52.5	30.4	19.7	38.0	49.3
All Data II	65	52.0	31.6	20.0	38.5	50.8
Placement Prob.						
Yes	51	50.3	32.5	23.5	43.1	51.0
No	17	57.4	22.4	5.9	23.5	47.1
Perform. Prob.						
Yes	52	50.6	33.2	26.9	46.2	57.7
No	12	53.6	19.8	0.0	16.7	33.3
Paving Ops.						
Good	21	60.1	23.1	4.8	14.3	38.1
Fair + Poor	44	50.2	30.9	27.3	47.7	52.3
Mixing Ops.						
Good	52	51.1	27.8	17.3	40.4	51.9
Fair + Poor	16	49.5	36.4	31.2	37.5	50.0
Pavement Perform.						
Good	17	59.0	26.6	11.8	23.5	35.3
Fair + Poor	40	55.0	33.2	15.0	30.0	42.5
Tenderness (IA)						
Yes	31	42.6	34.0	29.0	61.3	67.7
No	40	60.1	25.2	12.5	20.0	35.0
Shoving & Rutting (IB)						
Yes	28	44.2	35.9	28.6	53.6	60.7
No	44	58.1	25.1	13.6	27.3	40.9
Surface Flushing (IC)						
Yes	10	38.1	49.4	40.0	70.0	80.0
No	61	54.8	26.0	16.4	32.8	44.3
Segregation (ID)						
Yes	25	64.5	34.1	16.0	20.0	28.0
No	46	45.9	26.4	21.7	47.8	60.9
Mix Too Cold (IG)						
Yes	11	39.2	27.5	45.4	72.7	81.8
No	56	54.1	30.7	16.1	32.1	44.6
Stripping (IIC)						
Yes	30	41.6	29.5	33.3	56.7	70.0
No	35	60.9	31.1	11.4	25.7	37.1

Item	N	Ave.	S.D.	%<30	%<40	%<50
Ravelling (IID)						
Yes	24	54.0	34.1	12.5	25.0	45.8
No	41	50.9	30.5	26.8	48.8	56.1
Segregation (IIE)						
Yes	16	54.6	39.9	25.0	43.8	50.0
No	49	51.1	28.9	20.4	38.8	51.0
Cracking (IIF)						
Yes	19	35.6	29.4	42.1	73.7	84.2
No	45	57.7	29.7	13.3	26.7	37.8
Roughness (IIG)						
Yes	17	50.8	30.3	17.6	35.3	58.8
No	48	52.5	32.4	22.9	41.7	50.0

NOTE: Stripping (IE), Ravelling (IF), Mix Too Hot (IH), Rutting and Shoving (IIA), and Surface Flushing (IIB) did not have sufficient "yes" responses to be significant.

APPENDIX II

STATISTICAL CALCULATIONS

Item	Student-t Value "C" Value	Chi-squared Value C<30	C<40	C<50
During Construction (I)				
Any Problem	0.84	2.57	2.08	0.08
Tenderness	2.49	3.02	12.63	7.49
Shoving & Rutting	1.93	2.44	5.05	2.79
Surface Flushing	1.04	3.02	5.05	4.39
Segregation	(2.55)	(0.34)	(5.32)	(7.00)
Stripping	-	-	-	-
Ravelling	-	-	-	-
Mix Too Cold	1.49	4.80	6.38	5.08
Mix Too Hot	-	-	-	-
After Construction (II)				
Any Problem	0.30	4.14	3.51	2.32
Rutting & Shoving	-	-	-	-
Surface Flushing	-	-	-	-
Stripping	2.55	4.58	6.45	6.99
Ravelling	(0.37)	(1.84)	(3.57)	(0.64)
Segregation	(0.38)	0.15	0.12	0.00
Cracking	2.73	6.47	12.24	11.53
Roughness	0.19	0.21	0.21	0.39
Overall Ratings				
Paving Operation	1.30	4.50	6.83	1.14
Mixing Operation	0.19	1.45	0.04	0.02
Pavement Perform.	0.44	0.01	0.10	0.26

<u>NOTE</u>: the following symbols have been used:
- indicates insufficient data
a number in parenteses indicates a reverse relation

APPENDIX III

STATISTICAL SIGNIFICANCE

Item	Percent Significance "C" value	C<30	C<40	C<50
During Construction (I)				
Any Problem	NS	89.0	84.5	NS
Tenderness	98.5	91.5	99.9+	99.3
Shoving & Rutting	94.5	88.0	97.5	90.5
Surface Flushing	70.5	91.5	97.5	96.0
Segregation	(99.0)	NS	(98.0)	(99.2)
Stripping	-	-	-	-
Ravelling	-	-	-	-
Mix Too Cold	86.5	97.0	99.0	97.5
Mix Too Hot	-	-	-	-
After Construction (II)				
Any Problem	NS	95.5	94.0	87.0
Rutting & Shoving	-	-	-	-
Surface Flushing	-	-	-	-
Stripping	99.0	96.5	99.0	99.1
Ravelling	NS	(82.0)	(94.0)	NS
Segregation	NS	NS	NS	NS
Cracking	99.5	99.0	99.9++	99.9+
Roughness	NS	NS	NS	NS
Overall Rating				
Paving Operation	80.5	96.5	99.1	71.0
Mixing Operation	NS	77.0	NS	NS
Pavement Perform.	NS	NS	NS	NS

NOTE: the following symbols have been used:
- \- indicates insufficient data
- a number in parenteses indicates a reverse relation
- NS indicates the difference is not significant

Student-t Distribution Values

1-alpha:	99.9	99.0	98.0	95.0	90.0	80.0	70.0
t @ >30 df:	3.291	2.575	2.327	1.960	1.645	1.282	1.036

Chi-squared Distribution Values

1-alpha:	99.9	99.5	99.0	98.0	97.5	95.0	90.0	80.0	70.0
Chi @ 1 df:	10.827	7.879	6.635	5.412	5.024	3.841	2.706	1.642	1.074

403.39 Drying, Heating and Separating Aggregates into Designated Sizes:

(a) Drying - Aggregates shall be dried to the extent that any remaining contained moisture does not result in visible defects in the mixture such as slumping loads, boils or slicks.

Slumping loads shall not be incorporated into the pavement, but shall be disposed of by the Contractor at his expense and in a manner satisfactory to the Engineer.

Boils and slicks occurring in the pavement shall be immediately removed and replaced with suitable materials, all at the Contractor's expense.

The moisture content of the mix shall not exceed 0.7% at time of discharge from the mixing plant.

(b) Burner fuel - The Contractor shall use the same burner fuel for heating the aggregates throughout production of the asphalt mixture unless otherwise approved by the Engineer. To document the burner fuel actually utilized for heating the aggregates, the Contractor shall furnish the Engineer daily copies of invoices describing the burner fuel received for heating purposes.

(c) Aging asphalt - The burner used for heating the aggregates shall achieve complete combustion of the fuel and shall heat the aggregate sufficiently to achieve acceptable aging of the asphalt. Burner fuel combustion will be considered complete and acceptable aging of the asphalt attained, when "C" (percent of change in asphalt viscosity) in the following formula is equal to or greater than 40.0.

$$C = \frac{R-A}{B-A} \times 100 \text{ where;}$$

A = Absolute viscosity (OSHD TM 417) of original asphalt used in production of the mixture.
B = Absolute viscosity (OSHD TM 417) of rolling thin film oven residue (AASHTO T 240) for asphalt used in production of the mixture.
R = Absolute viscosity (OSHD TM 417) of asphalt removed from the mixture (OSHD Modified AASHTO T 170).

(d) Testing for asphalt aging - Testing to determine "C" will be made on a randomly selected sublot sample (subsection 403.16(b-2)) obtained from the first 500 tons of asphalt concrete production, from the next 2,000 tons of production, and from each 7,500 tons of production, thereafter.

Whenever "C" is less than 45 and represents 7,500 tons of production, two additional random sublot samples will be obtained and tested. Each of the three random samples will represent 2,500 tons of production.

For each failing "C" value (less than 40.0) representing 2,000 or 2,500 tons of production, a sample from each sublot (subsection 403.16(b-2)) of that 2,000 or 2,500 tons will be tested. Each of the random samples (failing and 3 or 4 additional) will represent 500 tons of production or portion thereof.

(e) Nonacceptable asphalt aging - Whenever "C" is less than 40.0, the Contractor shall make appropriate plant adjustments to comply with this requirement. Any mixture represented by such tests which has been placed will be rejected and shall be removed and disposed of by the Contractor at his expense and in a manner acceptable to the Engineer. However, if acceptable to the Engineer, the material may be left in place at the following reduction, in the COMPOSITE PAY FACTOR (CPF) calculated in accordance with subsections 403.16 and 106.19.

"C" Value		
Below	At or Above	Price Reduction
40.0	35.0	1%
35.0	30.0	3%
30.0	25.0	7%
25.0	20.0	14%
20.0	15.0	25%

For the first 2,500 tons of production, if the "C" value is less than 40.0 but greater than or equal to 25.0, removal of the pavement will not be required per this subsection nor will there be a reduction made in the CPF.

(f) Heating temperatures - For screen-type plants the temperature of the aggregates at discharge from the drier shall not exceed 325°F except when used for heat transfer in recycled mixtures. For drum mix plants the temperature of the mix at discharge from the mixer shall not exceed 325°F.

(g) Screening - Immediately after drying and heating, in plants which have plant screens, the aggregates shall be separated by screening into the designated sizes required for separate handling and proportioning at the mixing plant and each designated size of aggregate shall be separately handled or stored thereat for proper proportioning in the mix. The designated sizes of aggregates required for the mix shall be those specifically set forth for the kind of pavement and class of mix involved as set forth in the special provisions or called for by the plans and pertinent requirements given in subsection 403.17. The grading of each separated designated size of aggregate in the bins at the mixing plant shall be maintained uniform and within a tolerance of 20% oversize and 20% undersize.