# RECENT EVALUATION
# OF
# ASPHALT AGING IN HOT MIX PLANTS
# 1983-1985 "C" VALUE DATA

by

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## ABSTRACT

Starting in 1981 and continuing through July of 1983, "C" value data were collected from 29 different projects in Oregon. Results from the study indicated that the overall operation and construction of asphalt plants, burner fuel type, mixing temperature and the use of bag house dust collectors had a significant influence on the tenderness of the produced mix. The results were published in a 1984 report (Lund and Wilson, 1984).

In 1985, "C" values were again analyzed to see if any changes had occurred since the 1981-1983 study. Forty-nine projects constructed or under construction from August 1983 to July 1985 were reviewed, from which 193 individual "C" values were obtained. Comparing the results with the 1981-1983 data, indicated that individual variables such as burner fuel type, dust collection system, and plant type no longer are associated with changes in "C" values. Instead the entire operation (adjustment) of the asphalt plant is the major influence on the "C" value. Due to plant adjustments, several contractors, having poor results in the past, have been able to raise their average "C" value.

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# INTRODUCTION

## Background

Starting in 1981 and continuing through July of 1983, "C" value data were collected from 29 different projects in Oregon. A total of 111 samples were evaluated and the results compared against characteristics of the asphalt mixture and the construction project. 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.

Results from the study indicated that the overall operation and construction of asphalt plants, burner fuel type, mixing temperature and the use of bag house dust collectors had a significant influence on the tenderness of the produced mix. The results were published in a 1984 report (Lund and Wilson, 1984).

In 1984, a follow-up survey was made on all of the projects covered in the 1983 study. A questionnaire was developed and 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. The responses to the questionnaire appeared to identify and confirm relationships between the "C" value and asphalt mix problems that were noted in the 1983 study. The strongest correlation appeared 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 mix being too cold. The long term significant problems developing after construction were stripping and cracking. The correlation also indicated that projects with problems had "C" values below 40.

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 Composite Pay Factor calculated (OSHD Spec. 403.39).

## The 1985 Study

In 1985, "C" values were again analyzed to see if any changes had occurred since the 1983 study. Forty-nine projects constructed or under construction from August 1983 to July of 1985 were reviewed, from which 193 individual "C" values were obtained. Data on contractor operation, asphalt plant type, dust collection system, asphalt grade and brand, burner fuel and lime treatment were collected for each project. These data were again then compared against the "C" values from the project.

An additional 11 projects and 76 individual "C" values were added to the study in late August, 1985. These latter values were just used in the analysis of the contractor operation (see Figure 1).

## DATA ANALYSIS OF THE 1983-1985 PROJECTS

The data were analyzed in a manner similar to that for the 1984 report on the 1981-83 projects. This was done to provide a comparison between the two studies. Data for the 1983-1985 projects had an average "C" value for the 49 projects of 50.3 with a standard deviation of 28.4 and a range from -19.0 (very soft asphalt - tender mix) to 159.6 (very hard asphalt - stiff mix). A total of 14 percent of the test values had a value below 30 (1983-84 failure limit) and 41.5 percent a value below 40 (1985 failure limit). Data for the 1981-83 projects had a mean value of 53.6, 31 percent had value below 30 and 42 percent had value below the 40 limit. This shows an improvement of "C" value for the 1985 study from the 1984 study in that a smaller percentage of tests fail the 30 "C" value limit. The percentage failing the new 40 "C" value limit is near the same for both studies.

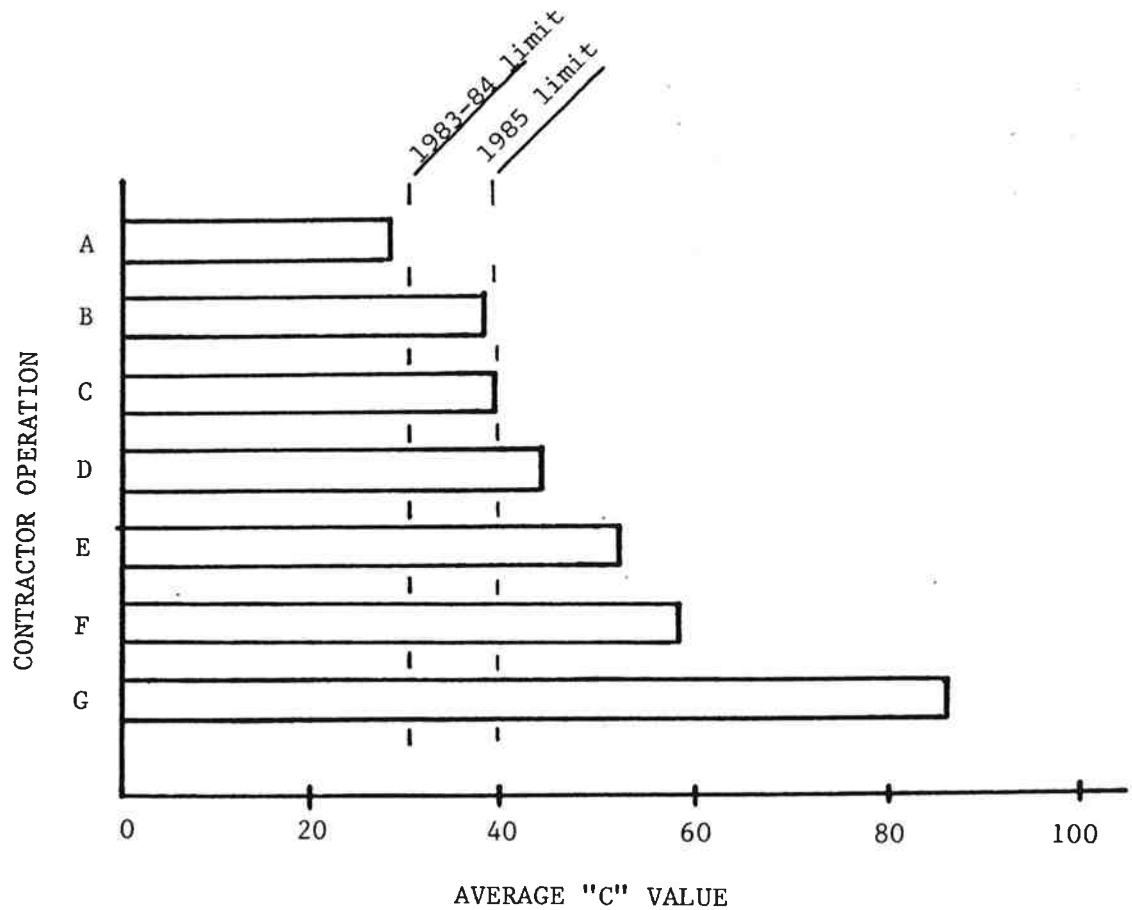
## Variables Analyzed

The following variables were analyzed, and where possible, are compared with results from the 1983 study.

### 1. Contractor Operation

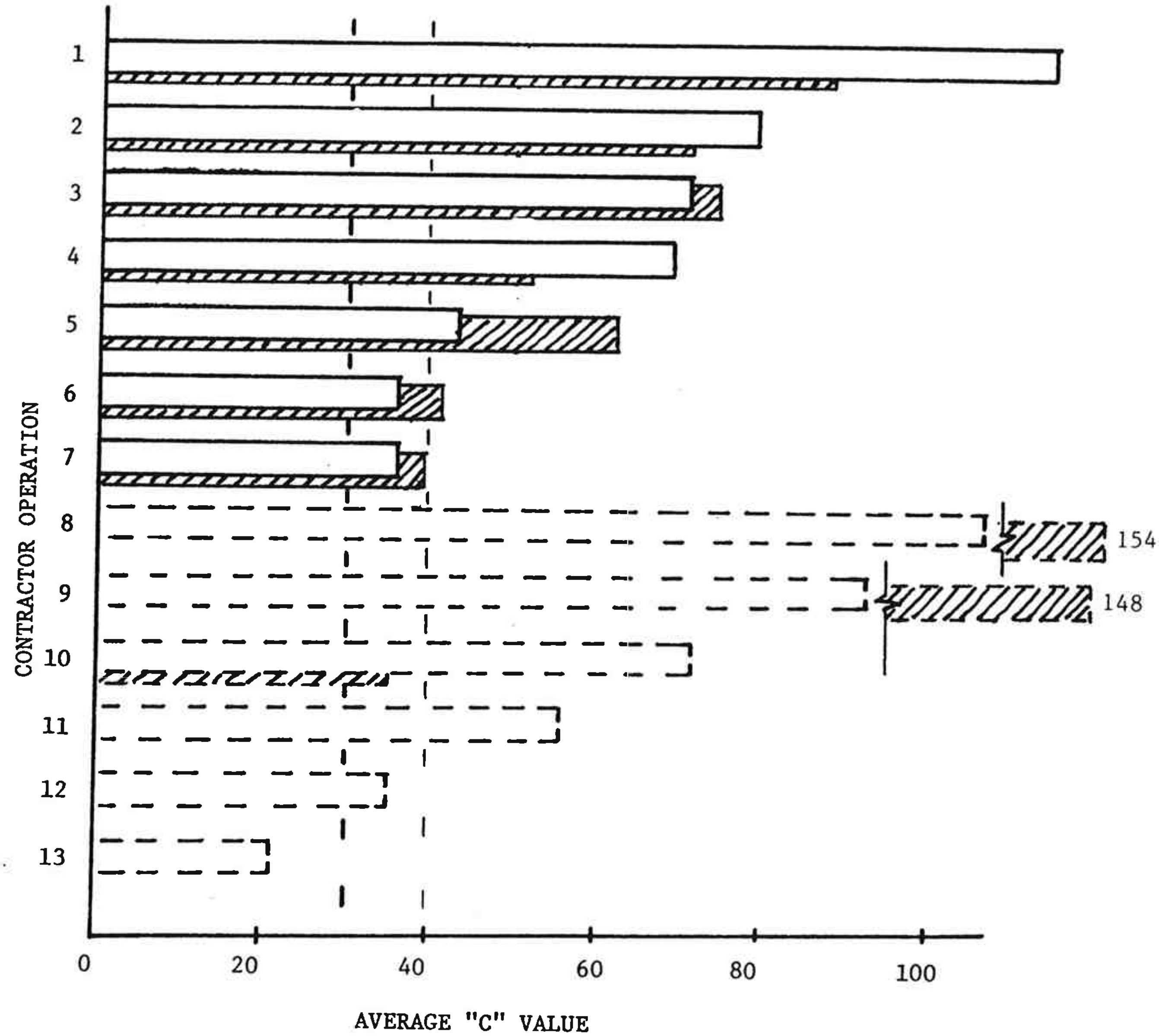
Seven new contractors, not analyzed in the 1983 study, had sufficient data for analysis. The results are shown in Figure 1. One contractor (A) had extremely poor results with a majority of the tests from the project failing both the 30 and 40 "C" value criteria. Three other contractors (B, C and D) had marginal results with a high percentage of failures. The remaining three had good results.

New data were available on ten of the original 13 contractor operations analyzed in the 1983 study. The results indicated that the average "C" value for each contractor remained essentially the same, with the three operations with the lowest average "C" value improving slightly. The overall change was not statistically significant. The 1981-83 data is reproduced in Figure 2, with the 1983-85 data shown for comparison. The most recent data is shown as a cross-hatched bar in the figure and as numbers in parenthesis in the table below. The dashed bars indicate operations with only one or two data points. As can be seen, two operations still have extremely low average "C" values and both would have 54 percent failing the 1985 specification of




| Ops. letter | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | Percent failures <40 |
|---|---|---|---|---|---|
| A | 34 | 28 | 18 | 62 | 88 |
| B | 20 | 38 | 6 | 5 | 55 |
| C | 8 | 39 | 30 | 50 | 75 |
| D | 7 | 44 | 29 | 28 | 43 |
| E | 3 | 52 | 7 | 0 | 0 |
| F | 13 | 58 | 14 | 0 | 8 |
| G | 4 | 86 | 49 | 0 | 0 |

FIGURE 1. Contractor operation vs. average "C" value, 1983-85 data only. (New since 1981-83 study)




| Ops. number | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | <40 |
|---|---|---|---|---|---|
| 1 | 9 (4) | 115 (88) | 65 (15) | 11 (0) | (0) |
| 2 | 6 (16) | 79 (71) | 16 (32) | 0 (6) | (6) |
| 3 | 4 (5) | 71 (74) | 39 (71) | 0 (20) | (40) |
| 4 | 11 (3) | 69 (52) | 16 (7) | 0 (0) | (0) |
| 5 | 6 (3) | 43 (62) | 19 (19) | 33 (0) | (0) |
| 6 | 5 (59) | 36 (41) | 8 (21) | 40 (19) | (54) |
| 7 | 49 (39) | 36 (39) | 47 (14) | 49 (28) | (54) |
| 8 | 2 (1) | 107(154) | 8 - | 0 (0) | (0) |
| 9 | 2 (1) | 93(148) | 61 - | 0 (0) | (0) |
| 10 | 2 (1) | 72 (35) | 4 - | 0 (0) | (100) |
| 11 | 1 - | 56 | - | 0 | |
| 12 | 1 - | 35 | - | 0 | |
| 13 | 2 - | 21 | 46 | 50 | |

FIGURE 2. Contractor operation vs. average "C" value.

40.

**2. Plant Type**

Seven of the original 16 plants studied in 1983 had enough new information for comparison. Five were drum mixer plants and two were batch plants. The comparison is shown in Figure 3 (reproduced from the original report). As can be seen, the two plants (with more than two data points) with the lowest average "C" values did improve their average, however all of the other plants dropped in average "C" value. The two plants having the lowest average "C" values also would have approximately 50 percent of their tests failing the 1985 specification limit of 40. The average value for all drum mix plants and batch plants are essentially the same, differing from the 1983 study where drum mixer plants had the lowest average "C" value.

**3. Dust Collection System**

In the 1983 study, bag house dust collection systems had a significantly lower average "C" value and higher failure rate when compared with wet scrubbers. In the 1985 study, the two systems had essentially identical results as shown in Figure 4.

**4. Asphalt Cement Grade and Supplier**

Of the two most used asphalt cements, the AC20 grade dropped significantly in average "C" value and increased in the percentage of failures, whereas the AR4000W grade did not

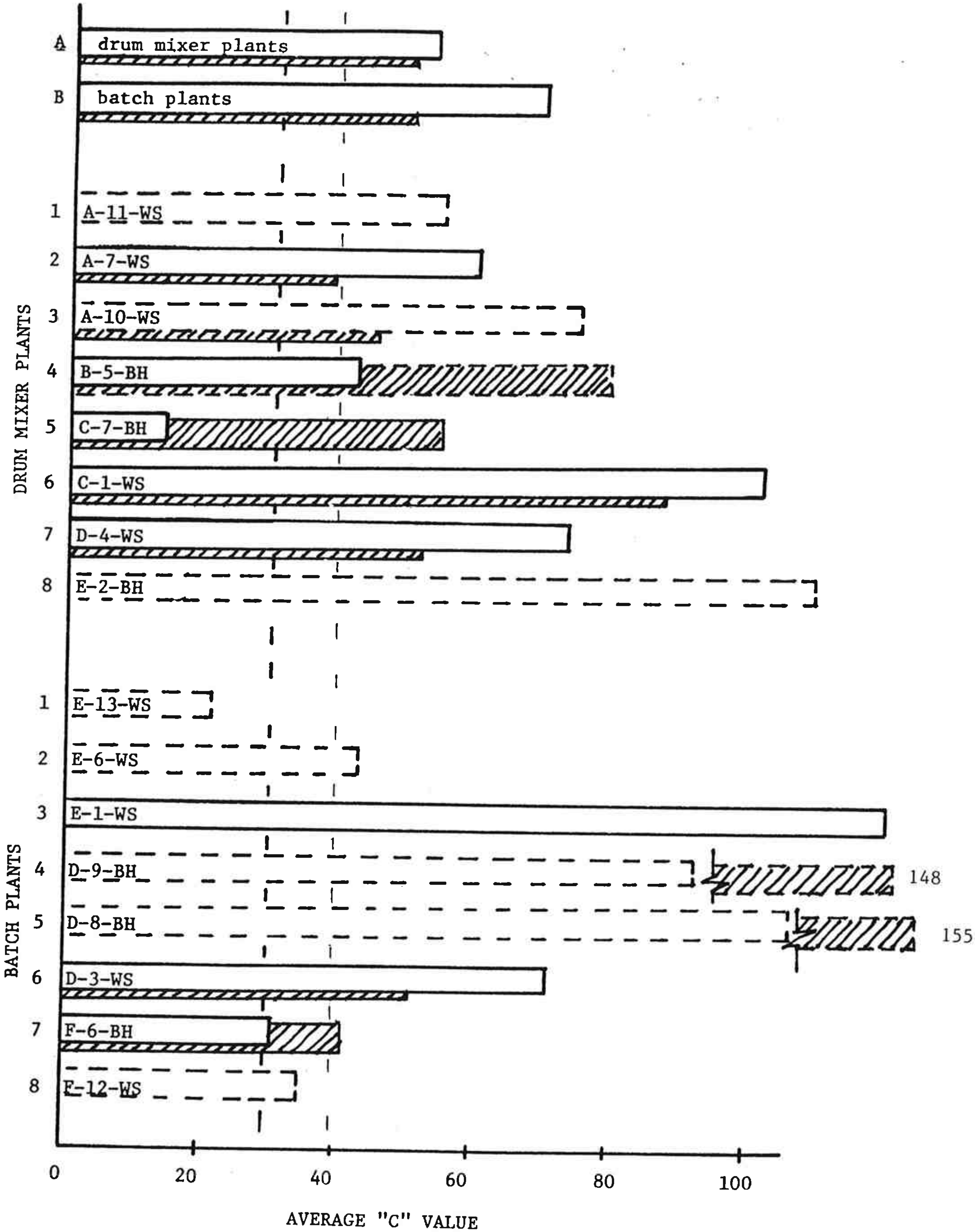
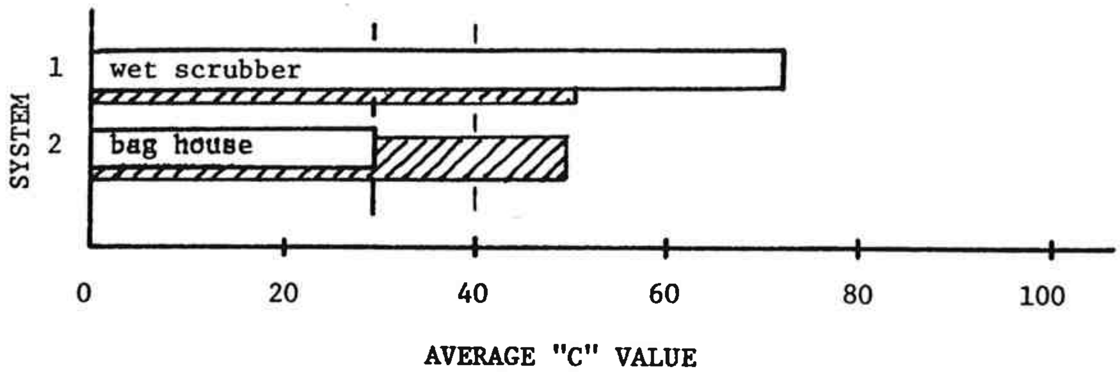



FIGURE 3. Asphalt plant type vs. average "C" value. Symbol meaning: A through F are plant manufactures, 1 through 13 are contractor operation (Fig. 2), and WS = wet scrubber, BH = bag house.

| Plant type | Number of tests | | Mean "C" value | | Standard deviation | | Percent failures <30 | | <40 |
|---|---|---|---|---|---|---|---|---|---|
| A | 82 | (106) | 54 | (50) | 52 | (22) | 35 | (10) | (35) |
| B | 16 | (87) | 74 | (50) | 51 | (35) | 19 | (18) | (49) |
| | | Drum mixer plants | | | | | | | |
| 1 | 1 | - | 56 | | - | | 0 | | |
| 2 | 19 | (31) | 61 | (39) | 46 | (16) | 26 | (26) | (48) |
| 3 | 2 | (2) | 72 | (45) | 4 | (14) | 0 | (0) | (50) |
| 4 | 6 | (1) | 43 | (80) | 19 | - | 50 | (0) | (0) |
| 5 | 28 | (2) | 14 | (55) | 30 | (10) | 75 | (0) | (0) |
| 6 | 7 | (4) | 103 | (88) | 70 | (15) | 14 | (0) | (0) |
| 7 | 16 | (3) | 70 | (52) | 14 | (7) | 0 | (0) | (0) |
| 8 | 1 | - | 111 | | - | | 0 | | |
| | | Batch plants | | | | | | | |
| 1 | 2 | - | 21 | | 46 | | 50 | | |
| 2 | 2 | - | 44 | | 2 | | 0 | | |
| 3 | 3 | - | 122 | | 59 | | 0 | | |
| 4 | 2 | - | 93 | | 61 | | 0 | | |
| 5 | 2 | - | 107 | | 8 | | 0 | | |
| 6 | 4 | (3) | 71 | (51) | 39 | (12) | 0 | (0) | (33) |
| 7 | 3 | (60) | 31 | (41) | 6 | (21) | 67 | (18) | (53) |
| 8 | 1 | - | 35 | | - | | 0 | | |

FIGURE 3. continued. Asphalt plant type vs. average "C" value.




| Dust system | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | <40 |
|---|---|---|---|---|---|
| 1 | 54 (110) | 72 (51) | 44 (26) | 9 (13) | (39) |
| 2 | 42 (83) | 30 (50) | 40 (31) | 62 (16) | (45) |

FIGURE 4. Dust collection system vs. average "C" value.

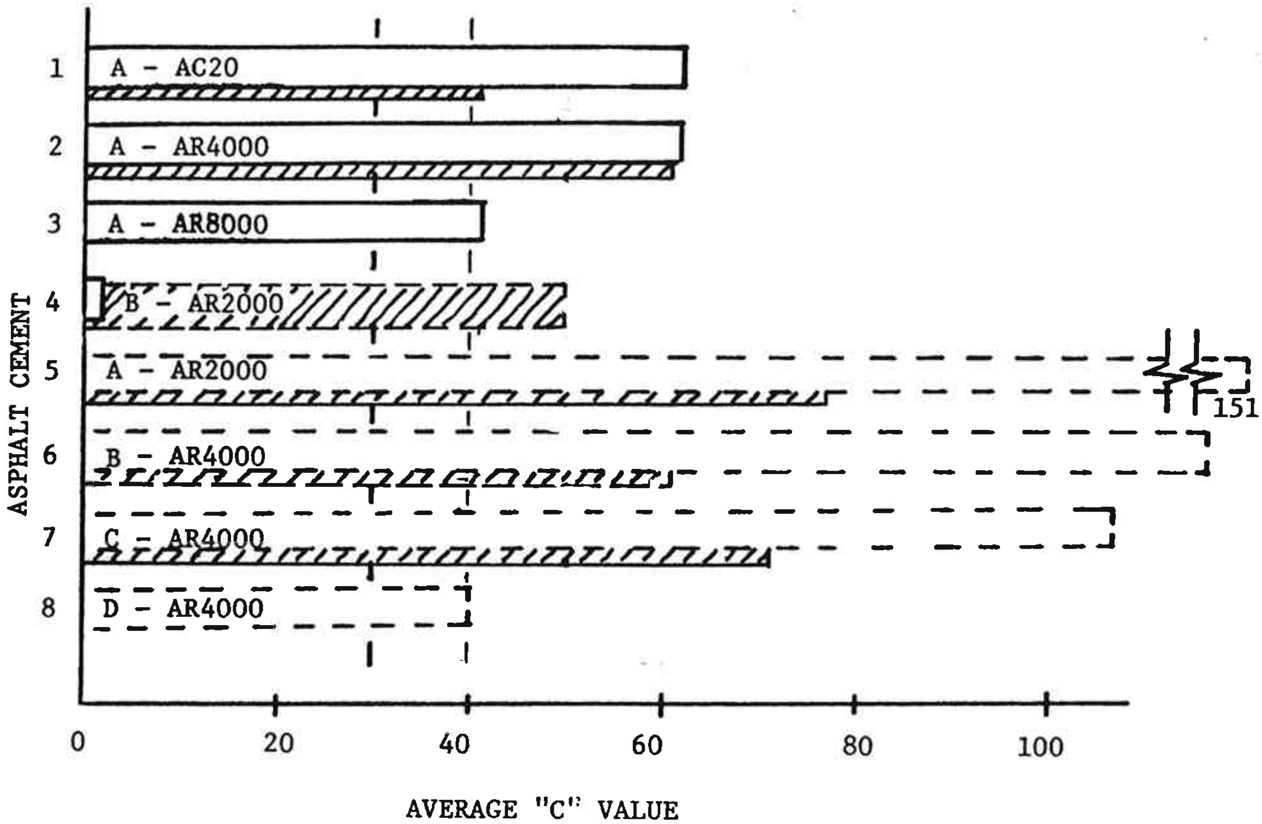
change. The remaining grades and suppliers did change, but due to the low number of data points, the results are probably inconclusive. The comparison between the two data sets is shown in Figure 5. A second supplier of AR4000W, not available in the 1983 study, is shown as item 9 in the table.

**5. Burner Fuel Type**

Three burner fuels were common between the two studies; No. 2 fuel oil, a commercial brand reclaimed fuel oil (referred to as brand A), and natural gas and propane. As shown in Figure 6 the results for the No. 2 fuel oil remained essentially unchanged, whereas the other two produced poorer results. The difference between the three fuels from the 1983-85 data is not statistically significant. Again the most recent data are shown as a cross-hatch bar and the numbers in parenthesis in the table below.

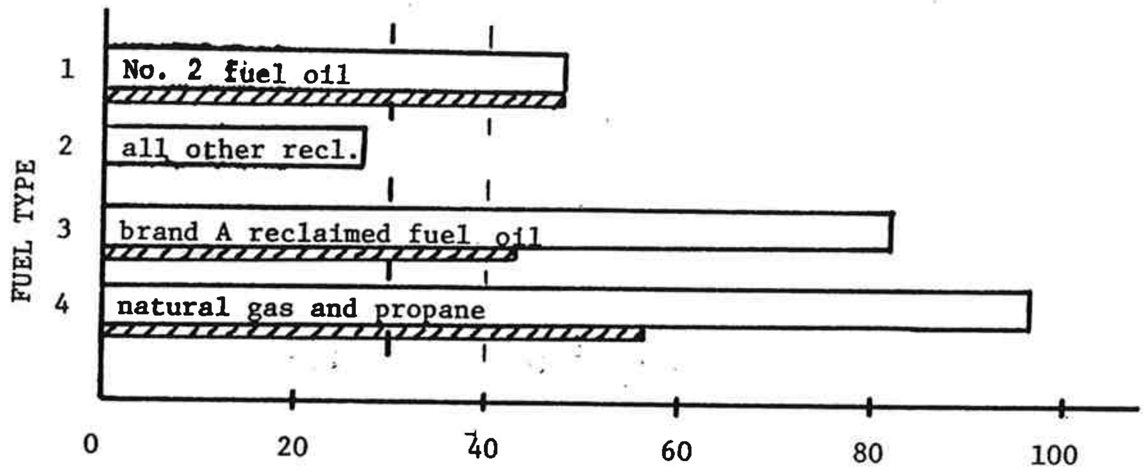
**6. Lime Additives**

In the past two construction seasons, dry lime has been added to the asphalt mix or the aggregate has been treated with a lime slurry on some projects. Lime is used as a means to improve asphalt-aggregate adhesion, especially where freeze-thaw is a problem or in open graded mixes to increase the effective viscosity of the asphalt cement. No data on lime additives were available from the 1983 study. Even though there were differences between treated mixes and untreated mixes, as shown




| Asphalt cement | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | <40 |
|---|---|---|---|---|---|
| 1 | 4 (54) | 62 (41) | 15 (14) | 0 (13) | (52) |
| 2 | 66 (61) | 62 (61) | 42 (33) | 30 (10) | (31) |
| 3 | 3 - | 41 - | 21 - | 33 - | - |
| 4 | 16 (2) | 2 (50) | 39 (24) | 56 (0) | (50) |
| 5 | 1 (5) | 151 (77) | - (45) | 0 (0) | (0) |
| 6 | 2 (2) | 117 (61) | 51 (83) | 0 (50) | (50) |
| 7 | 2 (6) | 107 (71) | 8 (47) | 0 (17) | (17) |
| 8 | 2 - | 40 - | 23 - | 50 - | - |
| 9 | - (27) | - (42) | - (8) | - (4) | (41) |

FIGURE 5. Asphalt cement grade and supplier vs. average "C" value
Letters A through D designate different suppliers.




| Fuel type | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | <40 |
|---|---|---|---|---|---|
| 1 | 45 (124) | 48 (48) | 27 (25) | 33 (15) | (53) |
| 2 | 26 - | 27 - | 49 - | 41 - | - |
| 3 | 11 (19) | 82 (43) | 44 (31) | 9 (26) | (53) |
| 4 | 16 (44) | 97 (56) | 58 (35) | 12 (16) | (39) |

FIGURE 6. Burner fuel type vs. average "C" value.

in Figure 7, these differences were not statistically significant. Additional study will be performed in the future on the effects of various additives on the "C" value.

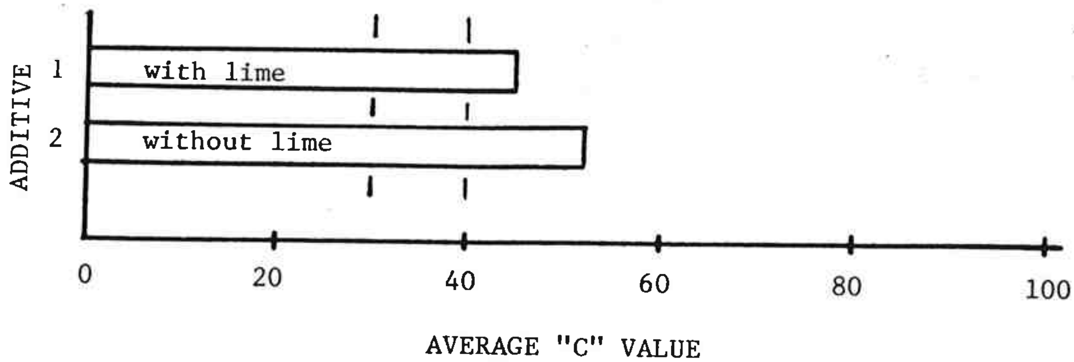
### 7. Asphalt Concrete Mix Class

Figure 8 shows the comparison between the three common asphalt mix types. As can be seen, the new data indicate there is very little difference between them and that the average value has decreased. The standard deviation of the "C" value has also been reduced.

## DISCUSSION AND CONCLUSIONS

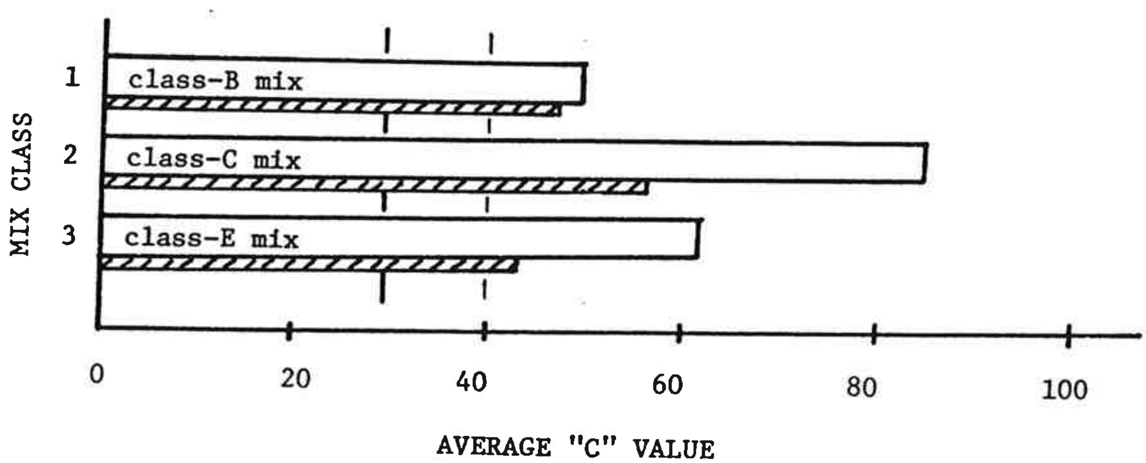
### Discussion

The comparison of results between the 1981-83 data and the 1983-85 data indicate some significant changes. No longer do plant type, dust collection system and burner fuel type appear to significantly affect the "C" value. Evidently, operators have been able to adjust for these individual variables and produce mix with adequate "C" values. The item that still appears to influence the "C" value is the overall operation of the asphalt mixing plant. Rather than one individual item influencing the results, a combination of factors such as burner adjustment,




| Additive | Number of tests | Mean "C" value | Standard deviation | Percent failure <30 | Percent failure <40 |
|---|---|---|---|---|---|
| 1 | 52 | 45 | 15 | 3 | 24 |
| 2 | 141 | 52 | 32 | 24 | 56 |

FIGURE 7. Lime treatment vs. average "C" value (1983-85 data).




| Mix class | Number of tests | Mean "C" value | Standard deviation | Percent failures <30 | Percent failures <40 |
|---|---|---|---|---|---|
| 1 | 86 (86) | 50 (47) | 46 (21) | 34 (13) | (40) |
| 2 | 8 (71) | 85 (56) | 56 (33) | 25 (7) | (37) |
| 3 | 4 (3) | 62 (43) | 15 (14) | 0 (0) | (67) |

FIGURE 8. Asphalt concrete mix class vs. average "C" value

where the asphalt cement is introduced in drum driers, the amount of air pushed through the drier, etc., are the controlling items.

Comparing the summary tables from the 1983 report as shown in Tables 1 and 2, some noticeable improvements have taken place. Under contractor operation (Table 1) all three operations having problems in 1983 have improved their operation. Contractor operation No. 5 has improved significantly and the other two only slightly. Operators No. 6 and No. 7 still have critically low average "C" values and a high number of failures. As seen in Table 2, three plants have improved in operation, however two new ones are now having problems.

In addition to the plant operation, AC20 asphalt cement appears to produce low "C" values. Even though this grade was used on nine different projects, the majority of the samples (89%) were associated with one contractor. Since this contractors operation has the lowest average "C" value of those studied, the low values for this asphalt cement is most likely due to the plant's's operation rather than the properties of the asphalt cement.

| Contractor Operation # | Pavement with reported problem | Drum mix plant used | Batch or drum mix plant with low "C" value | Batch or drum mix plant with bag house, | Asphalt cement used with low "C" value | Plant using reclaimed fuel | High percentage of failing "C" values | High number of potential problems | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | x | x | | | | | | | |
| 2 | | x | | | | x | | | |
| 3 | x | | | | | | | | |
| 4 | | x | | | | | | | |
| 5 | x | x | x | x | | x | x | *** | (improved+) |
| 6 | | | x | x | x | | x | *** | (improved) |
| 7 | x | x | x | x | x | x | x | *** | (improved-) |
| 8 | | | | x | | | | | |
| 9 | | | | x | | | | | |
| 10 | | x | | | | | | | |
| 11 | | x | | | | | | | |
| 12 | | | x | | | | | | |
| 13 | | | | | x | | x | | |

**TABLE 1. Summary of contractor operation characteristics. (see Fig. 2).**

| Plant # | Plant with low "C" values | Plant using bag house | Asphalt cement used with low "C" values | Plant using reclaimed fuel | Pavements with reported problems | High percentage of failing "C" values | High number of potential problems | |
|---|---|---|---|---|---|---|---|---|
| | | | drum mix plants | | | | | |
| 1 | | | | | | | | |
| 2 | | | x | x | | | | |
| 3 | | | | | | | | (in trouble) |
| 4 | x | x | | x | x | x | *** | (improved) |
| 5 | x | x | x | x | x | x | *** | (improved+) |
| 6 | | | | | x? | | | |
| 7 | | | | x | | | | |
| 8 | | x | | | | | | |
| | | | batch plants | | | | | |
| 1 | x | | x | | | x | *** | (no data) |
| 2 | x | | x | | | | | |
| 3 | | | | | x | | | |
| 4 | | x | | | | | | |
| 5 | | x | | | | | | |
| 6 | | | | | x | | | |
| 7 | x | x | | | | x | *** | (improved) |
| 8 | x | | | | | | | |

**TABLE 2. Summary of asphalt plant characteristics (see Fig. 3).**

## Conclusions

The "C" value still appears to be a good indicator of potential problems from tenderness of asphalt paving mixes, especially during the initial placement time. The critical and most influential variable affecting this value is the operation (adjustment) of the asphalt plant. Once the plant is in balance, the tenderness of the mix is generally reduced. Several contractors with low average "C" values and high failure rate were able to improve their performance over the past two years since the original study. The one new contractor experiencing low "C" values has seemed to be reluctant to make major changes in his plant operation.

The "C" value test provides a reliable and rapid method to determine whether or not asphalt cement contained in an asphalt concrete mixture is of the consistency expected for the mix design. This in turn will obtain the optimum conditions for pavement construction and performance. Pavement tenderness during and following construction is one of the major consequences from an unexpected soft consistency of asphalt in a mix. This type of mix will result in a low level of resistance to deformation or pavment rutting and loss of asphalt-aggregate adhesion.

## REFERENCES

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