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FINAL REPORT

PILOT STUDY TO DETERMINE COMPACTION LEVEL OF PLANT MIX OVERLAYS

by

C. S. Hughes
Assistant Head

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

Charlottesville, Virginia

May 1977
VHTRC 77-R49

343b

SUMMARY

Because some of the Department's bituminous overlays have displayed cracking in the short period of three to five years, and because few if any density controls are exercised in maintenance plant mix schedules, the Bituminous Research Advisory Committee recommended that the Research Council undertake a study to determine the compaction level generally being attained on maintenance overlays.

Data taken over the 1975-76 paving seasons, indicate that the Department's specification requirement is not being met consistently. For example, in 1976 only 16% of the maintenance projects tested met the specification.

Because of these poor density results, it is recommended that nuclear control strips be used on maintenance overlays as they are on new construction.

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INTRODUCTION

As has been known for sometime and recently has been emphasized,(1) the void content of bituminous mixes — along with asphalt consistency, asphalt content, and air temperature — is a major property in the provision of stability and durability. Of these four, in Virginia the asphalt consistency is limited by specifications on either the penetration or viscosity, and the asphalt content is controlled by design and extraction. The air temperature is beyond the control of the engineer. In construction contracts, the void content is held to a minimum by using the control strip procedure to approach the maximum density. However, it is believed that few, if any, density, or consequently void, controls are exercised in maintenance plant mix schedules, although the specifications require a minimum of 92% of the maximum theoretical density (MTD).

Overlays are being placed that develop cracks in the short period of three to five years. And while it is not the author's intention to attribute all overlay failures to a lack of density, it is reasonable to believe that inadequate density is a contributing factor.

If the average density on a maintenance schedule is 91% of the MTD, and the average density can be increased 2% to 93%, it is theoretically possible, other factors being equal that an additional two years of service life could be obtained and thus substantial savings could be realized by the Department.

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(1) Finn, F., K. Nair, and J. Hillard, Final Report on NCHRP Project 9-4, "Minimizing Premature Cracking in Asphalt Concrete Pavement." Transportation Research Board.

PURPOSE

The purpose of this study was to implement the recommendation of the Bituminous Research Advisory Committee that a pilot study be undertaken to determine the compaction level of plant mix overlays and to determine if higher levels could reasonably be attained.

This report contains the results of statistical analyses comparing the density results from three construction districts operating under special control procedures and those from three districts operating under normal procedures for maintenance schedules during 1975 and 1976.

PROCEDURE

In the three control districts — Bristol, Suffolk, and Staunton · inspectors equipped with nuclear gauges used control strip density procedures on maintenance overlay schedules. On all schedules having paving lengths exceeding .50 mile (800 metres), the inspector required roller patterns and control strip densities and ran 2,000 foot (610 metres) test sections as specified with the control strip procedure. This experimental work included S-5, S-4, I-2, and I-3 mixes only.

After completion of the paving, cores were taken from each section at the rate of one core per 1,000 lane feet (305 metres). The cores were brought to the Research Council where densities and maximum theoretical densities were determined. These results were compared to results from cores taken from the three districts where the normal compaction control procedures were used, namely the Salem, Lynchburg, and Culpeper Districts. Sections of overlay exceeding .50 mile (800 metres) in length were cored at the same rate of one core per 1,000 lane feet (305 metres) and the same tests were performed at the Research Council.

The Research Council performed statistical analyses to determine if any significant differences existed between the two types of compaction control as reflected by the density results.

BITUMINOUS DENSITY SPECIFICATION

Figure 1* depicts statistically the density specification requirement from the Road and Bridge Specification Sec. 320.07 on compaction, which states in part that

*Figures and tables are appended.

> Rolling shall be continued until ... a minimum density of 92% of the theoretical maximum density has been obtained.
>
> Not more than one sample in every 5 shall have a density less than that specified and the density of such sample shall not be more than 2 percent below the minimum specified.

The specification, based on a normal distribution verified from the data in the study, requires a project average density of at least 92.8% MTD when the standard deviation is not greater than .93% MTD in order that not more than one sample in every 5 shall be between 90% and 92% MTD. If the standard deviation is higher than .93%, a higher project density average than 92.8% would be necessary in order to meet the specification. Figure 1 then serves as a basis on which the density results can be compared.

RESULTS OF ANALYSES

1975 Data

The 1975 results summarized in Table 1,[2] which showed that the specification was not met by most contractors, were the basis of the following recommendation:

> Because of the low density results obtained on maintenance overlays during the 1975 season, it is recommended that the study be continued in the same six districts during the 1976 season. Furthermore, it is recommended that the study be extended to include as many schedules within the districts as possible to provide a sound basis for the statistical analysis. Also, it is recommended that the materials technician or construction inspector, using the control strip procedure, try at least seven passes before terminating the roller pattern.

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(2) Hughes, C. S., "Interim Report — Pilot Study to Determine Compaction Level of Plant Mix Overlays," Virginia Highway & Transportation Research Council, p. 5, January 1976.

1976 Data

It was anticipated that with greater attention to compaction, the 1976 results would be better than those for 1975. Unfortunately this was not true as the following analysis shows.

Overall 1976

Table 2 shows the results for the three districts using the normal density procedures with no control strips. The numbers in parentheses under the numbers of cores indicate the total numbers of cores per district and the total number for the three districts. Table 3 presents the same data for the three districts in which control strips were used.

From a comparison of the grand average percent MTD results in Table 2 with those in Table 3, it can be seen that no difference exists. These results indicate that, at least in this study, the control strip technique was not effective in obtaining adequate densities. A more detailed look at Table 2 indicates that the Salem District obtained significantly better densities than the other two districts not using control strips. In the districts where control strips were used (Table 3), there is no difference between districts.

Differences between projects are evident in all districts and are not unexpected. Part of the differences relate to mix type. I-2 mixes evidently are easier to compact than the S-5 mixes (probably due to the greater application rates) as evidenced by the average density of 91.8% MTD as compared to 90.7% for all S-5 mixes. However, there are undoubtedly other factors involved, including the density of the underlying pavement, roller characteristics, workmanship, level of inspection, and application rate.

The overall results indicate that in spite of the emphasis being placed on the low densities obtained in 1975, the overall results for 1976 were no higher.

Before looking at reasons why higher densities were not obtained, it may be beneficial to look at the levels of compaction obtained district by district.

District by District

Figures 2 through 7 show the normal curves for the density results in the six districts. The percentages shown indicate the percent population below the required 92% minimum, which in order to meet the specification as shown in Figure 1 should not exceed 20%. It is obvious that the distributions for all districts show appreciably greater percentages than 20% below the specification limit.

On a project basis, the data in Tables 2 and 3 reveal that:

1. Lynchburg had 10 projects, none of which met specifications;
2. Salem had 5 projects, 2 of which met specifications;
3. Culpeper had 5 projects, none of which met specifications;
4. Bristol had 16 projects, 2 of which met specifications;
5. Suffolk had 6 projects, 1 of which met specifications; and
6. Staunton had 8 projects, 3 of which met specifications.

Summarizing, only 8 out of 50 (16%) maintenance projects had densities that met the specifications and on only 2 of these were S-5 mixes used. What is even more disturbing is that the densities were worse in 4 of the 6 districts in 1976 as compared to 1975.

The conclusion is obvious; the Department is consistently paying for out of specification material and consequently the overlays cannot perform as they are expected to.

REASONS FOR LOW DENSITIES

Although there are likely to be several reasons for the low densities, the primary reason is probably the lack of compactive effort. In the districts where no control was used to increase the compactive effort, the densities were not likely to increase unless the inspector and/or contractor called for an increase in the compactive effort. However, it was a surprise to find that the districts which used control strips did not produce higher densities as has been found on construction projects. A closer look was taken at the control strip data to see if a reason for this occurrence could be determined.

First, it became obvious that the increase in compactive effort as recommended was not effective as evidenced by the decrease in the average number of roller passes (7.0 passes in 1975 down to 6.3 passes in 1976).

Also the results in Table 4 indicate that the control strip procedure as used in this study did not provide an adequate density control mechanism, even when failing test sections occurred. This finding indicates that little importance is placed on the value of adequate densities in maintenance work.

The requirement that 80% of the density population be above 92% MTD is not overly restrictive, as demonstrated on those projects where special attention has been given to density. Granted that obtaining the proper density level is the responsibility of the contractor, if proper control is not exercised by the contractor, it would seem prudent for the state to institute practices to assure adequate density and thus help assure adequate performance.

RECOMMENDATION

Because it is important to obtain density in all plant mix overlays, and because the 1975 and 1976 density results indicate that the density specification is being met on only 16% of the maintenance schedules, it appears that extraordinary measures are warranted to assure adequate densities.

It is recommended that an inspector equipped with a nuclear gauge be assigned to each maintenance schedule to control density as is now done on construction projects. An alternative recommendation is to institute a penalty system using density cores to determine conformance to specifications.

APPENDIX

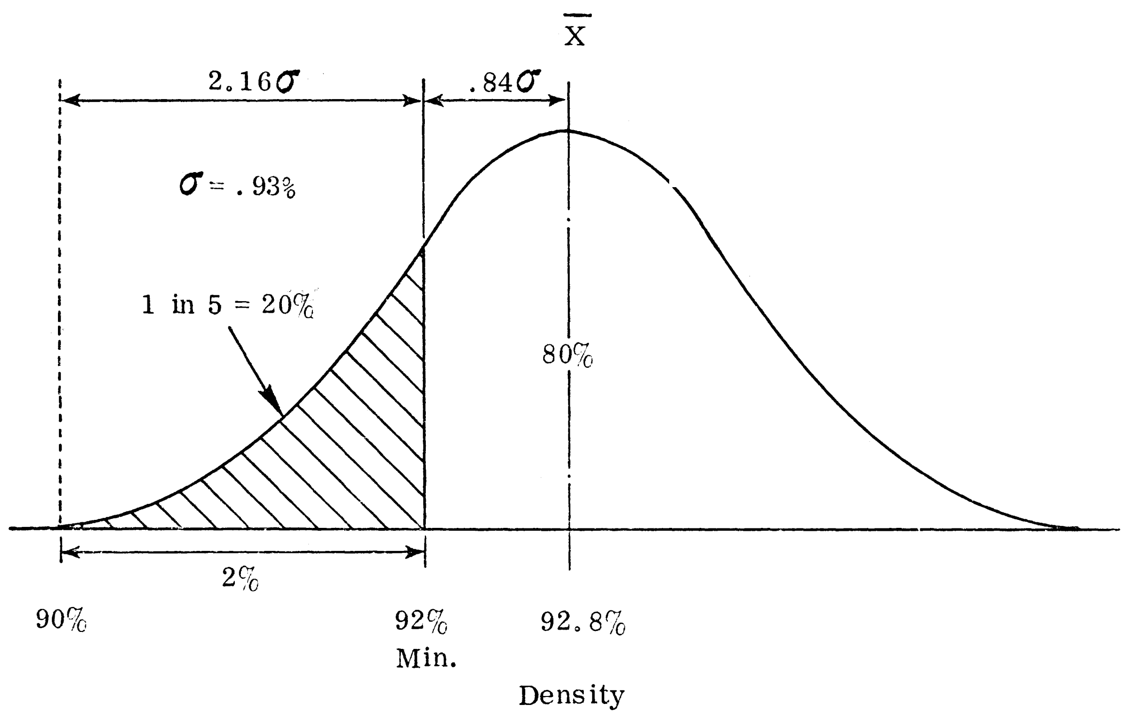

Figure 1. Virginia Department of Highways & Transportation density specification expressed statistically.

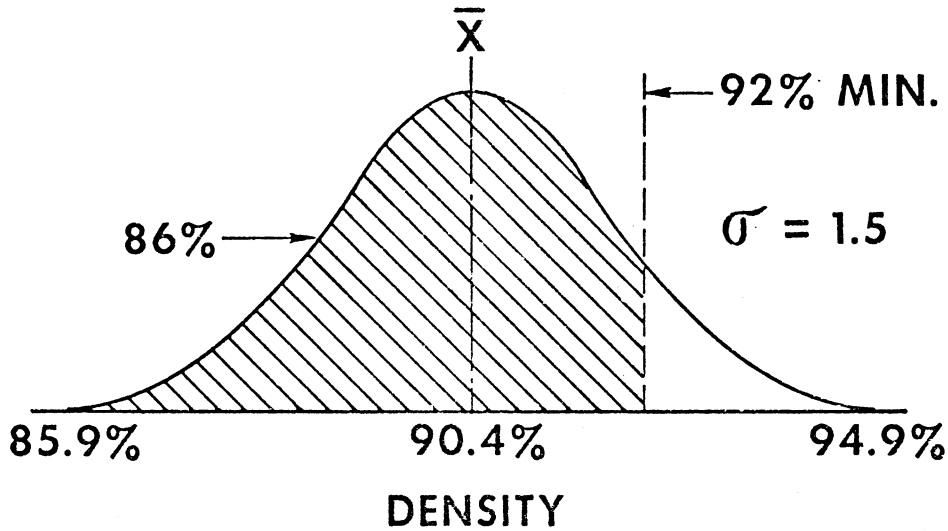

Figure 2. Lynchburg District 1976 — no control strip.

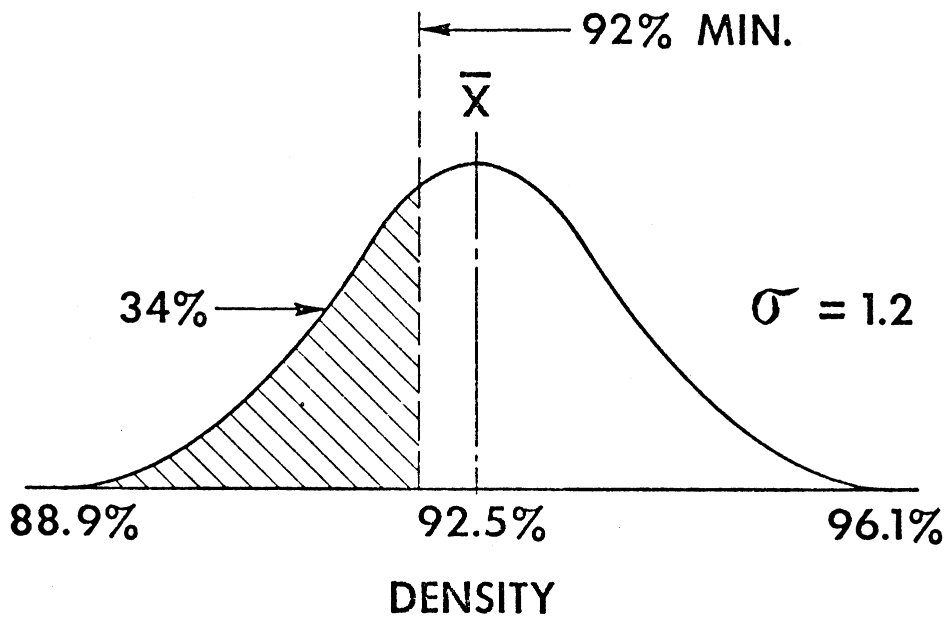

Figure 3. Salem District 1976 — no control strip.

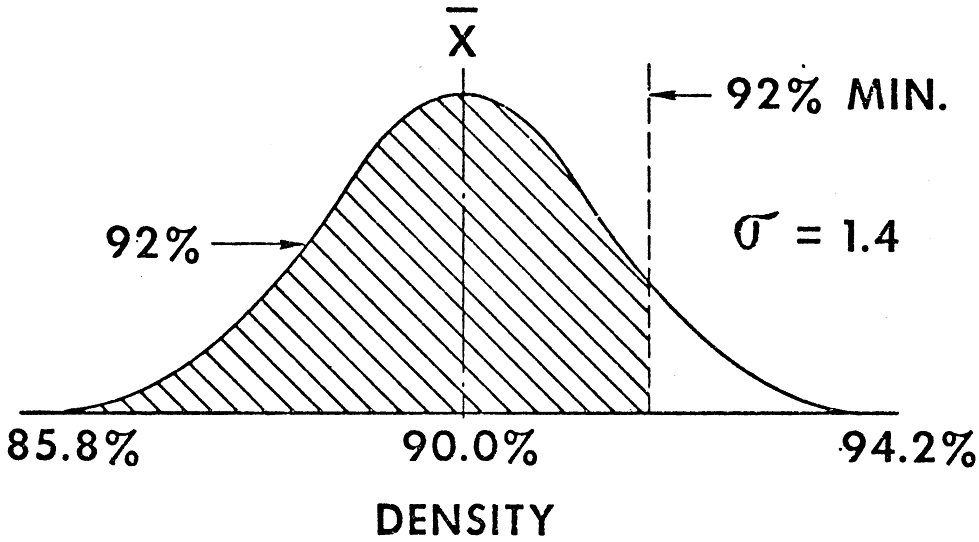

Figure 4. Culpeper District 1976 — no control strip.

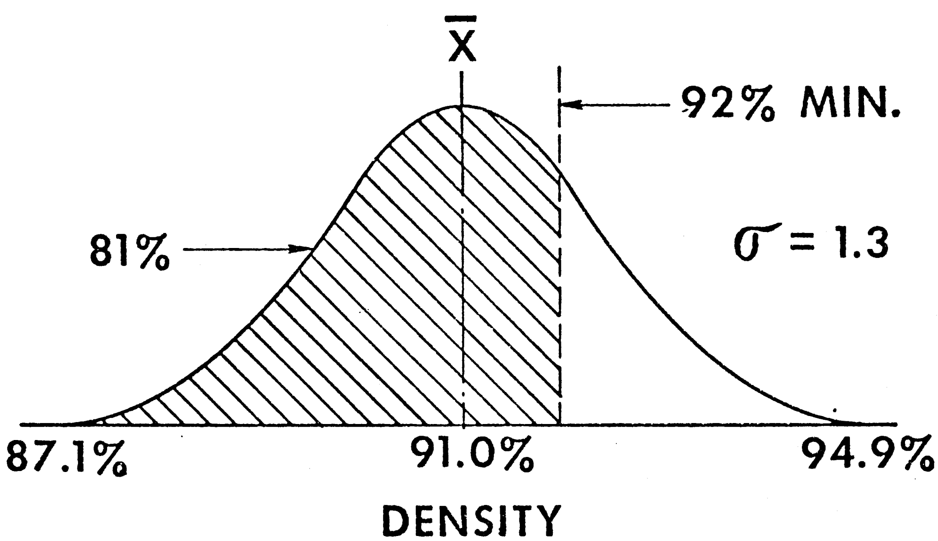

Figure 5. Bristol District 1976 — control strip.

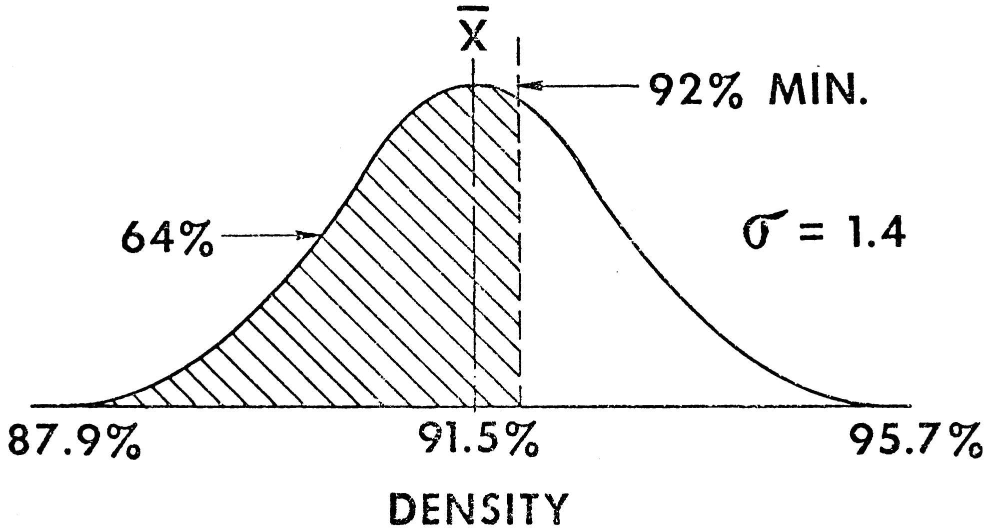

Figure 6. Suffolk District 1976 — control strip.

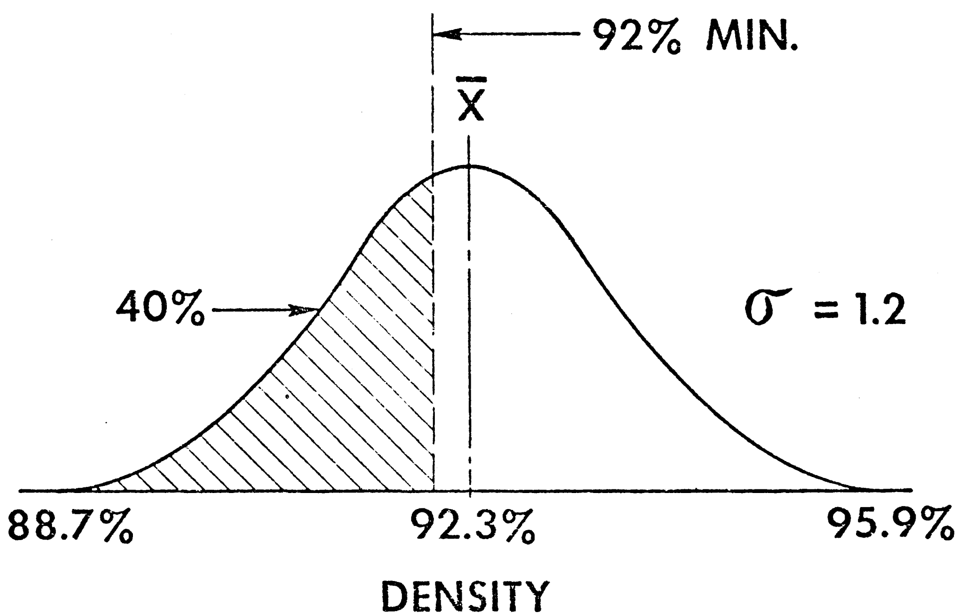

Figure 7. Staunton District 1976 — control strip.

Table 1

Grand Average Densities by District — 1975 Data

Districts With No Control Strip		
District	% MTD	% Below Spec.
Lynchburg	90.8	73
Salem	91.6	63
Culpeper	91.6	56
Districts With Control Strip		
District	% MTD	% Below Spec.
Bristol	90.8	69
Suffolk	89.3	87
Staunton	93.4	21
GRAND AVERAGE	91.0	67

Table 2

Districts Not Using Control Strips

District	Route	Mix	No. of Cores	Avg. % MTD	Std. Dev.
Lynchburg Dist.					
	654*	S-5	52	89.5	1.6
	24	S-5	27	90.1	1.7
	60	I-2	40	92.2	2.4
	60	I-2	40	92.7	1.6
	41	S-5	31	89.3	1.1
	58	S-5	25	90.6	1.6
	29	S-5	81	89.1	1.3
	15	S-5	11	90.9	1.3
	60	S-5	24	90.6	1.6
	15	S-5	38	91.2	1.3
District Average			(369)	90.4	1.5
Salem Dist.	581	S-5	29	92.6	1.1
	43	I-2	55	91.8	1.6
	94	S-5	35	93.5	0.9
	11	S-5	40	92.1	0.9
	8	S-5	39	92.9	1.2
District Average			(198)	92.5	1.2
Culpeper Dist.	33	S-5	9	88.4	1.8
	522	I-2	10	90.1	1.1
	230	I-2	10	89.2	1.7
	29	S-5	10	92.2	1.5
	66	S-5	9	89.9	1.1
District Average			(48)	90.0	1.4
GRAND AVERAGE			(615)	91.0	1.4

*Cracking indicated possibility of excessive rolling.

Table 3

Districts Using Control Strips

District	Route	Mix	No. of Cores	Avg. % MTD	Std. Dev.
Bristol Dist.	11	S-5	15	90.1	1.0
	11	S-5	16	92.0	1.3
	601	I-3	20	90.8	1.8
	11	I-2	11	92.3	1.8
	81	S-5	31	89.7	1.0
	81	S-5	35	88.6	1.5
	91	S-5	15	89.9	2.1
	460	I-2	46	90.7	1.0
	67	I-2	9	92.6	0.7
	23	S-5	8	90.5	0.8
	460	I-2	22	90.8	1.1
	94	I-2	25	91.3	1.8
	11	S-5	5	91.1	1.2
	72	I-2	14	92.6	0.9
	65	I-2	16	91.4	1.3
	58	I-2	29	92.8	1.1
District Avg.			(317)	91.0	1.3
Suffolk Dist.	32	S-5	21	93.0	1.2
	186	I-2	18	92.3	1.4
	60	S-5	15	89.1	2.1
	258	S-5	11	93.4	1.8
	168	S-5	38	90.6	1.3
	301	I-2	16	91.5	1.1
District Avg.			(119)	91.5	1.4
Staunton District	522	I-2	8	88.8	1.3
	627	I-2	4	90.9	1.4
	55	I-2	7	91.8	0.4
	277	I-2	8	94.5	0.8
	501	I-2	18	91.5	1.4
	340	I-2	11	92.2	1.1
	826	I-2	6	93.6	1.0
	687	I-2	12	94.8	1.8
District Avg.			(74)	92.3	1.2
GRAND AVG.			(510)	91.3	1.3

Table 4

Comparison of Passing Projects in Control Strip Districts

District	No. Projects	No. Met Specs.	No. Passed Control Strip
Bristol	16	3	3
Suffolk	6	1	3
Staunton	8	3	7