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INTERIM REPORT

PILOT STUDY TO DETERMINE COMPACTION LEVEL OF PLANT MIX OVERLAYS

by

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

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SUMMARY

To summarize the 1975 density data gathered in a pilot study of plant mix overlays, it is obvious that the density specified by the Virginia Department of Highways & Transportation is not being obtained by most contractors. Further, evidently the lack of density is due to inadequate rolling. It appears that seven or eight passes will generally be necessary to adequately compact surface mixes.

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INTRODUCTION

As has been known for sometime, and recently has been reiterated, [1] the void content of bituminous mixes is one of the four most important properties in the provision of stability and durability. The other properties are the asphalt consistency, asphalt content, and air temperature. Of these four, in Virginia the asphalt consistency is limited by asphalt specifications (either 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 percent of the maximum theoretical density (MTD).

Overlays are being placed that display cracking in the short period of three to five years. It is not the author's intention to attribute all overlay failures to a lack of density; however, because of the lack of density control it is reasonable to believe that inadequate density is a contributing factor.

If, as will be shown later, 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. Substantial savings could be realized by the Department if the above can be accomplished.

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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

At present, personnel and equipment (primarily nuclear density gauges) are available to determine the level of compaction being obtained on overlays at no additional cost to the Department.

PURPOSE

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

More specifically, this report contains the results of a statistical analysis made between density results from three districts operating under special density control procedures and those from three districts operating under normal density control procedures.

PROCEDURE

In three control districts — Bristol, Suffolk, and Staunton — inspectors equipped with nuclear gauges conducted control strip density procedures on maintenance overlay schedules. On all schedules having paving lengths exceeding .50 mile (800 meters) the inspector required roller patterns and control strip densities and ran 2,000 foot (610 meters) test sections which are specified with the control strip procedure. This experimental work applied to 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 meters). 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 three districts where the normal compaction cor procedures were used, namely the Salem, Lynchburg, and Culpeper Districts. Sections of overlay exceeding .50 mile (800 meters) in length were cored at the same rate of one core per 1,000 lane feet (305 meters) and the same tests were performed at the Research Counci

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.

RESULTS OF ANALYSES

Overall

In this comparison of results between projects and districts the percent MTD values are reported. Table 1 shows the results for the three districts using only the normal density procedures and no control strips. The numbers in parentheses under

No. of Cores indicate the total number of cores per district and the total number for the three districts. Table 2 presents the same data for the three districts in which control strips were used to control the density of the projects.

The results in Table 1 indicate that although there is variability between projects (as would be expected) the district averages are very close to the grand average of 91.1% MTD for the three districts. Observe also that most projects utilized S-5 mixes.

Table 1

DISTRICTS NOT USING CONTROL STRIPS

District 1	Mix	No. of Cores	Avg. % MTD
	S-5	9	91.7
	I-2	6	93.3
	S-5	3	87.8
Dist. $\bar{x}$		(18)	91.6
District 2	S-5	10	89.3
	S-5	30	89.7
	S-5	56	92.3
	I-2	45	88.6
	S-5	20	91.6
	S-5	31	89.3
	S-5	9	90.7
Dist. $\bar{x}$		(201)	90.8
District 3	S-5	18	91.1
	S-5	35	92.2
	S-5	22	91.0
		(75)	91.6
Grand Avg.		(294)	91.1

The results in Table 2 also show considerable variability between projects and more variability between districts than was found where no density control strips were used. A close look at the results shows that District 1, with the highest densities, had no S-5 mixes. It has been considered and these limited data tend to confirm that it is harder to obtain density on S-5 than it is on I-2, I-3, or B-3 mixes. Therefore, the type of mix may be partially responsible for the density variability between districts. Aswill be shown later, it is possible one district used better control strip techniques. However, the grand average for the three control strip districts was

91.0% MTD. If only results of S-5 mixes are compared, the no control districts averaged slightly higher densities than the control strip districts. At any rate, where no control was provided the densities were as high as those where control strips were utilized. And all districts but one averaged densities below the required minimum of 92% MTD. This finding should not be the case but before looking into reasons why no difference existed, it would be beneficial to look into the level of compaction being obtained district by district.

Table 2

DISTRICTS USING CONTROL STRIPS

District 1	Mix	No. of Cores	Avg.% MTD
	I-3	4	92.2
	I-3	4	93.8
	I-3	2	94.6
	B-3	4	94.0
	I-2	4	90.8
	I-2	19	94.0
	I-2	6	93.3
Dist. $\bar{x}$		(43)	93.4
District 2	S-4	9	87.6
	S-5	16	88.3
	I-2	12	91.0
	S-5	6	91.0
Dist. $\bar{x}$		(43)	89.3
District 3	I-2	14	89.4
	S-5	11	92.0
	S-5	25	91.2
	S-5	6	90.5
	S-5	3	90.9
	S-5	47	90.5
	I-2	11	92.0
Dist. $\bar{x}$		(117)	90.8
Grand Avg.		(203)	91.0

District by District

Figure 1 depicts statistically the density specification requirement from the Road and Bridge Specification Sec. 320.07 compaction.

> "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 no greater than .93 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 for each district can be compared.

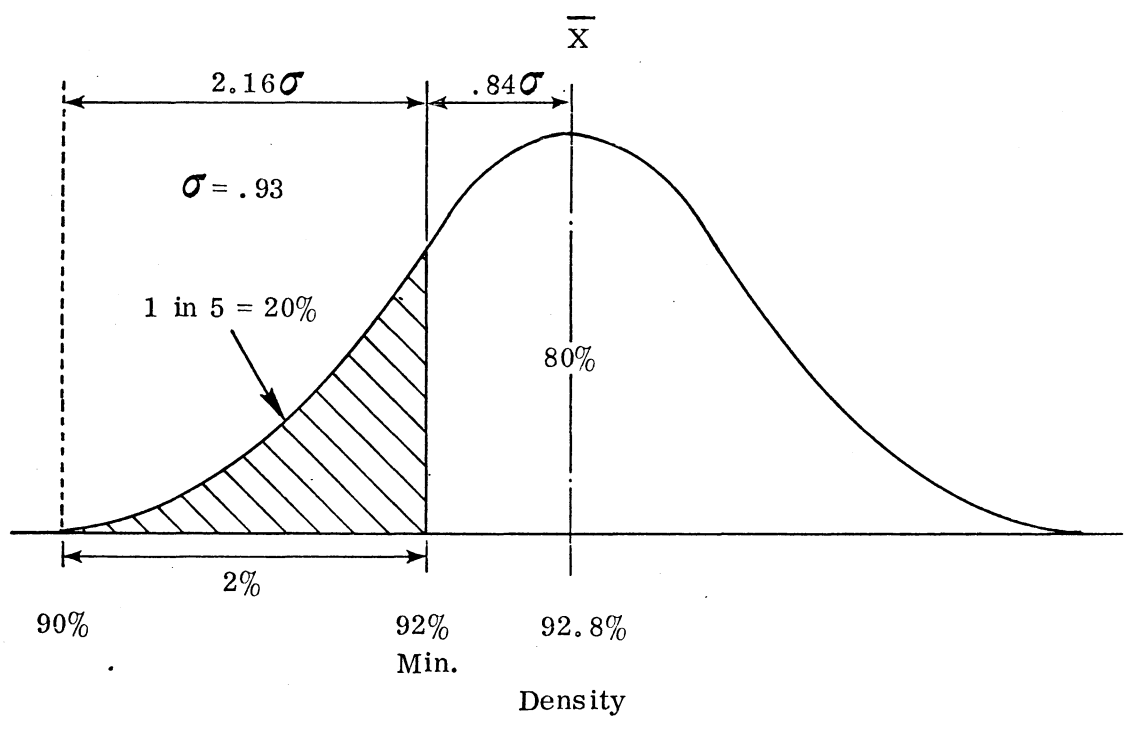

Figure 1. Virginia Department of Highways & Transportation density specification expressed statistically.

Figures 2 through 7 show normal curves for the density results of districts 1 through 3 not using control strips and control strip districts 1 through 3 respectively. The percentages shown indicate the percent population below the required 92% minimum.

Figure 4 shows what was intimated earlier, that district 1 using the control strip is the only one that approached meeting the specification on a district wide level.

The conclusion is obvious, the Department is not consistently getting the density specified and paid for and consequently the overlays are not performing as should be expected.

Reasons for Low Density Results

Although there are several reasons why the densities may be low, there are probably two that are primarily responsible. First if the S-5 mixes are designed in the laboratory to have a high voids total mix (VTM), the resulting VTM in the field must also be high. However, specifications require that the VTM range for design be 3 to 6%. With the attention this property has been given lately, the mix design is probably not the most prominent cause of low densities.

The second reason, and the one most obvious, is the lack of compaction being exerted on the pavement. The best way of determining if this lack of compaction is the reason for the low densities would be to look at the type and number of rollers being used and the number of passes of the rollers.

For the three districts using the control strip procedure the roller patterns provide some of the needed information. Most of the roller patterns indicate that 3 wheel 12 ton or vibratory rollers were used. Because of this, it can be assumed that the types and number of rollers were adequate. The number of passes shows a very interesting trend when correlated with density. Figure 8 shows this correlation. It is obvious that the density increases with the number of passes. That is no revealation. However, it appears that at least 7 passes are necessary to produce an average of 92% MTD on a project. On the 5 projects using only 4 passes, the 92% MTD was not achieved. This is also true of the three projects on which 6 passes were used. The densities averaged for equal number of passes provided the data in Table 3.

The reason that many of the patterns had only 4 passes has to do with the way the roller pattern procedure is written. The procedure states in effect that if the density does not increase at least 0.5 pound (0.2 kg) per pass, the pattern will be discontinued. The author takes full responsibility for this statement but feels that it must be interpreted with experience. The author does not recommend terminating a roller pattern on an S-5 mix after 4 passes. From these data it appears that to achieve at least an average of 92% MTD 8 passes would be recommended.

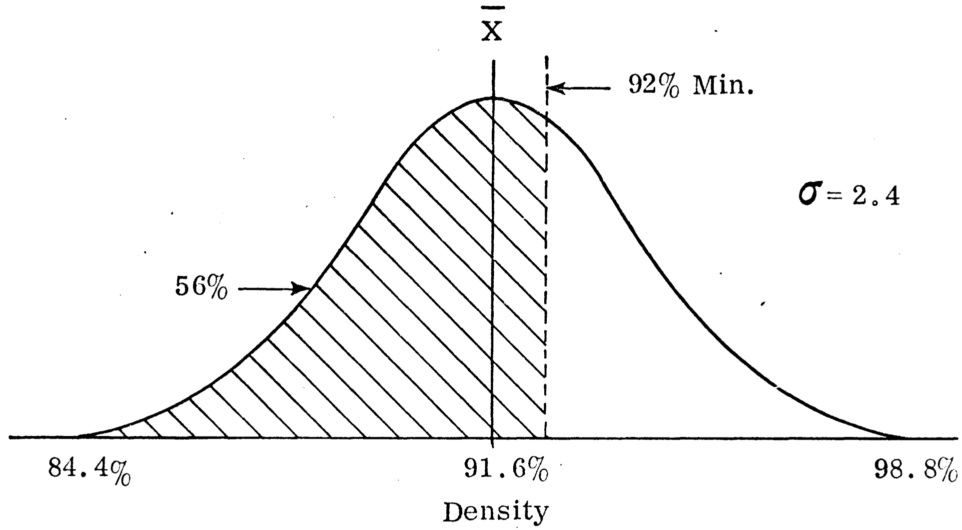

Figure 2. No control strip District 1.

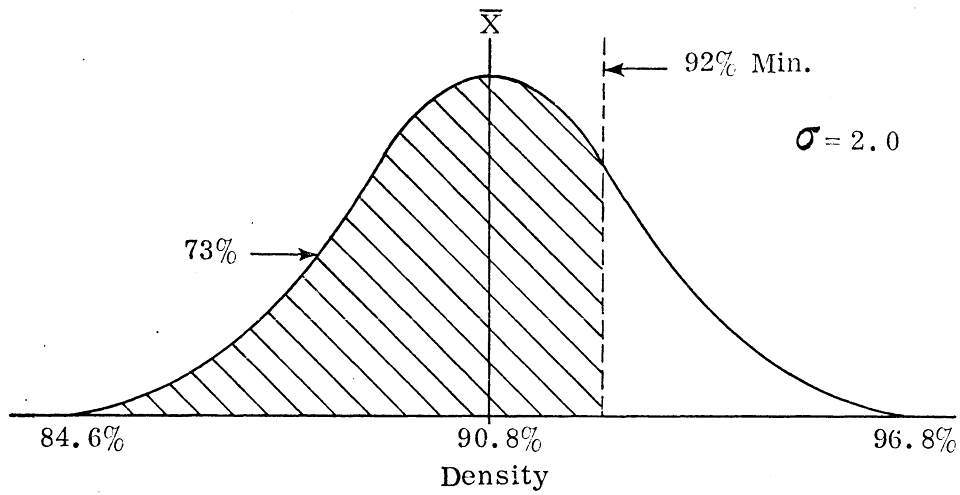

Figure 3. No control strip District 2.

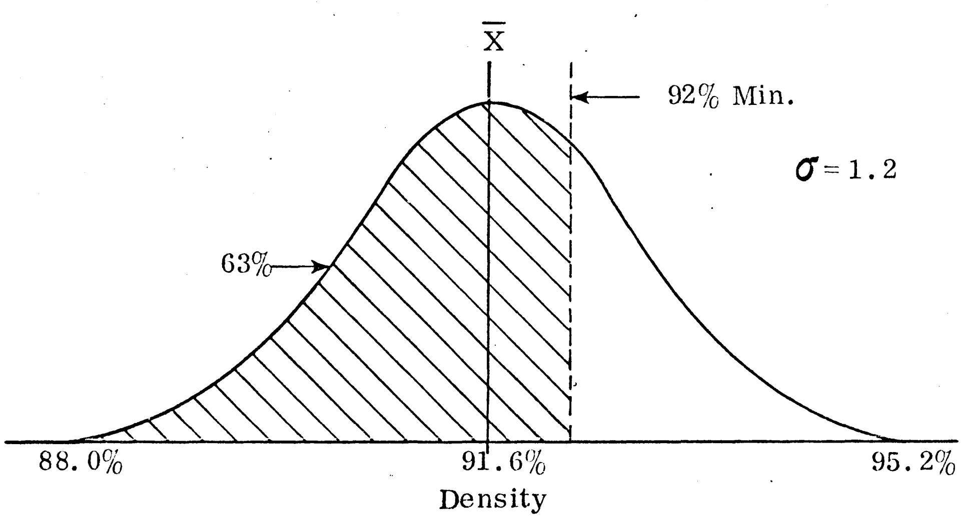

Figure 4. No control strip District 3.

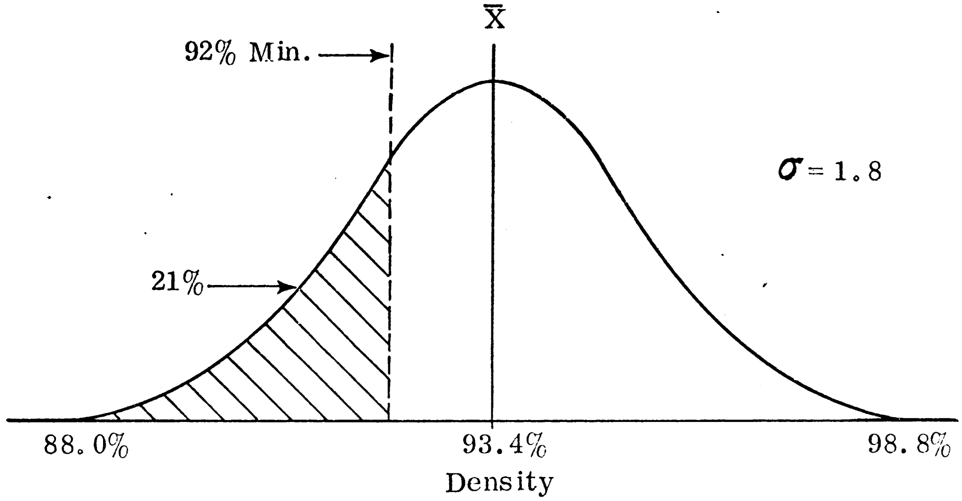

Figure 5. Control strip District 1.

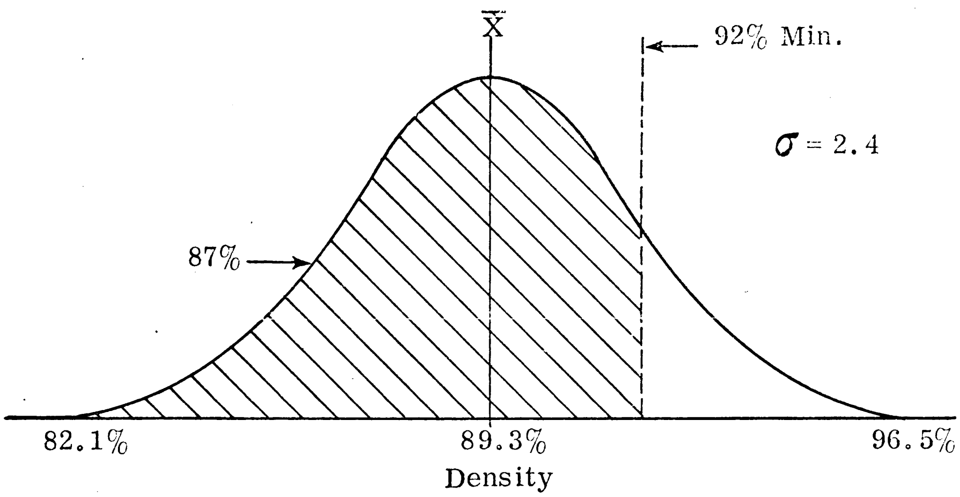

Figure 6. Control strip District 2.

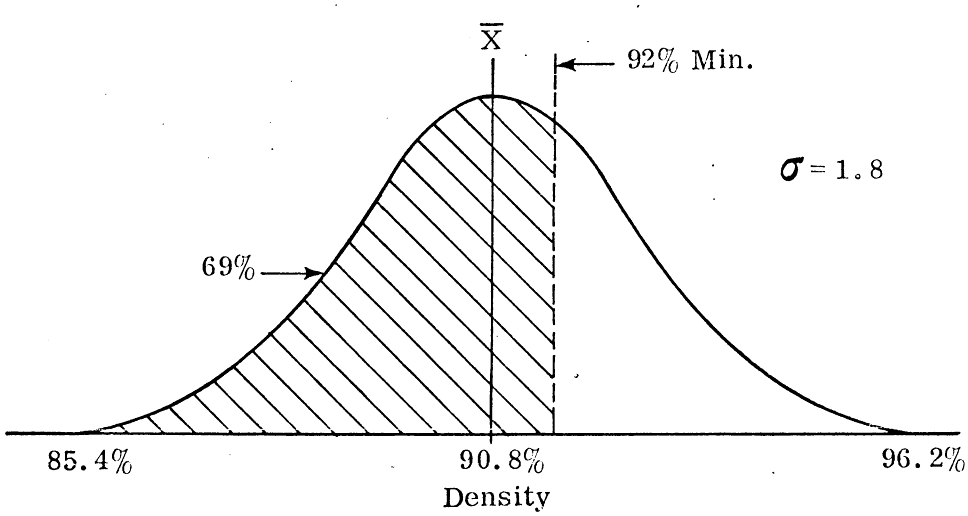

Figure 7. Control strip District 3.

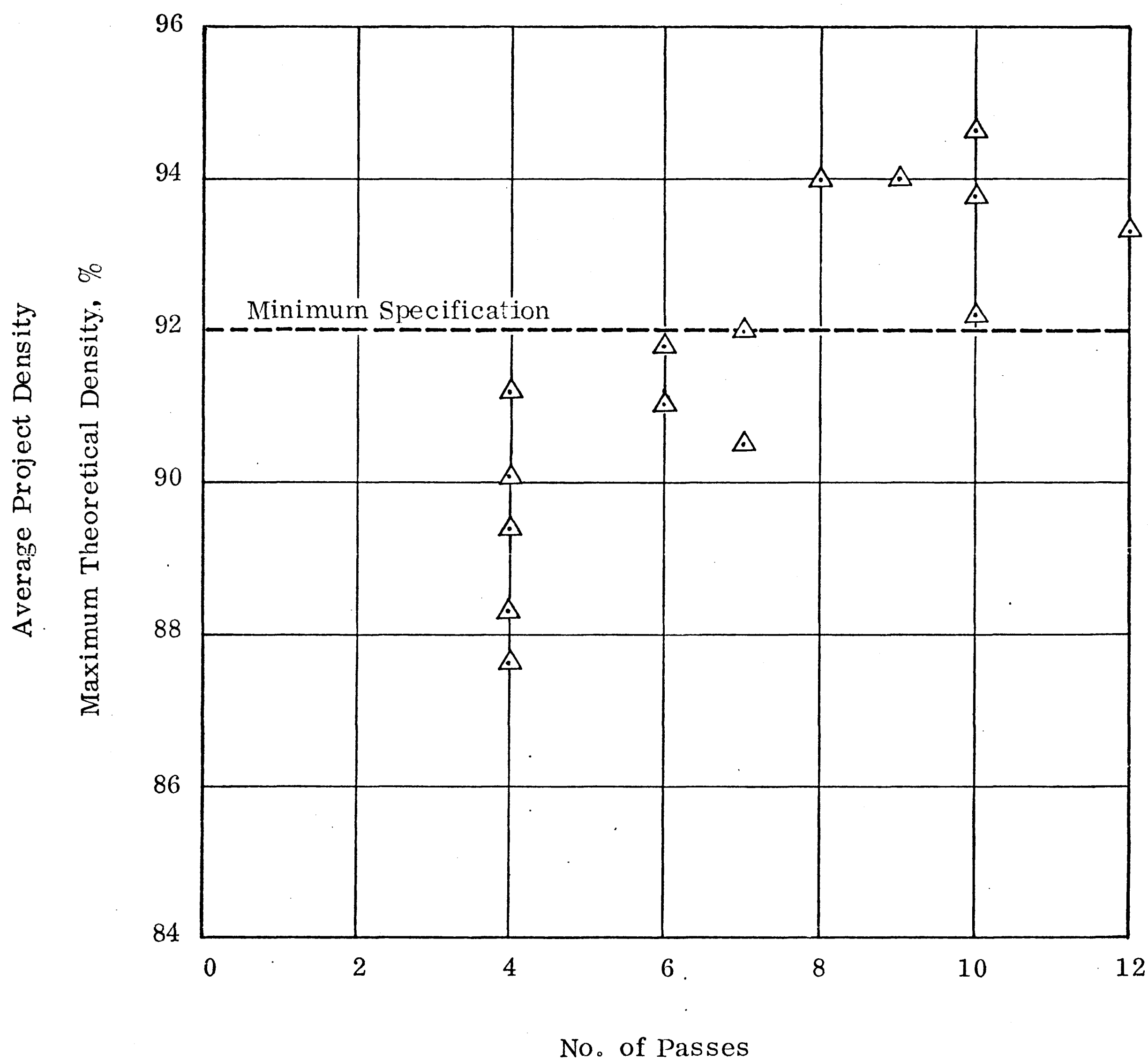

Figure 8. No. of passes vs. density.

Table 3

AVERAGE DENSITY FOR NO. OF PASSES

No. of Passes	Average Density
4	90.1
6	91.1
7	91.5
8	94.0
9	94.0
11	93.3
12	93.3

Absolute Results

It would be desirable to be able to correlate nuclear densities with core densities. This would enable the establishment of an absolute density in the field which could easily be converted to % MTD. In turn, this would allow more flexibility in the specification.

To determine whether or not an absolute density value could be obtained, the nuclear densities were correlated with core densities. Because of the number of gauges involved in the field testing, it was obvious that a meaningful correlation could not be established. A few gauges gave fairly close results; however, many of the older gauges did not produce densities that agreed with the core densities.

This attempt was not carried any further.

RECOMMENDATION

Because of the low density results obtained on maintenance overlays during the 1975 reason, 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 district 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.