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FINAL REPORT

EVALUATION OF NEW ASPHALT CONCRETE DENSITY SPECIFICATION

by

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Research Scientist

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
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the University of Virginia)

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ABSTRACT

The purpose of this investigation was to evaluate a new asphalt concrete density specification that utilizes a nuclear gauge and a control strip technique. The specification was studied on two field projects, and recommendations were made to improve it. The recommendations were to eliminate the correction factor, increase the number of density determinations, adopt a uniform policy in establishing the Marshall density, and provide instruction concerning roller patterns.

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INTRODUCTION

A flexible pavement task force composed of representatives from industry, the Virginia Department of Transportation, and the Federal Highway Administration drafted a new asphalt concrete density specification. This specification was used during the latter part of the 1987 construction season. It is based on one currently used in Florida; however, the task force made some changes that were deemed to be beneficial. It is based on the control strip technique. Although most tests are performed with a nondestructive nuclear density gauge, bulk specific gravity tests are conducted on a few plugs sawed from the control strip to ascertain that a minimum density is being achieved.

Even though the basic specification has been used in Florida, it was changed by the task force, and it was new to Virginia; therefore, the task force asked the Research Council to evaluate it.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the new density specification. Field data were collected from two field projects, and contacts were made with those responsible for enforcing the specification to determine whether there were difficulties.

DESCRIPTION OF SPECIFICATION

The specification, which is contained in Appendix A, is summarized in the following steps.

1. Set up a roller pattern to obtain the maximum density.

2. Measure the nuclear density and plug or core density at 3 locations in the control strip to establish a correction factor.

3. Apply the correction factor to the average of 10 nuclear measurements from the control strip to obtain the target density. The target density must be at least 96 percent of the Marshall density.

4. The average of 5 nuclear measurements from the test section with the correction factor applied must be between 98 percent and 102 percent of the target density to get 100 percent pay.

GENERAL APPROACH

The investigation attempted to determine if the number of tests was sufficient to yield statistically valid results, whether the nuclear densities failed specification criteria when insufficient compaction (high voids) resulted, and whether changes were needed to improve the specification. Comparisons were made between average densities computed from the specified number of tests and average densities computed when additional tests were used (Table 1). Although not required under the specification, density tests were performed on plugs removed from the test section in order to obtain additional information on the degree of compaction being achieved.

Table 1
Tests

Location	Type	Number	
		DOT	Research
Control Strip	Bulk Specific Gravity	3	5
Control Strip	Nuclear	10	10
Test Section	Bulk Specific Gravity	0	5
Test Section	Nuclear	5	10

FIELD INVESTIGATION

Locations

Contractors were allowed to use the new density specification in lieu of the current density specification, which was based on pavement voids. Since the specification was approved rather late in the summer of 1987, it was difficult to locate satisfactory projects; however, two projects were finally located, Route 237 in Arlington and Route 220 in Henry County. Approximately one day's production was evaluated on each project.

Tests

The bulk specific gravity (ASTM Test method D2726) was determined on 4 in x 4 in plugs that were sawed and removed from the pavement, and the density was computed.

Nuclear density tests were performed with a "thin lift" gauge that is designed to measure only the density of the layer being evaluated. A regular nuclear gauge, which reads density 3 to 4 in deep, was also used on the Route 220 project.

Dynaflect tests were planned to determine whether the underlying layers were strong enough to support the compaction of the surface mix but were canceled because of difficult traffic control problems. There were no apparent support problems detected by visual inspection.

RESULTS

Correction Factor

A correction factor was established for each project by subtracting the average nuclear density of three locations from the average plug density at the same three locations in the control strip as follows:

Correction factor = Plug density of control strip
- nuclear density of control strip.

The correction factor was used to compute the target density and the corrected nuclear density of the test section as follows:

Target density = Nuclear density of control strip (10 tests)
+ correction factor.

Test section density = Nuclear density of test section
+ correction factor.

It is evident that the correction factor not only affects the acceptance of the control strip, it also affects the acceptance of the test section; therefore, it is important that the correction factor be precise. The correction factor was calculated using three locations in the control strip as the specification required; but it was also calculated using two additional locations in the control strip (for a total of five) and five locations in the test section. The correction factor should have remained constant if the mix did not change appreciably. Although the correction factor was consistent for Route 220 (-0.1 to -0.6) (see Table 2), it varied from -1.0 to +1.7 for Route 237 (see Table 3). A study by Hogan (1) (see Figure 1) revealed that correction factors can vary considerably on a single project, thereby introducing considerable error in the final density determination. A study in England revealed that the correction factor varies with density; therefore, a single determination would not be applicable at the wide range of densities found in a test section (2) (see Figure 2). If the correction factor was constant, the line of best fit would be parallel to the equivalence line in Figure 2. Use of the correction factor involves a sign manipulation, which also may be confusing to inspection personnel. Because of the inherent variation and possible confusion, the correction factor should be eliminated if possible.

Table 2
Densities and Correction Factors, Route 220

No. of Locations	Plug Density, pcf		Nuclear Density, pcf		Correction Factor	
			Control Strip			
3	147.5		148.0		-0.5	
5	148.3		148.3		0	
10	-		148.3		-	
			Test Sections			
No. of Locations	#1	#2	#1	#2	#1	#2
5	143.1	149.4	143.7	149.5*	-0.6	-0.1
10	-	-	142.8	148.5**	-	-

*Only 3 locations
**Only 6 locations

Table 3
Densities and Correction Factors, Route 237

No. of Locations	Plug Density, pcf	Nuclear Density, pcf	Correction Factor
		Control Strip	
3	134.3	134.8	-0.5
5	133.7	134.7	-1.0
10	-	131.9	-
		Test Sections	
5	134.2	132.5	+1.7
10	-	134.3	-

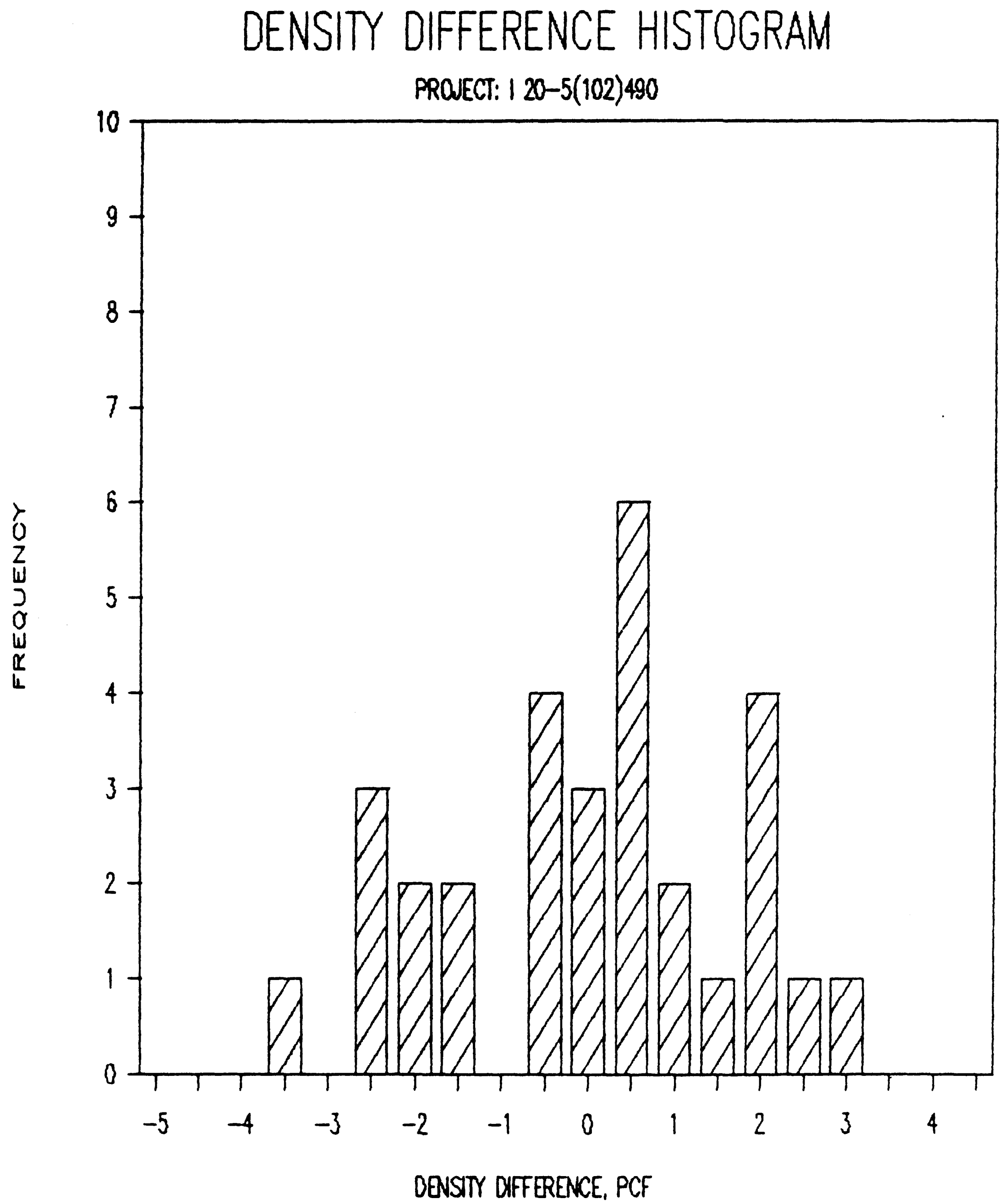

Figure 1. Density difference (correction factor) (1).

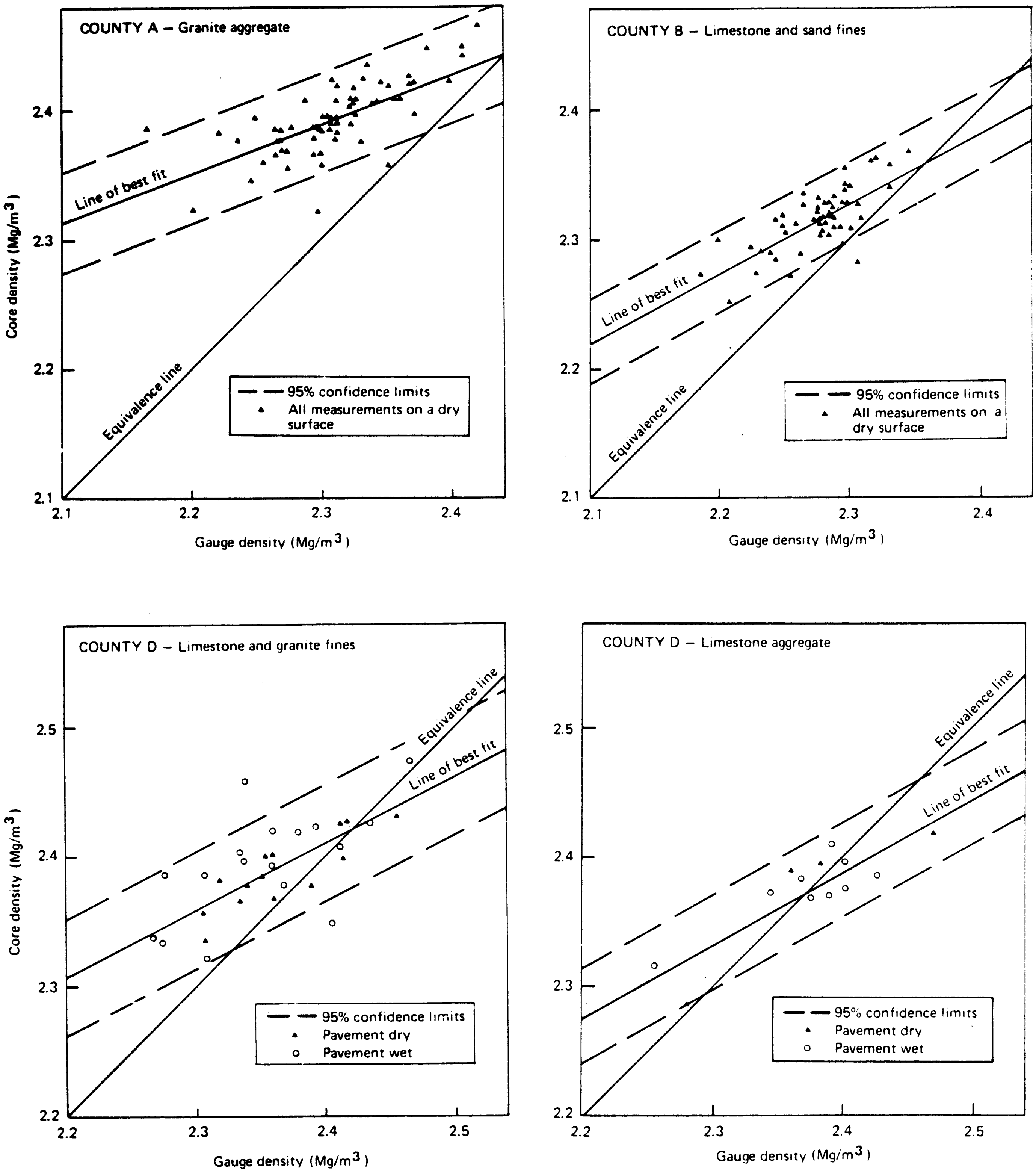

Figure 2. Comparison of core and gauge densities (2).

Density Determinations

The average values of plug densities at 3 and 5 locations are relatively consistent; however, the average nuclear densities at 3, 5, and 10 locations have a larger spread, which was expected (Tables 2 and 3). An investigation by the Transport and Road Research Laboratory (2) revealed that at least 5 cores or 10 nuclear readings are necessary to yield values within 2 percent (3 pcf) of the mean density, which is a reasonable goal. The present practice of using 3 determinations yields a repeatability of approximately ±4 pcf.

Similarly there need to be 10 nuclear tests per test section instead of the 5 specified tests to duplicate a nuclear density repeatability of ±3 pcf. It is the author's opinion that 5 additional nuclear tests would require very little additional time for testing, and the extra effort would be beneficial.

A regular nuclear gauge, which measures the material beyond the surface layer, appeared to yield higher densities than those obtained with the thin lift gauges. The apparent higher densities probably resulted because of the influence of the underlying layers.

Table 4 indicates the percentage of Marshall density that was achieved in the control strips, the percentage of the target density that was achieved in the test sections and voids (VTM) in the test sections. The voids appear to be high on Route 237 and in test section #1 on Route 220. Examination of the acceptance criteria, i.e., that the percentage of Marshall density must be greater than 96 percent for the control strip and test section density must be between 98 and 102 percent of the control strip density, reveals that both of these sections failed one of these criteria; therefore, the method appears to be a good indicator of the compaction level.

Table 4
Densities and Voids

	Route 237	Route 220	
		#1	#2
Marshall density, pcf	145.7	154.4	154.4
Control strip density, pcf (Target density)	131.4	147.8	147.8
% of Marshall density	90.2 (F)*	96.3 (P)*	96.3 (P)
Test section density, pcf	132.5	143.2	149.0
% of target density, pcf	100.8 (P)	96.9 (F)	100.8 (P)
% VTM in test section	14.6	11.2	7.3

*F (fails) or P (passes) criteria

GENERAL OBSERVATIONS

There was some confusion about how to determine the Marshall density that was used to accept or reject the control strip.

When a mix is produced for the first time in a construction season, the only value that is available is the Marshall design density that was approved prior to construction. Once the paving commences, Marshall densities from field samples can be used, provided an adequate number of sets are averaged. A single set of samples should not be used because of variability of the materials, variability of sampling, and inherent testing variability. A uniform policy should be adopted concerning the Marshall density that is to be used.

The contractor was free to choose the location of nuclear density tests, and this freedom allowed the results to be biased. It would be preferable for the inspector to specify where the tests are to be made and also monitor some of the measurements.

Many contractors and inspectors have not had experience recently in setting up roller patterns; therefore, it is suggested that they should be instructed in this.

CONCLUSIONS

Because of excessive variability and the possible error associated with the correction factor, it should be deleted and the control strip acceptance should be based on plug densities. Acceptance of the test sections should be based on using the uncorrected average nuclear density of the control strip as the target density.

The number of plug densities on the control strip should be increased from 3 to 5, and the number of nuclear densities on the test section should be increased from 5 to 10. These changes should result in density determinations that are repeatable within 2 percent (± 3 pcf) in both cases. In order to eliminate bias the inspector should specify where density measurements are to be made.

Contractors and inspectors should be instructed in the use of roller patterns, and a uniform policy should be adopted in the selection and/or computation of Marshall density that is used to accept the control strip.

RECOMMENDATIONS

1. Eliminate the use of the correction factor.
2. Increase the number of plug densities on the control strip from 3 to 5.
3. Increase the number of nuclear densities on the test section from 5 to 10, and have the inspector specify where the measurements are to be made.
4. Adopt a uniform policy in the selection of the Marshall density that is used to accept the control strip.
5. Instruct inspectors and contractors in setting up roller patterns.

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REFERENCES

1. Hogan, Michael C., "Evaluation of the Troxler Model 4640 Thin Layer Density Gauge," Texas State Department of Highways and public Transportation, District 18 Laboratory, June 1987.

2. "Nuclear Gauges for Measuring the Density of Roadbase Macadam: Report of a Working Party," Supplementary Report 754, Transport and Road Research Laboratory, Crowthorne, Bershire, England, 1982.

SPECIAL PROVISION FOR
BITUMINOUS CONCRETE PAVEMENT

Section 320.07 of the 1982 Road and Bridge Specifications is amended to replace the sixth, seventh and eighth paragraphs with the following:

The density of each course, with the exception of patching, leveling and intermediate courses less than 1¼ inches thick, shall be determined by the use of the Nuclear Density Gauge, Troxler, Model 4640 or equal, with printout, using the backscatter method. The gauge shall be furnished and operated by the Contractor. The required density of the completed course shall be at least 98.0 percent and not more than 102.0 percent of the average density of the control strip.

The project will be divided into "control strips" and "test sections" by the Engineer for the purpose of defining areas represented by each series of tests.

Construction of control strips shall be accomplished in accordance with Section 320 of the Specifications.

The term Control Strip Density is the average of ten nuclear determinations selected at stratified random locations on the control strip.

One control strip shall be constructed at the beginning of work on each roadway and shoulder course and each lift of each course. An additional control strip shall be constructed when a change is made in the type or source of material, or compactive equipment, or whenever a significant change occurs in the composition of the underlying pavement structure or the composition of the material being placed from the same sources. Either the Department or the Contractor may initiate an additional control strip at anytime. During the evaluation of the initial control strip, paving operations may continue. However, production shall be discontinued during construction and evaluation of the additional control strips.

The length of the control strip shall be approximately 300 feet regardless of the width of the course being placed. On the first day of construction or beginning of a new course, the control strip shall be started between 500 and 1,000 feet from the beginning of the paving operation. The thickness of the control strip shall be the same as that specified from the course of which it is to be a part. The control strip shall be constructed using the same paving and rolling equipment and the same procedures as those used in laying the asphalt course of which the control strip is to become a part. Every control strip shall remain in place and become a portion of the completed roadway. One nuclear reading shall be taken at each stratified random location. No determination will be made within one foot from the edge of any application width. The average of these ten determinations will be the control strip density read to the nearest 0.1 percent. A correction factor will be developed to correct the control strip density, in accordance with VTM-76, from cores or sawed plugs and in accordance with Table 1 and VTM-22.

If the corrected control strip density meets the requirements of Table 1, the control strip is acceptable and the nuclear control strip density shall be the target nuclear control strip density. If the corrected density does not meet the required density, the Contractor shall change his compactive effort to produce a higher density. The Engineer will evaluate the foundation conditions when an acceptable control strip density cannot be obtained and in the event it is determined that the required density cannot be obtained because of the condition of the existing surface, the Engineer will establish that the rolling pattern producing the optimum density level obtained in the control strip shall be used instead of nuclear density acceptance. All pay adjustment provisions will be waived for that portion of the pavement so identified by the Engineer.

TEST SECTION (LOT)

For the purpose of acceptance, each day's production shall be divided into lots. The standard size of a lot, 5 sublots, shall consist of 5,000 linear feet of any pass made by the paving train regardless of the width of the pass or the thickness of the course. One test within each sublot shall be randomly located. Pavers traveling in echelon will be considered as two passes. When at the end of a day's production or the completion of the project, a partial lot occurs, then the lot size shall be redefined as follows:

If a partial lot contains 1 or 2 sublots with their appropriate test results, then the previous full size lot will be redefined to include this partial lot and the evaluation of the lot will be based on either 6 or 7 sublot determinations. If the partial lot contains 3 or 4 sublots with their appropriate test results, this partial lot will be redefined to be a whole lot and the evaluation of it will be based on the 3 or 4 sublot determinations. Readings shall not be taken within one foot of the edge of any application width. Once the average nuclear density of the lot has been determined, the Contractor will not be permitted to provide additional compaction to raise the average.

Should two consecutive sublots produce density results beyond the ranges listed in Table 2, the Contractor shall take appropriate corrective action to include cessation of production, if necessary and shall notify the Engineer of the entire situation, as soon as possible.

BASIS OF PAYMENT

Payment will be made in accordance with Table 2 except that payment for those thicknesses less than the values listed in column "T", Table 1, shall not be adjusted.

TABLE 1

Density Requirements

Mix Type	Thickness, T, in.**	Density	Minimum Control Strip Density %
S-3		N	
S-4		N	
S-5	1¼	Y	96
S-5 Mod.	1¼	Y	96
S-6	1¼	Y	96
S-7	2	Y	96
S-9	1½	Y	96
S-10	1½	Y	96
S-10 Mod.	1½	Y	96
I-2	1½	Y	96
No. VA S-5 Mod.	1¼	Y	96
B-3		*	96

Note: Y - Corrected Nuclear Density Required, Percent of Marshall Lab Density

N - Compaction will be accomplished by standard rolling pattern

* - Density required only when specifically required by contract documents; otherwise, compaction will be accomplished by standard rolling pattern.

** - See Basis of Payment

TABLE 2

Payment Schedule for Density

Percent of Target Nuclear Control Strip Density	Percent of Payment
Less than 96.0	75
96.0 to less than 97.0	90
97.0 to less than 98.0	95
98.0 to 102.0	100
Greater than 102.0	95