Compaction Control of Granular Base Course Materials by Use of Nuclear Devices And a Control Strip Technique

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In an attempt to overcome some of the problems encountered in the compaction control of granular base materials through conventional methods, Virginia has recently developed a new approach. A control strip is constructed by the contractor, a density standard is established through nuclear moisture-density testing, and this standard is used as the basis for controlling the compaction of other sections built with like material. The method has proven to be very satisfactory on three projects, and will be used on eight more that are now ready for advertisement.

•IN MOST conventional methods of compaction control of granular base course materials, some weak points exist. These can be summarized briefly as follows:

1. Tests are time-consuming. The conventional method of digging a test hole, determining the weight and moisture content of the material removed, and the volume of the hole is tedious and time-consuming. This can impede construction.

2. Maximum density must be determined in the laboratory. The determination of the maximum density of the fine portion of a base course material is relatively simple. However, when the material contains an appreciable amount of coarse fraction, a correction is necessary. No single method for determining the correction factor is widely accepted.

Laboratory compaction tests for the total sample are available; however, they are not widely used because inclusion of the coarse fraction necessitates the use of relatively large molds and introduces such factors as degradation and wall friction.

The values obtained by both the use of correction factors and tests on the total sample have been questioned in some cases because they have not been obtainable in the field regardless of the amount of compaction effort.

3. Methods give a poor estimate for acceptance or rejection. Since conventional tests are time-consuming, one value is taken to represent a large volume of material. This one value provides a poor estimate on which to base acceptance or rejection, because high variability might exist.

It is not the intention of the authors to condemn conventional tests on the basis of the weak points summarized, but rather to note that the method offered in this paper can overcome these inadequacies because of the following features:

1. Nuclear tests can be made quickly and easily;
2. A field control strip provides a practically achievable density; and
3. The speed of nuclear testing permits determinations to be made for each section of material, which provides a sound statistical basis for decision making.

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GENERAL PROCEDURE

The Control Strip Technique

The control strip technique is by no means a new concept. It has been used by some states, notably Ohio, for many years. In general, the technique involves the construction of a control strip of the material at the job site. This is achieved by selecting an area on a firm subgrade or subbase and rolling it in increments of compactive effort with equipment of a specified minimum weight, and with the material at optimum moisture content as determined in the laboratory and corrected for the coarse fraction. To obtain a roller pattern, density tests are performed after each rolling until no further increase in density is detected.

The completed control strip becomes a part of the construction and the rest of the project is controlled in larger "test sections" in each of which the density must be a certain percentage of that of the control strip. In these test sections, however, neither the moisture content nor compaction equipment is controlled by the enforcing agency. Failure to achieve the required density within a section means additional rolling and retesting. A new control strip is required when a change in material is detected. The whole technique is predicated on the fact that the gradation of the material remains within specified limits.

Use of Nuclear Equipment

In both the construction of the control strip and the testing of the test sections, a number of determinations sufficient for providing the desired accuracy are required. This means that several density tests must be made. Conventional density tests are too time-consuming and therefore not practical for this purpose. Nuclear methods, on the other hand, being quite rapid, can be used successfully (1-min moisture and 1-min density readings constitute a test in this procedure). Any sufficiently sensitive calibration curve can be used since any effects from chemical composition, surface texture, etc., encountered in the test section have been encountered in the control strip. However, since this method is nondestructive, if "crusting" occurs, that is, if there is a greater density on top than on the bottom, it can be passed undetected.

Specific Procedure

Rolling Pattern—The roller pattern is obtained on the control strip, a 300-ft section of one-lane roadway. Figure 1 shows a typical roller pattern after each pass of a vibratory roller. Each point is the average of three tests taken on the control strip. This figure shows that the maximum attainable dry density was about 139 pcf and that it occurred after eight passes with the roller.

Control Strip—In order to obtain a very good estimate of the dry density of the control strip after the maximum density has been reached, ten random moisture and density tests are run. This number of tests provides a very good indication of the dry density of the material, and a percentage of this figure is used to determine compaction compliance on the remaninder of the project.

Test Section—Each 2000 ft of one-lane roadway is then designated as a test section. Each section is tested randomly at five locations. From a statistical analysis, it has been found that the average of these five tests should be at least 98 percent of the average obtained on the control strip, and each individual test value should be at least 95 percent of the average control strip density.

EXPERIENCE GAINED

Experimental Project

During the summer of 1964 the compaction of the aggregate base course of a project on Route 6 in central Virginia was constructed using the control strip technique with the nuclear equipment and then the level of compaction checked by conventional procedures.

Experience on this project indicated that the control strip technique way as sensitive as the conventional procedures. Furthermore, the conventional density tests run indi-

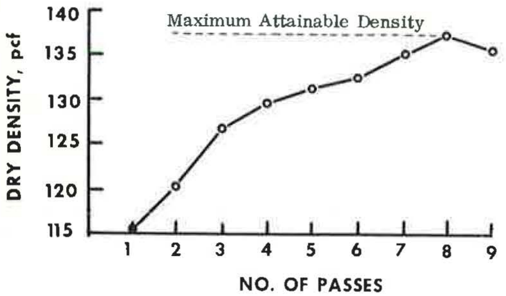


Figure 1. Roller pattern, vibrations roller.

cated that the compaction level achieved was equal to or above that desired. This initial work indicated that both the contractor and testing personnel were satisfied with the method.

Additional Projects

Encouraged by the results of the work done on Route 6, three more projects were let using the control strip technique for compaction control. Two of these projects have been successfully completed and one is well under way. No major difficulties have been encountered thus far.

As an indication of the type of data obtained on these projects, Appendix A, which includes typical data for roller pattern, control strip and test section, was prepared.

Current Status

As experience is gained with this technique and funds become available for the purchase of additional nuclear gages, more projects are being advertised using this technique. This past fall eight more projects, one in each construction district of the Virginia Department of Highways, were let to contract. The special provision governing the use of this technique is shown in Appendix B.

SUMMARY

The method described in this paper has several advantages and some disadvantages as compared to conventional test methods.

Advantages

1. The use of nuclear methods results in a better estimate of the variability because the data lend themselves to statistical analysis;
2. No laboratory test for density is required;
3. No correction for gradation of the material is required;
4. Testing is physically easier and more rapid;
5. Any calibration curve can be used with nuclear devices as long as the sensitivity of the curve is adequate; and
6. Psychological advantages exist for contractor and testing personnel since for the project the contractor is asked only to achieve a certain percentage of the density he has achieved in the control strip.

Disadvantages

1. Since the method is nondestructive, the distribution of density throughout the base course cannot be detected. If crusting occurs, it can be passed undetected. (There has been no indication that crusting is actually a problem and this condition should not occur when proper equipment is used.)
2. The cost of nuclear equipment is much higher than that of conventional equipment. If, however, one realizes the higher level quality control achieved with the same amount of time, then the initial price difference can be tolerated.

In conclusion, it can be said that, based on the experience gained within the last few years, the use of the control strip technique with the nuclear devices can be very successful and is recommended. It is apparent to the authors that this system has certain disadvantages, but these are far outweighed by its advantages.

Appendix A

ROLLER PATTERN

Date 7-18-66 | Project 0029-039-101 6501

Section No. Roller pattern #3 | Sta. 826 + 50 to Sta. 829 + 50

Type Material SBM-1 | Width 26' Remarks: 6" deep

Standard Count

Density	Moisture
60982	9300
60967	9362
61497	9608
61549	9550
Total 244995 Average 61249	Total 37820 Average 9455

Test 1 — after 3 passes with vibratory roller

Station	Density	Moisture
826 + 75	38270	4094
827 + 50	39295	4137
828 + 25	38550	4009
Total	38705	4080
C.R.	.632	.431

Test 2 — after 6 passes with vibratory roller

Station	Density	Moisture
826 + 75	35077	4579
827 + 50	37190	4280
828 + 25	35871	4368
Total	36046	4409
C.R.	.589	466

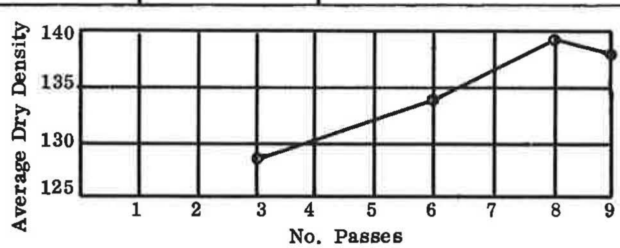
Test 3 — after 8 passes with vibratory roller

Station	Density	Moisture
826 + 75	36602	4571
827 + 50	36212	4246
828 + 25	34826	4383
Total	34880	4400
C.R.	.569	.465

Test 4 — after 9 passes with vibratory roller

Station	Density	Moisture
826 + 75	35423	4406
827 + 50	36494	4227
828 + 25	33770	4500
Total	35229	4378
C.R.	.587	.463

Test	Wet Density —	Moisture =	Average Dry Density
1	137.3	8.0	129.3
2	144.0	9.2	134.8
3	146.8	9.1	137.7
4	144.5	8.6	135.9



CONTROL STRIP DENSITY

Date 7-26-66 Project 0029-039-101-6501

Type Material SBM-1

Sta. 826 + 50 to Sta. 829 + 50 Width 26'

Depth 6"

Standard Count

	Density				Moisture	
	61240				9459	
	61207				9505	
	61310				9592	
	61105				9591	
Total	244862	Mean 61216		Total	38147	Mean 9536

	Test	Station	Density	Moisture
	1	826 + 50	33039	4765
	2	826 + 65	36687	4747
	3	826 + 80	32133	4603
	4	826 + 95	34874	4604
	5	827 + 10	35770	4678
	6	827 + 25	34275	4532
	7	827 + 40	34436	4595
	8	827 + 55	33775	4724
	9	827 + 70	34637	4666
	10	827 + 85	34710	4860
Total			344336	46774
Mean			34433	4677
C.R.			.562	.490

Wet Density 147.5 — Moisture 11.0 = Dry Density 136.5

Dry Density Requirement

(.98)	(136.5)	= 133.8	= Mean Density Requirement
(.95)	(136.5)	= 129.7	= Individual Density Requirement

TEST SECTION DENSITY

Date 7-27-66

Project 0029-039-101 6501

Section No. 12

Sta. 796 + 50 to Sta. 814 + 50

Type Material SBM-1

Width 13' Rt.

Remarks 6" Deep

Standard Count

	Density			Moisture	
	61099			9538	
	61046			9458	
	61027			9540	
	61227			9547	
Total	244399	Mean 61100	Total	38083	Mean 9521

Test	Station	Density	Moisture
1	796 + 50	35118	4709
	C.R.	.575	.495
2	798 + 50	35158	4444
	C.R.	.575	.467
3	800 + 50	35196	4612
	C.R.	.576	.484
4	802 + 50	33448	4701
	C.R.	.547	.494
5	804 + 50	36139	4841
	C.R.	.591	.509

Sample	Wet Density −	Moisture =	Dry Density	Requirement	Passing
1	145.8	11.2	134.6	129.7	✓
2	146.0	10.2	135.8	129.7	✓
3	146.0	10.8	135.2	129.7	✓
4	150.0	11.2	138.8	129.7	✓
5	143.5	11.7	131.8	129.7	✓
Mean			135.2	133.8	✓

Appendix B

VIRGINIA DEPARTMENT OF HIGHWAYS
SPECIAL PROVISIONS FOR
NUCLEAR FIELD DENSITY TESTING OF
AGGREGATE BASE AND SURFACE COURSES

February 23, 1965
Rev. 10-19-66

Section 308 of the 1966 edition of the Road and Bridge Specifications is amended in this contract to require the construction of density control strips for the purpose of using the nuclear field density testing device. The revisions are as follows:

At the beginning of the work the Contractor shall build a control strip of the material on an approved and stable subgrade for the purpose of the Engineer's determining density requirements for the project. This control strip will be at least 400 square yards in area and of the same material and depth to be used in the remainder of the work. Compaction will be carried out with conventional rollers approved by the Engineer until no appreciable increase in density is accomplished or until in the opinion of the Engineer no appreciable increase in density will be obtained by additional rolling. Upon completion of the rolling, the density of the strip will be determined by use of a portable nuclear test device.

The compaction of the remainder of the aggregate base course material shall be governed by the density of the control strip. The material shall be tested by sections of approximately 2800 square yards each. The mean density of 5 randomly selected sites from the test section shall be at least 98 percent of the mean density of 10 tests taken from the approved control strip. Placing, compacting and individual testing may be done in subsections of approximately 280 square yards each. When the mean of the test section is less than 98 percent of the control strip mean, the Contractor may be required to rework the entire section. Also, each individual test value shall be at least 95 percent of the mean value of the control strip. When an individual test value is less than 95 percent of the control strip mean, the

Contractor shall be required to rework the area represented by that test.

Each test section shall be tested for thickness and any deficiency outside the allowable tolerance shall be corrected by scarifying, placing additional material, remixing, reshaping and recompacting to the specified density.

A new control strip may be requested when:

(1) A change in the source of the material is made, or

(2) a change in the material from the same source is observed, or

(3) ten (10) test sections have been approved without the construction of additional control strips.

Note: The Contractor's attention is directed to the fact that the method for determining density and the requirements for density as described in Section 308.05 have been replaced by the method of determination and requirements for density stated hereinabove.