# FINAL REPORT

# PROBLEMS IN ACHIEVING DENSITY IN ASPHALTIC CONCRETE

by

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Research Engineer

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

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# ABSTRACT

This investigation was undertaken in an attempt to identify the causes of low densities in asphaltic concrete placed on 9 projects. The most prevalent cause, which accounted for the difficulties on 5 of the 9 projects, appeared to be improper mix design and/or variability within the aggregate. The use of travel speeds in excess of that specified for the rollers employed was the second most prevalent cause of trouble.

Means by which field personnel can determine the causes of low densities are given in the report.

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## INTRODUCTION

Highway engineers generally agree that the density of asphaltic concrete has an influence on its resistance to weathering and traffic wear. A low density can adversely affect the quality and service life of the highway.

Recently, increased emphasis has been placed on obtaining the required field density of asphaltic concrete, particularly on maintenance overlays. Proper compaction has been emphasized at the Virginia Department of Highways and Transportation inspectors' schools, and a density specification for maintenance overlays which is in the developmental stage states that the contractor will be paid according to the density achieved.

If there are repeated problems with compaction, it is advantageous to identify their causes.

## PURPOSE

The purpose of this study was to examine paving projects with reported low densities so as to identify the likely causes of the failure to obtain higher densities and suggest improvements.

## PROCEDURE

Each state district materials engineer was contacted in May 1978 and asked to notify the author of any problems being encountered in attaining the required density in asphaltic concrete on new construction and maintenance overlays. Problems were reported on six projects from four highway districts. In addition, problems on three projects were revealed through a current study on the influence of additives on compaction. The following steps were taken in an attempt to identify the causes of the problems on these nine projects.

1. The paving and rolling procedures were observed to detect any improper practice such as rolling faster than the recommended 3 mph speed.

2. In the case of vibratory breakdown rollers, a check was made to see if the proper vibration frequency was being used.

3. A roller pattern was obtained with a nuclear density gage and the density of a plug cut from the test strip was measured to determine if the optimum number of roller passes produced an acceptable density.

4. A sample of plant mix was taken, 50-blow Marshall specimens were made in the lab, and the density and voids were computed. As a rule of thumb, the achievable pavement density is 95% of the Marshall density. A survey of compaction practices revealed that 14 states require a minimum pavement density of 95% of the laboratory Marshall density.(1)

## RESULTS

Difficulties in achieving the required density were reported for the paving projects listed in Table 1, all of which called for the placement of an S-5 surface mix. The projects on Routes 612, 24, and 460 were being monitored in a study of the effects of additives on compaction, but the results have been included in this report because of the low densities.

(1) "State of the Art: Compaction of Asphalt Pavements", Special Report 131, Highway Research Board (1972).

Table 1

Summary — Compaction Problems and Recommendations

| District | Route | Problem | Observations, Recommendations |
|---|---|---|---|
| Culpeper | 17 | Low density | Change mix design. |
| Culpeper | 612 | Low density | Change mix design. |
| Lynchburg | 24 | Low density | Change mix design. |
| Richmond | 85 | Low density and tender mix | Density was satisfactory; tenderness caused by materials. |
| Richmond | 460 | Low density | Change mix design. |
| Salem | 77 | Low density | Decrease in travel speed of vibratory roller. Sufficient density was achieved. |
| Salem | Ramps 581 | Tender mix Low density | Mix was "pushing" after optimum number of passes. Reduce rolling. |
| Staunton | 64 | Low density Tender mix | Change mix design. |
| Staunton | 259 | Low density | Error in density determinations. |

## Culpeper District — Route 17

Densities less than 90% of the maximum theoretical density (MTD) were reported. Upon arrival on the job, the writer checked the speed and frequency of the vibratory breakdown roller and found the latter to be approximately 2,000 vpm, which is usually satisfactory. However, after consultation with a representative of the roller manufacturer, the paving superintendent decided to lower the frequency to 1,450 vpm the next day in an effort to attain a higher density.

A roller pattern obtained with a nuclear density gage indicated an optimum compactive effort of approximately 6 passes. A plug sawed from the control strip revealed a density of 88% MTD. The density of Marshall specimens made from the plant mix was only 93.1% MTD; therefore, 95% of the Marshall density, or approximately 88% MTD, could be expected in the field. Also the voids total mix in the Marshall specimens were greater than the 3% to 6% value allowed in Virginia specifications. The problem was caused by the mix design or a change in materials.

## Culpeper District — Route 612

On this project an approximately 0.43-lane-mile section was paved with a mix containing an additive and a 0.38-lane-mile section with a mix containing no additive to determine the effect of the additive on the compaction of asphaltic concrete. Marshall specimens made from the plant mix of both sections averaged 94% MTD; therefore, the density that could be expected in the pavement was 0.95 x 0.94 = 89% MTD. The density of 20 cores, 10 from each section, was 87% MTD. It was observed that the breakdown roller speed was faster than the 3 mph recommended speed,[2] and although the density could have been improved slightly by using a slower rolling speed, the mix could not have been compacted to the required 92% MTD.

The low densities appeared to be primarily related to the mix design; however, some improvement could have been made by decreasing the roller speed.

## Lynchburg District — Route 24

This project, like the previous one, was originally monitored for the study on the effect of additives. Approximately 1.4 lane miles of a mix with no additive were placed along with 1.6 lane miles of a mix containing an additive. Twenty cores, 10 from each section, averaged 87.8% MTD. Marshall specimens made from the plant mix with and without additive averaged 93.1% MTD; therefore, the density that could be expected in the pavement was 0.95 x 0.93 = 88% MTD. The percent voids in the Marshall specimens was greater than the 3% to 6% value allowed in Virginia specifications. The low densities appeared to be related to mix design as indicated by the high voids in the Marshall specimens.

## Richmond District — Route I-85

The contractor reported problems in obtaining the required density when placing the S-5 mix at a rate of 170 psy on Route I-85 south of the Petersburg city limits. A vibratory breakdown roller and tandem finish roller were used to compact the mix.

Previous results had indicated an acceptable average compaction of 92.5% MTD; however, the contractor's main concern was some low values of approximately 88% MTD.

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(2) "Asphalt Technology and Construction — Instructor's Guide", Educational Series No. 1 (ES-1), The Asphalt Institute (January 1971).

The mix exhibited tenderness and pushed in front of the roller after several passes. A roller pattern was obtained with a nuclear density gage but plugs sawed from the control strip yielded only 89% MTD. A sample of plant mix was obtained from a truck and compacted into Marshall specimens in the lab. The resultant density was 95.4%; therefore, 0.95 x .954 = 91% could be expected in the pavement.

Although there were some problems with the mix being tender, the density was acceptable. The variability in the density values was slightly high and included several low values which concerned the contractor. The tenderness of the mix was probably caused by a change in the gradation and/or a high sand content, because it was discovered that the mix design had been changed at the plant with no notification of road personnel.

## Richmond District — Route 460

This study, which also was monitored in the study of additives, consisted of two 0.33-lane-mile sections of mix, one section with an additive and the other without. Marshall specimens made from the plant mix with and without additive averaged 94.5% MTD; therefore, the achievable density in the pavement was approximately 0.95 x 0.945 = 90% MTD. The average density of 24 cores was 90.2% MTD. The density problem appeared to be related to the mix design.

## Salem District — Route I-77

Research Council personnel did not investigate this problem because it was solved and corrected by district personnel. The low densities were caused by the vibratory rolling being performed at too fast a speed. When the roller was slowed to a proper operating speed of 2-3 mph, a satisfactory density was achieved.

## Salem District — Route I-581 Ramps

The district materials personnel reported a tender mix and low densities (90%-92% MTD). The paving contractor was working under the requirement that each ramp could be closed to traffic no longer than 2 hours. This requirement necessitated that the rollers stay very close to the paver and that the paving progress at a steady pace. A three-wheel, steel breakdown roller and a tandem finish roller were used.

Observation of the paving operations indicated that the mix was stable under the first 5 or 6 passes of the breakdown roller, but became tender and unstable when additional passes were applied. A roller pattern indicated that 5 passes provided the maximum density; however, more passes were being applied. Samples were sawed from the pavement at two locations that had received different compactive efforts. The sample that had received 5 passes of the breakdown roller had 93.4% MTD and the sample that had received more than 5 passes yielded 91.5% MTD.

It was recommended that no more than 5 or 6 passes of the breakdown roller be applied.

## Staunton District — Route I-64

District personnel reported densities less than 90% MTD the day of the investigation; however, most of the previous densities had been satisfactory (92%-94% MTD). The rate of application was 125 psy and although night temperatures were rather cool (September 27, 1978), the ambient temperature was 70°F the day of the observation. The contractor had discontinued use of a vibratory roller because of mix tenderness and a three-wheel steel roller and tandem finish roller were used during the investigation. The mix was observed to be pushing after about 6 passes of the breakdown roller.

A roller pattern obtained with a nuclear density gage indicated an optimum of 6 passes of the breakdown roller, and a section of pavement sawed from the control strip yielded a density of 88% MTD. Marshall specimens made from the plant mix yielded 93.8% MTD. As stated previously, the density that can be expected in the pavement is 95% of the Marshall density, which in this case was 89%. The proportions and/or gradation of the aggregate had apparently changed enough to result in low densities. It was recommended that the mix be redesigned.

## Staunton District — Route 259

Upon arriving on the job, the writer discovered that the problem of low density had been solved the previous day by district personnel. Faulty scales had apparently resulted in erroneous results and the equipment had been replaced. A section sawed from the pavement showed 95% MTD.

## SUMMARY

The low densities investigated can be attributed to either —

1. the mix designs,
2. rolling techniques, or
3. faulty measurements of density.

Inadequate mix designs or variabilities in materials caused the problems on 5 of the 9 projects. Although the mix could have been designed properly originally, a change of the aggregate and/or gradation could have resulted in a mix that could not be compacted to the required 92.5% MTD in the pavement. The field Marshall test should be used to determine if a mix changes or if the required density is achievable. A general rule of thumb is that 95% of the Marshall density can be achieved in the pavement if proper construction techniques are used.

The second most prevalent cause of the problems was improper rolling techniques. Vibratory and static breakdown rollers should not be operated faster than 3 mph. The vibration frequency generally should be 1,400 to 1,800 vpm for base mixes (thick lifts) and 1,700 + vpm for surface mixes (thin layers). A roller pattern should be established for a new mix and rerun when the mix or compaction equipment changes. If density problems are encountered, the inspector can spot-check to determine if the proper number of passes are being applied. As observed on one project, it is possible for a mix to push after the optimum number of passes have been applied, but the occurrence of this phenomenon is unusual.

Field and lab density measurements should be made on several samples to ascertain if the field measuring equipment is operating properly.

## RECOMMENDATIONS FOR CHECKING LOW DENSITIES

1. If the density is measured in the field, recheck several cores in the district lab to ascertain if field measurements are valid.
2. Check Marshall densities of samples made from mix taken at the plant to determine if the required density is achievable. Periodic checks will also ensure that the mix is not changing.
3. Check travel speed of breakdown roller and, if vibratory roller is being used, its frequency. A vibrometer can be used to check the frequency.

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