Investigation of the Interrelationship Between Base Pavement Stiffness and Asphalt Overlay Compaction

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The degree that base pavement support influences the compactibility of an asphaltic concrete (AC) overlay was determined. As a secondary objective, the FAA Eastern Region in-place air voids compaction standard was compared with the FAA National percent Marshall density compaction standard. Field data were collected on three paving projects in FAA's Eastern Region. Nondestructive testing (NDT) was used to quantify the stiffness of base pavements before construction of overlay. After overlay construction, the unit weights of the asphalt overlays were determined at the same locations at which NDTs were performed, and in-place air voids and percent Marshall densities were computed. Statistical techniques were used to investigate correlations between stiffness and AC density (i.e., unit weight, in-place air voids, and percent Marshall density). Although a mild correlation between stiffness and density was found at one project, no general trends were detected for the other projects or from regression analyses performed on combined data bases. This finding may suggest that base pavement stiffness is not a primary variable in affecting overlay compaction on airport pavements; however, the effect of stiffness may have been masked by other external variables, such as temperature, rolling, mix properties, or quality control. Finally, apparent inconsistencies in acceptable quality level and payment were observed between FAA Eastern Region and FAA National density acceptance plans. A follow-up study was initiated by FAA to evaluate the basis both of Eastern Region and National acceptance plans for AC. Recently completed, the new study made definitive recommendations for both acceptance plans with regard to (a) acceptance requirements; (b) quality control requirements; (c) acceptance limits for air voids, stability, flow, and density; and (d) a payment adjustment plan for density.

Because of the high tire pressures and gross wheel loads of modern aircraft, airport pavement construction requirements are necessarily more demanding than those for road construction. This is especially true of asphaltic concrete (AC), both in terms of material and compaction requirements. Highway specifications vary from state to state with respect to AC compaction, but the FAA P–401 specification (*1*) requires AC to be compacted to a target density of 98 percent of 75-blow Marshall density for air carrier airports.

A statistically based acceptance procedure for AC was incorporated into the FAA P–401 specification, and payment adjustment factors were specified for various levels of noncompliance with the density standard. The use of a prescribed acceptance procedure tended to make the specification more enforceable, especially in terms of assessing reduced payments for material not complying with the specification.

Although these acceptance procedures may have heightened contractor awareness of the need for meeting the compaction standard, they also resulted in concern that achieving the standard may not always be possible. Contractors and engineers were particularly concerned that the density requirements would be overly restrictive for overlays on existing pavements that were either extremely weak or variable, which was reportedly the case at many smaller general aviation or commuter airports.

In his study on field compaction of bituminous mixes (*2*), McLaughlin identified 14 parameters that affect pavement compactibility. Of these, high stability, low material temperature, improper equipment, testing error, and weak support systems were found to be at fault most often.

Although contractors generally disagree on the effect of process control on lack of compaction, their most common view is that lack of compaction is usually caused by weak or yielding pavement layers. Proof rolling has been attempted before placement of asphalt overlay to identify areas that could be exempted from the compaction standards, but the results have been inconclusive because of the subjective nature of this process. With many thousands of dollars at stake, as well as the future serviceability of a rehabilitated pavement system, it is generally agreed that a more objective quantitative evaluation process is required.

Although the effect of base pavement support on asphalt compactibility does have intuitive appeal, there is no general agreement that it is a primary variable in influencing the compaction of an AC overlay. FAA has argued that, in developing the acceptance limits for P–401 density, a wide variety of support systems were examined (*3*,*4*). According to FAA, this resulted in the choice of an acceptable quality level (AQL) for asphalt density, which addressed not only the needs of the FAA, but also the condition of the base pavement and the capabilities of the industry.

With nondestructive testing (NDT) generally recognized as a valid analytical tool for pavement evaluation, it was believed that NDT could be used to objectively determine whether base pavement stiffness affects asphalt compaction and, if so, to what extent. If the stiffness of the support system does affect compaction, then it was hoped that a limiting pavement stiffness could be established. Below this limiting stiffness, a lesser density standard, or a methods specification, could then be applied.

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OBJECTIVES

As explained, the basic objective of the research was to determine the degree, if any, that base pavement support influences the compactibility of an AC overlay. If pavement support was found to affect overlay compaction, and, if that effect could be quantified, then a limiting support condition would be determined below which consideration could be given to modifying the current P-401 density standard.

In order to achieve these objectives, NDT was used to quantify preoverlay pavement support conditions. Because primary FAA guidance on NDT involves use of the dynamic stiffness modulus (DSM) (*5,6*), pavement support was defined as the DSM at a particular test location.

As required by FAA, asphalt compaction is defined as the percent of daily Marshall density of field cores. For this study, to allow for economical acquisition of a large data base without operational disruption of or damage to the new pavement surface, the field unit weight of the overlay was determined by nuclear density testing. Any required calibration of the nuclear density device was accomplished through correlation with core density samples.

To accomplish the basic objectives of the study, specific procedures were determined as follows:

1. NDT was performed at three airports in FAA's Eastern Region to obtain data on pavement support conditions before construction of programmed overlays. The NDT program was designed to obtain data for DSM computation and for possible future layered elastic analyses. Approximately 100 tests were performed at each location, within 1 or 2 days of the scheduled overlay.
2. Daily production Marshall and maximum theoretical density (by the Rice method) test results (performed by others) were used to develop a reference data base for compaction computations. Normally, the Eastern Region specification requires four Marshall tests (with specimens compacted at 250°F) and two Rice tests daily.
3. After completion of the overlay, nuclear density testing was performed at the same locations as the NDT tests to determine the unit weights and relative density of the overlays. Several cores were also taken at NDT locations at each airport to establish a core density data base and for correlation of the nuclear density device. Because FAA's Eastern Region uses in-place air voids as its compaction standard (*7*), the unit weights were also used to determine both the percent Marshall density and the in-place air voids at each location.
4. Linear and nonlinear regression analyses were performed to determine whether a correlation between DSM and asphalt density (i.e., percent Marshall density or in-place air voids) exists and could be quantified.
5. The existence of a limiting base pavement stiffness (i.e., DSM) was investigated, below which acceptance procedures other than those currently in use could more aptly apply.
6. Construction acceptance test data were collected to evaluate mix properties or other variables that may have influenced compaction.
7. Although not originally envisioned as part of the research, the collection of data both on percent Marshall density and in-place air voids enabled a comparison of the two compaction standards.

PROJECT DESCRIPTIONS

For field data acquisition, three candidate airports were selected in FAA's Eastern Region. In selecting sites, an attempt was made to obtain data at airports having relatively weak and stiff support conditions, with differing base pavement thicknesses and subgrade soils. Also, because most compactibility concerns had to do with overlay construction, initial candidate sites were limited to those that had overlay construction.

After consultation with FAA, the following projects were identified for field data collection:

- Teterboro Municipal Airport—Runway 1–19 overlay;
- Leesburg Municipal Airport—parallel taxiway overlay; and
- Ocean City Municipal Airport—apron overlay and parallel taxiway extension.

DATA COLLECTION

At each project, field data collection consisted of the following:

1. Assembling contract documents (i.e., plans and specifications),
2. Laying out nondestructive and density test locations using reproducible control points,
3. Performing NDT before overlay construction,
4. Assembling acceptance and quality control test results (performed by others) as required by the FAA Eastern Region P-401 specification,
5. Performing density tests at previously referenced NDT locations after overlay construction, and
6. Obtaining core density test data (performed by others) at selected nuclear test locations for calibration of nuclear test devices.

Nondestructive Testing

Because FAA guidance on NDT references the DSM using a vibratory test device (*5,6*), this control test was used for the correlation analysis. In normal practice, the primary purpose of NDT is to determine the dynamic properties of pavement systems for design. However, for this study, NDT was used to determine the stiffness of various pavement structures before receiving an overlay.

The NDT equipment (dynamic loading system) used for the testing program was designed to generate a dynamic load on the pavement surface and to measure the resultant vertical response of the pavement system, including subgrade, base courses, and surface layers. The equipment includes a microcomputer, which allows rapid data processing during testing. The reliability and repeatability of the dynamic loading system and NDT procedures in general have been demonstrated in several studies (*8–10*).

The equipment generates a dynamic load over a broad frequency range and has the following performance features:

Vibratory force range	500 to 10,000 lb
Impulse force range	5,000 to 25,000 lb
Frequency range	3 to 100 Hz

The DSM (or load sweep) test procedure (*5,6*) is conducted in the vibratory mode at 15 Hz at two force levels, with the DSM defined as the slope of the resulting load-deflection curve.

For asphalt pavements, the DSM at test temperature is adjusted to the DSM at standard 70°F for pavements with asphalt 3 in. thick or more (e.g., Leesburg and Teterboro), using the procedures detailed in the references. For regression analyses (described in a later section), both temperature-adjusted and temperature-unadjusted DSMs were used. To minimize the effects of NDT variance, each test was performed twice at each test location with the results averaged for the regression analysis.

Nuclear Density Testing

Nuclear density tests were performed at NDT locations within 1 to 2 weeks after overlay construction. Test points were carefully located to be as close as possible to the NDT locations.

At each site, nuclear density tests were performed with a Troxler 3411–B nuclear density device used in the backscatter mode. According to manufacturer's recommendations (*11*), backscatter tests were performed at the same locations both before and after overlay construction to factor out the effects of the base pavement unit weight in measuring the unit weight of the relatively thin overlays. The density tests with the Troxler 3411–B were performed by averaging four 15-sec tests, with the gauge rotated 90 degrees after each 15-sec test, holding the probe in the same location.

At Teterboro, an independent set of nuclear tests was performed with the Troxler 4640 Thin Lift nuclear gauge, owned and operated by the Troxler Corporation. Thin Lift measurements were taken at the same locations as the 3411–B measurements. Although the Thin Lift gauge was also available at Ocean City and Leesburg, only a limited amount of data was collected because of time constraints.

Regression Analysis

Because the FAA standard for asphalt density testing is from core unit weight measured in accordance with ASTM 2726, several nuclear density tests were performed near cores taken for normal project acceptance testing. A comparison of nuclear and core unit weights was made, and regression analyses were conducted on the data from each project and on a combined data base.

From tables presented by Young (*12*), the significance of the correlation was examined by comparing the probability (p) of obtaining a given correlation coefficient (R) for a given data set according to accepted rules. A commonly used rule of thumb in interpreting values of R is to regard the correlation as significant if there is less than 1 chance in 20 ($p = 0.05$) that the value will occur by chance.

For Teterboro, a significant correlation ($p < 0.001$) between the Thin Lift results and cores was obtained. Essentially, the analysis indicates that at Teterboro, the Thin Lift results could be used without correction. Although the data bases were smaller, poorer correlations were obtained with the Thin Lift gauge at Ocean City and Leesburg.

At Leesburg, a significant correlation ($p < 0.001$) was obtained for the 3411–B gauge without the thickness correction suggested by the manufacturer. The regression equation obtained at Leesburg was similar to that reported by Burati (*13*) at Morristown.

Correlations of lesser significance were obtained at Ocean City, possibly because of the smaller data base.

On the basis of the analysis of core versus nuclear densities, the following data were used at each project:

- Teterboro—Thin Lift gauge without correction.
- Leesburg—3411–B gauge without thickness correction using the following equation:

$$\text{core density} = 50.63 + 0.634 * \text{nuclear density}.$$

- Ocean City—3411–B gauge without thickness correction using the following equation:

$$\text{core density} = 40.89 + 0.736 * \text{nuclear density}.$$

Marshall Test Data

Because the FAA Eastern Region and National P–401 specifications require daily Marshall testing, Marshall acceptance test data (acquired by others during production) were collected for each project. All samples for Marshall testing were selected by random sampling on a lot basis according to FAA Eastern Region standards (*14*), with a lot defined as 1 day's production. The data were used to compute percent Marshall density and in-place air voids at each nuclear test location for correlation with NDT DSM data. Average Marshall test data for each airport are presented in Table 1.

DATA ANALYSIS

Regression Analysis

Linear and parabolic regression analyses were performed on the data. For each case, the DSM was considered the independent variable (x) and percent Marshall density, in-place air voids, and mat unit weight were considered dependent variables (y). In other words, for each airport an attempt was made to develop regression equations for

- Percent Marshall density as a function of DSM,
- In-place air voids as a function of DSM, and
- Mat unit weight as a function of DSM.

Because of unit weight variances between projects, regression analyses on the combined data base were only performed for DSM versus percent Marshall density and in-place air voids.

In all cases, a better fit was obtained from linear analysis than from nonlinear analysis; therefore, only the linear regression equations were reported. Because statistically significant correlations were found only at Teterboro, these results are presented in Table 2.

TABLE 1 MARSHALL TEST DATA SUMMARY

Project	Gmb	Gmm	%AC	Stability (lbs)	Flow (.01 in)	Voids	Unit Wt (pcf)
Teterboro	2.528	2.612	5.2	2303	10.9	3.2	157.7
Leesburg	2.605	2.677	5.3	2826	12.8	2.7	162.5
Ocean City	2.441	2.501	5.45	2215	11.1	2.4	152.3

Gmb = Bulk Specific Gravity of Marshall Specimen

Gmm = Maximum Theoretical Density of Mixture

%AC = Average Asphalt Content During Production

TABLE 2 RESULTS OF REGRESSION ANALYSES AT TETERBORO PROJECT

Y = AX + B

X	Y	n	Slope (a)	Intercept (b)	R	P
A. Nuclear Gauge Data - DSM Not Temperature Corrected						
DSM	% Marshall	104	0.000011	0.955	0.252	0.01
DSM	% Air Voids	104	-0.00001	0.080	-0.308	<0.01
DSM	Unit Wt	104	0.00242	150.04	0.326	<0.01
B. Nuclear Gauge Data - Temperature Corrected DSM						
DSM	% Marshall	104	0.000009	0.954	0.291	0.01
DSM	% Air Voids	104	-0.00001	0.081	-0.354	<0.01
DSM	Unit Wt	104	0.00203	150.0	0.364	<0.01
C. Core Data - DSM Not Temperature Corrected						
DSM	% Marshall	18	0.000012	0.951	0.555	0.02
DSM	% Air Voids	18	-0.00001	0.085	0.598	0.01
DSM	Unit Wt	18	0.00246	149.49	0.598	0.01
D. Core Data - Temperature Corrected DSM						
DSM	% Marshall	18	0.000009	0.952	0.565	0.01
DSM	% Air Voids	18	-0.00001	0.084	-0.612	<0.01
DSM	Unit Wt	16	0.00195	149.59	0.612	<0.01

In evaluating the results, the following observations are noted:

1. For the Teterboro project, significant (i.e., $p < 0.05$) correlations were found between DSM and all y parameters. However, because the average percent Marshall density for the project, at 96.5 percent, is less than the FAA target average of 98.0 percent, the predictive equations may not be appropriate. This result was found for regression analyses conducted on data bases using both the temperature-corrected and temperature-uncorrected DSM results.
2. For the Leesburg and Ocean City projects, no correlations were found between DSM and any of the y parameters.
3. Regression analyses on the combined data base found no correlation between DSM results and either percent Marshall density or in-place air voids.
4. In all cases, similar results were found from regression analyses of both nuclear- and core-generated density data.

Class Groupings

In a second attempt to evaluate the data, the DSM results for each project and the combined data base were sorted in ascending order, with corresponding percent Marshall density, in-place air voids, and unit weights. Class intervals of each hundred measure of DSM (i.e., 200, 300, 400, etc.) were chosen, and DSM (without temperature correction), percent Marshall density, in-place air voids, and unit weights were statistically processed to yield the mean, standard deviation, and coefficient of variance of each parameter within each interval.

No trends were readily apparent either from comparison of averages or coefficients of variance of the data. In other words, the data suggest that, under the conditions of this study, a stiffer support system (as characterized by the DSM), did not result in a higher degree of compaction. Further, variability in base pavement stiffness does not necessarily result in variability in compactibility.

Discussion of Results

A broad range of DSM values (approximately 200 to 2,000 kips/in.) was involved in this study, representing an approximate 10-fold increase in pavement support conditions. Thus, the range of the independent variable should have been sufficient to detect any significant trends in the dependent variables.

However, analysis of the regression and class grouping results found no consistent correlation between base pavement stiffness and compactibility. Although statistically significant correlations were obtained at Teterboro for all parameters, the improvement in correlation coefficients for regression analyses on data using the temperature-corrected DSM results may suggest that the correlations are less robust than suggested by the correlation coefficients.

With this background, analysis of the data collected during this study can be broadly interpreted in two ways:

1. Although base pavement support conditions may influence compaction of an asphalt overlay, the effect of the base pavement may be masked by numerous other variables (*2*). This can mean either that the other variables (e.g., equipment, quality control, and temperature) overwhelmed the effect of base pavement stiffness or that base pavement stiffness is not a significant variable in influencing compaction. In other words, if proper mix design and construction procedures are followed, base pavement stiffness (or the lack thereof) may only then be observed to influence the compactibility of an asphalt mat.
2. Base pavement stiffness on airports designed according to FAA standards has little or no effect on the compactibility of an asphalt overlay.

In developing this study, it was thought that concentrating the data collection at individual airports with the same contractors, mix, and equipment would represent a real-world situation yet reduce the effect of outside variables. However, the scope of the study did not allow detailed observation of construction or analysis of such variables as mix properties, quality control, and compaction temperatures. The purpose was to collect appropriate data as objectively as possible for statistical analysis.

COMPACTION STANDARDS

At the outset of this study, it was recognized that there were differences in density testing requirements between the FAA National (*1*) and Eastern Region (*7*) P–401 specifications. Although the study required evaluating correlations on the basis of both percent Marshall density (National requirement) and in-place air voids (Eastern Region requirement), it was thought that the two requirements were essentially different measurements of the same standard. However, in evaluating the density data collected at the airports, it appeared that the two specification requirements, or application of the two statistical acceptance plans, may be resulting in different density standards.

The National P–401 specification defines compaction in terms of a percentage of the 75-blow Marshall density. A target average density of 98 percent was established with substantial compliance (i.e., full payment) defined as 90 percent of the material in a lot having a density greater than 96.7 percent. The lower tolerance limit of 96.7 percent was established by working back from the target density at an assumed standard deviation of 1 percent. The 1 percent standard deviation for percent Marshall density was confirmed through test results from nuclear devices and cores. Marshall voids are specified to fall between 3.0 and 5.0 percent.

On the other hand, the Eastern Region P–401 specification defines compaction in terms of in-place air voids. Although no target density is specified, substantial compliance is defined as 90 percent of the material falling within lower and upper tolerance limits of 1.0 and 7.0 percent, respectively. For Marshall voids, 90 percent of the material is specified to fall within lower and upper limits of 1.0 and 5.0 percent, respectively.

In equating the two requirements, the percent Marshall target density and the midrange Marshall air voids for the National specification can be compared with the midrange of in-place and Marshall air voids for the Eastern Region specification. This would result in an average in-place air void content of approximately 6.0 percent with the National requirements and 4.0 percent with the Eastern Region specification. With a midrange Marshall air voids content of 3.0 percent required by the Eastern Region, approximately 99 percent Marshall density would be needed to achieve the midrange requirement of 4.0 percent. Further, in applying the upper limits of both criteria to obtain full acceptance, the National specification will allow a maximum average in-place air voids content of 7.0 percent (5.0 percent Marshall laboratory voids plus 2.0 percent from 98 percent compaction). Applying the Eastern Region's acceptance criteria, the maximum allowable air voids for full payment (i.e., 90 percent within limits) is approximately 5.7 percent, assuming a 1.0 percent standard deviation for in-place air voids.

However, the percent compaction actually achieved will vary both with the Marshall air voids achieved during production and with the in-place air voids resulting from field compaction. The percent compaction can be estimated by subtracting the Marshall air voids from the in-place air voids. For example, applying the acceptance criteria for laboratory Marshall air voids, an acceptable average Marshall voids content to meet 90 percent within limits criteria would be approximately 1.7 percent at 90 percent within limits, using the 0.6 percent standard deviation for Marshall air voids suggested in the Eastern Region specification. Therefore, translating to percent Marshall density, the Eastern Region specification would allow full payment with an average percent Marshall density from compaction of approximately 96 percent. For convenience, if 2.0 percent is considered a minimum practical average for Marshall air voids, a minimum average required Marshall density from compaction of 96.3 percent would be required to meet the upper limit 5.7 percent in-place air voids for full payment.

A comparison of the criteria from each specification is presented in Table 3.

In applying the extreme limits of the acceptance criteria from both specifications, the two specifications may have different criteria for defining acceptable material. The acceptance data for all projects, calculated using the nuclear density device, also suggest inconsistency between the two requirements. These data are summarized as follows:

Nuclear Device Tests	*Percent*
Average Marshall air voids	2.8
Average in-place air voids	6.2
Standard deviation for in-place air voids	1.1
Average percent Marshall density	96.6
Standard deviation for percent Marshall density	1.0
Percent asphalt content	5.3

Further, applying the payment schedule formulas from each specification would result in different contractor payments. Assuming a normal distribution for the combined data collected during the study, the percent of material within specification limits would be less than 50 percent under the National specification versus approximately 77 percent of material within limits with the Eastern Region specification. This would result in 50 percent payment under the National specification versus 94 percent payment under the Eastern Region specification for the same material.

On the basis of the preceding discussion, it appeared that both specification requirements should be reevaluated to ensure consistency and establishment of an appropriate, acceptable quality level. This was confirmed by a recently completed follow-up study (*15*), which examined the basis for the Eastern Region and National P-401 acceptance plans. The new study resulted in the following conclusions and recommendations:

TABLE 3 COMPARISON OF COMPACTION STANDARDS

	Specification (%)	
Criterion	National	Eastern Region
Midrange Marshall air voids	4	3
Midrange in-place air voids	6	4
Midrange percent Marshall density	98	99
Minimum Marshall air voids	3	2[a]
Maximum in-place air voids	7	5.7
Minimum average Marshall density	98	96.3

[a]Considered minimum practical; theoretical minimum is 1.7 percent.

1. The Eastern Region procedures can result in a lesser density standard than normally achieved with the National specification. This decrease can have an adverse effect on other quality considerations, such as stability.
2. Either a unified FAA density standard based on percentage of Marshall density should be adopted for all FAA regions or the Eastern Region should modify its Marshall air voids limits to ensure that a minimum of 98 percent of Marshall density is achieved at all Marshall and in-place air voids contents. Revised Marshall air voids acceptance limits are recommended by McQueen (*15*).
3. Acceptance and quality control characteristics were delineated for both specifications. On the basis of the literature search, and pending the outcome of Strategic Highway Research Program (SHRP) research, Marshall stability, flow, and air voids were suggested for statistical acceptance of plant-produced material, with percent Marshall density suggested for statistical acceptance of field material. Tests for gradations and asphalt content were delineated as part of the contractor's quality control responsibility.
4. A new payment plan was suggested because of the nonuniformity in payment when based on density. The density payment plan contains crediting provisions (*16*) to ensure 100 percent contractor payment at the specified AQL. A reduced payment plan was not suggested for compliance with Marshall characteristics at this time.

CONCLUSIONS

On the basis of the study results, the following conclusions are offered:

1. At the Leesburg Airport, a significant correlation between unit weight determined by the Troxler 3411-B nuclear density device and that determined from cores was established similar to that reported by Burati (*13*).
2. The Troxler 4640 Thin Lift nuclear gauge densities correlated with core densities at Teterboro without correction. However, poor correlations were obtained at the Leesburg and Ocean City projects.

3. From the compaction data obtained at the three airports, a 1.0 percent standard deviation was found for percent Marshall density from both core and nuclear devices. A 1.1 percent standard deviation was found for in-place air voids with the nuclear devices and a 1.2 percent standard deviation was found from cores.

4. For the Teterboro project (see Table 2), significant (i.e., $p < 0.05$) correlations between DSM and all y parameters (i.e., percent Marshall density, in-place air voids, and unit weight) were found. However, because the average percent Marshall density for the project (96.5 percent) is less than FAA's target average of 98.0 percent, the predictive equations may not be appropriate.

5. For the Leesburg, Ocean City, and combined data bases, no correlations were found between DSM and any of the y parameters.

6. In grouping the data into class intervals as a function of DSM, no trends are readily apparent from comparison of averages or coefficients of variance of the data bases. This lack suggests that, under the conditions of the study, a stiffer support system does not necessarily result in a higher degree of asphalt compaction.

7. On the basis of the data analysis, base pavement stiffness appears to have no consistent effect on asphalt compactibility. It is assumed that other outside variables (e.g., equipment, mix characteristics, temperature, or quality control) masked the effect of base pavement stiffness or simply that base pavement stiffness is not a significant variable in influencing compaction.

8. Existing support conditions at airports designed to FAA standards may be too stiff to reveal any loss in compactibility caused by weak or yielding base pavements.

9. Evaluation of acceptance procedures for mat density required by the National and Eastern Region P–401 specifications suggested that the specifications may be inconsistent in requiring different acceptable quality levels, resulting in different contractor payments for the same material. This assumption was confirmed during a follow-up study (*15*), which recommended changes to acceptance procedures for both specifications.

RECOMMENDATIONS

Although the study provided useful information, the data did not conclusively prove the existence or nonexistence of a robust correlation between base pavement stiffness and asphalt compactibility. The data obtained at one airport did suggest that the compactibility of an asphalt overlay can be influenced by base pavement support conditions, but no correlations were obtained at the other two airports. Investigation of the interrelationship between stiffness and compaction will require data acquisition under a more controlled environment.

Useful information was provided on the use of nuclear density devices for acceptance or quality control testing during asphalt overlay construction. If the Thin Lift nuclear gauge proves to be more reliable than other gauges (*17*), yielding results consistent with core densities, then the Thin Lift gauge will enable a greater number of acceptance tests to be performed at little or no additional cost.

Further, this study and a follow-up study suggested that apparent inconsistencies exist between the density acceptance procedures required by the National and Eastern Region P–401 specifications. These inconsistencies can result in different acceptance decisions and different payment for material of equal quality, depending on which specification is applied.

Additional research efforts may provide more definitive data on quantifying the interrelationships between base pavement stiffness and asphalt compaction, as well as refinement of National or Eastern Region density acceptance procedures to ensure consistency in quality and payment.

The following recommendations are offered:

1. Because of the good correlation between unit weights obtained by the Troxler Thin Lift nuclear gauge and core weights at Teterboro, the use of the Thin Lift gauge as an acceptance or quality control tool should be further researched.

2. In order to research the interrelationship between base pavement stiffness and asphalt compaction, the effects of extraneous variables should be eliminated by construction of several test strips, using the same material, contractor, construction equipment, and quality control procedures.

3. The National and Eastern Region acceptance plans should be reevaluated to define a consistent AQL and basis of payment for materials of the same quality. This recommendation was accomplished in the follow-up study (*15*), resulting in definitive recommendations for each acceptance plan with regard to (a) acceptance requirements, (b) quality control requirements, (c) acceptance limits for air voids, stability, flow, and density, and (d) a payment adjustment plan for density.

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