Evaluation of Pavement Layer Moduli Using Field Plate Bearing Load Test

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A recent experimental program on evaluating the bearing characteristics of existing pavement base, subgrade, and embankment soils using field plate bearing load test is presented. The field investigation is a part of a larger research project to study the existing pavement layer moduli and to implement the laboratory resilient modulus test method in Florida. The plate bearing load tests were conducted on 20 flexible pavement sites across Florida. At each site, the bearing characteristics of the base, subgrade, and embankment layers were determined. The plate load test results are summarized and presented, and the layer moduli of the pavement soils are characterized. The pavement layer moduli were verified through comparison with the results obtained from elastic layered solution ELSYM5 program.

AASHTO adopted for use in the 1986 *Guide for Design of Pavement Structures* (*1*) the resilient modulus test, AASHTO T-274-82, for determining properties of roadbed soils and pavement components. The criticism and controversy that followed have resulted in numerous publications and subsequent modifications aimed at resolving the difficulties generated by the test method. As a result, a number of nationwide studies have been undertaken to search for possible solutions and alternative test methods, such as the NCHRP 1-28 project.

The Florida Department of Transportation (FDOT) undertook a research study to possibly implement the 1986 AASHTO flexible pavement design procedures. The primary objective of the study was to develop reliable correlations between the laboratory-measured resilient modulus and the in situ layer modulus of pavement soils as measured by field plate load test on subgrade soils and untreated base/subbase materials in Florida. The main thrust was to implement the 1986 AASHTO design guide for pavement structures with the resilient modulus test for Florida conditions.

This paper presents the field experimental program using the plate load test to evaluate the bearing characteristics of pavement base, subgrade, and embankment soils. The research reported herein is a part of the aforementioned study to correlate field pavement layer moduli as measured by the plate load test with laboratory-measured resilient moduli for pavement soils throughout Florida.

FIELD EXPERIMENTAL PROGRAM

The objective of the field experimental program was to characterize the in situ bearing behavior of pavement layers on selected types of pavement soils. To achieve the objective, field plate bearing load tests were conducted on 20 flexible pavement sites in Florida. The sites were scattered evenly about the state to better represent different soil conditions in Florida (Figure 1). The selection of sites took into consideration soil type and history, pavement layer homogeneity, layer thickness, and operational considerations.

Plate bearing load tests have been used for designing and evaluating pavement structures since the 1940s (*2,3*). The test procedures may vary somewhat depending on the adopted agencies, but the method is generally in close agreement with ASTM D-1195. FDOT routinely uses the plate load test to evaluate the in situ layer modulus of flexible pavement subbase and subgrade soils. In Florida the plate load test is designated as FM 5-527 (*4*).

Test Procedure

The testing apparatus consists of a water tanker with 27 240 kg (60,000 lb) and a hydraulic jack with a spherical bearing attachment capable of applying and releasing the load increments. The hydraulic jack has sufficient capacity for applying the maximum load required and is equipped with an accurately calibrated gauge that indicates the magnitude of the applied load. A circular steel plate 3.66 m (12 in.) in diameter is used for applying the load. A schematic illustration of the test setup is shown in Figure 2.

An aluminum alloy deflection beam is used to mount two graduated [in units of 0.0254 mm (0.001 in.)] dial gauges for measuring deflections (Figure 3). Before the incremental testing loads are applied, three seating loads are applied to seat the loading system and bearing plate. Each seating load is to produce a total deflection of about 0.762 mm (0.030 in.). Each of the three seating loads is applied in four or five uniform increments. After each increment of test load has been applied, the deflection is allowed to continue until a rate of no more than 0.0254 mm/min (0.001 in./min). The load and deflections are then recorded. This procedure continues until the average total deflection of 1.27 mm (0.05 in.) plus average rebound deflection from third seating load has been reached.

Field Testing Program

The actual field plate load test took place in three stages at each site. In the first stage, the asphalt concrete structural layer was cut, approximately 1.678 × 3.355 m (5.5 × 11 ft), and removed to expose the underlying base layer. The asphalt concrete slab was saved for possible future testing. Then the plate bearing load test was performed on the base layer. Before testing, the in situ density and moisture content of the base layer were obtained using a nuclear gauge device. In addition, the speedy moisture content test was con-

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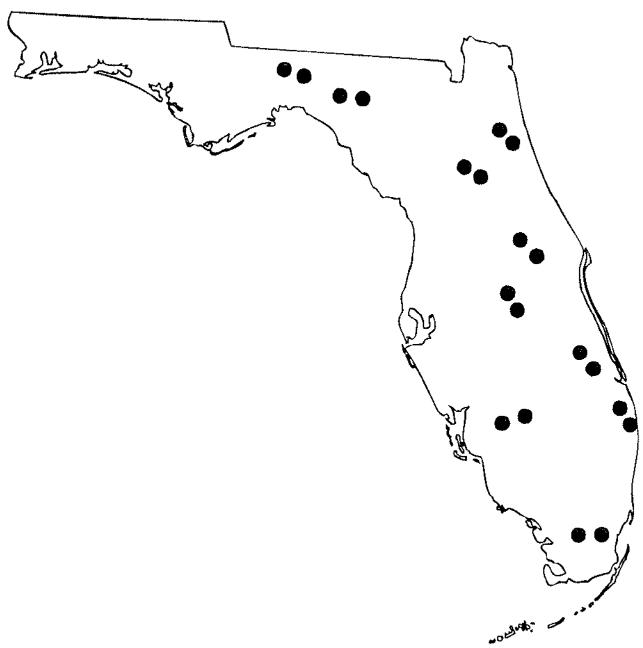

FIGURE 1 Location map of field test sites.

ducted to check the moisture content data. After the test, representative bag samples of the base material were taken for future testing of the resilient modulus in the laboratory.

In the second stage, the base materials were excavated and the stabilized subgrade layer was exposed and leveled. Care was taken not to disturb the soil in the test layer. Before the test, the in situ moisture and density were again measured. Sufficient bag samples were taken after the plate load test for further laboratory evaluation.

In the third stage of the test, the stabilized subgrade layer was again removed to expose the embankment layer. The moisture and density of the embankment layer were measured before the test and the soil samples were taken after the plate load test. After the load testing program, the embankment soil layer was excavated up to more than 1 m below the tested stratum to check the layer homogeneity. The three-stage field testing procedure is illustrated schematically in Figure 4, and a plan view of the three-stage loading areas is presented in Figure 5.

EXPERIMENTAL RESULTS

A typical load-versus-deflection curve of the plate load test results is shown in Figure 6. The residual deflection is determined by connecting the straight portion of the load-deflection curve with a straight line that intersects the x-coordinate. The intercept deflection value is the corrected deflection value induced by the seating loads. This value is added to the selected total deflection. So, the first portion of the load-deflection curve is a straight line and the second has only relatively slight curvature before any break or considerable increase in curvature occurs. To eliminate influences of the imperfectly elastic behavior of soils, only the straight portion of the load-deflection curve is selected for modulus determination.

Determination of Pavement Layer Modulus

Theoretical Background

The theory of stresses and displacements in a two-layer system was developed in accordance with the method of the theory of elasticity by Burmister in the early 1940s (*5,6*). The validity and competence of the layered system theory was tested by using plate bearing tests. The general solution of the two-layer problem is based on the following assumptions and conditions:

1. The soils of each of the two layers are assumed to be homogeneous, isotropic, elastic materials, for which Hooke's law is valid.
2. Surface Layer 1 is assumed to be infinite in extent in the horizontal direction, but of finite thickness (h). The underlying Layer 2 is assumed to be infinite in extent in the horizontal and vertical (downward) directions.
3. The boundary and continuity conditions require that the layers are in continuous contact and that the surface layer is free of shearing and normal stresses outside the loaded area.

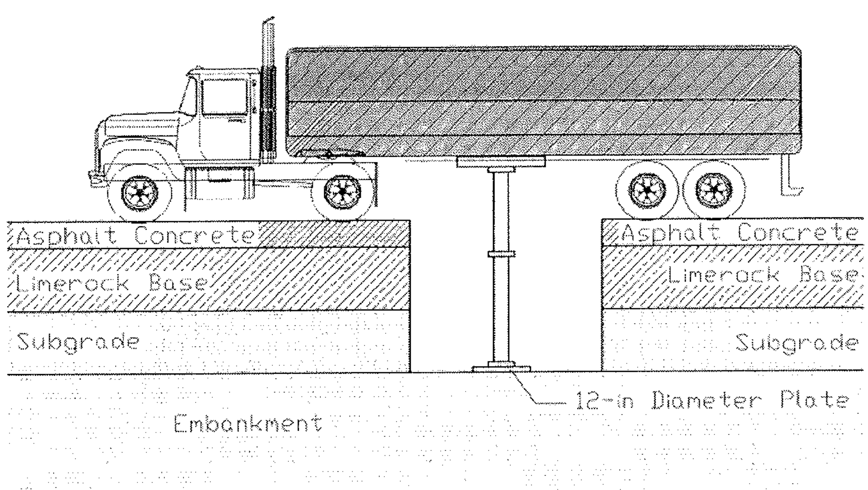

FIGURE 2 Schematic illustration of test setup.

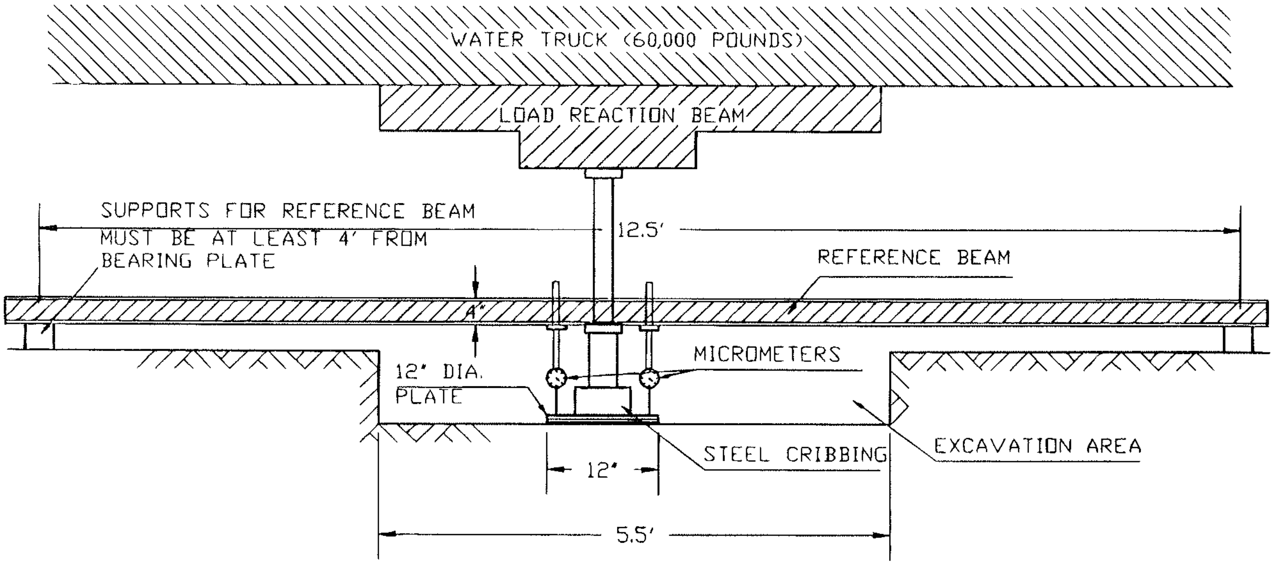

FIGURE 3 Close-up of plate bearing test (1 ft = 0.305 m).

By assuming Poisson's ratio $\mu = 0.5$, the settlement equations given by Burmister are as follows:

For flexible plate,

$$\delta = 1.5paF_2/E_2 \tag{1}$$

For rigid plate,

$$\delta = 1.18paF_2/E_2 \tag{2}$$

where

δ = surface deflection at center of circular plate,
p = unit load on circular plate,
a = radius of plate,
E_2 = modulus of elasticity of lower layer, and
F_2 = dimensionless factor depending on ratio of moduli of elasticity of Layers 1 and 2 as well as the depth-to-radius ratio.

Burmister's curves of F_2 for various depth ratios and moduli of elasticity are presented elsewhere (*5*).

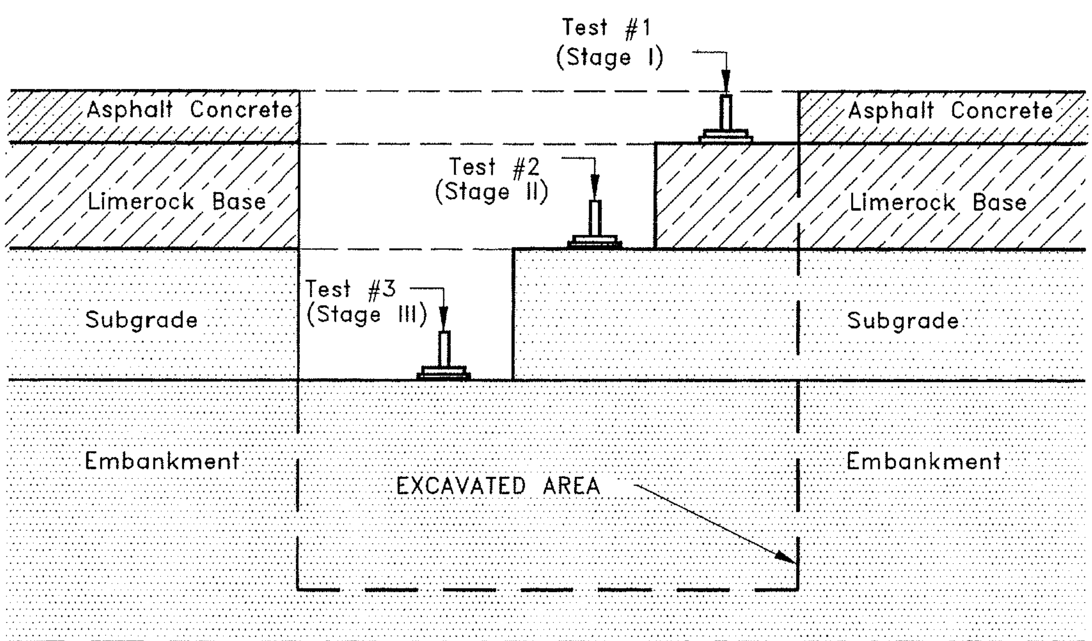

FIGURE 4 Schematic illustration of field test procedure.

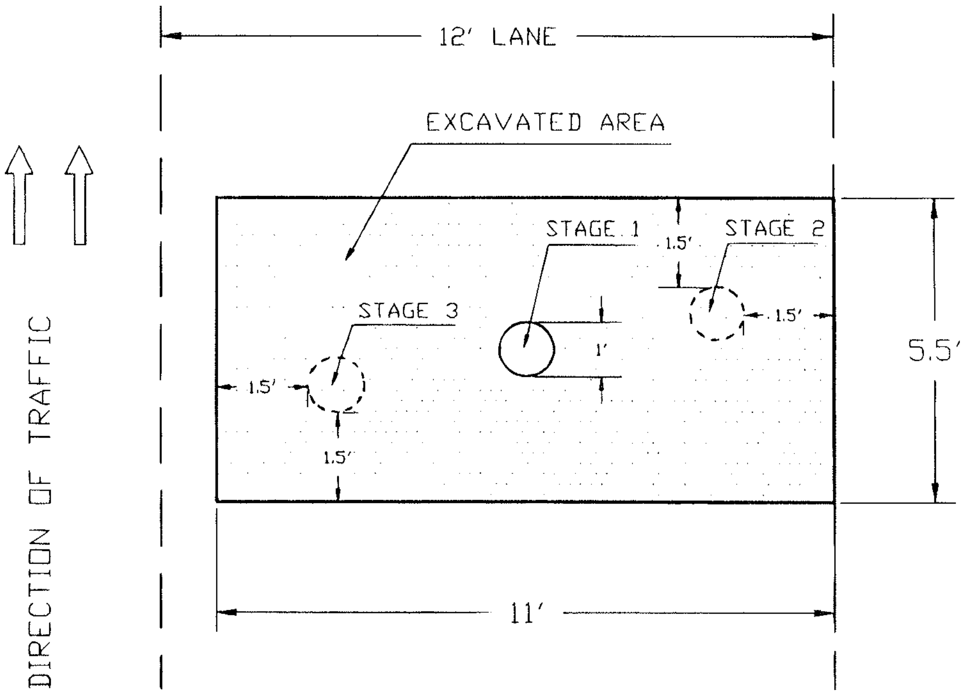

FIGURE 5 Plan view of plate loading areas (1 ft = 0.305 m).

The modulus of elasticity (E_{eR}) of the equivalent base/subgrade layer or subgrade/embankment layer of plate bearing test can be obtained by rewriting the basic Burmister equation for the rigid plate test as follows:

$$E_{eR} = 1.18pa/\Delta_R \tag{3}$$

where E_{eR} is the modulus of elasticity of combined base/subgrade layer or subgrade/embankment, and Δ_R is deflection.

Burmister's two-layer deflection factor can be expressed as

$$F_2 = E_{2R}/E_{eR} \tag{4}$$

where E_{2R} is the modulus of elasticity of lower layer.

The equivalent modulus (E_{eR}) of combined base, subgrade, and embankment layer can be obtained from the field plate bearing test in the first stage of the test. The equivalent modulus of combined subgrade and embankment layer can be determined at the second

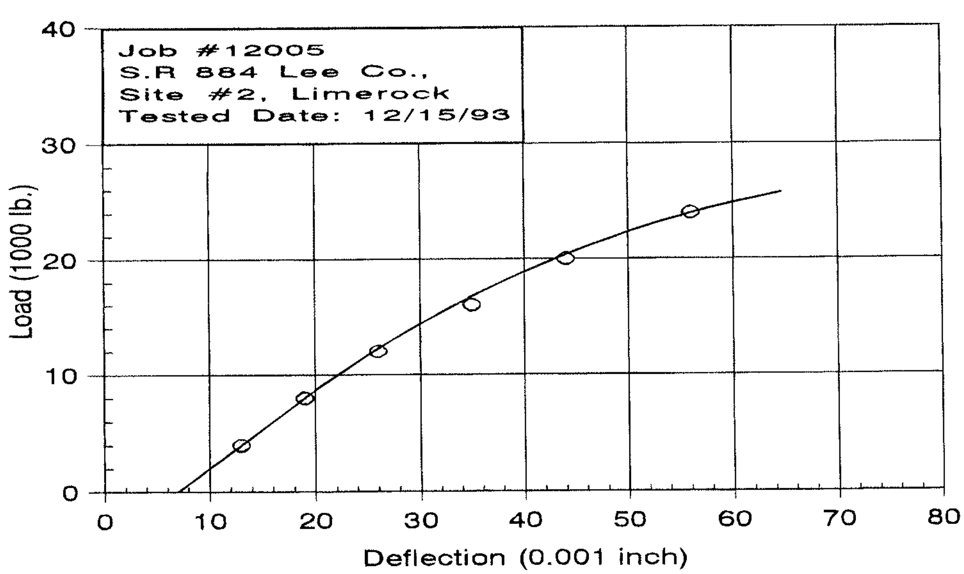

FIGURE 6 Typical load-deflection curve of test results (1 lb = 4.45 N; 1 in. = 25.4 mm).

TABLE 1 Computational Results for Determination of Layer Moduli

DISTRICT 1	Equivalent Modulus (psi)	Layer Thickness (in)	Deflection Factor (F2)	h/a	Ratio of Modulus	Layer Modulus (psi)
Lee Co., Site #1, S.R. 884						
Base (Limerock)	31,300	11.5	0.6	1.917	2.6	**48,828**
Subgrade (Fine Sand)	18,780	12	0.556	2	2.9	**30,256**
Embankment (Fine Sand)	10,433					**10,433**
Lee Co., Site #2, S.R. 884						
Base (Limerock)	38,523	9.5	0.929	1.583	1.3	**46,504**
Subgrade (Fine Sand)	35,772	12	0.618	2.083	2.2	**48,607**
Embankment (Fine Sand)	22,094					**22,094**
Polk Co., Site #1, U.S. 17						
Base (Limerock)	38,524	9	0.765	1.5	1.8	**53,026**
Subgrade (Silty Sand)	29,459	14	0.531	2.333	2.8	**43,820**
Embankment (Fine Sand)	15,650					**15,650**
Polk Co., Site #2, U.S. 17						
Base (Limerock)	53,657	9	0.729	1.5	1.8	**70,427**
Subgrade (Silty Sand)	39,126	13	0.889	2.167	1.2	**41,734**
Embankment (Fine Sand)	34,778					**34,778**
DISTRICT 2	Equivalent Modulus (psi)	Layer Thickness (in)	Deflection Factor (F2)	h/a	Ratio of Modulus	Layer Modulus (psi)
Alachua Co., Site #3, U.S. 301						
Base (Limerock)	65,896	9.5	0.5	1.583	4.1	**135,087**
Subgrade (Fine Sand)	32,948	12	0.38	2	6	**75,120**
Embankment (Fine Sand)	12,520					**12,520**
Alachua Co., Site #4, U.S. 301						
Base (Limerock)	78,251	9	0.565	1.5	3.1	**136,987**
Subgrade (Silty Sand)	44,189	8	0.16	1.333	105	**742,770**
Embankment (Clay)	7,074					**7,074**
*Clay Co., Site #5, U.S. 17						
Base (Limerock)	55,645	8	0.6	1.333	3.1	**103,500**
Subgrade (Fine Sand)	33,387	12				
(Subgrade) (Fine Sand)	34,778	12	0.72	2	1.8	**45,072**
(Embankment) (Silty Sand)	25,040					**25,040**
*Clay Co., Site #6, U.S. 17						
Base (Limerock)	50,081	7	0.623	1.167	3.3	**103,293**
Subgrade (Fine Sand)	31,301	14				
(Subgrade) (Fine Sand)	34,778	14	0.75	2	1.7	**41,734**
(Embankment) (Fine Sand)	26,084					**26,084**

(continued on next page)

stage of the test. At the third stage, the modulus of embankment can be calculated directly from the test since embankment soil is considered as one type of material. This is warranted by excavating the embankment more than 1 m deeper after the third stage of the test to check the soil homogeneity.

Computational Procedure

To determine the modulus of elasticity for each soil layer from plate bearing tests, Burmister's two-layer equation was used repeatedly. At the third stage of the test, the elastic modulus of the embankment layer was calculated directly from Equation 3, and at the second stage of the test, as a typical two-layer problem, F_2 was determined by using Equations 3 and 4. Then from Burmister's curves of F_2, the ratio of the elastic moduli was obtained and the modulus of subgrade was determined. At the first stage of the test, the subgrade and embankment soil were considered as one-layer soil with an equivalent modulus, which combined the subgrade and embankment moduli, and with an infinite depth. Equations 3 and 4 and Burmister's curves of F_2 were used again to obtain the modulus of elasticity of the base layer.

TABLE 1 (*continued*)

DISTRICT 3	Equivalent Modulus (psi)	Layer Thickness (in)	Deflection Factor (F2)	h/a	Ratio of Modulus	Layer Modulus (psi)
Jefferson Co., Site #1, U.S. 27						
Base (Limerock)	31,300	6.5	0.656	1.083	3.5	71,841
Subgrade (Silty Clay)	20,526	6.5	0.642	1.083	3.8	50,080
Embankment (Silty Clay)	13,179					13,179
Jefferson Co., Site #2, U.S. 27						
Base (Limerock)	46,951	7.5	0.667	1.25	2.6	81,383
Subgrade (Silty Clay)	31,301	11.5	0.75	1.917	1.6	37,560
Embankment (Silty Sand)	23,475					23,475
Gadsden Co., Site #2, U.S. 27						
Base (Limerock)	57,785	9.6	0.481	1.6	4.2	116,857
Subgrade (Silty Sand)	27,823	10.5	0.9	1.75	1.2	30,048
Embankment #1 (Silty Sand)	25,040	9	0.833	1.5	1.4	29,214
Embankment #2 (Clay)	20,867					20,867
Gadsden Co., Site #3, U.S. 27						
Base (Limerock)	62,601	8.5	0.625	1.417	2.8	109,553
Subgrade (Fine Sand)	39,126	23	0.4	3.833	3.4	51,645
Embankment (Clay)	15,650					15,650
DISTRICTS 4 AND 6	Equivalent Modulus (psi)	Layer Thickness (in)	Deflection Factor (F2)	h/a	Ratio of Modulus	Layer Modulus (psi)
Dade Co., Site #1, U.S. 41						
Base (Limerock)	119,459	13	0.749	2.167	1.5	134,245
Subgrade (Limerock)	89,430	13	0.8	2.167	1.3	93,007
Embankment (Limerock)	71,544					71,544
Dade Co., Site #2, U.S. 41						
Base (Limerock)	104,335	9.5	0.92	1.583	1.2	115,571
Subgrade (Limerock)	96,309	12.5	0.72	2.083	1.6	111,291
Embankment (Limerock)	69,557					69,557
Martin Co., Site #3, U.S. 1						
Base (Limerock)	58,919	10	0.708	1.667	1.9	79,295
Subgrade (Fine Sand)	41,734	12	0.286	2	12	143,076
Embankment (Fine Sand)	11,923					11,923
Martin Co., Site #4, U.S. 1						
Base Limerock)	48,154	9	0.557	1.5	3.4	91,219
Subgrade (Silty Clay)	26,829	12	0.667	2	2.2	39,349
Embankment (Fine Sand)	17,886					17,886

The pavement layer moduli are determined following the preceding procedures, and the results are presented in Table 1, along with the computational data. The use of these principles may be illustrated by an example. Taking the field test site of Lee County, Site 1 on SR-884, as an example, the equivalent modulus of combined base, subgrade, and embankment is 215 657 kPa (31,300 psi), the equivalent modulus of combined subgrade and embankment is 129 394 kPa (18,780 psi), and the modulus of elasticity of embankment is 71 883 kPa (10,433 psi). These values are calculated directly from the field plate bearing test by using Equation 3. The thickness is 3.508 m (11.5 in.) for the base layer and is 3.66 m (12 in.) for the subgrade layer. The ratio of the base layer thickness to the radius of bearing plate is h/a = 3.508/1.83 = 1.917. Similarly, the ratio of the subgrade layer depth to the radius of plate is h/a = 3.66/1.83 = 2.

At the second test stage, Burmister's two-layer deflection factor can be obtained from Equation 4. The ratio is $F_2 = E_3/E_{e2}$ = 71,883/129,394 = 0.556. Knowing F_2, and depth ratio h/a, from Burmister's family of curves, the ratio of the modulus of elasticity of subgrade to embankment $E_2/E_3 = 2.9$ is determined. Therefore, the modulus of elasticity of subgrade is $E_2 = 2.9 \times 71,883$ = 208 461 kPa (30,256 psi).

TABLE 1 (*continued*)

DISTRICT 5	Equivalent Modulus (psi)	Layer Thickness (in)	Deflection Factor (F2)	h/a	Ratio of Modulus	Layer Modulus (psi)
Seminole Co., Site #1, U.S. 414						
Base (Limerock)	37,514	12	0.556	2	3	62,601
Subgrade (Silty Sand)	20,867	12		2		20,867
Embankment (Silty Sand)	25,040					25,040
Seminole Co., Site #2, U.S. 414						
Base (Limerock)	39,537	12	0.633	2	2.1	52,584
Subgrade (Silty Sand)	25,040	13.5	0.909	2.25	1.2	27,317
Embankment (Fine Sand)	22,764					22,764
Osceola Co., Site #3, U.S. 441						
Base (Coquina)	46,951	8	0.627	1.333	3	88,377
Subgrade (Fine Sand)	29,459	12	0.708	2	1.8	37,561
Embankment (Fine Sand)	20,867					20,867
Osceola Co., Site #4, U.S. 441						
Base (Coquina)	37,560	11	0.625	1.833	2.4	56,340
Subgrade (Fine Sand)	23,475	18	0.577	3	2.3	31,131
Embankment (Fine Sand)	13,535					13,535

*This test site was finished on different days.
Metric Conversion Factors: 1 psi = 6.89 KPa; 1 in = 25.4 mm

At the first test stage, consider the subgrade and embankment as one layer with the equivalent modulus of 129 394 kPa (18,780 psi). Burmister's two-layer deflection factor again can be calculated from Equation 4. The value is E_{e2}/E_{e1} = 129,394/215,657 = 0.6. Also from Burmister's family of curves, the ratio of the modulus of elasticity of the base to the equivalent subgrade and embankment modulus is 2.6. The modulus of elasticity of the base layer is E_1 = 129,394 × 2.6 = 336 424 kPa (48,828 psi). Following these procedures, the computational results of layer moduli are summarized in Table 1.

Presentation of Results and Discussion of Anomalies

Data of plate bearing load tests from 20 test sites as well as in situ densities and moisture content are summarized and presented in Table 2. The layer moduli calculated from plate bearing load tests by repeatedly using Burmister's two-layer equations are very reasonable for most of tested sites. However, there are several anomalies in the test results and a closer examination is necessary.

In the first case, involving the subgrade of Test Site 4 at US-301 in Alachua County, the layer modulus of elasticity was found to be an unusually high value of 5 117 685 kPa (742,770 psi). A possible reason for this is that there may be a measuring error during the field investigation. The other possible reason may be due to the extremely low layer modulus of the embankment from plate bearing test. The moisture content of the embankment layer was 28.5 percent during the field test. When the subgrade soil was excavated and the 3.66-m (12-in.) plate was loaded, the water beneath the plate would possibly dissipate to cause excessive deflection of the plate. This resulted in an unusually low value of the modulus of the embankment. This case should not be considered representative of the actual condition.

In the second case, involving Test Site 1 at US-414 in Seminole County, the value of 143 774 kPa (20,867 psi) for the equivalent modulus of subgrade and embankment layer was lower than that of the layer modulus of embankment [172 526 kPa (25,040 psi)] from the plate load test. Burmister's two-layer theory could not be used for this case. The test site was located in a dead-end zone without any traffic. There was evidence during excavation after completion of the field test that the subgrade soil was poorly compacted.

The third case involved Test Site 3 at US-1 in Martin County, for which the value of elastic modulus of subgrade was unusually high [985 794 kPa (143,076 psi)] compared with the results of nearby Site 4. The reason for this was uncertain.

It should be noted that the deflection of the linear portion of the load-deflection curve was used to calculate the equivalent modulus from the plate bearing load test. The linear portions of load-deflection curves were within a deflection of 1.016 mm (0.04 in.) for most base layers. For subgrade and embankment layers, the linear zone was within 0.381 to 0.762 mm (0.015 to 0.03 in.). The observed deflection values were considered to be representative of the pavement soils in Florida (*7*).

ELSYM5 Calibration and Comparison

The ELSYM5 program for IBM-PC and compatible computers was used to calculate the load-deflection curve on the basis of the field-tested condition. All of the experimental results were calibrated using the ELSYM5 computer runs.

The ELSYM5 program is based on elastic layered computer model. The program assumes that each layer is composed of weightless, homogeneous, isotropic materials. The materials behave in an ideally elastic manner, according to Hooke's Law. Each layer is of uniform thickness and infinite width in all horizon-

TABLE 2 Summary of Field Experimental Results

DISTRICT 1	Equivalent Modulus (psi)	Layer Modulus (psi)	Wet Density (pcf)	Dry Density (pcf)	M.C (%)	AASHTO Classification	Layer Thickness (in)
Lee Co., Site #1, S.R. 884							
Base (Limerock)	31,300	48,828	127.9	111.2	15.1	Limerock	11.5
Subgrade (Fine Sand)	18,780	30,256	109.9	105.2	4.4	A-3	12.0
Embankment (Fine Sand)	10,433	10,433	111.2	104.7	5.9	A-3	
Lee Co., Site #2, S.R. 884							
Base (Limerock)	38,523	46,504	132.1	114.8	15.0	Limerock	9.5
Subgrade (Fine Sand)	35,772	48,607	111.5	107.7	3.5	A-3	12.5
Embankment (Fine Sand)	22,094	22,094	111.9	107.4	4.3	A-3	
Polk Co., Site #1, U.S. 17							
Base (Limerock)	38,524	53,026	136.4	124.8	9.4	Limerock	9.0
Subgrade (Silty Sand)	29,459	43,820	122.3	111.0	10.2	A-2-4	14.0
Embankment (Fine Sand)	15,650	15,650	118.9	104.8	13.5	A-3	
Polk Co., Site #2, U.S. 17							
Base (Limerock)	53,657	70,427	131.9	119.5	10.3	Limerock	9.0
Subgrade (Silty Sand)	39,126	41,734	121.2	112.4	7.8	A-2-4	13.0
Embankment (Fine Sand)	34,778	34,778	123.1	111.0	11.2	A-3	
DISTRICT 2	Equivalent Modulus (psi)	Layer Modulus (psi)	Wet Density (pcf)	Dry Density (pcf)	M.C. (%)	AASHTO Classification	Layer Thickness (in)
Alachua Co., Site #3, U.S. 301							
Base (Limerock)	65,896	135,087	134.2	121.7	10.2	Limerock	9.5
Subgrade (Fine Sand)	32,948	75,120	120.3	107.6	11.8	A-3	12.0
Embankment (Fine Sand)	12,520	12,520	116.8	100.6	15.9	A-2-4	
Alachua Co., Site #4, U.S. 301							
Base (Lime rock)	78,251	136,987	131.2	118.6	10.6	Limerock	9.0
Subgrade (Silty Sand)	44,189	742,770	119.2	102.4	16.4	A-2-4	8.0
Embankment (Clay)	7,074	7,074	125.7	97.8	28.5	A-6	
Clay Co., Site #5, U.S. 17							
Base (Limerock)	55,645	103,500	127.6	115.7	10.3	Limerock	8.0
Subgrade (Fine Sand)	33,387		108.9	103.3	5.4	A-2-4	12.0
(Subgrade) (Fine Sand)	34,778	45,072	106.9	99.7	7.2	A-2-4	12.0
Embankment (Silty Sand)	25,040	25,040	110.6	101.6	8.8	A-3	
Clay Co., Site #6, U.S. 17							
Base (Limerock)	50,081	103,293	133.2	120.0	11.0	Limerock	7.0
Subgrade (Fine Sand)	31,301		114.6	100.4	14.1	A-3	12.0
(Subgrade) (Fine Sand)	34,778	41,734	112.9	101.8	11.0	A-3	12.0
Embankment (Fine Sand)	26,084	26,084	111.0	101.9	9.0	A-3	

tal directions. The bottom elastic layer may be semi-infinite in thickness or may be given a finite thickness, in which case the program assumes the bottom elastic layer supported by a rigid base. The boundaries between the layers are assumed to be full friction. The surface is free of shear, and the loads applied there are assumed to be identical, vertical, and uniform over a circular area.

The modulus of elasticity for each layer along with the load data were input into the computer program, and the deflections were obtained as output. The load-deflection relationships from ELSYM5 were compared with the field test results as demonstrated in Figures 7, 8, and 9 for the example case. It should be noted that since the field test was performed on a rigid plate, a factor of nonuniform pressure of 1.18/1.5 was used to modify the deflection values; refer to Equations 1 and 2.

As the figures indicate, it is apparent that the deflections calculated from ELSYM5 are almost identical with the field test results in the straight-line portion of the embankment soil layer. The reason is that the modulus of elasticity of embankment is calculated

TABLE 2 (*continued*)

DISTRICT 3	Equivalent Modulus (psi)	Layer Modulus (psi)	Wet Density (pcf)	Dry Density (pcf)	M.C. (%)	AASHTO Classification	Layer Thickness (in)
Jefferson Co. Site #1, U.S. 27							
Base (Limerock)	31,300	71,841	132.2	117.5	12.5	Limerock	6.5
Subgrade (Silty Clay)	20,526	50,080	126.4	110.2	14.7	A-4	6.5
Embankment (Silty Clay)	13,179	13,179	115.4	100.4	14.9	A-2-6	
Jefferson Co. Site #2, U.S. 27							
Base (Limerock)	46,951	81,383	131.8	118.1	11.6	Limerock	7.5
Subgrade (Silty Clay)	31,301	37,560	134.9	123.7	9.0	A-4	11.5
Embankment (Silty Sand)	23,475	23,475	134.3	120.1	11.8	A-2-4	
Gadsden Co. Site #2, U.S. 27							
Base (Limerock)	57,785	116,857	133.4	120.3	10.8	Limerock	9.6
Subgrade (Silty Sand)	27,823	30,048	130.4	115.5	13.2	A-2-4	10.5
Embankment #1 (Silty Sand)	25,040	29,214	125.2	110.4	13.3	A-2-4	9.0
Embankment #2 (Clay)	20,867	20,867	125.1	100.0	25.2	A-6	
Gadsden Co. Site #3, U.S. 27							
Base (Limerock)	62,601	109,553	129.8	117.1	10.8	Limerock	8.5
Subgrade (Fine Sand)	39,126	51,645	127.7	113.5	12.5	A-3	23.0
Embankment (Clay)	15,650	15,650	126.1	99.7	26.5	A-6	
DISTRICTS 4 AND 6	**Equivalent Modulus (psi)**	**Layer Modulus (psi)**	**Wet Density (pcf)**	**Dry Density (pcf)**	**M.C. (%)**	**AASHTO Classification**	**Layer Thickness (in)**
Dade Co., Site #1, U.S. 41							
Base (Limerock)	119,459	134,245	140.4	132.1	6.2	Limerock	13.0
Subgrade (Limerock)	89,430	93,007	126.3	118.6	7.3	Limerock	13.0
Embankment (Limerock)	71,544	71,544	132.9	121.5	9.2	Limerock	
Dade Co., Site #2, U.S. 41							
Base (Limerock)	104,335	115,571	143.9	133.8	7.5	Limerock	9.5
Subgrade (Limerock)	96,309	111,291	140.0	129.3	7.9	Limerock	12.5
Embankment (Limerock)	69,557	69,557	129.5	119.3	8.5	Limerock	
Martin Co., Site #3, U.S. 1							
Base (Limerock)	58,919	79,295	136.0	128.5	5.8	Limerock	10.0
Subgrade (Fine Sand)	41,734	143,076	118.9	113.1	5.2	A-3	12.0
Embankment (Fine Sand)	11,923	11,923	111.8	105.4	5.4	A-3	
Martin Co., Site #4, U.S. 1							
Base (Limerock)	48,154	91,219	132.7	123.9	7.1	Limerock	9.0
Subgrade (Silty Clay)	26,829	39,349	121.5	115.2	5.5	A-4	12.0
Embankment (Fine Sand)	17,886	17,886	113.9	110.0	2.6	A-3	

(continued on next page)

directly from the field test using elasticity theory based on Equation 3. The deflections from ELSYM5 at the subgrade layer match well with the actual field test straight-line portion of the load-deflection curve. The differences between the ELSYM5 load-deflection line and the straight-line portion of field test curve are within about 10 percent for this case, but in most cases they are within about 7 percent for the subgrade layers. For the base layers, the predicted deflections from ELSYM5 are in close agreement with the straight-line portion of the actual field load-deflection curve. The differences are within about 15 percent, but most of them are within about 10 percent.

It is interesting to note that for the base layer, deflections from the ELSYM5 with input of the elastic modulus of three layers are almost the same as with input of two layers modulus and a lower layer of combined subgrade and embankment modulus. It is warranted that the subgrade and embankment soil can be considered as one-layer soil with an equivalent modulus when the elastic modulus of the base layer is calculated using Equations 3 and 4.

TABLE 2 (*continued*)

DISTRICT 5	Equivalent Modulus (psi)	Layer Modulus (psi)	Wet Density (pcf)	Dry Density (pcf)	M.C. (%)	AASHTO Classification	Layer Thickness (in)
Seminole Co., Site #1, U.S. 414							
Base (Limerock)	37,514	62,601	134.7	123.7	8.8	Limerock	12.0
Subgrade (Silty Sand)	20,867	20,867	120.1	109.8	9.4	A-2-4	12.0
Embankment (Silty Sand)	25,040	25,040	120.4	111.8	7.7	A-2-4	
Seminole Co., Site #2, U.S. 414							
Base (Limerock)	39,539	52,584	127.0	115.9	9.4	Limerock	12.0
Subgrade (Silty Sand)	25,040	27,317	125.7	111.1	13.2	A-2-4	13.5
Embankment (Fine Sand)	22,764	22,764	116.6	103.9	13.3	A-3	
Osceola Co., Site #3, U.S. 441							
Base (Coquina)	46,951	88,377	134.1	128.3	4.5	Coquina	8.0
Subgrade (Fine Sand)	29,459	37,561	123.2	118.2	4.2	A-3	12.0
Embankment (Fine Sand)	20,867	20,867	107.5	103.5	3.9	A-3	
Osceola Co., Site #4, U.S. 441							
Base (Coquina)	37,560	56,340	138.2	132.4	4.2	Coquina	11.0
Subgrade (Fine Sand)	23,475	31,131	130.4	121.9	7.3	A-3	18.0
Embankment (Fine Sand)	13,535	13,535	119.2	106.3	12.1	A-3	

Metric Conversion Factors: 1 psi = 6.89 KPa; 1 pcf = 16.02 Kg/m^3; 1 in = 25.4 mm

CONCLUSIONS

The conclusions from this experimental study are summarized here:

1. The field plate bearing load test was successfully carried out to evaluate the layer properties of pavement soils. The equivalent elastic modulus of the pavement layered system was obtained from the test, and the modulus of elasticity of the component layer could be determined from the test data.
2. Burmister's two-layer theory was used to backcalculate the modulus of elasticity of each layer from the plate bearing test. The validity was warranted by the ELSYM5 program.
3. Results of the plate bearing tests were considered to be representative of base, subgrade, and embankment materials in Florida.

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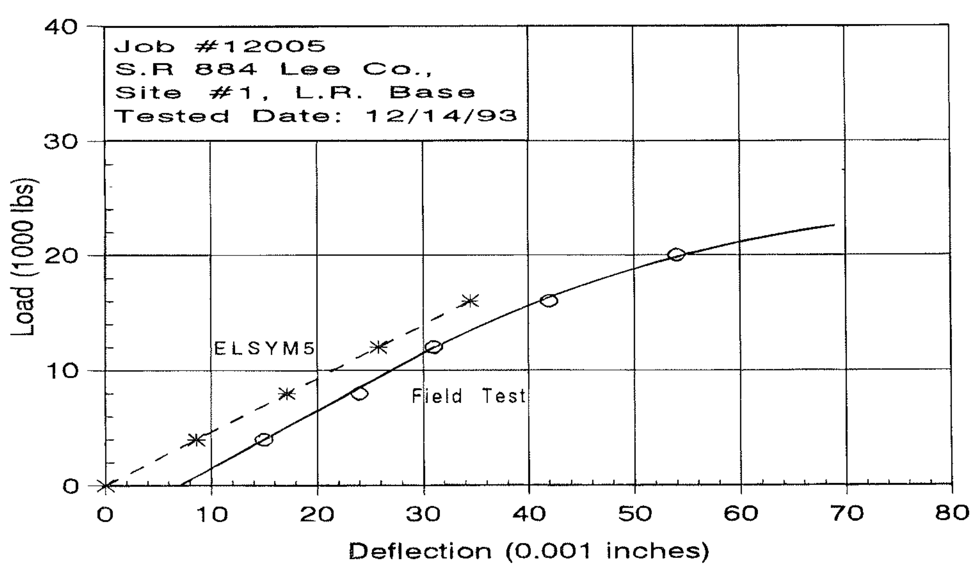

FIGURE 7 Typical ELSYM5 calibration for base layer (1 lb = 4.45 N; 1 in. = 25.4 mm).

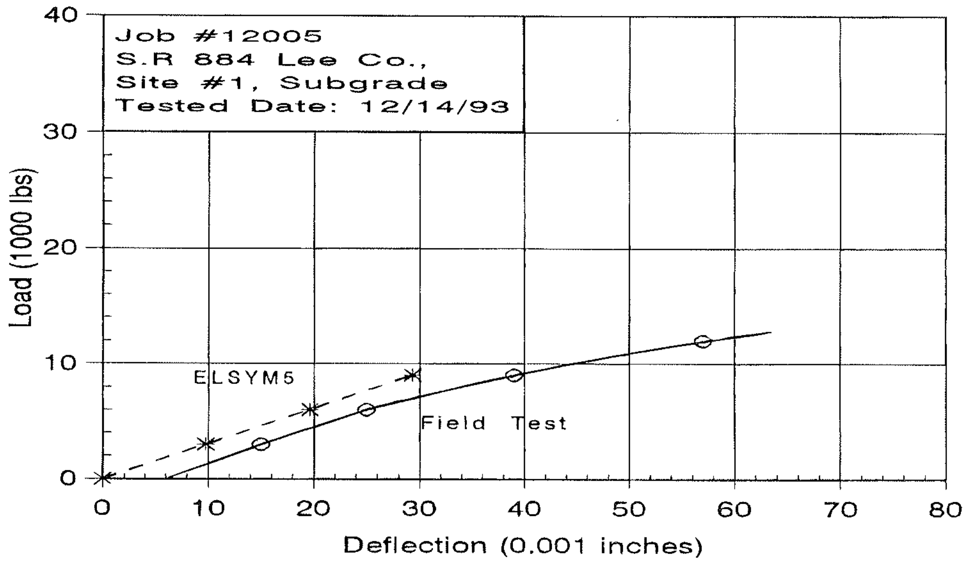

FIGURE 8 Typical ELSYM5 calibration for subgrade layer (1 lb = 4.45 N; 1 in. = 25.4 mm).

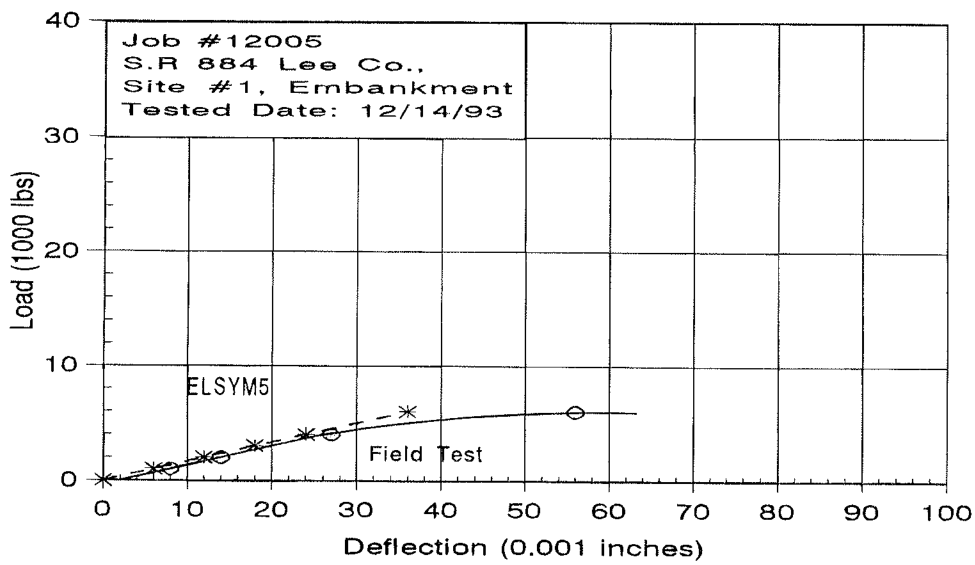

FIGURE 9 Typical ELSYM5 calibration for embankment layer (1 lb = 4.45 N; 1 in. = 25.4 mm).

gram was conducted by the Pavement Evaluation Section under the supervision of William G. Miley of the FDOT State Materials Office. The field logistics were provided by the FDOT District Materials/Maintenance offices. This research was initiated by William Lofroos and Bruce Dietrich through the Pavement Management Office. Michael Dowell was the FDOT project manager. Richard Long, Director of the FDOT Research Center, and Jo Penrose provided financial and contractual support.

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