Volume I
Section 2.1

STRUCTURAL LAYER COEFFICIENTS FOR FLEXIBLE PAVEMENT BASE MATERIALS

2.1.1 PURPOSE

To determine the structural layer coefficient to be assigned to a base course material for use in designing flexible pavement systems as documented in the Flexible Pavement Design Manuals of the Florida Department of Transportation (Department).

2.1.2 AUTHORITY

Section 334.044(10)(a) and (b), Florida Statutes

Section 334.24(2) and (4), Florida Statutes

Florida Department of Transportation Standard Specifications for Road and Bridge Construction (Specifications)

Chapter 14-103, Aggregate Source Approval (Aggregate Rule)

2.1.3 SCOPE

Principal users are the Pavement Design Office (PDO), State Construction Office (SCO), State Materials Office (SMO), District Materials and Research Offices (DMROs), District Construction Offices (DCOs), and District Maintenance Offices.

2.1.4 GENERAL INFORMATION

A study to determine the structural layer coefficient of a base course material not previously assigned a coefficient, or to consider modifying the structural layer coefficient previously assigned to a material, serves the interests of the public by providing information resulting in the most cost-effective structural design of flexible pavement systems.

The present flexible pavement design system takes into consideration the support provided by the underlying soil (soil support value), the loads anticipated to be applied to the pavement during its design life (18Kip Equivalent Single Axle Loads) and the strength required in the pavement (Structural Number) to distribute the traffic loads to the underlying soil. Flexible pavement design criteria currently in use by the Department are empirical in nature. They are based on data relating load-response measurements on test-pit pavements and in-service pavements, and performance observations of in-service pavements, to the factors which affect the performance of a flexible pavement system.

Records indicate that from the mid 50's to the early 60's, the Department used a pavement design procedure with no direct consideration given to the strength of the base course materials. During this same period, the Limerock Bearing Ratio (LBR) test was being developed based on research work by Gartner, Zimpfer and Bransford. The LBR test is a means of assigning a support value to soils and a strength value to subgrade, subbase and base course materials.

In 1962, the first Interim Design Guide based on the AASHTO Road Test was issued to the States. In addition to evaluating other variables, it required the evaluation of layer coefficients and structural numbers. According to the Interim Guide, "Because of widely varying environments, traffic, and construction practices, it is suggested that each agency establish layer coefficients applicable to its own practices and based on its own experience." Experimental projects were constructed by the Department in Chiefland and Crestview to study three principal variables (type of base material, type of subbase material and the thickness design of surface, base and subbase). Later three more experimental projects were constructed in Lake Wales, Marianna, and Palm Beach, primarily for determination of base material equivalencies.

In the late 60's, the Department began a field evaluation program of existing pavements which included trenching, laboratory tests (LBR, etc.) and field tests (plate bearing, in-place moisture and density, etc.).

From 1968 to 1971, test pit studies were conducted on various base materials to characterize their resistance to repeated loads at optimum moisture content and at soaked moisture conditions.

In the mid 70's a minimum LBR strength requirement was added to the limerock base specification and the Department Flexible Pavement Design Manual was published, listing layer coefficients for the various base materials. This Design Manual was patterned after data published in the AASHTO Interim Guide.

In the early 80's the Dynaflect and field plate load test were used in pavement evaluation to determine soil support and module of base and subgrade materials from which layer coefficients may be estimated using the 1986 AASHTO Design Guide Nomographs.

Layer coefficients are currently used in the Department flexible pavement design process in the following manner.

A design structural number (SN) is calculated using the basic AASHTO performance model. The following equation is then used to convert this SN value to actual layer thickness:

$SN = a_1*D_1 + a_2*D_2 + a_3*D_3 + a_4*D_4$

where:

a_1, a_2, a_3, a_4 = Layer coefficients representing the strength of their respective layer.

D_1, D_2, D_3, D_4 = Layer thickness in inches.

Layer 1	=	Friction Course
2	=	Structural Course
3	=	Base Course
4	=	Stabilized Subgrade

2.1.5 EVALUATION REQUIREMENTS

It is the responsibility of the SMO, with appropriate input and support from the State Pavement Design Engineer, the DMROs and the Flexible Pavement Committee to evaluate a base course material and to determine the structural coefficient to be assigned that material. The SMO will conduct all testing for the evaluation and prepare a report. Final recommendations regarding the structural layer coefficient will be based on a joint review of engineering data by the SMO, DCO, and State Pavement Design Engineer.

For a material which has not previously been assigned a structural layer coefficient, evidence must be submitted that an existing road or street constructed using the material as its base course is exhibiting satisfactory performance.

For material which has been previously assigned a structural layer coefficient, the Department may reevaluate this material based on field performance.

The material supplier shall submit certified test results for tests required in ***Section 2.1.5.2*** along with representative samples of material for Department verification of those tests.

In order to clearly present the requirements for determination of structural layer coefficients, base course materials will be classified as follows:

Granular Materials

Cement Bound Materials

Asphalt Bound Materials

The following sections of this procedure set out the requirements for evaluation of each category.

2.1.5.1 Eligibility Criteria

A. Granular Materials

For granular materials, the following criteria must be met prior to beginning an evaluation:

1. If no governing Standard Specification exists for the proposed material, a Special Provision, Technical Provision, Developmental Specification, or some other document acceptable to the Engineer must be submitted. The submitted document must define the physical and chemical properties of the material

2. For a material not currently assigned a structural layer coefficient, evidence must be submitted by the producer to substantiate that the source and the quality control(QC) program proposed by the producer is likely to be approved under the ***Aggregate Rule.*** In addition, the producer must

demonstrate that sufficient quantities of the proposed material will be available to provide a cost-effective alternate to existing approved materials.

3. Based on past performance data, certain types of base course materials as listed below shall have a minimum content of magnesium and calcium carbonate as follows:

Material	Minimum % Carbonates
Limerock	70
Shell	50
Cemented Coquina	50
Shell-Rock	50

4. The portion of base course material passing the No. 40 Sieve shall be non-plastic and shall have a liquid limit not exceeding 35.

5. The material must have a minimum LBR Value of 100.

B. Cement Bound Materials

For cement bound materials, the following criteria must be met prior to beginning an evaluation:

1. Designation of the type of cement bonded material proposed. In general, this will be either a soil-cement or cement treated aggregate material.

2. There must be a Specification covering how the soil -cement or cement treated aggregate material is to be constructed including:

(a) The criteria for determining the mix proportions (Strength Design or Brush Loss). If proportioning is to be based on Strength Design, the design minimum strength must be specified.

(b) Provisions requiring the Contractor to control the quality of the cement-bonded material through process control and sampling and testing of the mixture.

C. Asphalt-Bound Material

The following criteria must be met prior to beginning an evaluation on materials proposed as an exception to the above. In most cases the ***Specification Section 334*** (or mixture type SP12-5 when applicable), with their currently assigned layer coefficients, will apply for asphalt bound material.

1. For identification purposes, there must be a Specification covering the mixture and the physical and chemical properties of the component materials proposed for consideration including any additives or admixtures.

2. For a material not currently assigned a structural layer coefficient, evidence must be submitted by the producer to substantiate that the source and the quality control program of the aggregate components proposed by the producer is likely to be approved under the ***Aggregate Rule***.

2.1.5.2 Laboratory Testing

For materials meeting the eligibility criteria stated in ***Section 2.1.5.1***, a laboratory study may be initiated. The initiation of the study shall be subject to the availability of funding and the demonstrated potential of the material. The study will be performed at the SMO, and shall include tests as indicated in ***Tables 1-3***.

A. Granular Materials

Table 1. Laboratory Tests for Granular Materials

Test Name	Test Procedure
Limerock Bearing Ratio	FM 5-515
Liquid Limit/ Plastic Index	FM 1-T 089, FM 1-T 090
Gradation	FM 1- T 088
Percent Carbonates*	FM 5-514

Laboratory Resilient Modulus	AASHTO T 307
Triaxial Shear Strength*	FM 1-T 297

*When appropriate

B. Cement Bound Materials

Table 2. Laboratory Tests for Cement Bound Materials

Material Type	Test Name	Test Procedure
Cement Bound: on aggregate material	Gradation (including minus 200 material)	FM 1- T 088
	Liquid Limit/ Plastic Index	FM 1-T 089, FM 1-T 090
	Organic Content	FM 1-T 267
Cement Bound: on cement bonded material	Moisture and Density Relationship	AASHTO T 134
	Unconfined Compression	FM 5-520
	Wetting and Drying Test for Compacted Soil-Cement Mixtures	AASHTO T 135

C. Asphalt-Bound Materials

For asphalt bound materials, the tests shown in Table 3 will be conducted on the aggregate component. Additionally, testing shall be conducted to determine that the coarse aggregate meets the requirements of ***Specification Section 901.*** The fine aggregate component shall meet the requirements of ***Specification Section 902***. The asphalt component shall meet the requirements of PG 67-22 of ***Specification Section 916***. The producer will prepare a mix design using ***Superpave Design Procedures, AASHTO PP28-01***. In order for the mix to be considered for further evaluation, the bituminous mixture shall meet the minimum requirements of Type B-12.5 for the Superpave design properties shown in ***AASHTO PP28-01*** and

Specification Section 334. The SMO will verify the mix design and determine the elastic modulus of the asphalt bound base material using the resilient modulus test methods (current AASHTO or ASTM test method and other tests determined appropriate).

Table 3. Laboratory Tests for Asphalt Bound Materials

Test Name	Test Procedure
L.A. Abrasion for large aggregate	ASTM C 535
L.A. Abrasion for small aggregate	ASTM C131
Absorption, specific gravity	ASTM C 127
Porosity	ASTM D 4612
Soundness	ASTM C 88
Gradation	ASTM C 136
Minus 200	ASTM C 117
Soft and Friable Particles	ASTM C 142
Particle Shape	ASTM C4791
Potential Reactivity: alkali-carbonate, alkali-silica	ASTM C289
Volume Change: swell, unstable materials	ASTM D 4792
Petrographic Analysis	ASTM C 295
pH	ASTM G 51
Slaking	ASTM D 4644
Chlorides	ASTM D 1411
Insoluble Residue	ASTM D 3042

Staining Materials	ASTM C 641

2.1.5.3 Test Pit Study

If the Director, Office of Materials determines that the above laboratory tests suggest that a test pit study may yield information which will result in improved cost effectiveness in construction of flexible pavement systems, a study in the Department Test Pit may be initiated.

A. Granular and Asphalt Bound Materials

For granular materials and asphalt bound materials, the indoor test-pit study shall consist of:

1. Construction of a standard 10.5" thick layer of the new base material in the test pit using Department established method for test pit studies.

2. Performance of repetitive plate load tests on the new base material under three moisture conditions:

   (a) as constructed

   (b) drained with water level 24” below bottom of base

   (c) soaked (with water level at surface of base)

3. Measurement of total and permanent deformations under repetitive load and determination of a modulus value of the base material.

B. Cement Bound Materials

For cement bound materials, the indoor test-pit study shall consist of:

1. Constructing a standard thickness of the cement bound material using Department established method for test pit studies.

2. Performing repetitive plate load tests on the base material. One or both of the following moisture conditions may be used.

   (a) As-constructed tests will be performed at curing periods of 7, 14 and 28 days.

(b) Soaked (water level at surface of base) on the 28th day of the curing period the water level in the test pit will be raised to the surface of the base and tests will be performed after the water level has stabilized.

3. Measuring total and permanent deformations under repetitive load and computing equivalent resilient modulus of the material.

2.1.5.4 Full Scale Field Testing

Research and field studies indicate that many factors influence the layer coefficients. The layer coefficient may vary with thickness, underlying support, position in the pavement structure, etc. Therefore, it is important that the structural coefficients be verified through field testing. If the Director, Office of Materials determines that the Department Test Pit study indicates that there is a high probability that a full scale test road study may produce information which will result in improved cost-effective design of flexible pavement systems, a test road study may be initiated if funds are available. This study shall consist of:

1. Selection of a suitable site within a Department project for construction of one or more test sections and one or more control sections with limerock base course. Limerock is used in control sections as the Department has extensive performance data on this material.

The following factors will be considered for selection of a test site:

(a) Volume of truck traffic and the pavement design will be such as to yield significant results in a reasonable period of time.

(b) Minimum of 1500', including transitions, for each test or control section with suitable horizontal and vertical alignment for obtaining performance measurements on the completed test site.

(c) Uniformity of subsurface conditions.

2. Preparation of plans and specifications for construction of test sections. The specifications will provide for a high level of QC in construction of test sections so as to achieve uniformity in each element of the pavement system. (e.g. A maximum and minimum LBR value for subgrade material, a

maximum and minimum density requirement for subgrade and base.) This level of QC is necessary in order to reduce variability and thus allow a more effective evaluation of data.

3. Construction of test sections. Increased inspection and testing will be performed to assure that the level of quality control specified is being achieved and to obtain the as-constructed properties of the various elements of the test sections. In addition to the acceptance testing done by project personnel, additional testing will be done by project personnel and personnel from the SMO.

These additional tests consist of:

(a) Field plate load tests on each pavement component of embankment, subgrade and base, ***FM 5-527***.

(b) In-site density tests at the plate load test locations, ***FM 1-T 238***.

4. During construction, records will be maintained in regard to the construction techniques utilized to place, compact and finish the pavement components. Any problems encountered or special techniques required will be noted.

5. Perform post-construction measurements on the pavement surface. These tests include:

(a) Falling Weight Deflectometer Testing, ***FM5-606***

(b) Rut Depth Measurements

(c) Cracking and Patching Surveys

(d) Tests for roughness using currently approved method.

(e) Properties of the recovered binder materials, ***AASHTO M 230*** and ***AASHTO M 322*** (asphalt bound material only)

(f) In place voids analysis on core samples, ***AASHTO 1-T 166*** and ***AASHTO 1-T 209***(asphalt bound materials only)

(g) Split tensile strength on core samples, ***FM 1-T 283*** (asphalt bound materials only)

These tests will be made periodically to evaluate the performance of the base material. The test period will be determined based on the pavement design and actual truck traffic but will continue as long as significant data is being obtained.

2.1.5.5 Evaluation of Data

Evaluation of the data obtained during the various phases of a study to determine the structural layer coefficient of a base course material will be done in accordance with the following:

A. Laboratory Testing

1. Granular Materials and Cement Bound Material

A comparison will be made between the characteristics of the base course material being evaluated and the characteristics of base course materials known to perform well as a component of a flexible pavement system. If this comparison indicates that the material being evaluated is likely to perform well as a base course, a test pit study may be initiated.

2. Asphalt Bound Material

A comparison will be made between the characteristics of the base material being evaluated and the characteristics of base course material known to perform well as a component of a flexible pavement system. An initial structural coefficient may then be established based on ***1986 AASHTO "Guide for Design of Pavement Structures***" ***Figure 2.9*** as well as historical performance data of similar mixes. If this comparison indicates that the material being evaluated is likely to perform well as a base course, a test pit study may be initiated.

B. Test Pit Study

A comparison will be made between the modulus values and total and permanent deformations measured for the base course material being evaluated and these values for base course materials known to perform well as a component of a flexible pavement system. The effect of moisture on the base course material will be evaluated using the data obtained when the water level in the test pit was maintained at the top of the base course.

This evaluation plus laboratory testing data may, result in assigning a tentative structural layer coefficient to the material for use in designing a full scale test section. If the material currently has a layer coefficient and is being reevaluated, the Director, Office of Materials may assign a revised interim coefficient for designing a full scale test section.

C. Full Scale Field Testing

The following steps will be used to evaluate the data obtained from a field test site:

1. Compare modulus values of base, subgrade and embankment materials between test and control sections.

2. Compare total and permanent deformations between test and control sections.

3. Compare pavement performance measurement between test and control sections.

D. Research by Other Agencies

Structural layer coefficients assigned to a similar material by the ***AASHTO Guide for Design of Pavement Structures*** and recommendations contained in that ***Design Guide*** plus information in ***NCHRP, TRB*** and ***FHWA*** publications will be considered.

2.1.5.6 Recommendations for Structural Layer Coefficient

A recommended structural layer coefficient will be developed by the Director, Office of Materials on the basis of evaluation of the data obtained from the various studies conducted with engineering judgment applied to account for the factors which cannot be fully considered in these studies.

2.1.6 TRAINING

None required.

2.1.7 FORMS

None required.