5 Design Input—Materials Properties for Mechanistic Design

5.1 Characterizing Materials within the Pavement Structure as Input for the AKFPD

This manual provides methods for determining the thickness of pavement structural layers in new construction projects and overlay for pavement rehabilitation projects. Design procedures presented here require design inputs that accurately represent real loadings and materials conditions. Considerable engineering judgment is required to properly select design inputs. In most cases, the designer will work with the Materials Section to obtain these values.

Aggregate layers are characterized in terms of their elastic properties. Specifically, these properties are repeated load, i.e., “dynamic” elastic modulus (a measure of stiffness called resilient modulus and noted by the symbol “M_R”) and Poisson’s ratio (deformational characteristic, noted by the symbol “μ”). M_R and μ are defined in Section 4.3.1 where program input values are discussed in detail.

For designing most new pavement structures, mechanistic properties of the various layers are often obtained from DOT&PF-approved tables. These tables provide reasonably accurate estimates of mechanistic properties for aggregate materials based on P_{200} content.

Values for M_R can also be obtained through laboratory testing or through the process of “backcalculation”, using data collected in the field by deflection testing equipment. Derivation of mechanistic properties from laboratory tests and backcalculation is applicable mostly to the design of overlays for existing pavements. Laboratory test methods recommended for determining the modulus values of asphalt concrete and soil/aggregate materials are, respectively, ASTM D7369 Resilient Modulus for Asphalt Mixtures and AASHTO T307 Resilient Modulus for Soils and Aggregate.

5.2 Materials Properties—Recommended Presumptive Values for New Construction and Reconstruction Designs

5.2.1 Resilient Modulus (M_R) Values

Usually layer resilient modulus values (M_R) for materials used in new construction are not known. The designer may use presumptive modulus values as shown in Tables 5-1 and 5-2. Material containing excess fines may cause significant thaw weakening of the overlying pavement structure. As a design quality control measure, seek concurrence in the selected modulus values from regional or headquarters pavement materials experts.

Table 5-1 Pavement Layer Moduli (ksi)

Material Type	P_{200}	Spring	Summer & Fall	Winter
Asphalt Concrete (Modified Asphalt)	—	450	400	1,200
Asphalt Concrete (Unmodified asphalt)	—	350	300	1,200
Aggregate Base	<6%	40	50	100
Selected Material Type A	<6%	35	40	90
Subbase F	<6%	35	40	90
Selected Material Type B	<10%	20	30	50
Selected Material Type C & Subgrade	<30%	10	10	10

Table 5-2 Pavement Layer Moduli (with excess fines) (ksi)

Material Type	P_{200}	Spring	Summer &	Winter
Aggregate Base	<10%	20	30	50
Selected Material Type A, B	<10%	20	30	50
Selected Material Type B	<18%	10	10	10
Selected Material Type C	>30%	10	10	10
Subgrade	>30%	5	5	5

5.2.2 *Resilient Modulus Values for Stabilized Base Course Materials*

Table 5-3 shows presumptive modulus values for stabilized base course materials.

Table 5-3 Stabilized Base Course Moduli (ksi)

Material Type	Spring	Summer & Fall	Winter
CABC ; RAP (50:50)[1]	80	90	120
EATB, 3% Emulsion[1]	100	100	300
ATB, 4% Asphalt[2]	200	200	600
Foamed Asphalt Stabilized Base[1]	110	100	400

1. lightly bound: use Ullidtz
2. heavily bound: use TAI

Design with lightly bound asphalt-treated base courses (containing < 4% asphalt cement) using the mechanistic design procedure and by controlling the vertical compression stress at the top of the treated bases and horizontal tensile strain at the bottom of the asphalt concrete pavement layer.

Design with heavily bound asphalt-treated base courses (containing ≥ 4% asphalt cement) using the mechanistic design procedure and by controlling the horizontal tensile strain at the bottom of the asphalt-treated base courses and the asphalt concrete pavement layers.

Verify the validity of presumptive modulus values with regional or headquarters Materials section personnel.

5.2.3 Poisson's Ratio Values

Table 5-4 shows recommended Poisson's ratios for various pavement structure materials. As a design quality control measure, seek concurrence in the selected Poisson's ratio values from regional or headquarters pavement materials experts.

Table 5-4 Poisson's Ratio Values

Material Type	Poisson's Ratio (μ)
Asphalt Concrete	0.30
Aggregate Base	0.35
Selected Material Types A and B	0.40
Selected Material Type C	0.45
Subgrade Materials	0.45

5.3 Materials Properties—Laboratory Testing to determine Values for New Construction and Reconstruction Designs

Much of the mechanistic pavement design work done for DOT&PF relies on presumptive M_R and Poisson's ratio values (see Section 5.2), although backcalculated values for M_R are often obtained based on deflection test data for overlay design work (see Section 5.4). This section provides guidance for those rare design situations where laboratory testing may be required. Testing might be required, for example, for designs involving unusual or experimental material types not listed in the Section 5.2 tables.

5.3.1 Resilient Modulus Values

For determining M_R of unbound soils (including subgrade soils) or unbound or lightly bound bases or subbase materials, use AASHTO T307 *Test for Determining the Resilient Modulus of Soils and Aggregate Materials*

For determining M_R of asphalt-bound materials such as asphalt concrete or other heavily asphalt-bound base materials, use ASTM D7369 *Standard Test Method for Determining Resilient Modulus of Bituminous by Indirect Tension Test*.

For heavily bound pavement, base, or subbase materials with a cementing agent other than asphalt, consult regional or headquarters Materials personnel for a recommended test method.

5.3.2 Poisson's Ratio Values

For all normal pavement design work the designer will use presumptive Poisson's ratio values. Table 5.4 contains recommended Poisson's ratios for common pavement structure materials. As a design quality control measure, the designer should seek concurrence in the selected Poisson's ratio values from regional or headquarters pavement design experts. Also solicit materials expertise for determining Poisson's ratio values for unusual materials.

5.4 Materials Properties—Values determined from Field Tests for Overlay Designs

5.4.1 Backcalculation Program

DOT&PF recommends the backcalculation program ELMOD, developed by Dynatest Consultants Inc. Backcalculation of layer modulus values should be done only by personnel with experience in performing backcalculations.

The minimum asphalt concrete thickness for which a modulus can be backcalculated is 3.5 inches, because of the plate size on the falling weight deflectometer. For thinner layers, the asphalt concrete pavement must be cored and tested in the laboratory or presumptive moduli values in Table 5-1 can be used.

5.4.2 Deflection Testing

DOT&PF currently uses a falling weight deflectometer (FWD) to measure the dynamic deflection for pavement rehabilitation design. Seek advice from regional or headquarters pavement design experts to schedule and perform such testing.

5.4.3 Selecting Test Locations

Working with the Materials Section, select test locations as an average representation of the present surface condition and where the original pavement structure is free from patching. If alligator cracking is not prevalent, adjust test locations to avoid the cracking. If alligator cracking cannot be avoided, note it in the data. If alligator cracking is prevalent, assume a reduced modulus (contact the regional materials engineer). Select a test section to represent each type of terrain the project passes through.

Choose a minimum of 20 evenly spaced deflection test locations within a selected mile. If the pavement structure is thought to be frost-susceptible, consider increasing the number of tests. It is preferable to mark the test locations with paint for repeated testing of exact points in subsequent weeks. White painted markings on the centerline have been found to last longer and are easier to locate by field crews.

5.4.4 When to Test

Perform FWD deflection testing during the spring thaw period when pavement strength is at a minimum. A weekly set of deflection tests should begin when the pavement structure begins to thaw and must continue through the period when peak deflections occur. Perform at least one set of readings in the summer and another in the fall.

Base the decision of when to begin testing on actual field evidence, such as small test pits, frost tubes, or soil temperature data, if available. If deflection testing cannot be perform during the peak period, contact the regional materials engineer for a seasonal adjustment factor.

Testing during periods when night temperatures are below freezing should not begin before late morning. This is to prevent the bridging effect of the temporarily frozen surface layer from depressing the true rebound deflection readings.

5.4.5 Testing Procedure

See the falling weight deflectometer operation manual available from the Materials Engineer.

5.4.6 Safety Equipment and Precautions

Because of frequent stops when FWD testing, take all necessary safety precautions. Use appropriately attired flaggers as necessary to control traffic. High-level warning devices, such as vehicle-mounted arrow boards, are best (see part 6 of the *Manual on Uniform Traffic Control Devices for Streets and Highways,*[(20)] for detailed procedures). One or two vehicles with warning signs will be required, depending on traffic levels and sight distances.