AASHTO Pavement Thickness Design Guide

When designing pavement thickness for flexible and rigid pavements, the following considerations should be used.

1. Performance criteria (serviceability indexes). Condition of pavements are rated with a present serviceability index (PSI) ranging from 5 (perfect condition) to 0 (impossible to travel).
   a. Initial serviceability index (Po) – Po is considered to be that PSI immediately after the pavement is open. AASHTO values are 4.5 for rigid pavement and 4.2 for flexible pavement.
   b. Terminal serviceability index (Pt) – Pt is considered to be that PSI that represents the lowest acceptable level before resurfacing or reconstruction becomes necessary.

      - Pt = 2.00 for Secondary Roads, Local Residential Streets.
      - Pt = 2.25 for Minor Collectors, Industrial and Commercial Streets.
      - Pt = 2.50 for Major Collectors and all Arterials.

   c. Serviceability loss (dPSI) – dPSI is the difference between Po and Pt (Po-Pt). The dPSI is the basis for the pavement design.

2. Design variables

   a. Analysis period (n) – n is the period of time for which the analysis is to be conducted. Normally 50 years for concrete and 30 years for asphalt.
   b. Design Traffic (ESALs) – ESALs is the estimate of number of Equivalent 18 kip Single Axle Loads (ESALs) during the analysis period is required. This value can be estimated based on:

      - The Average Annual Daily Traffic (AADT) in the base year
      - The average percentage of trucks expected to use the road
      - The average annual traffic growth rate, and
      - The analysis period

      To estimate the design ESALs, the following procedure may be used.

      1.) Obtain an estimate of the design AADT for the beginning, or base year of the analysis period.
      2.) Obtain an estimate of the average percentage of the AADT that will be trucks.
      3.) Calculate the ESALs for the base year.
      4.) Calculate the growth factor based on the annual traffic growth rate (r - %) and the analysis period (n). Growth Factor = (((1+r)^n) – 1)/r
      5.) Multiply the base year ESALs by the Growth Factor to obtain the total ESALs for the analysis period.

c. Reliability (R - %)/ Normal Deviation (ZR) – R is the probability that the design will succed for the life of the pavement. The following reliability and normal deviation (ZR) values are recommended.

- Local Streets: R = 80%, ZR = -0.841
- Collector Streets: R = 88%, ZR = -1.270
- Arterial Streets: R = 95%, ZR = -1.645

d. Overall standard deviation (So) – So is the coefficient which describes how well the AASHTO Road Test data fits the AASHTO Design Equations. The lower the overall deviation, the better the equations model the data. The following ranges are recommended.

- Rigid Pavements: 0.30 to 0.40
- Flexible Pavements: 0.40 to 0.50

3. Material properties for structural design

a. Roadbed soil resilient modulus (MR) – MR is the property of the soil which indicates the stiffness or elasticity of the soil under dynamic loading. MR is also adjusted for seasonal fluctuation from temperature etc.

b. Modulus of subgrade reaction (k and kc) – k is the modulus of the subgrade soil.

c. Approximate relationship of k to MR: k=MR/19.4

d. Composite modulus of subgrade reaction (kc) - kc is the composite modulus of the subbase materials, which will take into account any base placed on top of the subgrade. If a base is used kc is input into the equation rather than k.

Type of Soil	Subgrade Strength	K Value Range (pci) (Rigid Pavement)	Resilient Modulus MR, (psi) (Flexible Pavement	CBR
Silts and clays of high compressibility (liquid limit >= 50), natural density (not recommended for subgrades without treatment)	Very Low	50 - 100	1000 - 2700	3 or less
Fine grain soils in which silt and clay size particles predominate (low compressibility, liquid limit < 50)	Low	100 - 150	2700 - 4000	3 to 5.5
Poorly grades sands and soils that are predominately sandy with moderate amounts of silts and clays (well drained)	Medium	150 - 220	4000 - 5700	5.5 to 12
Gravely soils, well graded sands, and sand gravel mixtures relatively free of plastic fines	High	220 – 250+	>5700	>12

Approximate composite modulus of subgrade reaction (kc) for various pavement conditions.

Subgrade k Value	Untreated Subbase Depth vs kc, pci, (LS=1)			
	4 in	6 in	8 in	10 in
50	27	31	34	37
100	43	47	51	56
150	57	62	66	71
200	70	74	78	85

- Crushed stone use k = 100 and kc = 150 for 6 to 12 in of thickness.

Subgrade k Value	Bituminous Subbase Depth vs kc, pci, (LS=0)			
	4 in	6 in	8 in	10 in
50	84	112	141	170
100	144	198	243	288
150	221	277	334	392
200	284	351	419	487

Subgrade k Value	Cement Treated Subbase Depth vs kc, pci, (LS=0)			
	4 in	6 in	8 in	10 in
50	101	145	193	245
100	185	258	334	414
150	265	360	460	563
200	341	457	577	700

Subgrade k Value	Lean Concrete Subbase Depth vs kc, pci, (LS=1)			
	4 in	6 in	8 in	10 in
50	104	156	205	262
100	192	271	354	443
150	274	378	488	603
200	353	480	612	750

e. Concrete properties – Modulus of Elasticity (Ec) and Modulus of Rupture (S'c). S'c is the 28 day Flexural Strength of the concrete. Ec can be derived from S'c as follows Ec = 5700(S'c). Flexural Strength (S'c) can also be approximated from compressive strength (fc) as follows: S'c = 2.3fc^0.667(psi).

f. Layer coefficients. Structural layer coefficients (ai) are required for flexible pavement design. A value for these coefficients is assigned to each layer material in the pavement structure in order to convert actual layer thickness into structural number (SN).

Component	**Coefficient**	**Minimum Thickness**
Surface/Intermediate Course		
Hot Mix Asphalt with Type A Aggregate	0.44	2
Hot Mix Asphalt with Type B Aggregate	0.40	2
Base Course		

Type B Hot Mix Asphalt	0.40	2
Asphalt Treated Base Class I	0.34	4
Bituminous Treated Aggregate Base	0.23	6
Asphalt Treated Base Class II	0.26	4
Cold-Laid Bituminous Concrete Base	0.23	6
Cement Treated Granular (Aggregate) Base	0.20	6
Soil-Cement Base	0.15	6
Crushed (Graded) Stone Base	0.14	6
Macadam Stone Base	0.12	6
Portland Cement Concrete Base (New)	0.50	
Old Portland Cement Concrete	0.40	
Crack and Seated PCC	0.25 – 0.30	
Rubblized PCC	0.20	
Cold in Place Recycled	0.22 – 0.27	
Subbase Course		
Soil-Cement Subbase	0.10	6
Soil-Lime Subbase	0.10	6
Granular Subbase	0.10	4
Soil-Aggregate Subbase	0.05	4

4. Pavement structural characteristics
   a. Coefficient of drainage (Cd or Mi) – Cd is the coefficient of drainage for rigid pavement design used to account for improved or decreased quality of drainage. Mi is the coefficient of drainage for flexible pavement design used to modify layer coefficients. Water under pavement is one of the primary causes of pavement failure. This will contribute to pavement pumping under large numbers of heavy loads.

      The following definitions are used as a guide:

      Excellent drainage – Material drained to 50% of saturation in 2 hours.
      Good drainage – Material drained to 50% of saturation in 1 day.
      Fair drainage – Material drained to 50% of saturation in 7 days.
      Poor drainage – Material drained to 50% of saturation in 1 month.
      Very poor drainage – Material does not drain.

      Based on these definitions the Cd or Mi value for Fair drainage would be 1.00. A value of 1.00 would have no impact on pavement thickness. Lower values increase the required pavement thickness; higher values decrease the required pavement thickness.

      Recommended values of Cd for rigid pavement

Percent of Time Pavement structure is exposed to moisture levels approaching saturation				
Quality of Drainage	< 1%	1 – 5%	5 – 25%	>25%
Excellent	1.25 – 1.20	1.20 – 1.15	1.15 – 1.10	1.10

Good	1.20 – 1.15	1.15 – 1.10	1.10 – 1.00	1.00
Fair	1.15 – 1.10	1.10 – 1.00	1.00 – 0.90	0.90
Poor	1.10 – 1.00	1.00 – 0.90	0.90 – 0.80	0.80
Very Poor	1.00 – 0.90	0.90 – 0.80	0.80 – 0.70	0.70

Recommended values of Mi for modifying structural layer coefficients of untreated base and subbase materials in flexible pavements

Percent of Time Pavement structure is exposed to moisture levels approaching saturation				
Quality of Drainage	< 1%	1 – 5%	5 – 25%	>25%
Excellent	1.40 – 1.35	1.35 – 1.30	1.30 – 1.20	1.20
Good	1.35 – 1.25	1.25 – 1.15	1.15 – 1.00	1.00
Fair	1.25 – 1.15	1.15 – 1.05	1.00 – 0.80	0.80
Poor	1.15 – 1.05	1.05 – 0.80	0.80 – 0.60	0.60
Very Poor	1.05 – 0.95	0.95 – 0.75	0.75 – 0.40	0.40

b. Load transfer coefficients for jointed and continuous reinforced pavements. The one item which distinguishes concrete pavement, is the type of joint used to control cracking and whether or not steel dowels are used in the joint for load transfer. Each design provides a different level of transfer of load from one side of pavement joint to the other. To adjust projected pavement performance for various designs, the load transfer coefficient (J) is used.

Load Transfer coefficients (J) for typical designs							
E-18's Millions	Doweled & Mesh		Aggregate Interlock Edge Support		Continuous Reinforcement		Class
	No	Yes	No	Yes	No	Yes	
Up to 0.3	3.2	2.7	3.2	2.8	-	-	Local Streets/Roads
0.3 to 1	3.2	2.7	3.4	3.0	-	-	Local Streets/Roads
1 to 3	3.2	2.7	3.6	3.1	-	-	Local Streets/Roads
3 to 10	3.2	2.7	3.8	3.2	2.9	2.5	Arterials/Highways
10 to 30	3.2	2.7	4.1	3.4	3.0	2.6	Arterials/Highways
Over 30	3.2	2.7	4.3	3.6	3.1	2.6	Arterials/Highways

c. Loss of support factor (LS) – LS is included in the design of rigid pavements to account for the potential loss of support arising from subbase erosion and/or differential vertical soil movement.

Typical ranges of LS for various types of base materials.

Type of Material	Loss of Support (LS)
Cement Treated Granular Base (E=1,000,000 to 2,000,000 psi)	0.0 – 1.0
Cement Aggregate Mixtures	0.0 – 1.0

(E=500,000 to 1,000,000 psi)	
Asphalt Treated Base (E=350,000 to 1,000,000 psi)	0.0 – 1.0
Bituminous Stabilized Mixtures (E=40,000 to 300,000 psi)	0.0 – 1.0
Lime Stabilized (E=20,000 to 70,000 psi)	1.0 – 3.0
Unbound Granular Materials (E=15,000 to 45,000 psi)	1.0 – 3.0
Fine Grained or Natural Subgrade Materials (E=3,000 to 40,000 psi)	2.0 – 3.0

5. Pavement Reinforcement

   a. General. There are two types of reinforced rigid pavements. Jointed Reinforced Concrete Pavement (JRCP) and Continuously Reinforced Concrete Pavement (CRCP). The major difference is that JRCP has joints and CRCP does not.

   b. JRCP

      1) Slab length (L) – distance between transverse joints.
      2) Steel working stress (fc) – typically a value equivalent to 75% of the steel yield strength is used for working stress. For Grade 40 and Grade 60 steel, the fc would be 30,000 psi and 45,000 psi, respectively.
      3) Friction factor (F) – F accounts for the frictional resistance between the bottom of the slab and the top of the underlying subbase or subgrade layer and is basically equivalent to a coefficient of friction.

Recommended friction factors (F)

Type of Material Beneath Slab	Friction Factor (F)
Surface Treatment	2.2
Lime Stabilization	1.8
Asphalt Stabilization	1.8
Cement Stabilization	1.8
River Gravel	1.5
Crushed Stone	1.5
Sandstone	1.2
Natural Subgrade Materials	0.9