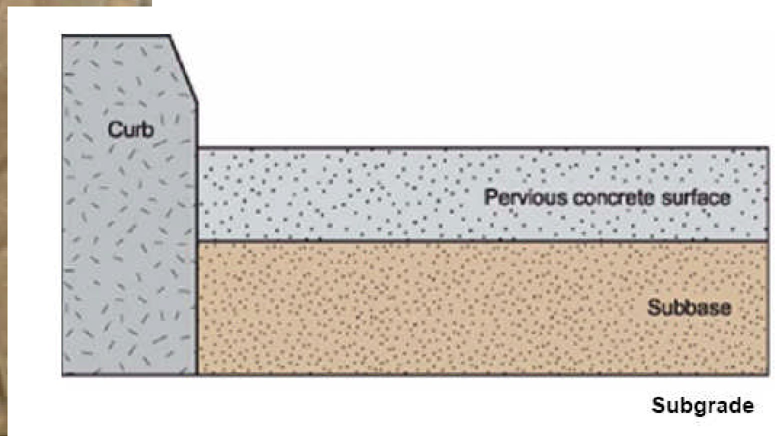
“Concrete Paving in NOVA” Conventional and Pervious Concrete & Streets and Local Roads

Rod Meyers, PE,
BASF Construction Chemicals

How Thick Should The Pervious Concrete Pavement Be?



ACI 552-10, Report on Pervious Concrete, section 3.3.1.1 Parking Lots

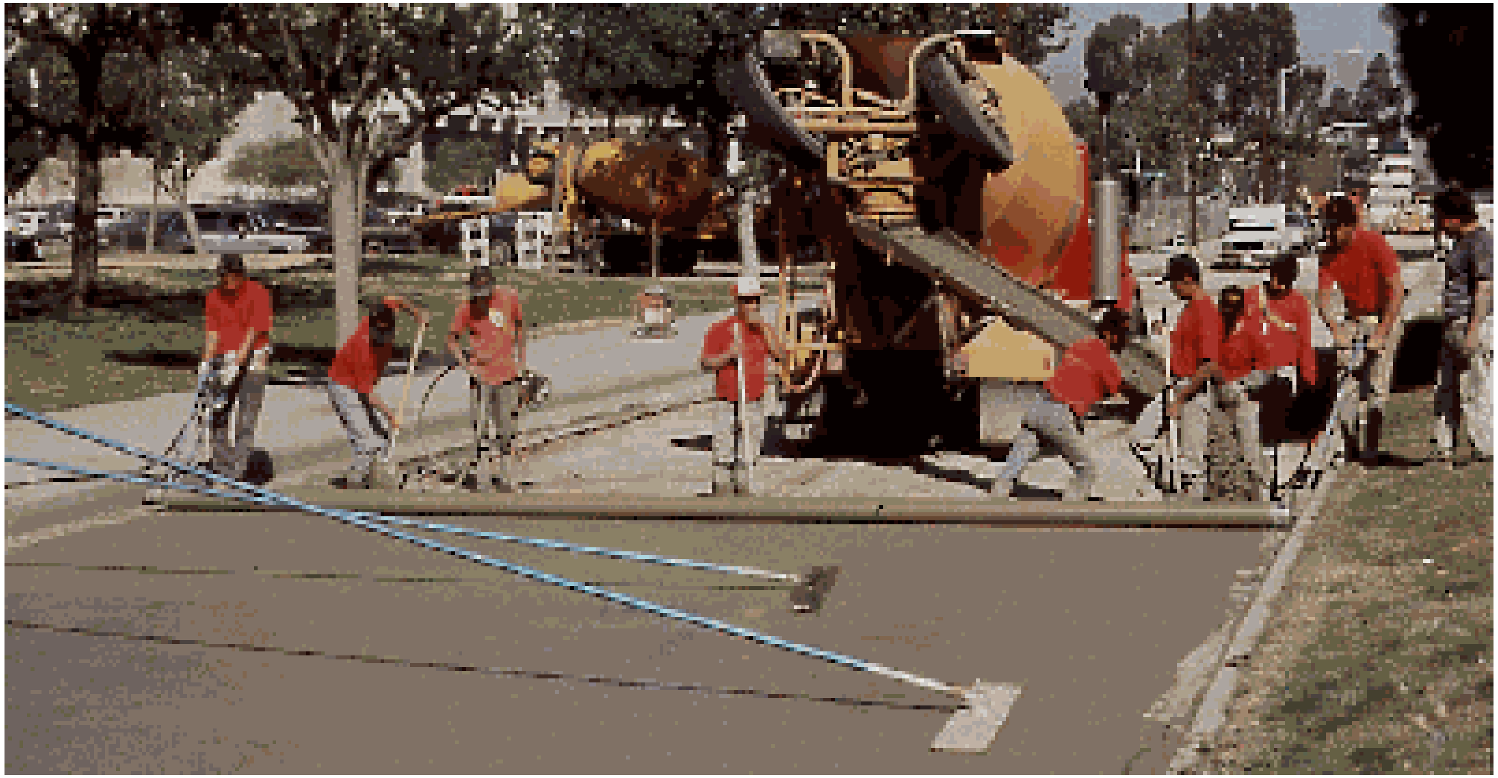
"The practical range of design thicknesses for pervious concrete pavements is from 5 to 12 in for plain parking lots."

VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 7

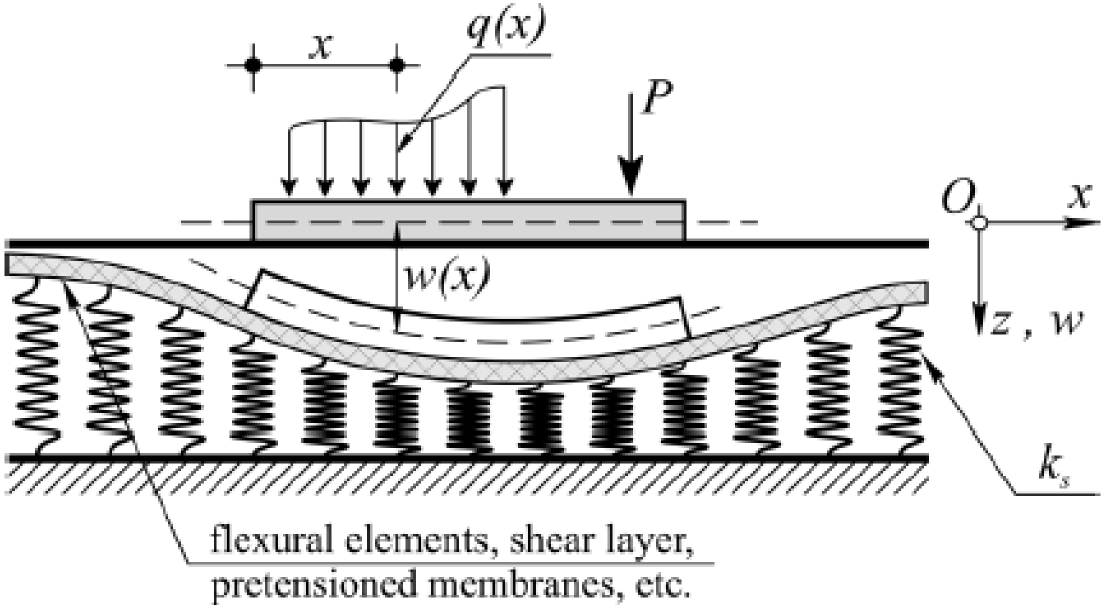
PERMEABLE PAVEMENT
VERSION 1.7
March 1, 2011

Table 7.6
Typical Thickness: 4 to 8 inches

Light Duty
Portland Cement Concrete
Pavements



Calculating Stresses in Pavement



PCA Pavement Stress Calculations Does anyone have a i5 Processor with Turbo Boost Technology?

$$\sigma_{eq_{in.-lb}} = \frac{6 \times (-970.4 + 1202.6 \times \log[\ell_{in.-lb}] + 53.587\ell_{in.-lb}) \times (0.8742 + 0.01088 \times k_{in.-lb}{}^{0.447})}{h_{in.-lb}{}^{2}} \times \left[\left(\frac{24}{SAL_{in.-lb}}\right)^{0.06} \times \frac{SAL_{in.-lb}}{18}\right] \times 0.894$$

$$\sigma_{eq_{SI}} = \frac{6 \times (-2659.85 + 1202.6 \times \log[\ell_{SI}] + 2.10972\ell_{SI}) \times (0.8742 + 0.427338 \times k_{SI}{}^{0.447})}{h_{SI}{}^{2}} \times \left[\left(\frac{106.757}{SAL_{SI}}\right)^{0.06} \times \frac{SAL_{SI}}{80.068}\right] \times 3.97672$$

$$\sigma_{eq_{in.-lb}} = \frac{6 \times (-2005.4 + 1980.9 \times \log[\ell_{in.-lb}] + 99.008\ell_{in.-lb}) \times (0.8742 + 0.01088 \times k_{in.-lb}{}^{0.447})}{h_{in.-lb}{}^{2}} \times \left[\left(\frac{48}{TAL_{in.-lb}}\right)^{0.06} \times \frac{TAL_{in.-lb}}{36}\right] \times 0.894$$

$$\sigma_{eq_{SI}} = \frac{6 \times (-777.437 + 1980.9 \times \log[\ell_{SI}] + 3.89794\ell_{SI}) \times (0.8742 + 0.427338 \times k_{SI}{}^{0.447})}{h_{SI}{}^{2}} \times \left[\left(\frac{213.515}{TAL_{SI}}\right)^{0.06} \times \frac{TAL_{SI}}{160.136}\right] \times 3.97672$$

$$\sigma_{eq_{in.-lb}} = \frac{6 \times (-88.54 + 134.0 \times \log[\ell_{in.-lb}] + 0.83\ell_{in.-lb}) \times (11.3345 + 0.2218 \times k_{in.-lb}{}^{0.448})}{h_{in.-lb}{}^{2}} \times \left[\left(\frac{72}{TriAL_{in.-lb}}\right)^{0.06} \times \frac{TriAL_{in.-lb}}{54}\right] \times 0.894$$

$$\sigma_{eq_{SI}} = \frac{6 \times (-276.788 + 134.0 \times \log[\ell_{SI}] + 0.0326771\ell_{SI}) \times (11.3345 + 8.78356 \times k_{SI}{}^{0.448})}{h_{SI}{}^{2}} \times \left[\left(\frac{320.272}{TriAL_{SI}}\right)^{0.06} \times \frac{TriAL_{SI}}{240.204}\right] \times 3.97672$$

ACPA Design Software

- Terminal serviceability index
- Allowable cracked slabs
- Pavement design life
- Reliability
- Traffic inputs

Light Duty Pavement Design

- Long term durability attractive
- Complex design methods are Overkill
- Not represented by AASHO Road Test
- AASHTO design method are overkill
- Design and QC based on fc

Design Tools

Types of Concrete Pavement

- Plain jointed pavement
- Plain-doweled pavement
- Reinforced-doweled pavement
- Continuously reinforced pavement

Typical Concrete Roads and Streets

- Plain jointed pavement
- ~~Plain-doweled pavement~~
- ~~Reinforced-doweled pavement~~
- ~~Continuously reinforced pavement~~

Curbs and Gutters

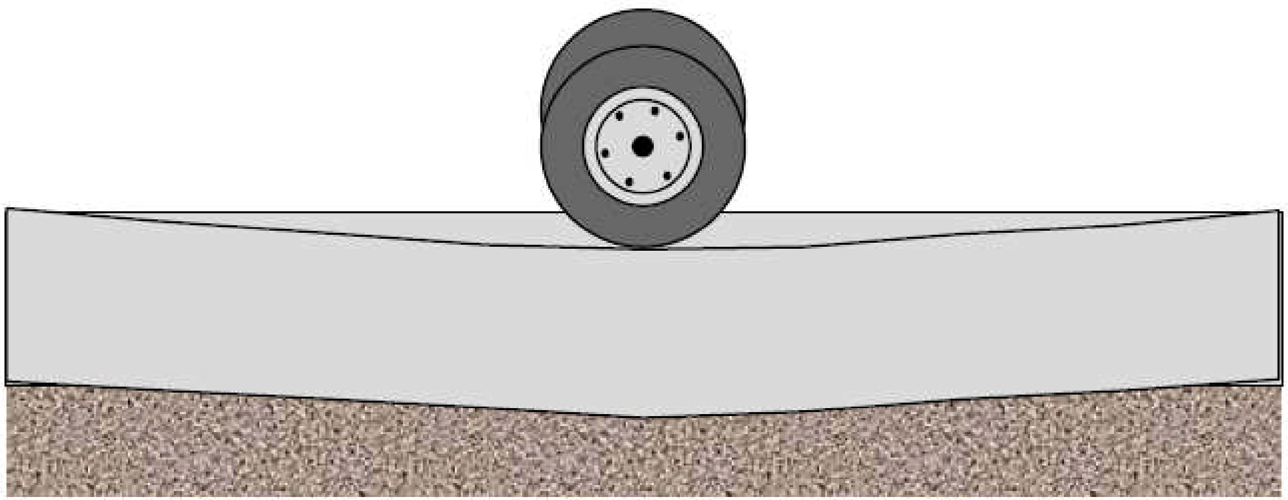
- Reduce edge stresses
- Used as side forms
- Allowed to use rounded joints

Functional Requirement

Support
Traffic Loads

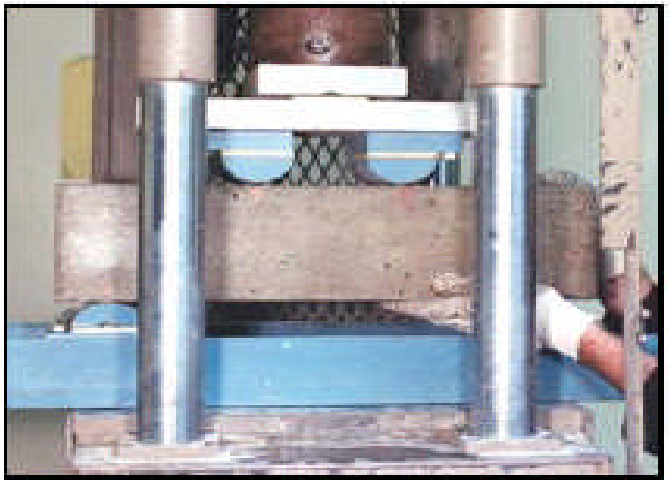
Flexural Strength

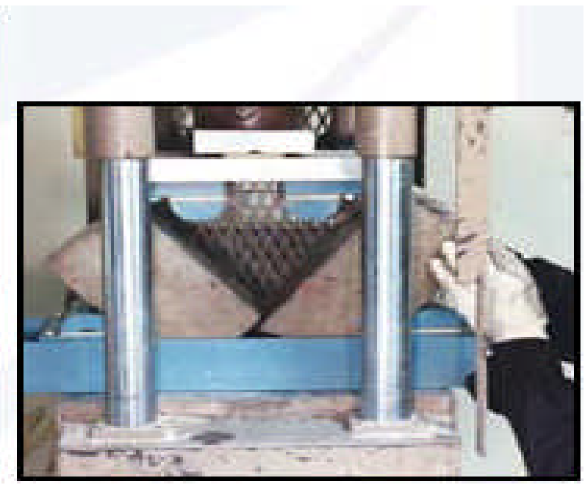
- Pavements are subject to bending stresses
- Flexural stresses and flexural strength govern design



Flexural Strength (MOR)

- ASTM C 78 Third-Point Loading of 6” by 6” by 30” beams
- High variability with flexural strength testing
- Results sensitive to specimen preparation, handling and curing procedures





Flexural Strength (MOR) from Compressive Strength Data ACI 330

For smooth-textured and round-shaped aggregates

$$MOR = 8 * (f'c)^{1/2} \quad \text{(psi)}$$

For rough-textured and angular-shaped aggregates

$$MOR = 10 * (f'c)^{1/2} \quad \text{(psi)}$$

$f'c$ = specified compressive strength (psi)

Flexural Strength from Compressive Strength Data PCA Design and Control of Concrete Mixtures

$$MOR = K * (f'c)^{1/2} \quad \text{(psi)}$$

K = factor from 7.5 to 10.0

f'c = specified compressive strength (psi)

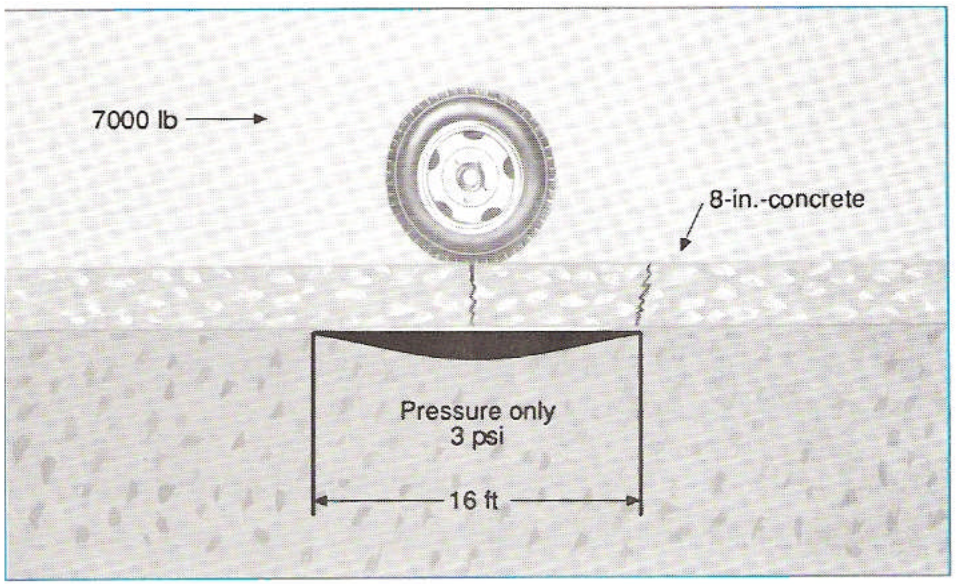
Calculated Flexural Strength, MOR (psi)			
	Compressive Strength, f'_c (psi)		
	3,500 psi	4,000 psi	4500 psi
MOR = 7.5 * $(f'_c)^{1/2}$	440	470	500
MOR = 8.0 * $(f'_c)^{1/2}$	470	500	540
MOR = 8.5 * $(f'_c)^{1/2}$	500	530	570
MOR = 9.0 * $(f'_c)^{1/2}$	530	570	600
MOR = 9.5 * $(f'_c)^{1/2}$	560	600	640
MOR = 10.0 * $(f'_c)^{1/2}$	590	630	670

Flexural Strength based on Compressive Strength

- $M_R = 8.7 * f_c^{1/2}$
- $f_c = 4{,}000$ psi
- $M_R = 8.7 * (4{,}000)^{1/2} = 550$ psi

Subgrade Support

- Concrete distributes load through slab action
- Load spread over large area



Subgrade Support Measured as:

- Modulus of Subgrade Reaction (k)
- California Bearing Ratio (CBR)
- Bearing Value
- Resistance Value (R)

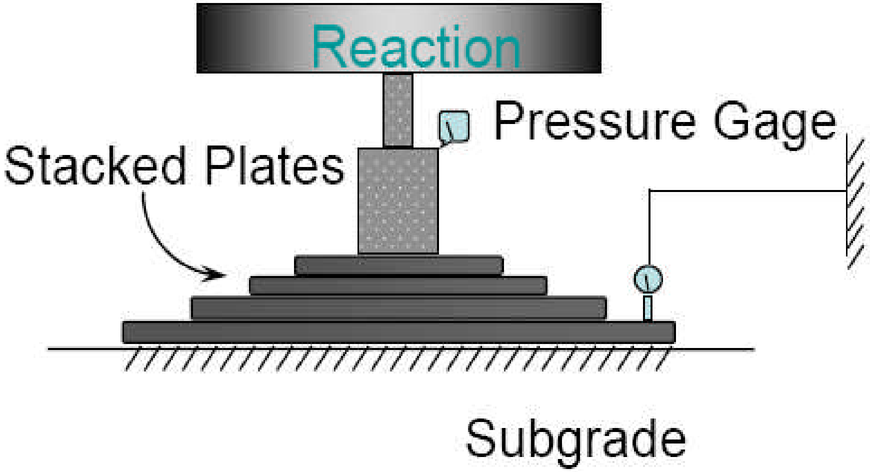
Modulus of Subgrade Reaction (k)

Modulus of
Subgrade Reaction,
k-value

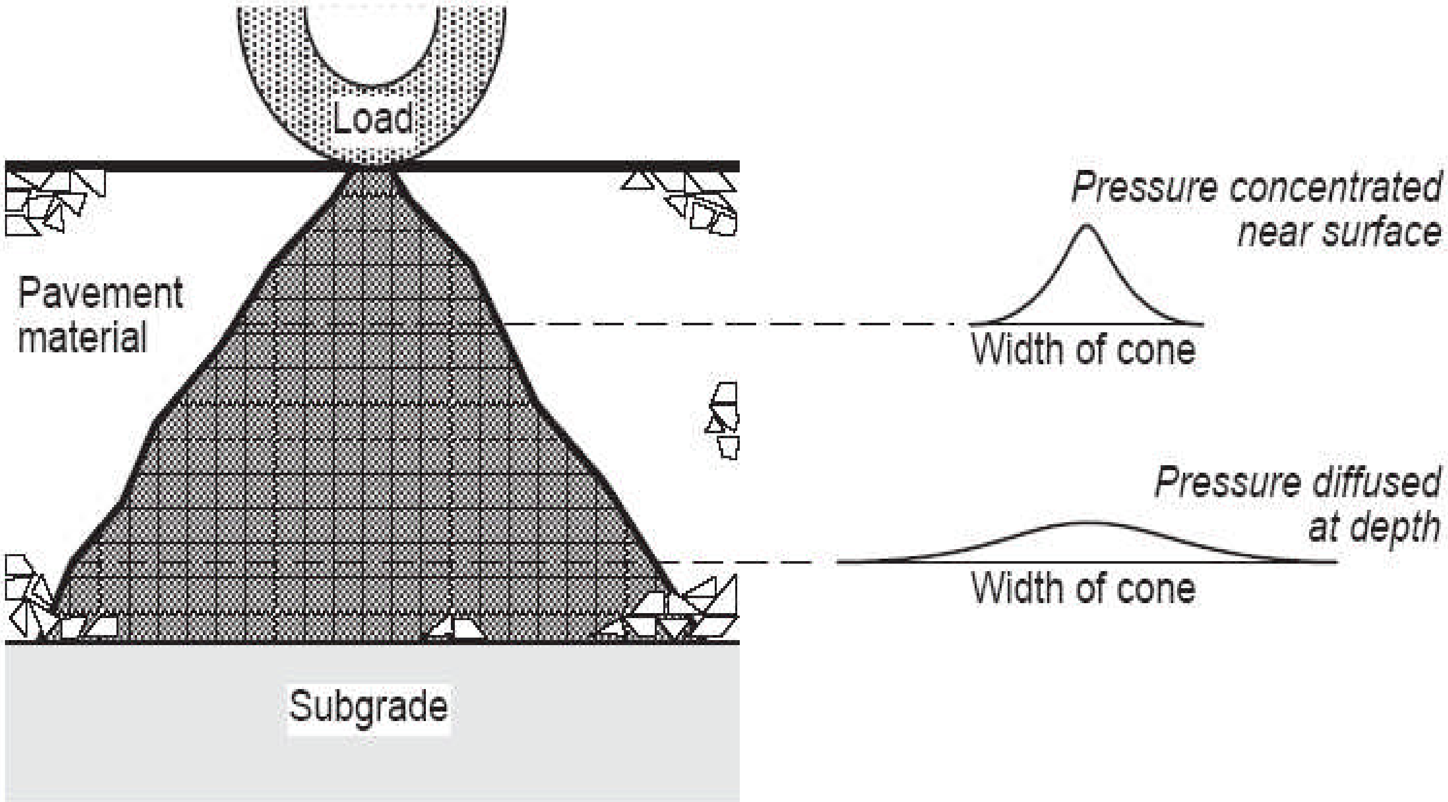
$$k = \frac{\text{Plate load on subgrade}}{\text{Plate deflection on subgrade}}$$

$$k = \frac{5.0 \text{ psi}}{0.5 \text{ in}} = 100 \text{ psi / in.}$$

Plate-Load Test

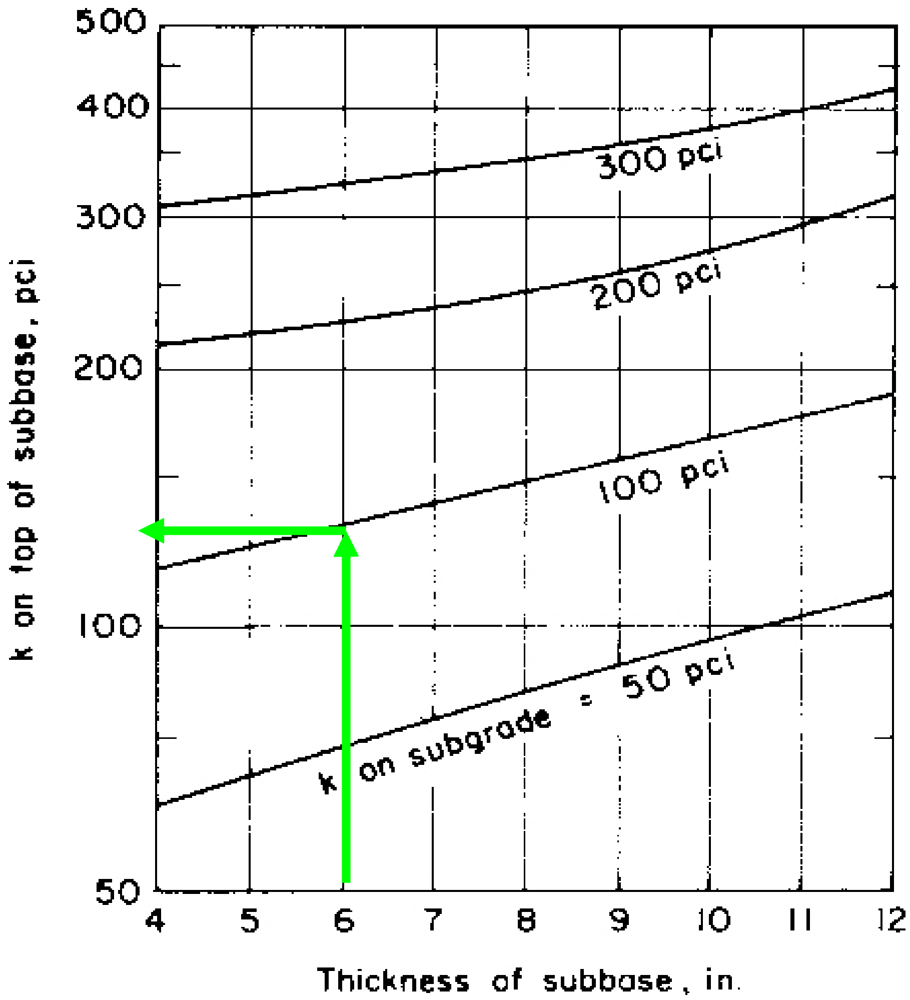


Subbase Improves Structural Capacity



Improving Subgrade Support with Granular Subbase

PCA



PCA Thickness Design
Axle-Load Data Not Available

- Simplified design procedure
- Table 9 –Axle-Load Categories
- Table 10 – k values for subgrade type
- Table 11 – Pavement thickness

Table 9 –Axle-Load Categories

Table 9. Axle-Load Categories

Axle-load category	Description	Traffic: ADT	Traffic: ADTT** %	Traffic: ADTT** Per day	Maximum axle loads, kips: Single axles	Maximum axle loads, kips: Tandem axles
1	Residential streets Rural and secondary roads (low to medium*)	200-800	1-3	up to 25	22	36
2	Collector streets Rural and secondary roads (high*) Arterial streets and primary roads (low*)	700-5000	5-18	40-1000	26	44
3	Arterial streets and primary roads (medium*) Expressways and urban and rural Interstate (low to medium*)	3000-12,000 2 lane 3000-50,000+ 4 lane or more	8-30	500-5000+	30	52
4	Arterial streets, primary roads, expressways (high*) Urban and rural Interstate (medium to high*)	3000-20,000 2 lane 3000-150,000+ 4 lane or more	8-30	1500-8000+	34	60

*The descriptors high, medium, or low refer to the relative weights of axle loads for the type of street or road; that is, "low" for a rural Interstate would represent heavier loads than "low" for a secondary road.

**Trucks — two-axle, four-tire trucks excluded.

Table 10 – k values for subgrade type

Approximate *k* Values

Type of soil	Support	*k* values range, pci
Fine-grained soils in which silt and clay-size particles predominate	Low	75–120
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130–170
Sands and sand-gravel mixtures relatively free of plastic fines	High	180–220
Cement-treated subbases (see page 6)	Very high	250–400

k = 100 pci

Improving Subgrade Support with Granular Subbase

PCA

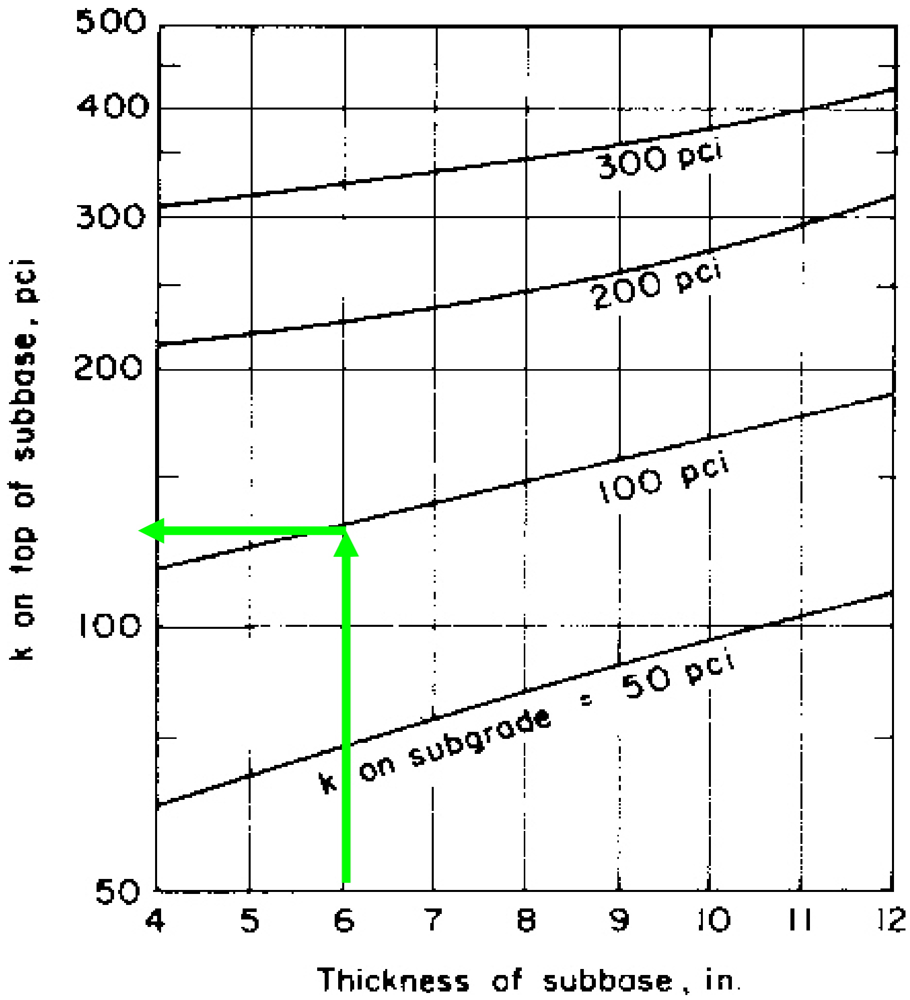


Table 10 – k values for subgrade type

Approximate *k* Values

Type of soil	Support	*k* values range, pci
Fine-grained soils in which silt and clay-size particles predominate	Low	75–120
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130–170
Sands and sand-gravel mixtures relatively free of plastic fines	High	180–220
Cement-treated subbases (see page 6)	Very high	250–400

k = 150 pci

Table 11 Pavement Thickness

Table 11. Allowable ADTT,* Axle-Load Category 1
Pavements with Aggregate-Interlock Joints (Dowels not needed)

	No Concrete Shoulder or Curb				Concrete Shoulder or Curb			
	Slab thickness, in.	Subgrade-subbase support			Slab thickness, in.	Subgrade-subbase support		
		Low	Medium	High		Low	Medium	High
MR = 650 psi					4		0.2	0.9
	4.5			0.1	4.5	2	8	25
	5	0.1	0.8	3	5	30	130	330
	5.5	3	15	45	5.5	320		
	6	40	160	430				
	6.5	330						
MR = 600 psi	5		0.1	0.4	4			0.1
	5.5	0.5	3	9	4.5	0.2	1	5
	6	8	35	98	5	6	27	75
	6.5	76	300	760	5.5	73	290	730
	7	520			6	610		
MR = 550 psi	5.5	0.1	0.3	1	4.5		0.2	0.6
	6	1	6	18	5	0.8	4	13
	6.5	13	60	160	5.5	13	57	150
	7	110	400		6	130	480	
	7.5	620						

Note: Fatigue analysis controls the design.

Note: A fractional ADTT indicates that the pavement can carry unlimited passenger cars and two-axle, four-tire trucks, but only a few heavy trucks per week (ADTT of 0.3 × 7 days indicates two heavy trucks per week.)

*ADTT excludes two-axle, four-tire trucks, so total number of trucks allowed will be greater—see text.

PCA Design of Concrete Pavements for City Streets

- Method 1 / Table 1
- Method 2 Thickness Design
- Select k-value
- Chart 1– Pavement thickness

PCA
Design of Concrete Pavement for City Streets Method 1

Table 1. Street Classifications and Normal Concrete Pavement Thicknesses

Street classification	Vpd or ADT 2-way	Lots, No.	Heavy commercial vehicles, 2-axle, 6-tire and heavier		Normal concrete pavement thickness, inches	Maximum axle load, kips	
			Percent	No. per day		Tandem	Single
Light residential	200	20-30	1-2	3-5	5-6	36	20
Residential	300-700	60-140	1-2	5-11	5-6	36	20
Residential collector	700-1,500	140-300	1-2	11-23	6-7	36	20
Collector	2,000-6,000		3-5	80-240	6-7	38	24
Minor arterial	3,000-7,000		10	300-700	7	46	35
Arterial	6,000-13,000		5-7	360-780	8	56	30
Major arterial	14,000-28,000		5	700-1,400	8-9	65	40
Business	11,000-17,000		3-5	440-680	8	56	30
Industrial	2,000-4,000		15-20	350-700	9	65	40

PCA
Design of Concrete Pavement for City Streets Method 2

k	Type of soil	Remarks
100	Silts and clays	Satisfactory
200	Sandy soils	Good
300	Sand-gravels	Excellent

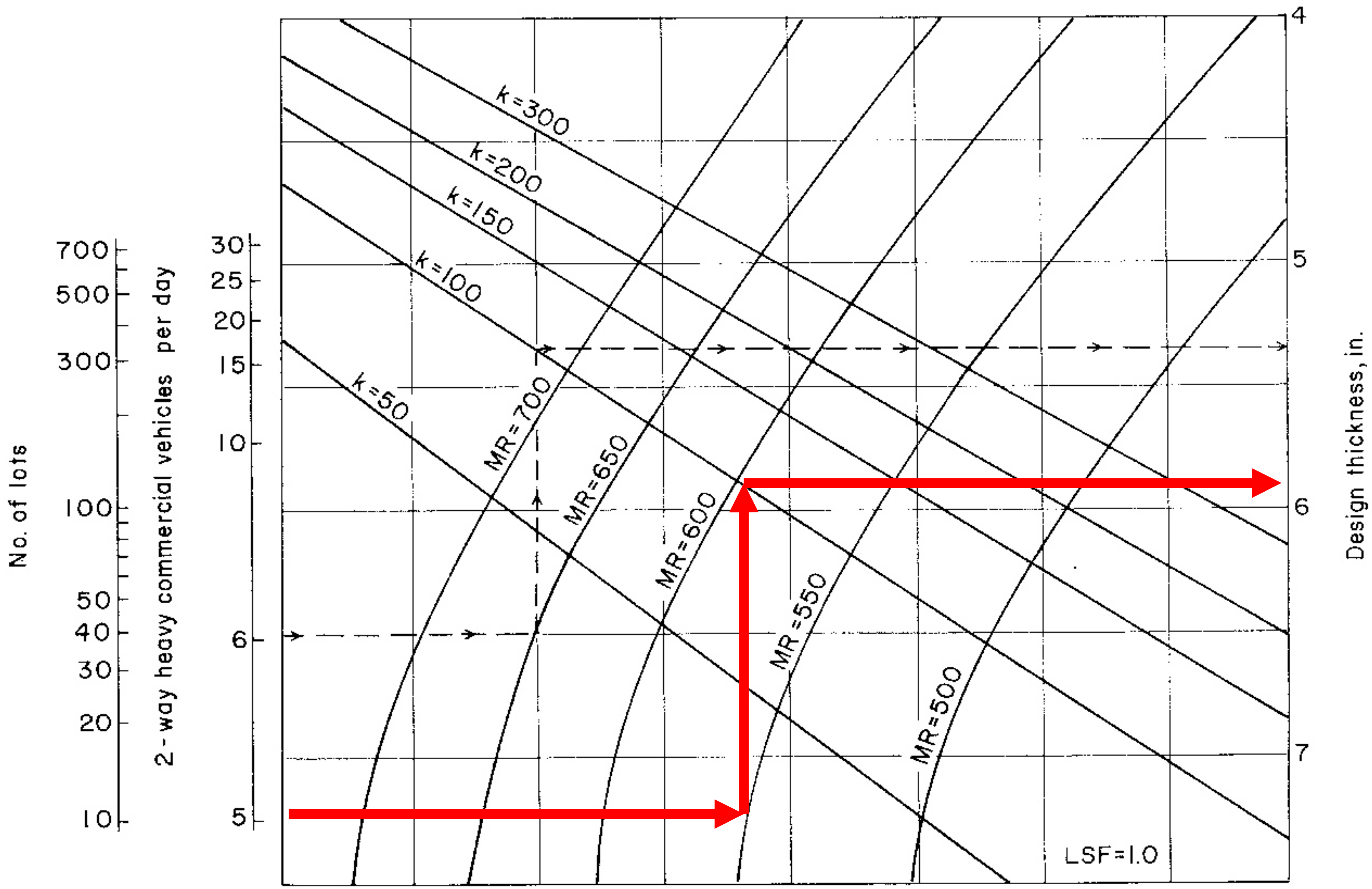


Chart 1. Thickness design chart for residential and residential collector streets for 35-year design life.

Virginia Department of Transportation

Pavement Design Guide For Subdivision And Secondary Roads In Virginia

DESIGN AADT		SUBBASE	BASE	SURFACE
	1		8" Aggregate Base Material, Type I, Size No. 21A	Blotted Seal Coat - Type D (See Note A)
	2		8" Soil Cement Stabilized (Native Soil or Borrow)	Blotted Seal Coat - Type C-1 (See Note A)
Up to 250 AADT	3	4" Select Material, Type I, II or III, Minimum CBR 30	6" Aggregate Base Material, Type I, Size No. 21A	Blotted Seal Coat - Type D (See Note A)
	4	4" Cement or Lime Stabilized Subgrade	4" Aggregate Base Material, Type I, Size No. 21A	Blotted Seal Coat - Type D (See Note A)
	5	6" Aggregate Base Material Type I, Size No. 21B	7" Plain Jointed Portland Cement Concrete	
Design Option shall only be used when SSV ≥ 10	6		3" Asphalt Concrete, Type BM-25.0	165 psy Asphalt Concrete, Type SM-9.5A or SM-12.5A

old 5"

ACI 330R-08
Thickness Design

- Table 3.3 Traffic categories
- Table 3.1 Subgrade support
- Table 3.4 Pavement thickness recommendation

ACI 330. Table 3.1 Subgrade soil types and approximate support values

Table 3.1—Subgrade soil types and approximate support values (Portland Cement Association 1984a,b; American Concrete Pavement Association 1982)

Type of soil	Support	*k*, psi/in.	CBR	*R*	SSV
Fine-grained soils in which silt and clay-size particles predominate	Low	75 to 120	2.5 to 3.5	10 to 22	2.3 to 3.1
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130 to 170	4.5 to 7.5	29 to 41	3.5 to 4.9
Sand and sand-gravel mixtures relatively free of plastic fines	High	180 to 220	8.5 to 12	45 to 52	5.3 to 6.1

Notes: CBR = California bearing ratio; *R* = resistance value; and SSV = soil support value. 1 psi = 0.0069 MPa, and 1 psi/in. = 0.27 MPa/m.

k = 140 pci

Traffic categories

Table 3.3—Traffic categories*

1. Car parking areas and access lanes—Category A		
2. Shopping center entrance and service lanes—Category B		
3. Bus parking areas, city and school buses Parking area and interior lanes—Category B Entrance and exterior lanes—Category C		
4. Truck parking areas—Category B, C, or D		
Truck type	Parking areas and interior lanes	Entrance and exterior lanes
Single units (bobtailed trucks)	Category B	Category C
Multiple units (tractor trailer units with one or more trailers)	Category C	Category D

*Select A, B, C, or D for use with Table 3.4.

ACI 330. Table 3.1
Subgrade soil types and approximate support values

Table 3.1—Subgrade soil types and approximate support values (Portland Cement Association 1984a,b; American Concrete Pavement Association 1982)

Type of soil	Support	*k*, psi/in.	CBR	*R*	SSV
Fine-grained soils in which silt and clay-size particles predominate	Low	75 to 120	2.5 to 3.5	10 to 22	2.3 to 3.1
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130 to 170	4.5 to 7.5	29 to 41	3.5 to 4.9
Sand and sand-gravel mixtures relatively free of plastic fines	High	180 to 220	8.5 to 12	45 to 52	5.3 to 6.1

Notes: CBR = California bearing ratio; *R* = resistance value; and SSV = soil support value. 1 psi = 0.0069 MPa, and 1 psi/in. = 0.27 MPa/m.

k = 140 pci

ACI 330. Table 3.4
Design thickness recommendations

Table 3.4—Twenty-year design thickness recommendations, in. (no dowels)

		k = 500 psi/in. (CBR = 50; R = 86)				k = 400 psi/in. (CBR = 38; R = 80)				k = 300 psi/in. (CBR =26; R = 67)			
	MOR, psi:	650	600	550	500	650	600	550	500	650	600	550	500
Traffic category*	A (ADTT =1)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.5
	A (ADTT = 10)	4.0	4.0	4.0	4.5	4.0	4.0	4.5	4.5	4.0	4.5	4.5	4.5
	B (ADTT = 25)	4.0	4.5	4.5	5.0	4.5	4.5	5.0	5.5	4.5	4.5	5.0	5.5
	B (ADTT = 300)	5.0	5.0	5.5	5.5	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0
	C (ADTT = 100)	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0
	C (ADTT = 300)	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0	5.5	6.0	6.0	6.5
	C (ADTT = 700)	5.5	5.5	6.0	6.0	5.5	5.5	6.0	6.5	5.5	6.0	6.5	6.5
	D (ADTT = 700)†	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
		k = 200 psi/in. (CBR = 10; R = 48)				k = 100 psi/in. (CBR = 3; R = 18)				k = 50 psi/in. (CBR = 2; R = 5)			
	MOR, psi:	650	600	550	500	650	600	550	500	650	600	550	500
Traffic category*	A (ADTT =1)	4.0	4.0	4.0	4.5	4.0	4.5	4.5	5.0	4.5	5.0	5.0	5.5
	A (ADTT = 10)	4.5	4.5	5.0	5.0	4.5	5.0	5.0	5.5	5.0	5.5	5.5	6.0
	B (ADTT = 25)	5.0	5.0	5.5	6.0	5.5	5.5	6.0	6.0	6.0	6.0	6.5	7.0
	B (ADTT = 300)	5.5	5.5	6.0	6.5	6.0	6.0	6.5	7.0	6.5	7.0	7.0	7.5
	C (ADTT = 100)	5.5	6.0	6.0	6.5	6.0	6.5	6.5	7.0	6.5	7.0	7.5	7.5
	C (ADTT = 300)	6.0	6.0	6.5	6.5	6.5	6.5	7.0	7.5	7.0	7.5	7.5	8.0
	C (ADTT = 700)	6.0	6.5	6.5	7.0	6.5	7.0	7.0	7.5	7.0	7.5	8.0	8.5
	D (ADTT = 700)†	7.0	7.0	7.0	7.0	8.0	8.0	8.0	8.0	9.0	9.0	9.0	9.0

*ADTT = average daily truck traffic. Trucks are defined as vehicles with at least six wheels; excludes panel trucks, pickup trucks, and other four-wheel vehicles. Refer to Appendix A.
k = modulus of subgrade reaction; CBR = California bearing ratio; R = resistance value; and MOR = modulus of rupture.
†Thickness of Category D (only) can be reduced by 1.0 in. (25 mm) if dowels are used at all transverse joints (that is, joints located perpendicular to direction of traffic).
Note: 1 in. = 25.4 mm; 1 psi = 0.0069 MPa; and 1 psi/in. = 0.27 MPa/m.

Thickness Design of Pervious Concrete

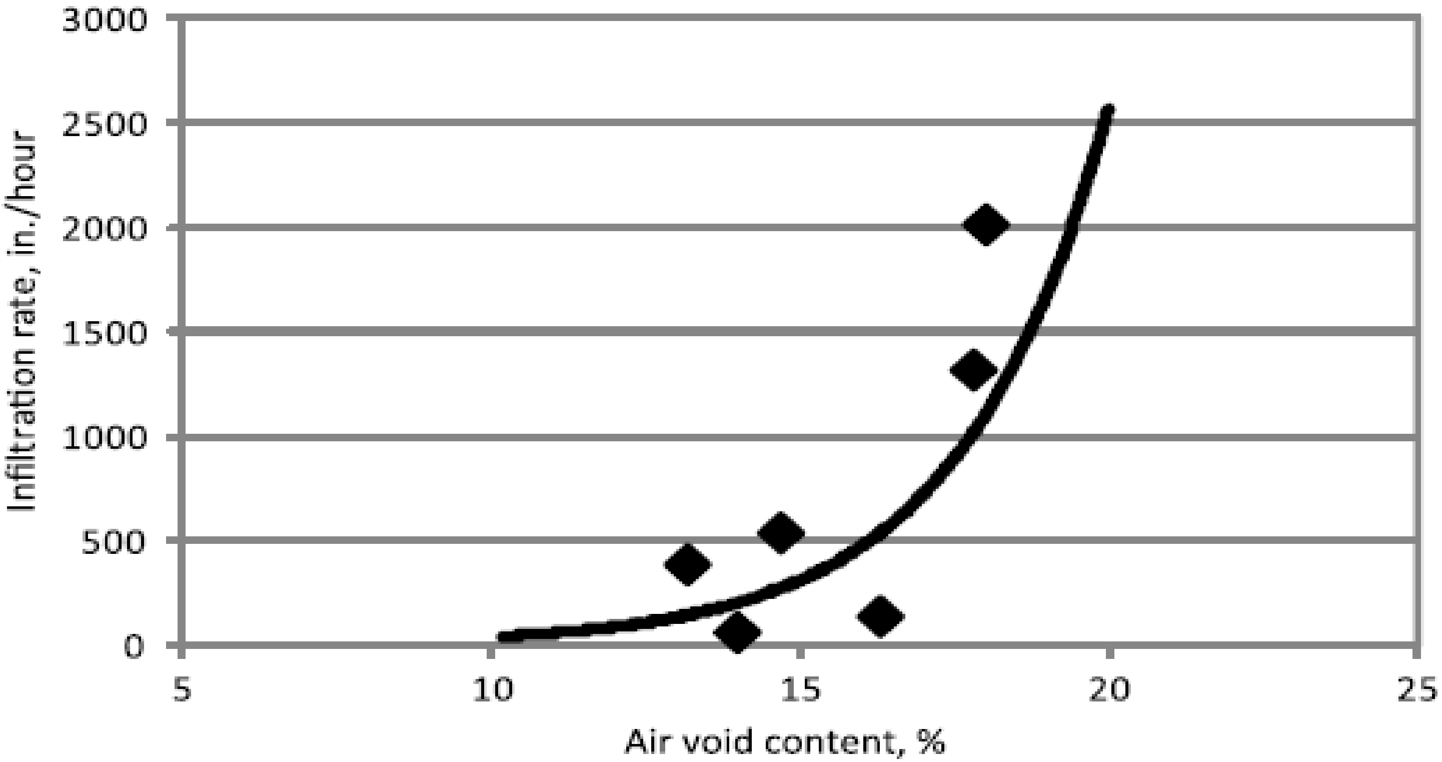
Pervious Concrete Applications

- Parking lots
- Streets/roads shoulders
- Sidewalks
- Driveways
- Light traffic areas

Applications:

Permeable pavements are effective for reducing imperviousness in pedestrian pavements, parking lots, driveways, plazas, and access roads. They may be used in both new and redevelopment applications in residential, commercial, and industrial projects. Permeable pavements are particularly useful in high-density areas where space is limited.

ASTM C1701 Infiltration Rate as a Function of ASTM C1688 Void Content



Specified Strength of Pervious Concrete

VIRGINIA DCR STORMWATER
DESIGN SPECIFICATION No. 7

PERMEABLE PAVEMENT
VERSION 1.7
March 1, 2011

Table 7.6

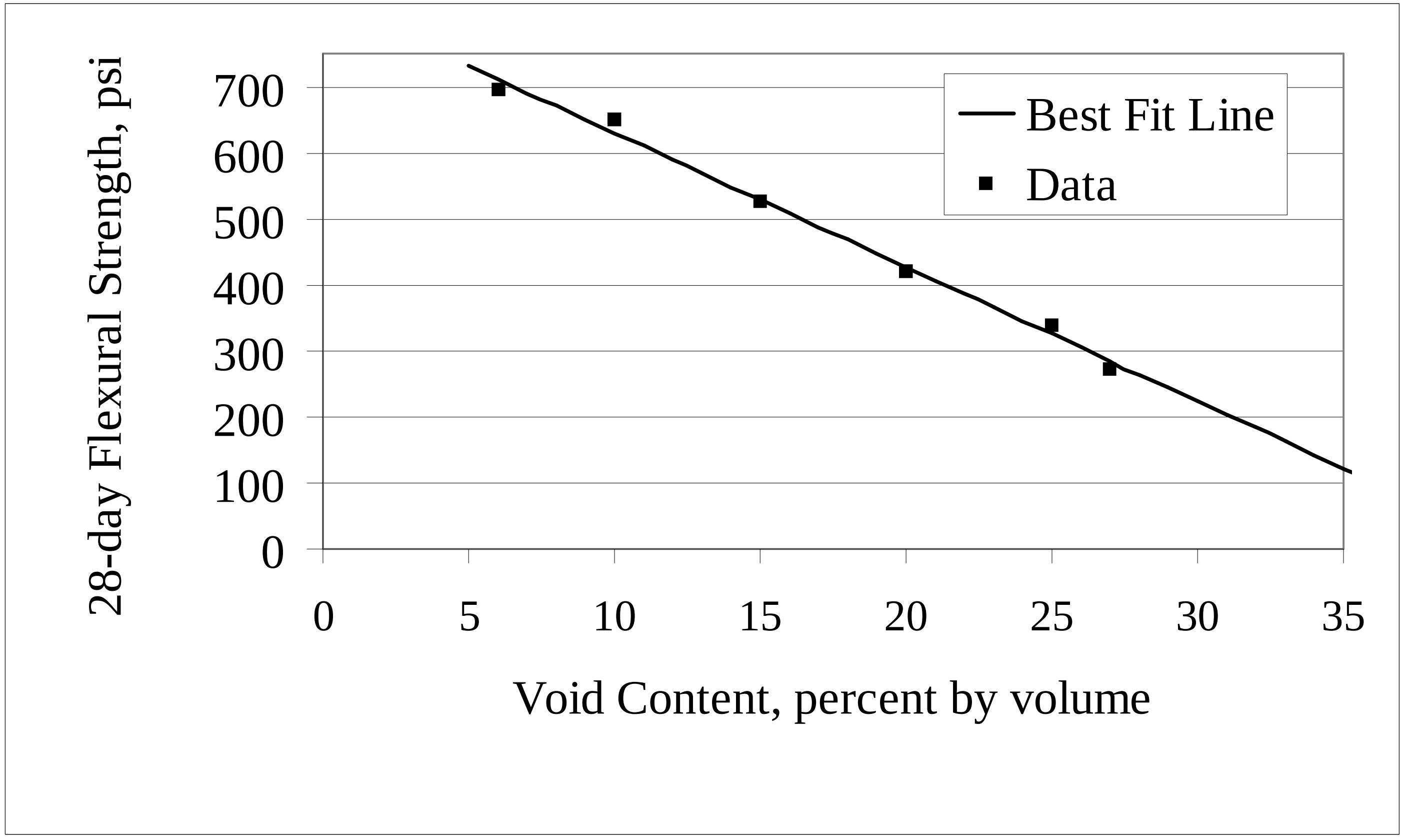
Compressive strength: 2.8 to 28 Mpa (400 psi to 4,000 psi)

Calculated Flexural Strength, MOR (psi)			
	Compressive Strength, f'_c (psi)		
	400 psi	2,000 psi	4,000 psi
MOR = 7.5 * $(f'_c)^{1/2}$	**150**	**340**	**470**
MOR = 8.0 * $(f'_c)^{1/2}$	**160**	**360**	**510**
MOR = 8.5 * $(f'_c)^{1/2}$	**170**	**380**	**540**
MOR = 9.0 * $(f'_c)^{1/2}$	**180**	**400**	**570**
MOR = 9.5 * $(f'_c)^{1/2}$	**190**	**420**	**600**
MOR = 10.0 * $(f'_c)^{1/2}$	**200**	**450**	**630**

The American Concrete Institute Committee Report ACI 522R-Pervious Concrete, Chapter 7.2.2 states:

"Guidance for structural design of conventional concrete pavements is provided in ACI 330R for parking lots and in ACI 325.12R for streets and roads. These documents cover many different aspects of paving design. The structural design recommendations in these documents, however, are not necessarily applicable for use with pervious pavement. **As there are no standardized test methods for strength of pervious concrete, design and specification by strength should be avoided**".

Flexural Strength vrs. Void Content



Flexural Strength, F_{mr} = 832.8 – 20.3 * (void content, %), psi

Specified Void Content of Pervious Concrete

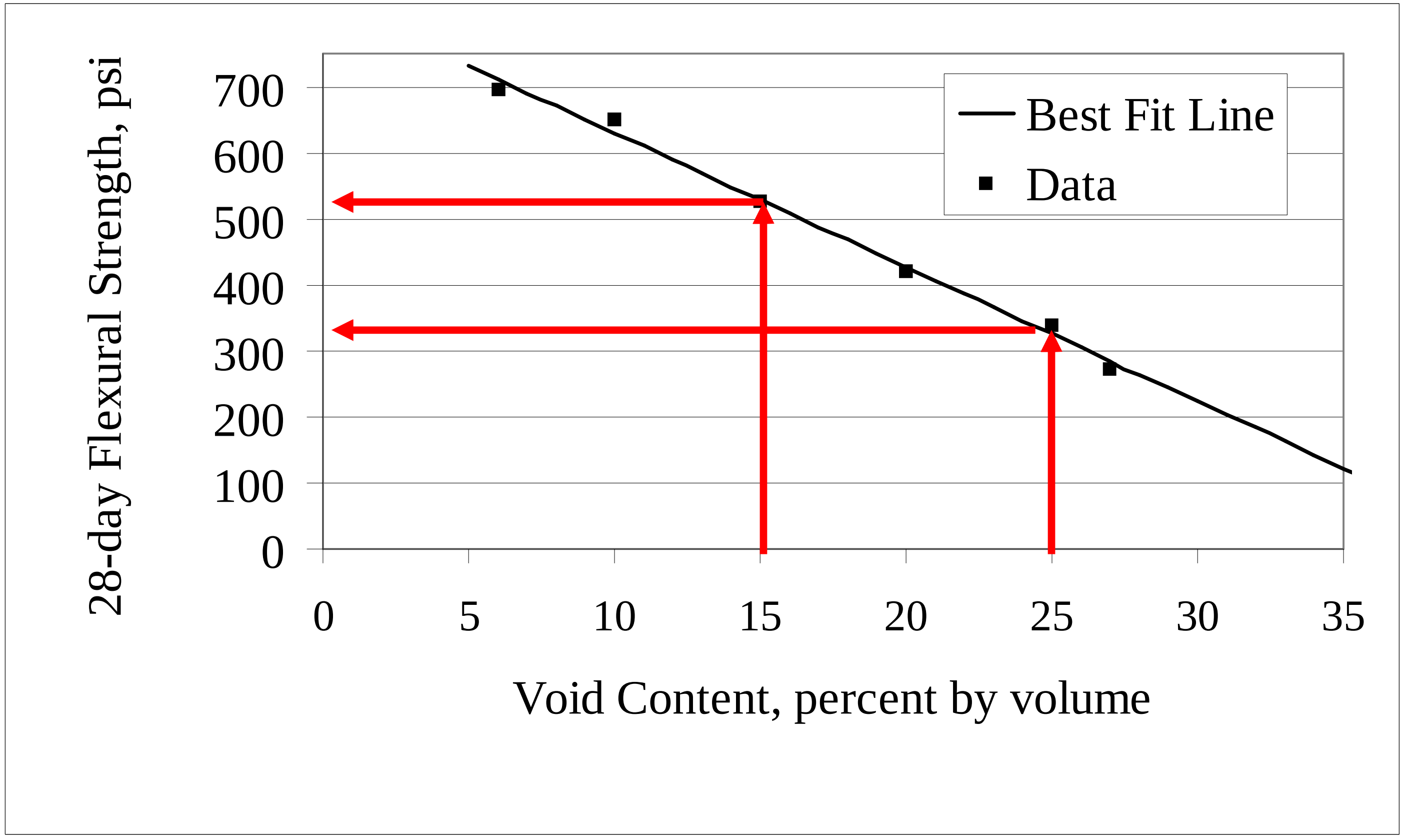
VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 7

PERMEABLE PAVEMENT VERSION 1.7 March 1, 2011

Table 7.6

Open Void Content: 15% to 25%

Flexural Strength vrs. Void Content



Flexural Strength, F_{mr} = 832.8 – 20.3 * (void content, %), psi

Testing Fresh Density

ASTM C1688 Density and Void Content of Freshly Mixed Pervious Concrete

0.25 ft^3 measure (standard air pot)

Standard Proctor Hammer

ASTM C1688

- Obtain sample ASTM C172
- Fill in 2 lifts
- Drop hammer full 12”
- Drop 20 times/lift

ASTM C1688 Void Contents

Air void content			Unit weight
Fresh concrete per ASTM C1688, %	Hardened concrete data (from cores), %	Difference between fresh and hardened concrete, %	Fresh concrete values per ASTM C1688, lb/ft^3
13.0	13.4	−0.4	134.6
11.5	18.9	−7.4	136.7
15.1	15.8	−0.7	130.8
12.9	13.8	−0.9	133.5
16.6	21.6	−5.0	127.5

Consistency and Water Content

Too little water

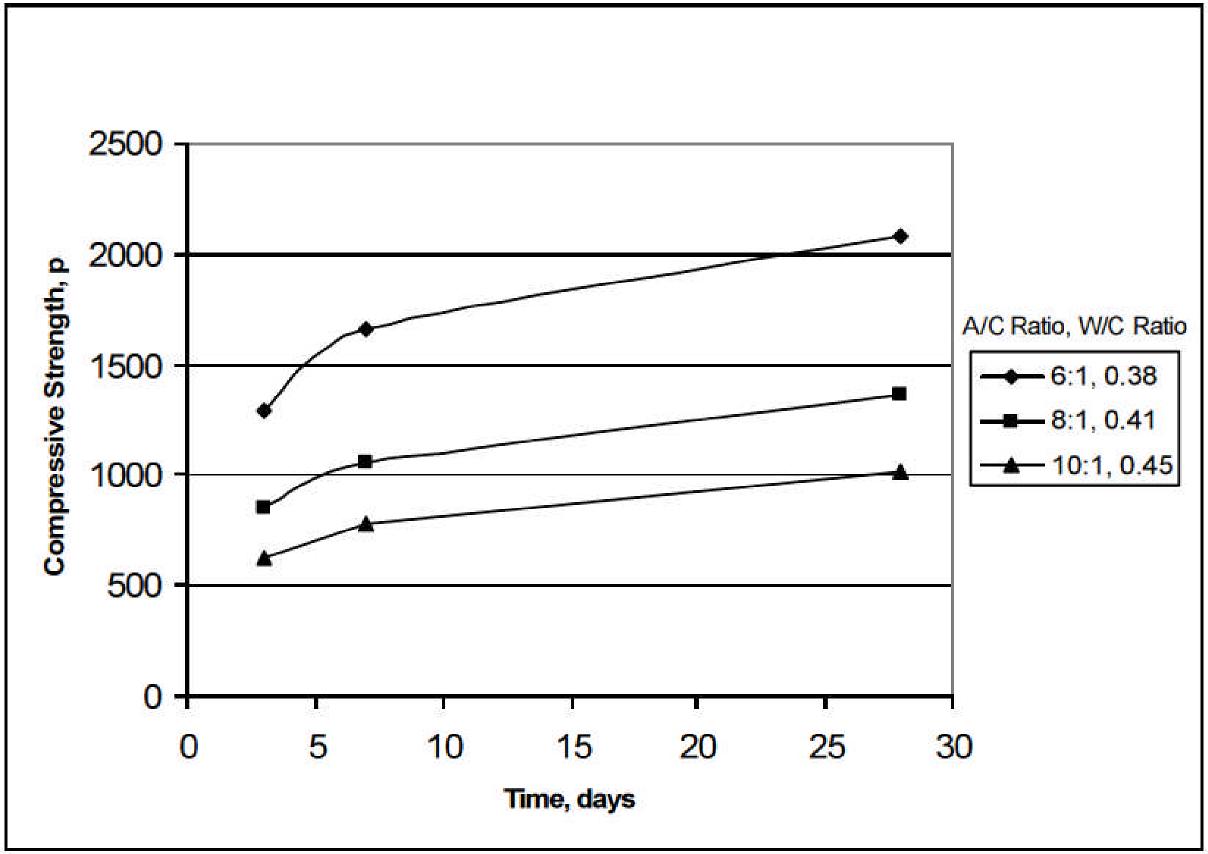
Proper Amount of Water

Too much water

(1) Tennis, P.D., Leming, M.L., Akers, D.J., Pervious Concrete Pavements, Portland Cement Association, PCA Serial No. 2828, 2004, page 8

ATTAINABLE COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE PAVING SYSTEMS

ANN MARIE MULLIGAN
B.A. University of Central Florida, 1995
B.S. University of Central Florida, 2003



High water content without stable paste

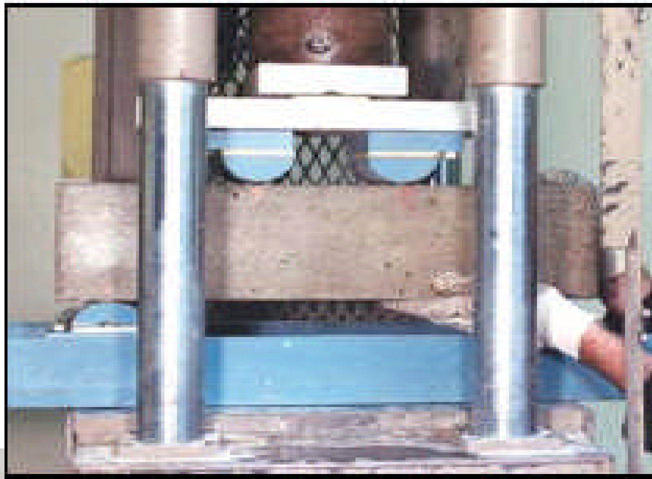
Increases Chances of Aggregate Raving

Abrasion Resistance

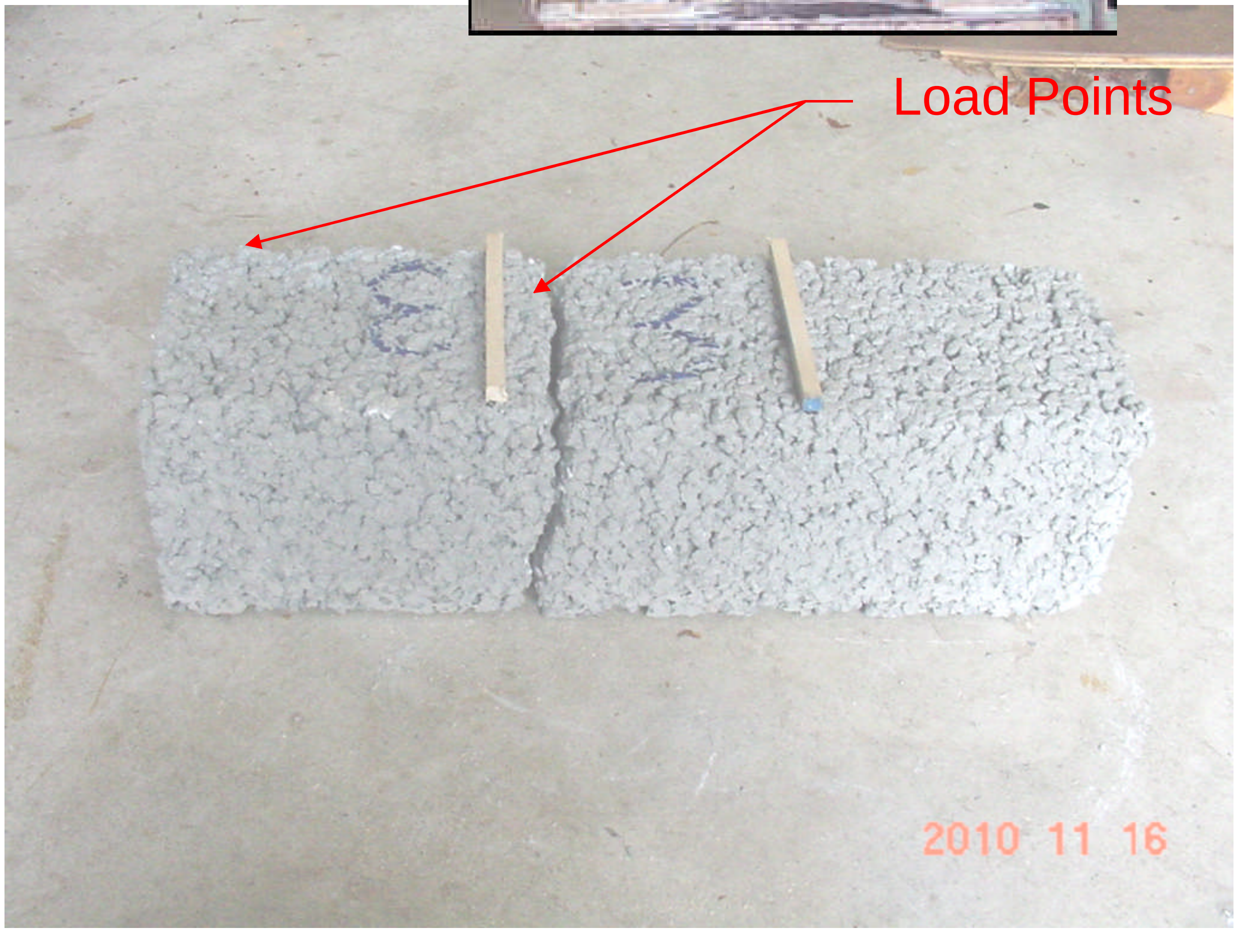
- ➢Turning lanes and high traffic volume applications may not be suitable

- ➢ Snow plows may ravel aggregate

Flexural Behavior



Does not always fail in middle



What Design Strength?

Engineering judgment may be the answer

Influence of Infiltration Rate of In-situ Soil

VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 7

PERMEABLE PAVEMENT
VERSION 1.7
March 1, 2011

If the proposed permeable pavement area is designed to infiltrate runoff without underdrains, it must have **a minimum infiltration rate of 0.5 inches per hour.** Initially, projected soil infiltration rates can be estimated from USDA-NRCS soil data, but they must be confirmed by an on-site infiltration measurement. Native soils must have silt/clay content less than 40% and clay content less than 20%.

USCS Soil Class	Field CBR
GW	60 - 80
GP	35 - 60
GM	40 - 80
GC	20 - 40
SW	20 - 40
SP	15 - 25
SM	20 - 40
SC	10 - 20
ML	5 - 15
CL	5 - 15
OL	4 - 8
MH	4 - 8
CH	3 - 5
OH	3 - 5

Group A : > 90% Sand
<10% Clay
PR > 5.67 in/hr

Group B : 10% -20% Clay
50 to 90% Sand
PR 5.67 – 1.42 in/hr

Group C : 20% - 40% Clay
< 50% Sand
PR 1.42 – 0.14 in/hr

Group D : > 40% Clay
< 50% Sand
PR < 0.14 in/hr

Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration.

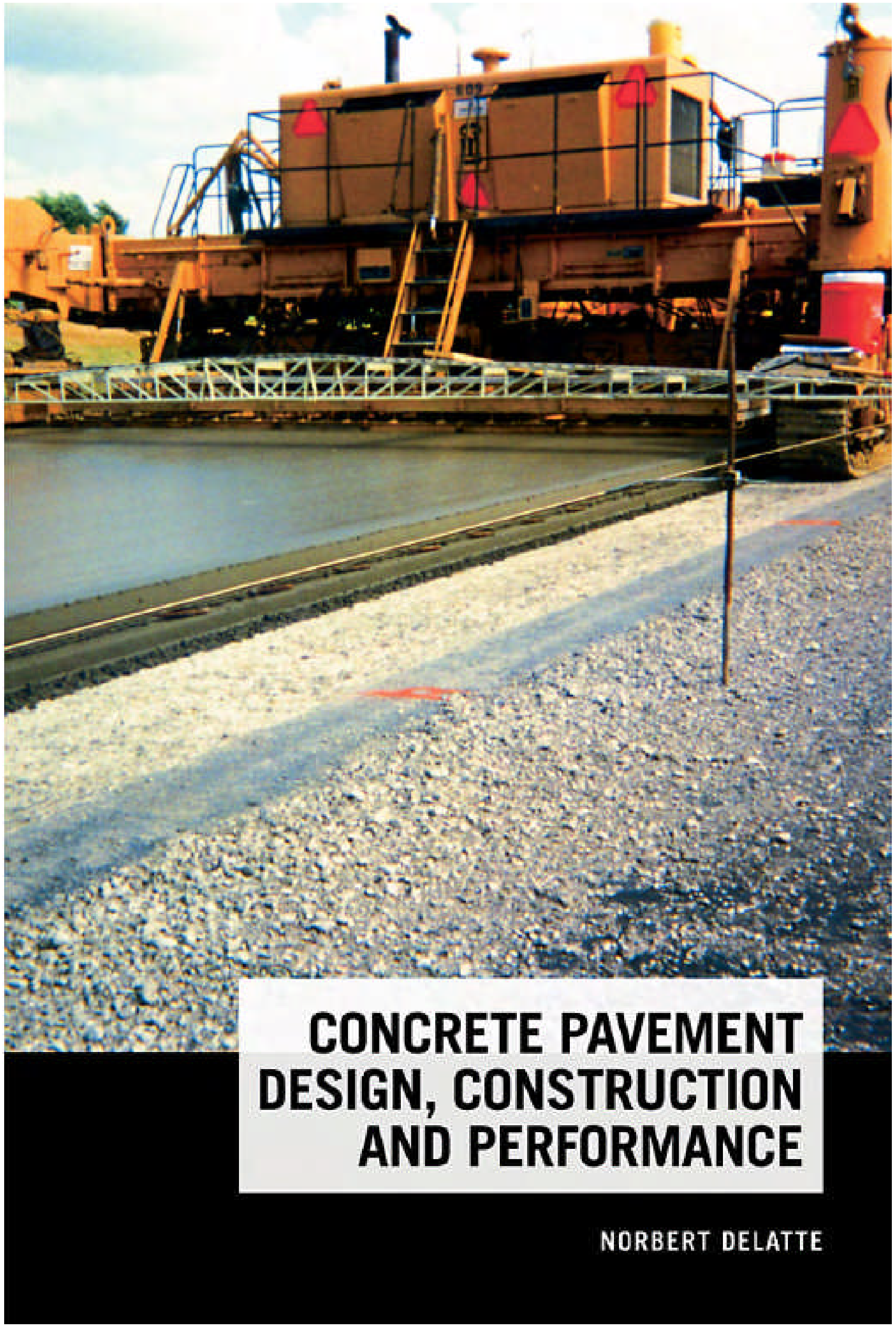
VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 7

PERMEABLE PAVEMENT
VERSION 1.7
March 1, 2011

Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration.

CBR Range: 4 to 40

Modulus of Subgrade Reaction: 125 to 400 pci



Concrete Pavement Design, Construction, and Performance

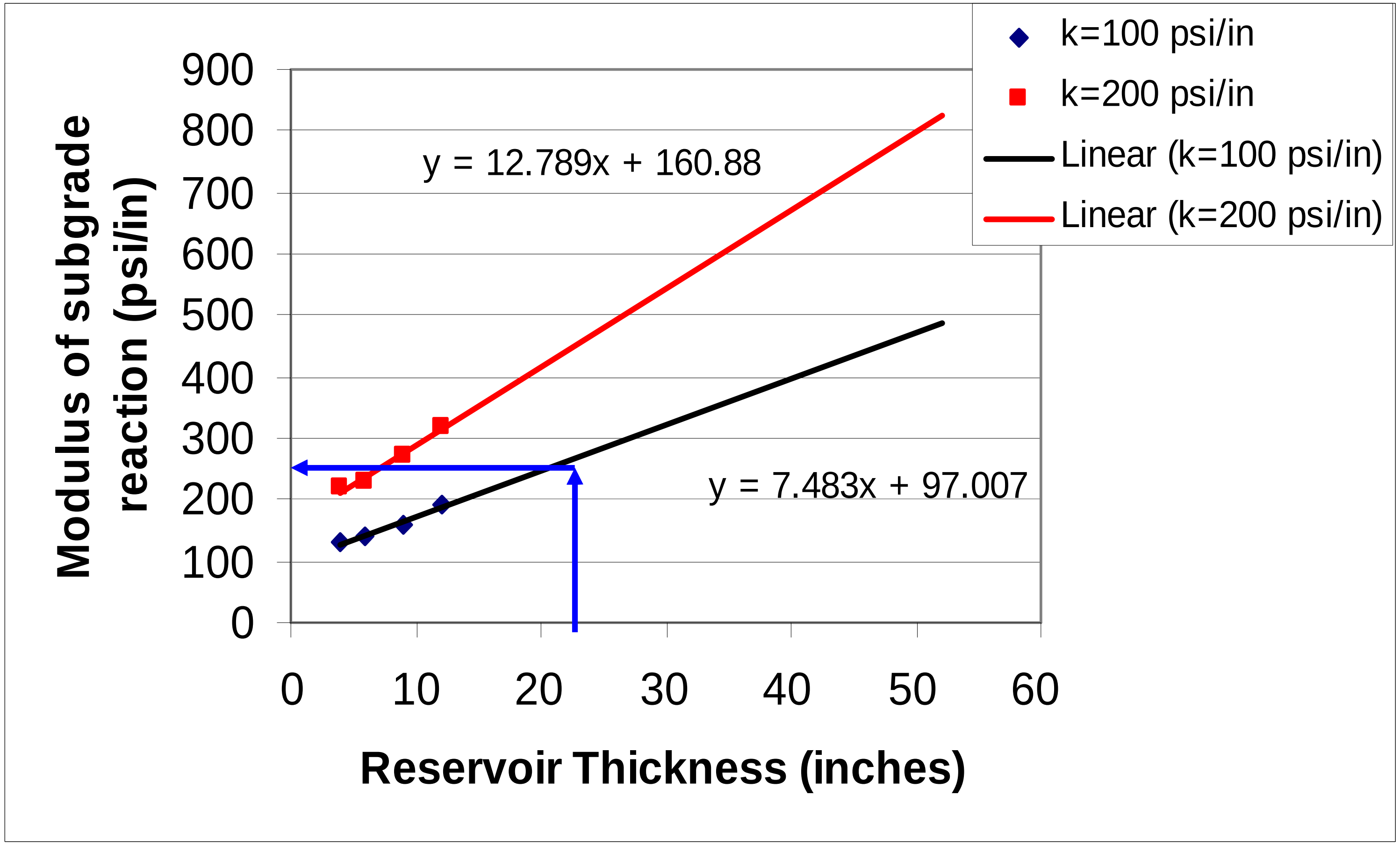
Norbert Delatte

Taylor & Francis
Taylor & Francis Group
LONDON AND NEW YORK

CBR = 2	13.5 MPa/m 50 psi/in	Concrete flexural strength							
		kPa	psi	kPa	psi	kPa	psi	kPa	psi
		3,100	450	2,750	400	2,400	350	2,100	300
Traffic	ADTT	Required pavement thickness							
		mm	in	mm	in	mm	in	mm	in
Residential	1	191	7.5	203	8	216	8.5	241	9.5
	10	216	8.5	229	9	254	10	276	10.5
Collector	25	241	9.5	254	10	280	11	305	12
	300	267	10.5	280	11	305	12	330	13
Minor	100	280	11	305	12	330	13	356	14
Arterial	300	292	11.5	318	12.5	343	13.5	381	15
	700	305	12	330	13	356	14	381	15
Major	700	330	13	356	14	381	15	419	16.5
Arterial	1500	330	13	356	14	394	15.5	432	17

CBR =3	*27 MPa/m 100 psi/in*	*Concrete flexural strength*							
		kPa	*psi*	*kPa*	*psi*	*kPa*	*psi*	*kPa*	*psi*
		3,100	*450*	*2,750*	*400*	*2,400*	*350*	*2,100*	*300*
Traffic	*ADTT*	*Required pavement thickness*							
		mm	*in*	*mm*	*in*	*mm*	*in*	*mm*	*in*
Residential	1	178	7	191	7.5	203	8	216	8.5
	10	191	7.5	216	8.5	229	9	241	9.5
Collector	25	216	8.5	229	9	254	10	280	11
	300	241	9.5	254	10	280	11	305	12
Minor	100	254	10	280	11	292	11.5	318	12.5
Arterial	300	267	10.5	280	11	305	12	343	13.5
	700	280	11	292	11.5	318	12.5	343	13.5
Major	700	292	11.5	318	12.5	343	13.5	368	14.5
Arterial	1500	305	12	318	12.5	343	13.5	381	15

Support Provided by Bedding and Reservoir Layer



Reservoir Layer

CBR = 10	54 MPa/m 200 psi/in	Concrete flexural strength							
		kPa	psi	kPa	psi	kPa	psi	kPa	psi
		3,100	450	2,750	400	2,400	350	2,100	300
Traffic	ADTT	Required pavement thickness							
		mm	in	mm	in	mm	in	mm	in
Residential	1	152	6	165	6.5	178	7	203	8
	10	178	7	191	7.5	203	8	229	9
Collector	25	203	8	216	8.5	229	9	254	10
	300	216	8.5	241	9.5	254	10	280	11
Minor	100	229	9	254	10	267	10.5	292	11.5
Arterial	300	241	9.5	267	10.5	280	11	305	12
	700	254	10	267	10.5	292	11.5	318	12.5
Major	700	267	10.5	292	11.5	305	12	343	13.5
Arterial	1500	280	11	292	11.5	318	12.5	343	13.5

Structural Number System

Developed by from

American Association of State Highway Officials

Road Test Data in 1961

The Structural Number (SN) is

analytically given by:

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

where

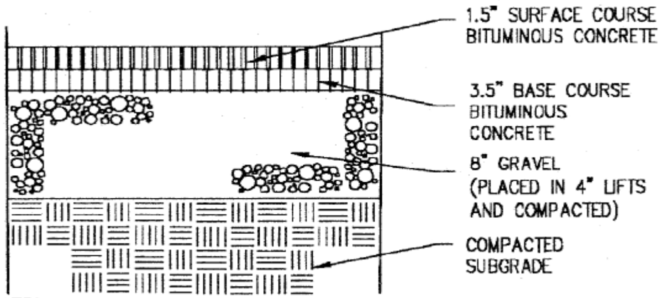
a_i = layer coefficient of layer i

D_i = thickness of layer i

Structural Numbers

Pavement Component	Structural Number
Portland Cement Concrete	0.50
Surface Course Asphalt Concrete Hot Mix	0.44
Base Course Asphalt Concrete Hot Mix	0.34
Stone Base	0.14

Specified Pavement Sections



NOTES:

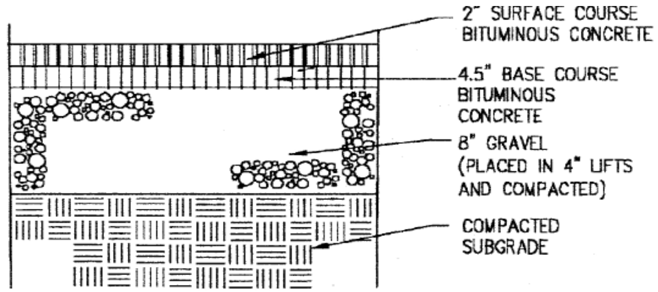
1. ALL FINISHED DRIVEWAY AND PARKING SUBGRADE SHOULD BE CONSTRUCTED AND COMPLY WITH "SITE PREPARATION" SPECIFICATION OF THE GEOTECHNICAL REPORT.

2. PRIOR TO PLACEMENT OF STONE BASE, THE ENTIRE SUBGRADE SHOULD BE PROOFROLLED WITH A 30-TON LOADED DUMP TRUCK. ANY SOFT AND UNSTABLE SUBGRADE SHOULD BE CORRECTED.

3. AFTER APPROVAL OF THE SUBGRADE, THE FLEXIBLE PAVEMENT SECTION SAHLL BE CONSTRUCTED. THE PAVEMENT SECTION SHOULD FOLLOW THE SPECIFICATIONS ON GEOTECHNICAL REPORT.

NOTE:
THE PAVING SECTION SHOWN HAS NOT BEEN DESIGNED FOR ACTUAL SOIL CONDITIONS, IN PLACE COMPACTION RESULTS, OR TRAFFIC VOLUMES SPECIFIC TO THIS PROJECT. IT IS RECOMMENDED THAT THE USER CONSULT WITH A LICENSED PROFESSIONAL GEOTECHNICAL ENGINEER FOR A SPECIFIC PAVING DESIGN BASED ON THE APPROPRIATE PARAMETERS PRIOR TO INSTALLATION OF THIS PAVING SECITON.

2 / 5 **LIGHT-DUTY ASPHALT PAVING**
NOT TO SCALE



NOTES:

1. ALL FINISHED DRIVEWAY AND PARKING SUBGRADE SHOULD BE CONSTRUCTED AND COMPLY WITH "SITE PREPARATION" SPECIFICATION OF THE GEOTECHNICAL REPORT.

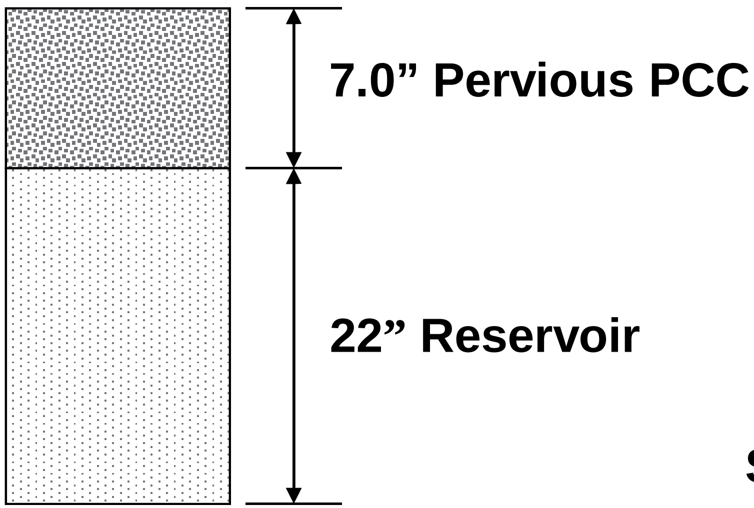
2. PRIOR TO PLACEMENT OF STONE BASE, THE ENTIRE SUBGRADE SHOULD BE PROOFROLLED WITH A 30-TON LOADED DUMP TRUCK. ANY SOFT AND UNSTABLE SUBGRADE SHOULD BE CORRECTED.

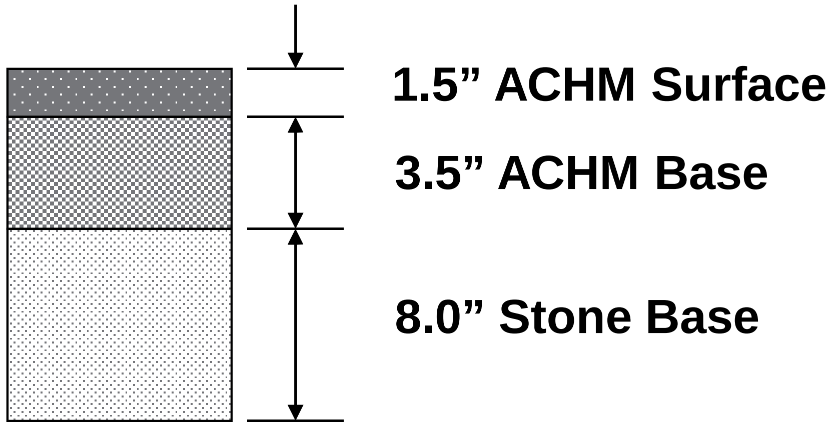
3. AFTER APPROVAL OF THE SUBGRADE, THE FLEXIBLE PAVEMENT SECTION SAHLL BE CONSTRUCTED. THE PAVEMENT SECTION SHOULD FOLLOW THE SPECIFICATIONS ON GEOTECHNICAL REPORT.

NOTE:
THE PAVING SECTION SHOWN HAS NOT BEEN DESIGNED FOR ACTUAL SOIL CONDITIONS, IN PLACE COMPACTION RESULTS, OR TRAFFIC VOLUMES SPECIFIC TO THIS PROJECT. IT IS RECOMMENDED THAT THE USER CONSULT WITH A LICENSED PROFESSIONAL GEOTECHNICAL ENGINEER FOR A SPECIFIC PAVING DESIGN BASED ON THE APPROPRIATE PARAMETERS PRIOR TO INSTALLATION OF THIS PAVING SECITON.

1 / 5 **HEAVY-DUTY ASPHALT PAVING**
NOT TO SCALE

Light Duty Parking Lot Pavement





Section

    6.0” PC Concrete
    22”   Reservoir

Structural Numbers

    22” * 0.14 = 3.08

    Total SN = 3.08

Section

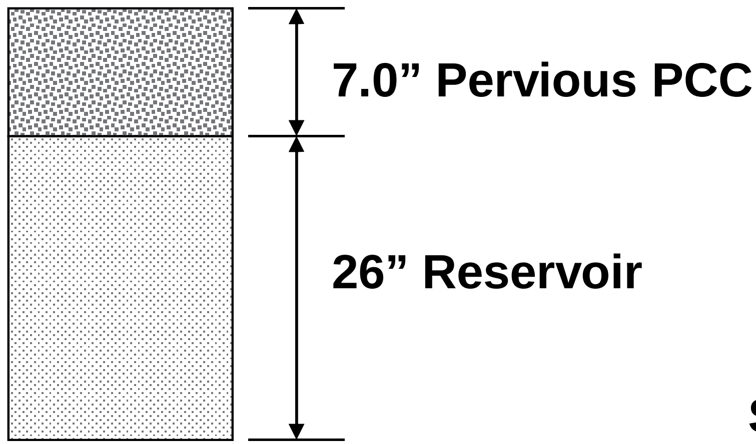
    1.5”   ACHM Surface
    3.5”   ACHM Base
    8.0”   Stone Base

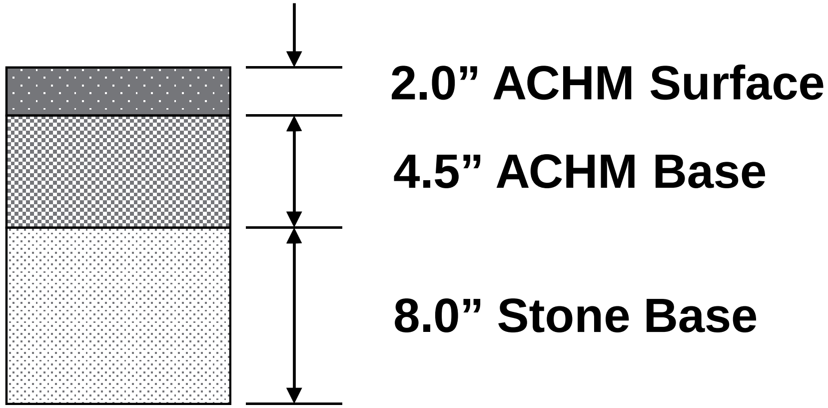
Structural Numbers

      1.5” * 0.44 = 0.66
      3.5” * 0.34 = 1.19
    + 8.0” * 0.14 = 1.12

    Total SN = 2.97

Heavy Duty Parking Lot Pavement





Section
6.0” PC Concrete
26.0” Reservoir

Structural Numbers
26.0” * 0.14 = 3.64

Total SN = 3.64

Section
2.0” ACHM Surface
4.5” ACHM Base
8.0” Stone Base
Structural Numbers
2.0” * 0.44 = 0.88
4.5” * 0.34 = 1.53
+ 8.0” * 0.14 = 1.12

Total SN = 3.53

“It is just about that sort of thing they would like”