

# OWEA 2018 Watershed Workshop

## A Technical Review of Pervious Pavement

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Erosion Control?



# Structural Design – AASHTO Flexible Pavement Design

1. Obtain Subgrade CBR (wet/soaked) value (typically 2-7)
2. Calculate Traffic Load
3. Calculate Structural Number
4. Design Subbase Stone Thickness Based on Layer Coefficients
  - 0.06 No. 2 Stone
  - 0.09 No. 57 Stone
  - 0.30 for setting bed and brick

## Other Structural Enhancements:

- Geoweb
- Geogrid
- Upgraded Geofabrics

# Traffic Loads – Maximum 1,000,000 ESAL's

Table 3-1. Road Classification, Description and Traffic (after BIA 2003)

Road Class	Description	Design ESALs*	Design TI**	Design Range for PICP on Non-stabilized, Open-Graded Aggregate Bases	***Potential Design Range for PICP with Stabilized Bases
Arterial	Through traffic with access to high-density, regional, commercial and office developments or downtown streets. General traffic mix.	9,000,000	11.5		
Major Collector	Traffic with access to low-density, local, commercial and office development or high density, residential sub-divisions. General traffic mix.	3,000,000	10		
Minor Collector	Through traffic with access to low-density, neighborhood, commercial development or low-density, residential sub-divisions. General traffic mix.	1,000,000	9		
Bus Passenger Drop-off	Public transport centralized facility for buses to pick up passengers from other modes of transport, or for parking of city or school buses.	500,000	8.5		
Local Commercial	Commercial and limited through traffic with access to commercial premises and multi-family and single-family residential roads. Used by automobiles, service vehicles and heavy delivery trucks. This category includes large parking lots at commercial retail facilities.	330,000	8		
Residential	No through traffic with access to multi-family and single-family residential properties. Used by automobiles, service vehicles and light delivery trucks, including limited construction traffic.	110,000	7		
Facility Parking and Alleys	Parking areas for automobiles at large facilities with access for emergency vehicles and occasional use by service vehicles or heavy delivery trucks.	90,000	7		
Commercial Parking	Restricted parking and drop-off areas associated with business premises, mostly used by automobiles and occasional light delivery trucks. No construction traffic over finished surfaces.	30,000	6		
Commercial Plaza	Predominantly pedestrian traffic, but with access for occasional heavy maintenance and emergency vehicles. No construction traffic over finished surfaces.	10,000	5		

\*ESAL = 18,000 lb (80 kN) equivalent single axle load

\*\*TI = Caltrans Traffic Index  $TI = 9 \times (ESALs/1,000,000)^{0.119}$

\*\*\*Consult a pavement engineer

# AASHTO Flexible Pavement Design

## Columbus Residential Design Policy

Typical short one to two block long loop street with no future extensions

- 1,500 cars/day
- 5% trucks
- 30 Year Design Life
- Directional Distribution = 50%
- Design Lane Distribution Factor = 100%
- B/C Ratio – Other Urban (Use 0.725)

Total ESALs: 299,962

Traffic Factors	202-1
	July 2016 Reference Section 202

RATIO OF B:C COMMERCIAL VEHICLES		
Functional Classification	B:C Ratio	
	Urban*	Rural*
Interstate (01)	4:1	7:1
Other Freeway or Expressway (02)	3:1	
Principal Arterial (03)	2:1	5:1
All Other (04, 05, 06, 07)	1:1	2:1

ESAL CONVERSION FACTORS				
Functional Classification	Rigid		Flexible	
	B	C	B	C
Interstate (01), rural*	1.53	0.37	0.98	0.29
Principal Arterial (03), rural*	1.67	0.44	1.06	0.33
All Other (04, 05, 06, 07), rural*	1.26	0.76	0.79	0.48
Interstate (01), urban*	1.46	0.46	0.93	0.34
Expressway & Freeway (02), urban*	1.38	0.72	0.90	0.47
All Other (03, 04, 05, 06, 07), urban*	1.64	0.53	1.04	0.41

\* The designer must determine if the location is urban or rural in character. The 2003 Highway Functional Classification System Concepts, Procedures and Instructions document available from the Office of Program Management should be used as a guide.



# Structural Thickness Design Example

CBR = 5.0

Total Flexible ESALs = 299,962

Resulting Structural No. = 2.95

Material	Layer Coefficient	Thickness (in)	Total
No. 2, 3, or 4 Stone	0.06	20	1.39
No. 57 Stone	0.09	4	0.36
Pavers & Setting Bed	0.30	4.625	1.39
		<b>Total</b>	<b>2.95</b>

# University California Davis Load Simulator



# University California-Davis Design Tables

Table 9.1: Design Table for PICP (Metric) (continued)

Number of Days in a Year When the Subbase has Standing Water (Wet Days)		50				90				120			
Resilient Modulus of Subgrade (MPa)	Dry	40	60	80	100	40	60	80	100	40	60	80	100
	Wet	24	36	48	60	24	36	48	60	24	36	48	60
Cohesion (kPa), Internal Friction Angle of Subgrade (°) <sup>1</sup>	Dry	10, 20	15, 25	20, 30	25, 35	10, 20	15, 25	20, 30	25, 35	10, 20	15, 25	20, 30	25, 35
	Wet	6, 12	9, 15	12, 22	15, 25	6, 12	9, 15	12, 22	15, 25	6, 12	9, 15	12, 22	15, 25
Lifetime ESALs (Traffic Index)		Minimum Subbase Thickness in mm ASTM #2 for 25 mm Allowable Rut Depth (All designs have 80 mm Paver, 50 mm ASTM #8 Bedding Layer, & 100 mm ASTM #57 Base Layer)											
50,000 (6.3)		175	150	150	150	210	150	150	150	230	150	150	150
100,000 (6.8)		285	180	150	150	325	215	150	150	340	235	150	150
200,000 (7.4)		395	285	185	150	430	320	215	150	450	335	235	155
300,000 (7.8)		455	340	240	160	495	375	275	195	515	395	290	215
400,000 (8.1)		500	380	280	200	535	415	310	235	555	435	330	250
500,000 (8.3)		530	410	305	230	570	445	340	260	590	465	355	275
600,000 (8.5)		555	435	330	250	595	470	360	280	615	490	380	300
700,000 (8.6)		580	455	350	270	620	490	380	300	640	510	400	315
800,000 (8.8)		600	470	365	285	640	505	395	315	660	525	415	335
900,000 (8.9)		615	485	380	295	655	525	410	330	675	540	430	345
1,000,000 (9.0)		630	500	390	310	670	535	425	340	690	555	440	360

<sup>1</sup> Default values based on testing cited in the literature (10,12)

Annual Number of Days with Rainfall (46 years of record)

Greater Than	
0.1"	71
0.25"	44
0.5"	24
1"	9
1.5"	3
2"	2

$$\text{MPa} = 17.61 \times \text{CBR}^{0.64} \quad (\text{CBR of 5} = \text{MPa } 49) \quad 290 \text{ mm} = 11.7''$$



## Subgrade Compaction & Proof Roll

### GeoFabric Layers

- Bottom and sides of trench

# GeoFabrics

## Tencate Mirafi RS-380i

- Reinforcement in weak soils
- High Infiltration Rate






Fabric	Permitivity	Grab Strength	Tear/Tensile Strength
ODOT Type D	0.05 sec <sup>-1</sup>	800 N	70 lbs
Mirafi RS-380i	0.9 sec <sup>-1</sup>	1500 N	180 lbs

# GeoWeb – Increases Strength



Doubles Layer Coefficient of  
the Stone Layer it Confines

The GEOWEB® Cell Dimensions

Relative Size <sup>1</sup>				
Name	GW20V (small cell)	GW30V (mid cell) <small>For All Other Applications      For Earth Retention<sup>4</sup></small>		GW40V (large cell)
Nominal Length x Width <sup>2</sup>	8.8 x 10.2 in (224 x 259 mm)	11.3 x 12.6 in (287x 320 mm)	10.5 x 13.0 in (267 x 330 mm)	18.7 x 20.0 in (475 x 508 mm)
Nominal Area <sup>3</sup>	44.8 in <sup>2</sup> (289 cm <sup>2</sup> )	71.3 in <sup>2</sup> (460 cm <sup>2</sup> )	68.3 in <sup>2</sup> (440 cm <sup>2</sup> )	187.0 in <sup>2</sup> (1206 cm <sup>2</sup> )
Cells per yd <sup>2</sup> (m <sup>2</sup> )	28.9 (34.6)	18.2 (21.7)	N/A	6.9 (8.3)
Nominal Depths				

1 All details and dimensions are nominal and subject to manufacturing tolerances.

2 Cell length and width will vary approximately ±10% through the recommended expansion range.

3 Cell area will vary only ±1% through the recommended section expansion range.

4 Cell dimensions for Earth Retention sections are fixed and NOT variable or nominal.









# Easton – Whole Foods





# Easton video

<https://youtu.be/2Kbk6-47WVo>

## LA Abrasion Test

- The standard LA abrasion test subjects a coarse aggregate sample to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres
- LA abrasion of 40 means 40% of the original sample passed through the No. 12 sieve (1.70 mm)



# No. 2, 3, or 4 Stone

- Testing Requirements
  - LA Abrasion Test <40 as per ASTM C-131
  - Angular particles >90% (no rounded river gravel)
  - Less than 2% passing No. 200 sieve
  - CBR >80%
- Recycled Concrete Typically Can't pass the LA abrasion test





Tech South

-Soft rock or  
contaminated material?

09/24/2013



## No. 57 Stone

- Testing Requirements
  - LA Abrasion <40
  - Angular particles >90% (no rounded river gravel)
  - Less than 2% passing No. 200 sieve
  - CBR >80%

# Compaction Equipment



10-12 Ton Roller



No. 57 Layer

# Deflectometer Testing

## Procedure

1. (3) Drops to Seat plate
2. (3) More Drops record readings
3. Take average of last (3) readings

Material	Maximum Deflection
No. 2, 3, or 4 Stone	1 mm
No. 57 Stone	0.5 mm

## Note

1. First lift of base stone may have high readings because the native subgrade will deflect and elevate the readings
2. Can only test to a depth equal to plate diameter = 12"



# Light Weight Deflectometer

- Purchased by CTL
  - \$6000
- Easy to use
- Good form of QA/QC between contractor and inspector
- Most tests passed, few small areas had to be re-rolled





# Poor Stone Compaction





## Lift Thickness

- 12" or less

09/24/2013



## No. 8 Setting Bed

- Testing requirements
  - LA Abrasion Test <40 as per ASTM C-131
  - Angular particles >90% (no rounded river gravel)
  - Less than 2% passing No. 200 sieve
  - CBR >80%

# Plate Compactor for Pavers





## Site Stabilization

- Use Sod
- No grass seed

# Concrete bands



- 18"x6" straight curb
- 12"x12" flush band



# Paver Material & Install Prices

Unilock Endura Color: \$4.50/SF delivered

Unilock Standard Color: \$2.60/SF delivered

Pine Hall Clay: \$4.50/SF delivered

Machine Install Price: \$3.00/SF (includes setting bed & chips)

Hand Install Price: \$5.00/SF (includes setting bed & chips)

# Machine Installation



# Clay Paver Parking Stall Installation

To Small of an  
area for  
machine  
installation, use  
hand setting  
prices



# Bid Item Costs – Public Bids

Item No.	Description	Total	Unit	Low Bid	Total Cost	Contractor Suggested Change	New Bid Cost	
203	EXCAVATION	11,411	CY	\$ 20.00	\$228,220.00	\$5.00	\$25.00	hard to work in existing streets
605	6" PVC PIPE UNDERDRAIN PERFORATED, AS PER PLAN	2925	LF	\$15.00	\$43,875.00			
660	SODDING, UNSTAKED	1,912	SY	\$ 12.00	\$22,944.00			
SPEC	PRESTO GEOWEB GW20V (3-inch), OR EQUAL	7,888	SY	\$8.00	\$63,104.00			
SPEC	PERVIOUS CONCRETE PAVERS (T=3 1/8")	70,794	SF	\$7.50	\$530,955.00			
SPEC	AGGREGATE BASE, AS PER PLAN NO. 57 STONE (T=4")	1,033	CY	\$51.00	\$52,683.00	\$5.00	\$56.00	more work to get to grade than anticipated
SPEC	AGGREGATE BASE, AS PER PLAN (NO. 2, 3, OR 4 STONE)	9,529	CY	\$39.00	\$371,631.00			
SPEC	WOVEN GEOSYNTHETIC Mifafi RS380i or EQUIVALENT	9,801	SY	\$5.30	\$51,945.30			



# Full Street Re-build Bid Prices

(70,794 SF pervious pavement)

Contractor	Bid
George Igel	\$3.6 million
Shelly & Sands	\$3.8 million
Conie Construction	\$4.1 million
Facemeyer	\$4.2 million
<b>Estimate</b>	<b>\$4.6 million</b>

## Includes

20% Force Account

\$405,000 street sweeper

\$129,000 contingency items

## Cost Per SF

Low bid (w/o force account, contingency, and sweeper) = \$34.60/SF



# Paver Installation Contractor

- Most Knowledgeable
- Typical Responsibilities
  - No. 8 Setting Bed
  - Set Pavers
  - Sweep in Chips
  - Plate Compact Finished Pavers
  - Replace Cracked or Chipped Bricks
  - Re-joint with Aggregate as needed until end of Warranty Period

Note: They will install the other layers of aggregate



# Construction Observations

- General contractor
  - Doesn't like to roll stone
  - Doesn't like shallow lift depths
  - Doesn't like sod
  - Doesn't like multiple mobilizations for pavement planning
  - Doesn't like to use plate compactor to compact stone at manholes
  - Doesn't like phased construction
    - Tree removal
    - Curb
    - Only wants subcontractors there once
- General contractor is typically least knowledgeable of the bunch
- Paver Installer is most knowledgeable
- Inspectors have never seen a project like this before
  - Deflectometer helps them quantify inspection



# Design Engineer

- Construction Observation Contract Recommended
- Answered a lot of Questions in Field
  - Contractor
  - Inspector
  - Residents
- Light Weight Deflectometer Training
- Attend Monthly Project Meetings



# Upcoming Standards

- City of Columbus
  - Supplement Spec 1525 – Permeable Pavement
  - Standard Details
    - Typical Section
    - Concrete Band Detail
    - Castings Detail
    - Laying Patterns
  - Green Infrastructure Design Manual
    - Location and Siting Guidelines

# East Dominion Before



# East Dominion After





**QUESTIONS?**