wgpaver.com

creativity

Dry-Pressed Permeable Clay Pavements

BRICK PERMEABLE PAVEMENTS

DESIGN
CONSTRUCTION
CREATIVE INSTALLATIONS

WHITACRE GREER
Quality Since 1900

The Brick Industry Association is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion for non-AIA members are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

This program also qualifies for ASLA/CES one credit hour.

Learning Objectives

- Know the materials and methods used in permeable segmental clay brick paving systems including a discussion on lifecycle costs.

- Identify the advantages and limitations of permeable clay pavements and permeable paving systems best practices.

- Learn how to select, specify and install these systems to achieve design goals while mitigating the effects on the site's ecosystem.

- Identify areas in which permeable clay brick pavers can contribute to sustainable environments through careful material selection and system design.

Contents

- Definitions
- Benefits
- Limitations
- Types of Exfiltration
- Basic System Designs
- System Construction and Important Components
- Product Information & Attributes of Dry-pressed Clay Pavers
- Resources and Useful Links

Definitions

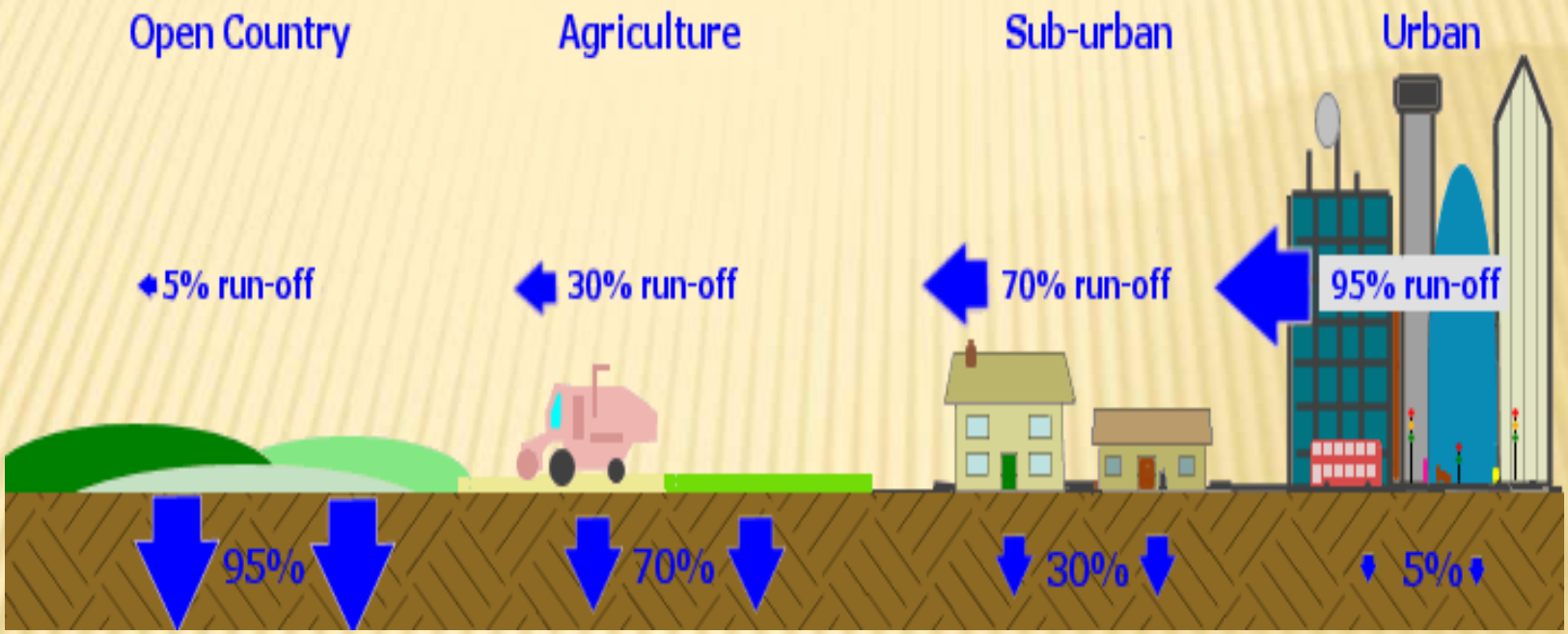
- **Pervious surface** – a surface that allows infiltration of water

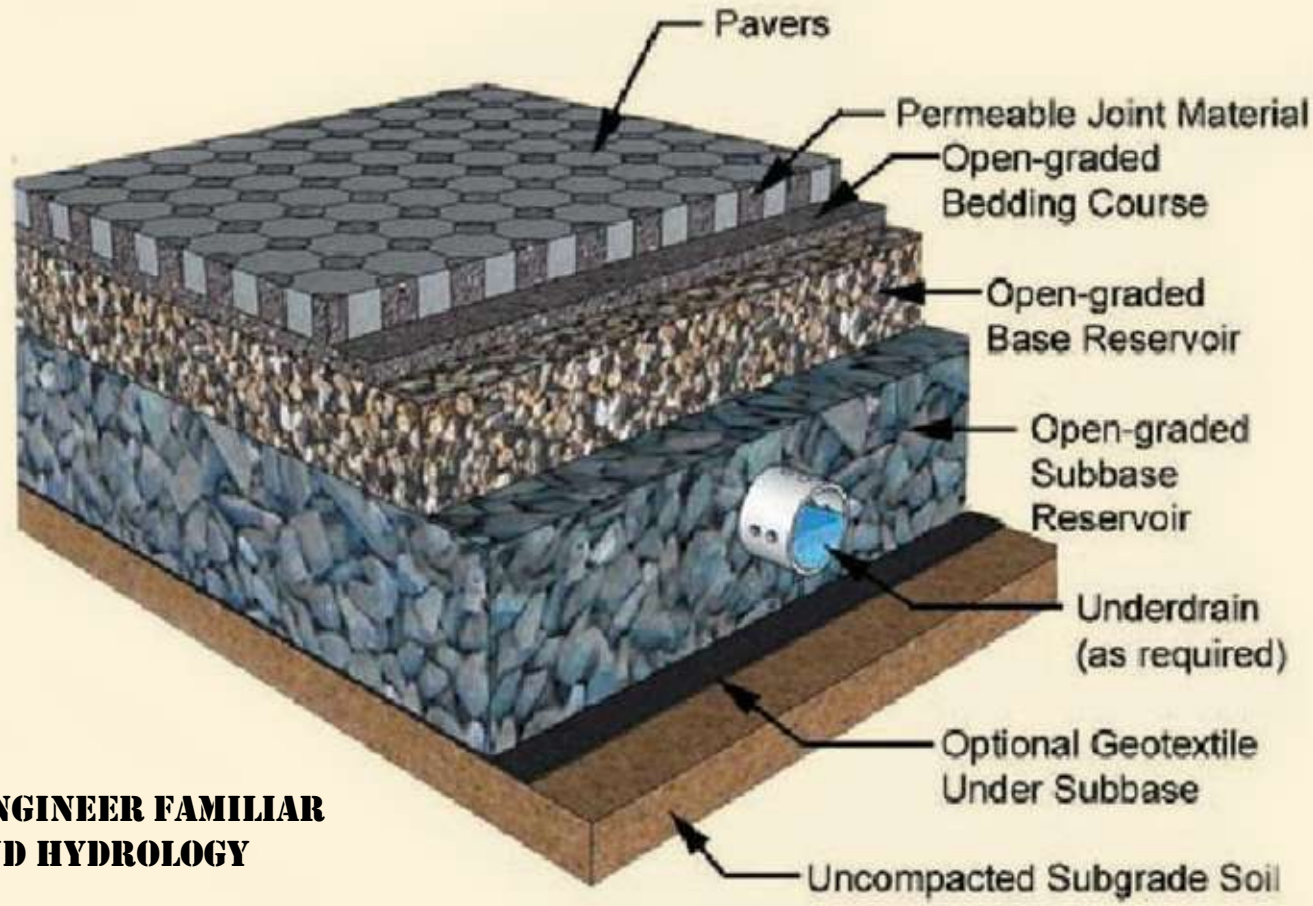
- **Porous pavement** – water passes through pores in the pavement

- **Permeable pavement** – water passes through stone filled joints between units

NPDES PHASE II
NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM AND EXCESS VOLUME

STORMWATER RUN OFF





CONSULT AN ENGINEER FAMILIAR WITH SOILS AND HYDROLOGY

Detail provided by ICPI.org

Benefits of a Permeable Pavement System

- Recharges ground water
- Filters storm water
- Decreases storm water runoff
- Meets EPA criteria for storm water best management practices
- Meets LID (Low Impact Development) for sustainable development
- Can be used for harvesting water for irrigation and/or gray water use

- Processes & reduces pollutants as compared to impervious surfaces
    - Zinc 62-88%
    - Copper 50-89%
    - Phosphorous 65%
      Recent 2012 UNH & TRCA captured 90+ %
    - Total suspended solids 60-90%
    - Oil adhering to aggregate particles will be digested by bacteria in the system
- Conserves onsite space (detention ‘pond’ under the pavers)
- Helps maintain predevelopment runoff levels

- Reduces or eliminates expenditures on retention and detention ponds as well as storm sewers
- Reduces or eliminates winter ice and slush puddles
- Reduces stream bank erosion from storm surge
- Qualifies for LEED and ASLA sustainable sites credits

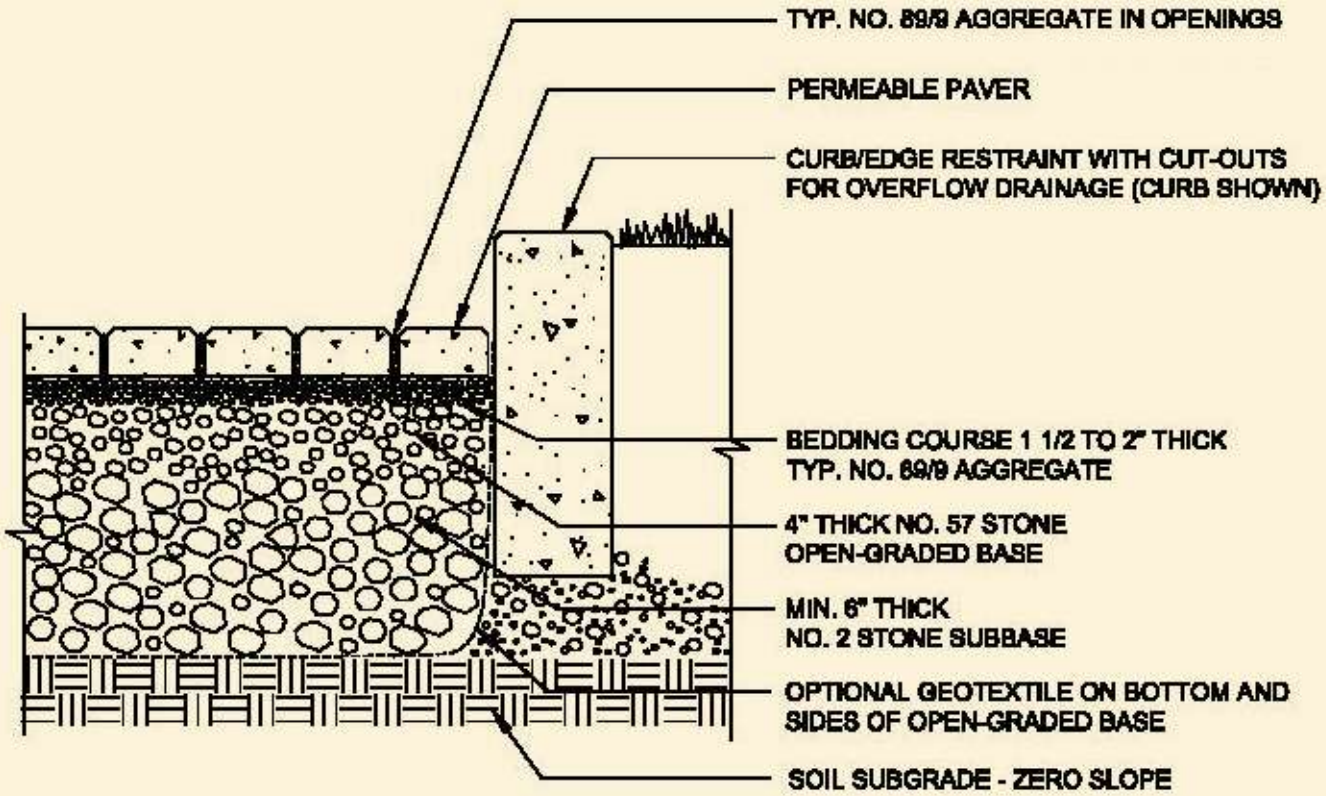
Limitations

No exfiltration system must be used when:

- There is <100 feet horizontally from pavement to drinking water supply
- There is <2 feet vertically to drinking water supply or bedrock
- Large amounts of contaminates are or may be present and can impact sub grade or aquifer. Example – a gas station

Types of Exfiltration

1. **Full exfiltration**
   - No under drains used
   - Works well in sandy well drained soils
2. **Partial exfiltration**
   - Under drains installed
   - Silty soils and some clay soils
3. **No exfiltration**
   - Impermeable liner
   - Under drains
   - Poor soils, solid rock or high water table
   - Within 100 feet of water supply

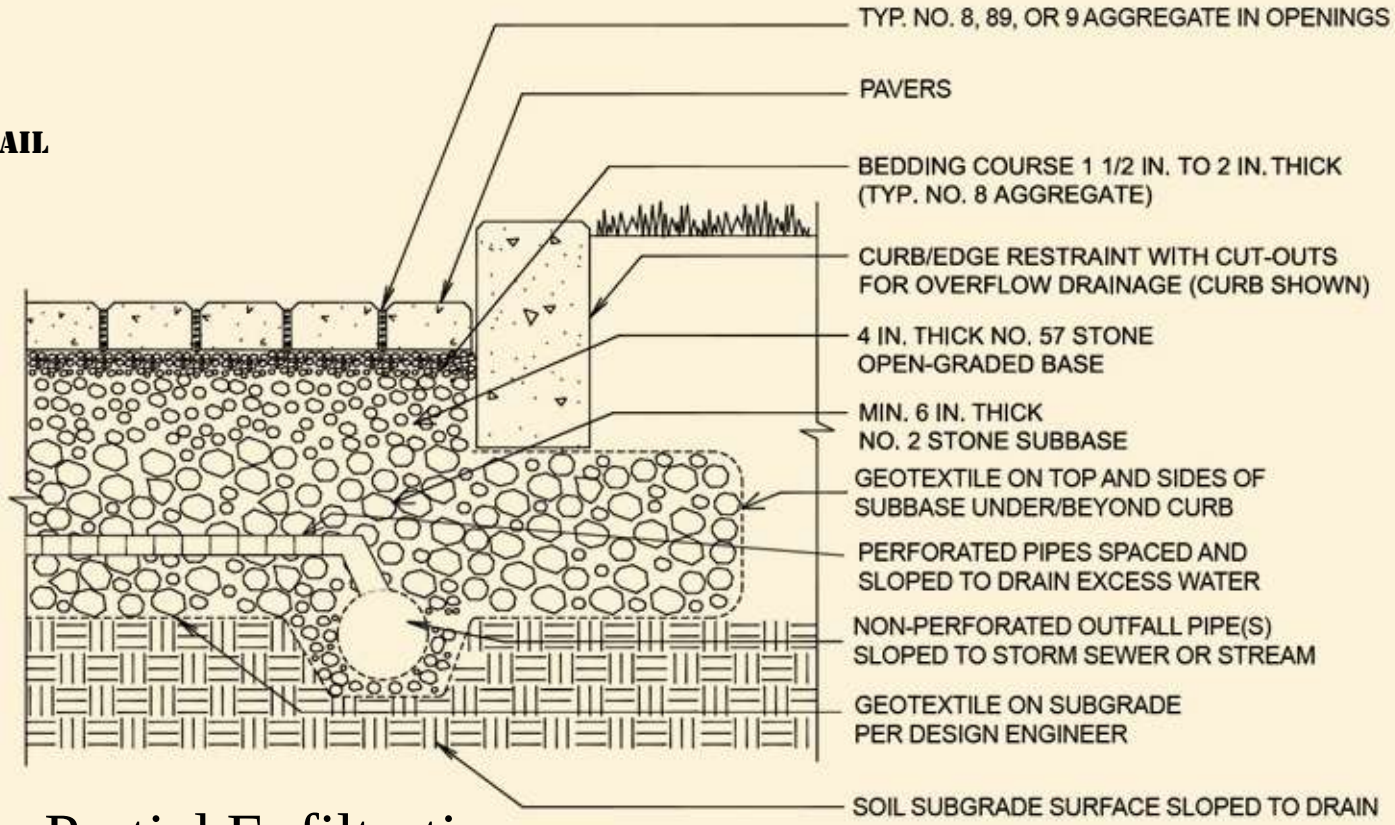


FULL EXFILTRATION

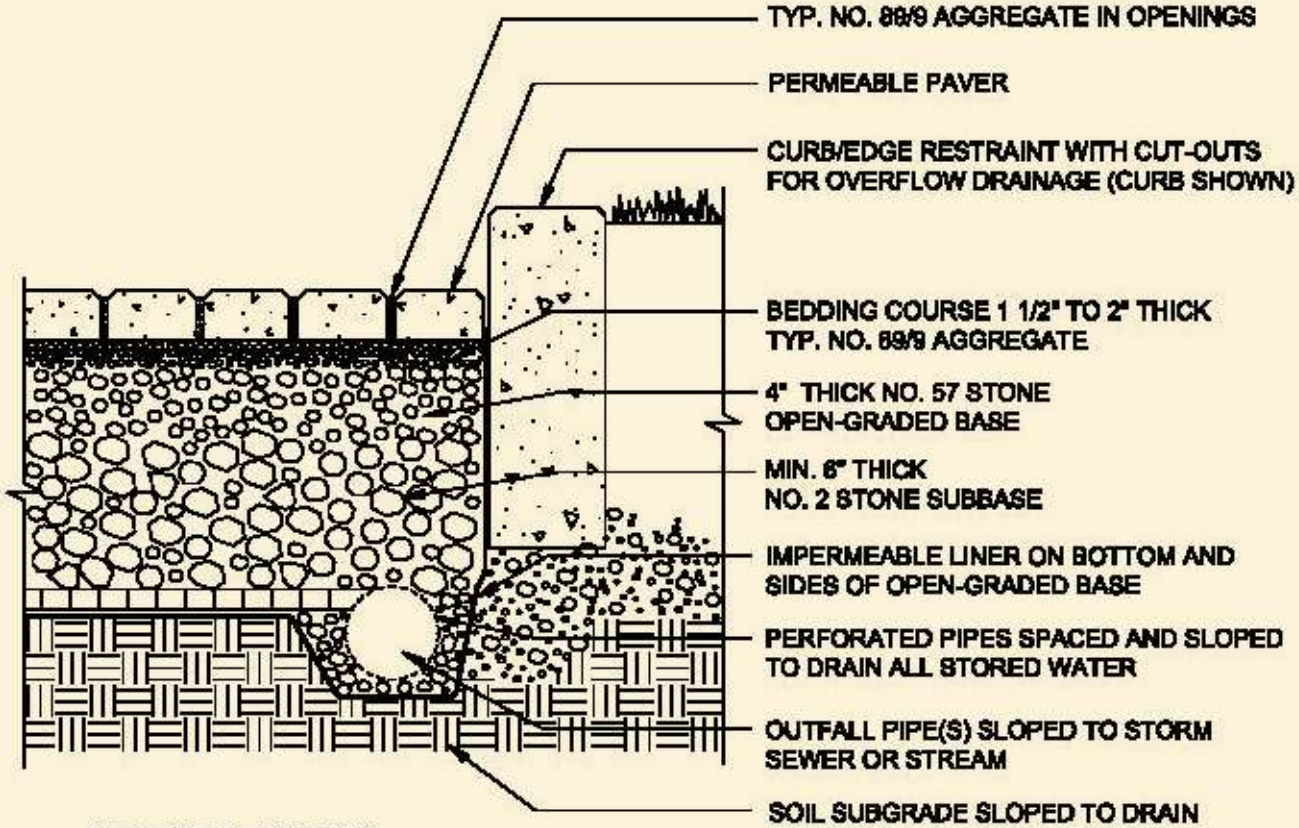
NOTE: CONSULT AN ENGINEER FOR HYDROLOGY AND
LOAD-BEARING DESIGN CONSIDERATIONS

ICPI DETAIL

ICPI DETAIL



Partial Exfiltration



NO EXFILTRATION

NOTE: CONSULT AN ENGINEER FOR HYDROLOGY AND LOAD-BEARING DESIGN CONSIDERATIONS

ICPI DETAIL

GENERAL

Pavement slopes of >5% require special consideration.

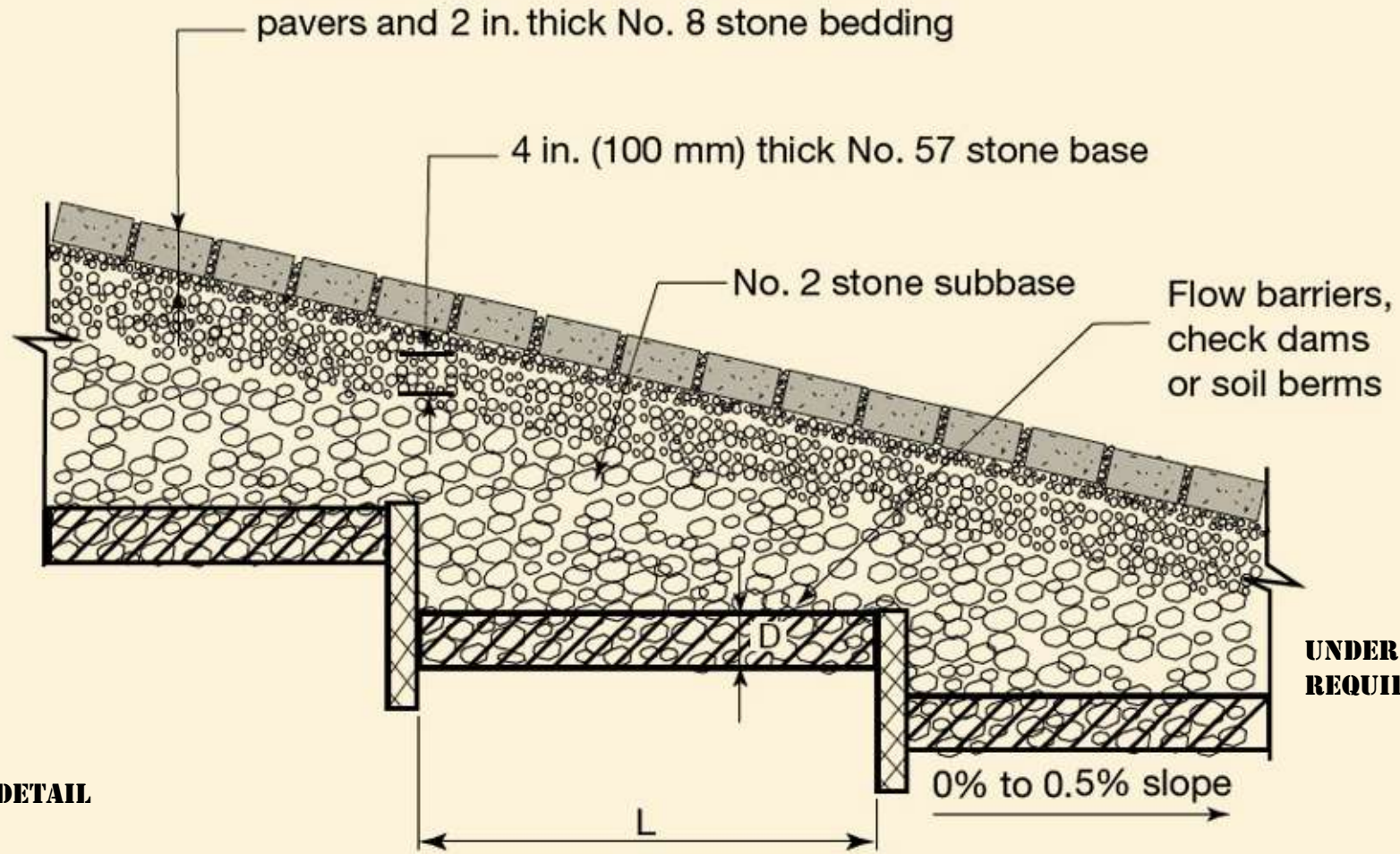
.Check dams/flow barriers in subgrade

.Terracing of pavement

Best results are achieved with pavement slopes of 1-5%

Expansive/clay soils with a California Bearing Ration <5 will require special considerations

- Deeper/thicker sub base
- Geotextile under the sub base
- Compaction of the subgrade (only recommended if the CBR is <5 or if required by an engineer) Compaction will reduce infiltration by 50-90%.



UNDER DRAIN REQUIRED

ICPI DETAIL

California Bearing Ratio (CBR) is a strength test that compares the bearing capacity of a material with a well graded high quality crushed and compacted limestone. The CBR for this high quality material is 100. Other materials are given a percentage value.

RESILIENT MODULUS– tests materials capability to recover after releasing a load

R-Value– test measures response of soil under pressure in a state of saturation (a CBR test with saturated/wet material)

OPEN GRADED AGGREGATES

- ASTM D 448
- NO FINES!!!!!!!!
- Sub-base = #2 (2 ½” to 1 ½”)
- Base = #57 (1” to 1/8”
- Bed & Joints =
  - #8 (3/8” to 1/16”)
  - or
  - #9 (3/16 to 1/16”)
  - or
  - #89 (mix of 8 & 9)

Demands a different level of construction skill.

Consider adding installer qualifications to specifications:

- 3 years experience with at least 75,000 square feet of permeable pavers installed
- 5 successful similar projects
- Experience installing clay/brick pavers
- Completion a permeable paving certification course

•And ...a preconstruction meeting covering scope, aggregates, edge restraints, compaction, keeping material and site sediment free

•Include a knowledgeable distributor or a manufacturer's rep.

•Material ordered in timely manner. Consider lead times.

Stormwater Utility Fees

- Many municipalities are instituting fees for runoff based on the rational that rain falling on private property belongs to the property owner therefore runoff removal should be paid as a user fee.

- Based on % of impervious cover

- Discounts or credits given for reducing runoff into municipal system

- Older cities with combined stormwater/sewage systems

Basic System Design Models (Volume Models)

• CAPTURE FIRST FLUSH. Recurring storms. ¾-1 ½" events, highest pollutant concentration

• EXTEND DETENTION/DELAY RUNOFF VOLUME 1-2 year events over 24 hour period

•REDUCE POST DEVELOPMENT peak DISCHARGE to PRE-DEVELOPMENT RATES 25 year, 24 hour event

•REDUCE FLOODING 100 year, 24 hour event

•DESIGN CONSIDERATIONS

•Structural requirements---pedestrian, vehicular

•Rainfall Intensity/Duration –design for first flush, 24 hour event, 2, 25, 100 year event

•Runoff contributed from adjacent areas –including off roofs

•Drainage sources and outlets

• Wells, depth to water table, horizontal distance to water sources, depth to solid rock

• Expansive soil, fill material, soil type, infiltration rate of subgrade soil

DETERMINE NATIVE SOIL INFILTRATION RATES

..Permeability/infiltration rate TEST PITS minimum two per 7000 SF or two per site if less than 7000 SF

- Rates <0.27-inches/hour will require additional sub base and drain pipes
- Frequently <0.5-inches/hour is used as a safety factor
- Approximate soil infiltration rates:
  - Group A sand – 8.0 -inches /hour, loamy/sand – 2.0 -inches /hour
  - Group B sandy/loam – 1.0 -inches /hour, loam – 0.5 -inches /hour
  - Group C silt loam – 0.25 -inches /hour, sandy clay loam – 0.15 -inches /hour
  - Group D clay – 0.05 -inches /hour

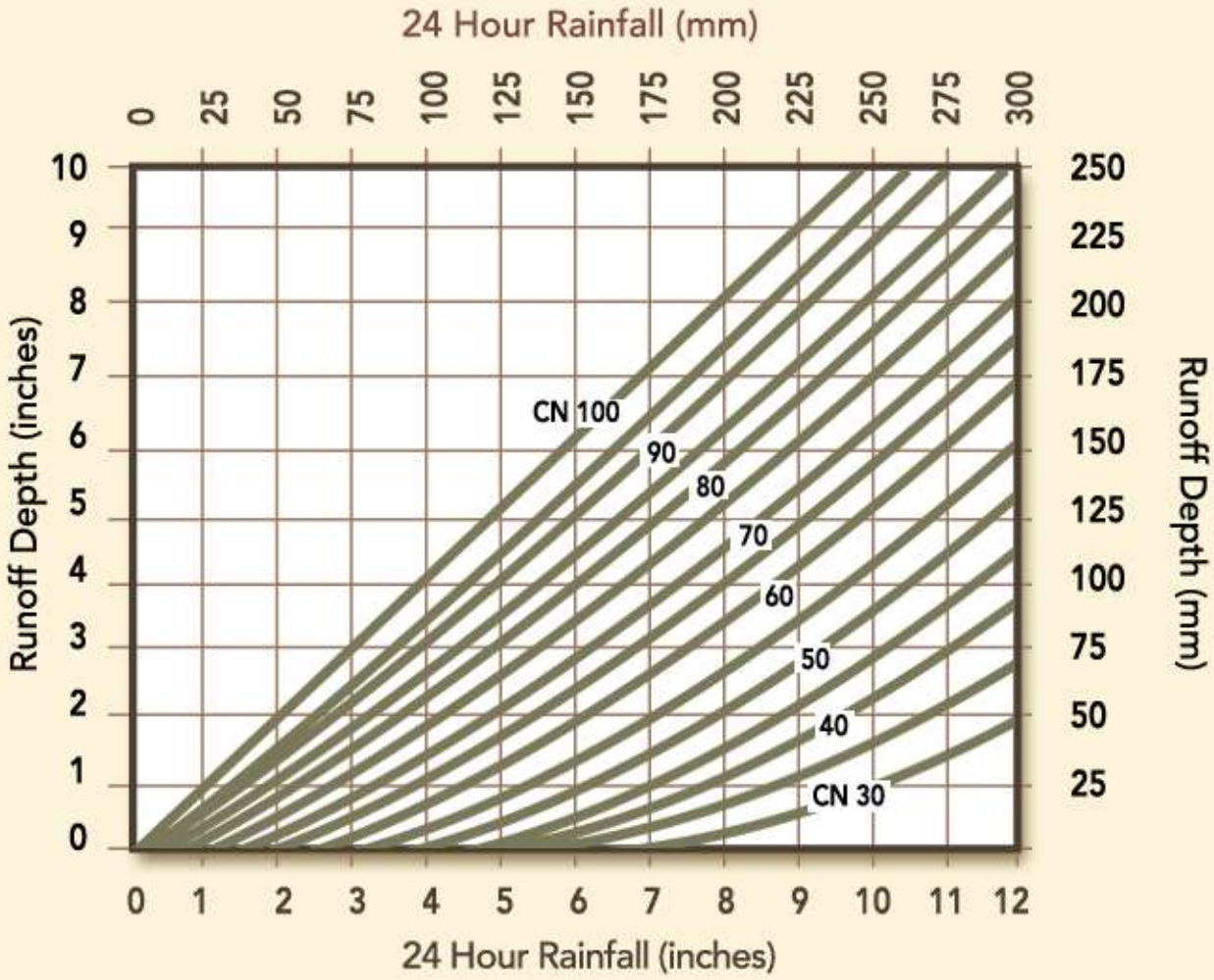
•CONSULT AN ENGINEER every site is unique

Other Methods to Calculate System Requirements

- CN- Curve Number- used to calculate pre and post development using established runoff curves for various surfaces.
  Works best on large areas (> 5 acres)

- Rational Method- typically used for sizing storm sewers
  Formula Q=CIA

Q = estimated peak flow in cubic ft./second
C = coefficient of runoff (permeable pavements have a conservative value of .25 for high infiltration soils and .4 on low infiltration soils- in new systems C= 0.0)
I = design rainfall intensity, inches/hour
A = drainage area in acres


24 Hour Rainfall (mm)
0
25
50
75
100
125
150
175
200
225
250
275
300
Runoff Depth (inches)
10
9
8
7
6
5
4
3
2
1
0
Runoff Depth (mm)
250
225
200
175
150
125
100
75
50
25
CN 100
90
80
70
60
50
40
CN 30
0
1
2
3
4
5
6
7
8
9
10
11
12
24 Hour Rainfall (inches)

Permeable Paver System Aggregates

Sub Base – #2 crushed aggregate, typically 6-18” thick

Base – #57 crushed aggregate, 4” thick

Setting Bed – #89, 1.5 – 2” thick

#2

#57

#89

ASTM D448 Sieve Sizes for No. 2, 57 & 9 Stone Sizes

	No. 2	No. 57	No. 9
3 in. (75 mm)	100		
2 in. (63 mm)	90 to 100		
2 in. (50 mm)	35 to 70		
1.5 in. (37 mm)	0 to 15	100	
1 in. (25 mm)		95 to 100	
3/4 in. (19 mm)	0 to 5		
1/2 in. (12.5 mm)		25 to 60	
3/8 in. (9.5 mm)			100
No. 4 (4.75 mm)		0 to 10	85 to 100
No. 8 (2.36 mm)		0 to 5	10 to 40
No. 16 (1.16 mm)			0 to 10
No. 50 (300 um)			0 to 5

Water Storage Capacity

	+40%	+30-35%	+20%

INFILTRATION RATE-POST CONSTRUCTION

- 12” Single Ring Infiltrometer
- Ring is “Sealed”
- Pour Water in to Desired Height
- Measure Drainage Time
- Post Construction
- 720 inches/hour
- ASTM C1781

HAWTHORNE PARK AVERAGE 800”/HOUR INITIAL INFILTRATION RATE

Infiltration Rates

Testing of installations in Philadelphia resulted in averages of
720 AND 800 INCHES PER HOUR

An EPA study in NJ reported **944 INCHES/HOUR IN 2010.**
787 INCHES/HOUR IN 2011
Project installed in the fall of 2009 (ICPI) **AN EPA ENGINEER ESTIMATED IT WILL TAKE 56 YEARS TO CLOG THE SYSTEM COMPLETELY.**

North Carolina State University studies indicate that **INITIAL INFILTRATION RATES OF UP TO 2000 INCHES/HOUR ARE NOT UNUSUAL.**

****FOR PROPERLY INSTALLED SYSTEMS**
****EDISON STUDY USED RECYCLED CONCRETE FOR SUBBASE—RESULT HIGH PH**

EXTREME RANGES

UNH two year study (PICP) recorded an **INFILTRATION RATE OF 3500 INCHES/HOUR.** After two years infiltration rate was **1000 INCHES/HOUR.** The native soil had a high infiltration rate of 3 inches per hour**.**

TRCA (Toronto Regional Conservation Authority) Two Year Study

Narrow Joint ¼”	**INITIAL RATE 60”/HR**	**AFTER TWO YEARS**	**13”/HR**
Wide Joint >1/2”	**INITIAL 204”/HR**		**55”/HR**

****TRCA REPORT ACKNOWLEDGES CROSS FLOW OF WATER FROM TEST CELL TO TEST CELL**

POROUS CONCRETE—WIDE JOINT——NARROW JOINT—ASPHALT

****TRCA ALSO INSTALLED GEOTEXTILE UNDER BED. NOT RECOMMENDED.**

INFILTRATION MYTH: CLOGGING

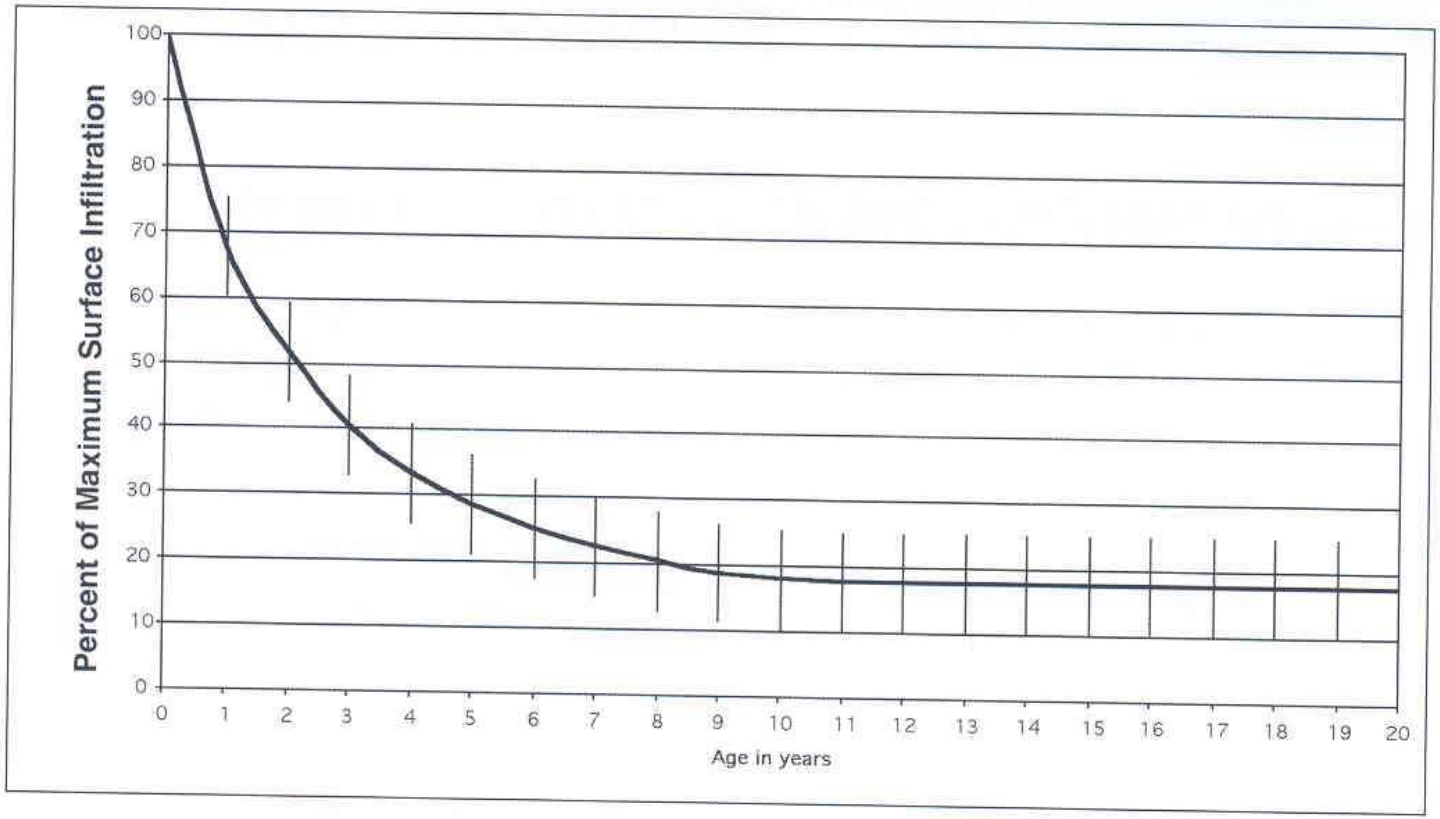


Figure 5. Overall trend of infiltration performance (Borgwardt 2006)

Construction of Permeable Systems

Sub grade should be relatively level (flat) for full exfiltration.

If drainage pipes are installed the sub grade should have a slight slope.
Slope sub grade away from building foundation-water proof + under drain.

Do not compact sub grade unless its CBR is <5.
Compaction will reduce permeability 50-90%.

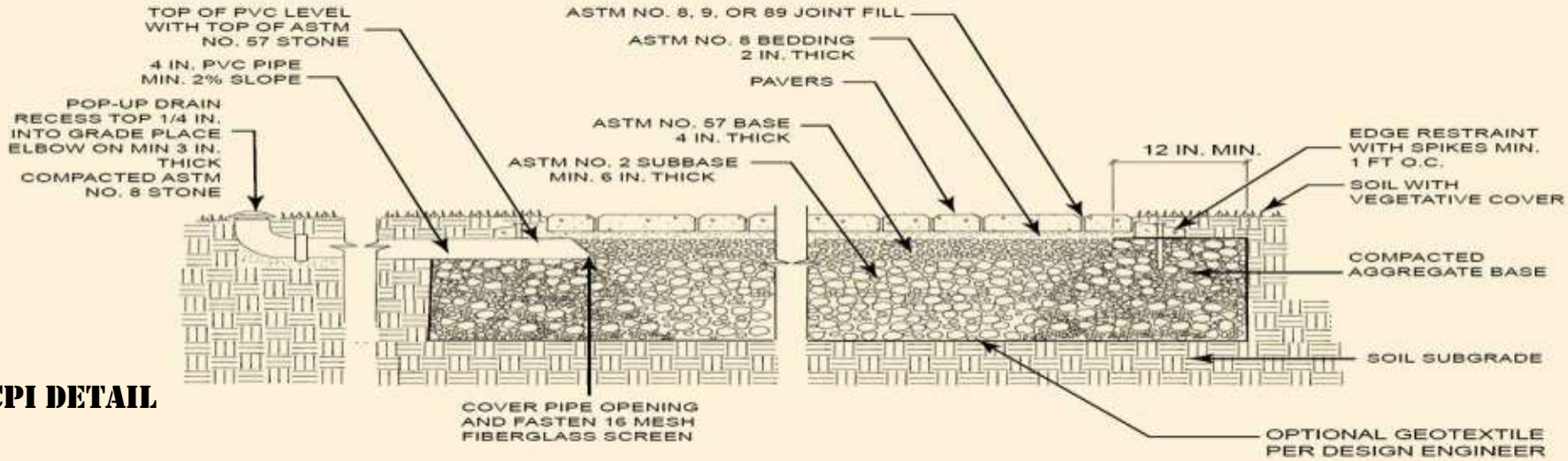
Maintenance and Site Housekeeping is Key

Preventing and diverting sediment from entering the sub base, base, setting bed and surface pavement must be the highest priority.

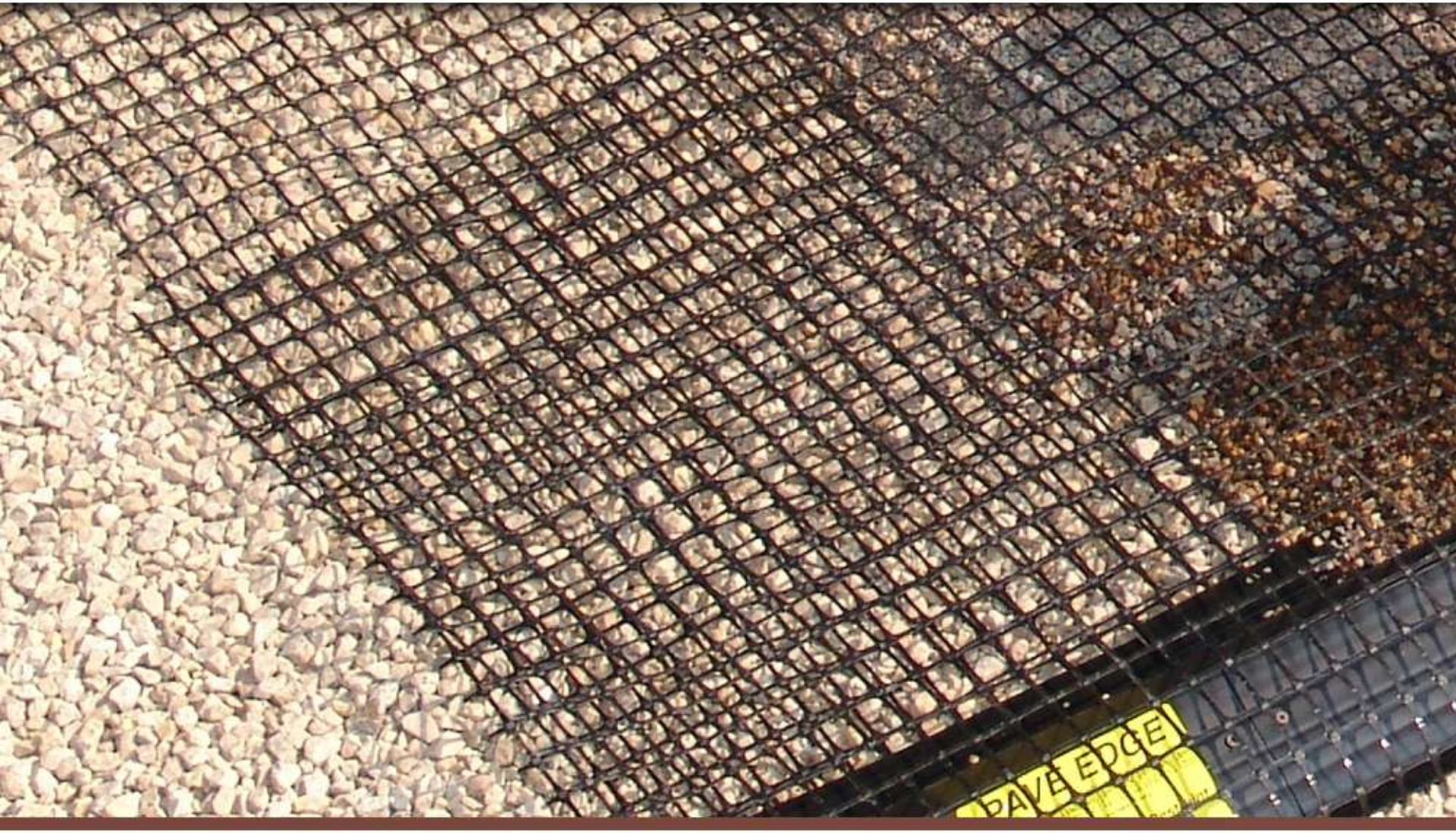
- Silt fences
- Keep muddy equipment away from the area
- Temporary drainage swales
- Protect area from runoff from adjacent areas that are not full vegetated.
- Proper Landscape Maintenance ..cover pavers when mulching, pruning and planting adjacent beds. Do not over fill mulch in beds.

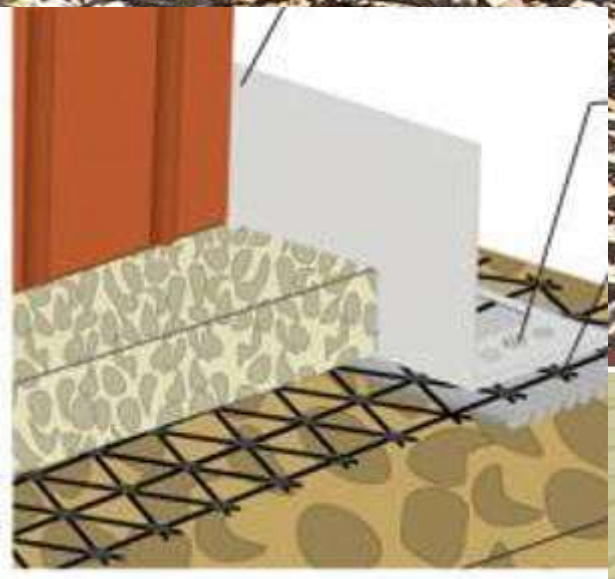
Edge Restraints

- Cast in place curb with overflow cutouts to bioswales
- Modification of commercial edging with geogrid
- Commercial edging spiked into dense graded aggregate, separated from open graded aggregate by geotextile


TOP OF PVC LEVEL WITH TOP OF ASTM NO. 57 STONE
4 IN. PVC PIPE MIN. 2% SLOPE
POP-UP DRAIN RECESS TOP 1/4 IN. INTO GRADE PLACE ELBOW ON MIN 3 IN. THICK COMPACTED ASTM NO. 8 STONE
ASTM NO. 8, 9, OR 89 JOINT FILL
ASTM NO. 8 BEDDING 2 IN. THICK
PAVERS
ASTM NO. 57 BASE 4 IN. THICK
ASTM NO. 2 SUBBASE MIN. 6 IN. THICK
12 IN. MIN.
EDGE RESTRAINT WITH SPIKES MIN. 1 FT O.C.
SOIL WITH VEGETATIVE COVER
COMPACTED AGGREGATE BASE
SOIL SUBGRADE
COVER PIPE OPENING AND FASTEN 16 MESH FIBERGLASS SCREEN
OPTIONAL GEOTEXTILE PER DESIGN ENGINEER

ICPI DETAIL


PAVE EDGE



Open Graded Aggregates

- **NO FINES!!! (NO SAND, NO SCREENINGS!!)**
- **PROPER COMPACTION!!!**

Sub Base #2 Stone

- Typically 6 – 18-inches thick
- Compact with 10-ton roller in 4 – 6-inch lifts
- With 13500 lbf compactor limit lift thickness to 3 – 4-inches

Base #57 Stone

- 4-inches thick
- Compact with 10-ton roller in one 4-inch lift
- With 13500 lbf compactor limit lift thickness to 2 -inch lifts

Compaction Testing for #57 Base

Nuclear density gauge

- Backscatter mode so material is undisturbed (no probe into base material)
- 5 readings 15-feet apart
- Calculate average density and compact again
- Take 3 additional readings
  - If density variation exceeds 1.2 lbs/cubic foot compact and retest
  - Otherwise accept

Stiffness gauge

- Produces vibrating force that is measured by sensors which records the force and its displacement time.
- Usually accurate within 5% of nuclear density testing

Compactors with Density Sensors

Indicates when maximum compaction is reached using vibration sensors similar to stiffness test

Compaction Testing for #2 Sub Base

- No proven measurement techniques available for this material

- Material is very stable

Bedding Material

#89 stone
Screed to 1 ½- 2 inches
Do not compact bed
Set pavers ¾ inch high to allow for settlement when compacted

Utilize string and chalk lines to keep bond lines straight
For vehicular areas- no cut pavers less than 1/3 of a paver

Fill joints, sweep off excess, compact pavers. USE A RUBBER MAT ON COMPACTOR PLATE to protect pavers
Compactor size 4000-5000 lbf
Repeat joint fill, compaction process

Permeable Pavers Perform Well in Cold Climates

- Ice and snow will melt and drain faster
- Reduces or eliminates icy pavements (black ice) and slushy puddles
- Reduces salt use
- Deicing pretreatment works well with permeable paver. Material sticks to solid unit surface.

Winter Maintenance

- Outfit plows with rubber cutting blades and mount plows on rollers – metal from plows and snow blowers will chip pavers

- Use rotary brooms when possible

- Salt will not harm pavers but may contribute to efflorescence – judicious use of deicing agents

- Salt mixed with sand will contribute to clogging of the system

- Use #9 stone in place of sand

- Heaving of pavement will typically not occur – pavements warmer
    - Water expands <9% when freezing – the system has 40% void space

Maintenance

•Preventative- removal of debris in joints, usually does not require removal of joint material-----brooms, leaf blower, rotary brush
Inspect for weed growth, crusting of joints
Inspect for ponding of water

. Restorative – requires some or complete removal of joint material to renew infiltration ----shop vacuum, riding litter vacuum, vacuum sweepers

• Yearly removal and replacing the upper +- ½- 1 “ of joint material is often recommended

Attributes of Clay Pavers

• Colorfast

• Superior freeze/thaw resistance

• Immune to structural damage by deicing products

• Salts may contribute to efflorescence in the early spring months

• Typically have higher compressive strengths than traditional paving products

• ADA compliant – joint widths and coefficient of friction

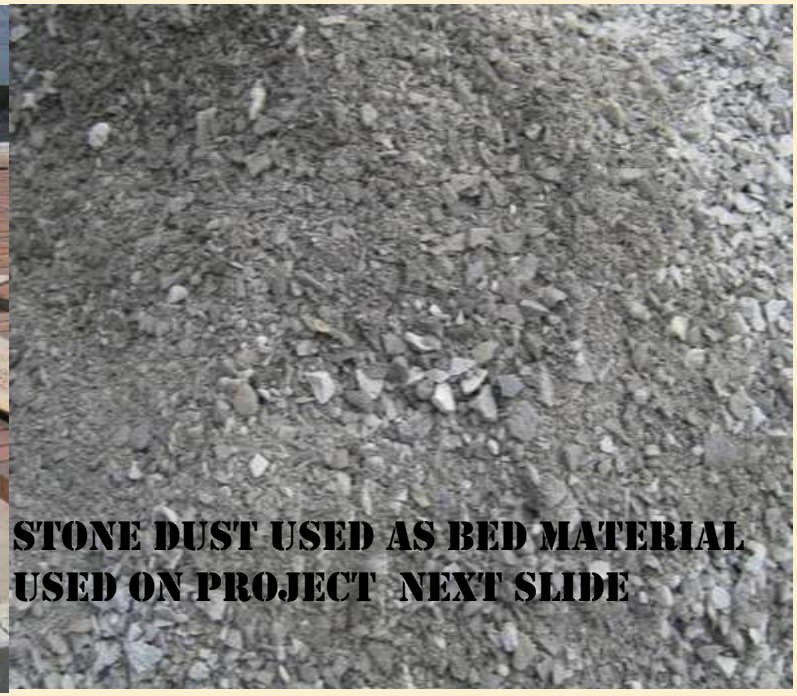
• 100% pre-consumer recycled product available (ASTM E2129-05)

• Many shades qualify for heat island effect credit for high SRI values

•Brick pavements 80-100 years old (Phila., DC, Balt, Boston)

The Good --The Bad-- and The Ugly (unqualified)

The BAD first



JOINT CLOGGING…….dust……dirt…….design (small retaining wall needed)

CLOSE UP OF CLOGGING
CROSS SECTION WASHED CLEAN STONE
NEEDED FOR BED & JOINT #89/9

IMPROPER EDGE
RESTRAINT

IMPROPER AGGREGATES USED

PROPER AGGREGATES
800”/HR

THE GOOD

Youngstown State University

Youngstown, OH

Wright State University

Dayton, OH

Georgia Tech

Atlanta, GA

Jerome Avenue Park

Margate City, NJ

University of Dayton

Dayton, OH

Miami Conservancy District

Dayton, OH

Maryland Residence

University of Maryland

Central NY Biotech Center

HOUSTON TX.

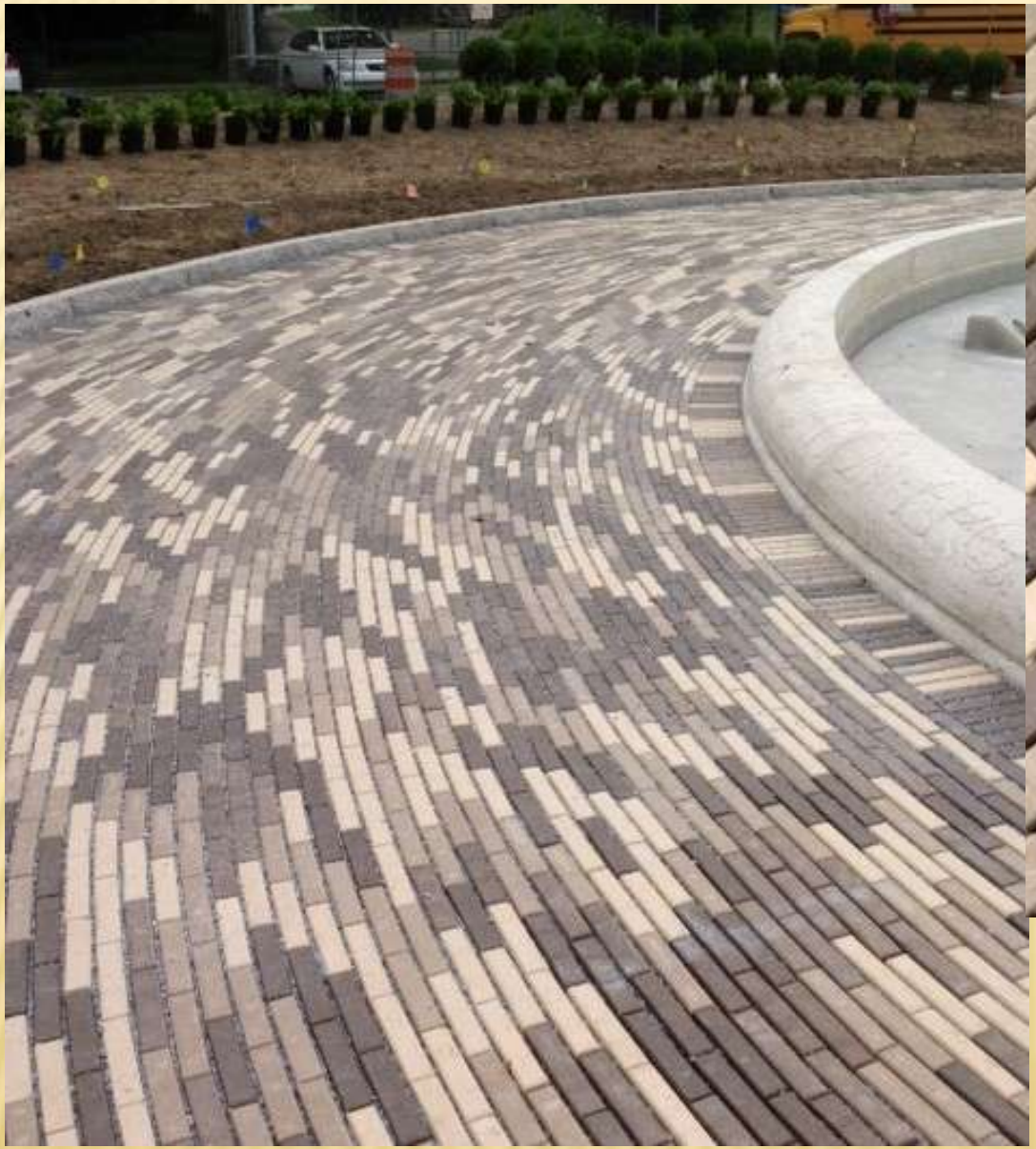
BAC BOSTON ARCHITECTURAL CENTER

Hawthorne Park Philadelphia

PHOTOS BY LRSLA STUDIO

SIDWELL FRIENDSHIP SCHOOL DC

UCONN



PHILADELPHIA
ITALIAN FOUNTAIN
FAIRMOUNT PARK

LEARNING OBJECTIVES

>CONSULT AN ENGINEER

>USE CORRECT AGGREGATES

>A QUALIFIED CONTRACTOR/INSTALLER IS A MUST

RESOURCES

- BIA TECH NOTE 14D
- ICPI TECH SPEC 18 & PICP DESIGN MANUAL
- NC STATE STORMWATER RESEARCH
- Univ. New Hampshire STORMWATER CENTER
- Toronto and Regional Conservation Authority (TRCA)

COLOR PALETTE

This concludes The American Institute of Architects Continuing Education Systems Course

Questions?

THE PAVER PLACE

WHITACRE GREER

Quality Since 1900

NC State Univ.- Univ. New Hampshire - (BIA)gobrick.com - icpi.org - wgpaver.com