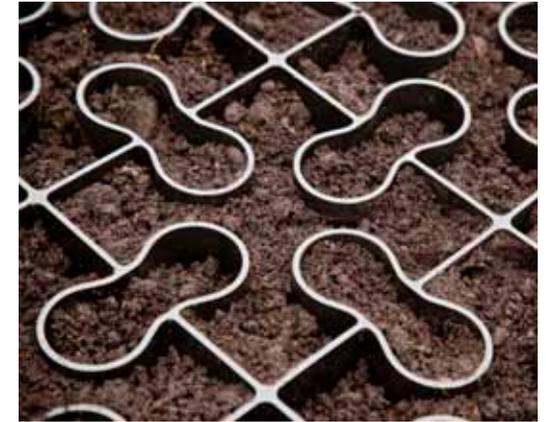


Permeable Pavements for Stormwater Control



Michael Dietz, Ph.D.
September 13, 2011
2pm

Welcome to the CLEAR Webinar Series!

This is the seventh in the 2011 series

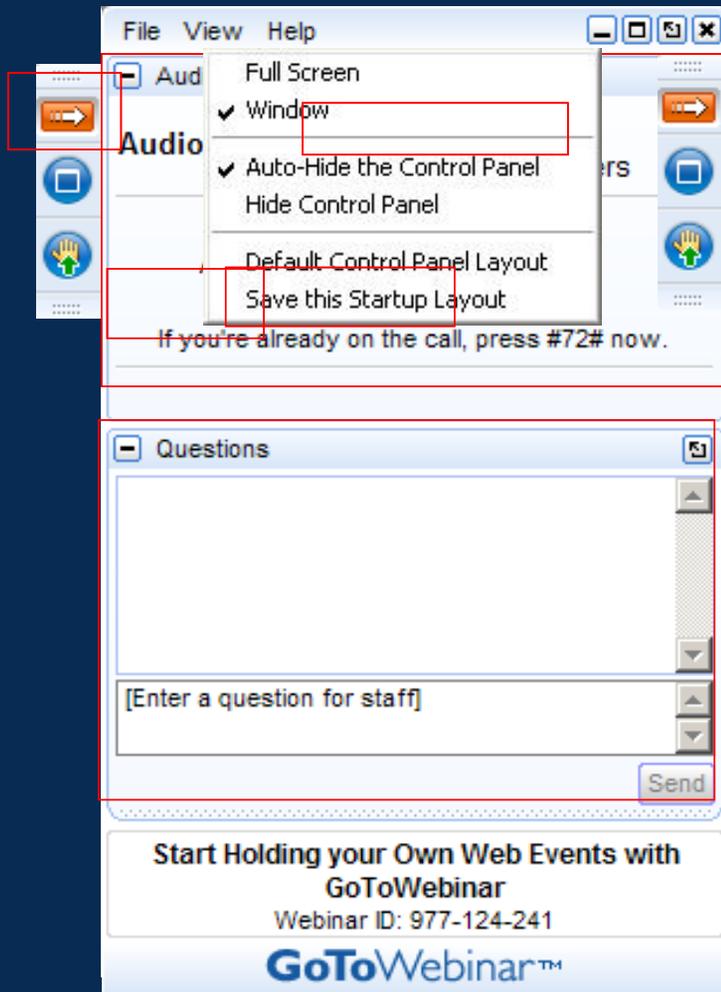
- Riparian Corridors, Now Online
- Affordable Housing, March 15
- Rain Gardens, April 19
- Google Maps Mashups, May 10
- Brownfields, June 14
- GPS, July 19
- **Permeable Pavements for Stormwater Control, September 13**
- **Farm-friendly Plans and Regulations, October 18**
- **CLEAR Web Tools, November 8**

Registration open

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Center for Land Use Education and Research

CLEAR's Mission:
To provide information,
education and assistance
to **land use decision
makers** in support of
balancing growth and
natural resource
protection.



University of Connecticut

- College of Ag. & Nat. Res., Dept. of Extension
- College of Ag. & Nat. Res., Dept. of Natural Resources & the Environment
- Connecticut Sea Grant

- Connecticut NEMO
- National NEMO Network
- Geospatial Training Program
- Land Use Academy
- Extension Forestry Program
- Lab for Earth Resource Information Systems
- Green Valley Institute



Outline for today's webinar

Common installation notes

Advantages/disadvantages of different types of pervious pavements

Research

Common maintenance notes

Costs



Why?

Traditional impervious surfaces have documented negative impacts to receiving waters

- Increases in peak flow rate
- Less recharge/filtration
- Increased pollutant loading

Alternatives to traditional pavement

Pervious Interlocking Concrete Pavers (PICPs)

Plastic grid pavers

Pervious concrete

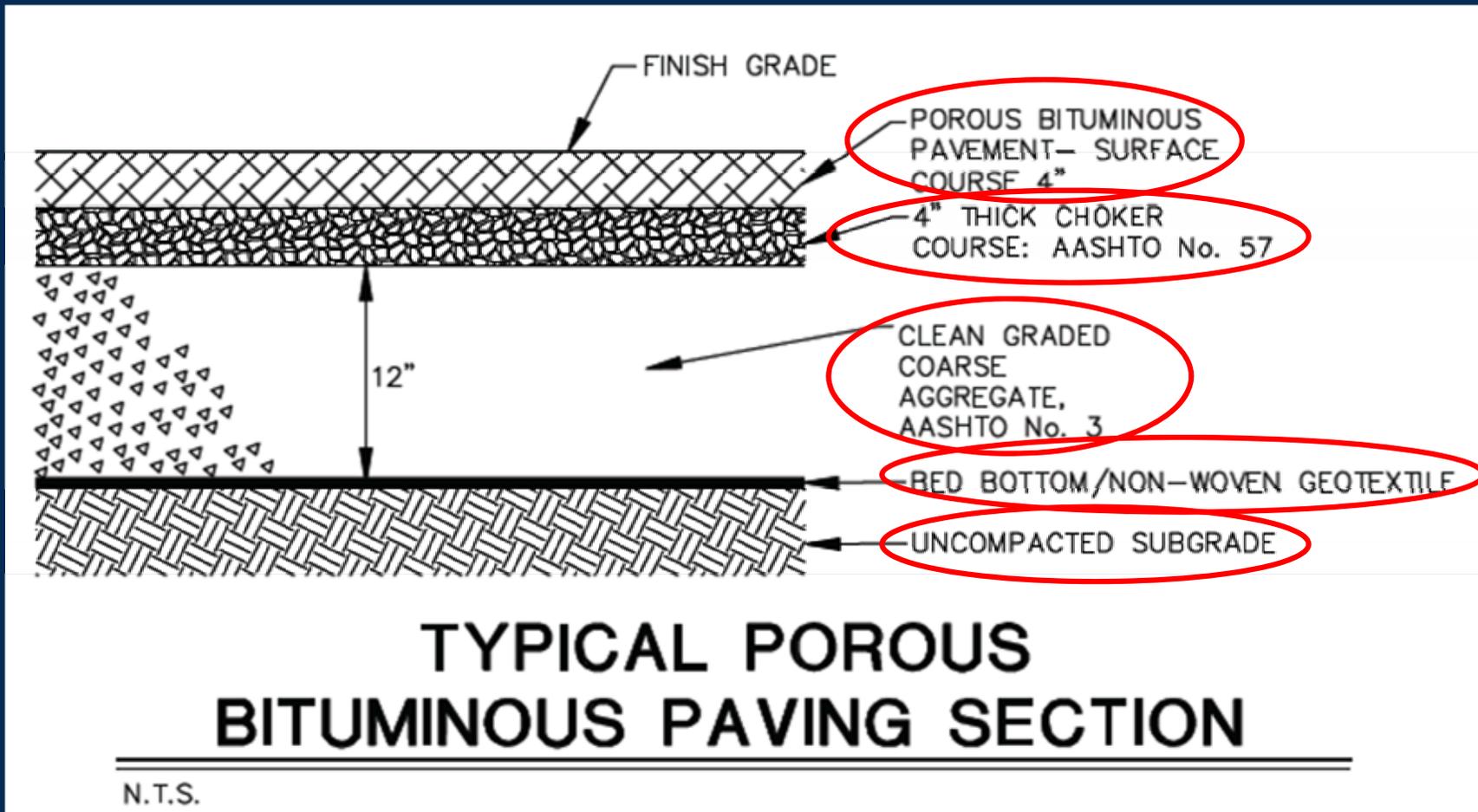
Pervious asphalt

Other options

All pervious pavements have one thing in common:

The base preparation is different than for traditional pavements, and needs to be designed for infiltration

Typical specification



Geotextile fabric beneath storage course-yes or no?

Carry-over from conventional design

- Prevent aggregate from migrating into subsoil and weakening integrity of surface
- Prevent fines from moving up from subsoil during times of high groundwater or infiltration

Known issues

- Clogging of fabric with fines from storage aggregate (URI)

Geotextile

Avoid if possible, but...

If it can't be avoided:

- Make sure fabric is **NON-WOVEN** type
- Ensure that washed stone really is washed

Permeable Interlocking Concrete Pavers (PICPs)

Similar to traditional block pavers

**When installed, there are voids in between pavers
that get filled with peastone or turf**

Permeable Interlocking Concrete Pavers (PICPs)

Uni Eco-Stone®



EcoGrid®



Turfstone®



Permeable Interlocking Concrete Pavers

Jordan Cove, Waterford, CT



Jordan Cove Urban Watershed Project, Waterford, CT

**Concrete Ecostone®
pavers**

**Traditional
pavement**



Pervious driveways



Material pricing

EcoStone (8 cm thick): \$3.75/ft²

Aquabrick (6 cm thick): \$3.00/ft²

**For small jobs, base preparation about equivalent, just
with different materials**

PICPs at UConn



PICPs

Benefits:

- Fairly easy to install
- Very durable surface, even in high traffic areas
- Much longer life than asphalt
- Easy to remove and replace small sections if subsurface utility repairs are needed

Negatives:

- Cost is fairly high (about 3-5x asphalt)
- Prone to clogging, but only in high-loading areas

Plastic grid pavers

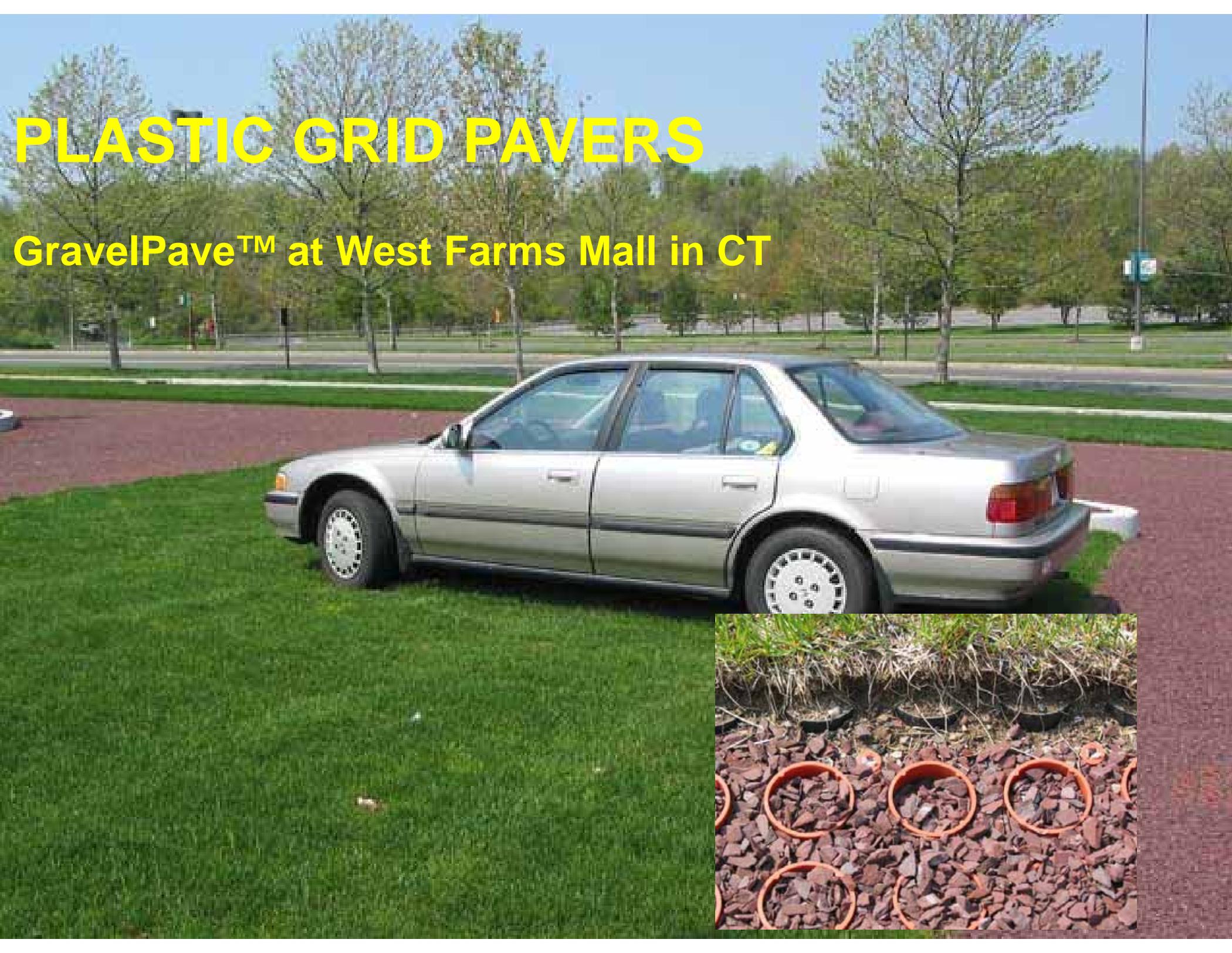
Plastic structure that is filled with turf or aggregate

- Turf works OK, but only in very low traffic areas

Comes in rolls or squares

PLASTIC GRID PAVERS

GravelPave™ at West Farms Mall in CT

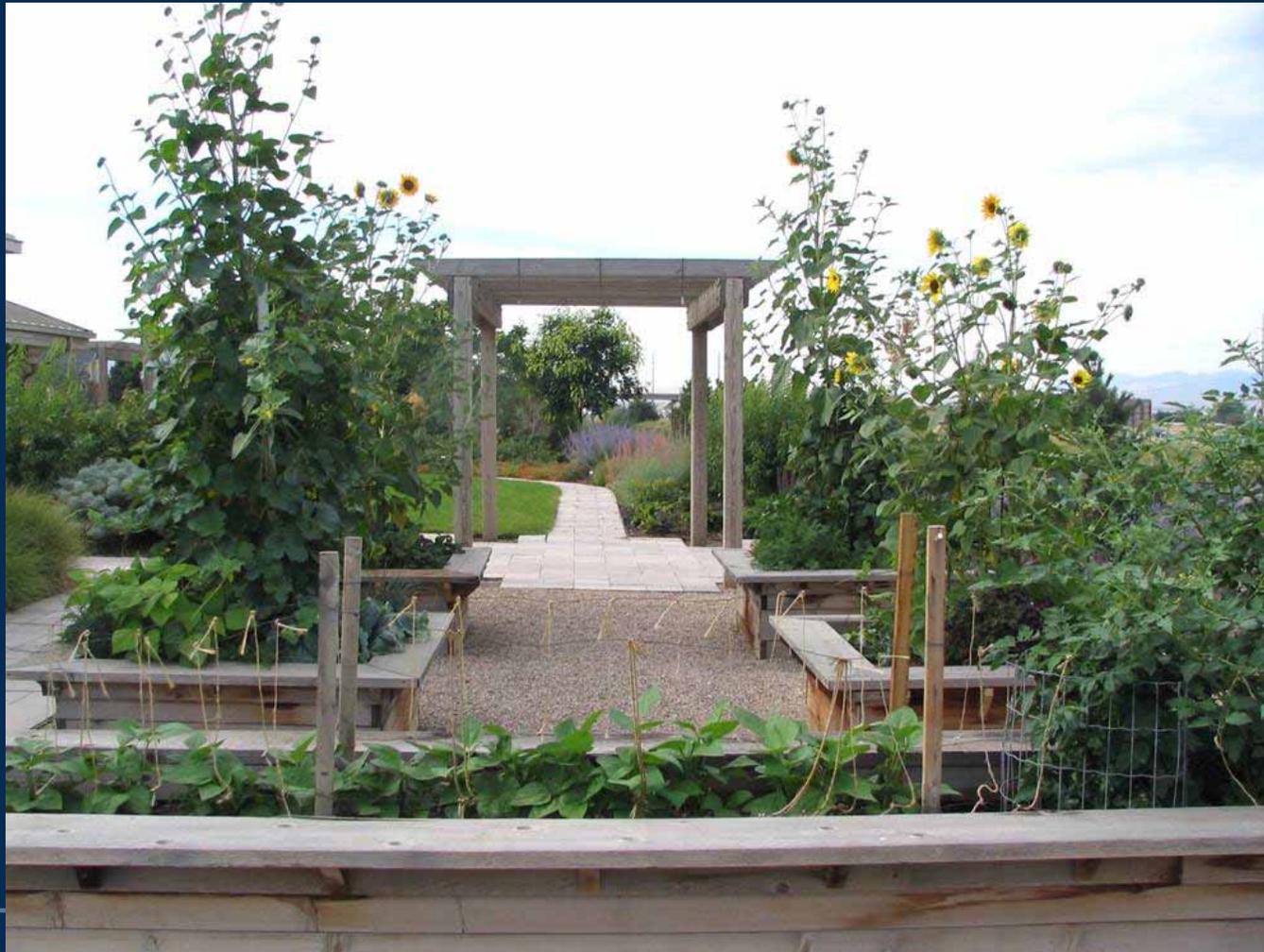


Utah House in Kaysville



GravelPave at Utah House

Pathways around raised beds



UConn plastic grid pavers



Plastic grid pavers

NetPave®50



Plastic Grid Pavers

Benefits:

- Fairly cheap to install (\$4-\$6/ft²)
- Generally not as prone to clogging since the entire surface is pervious

Negatives:

- Not as durable in high traffic areas
- Difficult to repair small sections
- Need to be extremely careful plowing snow

Pervious asphalt

Similar to regular asphalt, but no fines in the mix

Also called “popcorn mix”, or Open Graded Friction Course (OGFC)

Installed with same equipment

Cost about \$5/ft²

Pervious asphalt

University of NH Stormwater Research Center



Pervious asphalt at CT State Capitol



Pervious asphalt at UConn

Towers-2009



Northwoods-2010



Pervious Asphalt

Benefits:

- Cost competitive with traditional paving
- Can be applied with the same paving equipment used for traditional asphalt
- Extremely durable, even in high traffic areas

Negatives:

- Difficult to find an asphalt plant willing to mix it for small jobs
- May have “drain down” in hot climates
 - Special binders have been developed
- Can be prone to clogging

Pervious Asphalt: costs

From Gunderson, J, Roseen, R, Janeski, T., Houle, J., and M. Simpson. 2011. Cost-Effective LID in Commercial and Residential Development. *Stormwater*, March-April.

Table 1. Comparison of Material Unit Costs for Boulder Hills

Item	Conventional Option	Low-Impact Development Option	Cost Difference
Site Preparation	\$23,200.00	\$18,000.00	(\$5,200.00)
Temporary Erosion Control	\$5,846.50	\$3,811.50	(\$2,035.00)
Drainage	\$92,398.00	\$20,125.00	(\$72,273.00)
Roadway	\$82,054.00	\$127,972.00	\$45,918.00
Driveways	\$19,722.00	\$30,108.00	\$10,386.00
Curbing	\$6,464.00	\$0.00	(\$6,464.00)
Permanent Erosion Control	\$70,070.00	\$50,610.00	(\$19,460.00)
Additional Items	\$489,700.00	\$489,700.00	\$0.00
Buildings	\$3,600,000.00	\$3,600,000.00	\$0.00
Project Total	\$4,389,454.50	\$4,340,326.50	(\$49,128.00)

Table 2. Comparison of Material Unit Costs for Greenland Meadows

Item	Conventional Option	Low-Impact Development Option	Cost Difference
Mobilization / Demolition	\$555,500	\$555,500	\$0
Site Preparation	\$167,000	\$167,000	\$0
Sediment / Erosion Control	\$378,000	\$378,000	\$0
Earthwork	\$2,174,500	\$2,103,500	(\$71,000)
Paving	\$1,843,500	\$2,727,500	\$884,000
Stormwater Management	\$2,751,800	\$1,008,800	(\$1,743,000)
Additional Work-Related Activity (utilities, lighting, water & sanitary sewer service, fencing, landscaping, etc.)	\$2,720,000	\$2,720,000	\$0
Project Total	\$10,590,300	\$9,660,300	(\$930,000)

* Costs are engineering estimates and do not represent actual contractor bids.

Pervious concrete

Similar to regular concrete mix, minus the fines

- Portland cement, water, aggregate

Application is much different than traditional concrete

Cost about \$6-8/ft²

Pervious concrete

Villanova University



Pervious concrete at CT State Capitol



Pervious concrete in Milford, CT



Pervious concrete at UNH

<http://www.youtube.com/watch?v=ScsQYHMfabU>



Other pervious concrete in CT

Field house parking lot, UConn Storrs



Pervious Concrete

Benefits:

- Extremely durable, even in high traffic areas
- Cost can be competitive with traditional concrete
- Light color keeps surrounding area cooler than with darker pavements

Negatives:

- Application is much different than traditional concrete, and must be done by experienced contractors
- Because of the special application and special mix from the concrete plant, it can be more expensive
- Subject to the same issues as traditional concrete (i.e., curing time reaction with salt)

Problems with UConn pervious concrete



New twist on pervious concrete

Stormcrete



Stormcrete

Stormwater Compliance (Yarmouth ME)

- 5' x 8' x 5" thick
- Current price: \$7-8/square foot delivered to site

Can be used on large jobs, but fills niche for small jobs such as driveways or sidewalks

Other products

Variations on the theme of aggregate with binder,
minus the fines

Gravel-Lok

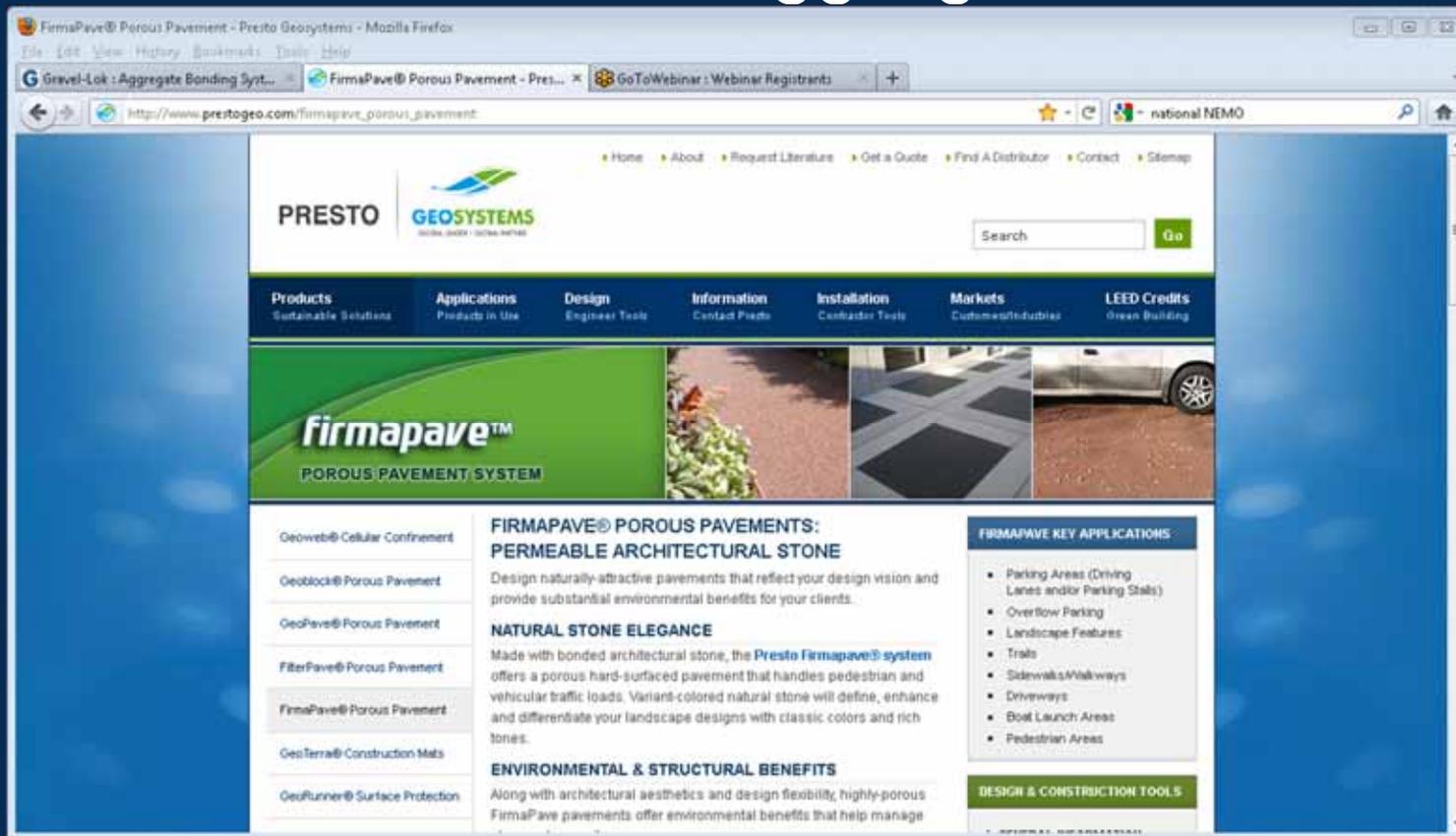
Polymer binder for any type of aggregate



5 gallons treats 60 ft², and costs \$4/ft²

FirmaPave

Polyurethane binder for aggregate



Flexi-Pave

Uses recycled tires as aggregate

Best for walkways, playgrounds, patios



Pervious pavers monitoring results

Washington (Brattebo & Booth, 2003)

- Grasspave[®], Gravelpave[®], Ecostone[®], Turfstone[®]
- Virtually all rainfall infiltrated
- Percolate water quality generally better than runoff from asphalt lot

North Carolina (Collins, et al., 2006)

- Zinc, ammonia, phosphorus and nitrogen concentrations were significantly reduced after infiltrating through Ecostone[®] pavers

Monitoring results continued

Connecticut (Gilbert & Clausen, 2005)

Runoff (average) from Ecostone[®] driveway was 72% less than asphalt
Concentrations of all pollutants lower in surface runoff from Ecostone[®] driveways, as compared to asphalt

Pennsylvania (Kwiatowski, et al., 2007)

ALL runoff infiltrated from storms 5 cm (2 inches!) or less in size

How about clay soils??

Recent research suggests that significant infiltration can still be achieved

- Dreelin, et al., 2006: Grasspave system over 10 inches of gravel, and a clay soil subgrade.
- Fassman & Blackburn, 2010: PICPs over storage course, clay soil subgrade. Runoff from PICPs essentially identical to predevelopment condition.

How about winter performance?

Numerous studies in cold climates have shown that a properly designed and properly installed permeable pavement application functions through the winter

May not need as much deicing salt

May need to be more careful plowing snow



How about groundwater contamination?

- **In most settings, pollutant concentrations are fairly low**
- **Most pollutants are adsorbed to soil and most are broken down over time**
- **Chloride can be a problem from deicing**
 - **No contamination found beneath pervious concrete application in PA**
- **Avoid pervious pavements in areas with high potential contaminant loading**
 - **Gas stations, transfer stations, etc.**

See Pitt, et al., 1999: Groundwater contamination potential from stormwater infiltration practices. *Urban Water*, Vol. 1, pp. 217-236.

Common maintenance notes



Issues with permeable pavers

Clogging

2002



2005



Maintenance

Permeable systems also require maintenance

- Depends on type
- Also depends on local environment
 - Lots of wind-blown fines?
 - Winter sanding?

**Best maintenance for PICPs, pervious concrete,
pervious asphalt: vacuum suction**

Costs

Pavement type	\$/ft²
Traditional asphalt	2
Pervious asphalt	5
Traditional concrete	7-8
Pervious concrete	6-8
Stormcrete	7-8
*Traditional block pavers	2-5
*PICPs	3-4
Plastic grid (GravelPave™)	4-6
*Gravel-Lok™	4
*Cost of materials only	

**These costs
do NOT
account for
infrastructure
savings**

In conclusion:

A variety of alternatives to traditional pavement exist

Not every one is appropriate for every application

Base preparation is critical to long-term function

Costs are generally higher on a per square foot basis, but can be cheaper for larger projects

Useful links

UNH Stormwater Center: <http://www.unh.edu/unhsc/>

EcoStone: <http://www.uni-groupusa.org/EcoFam.htm>

Aquapave: <http://aquapave.com>

Turfstone: <http://www.interlockonline.com/turfston.html>

Stormcrete: <http://www.stormwatercomp.com/>

URI pervious asphalt lot:

<http://www.uri.edu/ce/wq/NEMO/Publications/PDFs/PP.URICaseStudy.pdf>

Gravel-Lok: <http://www.gravel-lok.com/>

Firma-Pave: http://www.prestogeo.com/firmapave_porous_pavement

Flexi-Pave: <http://www.kbius.com/product-info/summary.html>



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