Flexible Plastic Porous Pavers:

A Green Paving Solution for Grass and Gravel

At the end of this program, participants will be able to:

- identify the components of a paving system and relay a brief history of the porous pavement industry
- discuss the differences between dense and porous pavements in terms of their impact on the environment
- compare porous paving systems to conventional paving systems in terms of their environmental, economic, and human benefits
- discuss the physical properties of flexible plastic porous pavers and discuss how porous paving systems for grass and gravel contribute to a sustainable built environment
- analyze case studies of successful porous pavement installations
- detail application, installation, and maintenance techniques of different porous paving systems, and
- analyze the sustainability benefits, attributes and performance criteria of flexible, plastic porous pavers relative to qualifying for credits under green building programs.

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What is Porous Pavement?

Introduction

Pavements are so much a part of our everyday lives that we hardly even notice them. Pavements currently occupy twice the area of buildings. Every year, the United States paves or repaves a quarter of a million acres of land.

The environmental problems associated with conventional pavements are well documented. Impervious surfaces, such as asphalt and concrete, pollute rainwater, deplete groundwater supplies, contribute to rising temperatures in cities, prevent tree growth, destroy aquatic habitat, and cause soil erosion.

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Source: apocalypse.org
Photo by Margaret Hart

Introduction

In response to these problems, engineers and architects are turning to a different class of paving materials known as porous pavements. Unlike conventional pavements, porous pavements have built-in networks of void spaces which allow water and air to pass through them. These pavements are not only beneficial to the environment, they can be used to create uniquely beautiful urban landscapes.

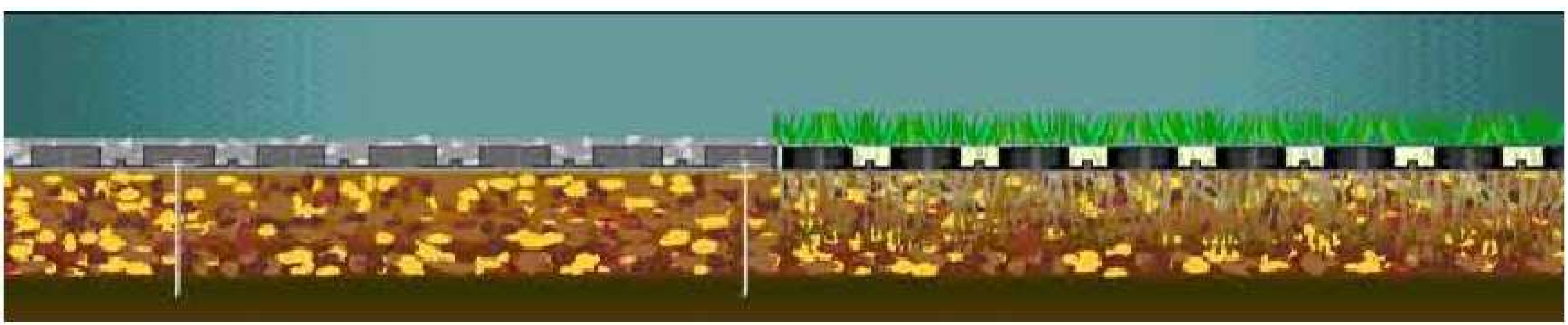
However, despite their benefits, porous paving materials are still relatively unknown in urban design and construction. This is partly due to the fact that the technology has just become advanced enough to make porous pavements a viable alternative.

Navy Pier, Chicago, Illinois

Porosity, Permeability, Perviousness & Infiltration

Although the literal definitions of the terms porosity, permeability, perviousness, and infiltration are different, the Stormwater Industry treats porous paving, permeable paving, and pervious paving as interchangeable. The terms themselves have different meanings. Below are the definitions of these words and how they relate to this presentation.

- Permeability - the rate at which a fluid flows through a porous substance under given conditions.
- Porosity (void space) - the portion of a volume of material that is not solid.
- Infiltration – the movement of a fluid into the surface of a porous substance.



Brief History of Pavements

Pebbles, cobblestones, and wood decking structures have been used for centuries to reinforce walkways and roads. Little did we realize that these traditional methods of surface or ground reinforcement had benefits over modern trends of sealing up the ground with dense paving. Concrete blocks were used in the 1940's to supplement lawns to make them capable of supporting traffic. Plastic grids, used for the same purpose, were created in the late 1970s and early 1980s.

A pavement is any surface built to bear traffic. The pavements most commonly used today are asphalt and concrete. These are known as "dense" or impervious pavements, because they allow very little air or water to pass through them.

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Source: www.ericandjoan.com

Porous Pavement

Pervious concrete was first used after World War II and pervious asphalt was invented not long after. These paving systems were originally developed to address problems with stormwater management, and it was only later that the environmental benefits porous pavements had to offer were realized. Recent innovations have allowed us to see the new potential for porous pavements systems and this is the focus of this course.

Photo by Jan Kellogg

A porous pavement is one which allows water to pass through it to the ground below. In order for a pavement to be classified as porous, enough water must pass through it to significantly impact hydrology, rooting habitat, and other environmental factors.

Source: Northeast Michigan Council of Governments, www.nemcog.org (accessed January 6, 2011)

Porous Pavement

The next section of this presentation identifies the effects that dense, impervious pavements have on water, air, ecosystems, and human welfare, and compares them to the minimal impact that porous pavements have on the same factors.

There are a wide variety of environmental problems associated with dense pavements and as the land area that pavements cover continues to increase, there is a pressing need for alternative paving solutions.

Benefits of Porous Pavement

Dense Pavement: Water Pollution

Pollutants from the atmosphere, vehicles, animal waste, and some paving materials build up on the surface of dense pavements. Rainwater washes these pollutants into surrounding water supplies. Because they cover such a large area, impervious pavements have become the most significant generators of urban runoff and pollution.

Another problem with dense pavements is that they prevent stormwater from regularly replenishing streams and underground aquifers. Runoff from storms sweeps through creeks and rivers in a flood, but when precipitation is light, groundwater and streams shrink. Detention basins are traditionally used to prevent flooding, however, they are not a perfect solution. They are expensive and take up land that could be used for other purposes. Furthermore, detention basins or "ponds" do nothing to improve water quality or replenish groundwater.

Source: www.usatoday.com/news

Dense Pavement: Impact on Urban Forests

An urban forest contributes greatly to the quality of life in a city by replacing carbon dioxide in the air with oxygen, improving air quality by removing sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and particulate matter, cooling the air by shading and transpiring, and reducing both glare and noise.

Since they are impervious, dense pavements have a negative impact on an urban forest. Tress planted in islands surrounded by dense pavement tend to be small and unhealthy since the dense pavements prevent both air and water from reaching trees.

Source: www.trevorhart.co.uk

Porous Pavement: Reduce Water Pollution

Porous pavements, on the other hand reduce pollution and improve urban hydrology by allowing water to seep into the ground on a regular basis. They allow pollutants to seep into the soil where they can degrade naturally instead of contaminating water supplies. Porous pavements replenish ground water and streams, and decrease the risk of flash floods.

Porous flexible gravel paver parking lot.

Dense Pavement: Urban Heat Island Effect

The urban heat island effect occurs when urban or developed land becomes and stays hotter than surrounding rural and undeveloped land.

Sunlight energy is absorbed by rooftops, pavements, structures, and other surfaces and is then converted and released as heat energy into the air. Since the spacing of man-made structures is much more dense in urban areas, more heat is released, causing the outside temperature in a city to be sometimes 6-8 degrees (F) hotter than rural areas.

Gravel surfaces can substantially cool down faster at night time than adjacent dense pavements as seen through this thermographic image. – images reprinted with permission from The National Center of Excellence on SMART Innovations for Urban Climate and Energy (www.asuSMART.org), Arizona State University.

Porous Pavement: Urban Heat Island Mitigation

As mentioned, porous pavements can contribute significantly to tree growth by allowing water and air to reach.

Additionally, porous pavements that include grass or other vegetation in their structure have a significant cooling effect on the environment around them.

Non-living porous pavements may also be cooler than normal asphalt. There is current research being done to determine to what degree this is true.

Reinforced grass pavement area.
World’s Fair Park, Knoxville, TN.

Porous Pavement: Quiet Streets

A typical solution to traffic noise is the construction of expensive noise barriers, usually in the form of thick walls that are not pleasing to the eye. Porous pavements are able to effectively stop noise at the source.

A porous surface absorbs sound energy. It also allows some of the air around a moving tire to be pressed into its pores, reducing air pressure and consequently producing noise that is both lower in loudness and pitch. Also, because porous pavement absorbs water, it decreases the splashing noise of tires driving across wet roads.

Delineated houlder parking on plastic grass porous pavement

Porous Pavement: Safe Driving

In addition to being less noisy, dry surfaces are also safer. Porous pavements absorb water from the surface, making it less likely that cars will hydroplane or slip on wet pavement. Porous pavements improve visibility in wet conditions and help improve traffic flow during rainstorms.

Porous Pavement: Costs & Regulations

Porous pavements are initially more expensive than dense pavements, however, they can reduce overall costs by performing necessary stormwater functions that would otherwise require additional pipes, reservoirs, fees, and land. Additionally, some porous pavements last longer than their dense counterparts, helping to save on repair costs over the long term. The life cycle cost of porous paving systems is also reduced because there is no need to re-pave after several years, such as it is for asphalt.

Many municipalities have imposed restrictions on new developments to ensure they have effective stormwater management systems, limited impervious coverage, and that they contribute to tree growth. Porous pavements can help developers meet these restrictions.

Grass porous pavement on the Pentagon Remote Delivery Facility (RDF), Arlington, VA

Porous Pavement: Aesthetics

Porous pavements merge natural environmental processes with urban infrastructure. This unique combination can result in startlingly beautiful urban spaces.

Porous pavements have been used in unique and creative ways to create parking lots that look more like parks, a forested amphitheater, or an elegant boardwalk that provides access to a fragile marshland. Their ability to combine functionality and aesthetics make porous pavements a useful tool for designing urban landscapes.

Grass porous pavement reinforced pedestrian area
The Lincoln Hill Club, Lincoln, CA

Porous Pavement: Preserving Eco-Systems

Porous paving systems can be used to create roads and walkways without disturbing a site's ecological equilibrium.

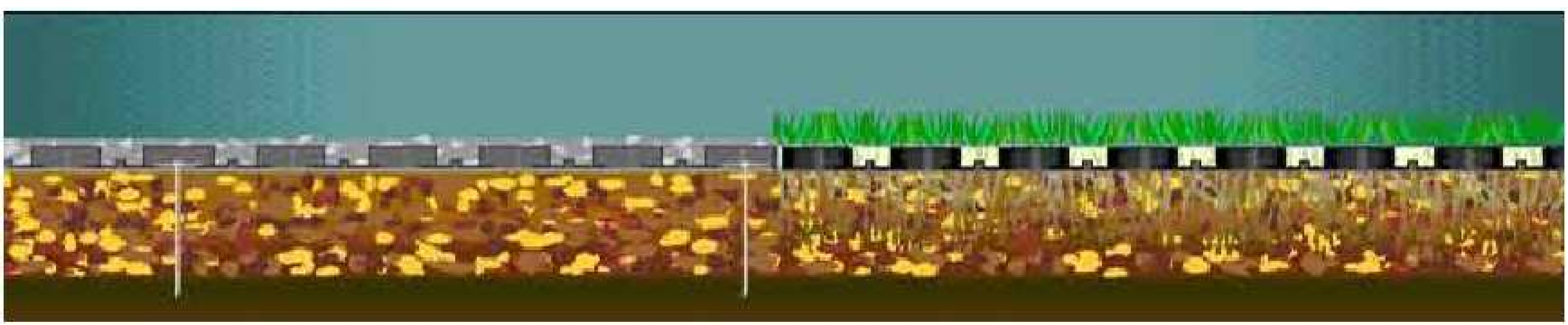
Compared to a porous paving system, stormwater runoff from a non-porous paving system has a higher flow velocity and temperature which can harm ecosystems downstream. A road made from porous asphalt is slightly more intrusive, but it also negates the need for curbs, gutters, drainage systems and other additions that may disrupt an area's ecosystem.

Types of Porous Paving Systems

Layers

Almost all pavements are made up of layers, also known as courses.

- Surface
  This course or top layer must be durable enough to withstand traffic making it relatively expensive compared to the rest of the pavement structure.
- Base
  This course extends the thickness of the pavement and is made up of less expensive material.
- Subgrade
  The soil below the base course.



Aggregate

Aggregate refers to a mass of crushed stone, such as gravel, crushed brick, or decomposed granite. To be permeable, the stones must all be the same size. Single size or "open graded" aggregate has 30 to 40 percent void space, making it extremely permeable to air or water. It is an inexpensive paving material used in almost all porous paving systems as a base course, but it can be used alone. It is often used in areas with low traffic such as residential driveways, infrequently used parking lots, and pedestrian walkways.

The main limitation of aggregate is that it can be lost or displaced, and unbound aggregate surfaces must be maintained with regular raking. When snowplowing the surface, a roller should be attached to the snowplow to prevent it from displacing the aggregate. In addition, traffic may grind down the pieces into a fine dust that clogs the pores of the pavement. Whether lost, displaced, or ground down, the aggregate will eventually need to be replaced. Finally, weeds can be controlled with herbicide.

Porous Turf

An un-reinforced turf surface can be designed to carry light traffic, since excessive traffic flow will damage the grass and compact the soil. Concrete or plastic can be used to reinforce the turf, but these methods can sometimes lead to an uneven walking surface. Sandy soil that resists compaction should be used. Certain species of grass are more resilient than others.

A turf pavement requires the same maintenance as a normal lawn. The better the maintenance, the more attractive the turf will be. Usual maintenance can include irrigation, mowing, fertilizer, aeration, reseeding, disease and insect control, weeding and traffic control.

In addition to its high permeability, a turf pavement offers environmental benefits; it absorbs carbon dioxide and emits oxygen and it actively cools the air around it.

Plastic Geocells

Plastic geocell structures can be used to support or stabilize a surface layer, keeping gravel or soil in place.

Essentially the same maintenance should be used for plastic geocells as for loose aggregate and turf pavements. Loose aggregate should be raked back into the geocells and for larger surfaces, a machine can be used to level the pavement.

Geocells with turf should be regularly maintained through watering, mowing, and fertilizing along with additional maintenance as required.

Paving Blocks & Paving Grids

Paving blocks

A porous paving system can be created by laying blocks of concrete, brick, or stone side by side to form a sturdy pavement. This system will be porous if the blocks are spaced widely enough. However, one disadvantage to this system is that after a number of years the aggregate in between the blocks can become clogged and crusted over. At this point, removing the top layer of aggregate and replacing it with fresh material can increase the permeability of the pavement. In addition, paving block pavements can be vulnerable to deep frost or swelling soil.

Paving grids

An alternate method to create a porous paving system is to use concrete grids filled with aggregate or grass. Maintenance guidelines for either grass or aggregate, depending on which one the grid is filled with, should be followed. Care should be taken when mowing grass since wheeled mowers may be difficult to maneuver across the grid; whip-style mowers tend to be easier to use on this paving system.

Porous Concrete

Made of open-graded aggregate and Portland cement, porous concrete has the ability to form a structure with wider pores than conventional concrete. Commonly used for driveways, walkways, and moderate traffic load areas, it can be expensive, but it may last longer than dense concrete. However, swelling soil will cause it to crack, and it has not yet been determined if porous concrete can be used in cold climates, although treatments such as air entrainment and polymer fiber reinforcing could improve its resistance to freezing.

If porous concrete becomes clogged with sand or other debris, it can be cleaned using a pressure washer and following with sweeping.

Porous Asphalt

Made of open-graded aggregate bound together by a bituminous asphalt binder, porous asphalt has a similar structure to that of porous concrete. This system is useful for draining excess water from highways, reducing the risk of hydroplaning, and improving visibility.

To maintain porosity, seal coats should never be used on porous asphalt. Porous asphalt roads that become clogged due to sanding in the winter should be vacuumed or swept to restore the pavement to its original permeability. However, it should be done before the pavement is completely clogged. When it is time to replace porous asphalt, the old material can be recycled and reused. Recycled porous asphalt is just as permeable as new porous asphalt.

Soft Porous Surfacing & Decks

Soft porous surfacing

Soft porous surfacing materials include chipped wood, crop by-products, engineered wood fiber, mollusk shells, and granular recycled rubber. Highly porous, yet inexpensive, these materials can bear a surprising amount of traffic and require relatively little energy to install. They are best suited for parks, gardens, trails, and low-traffic parking areas. A thick layer of mulch underneath the pavement can help to prevent weeds. Using new mulch can rob nitrogen from the soil, but placing a layer of older mulch between the new mulch and the soil can solve this problem.

Decks

A deck is considered a porous paving system if the spaces between the slats allows water to pass through it into the ground and if the desk is built slightly above the soil, not on it. This protects the soil underneath the deck from compaction. Decks are best suited as pedestrian walkways, sitting areas, and bridges. They can be highly permeable and are aesthetically pleasing.

Flexible Plastic Porous Pavers

Flexible plastic porous pavers are lattice-like, open celled structures that hold aggregate or turf to create grass or gravel porous pavements. Their structure prevents the displacement or compaction of the aggregate and turf, and since they are flexible, they can be used in environments where the soil swells and freezes.

Flexible plastic porous pavers are often made from recycled plastic and the plastic walls do not interfere with the permeability of the paving system.

The next section provides more information on the features, benefits, and installation methods of flexible plastic porous pavers.

Market Creek Plaza, San Diego, CA

Technology Comparison

Porous paving type	Traffic speeds	Traffic volume	Life span (years)	Maintenance	Cold climate performance	Acceptable loads	Infiltration rate	Biormediation
Flexible plastic porous pavers - grass	Low	Moderate	60	Low	Excellent	Heavy	Excellent	Excellent
Flexible plastic porous pavers - gravel	Low	Unlimited	25	Low	Excellent	Heavy	Excellent	Good
Decks	Low	Light	Varies	High	Excellent	Pedestrian	NA	NA
Soft porous surfaces	Very low	Light	10	High	Excellent	Light automobile	Excellent	Good
Turf unsupported	Low	Light	Varies	Moderate	Excellent	Light automobile	Good	Excellent
Open jointed paving blocks	Moderate	Unlimited	30	Very low	Moderate	Heavy	Low to moderate	Fair
Open celled paving grids	Moderate	Moderate to unlimited	20-25	Low	Moderate	Heavy	Moderate	Good
Pervious asphalt	All	Unlimited	15	High	Moderate	Heavy	Moderate	Fair
Pervious concrete	All	Unlimited	20-25	High	Low to moderate	Heavy	Moderate	Fair

Flexible Plastic Porous Pavers

Introduction

A flexible plastic porous paver is a permeable, sub-surface reinforcement structure that supports areas of grass and gravel. The plastic structure consists of a series of rings (cylinders) connected on a flexible grid system. The cylinders are engineered to withstand significant structural loads, and the grids provide stability, flexibility, and continuity over large areas. The ring and grid structure is 92 percent void allowing for the healthiest root zone for grass, or space for various types of gravel.

This section discusses the features, design considerations, and installation of grass and gravel porous paving systems. The layers and system components of grass and gravel porous paving systems are proprietary to each individual manufacturer, please consult individual manufacturers for specific system details.

Grass Porous Pavement

A grass porous pavement consists of the following:

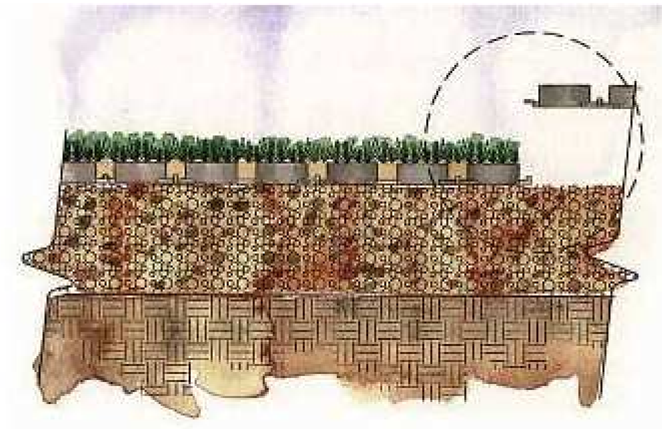
- a compacted sandy, gravel base course placed above subgrade
- a layer of a fertilizer and soil amendment combination
- a flexible, plastic grid structure filled with and
- a top layer that is thin cut sod, washed sod, or seeded.

System Components: Grass Porous Pavement

Base course

The base course is usually the same depth as that required for two inches of asphalt, plus the one inch required for the plastic grid structure. The composition of the base course is usually a mixture of clean sharp sand and ¾ inch minus gravel, or as outlined in a manufacturer's specifications.

The base should allow enough void space for water to percolate and grass roots to grow. If a material is used that will seal tight once compacted (such as limestone,) a 30% mixture of sand must be added to create the required void space.



System Components: Grass Porous Pavement

Soil amendment and fertilizer

The purpose of the soil amendment and fertilizer layer is to help the top grass layer root, and supply water and nutrients to the porous paving system. The components of this mixture are non-toxic, pH neutral, and are very slow to bio-degrade. It is organic, anionic, and not affected by minerals and salts in soils or waters. Plants roots penetrate the expanded components and remove the moisture and nutrients as needed, responding with rapid growth and more healthy vegetation. The water absorbing properties last the life span of the grass porous paving system and the fertilization lasts from 6 to 12 months. Contact individual manufacturers for details regarding formulations and application rates.

The benefits of using this layer include:

- less frequent irrigation, saving water, labor, and operation costs of irrigation equipment
- reduced sod transplanting shock and healthy soil chemistry
- more moisture retained in sandy soils
- greater porosity for heavy clay soils
- quick establishment of new plants, and
- greater utilization of fertilizer applications.

System Components: Grass Porous Pavement

<u>Flexible, plastic grid</u>

The flexible, plastic, sub-surface reinforcement structure comes in rolls which make it easy to cut and install. The individual rings are one inch deep and two inches in diameter. The plastic is a 100% pre-consumer recycled HDPE plastic resin, with minimum 3% carbon black concentrate added for UV protection.

The grid is rolled into place on top of the soil amendment layer, and is then backfilled with one inch of sand. Unlike rigid plastic porous pavers which must be cut with a saw, laid down one at a time, and snapped together, the flexible, plastic grid is rolled out and the grass locks the product together once the roots are established.

Why Sand in the Root Zone?

Sand root zones provide grass and grass porous paving systems with the essential elements for 100% grass coverage. Organic soil root zones cannot match the drainage ability, the ability to supply oxygen, and the compressive strength and stability of sand.

Sand drains extremely well under all weather conditions. Soil drainage quality diminishes under varying weather conditions and consequently, turf quality suffers. To prevent respiration deficiencies in the grass plant, oxygen levels in the soil air must be maintained at levels 50 percent or greater than oxygen levels in the atmosphere. Soil root zones in porous paving cannot provide essential oxygen mechanically or naturally, sand must be used. Prevention of high levels of carbon dioxide (CO_2) in the root zone occurs naturally in sand. Maintaining low (proper) CO_2 levels helps to ensure a quality plant.

Porous sand root zones provide a natural and extremely efficient oxygen supply. This is beneficial since mechanical aerators cannot be used on porous paving systems – damage to the plastic may occur, jeopardizing the integrity of the system.

System Components: Grass Porous Pavement

Top, grass course

The tops of the rings of the grid should be showing before turf, a grass species that is deep rooting and hardy, is laid. Large rakes or brooms can be used to evenly distribute the sand. In addition, on warm days, the sand should be wet to lower the sand temperature and provide moisture for the grass roots.

Turf can be laid over the rings, or seeding and hydromuclching is acceptable at this stage. The sod should contain very little soil since it may compact and kill the grass with use. A sod that has been washed, cut thin (1/2 inch), or grown in sand or sandy loam is acceptable. Using a heavy roller, the sod should be rolled to eliminate air pockets and to ensure the roots are in contact with the sand. The lawn should be watered according to climatic requirements. A regular lawn mower can be used for maintenance – there is no need to aerate.

Installation: Grass Porous Pavement

Proper installation is the critical difference between a successful porous pavement and a failing one. Flexible, plastic porous pavers are quick and easy to install, although it is very important to choose contractors who have previous experience with porous pavements and a comprehensive understanding of how they differ from conventional pavements.

Prepare compact base course

Apply soil amendment mixture

Roll out flexible, grid

Installation: Grass Porous Pavement

Fill rings with clean sharp sand

Lay sod or seed with mulch

Roll sod with heavy roller

Ready for use after two mowing cycles

Use regular mower – do not aerate

Applications: Grass Porous Pavement

Grass porous paving systems are used for:

- fire lanes
- overflow, stadium and event parking
- church parking
- grass "green" residential and commercial driveways
- utility access routes
- on-street parking - grass shoulders
- pedestrian walkways and "cow paths"
- handicap Parking
- emergency access
- infiltration basin reinforcement
- golf cart paths
- erosion control
- helicopter landing pads, and
- airplane transport areas.

Colorado Springs, CO

Biltmore Hotel, Coral Gables, FL

Denver, CO

Houston, TX

Gravel Porous Pavement

A gravel porous pavement consists of the following:

- a compacted sandy, gravel base course placed above subgrade (same as for grass)
- a geotextile fabric injection molded to a flexible, plastic grid structure, and
- a top layer of aggregate fill.

System Components: Gravel Porous Pavement

Fabric, ring, and grid

The flexible, plastic, sub-surface reinforcement structure comes in rolls which make it easy to cut and install. The individual rings are one inch deep and two inches in diameter. It is he molded onto a nonwoven, polyester filter fabric that acts as a barrier, thus creating a dust, weed, and pot hole free porous gravel parking/walking/riding area.

This system is specifically designed for aggregate containment porous paving. The cylinders displace the load onto an engineered base course and hold the decorative gravel in place. The fabric keeps the top-dress gravel from compacting into the road base.

Depending on the manufacturer, the flexible, plastic grid and fabric may be available in different colors, or custom matched, to blend with the aggregate fill.

System Components: Gravel Porous Pavement

Aggregate fill

One inch (compacted) of gravel fill that is clean washed, sharp, hard, angular, and 3/8" to 3/16" uniform, is required. Some examples are shown below. Gravel should be as free of fines as possible. To maintain porosity, soft stone materials with low durability that will break easily should be avoided.

Other possible fill materials include ground rubber, crushed glass, and crushed brick. Cement binders are commonly used. Thermoset binders may be cost prohibitive for some projects but they do offer unique design opportunities.

Examples of aggregate fill (from left to right): crushed granite 3/16", decomposed granite 3/8", hard limestone 3/8", carbon canyon 5/16", sanora tan 3/8", sharp angular pea gravel

Recycled glass

Installation: Gravel Porous Pavement


Prepare compact base course


Unroll paver, connect and cut as needed


Secure base with connectors


Pour and level aggregate fill

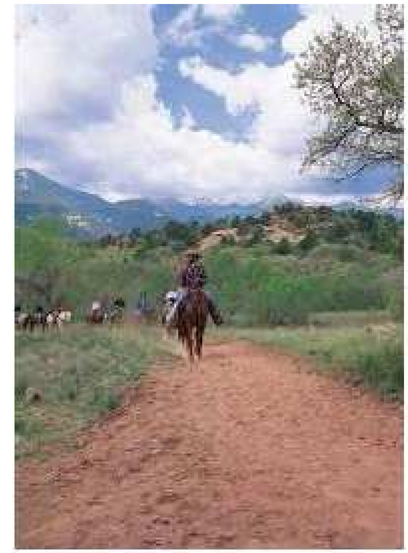

Use and maintain

Applications: Gravel Porous Pavement

Gravel porous paving systems are used for:

- all parking aisles and bays
- handicap parking spaces
- automobile and truck storage yards
- all service and access drives
- loading dock areas
- trails for multiple uses
- boat ramps
- outdoor bulk storage areas
- infiltration basins, and
- high-use pedestrian areas.

Oakdale Nature Reserve, IL



Colorado Springs, CO

Flagstaff, AZ

Vancouver, BC

Vancouver, BC

Design Advantages & Considerations

Support and strength

Even, empty flexible, plastic porous pavers (as described in this presentation) will support 2,100 psi (12,470 Kpa) – well over the 120 psi highest truck tire pressure allowed on public highways. This is a safety factor of 17 times. When the grass paver is filled with sand for part of the root zone medium, the strength increases to 5,700 psi (39,273 kPa). The safety factor then increases from 17 to 47 times. The heavier a vehicle, the more axles and tires it needs to support the load being carried.

Grass and gravel porous paving systems meet and exceed all loading criteria. Some vehicle loading examples include:

- auto tires: 40 psi
- truck tires: 110 psi
- DC-10 tires: 250 psi
- F-16 tires: 350 psi
- fire truck with outriggers: 78psi

Design Advantages & Considerations

Aesthetics

Flexible plastic porous pavers can deliver a beautiful surface and add a unique look to a site. Space constraints can be dealt with by combining the beauty of grass or gravel with the utility of paving.

Trees and other vegetation not only survive, they thrive. Garden paths, greenhouse aisles, sidewalks, park paths, and wilderness trails which use flexible plastic porous pavers a stable surface for strollers, bicycles, wheelchairs, and horses. There are no puddles or mud, and traction is very good. Tree roots break up hard surface sidewalks, but the flexible pavers flex to accommodate such shifts and gradient changes. Plus, with the high proportion of air, roots are discouraged from moving upward. Trails can resist the destructive forces of mountain bikes, allowing trails to be reopened regular bikes.

Design Advantages & Considerations

ADA Information

The Americans with Disabilities Act, www.ada.gov, requires that all public playgrounds be made accessible to over 43 million disabled Americans.

Flexible plastic porous pavers for grass and gravel are a cost effective solution to complying with ADA maneuverability and stabilizer requirements for a firm, safe surface.

A wheelchair accessible surface at the Pentagon Memorial, Arlington, VA

Design Advantages & Considerations

Delineation and marking

Depending on the flexible plastic porous paver product, traffic frequency, aesthetics, and function, various methods in delineation, marking, and striping are used to separate handicapped parking spaces, regular parking spaces, and fire lane routes etc. These include using:

- embedded bricks, railroad ties, or raised concrete strips
- painting (gravel only)
- pavement markers
- bumper stops
- rocks and other durable landscape material
- bushes, shrubs, or ground cover, and
- landscape lighting.

Design Advantages & Considerations

Maintenance and operation

Flexible plastic porous pavers for grass and gravel require very little maintenance when installed correctly.

The areas of a gravel installation that are the most frequently trafficked may require attention as gravel works its way out of the rings. Maintenance can be done easily by brooming the gravel back into place or by adding a small amount of stone, if necessary. The systems should only require attention once or twice a year.

A grass installation needs to be irrigated and fed in the same manner as a normal lawn. Aerating is nor advised since the process will damage the paving system.

By following a manufacturers recommendations, it is possible to plow a grass and a gravel porous pavement on a regular basis.

Green Building and Sustainable Design

Flexible, plastic porous pavers for grass and gravel process stormwater naturally, prevent erosion and soil migration, clean water of contaminants, provide for reuse of rainwater, or recharging rainwater to natural aquifers. Cool Communities programs can be realized by cool grass and gravel parking lots and more trees and thriving vegetation in parking lots. Greater vegetation allows for more absorption of carbon dioxide and production of oxygen while reducing reflection and absorption of solar heat energy.

Porous paving systems improve health and safety conditions for building employees and the general public. ADA compliant surfaces provide everyone with access to buildings and natural areas while enhancing the environment, with no damage to precious resources or wildlife.

In addition, flexible, plastic porous pavers meet the sustainability design requirements of many of today's green certification building programs.

U.S. Green Building Council

The U.S. Green Building Council (USGBC) is a 501(c)(3) non profit organization composed of leaders from every sector of the building industry working to promote buildings and communities that are environmentally responsible, profitable and healthy places to live and work. USGBC developed the LEED (Leadership in Energy and Environmental Design) green building certification program, the nationally accepted benchmark for the design, construction, and operation of high performance green buildings.

For detailed information about the council, their principles and programs, please visit www.usgbc.org.

LEED® Green Building Certification Program

The LEED® green building certification program is a point-based system where points are awarded for actions taken during design, construction, and use phases to reduce the impact a project and its construction will have on the environment and natural resources. The program has five main categories (Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, and Indoor Environmental Quality), and two additional categories (Innovation and Design Process and Regional Priority) for actions not specifically addressed in the five main categories.

LEED credit requirements cover the performance of materials in aggregate, not the performance of individual products or brands. Therefore, products that meet the LEED performance criteria can only contribute toward earning points needed for LEED certification; they cannot earn points individually toward LEED certification.

LEED Credits

Consult individual manufacturers for specific information about LEED programs and relevant credits, but as listed here, installation of a porous paving system which utilizes flexible, plastic porous pavers may help a building project satisfy the requirements of earning LEED credits in the following categories:

Minimum Project Requirements (MPR)

MPR #1 - Must comply with environmental laws

Sustainable Sites (SS)

SS Credit 2: Development Density and Community Connectivity
SS Credit 5.1: Site Development – Protect or Restore Habitat
SS Credit 5.2: Site Development – Maximize Open Space
SS Credit 6.1: Stormwater Design – Quantity Control
SS Credit 6.2: Stormwater Design – Quality Control
SS Credit 7.1: Heat Island Effect – Nonroof
SS Credit 7.2: Heat Island Effect – Roof

Materials and Resources (MR)

MR Credit 4: Recycled Content
MR Credit 5: Regional Materials

Case Studies

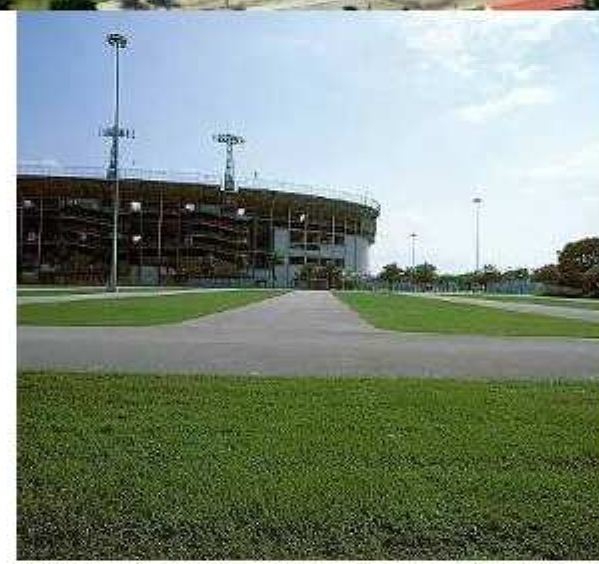
Case Study #1 – Orange Bowl Stadium

Project: Orange Bowl Stadium
Location: Miami, FL
Application: Parking lot
Project size: 24,260m2 (261,141 sq.ft.)
Product: Grass porous pavement
Install date: August 1995 and 1996

In 1995, the city of Miami was looking to build more parking spaces for its Orange Bowl Stadium. However, the stadium is located in a residential neighborhood and the residents advocated against covering a large area with asphalt. They said they would prefer the new parking lot to have the appearance of open space. Furthermore, the sewers in the area have a limited capacity and may not have been able to handle the extra runoff flowing from the new parking lot. Because of these concerns, the city decided to go with a grassy surface for the new parking lot.

Case Study #1 – Orange Bowl Stadium

The 1,745 parking spaces in the lot are paved with flexible plastic porous turf which is made up of one-inch-high rings. A base of thin, flexible ribs supports the rings. The flexible plastic cells have thin walls, which allow turf to be embedded into them. The driving lanes are paved with dense asphalt. Surface runoff from the asphalt drains onto the turf, where it is absorbed and treated.



On game days, the traffic on the parking lot is intense, with both vehicles and pedestrians moving across it all day. However, between game days, there is little to no traffic in the lot. In 2001, the grass in the lot was still in excellent condition. The grass is regularly maintained by same staff who care for the turf inside the stadium. The design and maintenance of the site have produced a very attractive parking lot. Neighbors think of the area as open space instead of as a parking lot.

Case Study #2 - Reliant Stadium & Astrodome

Project: Reliant Stadium and Astrodome (Reliant Park)
Location: Houston, TX
Application: Parking Lot and Stormwater Mitigation, Truck Access
Project size: 30,800 m^2 (317,000 sq ft) Grass Porous Pavement and
800 m^2 (8,600 sq ft) of Terra Cotta Gravel Porous Pavement
Product: Grass Porous Pavement and Gravel Porous Pavement
Install date: May 2002

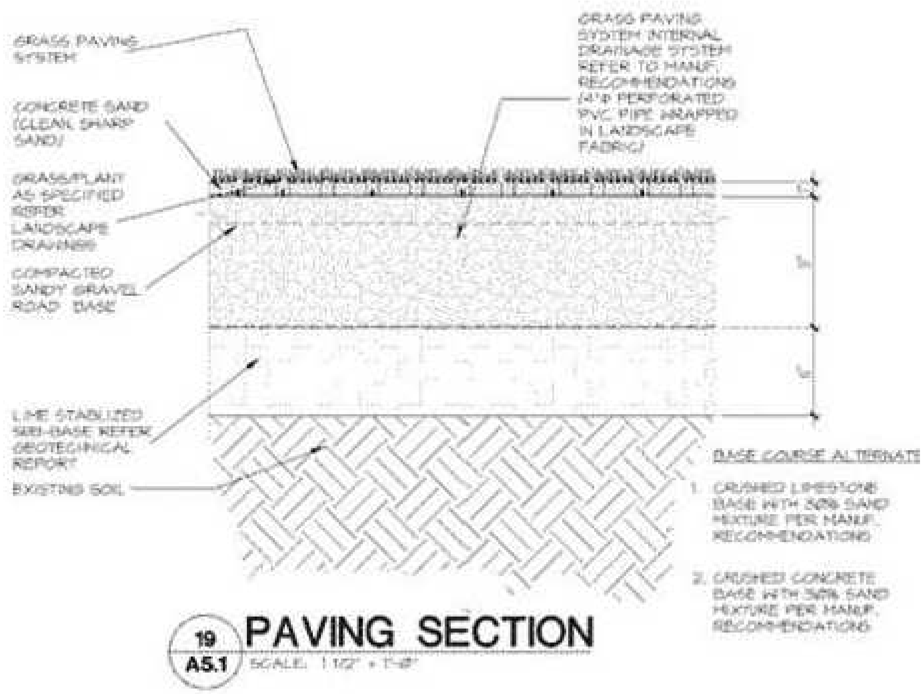
The area surrounding the old Astrodome had less than one acre of green space and was a sea of hot Texas asphalt. The designers of the new Reliant Stadium chose a grass porous pavement to help with the "Greening of Reliant Park."

Case Study #2 - Reliant Stadium & Astrodome

The seven acres of grass porous pavement installed is, presently, the largest engineered grass-porous paving system in the world, and an integral part of the thirty acre green park setting. The cooler site provides the area with nearly three more months of use for public and private festivals, and conventions, events formerly avoided because of the extremely high surface temperatures of Texas asphalt.

Case Study #2 - Reliant Stadium & Astrodome

As part of the "Greening of Reliant Park," 800 square meters of terra cotta gravel pavement was installed close to the Astrodome to be used as an emergency and truck access route. The cross section for this plan varied slightly from the normal grass porous pavement system technical specifications, since the system would be dealing with a tremendous amount of water. The grass pavement system is also a bioswale for much of the hard surface pavement.



Case Study #3 – Pentagon Building

Project: Pentagon RDF and Pentagon Building- LEED 2.0 Certified
Location: Arlington, VA
Application: Helicopter Landing Pad
Project size: 2040 m2 (22,000 sq ft)
Product: Grass Porous Pavement
Install date: July 2003

The Pentagon RDF is the largest green roof east of the Mississippi. The landscape architects needed to keep as much of the landscaped look as possible. Grass porous pavement was selected as a green alternative for the helicopter landing pads since it has a high compressive strength (5,721 psi), more than adequate to land a helicopter (other installations have seen jet aircraft driving over the system). The four grass porous pavement heliports (and one concrete) replace the heliports moved for security reasons because of the terrorist attacks of September 11, 2001.

Case Study #3 – Pentagon Building

The Pentagon RDF is a LEED Certified project. The grass porous paving system

contributed to the certification process with its 100% recycled content, stormwater benefits, and heat island mitigation.

Before Construction

Summary & Resources

Course Summary

- Dense pavements contribute to the urban heat island effect and prevent stormwater from replenishing streams and underground aquifers. Water runoff is hot and polluted thereby diminishing water quality and inhibiting the growth of trees and other vegetation.

- The environmental benefits of using flexible, plastic porous pavers for grass and gravel include their 100% recycled plastic composition, the reduction of stormwater runoff, urban heat island mitigation, filtration of pollutants, preservation and increase of vegetation and tree growth, prevention of soil erosion and migration, and the capture of airborne dust.

- The economic benefits of using flexible, plastic porous pavers for grass and gravel include their loading bearing strength, multiple-use surface, durability (unlimited traffic use), easy installation, and low maintenance.

- The benefits to humans and wildlife of using flexible, plastic porous pavers for grass and gravel include the preservation of green space, accessible surfaces (ADA compliant), cool surfaces, firelanes and emergency access, and aesthetics.

Resources

- Invisible Structures, Inc., www.invisiblestructures.com (accessed January 14, 2011)
- U.S. Green Building Council, www.usgbc.org (accessed January 14, 2011)
- U.S. Department of Justice, Americans with Disabilities Act, ADA Homepage, www.ada.gov (accessed January 14, 2011)
- Much of the information in this presentation is from the book *Porous Pavements*, by Bruce K. Ferguson, published in 2005 by the Taylor and Francis Group. Bruce Ferguson is an expert in environmental management of urban watersheds, having worked in the field for 25 years. He is a professor of landscape architecture and the Director of the School of Environmental Design at the University of Georgia. He has also written two other widely referenced books on stormwater management, *Stormwater Infiltration*, published in 1994, and *Introduction to Stormwater,* published in 1998.