PERMEABLE PAVING

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Permeable paving is a method of paving vehicle and pedestrian pathways that allows for infiltration of fluids. In pavement design the base is the top portion of the roadway that pedestrians or vehicles come into contact with. The media used for the base of permeable paving may be porous, to allow for fluids to flow through it, or nonporous media that are spaced so that fluid may flow in between the gaps. In addition to reducing surface runoff, permeable paving can trap suspended solids therefore filtering pollutants from storm water. Examples include roads, paths, and parking lots that are subject to light vehicular traffic, such as cycle paths, service or emergency access lanes, road and airport shoulders, and residential sidewalks and driveways. Although some porous paving materials appear nearly indistinguishable from nonporous materials, their environmental effects are qualitatively different. Whether it is pervious concrete, porous asphalt, paving stones or concrete or plastic-based pavers, all these permeable paving systems allow storm water to percolate and infiltrate the surface areas, bypassing the traditionally impervious materials traditionally impervious materials to the soil below. The goal is to control storm water at the source, reduce runoff and improve water quality by filtering pollutants in the substrata layers.

Applications

Permeable solutions can be based on: porous asphalt and concrete surfaces, concrete pavers (permeable interlocking concrete paving systems – PICP), or polymer-based grass pavers, grids and geocells. Porous pavements and concrete pavers (actually the voids in-between them) enable storm water to drain through a stone base layer for on-site infiltration and filtering. Polymer based grass grid or cellular paver systems provide load bearing reinforcement for unpaved surfaces of gravel or turf.

Grass pavers, plastic turf reinforcing grids (PTRG), and geocells (cellular confinement systems) are honeycombed 3D grid-cellular systems, made of thin-walled HDPE plastic or other polymer alloys. These provide grass reinforcement, ground stabilization and gravel retention. The 3D structure reinforces infill and transfers vertical loads from the surface, distributing them over a wider area. Selection of the type of cellular grid depends to an extent on the surface material, traffic and loads. The cellular grids are installed on a prepared base layer of open-graded stone (higher void spacing) or engineered stone (stronger). The surface layer may be compacted gravel or topsoil seeded with grass and fertilizer. In addition to load support, the cellular grid reduces compaction of the soil to maintain permeability, while the roots improve permeability due to their root channels.

In new suburban growth, porous pavements protect watersheds by delaying and filtering the surge flow. In existing built-up areas and towns, redevelopment and reconstruction are opportunities to implement storm water, water management practices. Permeable paving is an important component in Low Impact Development (LID), a process for land development in the United States that attempts to minimize impacts on water quality and the similar concept of sustainable drainage systems (SuDS) in the United Kingdom.

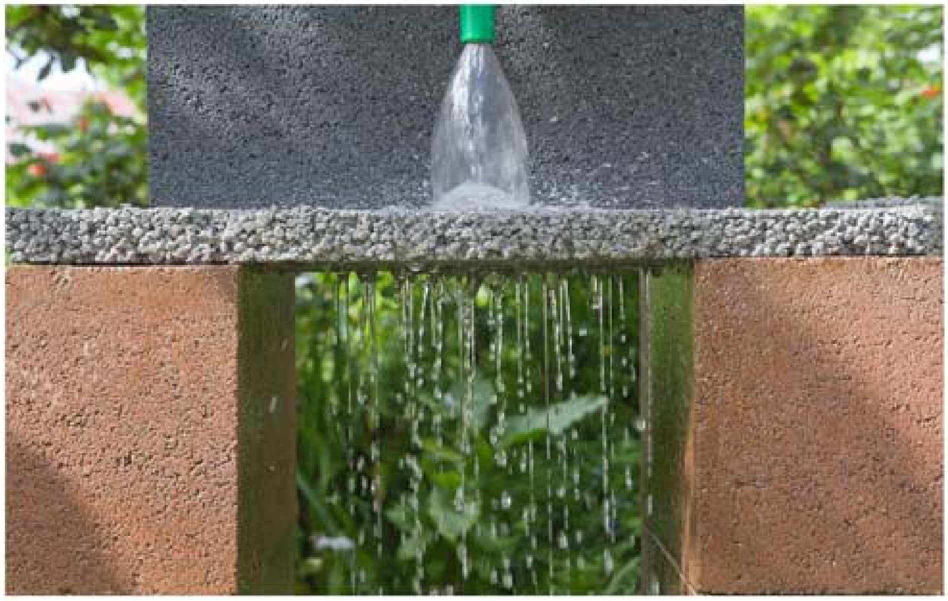
The infiltration capacity of the native soil is a key design consideration for determining the depth of base rock for storm water storage or for whether an under drain system is needed.

Advantages

Managing runoff
Permeable paving surfaces have been demonstrated as effective in managing runoff from paved surfaces. Large volumes of urban runoff causes serious erosion and siltation in surface water bodies. Permeable pavers provide a solid ground surface, strong enough to take heavy loads, like large vehicles, while at the same time they allow water to filter through the surface and reach the underlying soils, mimicking natural ground absorption. They can reduce downstream flooding and stream bank erosion, and maintain base flows in rivers to keep ecosystems self-sustaining. Permeable pavers also combat erosion that occurs when grass is dry or dead, by replacing grassed areas in suburban and residential environments.

Controlling pollutants
Permeable paving surfaces keep the pollutants in place in the soil or other material underlying the roadway, and allow water seepage to groundwater recharge while preventing the stream erosion problems. They capture the heavy metals that fall on them, preventing them from washing downstream and accumulating inadvertently in the environment. In the void spaces, naturally occurring micro-organisms digest car oils, leaving little but carbon dioxide and water. Rainwater infiltration is usually less than that of an impervious pavement with a separate storm water management facility somewhere downstream. In areas where infiltration is not possible due to unsuitable soil conditions permeable pavements are used in the attenuation mode where water is retained in the pavement and slowly released to surface water systems between storm events.

Trees
Permeable pavements may give urban trees the rooting space they need to grow to full size. A "structural-soil" pavement base combines structural aggregate with soil; a porous surface admits vital air and water to the rooting zone. This integrates healthy ecology and thriving cities, with the living tree canopy above, the city's traffic on the ground, and living tree roots below. The benefits of permeable on urban tree growth have not been conclusively demonstrated and many researchers have observed tree growth is not increased if construction practices compact materials before permeable pavements are installed.



Disadvantages

Runoff volumes
Permeable pavements are designed to replace Effective Impervious Areas (EIAs), not to manage storm water from other impervious surfaces on site. Use of this technique must be part of an overall on site management system for storm water, and is not a replacement for other techniques. During large storm event, the water table below the porous pavement can rise to a higher level, preventing the precipitation from being absorbed into the ground. Some additional water is stored in the open graded / crushed drain rock base, and remains until the sub grade can absorb the water.

For clay-based soils, or other low to 'non'-draining soils, it is important to increase the depth of the crushed drain rock base to allow additional capacity for the water as it waits to be infiltrated.

The best way to prevent this problem is to understand the soil infiltration rate, and design the pavement and base depths to meet the volume of water. Or, allow for adequate rain water runoff at the pavement design stage.

Pollutant load
Runoff across some land uses may become contaminated, where pollutant concentrations exceed those t ypically found in storm water. These "hot spots" include commercial plant nurseries, recycling facilities, fueling stations, industrial storage, marinas, some outdoor loading facilities, public works yards, hazardous materials generators (if containers are exposed to rainfall), vehicle service and maintenance areas, and vehicle and equipment washing and steam cleaning facilities. Since porous pavement is an infiltration practice, it should not be applied at storm water hot spots due to the potential for groundwater contamination.

All contaminated runoff should be prevented from entering municipal storm drain systems by using best management practices (BMPs) for the specific industry or activity.

Weight and traffic volumes
Reference sources differ on whether low or medium traffic volumes and weights are appropriate for porous pavements. For example, around truck loading docks and areas of high commercial traffic, porous pavement is sometimes cited as being inappropriate. However, given the variability of products available, the growing number of existing installations in North America and targeted research by both manufacturers and user agencies, the range of accepted applications seems to be expanding. Some concrete paver companies have developed products specifically for industrial applications. Working examples exist at fire halls, busy retail complex parking lots, and on public and private roads, including intersections in parts of North America with quite severe winter conditions.

Siting
Permeable pavements may not be appropriate when land surrounding or draining into the pavement exceeds a 20 percent slope, where pavement is down slope from buildings or where foundations have piped drainage at their footers. The key is to ensure that drainage from other parts of a site is intercepted and dealt with separately rather than being directed onto permeable surfaces.

Climate
Cold climates may present special challenges. Road salt contains chlorides that could migrate through the porous pavement into groundwater. Snow plow blades could catch block edges and damage surfaces. Sand cannot be used for snow and ice control on porous surfaces because it will plug the pores and reduce permeability. Although there are design modifications to reduce the risks, infiltrating runoff may freeze below the pavement, causing frost heave. Another issue is spalling damage. Spalling damage exclusively occurs on porous concrete pavement from salt application during the winter season. Thus porous paving is suggested for warmer climates. However, other materials have proven to be effective, even lowering winter maintenance costs by preserving salt in the pavement itself. This also reduces the amount of storm water runoff that is contaminated with salt chlorides. Porous pavement designed to reduce frost heave and spalling damage has been used successfully in Norway.

Furthermore, experience suggests that preventative measures with rapid drainage below porous surfaces be taken in order to increase the rate of snow melt above ground.

Cost
Some estimates put the cost of permeable paving at two to three times that of conventional asphalt paving. Using permeable paving, however, can reduce the cost of providing larger or more storm water BMPs on site, and these savings should be factored into any cost analysis. In addition, the off-site environmental impact costs of not reducing on-site storm water volumes and pollution have historically been ignored or assigned to other groups (local government parks, public works and environmental restoration budgets, fisheries losses, etc.) The City of Olympia, Washington is studying the use of pervious concrete quite closely and finding that new storm water regulations are making it a viable alternative to storm water.

Longevity and maintenance
Some permeable pavements require frequent maintenance because grit or gravel can block the open pores. This is commonly done by industrial vacuums that suck up all the sediment. If maintenance is not carried out on a regular basis, the porous pavements can begin to function more like impervious surfaces. With more advanced paving systems the levels of maintenance needed can be greatly decreased, elastomerically bound glass pavements requires less maintenance than regular concrete paving as the glass bound pavement has 50% more void space.

Plastic grid systems, if selected and installed correctly, are becoming more and more popular with local government maintenance personnel owing to the reduction in maintenance efforts: reduced gravel migration and weed suppression in public park settings.

Some permeable paving products are prone to damage from misuse, such as drivers who tear up patches of plastic & gravel grid systems by "joy riding" on remote parking lots at night. The damage is not difficult to repair but can look unsightly in the meantime. Grass pavers require supplemental watering in the first year to establish the vegetation; otherwise they may need to be re-seeded. Regional climate also means that most grass applications will go dormant during the dry season. While brown vegetation is only a matter of aesthetics, it can influence public support for this type of permeable paving.

A traditional permeable concrete paving brick tend to lose their color in relatively short time which can be costly to replace or clean and is mainly due to the problem of efflorescence.

Efflorescence
Efflorescence is a hardened crystalline deposit of salts, principally calcium carbonates, which migrate from the center of concrete or masonry materials to the surface, where they form insoluble deposits that harden on the surface. Efflorescence usually appears white, gray or black depending on the region.

Over time, efflorescence begins to degrade the overall appearance of masonry/concrete and may →

cause the surfaces to become slippery when exposed to moisture. If left unchecked, this efflorescence will harden whereby the calcium/lime deposits begin to affect the integrity of the cementations surface by slowly eroding away the cement paste and aggregate. In some cases it will also discolor stained or coated surfaces. Efflorescence forms more quickly in areas that are exposed to excessive amounts of moisture, such as near pool decks, spas, and fountains or where irrigation runoff is present.

The affected regions become very slick when wet. This can be of serious concern especially as a public safety issue to individuals, principals and property owners by exposing them to possible injury and increased general liability claims.

Efflorescence remover chemicals can be used to remove calcium/lime build-up without damaging the integrity of the paving surface.

Types of Permeable Pavement

Installation of porous pavements is no more difficult than that of dense pavements, but has different specifications and procedures which must be strictly adhered to. Nine different families of porous paving materials present distinctive advantages and disadvantages for specific applications. Here are examples:

Pervious concrete
Pervious concrete is widely available, can bear frequent traffic, and is universally accessible. Pervious concrete quality depends on the installer's knowledge and experience.

Plastic grids
Plastic grids allow for a 100% porous system using structural grid systems for containing and stabilizing either gravel or turf. These grids come in a variety of shapes and sizes depending on use; from pathways to commercial parking lots. These systems have been used readily in Europe for over a decade, but are gaining popularity in North America due to requirements by government for many projects to meet LEED environmental building standards. Plastic grid system is also popular with homeowners due to their lower cost to install, ease of installation, and versatility. The ideal design for this type of grid system is a closed cell system, which prevents gravel/ sand/turf from migrating laterally.

Porous asphalt
Porous asphalt is produced and placed using the same methods as conventional asphalt concrete; it differs in that fine (small) aggregates are omitted from the asphalt mixture. The remaining large, single-sized aggregate particles leave open voids that give the material its porosity and permeability. To ensure pavement strength, fiber may be added to the mix or a polymer-modified asphalt binder may be used. Generally, porous asphalt pavements are designed with a subsurface reservoir that holds water that passes through the pavement, allowing it to evaporate and/or percolate slowly into the surround soils.

Open-graded friction courses (OGFC) are a porous asphalt surface course used on highways to improve driving safety by removing water from the surface. Unlike a full-depth porous asphalt pavement, OGFCs do not drain water to the base of a pavement. Instead, they allow water to infiltrate the top 3/4 to 1.5 inch of the pavement and then drain out to the side of the roadway. This can improve the friction characteristics of the road and reducing road spray.

Single-sized aggregate
without any binder, e.g. loose gravel, stone-chippings, is another alternative. Although it can only be safely used in walkways and very low-speed, low-traffic settings, e.g. car-parks and drives, its potential cumulative area is great.

Porous turf
If properly constructed, Porous turf can be used for occasional parking like that at churches and stadia. Plastic turf reinforcing grids can be used to support the increased load. Living turf transpires water, actively counteracting the "heat island" with what appears to be a green open lawn.

Permeable interlocking concrete pavements

Permeable interlocking concrete pavements are concrete units with open, permeable spaces between the units. They give an architectural appearance, and can bear both light and heavy traffic, particularly interlocking concrete pavers, excepting high-volume or high-speed roads. Some products are polymer-coated and have an entirely porous face.

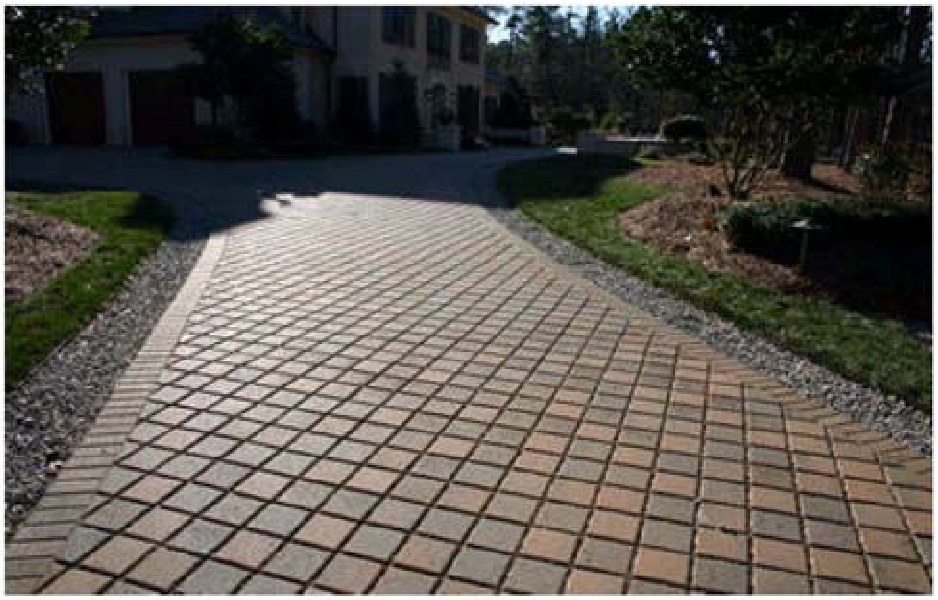
Permeable clay brick pavements

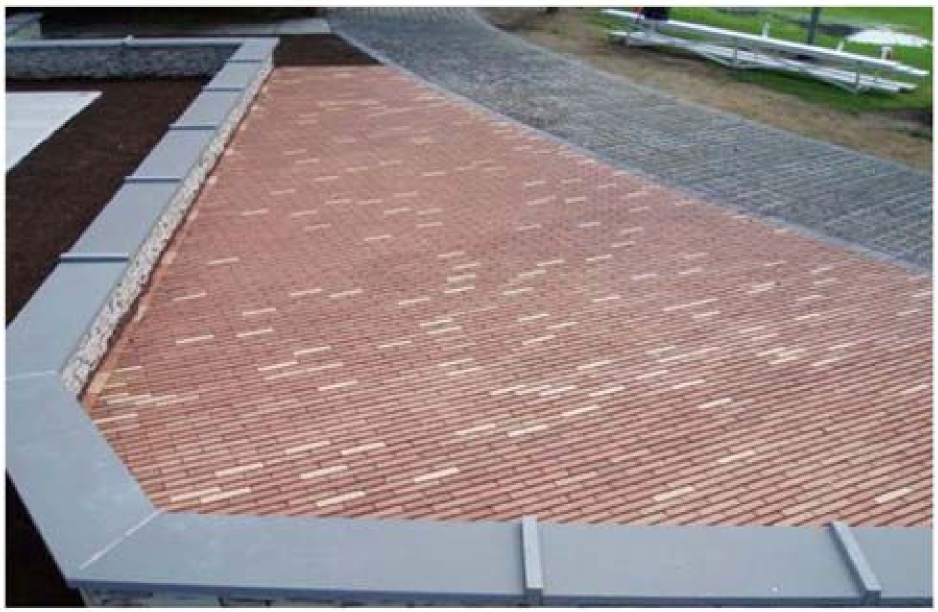
Permeable clay brick pavements are fired clay brick units with open, permeable spaces between the units. Clay pavers provide a durable surface that allows storm water runoff to permeate through the joints.

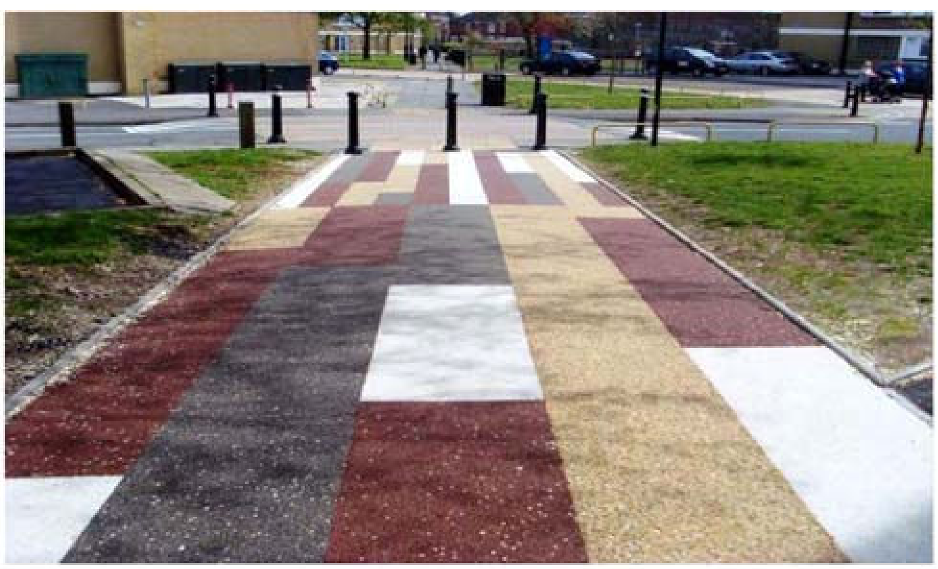
Resin bound paving is a mixture of resin binder and aggregate. Clear resin is used to fully coat each aggregate particle before laying. Enough resin is used to allow each aggregate particle to adhere to one another and to the base yet leave voids for water to permeate through. Resin bound paving provides a strong and durable surface that is suitable for pedestrian and vehicular traffic in applications such as pathways, driveways, car parks and access roads.

Bound recycled glass porous Pavement

Elastomerically bound recycled glass porous pavement consisting of bonding processed post-consumer glass with a mixture of resins, pigments, granite and binding agents. Approximately 75 percent of glass in the U.S. is disposed in landfills.







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Bottom image: Bound recycled glass porous Pavement courtesy of theartofdesignmagazine.com