Green Pavement

Llewellyn van Wyk

Principal Researcher

CSIR Built Environment

Introduction

Infrastructure is one of the key foundations of economic growth. South African cities have grown on the back of infrastructure investments like water, energy, transportation and increasingly telecommunications. Ultimately infrastructure investment should lead to improved quality of life.

However the scale of infrastructure maintenance and the backlog of infrastructure needs have made infrastructure investment and maintenance a real challenge for local authorities. As result, infrastructure standards are decreasing almost everywhere in the world. A new development paradigm has to be drafted that seeks to reduce infrastructure resource consumption during construction, operation and maintenance.

Green infrastructure is the new development paradigm. Green infrastructure combines the economic benefits of traditional ‘gray’ investment with the associated environmental and social benefits of the ‘green’ approach. For example, a traditional street is paved to enhance its transportation function, but is paved with porous or permeable pavement that also captures storm water, thereby reducing the load on the storm water system and reducing both construction and maintenance costs. A green roof adopts the same strategy to roofing.

Green infrastructure is therefore a term that is used to describe many types of environmentally friendly designs. The common denominator is a design component that “conserves natural ecosystem values and functions and provides associated benefits to human populations with a distinct economic value” (Benedict and McMahon 2001).

The basic features of green infrastructure can be subdivided into two groups (Economy League 2009):

- Green elements: porous pavement, green roofs, green buildings (housing stock, infrastructure addressing climate change/energy use), trees, trails, renewable energy, external building elements, wetlands, meadows, pervious and cool surfaces, and urban agriculture;
- Green spaces (integrating green elements): greenways, trails, park systems, wetlands, rain gardens, trees, swales, landscaping, open space, land conservation, storm water management, woodlands, and green streets.

Green storm water runoff management

Dealing with storm water runoff in a green way is the aim of sustainable urban drainage systems (SUDS), or green urban drainage. Conventional storm water management strategies are aimed at removing storm water as quickly as possible and transferring flooding and pollution downstream. However this approach has detrimental impacts on water resources and the wider environment. In developing countries use is often made of open channels instead of pipes with the concomitant associated risks of overflowing and flooding (as is often experienced in South African locations).

Green storm water runoff management mimics nature using man-made elements such as pervious pavement, soakaways, ponds, and gently sloping channels (swales) to attenuate and treat urban runoff (Reed 2004).

According to Reed (2004), in the absence of a managed runoff approach, poor storm water runoff management results in the following problems:

- Small floods damaging roads and buildings, causing disruption to lives and businesses;
- Pollution from overflowing latrines, soakaways and sewers, causing faecal pollution and disease;
- Cross contamination of water supplies;
- Wet soils leading to ideal conditions for worm infections;
- Providing habitats for vectors (mosquitoes and snails);
- Water pollution from diffuse sources (rubbish, animal faeces, air pollutants);
- Erosion of watercourses;
- Siltation of watercourses;
- Inconvenience;
- Safety;
- Landslides.

Reed (2004) argues that the benefits to be derived from the implementation of green storm water runoff management include:

- Better management of the quantity of storm water runoff;
- Ground water recharge;
- Wetland recharge;
- Reduction in flooding;
- Reduction in erosion;
- Increased river baseflows;
- Better management of the quality of runoff;
- Reduction in pollution of surface and groundwater;
- Reduction in siltation;
- Better use of runoff as a resource;
- Rainwater harvesting; and
- Ecological use.

Green pavement, the focus of this chapter, is therefore a sub-set of green storm water runoff management, which is in turn a sub-set of green infrastructure.

Green Pavement – Soft, Hard and Pervious

Soft pavement

Soft pavement is typically a water-permeable material such as loose aggregate which can vary in size, wooden decks, mulch pathways, or paving stones (Mendler and Odell, 2000).

Hard pavement

Hard pavement is also known as impervious surface areas and is typically bitumen and concrete pavements. Brick pavement can also be included as hard pavements although some water can permeate between the joints provided the joints are not caulked.

Pervious or porous pavement

Pervious or porous pavement can be asphalt, concrete (also referred to as porous concrete, permeable concrete, no-fines concrete, gap-graded concrete, and enhanced-porosity concrete), open-celled pavers, reinforced turf, concrete or plastic grids, or stabilised aggregate in light-traffic areas such as emergency-access lanes and overflow parking areas. Pervious or porous pavement is a unique and effective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, pervious or porous pavement is instrumental in reducing storm water runoff and recharging aquifers. In fact, the use of pervious or porous pavement is included in the Best Management Practices (BMPs) recommended by the US Environmental Protection Agency (EPA) for the management of storm water runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis.

Fig 1: One Grid Paving Block

Photo: Llewellyn van Wyk

Pervious or porous pavement has the added benefit of reducing concentrations of contaminated runoff, reducing infiltration, creating ‘heat islands’, reducing vehicle aquaplaning due to reduced ponding, and are aesthetically pleasing.

Case Study

In 2008 a section of porous pavement was laid on the CSIR Innovation Site on its Pretoria Campus (Louw 2008). The purpose of this experimental section was to evaluate the performance of porous concrete over time. The design of the parking area was essentially based on the guidelines as outlined in the CIRIA (C697) 2007 document Technical Paper No 8.

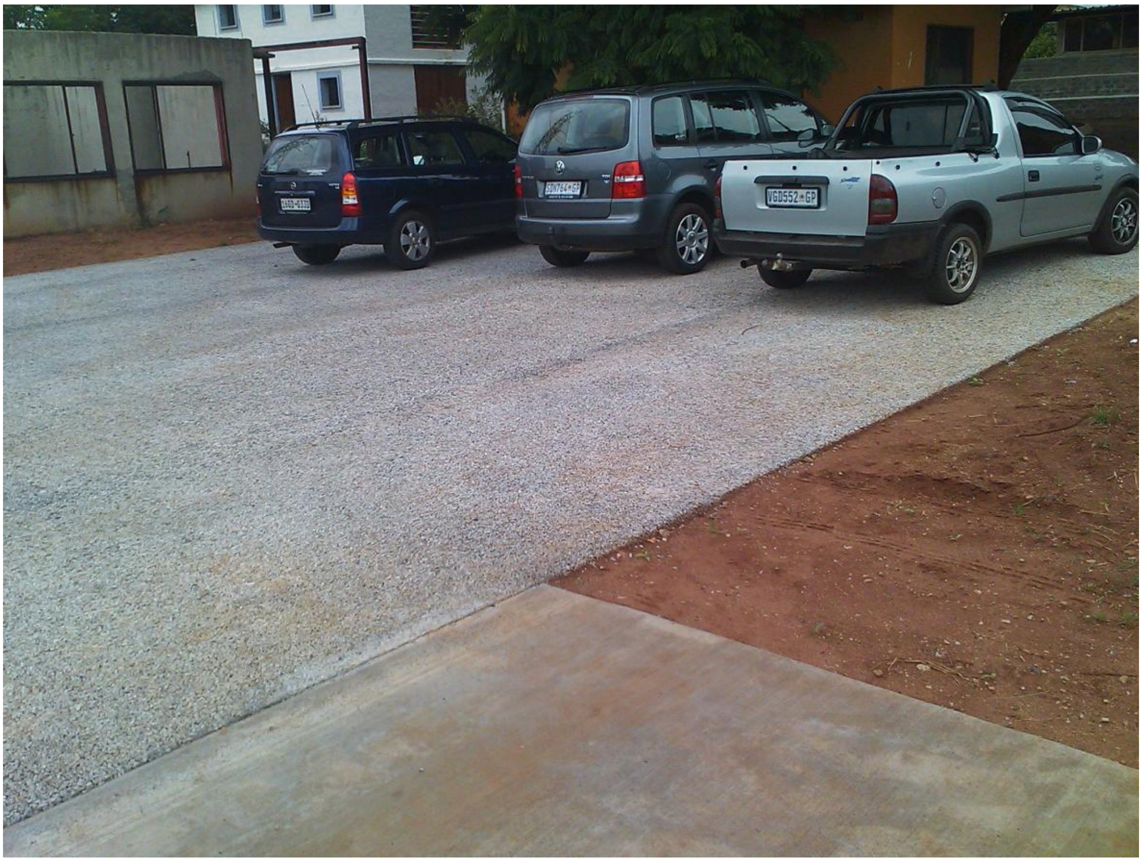

Fig. 2: Porous Concrete Pavement, CSIR Innovation Site, Pretoria
Photo: Llewellyn van Wyk

Composition

The in-situ material consisted of a red slightly plastic loam. The classification was A_2 -4(0), PI = ±2 CBR unstabilised = 40.

The trick was to lightly compact the in-situ material allowing the possibility of seepage not to be impeded or completely obstructed, but sufficiently compacted for constructing the designed layers.

The surface of the sub-grade, as treated above, was covered with a geo fabric (Kaytech U19) material for the following reasons.

a) Stopping the open graded aggregate being pushed into the sub-grade (red soil) and reducing available storage in aggregate layer.

b) The geo fabric also acts as a very sound reinforcing layer, which supports the compaction of the no fines crusher run i.e., there is no surging/undulations developing of the material during compaction process.

The drainage layer consisted of a crusher run aggregate from which the -6,7 material was screened out, leaving material with approx 40% of voids.

150 mm of the screened aggregate was placed and rolled with 2 78 Bomag pedestrian roller (or equivalent). 4 passes was specified but an extra pass or two were required to give a neat finished surface ready to receive the no fines concrete.

No tests were done to establish the void content of the layer. This can affectively be done in a laboratory if a simple apparatus is prepared. The void should equate to ± 33 to 40% of the volume of the aggregate placed which equates to approx 49.5 mm to 60 mm of rain water.

On the compacted crusher run (no fines) layer a no fines concrete was specified having decided to lay the – 13mm no fines concrete and – 9.5 mm no fines concrete. The thickness decided on was 75 mm (changed to 80 mm to suit shutters) using a 200 x 200 x 5.6 mm mesh i.e., (Ref 193 mesh). Further research work can be done on this final layer using a finer grading of aggregate and passing a light spin roller over the surface to obtain a smoother finish.

The smoothness of the final surface of the no fines concrete will no doubt affect the rate of dispersion of the water. The intensity of precipitation will affect the rate of dispersion.

The amount of water that can readily be absorbed according to our calculations is of the order of 75 mm to 90 mm of rain i.e. initially absorbed by the surface and sub-base.

The rate of seepage in the sub-grade was determined on the parking area by three test holes i.e. TP5, TP6 and TP9. and the time take for the water level to drop 25 mm in each hole …. 1894 min, 109,84 min and 34.35 min if 75 mm of rain fell, it would take 3 times, 18.94, 109.84 and 34.35 min to dissipate, (i.e. 56.82 min, 329,53 min, 103,05 min.) below the concrete and sub-base levels.

It must be noted that the sub-grade material on the site is an A_2 -4(0) material, slightly plastic and fairly porous have about 49.2% of voids.

If the water could be used consideration could be given to leading it away to a tank or reservoir. On this particular site the problem was getting rid of the storm water on the site. Normally this approach is particularly applicable to very flat sites, where a flat open drain could be used to lead off the water from the volume of no fine concrete and crusher run sub-base.

With a pervious concrete surface, the problem of the concrete (no-fines) silting up must be guarded against. The problem can be overcome by extensive planting of grass on the surrounding areas which can act as a sand trap.

It is important that the structural support chosen for the pervious pavement not to be greatly affected by moisture penetrating lower pavement layers (Offenberg , 2005).

It is important to not over-compact the sub-grade soils because a key feature of the system is its permeability. The Florida concrete and product association recommends compaction to only 92-96 of the modified proctor maximum density for sandy sub-grades. For silty or clay soils, the level of compaction will depend on the specifics of the pavement design. Care should be taken not to over-compact a soil with swelling potential (Offenberg , 2005).

There are four key elements to the success of a NFC surface (Offenberg , 2005):

- The sub-grade should be uniform and properly compacted;
- The concrete should have the correct amount of mix water;
- The concrete should be compacted and finished without excessive effort; and
- Curing should be performed in a timely manner and of sufficient duration.

Design Specifications (OHIO readymix concrete association , 2007):

- Aggregate:Cement ratio: 4:1 to 5:1
- Concrete mix unit weight: 1680-2080 kg/m^3
- Concrete mix void content: 15-25% (gravimetric air determined)
- Cement content: 297-356 kg/m^3
- Supplementary Cementious: fly ash 25% (max), slag 25% (max) or combined 35% (max)
- Water:Cement ratio: 0.27-0.35

Cautionary note, in some parts of South Africa ground water can be soft or acidic or both; NFC drains are not recommended under such conditions because leaching of calcium hydroxide from the NFC weakens the concrete downstream and leached lime can block outlet pipes and cause an unsightly stain below weep holes (Crosswell , 2001).

Two factors determine the design thickness of NFC (Tennis et al. , Unknown):

- The hydraulic properties, such as permeability, volume of voids; and
- The mechanical properties, such as strength and stiffness.

The hydraulic design considerations

- Rainfall expected;
- Pavement characteristics; and
- Intensity of surface run-off.

When designing a NFC stormwater management system, two conditions must be considered (Tennis et al. , Unknown):

- Permeability; and
- Storage capacity.

The theoretical storage capacity of the NFC is its effective porosity, that portion of the NFC system that can be filled with rain in service. As a general rule, soils with a percolation rate of 12mm/hr are suitable for sub-grade under pervious pavements. In tight, poorly draining soils, lower infiltration rates can be used for design but soils with substantial silt and clay content or high water table should be approached with some caution (Tennis et al. , Unknown).

For design purposes, the total downtime (time until 100% of the storage capacity has been recovered) should be as short as possible and generally should not exceed five days. For structural design purposes the roadbed (sub-grade) soil properties, pervious concrete materials characteristics and traffic loads should be considered. The design of a pervious pavement should normally provide 150-300mm layer of permeable sub-base (Tennis et al. , Unknown).

When bringing water from adjacent areas, ensure that flow of water into the pervious system does not bring sediment and soils that might clog the system. Aggressive chemicals in soils or water, such as acids and sulphates, are a concern to conventional concrete and pervious concrete alike, the open structure of pervious concrete may make it more susceptible to attack over a large area (Tennis et al. , Unknown).

The anticipated traffic carried by the pervious pavement can be characterised by equivalent 1800lb single axel loads (ADT). Flexural strength of pervious concrete may be subject to high variability, therefore, it is common to measure compressive strength and to use an empirical relationship to establish flexural strength for use in design (Tennis et al. , Unknown).

The South Africa literature recommends that NFC not be used as a surfacing due to low strength while the international literature suggests the complete opposite. It may be that the South African tests were undertaken sometime ago and much progress has been made since. Either way, new tests should be conducted to ensure that the strengths achieved internationally can be achieved in South Africa with local material and conditions.

Maintenance

The service life of NFC pavement system is highly dependent on clogging, which can be correlated to the ratio of permeable to impermeable catchment area. Research has shown that adoption of a maintenance regime that includes sweeping and/or vacuuming will keep the pavement effective over its service life (*Permeable Concrete Pavements.* , 2004).

During service, high pressure machine washing and vacuuming of in-situ pavements is recommended; this form of maintenance restores 80-90% of pavement void capacity (*Permeable Concrete Pavements*, 2004).

Conclusion

Green pavements are aimed primarily at supporting alternative storm water runoff management strategies, i.e., the water is not collected and discharged at some distant point, but managed on site. To this end green pavement facilitates the ingress of water into the soil through the pavement either through open joints or through porous materials.

The decision on what material to use will be influenced by the nature of the application, i.e., pathway, parking area, or road (with its different rate of traffic volumes).

Aggregates can and have been used with great success throughout South Africa for pathways and roads. Permeable paving (pavers with open joints or open grid blocks) can be used in most applications.

Although porous concrete is being used fairly extensively in the US, its use in South Africa is minimal. More experimental work is needed to develop a rational design for its various applications. However, in areas of light traffic volumes porous pavement can make significant contribution to reducing the volume of storm water discharged to the municipal storm water system.

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