Do Water Problems Exist in Our Minds?

John Harrison from TecEco thinks the solution is to change the way we think about the problem

Author Biography

Aubrey John Weston Harrison (he prefers to be called John Harrison) has degrees in science and economics and is a member of many organisations. Apart from running a large accountancy/consulting practice (John Harrison Accountants) he has had experience as a geologist (exploration and minerals separation) and in engineering and has been responsible for a number of innovations including the tech tendon method of pre stressing. John is managing director and chairman of TecEco Pty. Ltd. and best known around the world for the invention of Tec, Eco and Enviro-Cements which have attracted significant global interest because of their improved sustainability and potential to provide significant sequestration. John is an authority on earth systems science and sustainable materials for the built environment and was the founder of the Association for the Advancement of Sustainable Materials in Construction and is their current chair. He has been the keynote speaker at many conferences and recently co-chaired the successful SMB2007 conference. John is committed to finding ways of profitably reversing damaging materials and underlying molecular flows. In recent times he has concentrated on the research and development of Gaia engineering including TecEco Cement and kiln technologies. John is also very excited about the potential of pervious pavements to solve our water crises.

Introduction

Einstein said “We can't solve problems by using the same kind of thinking we used when we created them." Pervious Pavements are a different way of thinking about roads and an essential part of the solution to global urban water supplies.

Even though the climate over the last 10,000 years had been relatively mild and predictable compared with the many millions of years previously when Chaos ruled the earth, during this period we have been systematically destroying our climate, our aquifers and our land. The sequence: deforestation, agriculture, irrigation, salinity and aridity has all too often been repeated in too many places for two many years. It is plain to see that our failure to live harmoniously with nature and understand the natural water cycle cannot continue. We must change the way with think to solve the problem.

In years gone by forests and grassland covered most of our planet. When it rained much of the water naturally percolated though leaf litter and natural mulches that performed vital functions of slowing down evaporation and the rate of transport to rivers and streams, purifying and replenishing natural aquifers rather than polluting and adding salts to it. Our legacy has been to plough and pave this natural landscape with two major consequences - pollution and salinity.

Given global water shortages, the salinity poisoning our land, pollution, the cost of handling the volume and rate of flow of runoff we need to change our practices so as to mimic the way it was for so many millions of years before we started making so many changes.

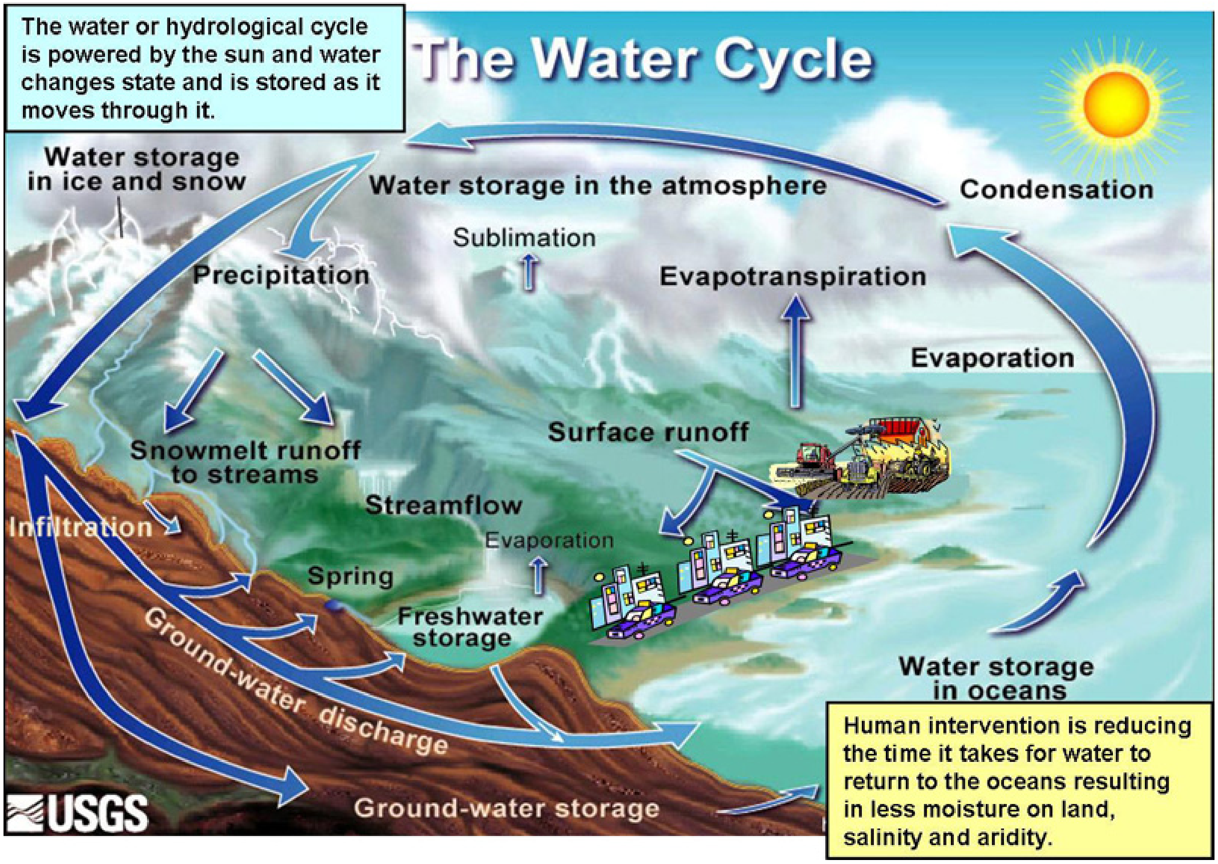

Figure 1 - The Water Cycle. Source USGS web site.

The water or hydrological cycle is powered by the sun and water changes state and is stored as it moves through it. Human intervention is altering this process and reducing the time it takes for water to return to the oceans resulting in less moisture on land, salinity and aridity.

The key to survival in the future will be learning from nature and mimicking her subtle ways. This article focuses on how our urban and agricultural practices have interrupted the water cycle, explains how roads have become our higher level drainage system and the many deficiencies in their current design. It offers the radical TecEco permecocrete pervious pavement solution.

Engineers have for years not understood the environmental consequences of our road networks in relation to which there are urgent water shortage, hydrological and environment quality preservation issues. Roads are not only surfaces for our cars to run, they perform many other functions including setting the drainage pattern for an area, carrying sewerage, water and electricity under them, influencing the climate and defining zones for wildlife. Road are the arteries, veins and lymphatic system to cities.

Mikhail Gorbachev, former President of the USSR and 1990 Winner of the Nobel Peace Prize said “Water, like religion & ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People write, sing & dance about it. People fight over it and all people, everywhere & everyday need it.” Many wars have been fought over water and when polluted it can cause disease. 1 in 5 people do not have access to clean water. Water covers 70% of the planet, yet only 1% is drinkable. 1/3 of the world’s population are stressed by the lack of it and by 2025 due to global warming this may be 2/3. It seems obvious to me that we must as a matter of urgency de-couple fresh water that falls from heaven and salt and pollution to address these issues. Yet we design roads to mix rainwater with pollution and it becomes storm water and irrigate and farm in such a way that poisoning of our land by salinity is inevitable. Gorbachev went on to say “Fortunately we have a history of meeting great challenges using imagination and out irrepressible capacity to adapt, and thousands of talented people around the world are already mobilised to the cause of preserving water for future generations. Just as we are moved by water, we must now move in order to save it.”

Pervious pavements are a major part of the answer to this challenge. Pervious pavements can decouple rainwater from pollution. Pervious pavement cleanses water then it is captured and enters storage for our use or is allowed to flows into our aquifers streams and rivers. Properly designed pervious pavements have permeable sub structures and both have significant internal surface area allowing the combined effects of oxygenation and bacterial action to cleanse water. Clean water is drinking water and a fundamental requirement for life. As global warming is severely impacting on water supplies around the world it is essential we start considering the widespread implementation of pervious pavement 'biofilters' and storage.

There are also engineering advantages. Pervious pavements reduce and control the rate of water flow decreasing the cost of drainage infrastructure and coastal pollution and the overloading of our existing drainage system. Other engineering advantages include improved vehicle and pedestrian safety, reduced maintenance of buildings due to seasonal ground movement and reduced costs of watering street trees.

We have a water crisis in Australia. This is the driest inhabited continent in the world - only Antarctica gets less rain. Most of Australia has experienced drought under El Nino conditions for the past few years and some major cities are seriously short of water. Yet giga litres of storm water go into our coastal water ways every year carrying with it significant levels of pollution. The water crisis in Australia is not going to be solved doing what he have done the way we have done it in the past. Instead of getting water into a pipe and getting rid of it as soon as possible we need to rethink the paradigm. In this context pervious pavements are a strong candidate for roads and footpath of the future. We also have a salinity problem for which we can only blame ourselves.

Given we are poisoning ourselves with our own wastes, recent climatic events and obvious sea level rises, it is essential we take action. In climax ecologies there is no waste. The solution is to “biomimic” nature using carbon and wastes. What better place to start with than our roads? Natural soils are permeable and cleanse water, so too should our roads be with the added advantage that if also made using eco-cements significant waste utilization and carbon sequestration would also occur.

In this article we introduce TecEco permecocrete made of Eco-Cement and waste aggregate. In pervious pavement this material is capable of sequestering significant amounts of carbon dioxide and reducing waste. In the context of Gaia Engineering or using our Tec-Kiln or both Eco-Cement can be made without emissions. To the extent that roads are made using Eco-Cements in permecocrete pervious pavements significant quantities of carbon dioxide can be sequestered. Tec and Eco-Cements allow greater use of recycled aggregates mainly because of their low alkalinity and excellent durability. Much building waste, currently accounting for some 45% of landfill could therefore be recycled as road aggregate. As a huge volume of materials are used to construct roads, utilization would be significant.

The Current Road Paradigm

Roads are the veins, arteries and lymphatic system of cities. They provide the network for the transport of resources and wastes, drainage, the route for all services, water, sewerage, electricity, gas and telephone etc.

Roads and associated services as they are today have not been thought out. They have evolved. In the past the agencies that are responsible for these networks and services have more or less acted independently of each other resulting in wasted resources and additional cost. How often do you see different crews unsustainably digging up the same bit of road?

The different functional components of roads are installed and maintained by separate departments within councils or by government that have tended to act independently of each other. There is no cohesive thought out approach, no questioning of fundamentals. Worse still there is little or no co-operation between the various parties involved as evidenced by the fact that roads are often torn up and repaired to place one service team only to be torn up again by another days later.

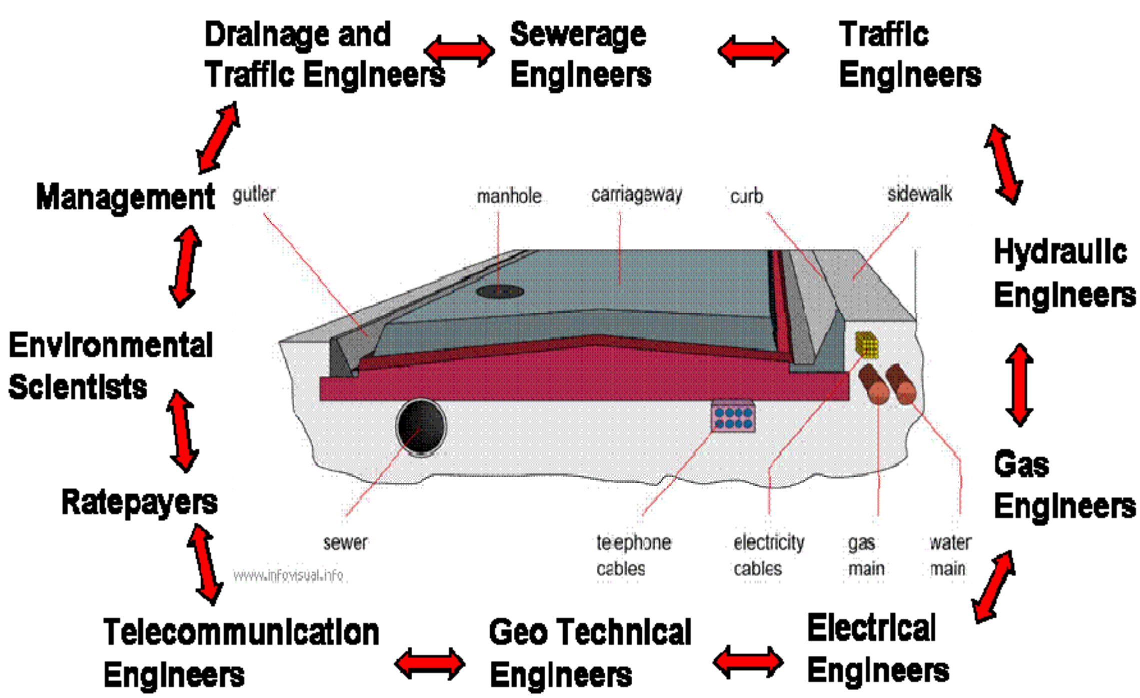

Figure 2 - People Working on Current Road Designs do not Work Together

The engineering paradigm too prevalent amongst the road building fraternity is that “Roads are for vehicles” “water on roads in dangerous” “collect it and get rid of it as quickly as possible.” Others involved with roads disagree. There are as the chief traffic engineer in Hobart, my home town said, sad and happy faces.

Without pervious pavements, reduced drainage areas bring more water into fewer drainage systems at a faster rate, eroding the banks of streams and rivers, and adding more sediment into the water. Researchers have shown that when 10 to 15 percent of an area is covered by impervious surfaces, the increased sediment and chemical pollutants in runoff have a measurable effect on water quality. When 15 percent to 25 percent of a watershed is paved or impervious to drainage, increased runoff leads to reduced oxygen levels and harms stream life. When more than 25 percent of surfaces are paved, many types of macro and micro-organisms in streams die from concentrated runoff and sediments (Smith 2001).

Given the current water crisis can this limited thinking be allowed to continue? Only a small percentage of water reticulated through a community is used for drinking, most is used for washing, laundry, flushing toilets or watering gardens. Perhaps the water caught by our road drainage systems could be used for these purposes. We need to be more holistic in our approach to roads and surely use them to harvest water.

Bio-Mimicking Roads

Originally roads were designed to carry traffic. They collected water on their impervious surfaces and dissected natural water ways so they had to be drained. As we became more “civilized” our streets and roads were all that remained unobstructed and also became the route for the installation of sewer, potable water and other services.

Roads and streets today not only provide surfaces along which vehicles can travel, they drain the land, carry our wastes away in sewers and bring us services like natural gas, electricity and water. The juxtaposition and interaction of these various functions has not been thought out. It has evolved.

In the past civil engineers who build roads have considered water to be a nuisance that increases the danger to traffic and something that must be got rid of in oversized drains as quickly as possible.

Millions of litres of water are captured by roads when it rains and redirected to drains, creeks, rivers and finally the sea with all the cigarette butts and other rubbish that collects on our roads. The affect is serious coastal pollution.

Storm water = Rainwater + Pollution

This rapid drainage of rain requires a high cost of investment in much larger drains than the original natural drainage replaced because water no longer percolates through natural vegetation and obstacles.

Would it not be better to leave the pollution on our streets where we can mechanically deal with it using machine that resemble giant carpet cleaners? Such machines have already been invented and are available for hire.

If we are to live more sustainably it is time we considered a more intelligent approach in relation to what roads do and started using technologies such as pervious pavements that mimic nature and decouple rainwater and pollution. The carriage of traffic is only one function. Australia is a land with critical water shortages in many areas and it is therefore important that we reconsider the role of roads in relation to water. It seems madness to allow millions of gigalitres to just drain away to sea every time it rains. Fresh water could be collected by pervious pavement and used. This paper is about changing the paradigm as to how we design and engineer roads using nature as our mentor[1].

The Pervious Pavement Solution

What is Pervious Pavement?

Figure 3 -Pervious pavement is a unique and effective means of addressing environmental issues. Image source: http://www.perviouspavement.org/

Pervious pavement is a permeable pavement surface with a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil or sub-surface drainage and in the process improves the water quality. Permeable materials such

[1] The term biomimicry was popularised by the book of the same name written by Janine Benyus Biomimicry is a method of solving problems that uses natural processes and systems as a source of knowledge and inspiration. It involves nature as model, measure and mentor. Geomimicry is similar to biomimicry but models geological rather than biological processes. The theory behind biomimicry is that natural processes and systems have evolved over several billion years through a process of research and development commonly referred to as evolution. A reoccurring theme in natural systems is the cyclical flow of matter in such a way that there is no waste of matter and very little of energy. Geomimicry is a natural extension of biomimicry and applies to geological rather than living processes. Pervious pavements mimic nature drainage.

as ancient lime mortars and pervious pavements are made using relatively mono graded materials. In the case of pervious pavement this translates as a lack of "fine" materials. No fines concrete or under asphalted gravel are names for common materials used.

TecEco Eco-Cement Permecocrete Pervious Pavement

Pervious pavements mimic nature. They are pavements with lots of holes in them and with subsurface drainage as required and usually a capacity to store water underneath or in a reservoir. Surface runoff water either soaks into an aquifer in suitable terrain or is captured above an impervious layer and drained preferably to underground storage for further use. Before infiltrating into the subsoil or sub-surface drainage the process improves water quality by providing surface area and aerobic conditions for cleansing.

Pervious pavements allow the earth to breathe, take in water and be healthy. The stone and soil under them acts as a reservoir and they clean the water a little like the filter on a fish tank. They are quieter and safer to drive on as they do not develop "puddles", have a good surface to grip and importantly, in Australia, some parts of the US and many other places in the world subdivisions made with pervious pavement that also have street trees can be several degrees cooler than surrounding suburbs without.

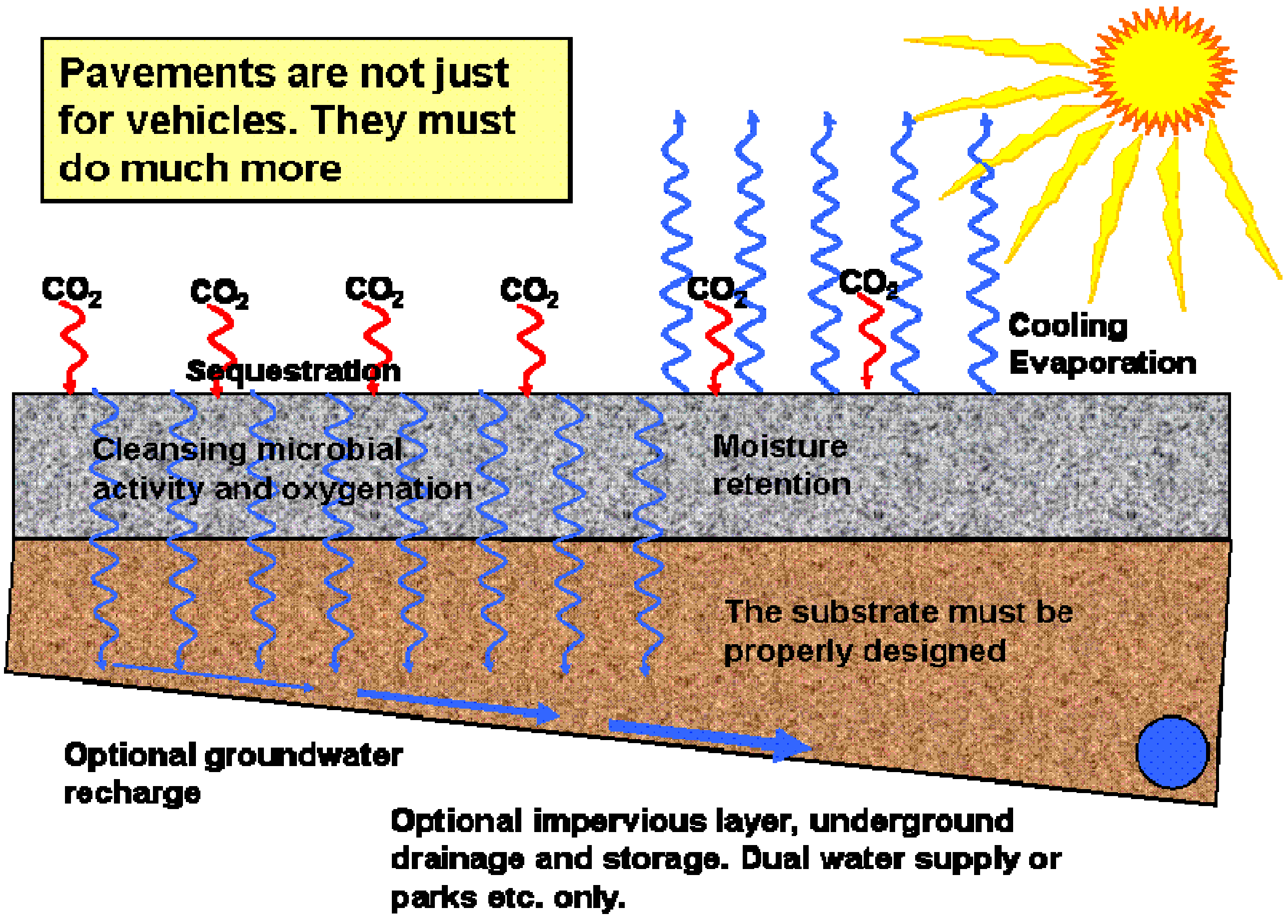

Figure 4 – Theoretical Cross Section of Pervious Pavement

There are many good reasons why councils and road authorities should switch to pervious pavement and the use of pervious pavements as road surfacing materials has grown considerably of the past 15 years thanks to the materials hydraulic and acoustic properties (Pagotto, Legret et al.).

A new and important reason for using pervious pavement that may just convince various authorities to use them is that TecEco Eco-Cement permecocrete will set in them and whereby they would also become a significant carbon sink. With their use several environmental issues would be addressed at once including water quality, replenishment of aquifers, "hot city syndrome" and atmospheric carbon reduction.

Permecocrete concrete pervious pavements are more rigid and potentially more serviceable than pervious asphalt and much more sustainable not being associated with fossil fuels having a lower embodied energy[2]. Asphalts are also carcinogenic[3] and rapidly rising in price now we have passed peak oil. TecEco permecocrete pervious pavements

[2] According to the Centre for Building Performance Research, Victoria University Wellington N. Z. the embodied energy of asphalt pavement is 3.4 MJ/kg whereas for 30 MPa pre-mix concrete is only 1.3 MJ/kg
[3] According to the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program and the City of Austin, the black emulsion sealcoat applied to asphalt pavement has extremely elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) and can significantly affect the quality of downstream water resources. PAHs are known to have adverse health effects on animals, plants and people. Small particles of sealcoat flake off as they are abraded by vehicle tires, and can wash into urban streams with rain and runoff. See http://www.concreteparking.org/Environmental/no%20toxic%20runoff.htm

represent a large scale market for Eco-Cement which sets by absorbing CO_2 as by design they allow the entry of abundant CO_2.

Table 1 - Permecocrete Pervious Pavement Compared to Asphalt

Eco-Cement Pervious Pavement	Asphalt
Set by absorbing CO_2 Can use recycled materials as long as they are hard and mono-graded	Carcenogenic to workers using it. Becoming more expensive as petroleum supplies dwindle.

De-Duplicating Road Design

If we are going to build roads in a new and smarter way then we may as well get it right.

In Australia we run many duplicate services down each side of a road. Given the high cost of installing infrastructure it would be smarter to adopt a system whereby services run down the middle of a road down what amount to giant box culverts. This has been tried in Putra Jaya, the new capital of Malaysia and from all accounts is successful.

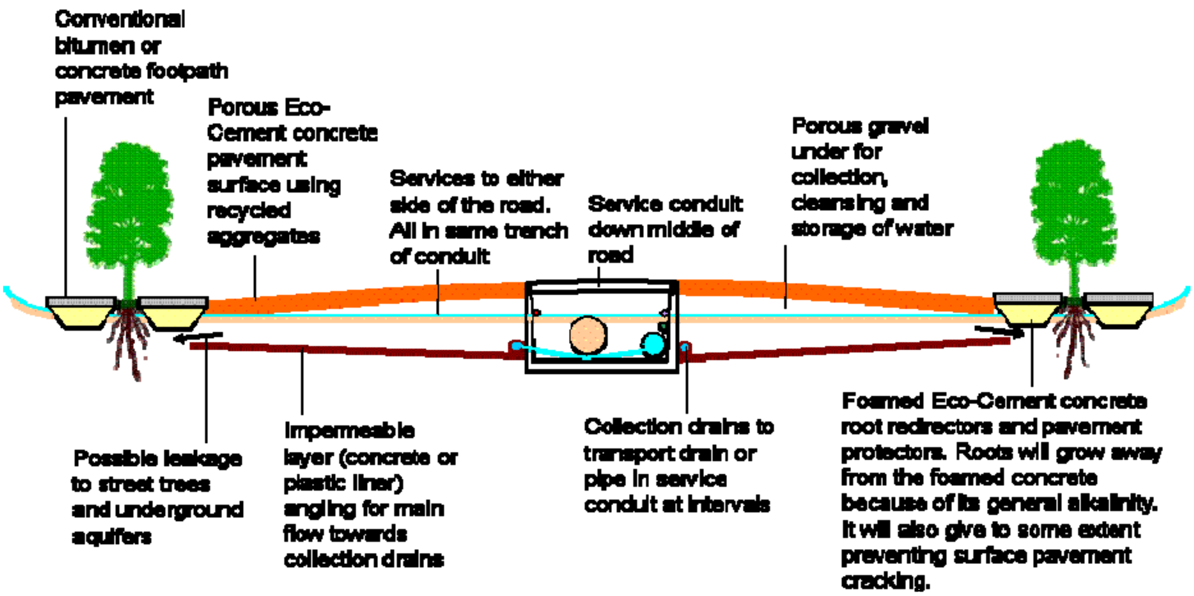

Figure 5 - A Possible Design for a More Holistic Road

Problems such as root push under pavement are like most others in our heads. The TecEco design depicted above prevents unwanted root growth by providing foamed concrete rich in lime too alkaline for growth and able to collapse with local swelling of roots. In our design water is capture before it can flow and pick up pollutants and is then fed to a pipe in the central conduit that goes to storage. It can also be redirected optionally to aquifers or street trees.

Collecting Water Using Pervious Pavement

An unknown but huge quantity of water is drained away to sea taking with it micro and macro polluting substances every time it rains on our cities.

This rapid drainage or rain requires a high cost of investment in much larger drains than the original natural drainage replaced because water no longer percolates through natural vegetation and obstacles. In urban and some agricultural areas water gets to the sea in hours not days! This water could be collected by permeable roads also acting as giant bio filters, subterranean reservoirs and collection and redistribution networks. (the city of Alexandria had huge underground cisterns)

The Water Dynamic

There is a relationship between the speed and volume of water, distance traveled and the pollution it picks up.

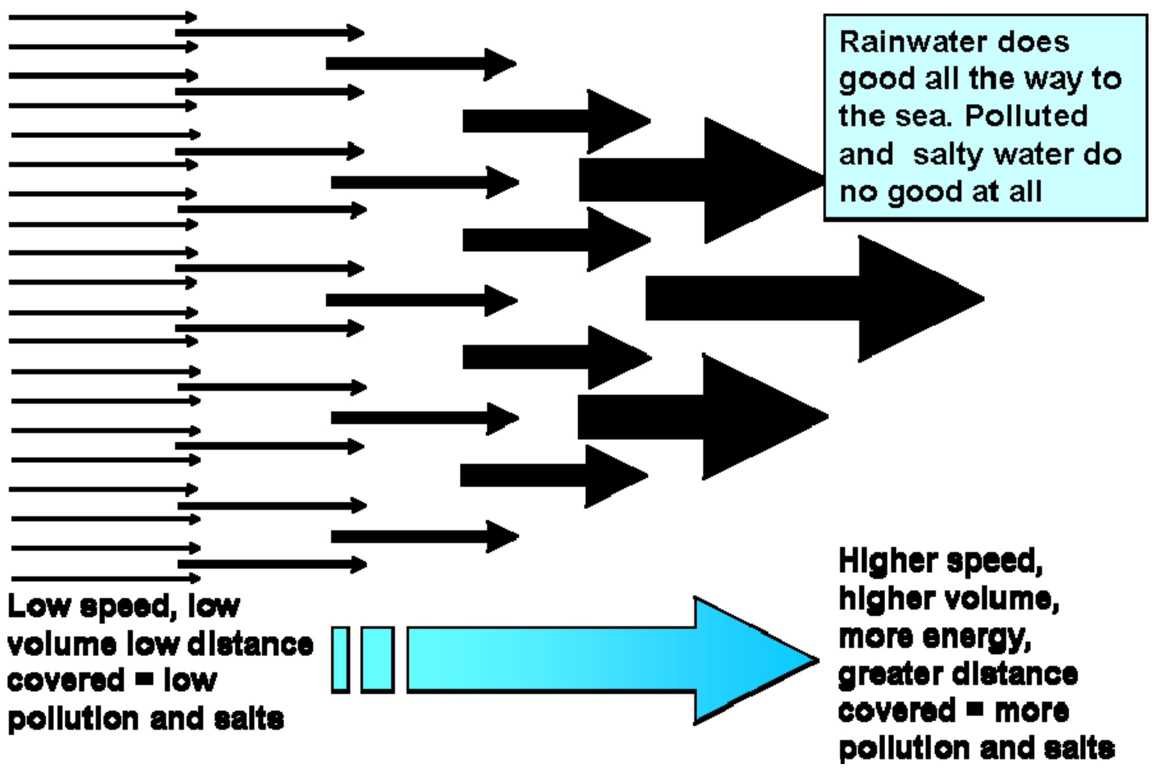

Figure 6 - Relationship between the Speed and Volume of Water and Macro-pollution

Most pollution and salinity issues can be explained in relation to this dynamic.

Types of Pollution

Storm water = Rainwater + Pollution
Salinity = Rainwater + Salts

Given the water crisis – why are we deliberately mixing rainwater with salt and pollution?

Pervious pavements uniquely allow rainwater salt and pollution to be de-coupled providing in situ filtration, cleansing and to some extent storage.

Types of Pollution

Pollution comes from two main sources; point and non-point and is of three main types – macro, micro and molecular. (See Table 1)

Point Source Pollution

Point source pollution is when high levels of pollution enter a water system such as a wetland or river from one source, such as a factory, mine, sewage plant or garbage dump. Point source pollution is easy to trace.

Non-Point Source Pollution

Non-point source pollution is when levels of pollution enter a water system at various points and from various sources. This type of pollution is the most difficult to monitor and manage. The most common non-point source of storm water pollution comes from local residents throughout a catchment.

Table 1 - Types of Pollution. (Adapted from EPA storm water code of practice from www.cwmb.sa.gov.au/kwc/section1/1-24.htm)

Litter Pedestrians dropping food wrappers , cigarette butts etc. Motorists tossing litter from their vehicles. Litter from building sites. Industry packaging and other waste materials. Trucks with uncovered loads which blows onto roads.	Macro
Leaves Deciduous trees drop their leaves in Autumn creating a significant pollution problem in the waterways. Excessive leaves enter the storm water system, choking waterways, reducing sunlight penetration and decomposing, causing nitrate pollution. This can create low oxygen conditions, killing animals.	Macro Micro and Molecular
Sediment Sediment is a major source of pollution in storm water. Excessive sediment chokes creek beds and reduces flow capacity as well as de-grading natural ecosystems by stifling aquatic plants and animals and blocking sunlight. Sources include construction sites, erosion along streams and rivers, soil erosion from poor management of agricultural activities, and road runoff.	Micro
Soaps and detergents Detergent and soaps tend to contain high levels of	Molecular

phosphorus. This chemical is a limiting factor in plant growth. Excessive amounts provide the nutrients required to fuel an algal bloom.	
Oil and grease Enter the storm water system via leaking engines, deliberate dumping and accidental spills. High levels of oil can directly threaten the life of animals in waterways.	Macro and Molecular
Nutrients Enter the storm water system via runoff from parks and farms that use fertiliser, effluent from sewage treatment plants and septic tanks, chemical and fertiliser spills, and rotting vegetation. Nutrients provide fuel for algal blooms which choke waterways, cut off light and hence kill off aquatic ecosystems. Excessive nitrogen is one of the major factors in the die back of sea grass in our rivers.	Molecular
Faecal coli forms Enter the storm water system by contamination with human or animal wastes. The main sources are dogs, horses, septic tanks and farm animals.	Macro Micro and Molecular
Heavy Metals Lead, zinc and copper are the major heavy metals entering the storm water system via roads, and in the case of lead, via exhaust. Elevated levels can cause death and mutation in animal populations.	Molecular

Molecular pollution

Salinity, heavy metal contamination, oils, persistent organics etc. are all examples of molecular pollution

Micro-Pollution

Includes fine silts, powders etc.

Macro Pollution

Beer cans, bottles, plastic bags etc.

Pervious Pavements and Pollution

Storm water is the major cause of reduction in water quality in rivers and the destruction of marine environments.

The reduction in natural cover has brought more water into fewer drains at a faster rate, eroding the banks of streams and rivers, and adding more sediment to the water which increases turbidity. "If you increase an impervious surface near a stream by creating a paved parking lot, for example, you directly affect the quality of life in the stream because of the runoff that surface will generate" (Goetz and Smith 2001).

The solution lies in using pervious pavements which filter water falling on them releasing it slowly to sub-surface drains, aquifers or storage and finally the sea. There is little or no surface run-off to carry rubbish into drains and streams.

How Pervious Pavements Purify Water

Pervious pavements filter water falling on them releasing it slowly to sub-surface drains or aquifers and finally the sea. There is little or now surface run-off to carry rubbish into drains and streams. Water quality is purified by the sub-pavement acting as a giant biofiliter allowing bacteria and oxygen to do their work and because surface rubbish does not contaminate it. Pervious pavements are so good at this we even suggest they should be mandatory in high risk area and pre-inoculated with the right bacteria to deal with the risk in the area on commissioning.

“Pervious pavements reduce pollutant levels and prevent contamination of soils under them” (Legret and Colandini). “Run off water quality is improved, for the main pollutants of run off water: heavy metal loads discharged into the environment are reduced from 20% (Cu) up to 74% (Pb); solids are detained at a rate of 87% and hydrocarbons are intercepted at an even higher rate (90%). It is basically the retention of fine particulate pollution (not subject to settling) by pervious pavement filtration that explains the reduction in the amount of hydrocarbons and metals. Other mechanisms however can also be at work, namely the retention of coarse particulate pollution by filtration and the retention of certain dissolved forms of metals, such as zinc and cadmium, by means of adsorption.” (Pagotto, Legret et al.)

Bacterial action is also important and in effect the sub-pavement under pervious pavements acts as a giant bio filter uncontaminated by surface rubbish. A pervious pavement with integral bacteria will improve water quality entering aquifers, streams and rivers. The critical "first flush" of pollutants is sent rapidly into the cross-section where constantly available sources of bacteria and microbes exist and have sufficient air exchange capability to maintain and allow them to perform their cleaning functions. Pervious pavements could act as both pavements and bio-filters at the same time.

Remediation using Pervious Pavement

Bio remediation involves treating contaminants on site by utilising organisms such as bacteria or fungi that break down chemicals naturally. Other nutrients are also usually added for the decomposing bacteria, most commonly by circulating oxygen and nitrates through the soil. In some cases more efficient bacteria or fungi are added to break down contaminants more quickly

Pervious pavements with appropriate sub surface engineering act like large scale bio filters providing aerobic surface area on which suitable bacteria or fungi can grow and do their work

As an example the ability of some bacteria such as Alcanivorax borkumensis to metabolize oil has been well known for more than a century. All though oil-eating bacteria are not common in unpolluted environments, they are plentiful where there is oil; A. borkumensis makes up as much as 90 percent of microbial populations in oil spills. The challenge in using these bacteria to clean up oil lies in creating the right conditions for them to grow faster and metabolize oil more efficiently. It follows by inoculating pervious substrates with other nutrients that cleanups could be accelerated.

Another example were pervious pavements may be useful is for cleaning up poly cyclic aromatic hydrocarbons (PAH's), again by appropriate inoculation and co-fertilisation.

It would be possible to inoculate pervious pavements in industrial areas with the right kind of bacteria to deal with heavy metals, near abattoirs and dairies and market gardens to deal with nitrogen and phosphorous and so on.

Advantages

- Possibly cheaper than other traditional remediation strategies, due to the elimination of costs lating to extraction and transport, chemical treatment and eventual disposal of waste.
- Reduced ongoing risk and cost incurred by maintenance of containment facilities.
- Low environmental impact compared to other remediation strategies.
- Removes the contaminant permanently from the spill site.

Disadvantages

- Bio remediation does not work for elements, which cannot be broken down. Elemental contaminants such as cadmium and lead must be dealt with using other methods.
- Problems when products of biodegradation are more toxic than the parent compound. (Some other remediation strategies also have this problem.)

  Research is currently directed at overcoming the following problems:

  - Bio remediation is slower than other treatment strategies. It can take from three months to years or more, depending on the contaminant and environment. Certain compounds such as PCBs (polychlorinated biphenyls) break down extremely slowly.
  - Results are unpredictable due to the relatively undeveloped nature of the science; effects of factors such as soil pH, temperature, soil salinity, air penetration, flow rates of groundwater and the composition of the soil itself on soil ecosystems are still poorly understood.
  - Overly high concentrations of contaminants are likely to kill bacteria before remediation takes place.

Examples where usage of the technology may prove beneficial include fuel refineries and depots, chemicals, cattle lots, diaries etc.

Reducing Salinity

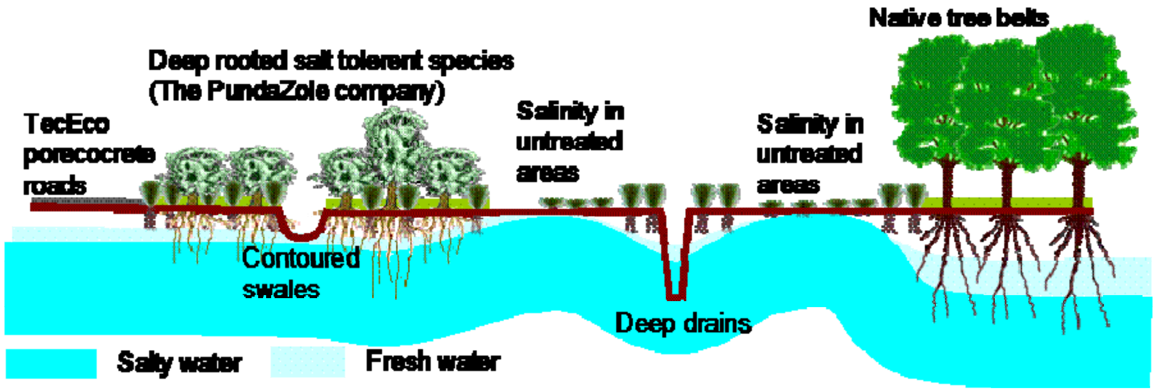

Figure 7 - Methods of Reducing Salinity

Salinity can be rectified by a combination of:

- Deep drainage.
- Mulching to increase humidity at ground level and reduce evaporative loss.
- Planting deep rooted salt tolerant species and leaving native belts that reduce the overall rate of evapotranspiration of the fresh water lens on top of ground water.
- Pervious rather than sealed surfaces (TecEco permecocrete pervious pavement).
  - Allowing capture of fresh water rather than run off.
- Maximising capture and use of fresh water and minimising irrigation water.
  - Replenishing aquifers with fresh rain water rather than recycled water through irrigation.

How Our Theories Differ

Many websites including the CSIRO and Australian government website on salinity when discussing salinity that is not clearly related to irrigation and the re-use of water seem to think that the problem relates to reduced evapotranspiration with agriculture and rising water tables that bring “ancient” salts to the surface. We think this analysis wrong. When land is cleared natural mulches and soil humus that retain water and reduce evaporation and rate of run off at the surface of soils are removed.

As a consequence what then happens is that fresh water does not enter the water table when it rains. It runs off into our rivers. According to the water dynamic discussed above it also picks up salt and pollution.

Other Advantages

Reduced Volume and Rate of Run Off.

With conventional pavement systems, reduced drainage areas bring more water into fewer drainage systems at a faster rate, eroding the banks of streams and rivers, and adding more sediment into the water. Pervious pavements are now seriously being considered by enlightened engineers around the world as a way of reducing run-off and improving safety.

“Pervious asphalt allows a gradual evacuation of water into the outlet (peak flows are limited and time of discharge longer). In addition, splashing is reduced as well as wind dispersion and evaporation. (Pagotto, Legret et al.)

Improved Pavement Safety.

Water penetrates through pervious pavements quickly leaving drier and safer surfaces with no standing water.

Drier pavements have the obvious effect of increasing friction between shoes or tyres and the foot, cycle path or road surface in wet weather and at the same time reducing road noise and spray, improving visibility.

Pavements are safer because they are not lubricated with a film of water flowing across the upper surface to the edge drains. As water does not tend to collect, sheet ice problems should be less in colder climates. The texture of pervious pavements is also much safer than smoother surfaces.

Improved Acoustic Properties.

Pervious pavements also absorb noise.

Less Maintenance on nearby Buildings and Superstructure.

Aquifers would be more regularly replenished resulting in less variable ground moisture content, reduced ground movement with wet dry cycles and less maintenance on buildings and infrastructure.

Water Storage and Use.

TecEco believe pervious pavements are essential for our long term survival on this planet. We cannot survive without water. We need to capture and store the water that falls on our cities for later use.

Using street areas for storage is not a new idea and was first instigated in Alexandria 2300 years ago and many systems are available today from large stone piles to pre cast plastic or concrete strengthening elements.

Transpiration Cooling - Hot City Syndrome and Pervious Pavement

The heat held by the stones on a pebble beach on a hot sunny day can be unbearable; It's the same in large cities. There are so many materials with high specific heat that during hot sunny weather and with no natural transpiration, due to the fact that we have paved all the ground, large cities just get hotter and hotter.

Architects, engineers and designers of cities need to come to grips with the properties of the materials they use. Hot city syndrome is one of a number of man made phenomena that the use of Eco-Cement permecocrete pervious pavements will reduce. The solution is to let the ground breathe and pervious pavements do this. In Australia, some parts of the US and many other places in the world it has been noted that subdivisions made with pervious pavement that also have street trees can be several degrees cooler than surrounding suburbs without because of the loss of the latent heat of evaporation of water. Evaporation after all is still the principle behind many cooling systems – so why do we pave the ground and prevent moisture entering or exiting?

Durability

Pervious pavements made with TecEco Eco-Cements would not be attacked by salts and would last considerably longer than conventional binders such as bitumen (in some countries referred to as asphalt) and Portland cement.

Sequestration

TecEco are also interested in pervious pavements because they would allow access by CO2 thereby curing Eco-Cement formulations with all the associated improvements in sustainability including massive waste utilization and large scale sequestration.

Disadvantages

The Clogging Myth

The experience of many engineers is that with relatively minor control and maintenance clogging will not reduce the infiltration rate below a design rate within the lifecycle of the pavement. Like any other kind of surface, pervious pavements have to be swept periodically to remove debris and suction cleaners or water under pressure can be used.

The consensus on the web seems to be that with relatively minor control and maintenance, clogging will not reduce the infiltration rate below a design rate within the lifecycle of the pavement.

Those who remain skeptics please also note that it is better to have pollution collected from a pervious pavement by machinery than pollute our coastal waterways

Figure 8 - A Frimokar Australia High Pressure Jet and Suction Cleaning Vehicle in Action

Practical Aspects of Laying Pervious Pavement

Ideally a pervious pavement should be made with stone aggregates and a cementitious binder and be similar to concrete to handle and install. In cold areas it is important that the pavement should not hold water otherwise in winter the water would freeze and cause cracking. It is also important to detail a pervious structural base and sub base for the pavement that has a high void ratio as this acts as a reservoir, and provide underground drainage as required. An impervious layer and suitable underground drains is required over soils unable to rapidly absorb water such as clays.

Pervious pavement, whether no fines concrete or under asphalted gravel is made without "fine" materials. Both porosity and permeability are positively influenced by a careful selection of the grading curve, the former (concrete) getting to outcomes (17%) completely comparable to the corresponding values of a draining and noise-reducing asphalt pavement (18÷20%) (Agostinacchio and Cuomo).

Strength of the actual pavement can be engineered to whatever is required, and durability is substantially dependent on how well what is under pervious pavement is engineered as if it moves, it will naturally break up.

Sustainability of Pervious Pavement

Pervious pavements made with TecEco Eco-Cements would utilise a considerable proportion of wastes such as fly ash and as they would carbonate, provide substantial abatement. Water entering aquifers, streams and rivers would be of higher quality and carry less macro pollutants. Fresh water replenishment of aquifers would reduce salinity and reverse falling water tables. Cities would be cooler (see above) reducing the use of air conditioning.

Pervious Pavement as Carbon and Waste Sinks?

With the invention of Eco-Cements pervious pavements can also act as carbon sinks and be made using waste materials. TecEco eco-cements set by absorbing carbon dioxide out of the air and will therefore set in pervious pavement. If made with carbon capture as TecEco propose then our roads could become giant carbon sinks.

Biomimicry-Geomimicry Using Pervious Pavement

Pervious pavements mimic the way the land surfaces covered in vegetation slowly filter and cleanse water that falls on them reducing the time taken for the water to return to the sea

Waste Utilisation by Pervious Pavement

After global warming, waste is potentially the next most pressing problem facing us. Building-related waste is substantial. According to Maria Atkinson of the Green Building Council of Australia the figure nationally of waste going to landfill from construction and deconstruction activities (predominantly relating to refurbishments) was around 40% (Atkinson 2003) and this figure is similar to that for other modern industrialised nations.

Because the flow of unwanted or waste materials is affecting our planet, we need to consider not just our buildings but the wastes produced when we construct and deconstruct them.

TecEco have been testing aggregates for pervious pavement made from recycled concrete and other solid building wastes with considerable success. Eco-cement pastes used with these wastes also benefit from the including of a percentage of “sticky” waste materials like fly ash.

Sequestration in Pervious Pavement

Concretes are the second most used material on the planet, next to water. Over 15 billion tonnes of concrete produced annually equates to well over two tonnes per man, woman and child. Although concrete is the most sustainable building material the shear quantity used gives any improvement a huge impact.

TecEco cements are made by blending reactive magnesium oxide with conventional hydraulic cements like Portland cement. They are environmentally friendly because in pervious concretes the magnesium oxide will first hydrate using mix water and then carbonate, forming strength-giving minerals in a low alkali matrix. Many different wastes can be used as aggregates and fillers without reaction problems. The reactive magnesia used in Eco-Cements is currently made from magnesite (a carbonate compound of magnesium) found in abundance. In the future TecEco hope to make Eco-Cements using magnesia produced by power stations as a result of their carbon storing or sequestration activities using the Tec-Kiln. The Gaia Engineering tececology embraces all these sub processes.

Magnesia hydrates to magnesium hydroxide in any concrete but only in permeable materials like bricks, blocks, pavers and pervious pavements will it absorb CO_2 and carbonate quickly. The greater proportion of the elongated minerals that form is water and carbon dioxide and they efficiently and effectively bond aggregates such as sand and gravel and wastes such as saw dust, slags, bottom ash etc. Eco-Cements can include more waste than other hydraulic cements because it is much less alkaline, reducing the incidence of delayed reactions that would otherwise reduce strength. Portland cement concretes on the other hand can't include large amounts of waste because the Portlandite causes delayed and disruptive reactions.

The more magnesium oxide in Eco-Cements and the more permeable it is, the more CO_2 that is absorbed. The rate of absorption of CO_2 varies with porosity. The more readily air can pass into the concrete the more quickly carbonation will occur. A typical Eco-Cements pervious pavement would be expected to fully carbonate (i.e. full absorption of CO_2) after a few months.

Strength in Eco-Cements Pervious Pavement

When Brucite carbonates it mainly forms lansfordite and nesquehonite which are respectively penta and tri hydrated carbonates.

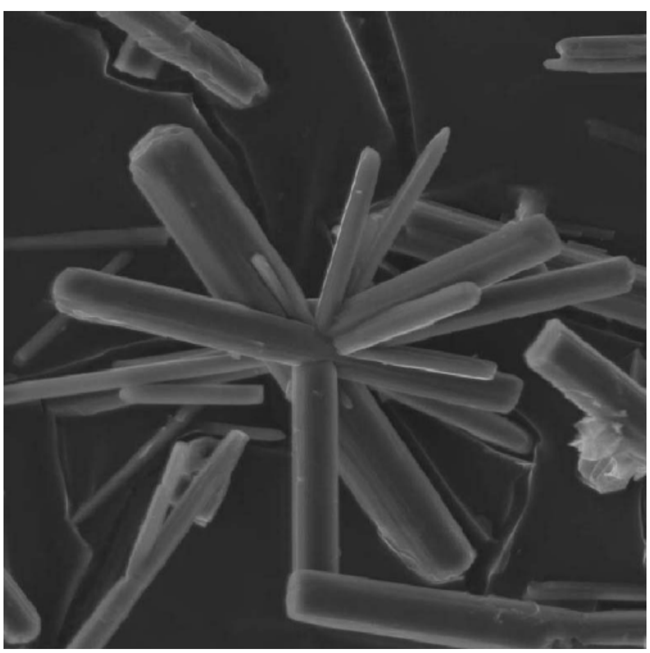

Figure 9 - SEM image of nesquehonite sample (Kloprogge, Martens et al. 2003)

The strength gain is mainly micro structural because of more ideal particle packing. Brucite particles at 4-5 micron are well under half the size of cement grains and the natural fibrous and acicular shape of lansfordite and nesquehonite tends to cause the mineral to lock together.

Magnesium is a small lightweight atom and the carbonates that form contain proportionally a lot of CO_2 and water. Total volumetric expansion from magnesium oxide to lansfordite, for example, is 811%.

$$Mg(OH)_2 + CO_2 => MgCO_3.5H_2O$$

Bond to Aggregate in Eco-Cements Permecocrete Pervious Pavement

Magnesium compounds are characterized by surface chemistry conducive to strong polar bonding to other materials with the result that their inclusion in cement formulations improves the performance of pastes for holding aggregate together in a pervious pavement structure.

Brucite forms electronically neutral layers that are bonded by polar bonding forces. The same forces are at the interfaces of $Mg(OH)_2$ and other materials resulting in strong bonding with most aggregate, fibres and the base structure. The mechanisms are comparable to those of calcium (in PC) but the forces are far greater because of the smaller size and higher charge density of magnesium. Electrostatic energy is inversely proportional to the square of the cation centre to the centre of the negative charges. In the case of Tec-Cement concrete (Calcium – Oxygen = 2.38 Å; Magnesium – Oxygen =2.10 Å), the forces are therefore 28% greater in the case of magnesium bonding compared to calcium (Lippmann 1973).

Nesquehonite, the main carbonate that forms in a pervious pavement has a more complex structure than Brucite but is also characterized by a strong surface potential for polar bonding. The structure of nesquehonite is characterized by infinite chains along [010], formed by corner sharing MgO_6 octahedra. Within the chains, CO_3 groups link three MgO_6 octahedra by two common corners and one edge, which causes strong distortions of the involved polyhedra. These chains are interconnected via hydrogen bonds only: each Mg atom is coordinated by two H_2O ligands, and one free water molecule is situated between the chains (Geister, Lengauer et al. 2000).

Comparison of Eco-Cement Pervious Pavement to Other Possible Carbonating Concretes

Eco-Cement has a number of advantages over PC and lime mixes for pervious pavement concrete:

The strength of the calcium carbonate and the magnesium carbonate are roughly the same, however the shape of nesquehonite (hydrated magnesium carbonate) is acicular improving the overall strength of the concrete due to the effect on the microstructure.

The lime used in carbonating mortar is a slacked lime, the setting reaction is therefore:

$Ca(OH)_2 + CO_2 => CaCO_3 + H_2O$

Whereas the in Eco-Cement the magnesium oxide is used leading to the two following reaction:

$MgO + H_2O => Mg(OH)_2$

$Mg(OH)_2 + CO_2 => MgCO_3\ 5H_2O$ (or $MgCO_3.3H_2O$) + H_2O

Note that significantly more material is formed from the starting material, which is the oxide in the case of an Eco-Cement. The consequence is that less Eco-Cement need be used than Portland Cement or lime, however the downside is a slightly slower setting and hardening time.

Standards for Pervious Pavement

There do not appear to be Australian standards for pervious concrete. In America the National Ready Mix Association (NRMA) has recently developed a pervious concrete contractor certification program to improve quality control for design and installations. A copy of CIP – 38 is available from the NRMA freely on the web. The ACI have also issued a report by committee 522 which is available from their web site. Standardised methods for post-construction testing, specifically for pervious cement concrete pavement, are being developed by the American Concrete Institute. The introduction of standards will assist the public sector accept pervious pavements as appropriate for the extended lifecycle requirements of public infrastructure and provide an indication of desired infiltration performance. It will be very important to make sure standards as they are developed are not limiting and based only on performance.

In terms lifting the bar for sustainability in building and construction it is important that the Green Building council of Australia, America and similar organizations elsewhere in the world provide increasing credits for the de-coupling of rainwater, salinity and pollution. Developers who capture rainwater in their subdivisions reducing pressure on water supplies need also to be rewarded as should owners in the area with lower water rates.

There is no doubt that the quality of installations will improve as experience increases, industry standards are developed and jurisdictions articulate and implement credits for the reduced costs they will incur.

Summary

Our legacy has been to pave the ground which had previously acted as a natural bio-filter, redirecting rainwater as quickly as possible to the sea. Given global water shortages, problems with salinity, pollution, volume and rate of flow of runoff we need to change our practices so as to mimic the way nature works.

There are significant environmental and other advantages in specifying pervious pavements. Their use will amongst other benefits reduce the overloading of our present drainage system, cleanse water before it enters aquifers, streams and rivers, improve safety, reduce maintenance on buildings due to seasonal ground movement and reduce the costs of watering street trees. Enlightened engineers around the world are seriously considering using pervious pavements as a way of reducing run-off related coastal pollution and improving safety. Now TecEco have improved pervious pavements by releasing permecocrete making them using binders that are carbon sinks and using aggregates that are recycled there is no excuse not to move on.

More information about pervious pavement is available in TecEco newsletters 29, 35 and 42. A good web site about managing storm water using pervious pavement is to be found at http://www.greenworks.tv/stormwater/porouspavement.htm

Appendix 1 – What Mikhail Gorbachev Has to Say about Water

“Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilisation, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. All people, everywhere and every day, need it.

We need it for drinking, for cooking, for washing, for food, for sanitation, for industry, for energy, for transport, for rituals, for fun, for life. And it is not only humans that need it: all life everywhere is dependent on water to survive.

But we stand today on the brink of a global water crisis. Although certain parts of the world have abundant water resources, supplies of drinking water are inadequate in many regions. Let us acknowledge that access to clean water is a universal human right, and in so doing accept that we have a corresponding universal responsibility to ensure that the forecast of a world, where in 25 year’s time, two out of every three persons face water stress is proven wrong.

Without water security, social, economic and national stability are imperiled. This is magnified where water is shared across borders and becomes crucial where water stress exists in regions of religious, territorial or ethnic tension. Thus we are faced with a mighty challenge.

Fortunately we have a history of meeting great challenges using imagination and out irrepressible capacity to adapt, and thousands of talented people around the world are already mobilised to the cause of preserving water for future generations.

Just as we are moved by water, we must now move in order to save it.”

Mikhail Gorbachev
President, Green Cross International

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