The urban water challenge

In urban areas only about 5% of rainfall infiltrates the ground.
AIMS OF PERMEABLE PAVEMENTS

MAXIMISE INFILTRATION

TRAP POLLUTANTS

DELAY or MINIMISE RUNOFF

CARRY TRAFFIC
TYPICAL PERMEABLE PAVEMENT CROSS-SECTION

- Pavers
- Bedding, also used in drainage voids
- Permeable Base
- Drainage Voids
PERMEABLE PAVING OBJECTIVES

- MINIMISE FLOODING & EROSION
- MINIMISE STORMWATER DRAINAGE
- REPLENISH GROUNDWATER
- STORE WATER FOR REUSE
- TRAP POLLUTANTS
- IMPROVE WATER QUALITY
- IMPROVE LANDUSE
WATER SENSITIVE URBAN DESIGN

All these criteria can be addressed using PERMEABLE PAVEMENTS.
PERMEABLE PAVING RESEARCH

Structural and/or Hydraulic Tests include:

- **GERMANY/AUSTRIA**
  - University of Karlsruhe
  - University of Hanover
  - Technical University of Vienna

- **UK**
  - University of Coventry

- **CANADA**
  - Guelph University

- **AUSTRALIA**
  - University of New South Wales
  - University of South Australia

- **USA**
  - Texas A & M University
  - Northeastern University
  - University of Washington
  - North Carolina State University
  - University of Georgia
Laboratory research into PICP began in Australia in the early 1990’s at UNSW. At that time there was no production of permeable paving in Australia. Early work was funded by European and North American groups and collaborations between UNSW and European universities were established (TU, Wien). Once PICP manufacture commenced in Australia, research began at UniSA and some small field trials were conducted and reported in Adelaide.
RESEARCH IN AUSTRALIA

1. University of New South Wales (since early 1990’s)
   - Measurements of Infiltration & runoff
   - Detailed evaluations of bedding & jointing materials
   - Measurement of load-carrying structural performance
   - Evaluations of Permeable Basecourse materials
   - Collaboration with Technical University of Vienna

2. University of South Australia
   - Measurements of Infiltration
   - Measurements of pollution trapping/clogging
   - Measurements of structural performance
   + others

> 7 permeable paving systems have been evaluated in Australia
TESTS OF PERMEABLE PAVING

include:

1. **Infiltration Tests** of permeable pavers, bedding and drainage materials

2. **Structural Loading Tests** of permeable pavers

3. **Pollution Control Tests** of permeable pavements, TSS retention etc.

4. **Repeated Triaxial Loading Tests** of permeable basecourse materials
1. **Flood mitigation** by retention or detention i.e. *water quantity*.
2. **Pollutant removal** by filtration or retention i.e. *water quality*.
3. **Water conservation** by collection and re-use i.e. *water harvesting*. 
POLICIES FOR MANAGING URBAN RUNOFF

Guiding Principles:

Water Quality  Flood Control  Environmental Impacts
PERMEABLE PAVING DESIGN PROCESS

STEP 1: PAVEMENT TYPE SELECTION

TRAFFIC & RAINFALL

SURFACE

- Paver type and thickness

SUBGRADE CONDITIONS

PAVEMENT CROSS SECTION

- Full infiltration?
- Partial infiltration?
- No infiltration?

PAVEMENT MATERIALS

- Unbound or Bound?

STEP 2: HYDRAULIC ANALYSIS (PERMPAVE)

FLOOD CONTROL?

- Design Storm

POLLUTION CONTROL?

- Hydraulic Effectiveness Curves

HARVESTING?

STEP 3: STRUCTURAL ANALYSIS (LOCKPAVE)

- Car Parks?
- Roads and Streets?
- Industrial Pavements?
Paving

LOCKPAVE ® — PERMPAVE ®
Software Package for Concrete Segmental and Permeable Pavements

University of South Australia

Concrete Masonry Association of Australia
Early research established that PICP could cope with Australian rainfall and with heavy traffic loads.

Routine construction of PICPs in Australia commenced more than 12 years ago including high-profile paving projects e.g. Sydney Olympics Precinct.

Most of these PICPs have performed well over time without any systematic maintenance.
PERMEABLE PAVING APPLICATIONS

- PEDESTRIAN AREAS
- DRIVEWAYS
- PARKING LOTS
- LANES
- STREETS
SYDNEY SPORTS GROUND
constructed in 1998
OLYMPICS COMPLEX, SYDNEY
constructed in 1998
Joints and Drainage Voids filled with 2-5 mm aggregate
Installed over dense-graded 20mm granular basecourse (DGB20)
PARKING AREAS

KIRKCALDY AVENUE, GRANGE, SOUTH AUSTRALIA
constructed in 1999

Monitored by UniSA since construction
Municipal Car Park, Camperdown, constructed in 1999
Rear Access Service Laneway, Adelaide, constructed in 2010
SMITH STREET, MANLY

Constructed in 2001

(Retrofit of an urban street built around 1900)
PERMEABLE AGGREGATE BASE

GEOFABRIC

2-5mm AGGREGATE BEDDING & JOINTING

ECOLOC PAVERS
PICP KIAMA, NSW
constructed in 1997
Prior to 2009, there had been no quantitative assessment of in-service performance of PICP in Australia.

The Concrete Masonry Association of Australia (CMAA) decided to fund a study of PICP that had been in service for periods of around 10 years.

This was done in early 2009 jointly by:

- School of Natural & Built Environments, and Centre for Water Science and Systems, University of South Australia.
- School of Civil and Environmental Engineering, University of New South Wales.
The prime objectives were:

- To assess the overall in-service performance of a wide range of aged pavements using in-situ tests
- To measure current infiltration rates
- To examine clogging of the jointing materials

A total of 10 PICPs that had been in service for 8 to 10+ years were chosen for study
TEST PAVEMENTS

- Public spaces
- Car parks
- Laneways
- Residential streets
- Roads

ALL WERE SUBJECT TO TRAFFIC
PUBLIC SPACE PAVEMENTS
Pedestrians + service vehicles

SYDNEY SPORTS GROUND

EcoTrihex pavers

SYDNEY OLYMPIC PRECINCT
PARKING AREAS

Cars + service vehicles

- Municipal Car Park, Camperdown, constructed in 1999
- Karrabee Avenue, Sydney, constructed in 2000
INfiltration Tests - 2009

Double Ring Infiltrometer
Measuring 1 sq m of paving
INFILTRATION TEST PROCEDURE

1. Tested in both high and low areas
2. Each location was thoroughly soaked before testing
3. Each test was repeated several times.
SURFACE PREPARATION

Each site was tested “as found” without first cleaning surface
JOINTING MATERIALS - SAMPLING

- The jointing materials were sampled from 0 to 30 mm - top
  30 to 60 mm - bottom
- Gradings were measured in laboratory
- Typically, the gradings were coarser in the upper 30 mm
Clogging was recorded in upper 30 mm
JOINT CLOGGING

Permeability drops with capture of material such as pollutants passing 200# sieve
SURFACE PREPARATION

Only 1 site (Olympics) was known to receive routine sweeping:

...this appeared to be largely ineffectual
JOINTING MATERIALS – OLYMPIC PARK

Sieve Size vs % Passing Sieve for different OPs:

- **OP 1**
- **OP 2**
- **OP 3**
- **OP 4**

Each graph shows two curves for Upper and Lower, indicating the percentage of passing through different sieve sizes.
EFFECTS OF SWEEPING WITH BROOM

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>CONDITION</th>
<th>INFILTRATION mm/h</th>
<th>INFILTRATION l.sec/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney Sports Ground, Moore Park</td>
<td>As found</td>
<td>216</td>
<td>601</td>
</tr>
<tr>
<td></td>
<td>Swept</td>
<td>320</td>
<td>889</td>
</tr>
<tr>
<td>Smith St, Manly</td>
<td>As found</td>
<td>168</td>
<td>438</td>
</tr>
<tr>
<td></td>
<td>Swept</td>
<td>306</td>
<td>851</td>
</tr>
</tbody>
</table>

Sweeping with a stiff broom for < 1 minute greatly increased infiltration
FIELD TEST RESULTS

1. Most PICPs maintained high infiltration rates after 10 years of service despite a lack of systematic maintenance.
2. Clogging was observed at all sites.
3. Most of the fine sediment causing clogging is retained close to the surface from whence it can be removed by street sweepers.
4. Infiltration can be greatly increased by sweeping surface.
5. A clogging factor must be applied in the design of permeable pavements.
1. Permeable pavements can make a significant contribution to sustainability consistent with the concepts of Water Sensitive Urban Design (WSUD).
2. Overseas studies show this can be achieved without increase in project costs.
3. Since the early 1990s, Australian research has embraced measurements of infiltration rates, structural capability, pollution trapping and clogging.
4. Australian-specific software and manuals have been developed for the design of PICPs for managing rainfall runoff, water quality and harvesting and to withstand traffic loads.
5. Field studies have confirmed that clogging of PICP is a natural on-going process that must be considered in design.
6. Subject to correct design, PICP can be expected to serve satisfactorily for periods comparable to other forms of pavement.
Paving

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University of South Australia
Concrete Masonry Association of Australia
The Concrete Masonry Association of Australia (CMAA) is a national organisation funded by the Australian concrete masonry industry.

The CMAA publishes technical manuals, data sheets and software packages, relating to concrete block walling, concrete paving, permeable paving and concrete masonry retaining walls, which are free to download from this website. The Association also conducts workshops and courses and provides a technical advisory service for the construction industry and other users of concrete masonry products.

Representing the concrete masonry industry on national issues, especially in technical marketing areas, is the primary focus of CMAA's strategic objectives.