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Kiss and Cries: The Woes of R & D in Geosynthetics

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GROUP OF EIGHT AUSTRALIA

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GEOSYNTHETICS DEVELOPMENT MILESTONES

1960's-1970's
Development of geotextiles
GMBs for water containment
BGM
Geotubes
PVD's for soil consolidation
Erosion control

1980's
Geogrids and Geostrips for soil reinforcement
GMBs for environmental applications.
GCLs for environmental applications.
Geonets for drainage
Geotextile for hydraulic applications

1990's
Geocells
Active geosynthetics (initiate physical change to the soil matrix)

2000's
Geotextiles and Geogrids for column reinforcement
Geodetect

2010's-2020's
Smart geosynthetics (sensing properties, self-healing, 3D printing, etc.). Active geosynthetics (initiate biological, chemical change to soil matrix)
GMBs and GCLs for extreme environments

R & D

R & D is not always directed to technologies or materials innovation. Operations and processes can have just as much impact.

1 Historical

Kettleman Hill Landfill (USA).

2 Decennary

Geomembrane welds.

3 Contemporary

Polymer-modified bentonites/polymer enhanced GCLs.

Kettleman Hills (USA) Landfill Failure

- Hazardous waste landfill
- Slope Height = 27 m
- Bowl-shaped volume
- Side slopes:2H:1V (26°) to 3H:1V (18.5°)
- Waste placement began in 1987

Kettleman Hills Landfill (USA) March 1988: Failure

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Kettleman Hills (USA) Landfill Failure

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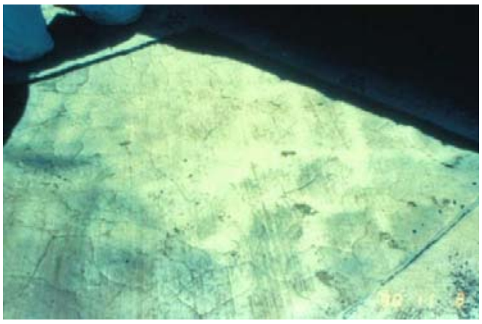
- Designed based on database values



- Smooth geomembrane
- Low interface shear strength
- Friction angle ~8^o against GTX and ~ 12^0 against clay

Kettleman Hills (USA) Landfill Failure

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LESSONS LEARNED

- Slope failure in waste containment systems are expensive [an estimated total loss of about US$30M for all parties involved]
- Large variability in measured interface-strengths (function of normal stress, post peak strength loss, weak geosynthetics interfaces, etc.)
- Site specific shear testing is required
  1. Site-specific soils
  2. Site specific products
  3. Site-specific conditions

MAJOR OUTCOMES

- Development of textured geomembrane.
- Identification of the need to provide fill sequencing plan

Geomembrane seams behaviour

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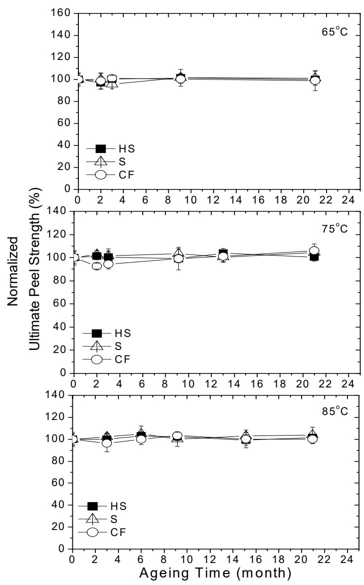
- Typically > 1500 m of weld/ha
- Welds are a critical location with respect to GMB service-life
- Shear and peel tests are usually performed to obtain quantitative measurements of seam strength.
- Test results are used as acceptance criteria to evaluate the bond strength

GMB Seams behaviour, Monash University, Zhang (2013)



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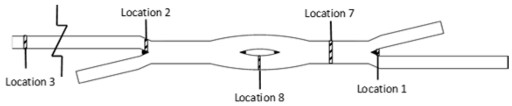
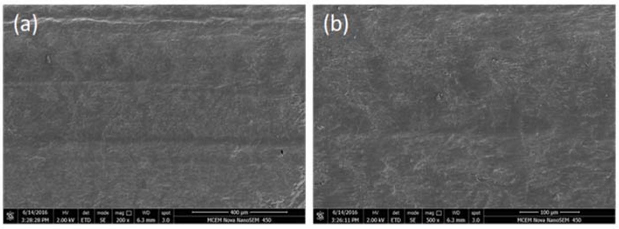
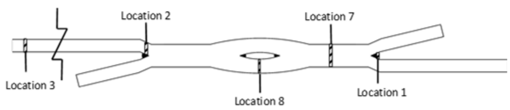
SEM on Heat Affected Zone, condition HS (location 2)

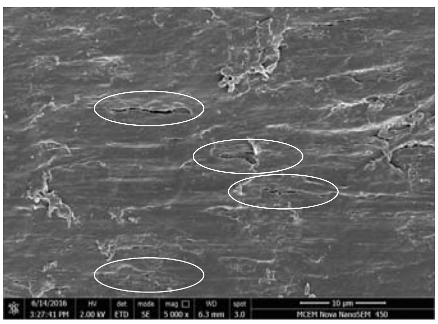




Under low magnification, surface distortion can be observed

SEM on Heat Affected Zone, condition HS (location 2)





Increasing the magnification, cracks are observed parallel to the weld.

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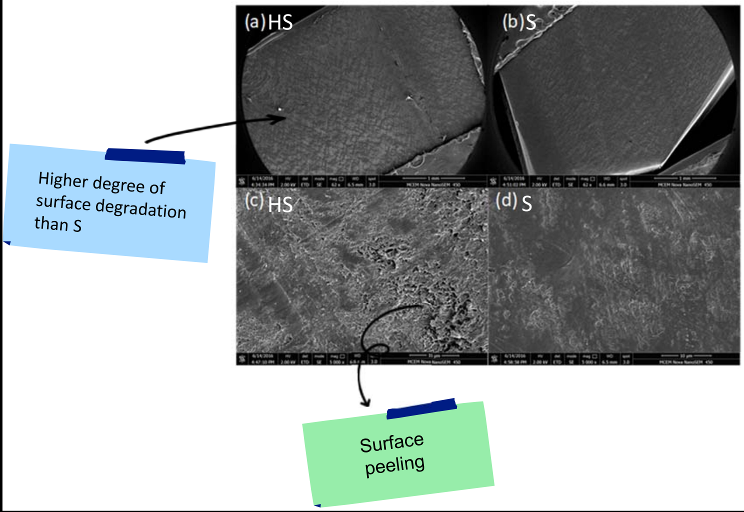
SEM view of seam HS and seam S in acidic condition (pH = 1.5, at 85ºC for 628 days)



62 x magnification with scale bar of 1mm

5000 x magnification with scale bar of 10µm

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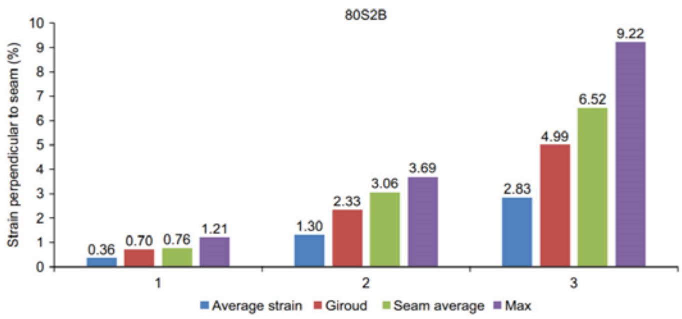
- strain concentrations at the HAZ are greater than originally thought (see data below from Kavazanjian et al., 2017)



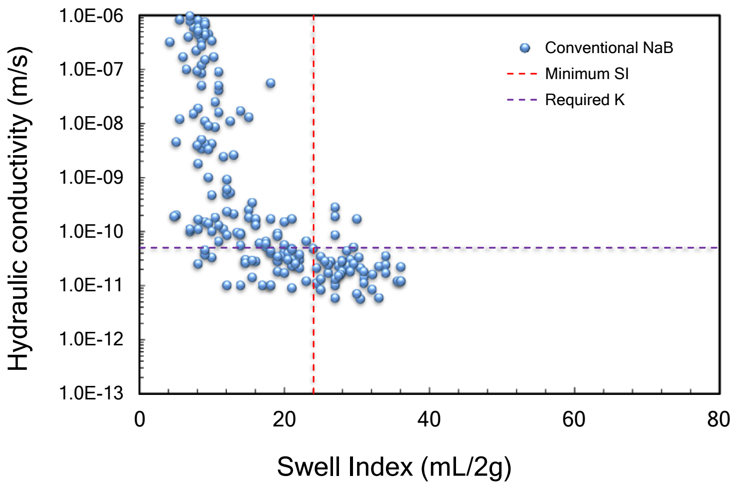
Summary:

- Peel and shear strength, do not adequately characterize molecular structure changes nor identify microstress cracks within the bonded sheets.

ASTM D5890-2019
Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners

This test method covers an index method that enables the evaluation of swelling properties of a clay mineral in reagent water for estimation of its usefulness in GCLs. *<u>This test method is not applicable for clays with polymers</u>*

Swell index-Hydraulic conductivity correlation



Swell index-Hydraulic conductivity correlation

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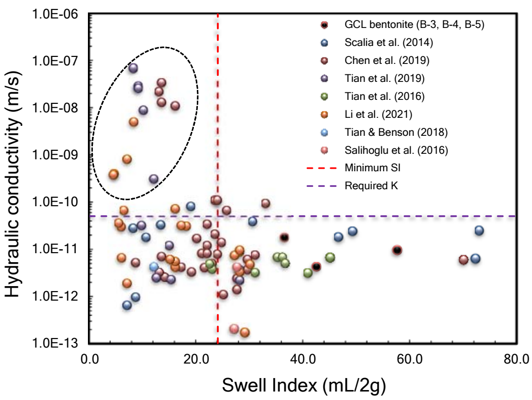
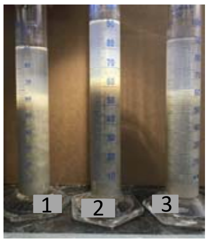
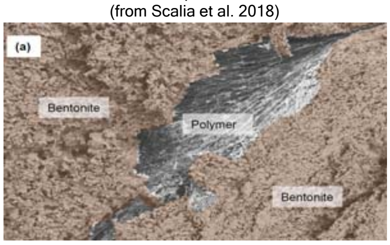




SEM of BP GCL after permeation with DI water (from Scalia et al. 2018)



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Swell index-Hydraulic conductivity correlation

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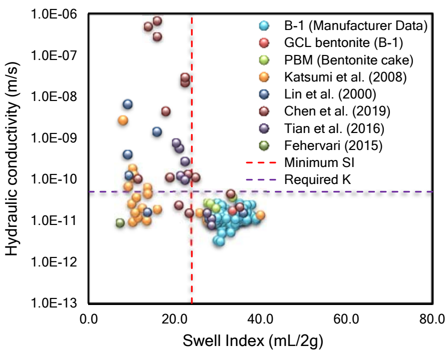

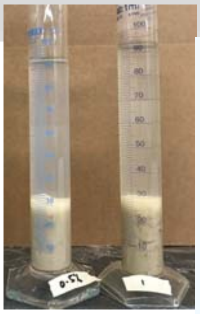

Surface very smooth and uniform. Bentonite dispersed evenly

Clumps rather than dispersion

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Swell index-Hydraulic conductivity correlation

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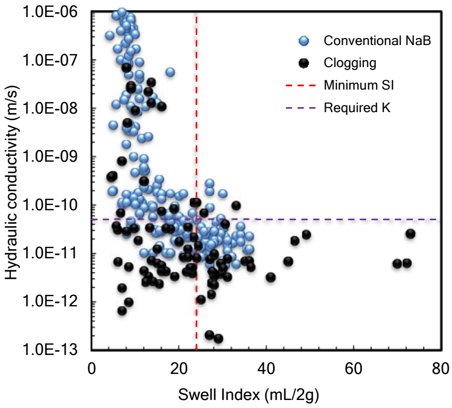

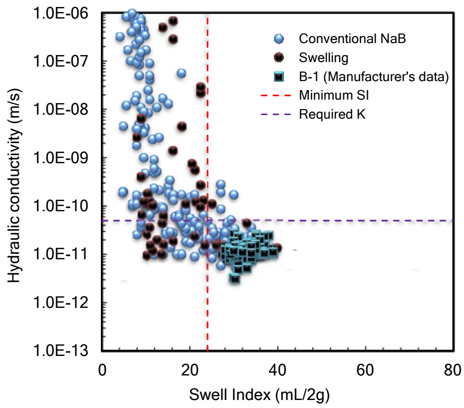

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Swell index: Polymer elution effect

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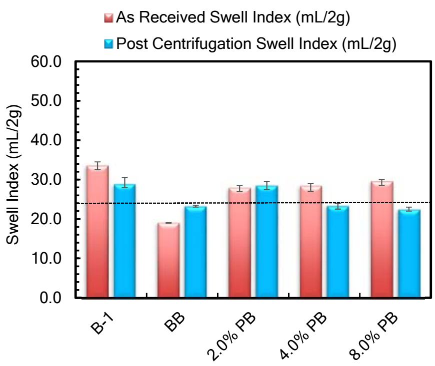

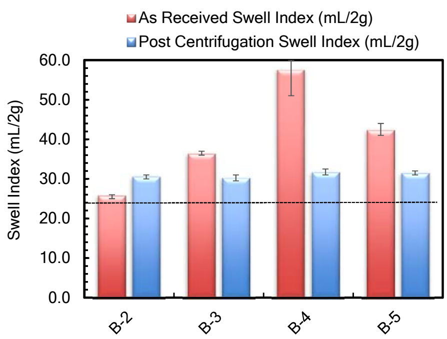

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Future:

Smart materials

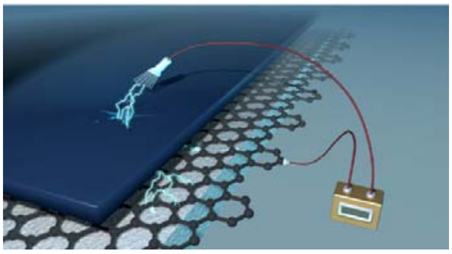
Need to design infrastructure that is more resilient and sustainable in the face of a changing climate

Need to develop means to monitor and predict the behaviour of aging infrastructure to enhance and safely prolong their design life

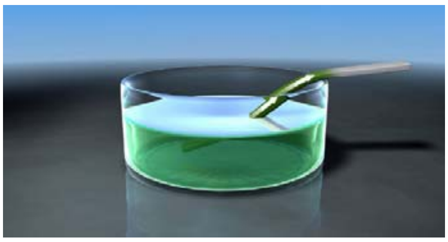
Smart Materials:

Non longer a fallacy

Graphene-based industrial coating designed to be applied to non-woven geotextiles transforming them into low cost leak detection system.



Can also transforms hydrophobic geotextiles into highly wetting materials or vice-versa



Source: www.imgne.com

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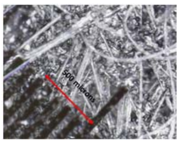
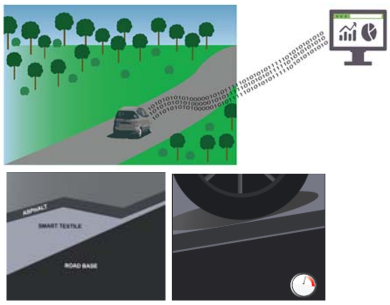
Graphene-coated geotextile used as a distributed sensor embedded in a pavement structure to provide spatially continuous information on the pavement hydro-thermo-mechanical loading

Micro X-ray CT Image

Network of conductive paths formed by the graphene coating





Harini (2020- ongoing)-Monash University

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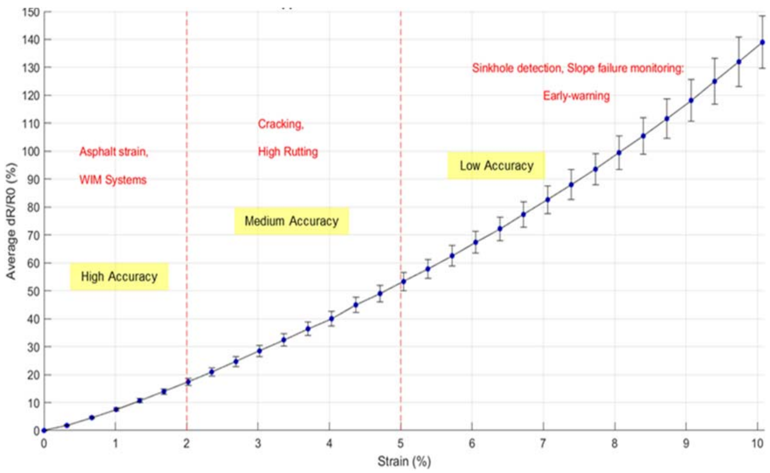

Harini (2020- ongoing)-Monash University

Self-healing polymers (CSIRO)

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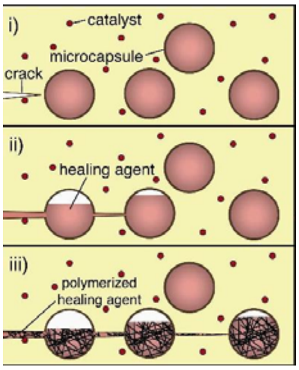
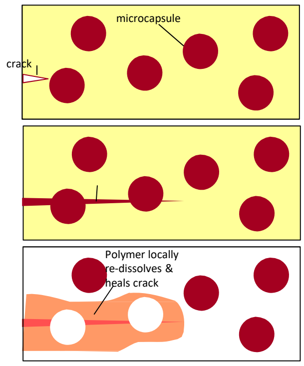
- Self-healing polymers respond to damage by self-repair.
- Many such polymers contain capsules of a healing agent that rupture when the polymer cracks.
- Healing agent is then released to 'heal' the crack.





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X-ray microtomography - qualitative results (CSIRO)

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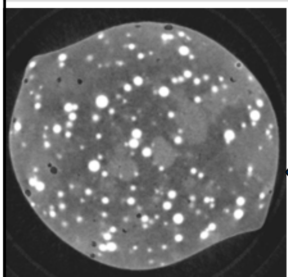
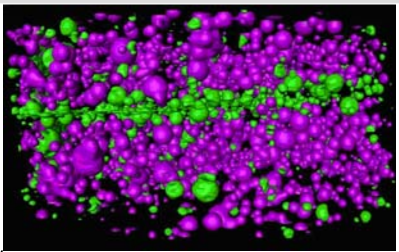
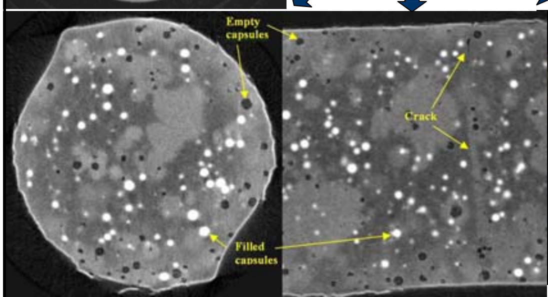


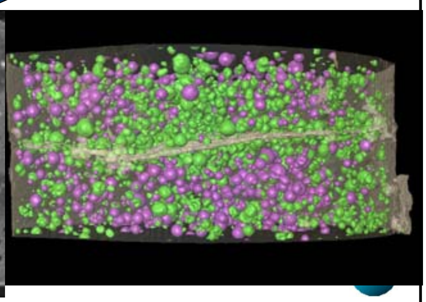
Tomographic sections and 3D rendered views

15% by weight after 7 days

after 3 months







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Importance of Collaboration

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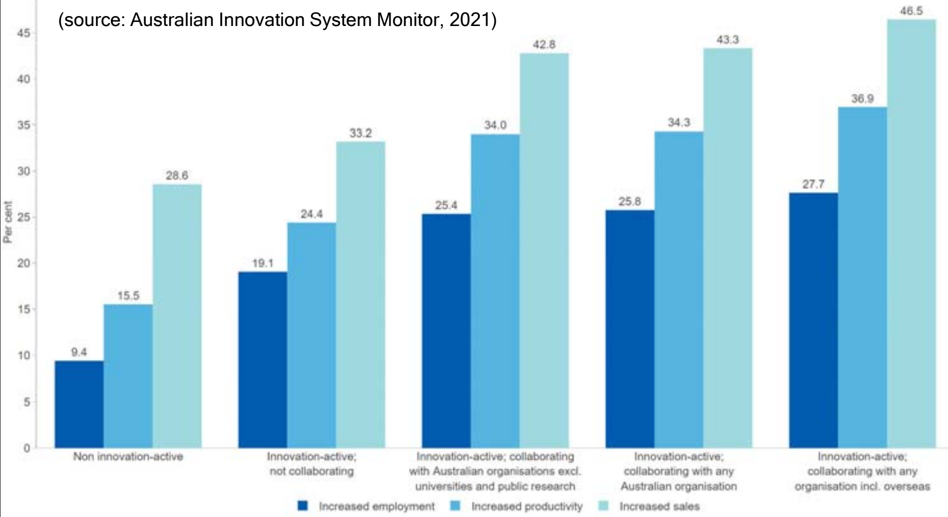
(source: Australian Innovation System Monitor, 2021)



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1.79%

Australia's R & D intensity (GERD as share of GDP) in 2017-2018

21%

Decline of R & D intensity in a space of a decade.

Australia's Gross Expenditure on R&D
(source: Australian Innovation System Monitor, 2021)

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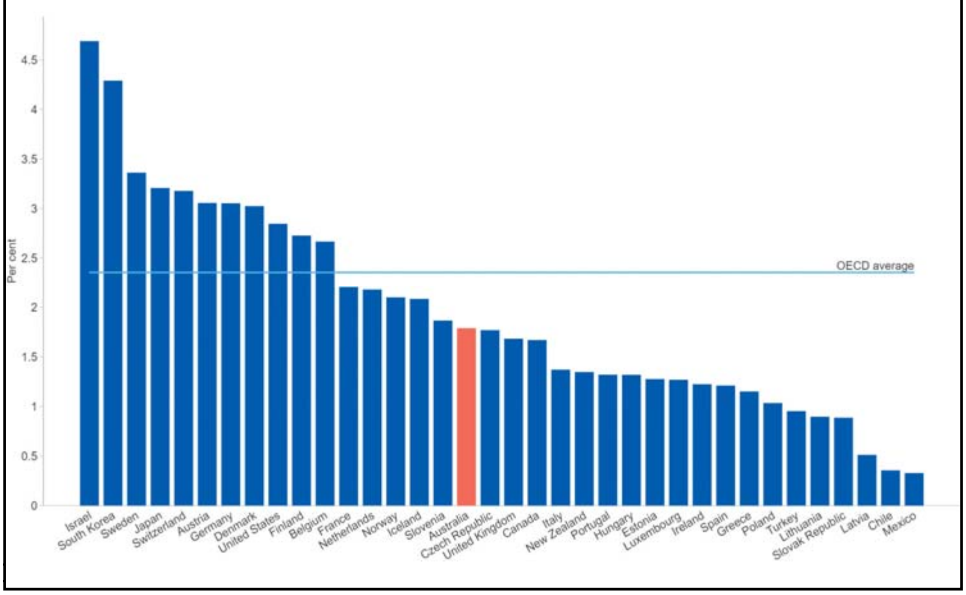

High Education Expenditure on R&D
(source: Australian Innovation System Monitor, 2021)

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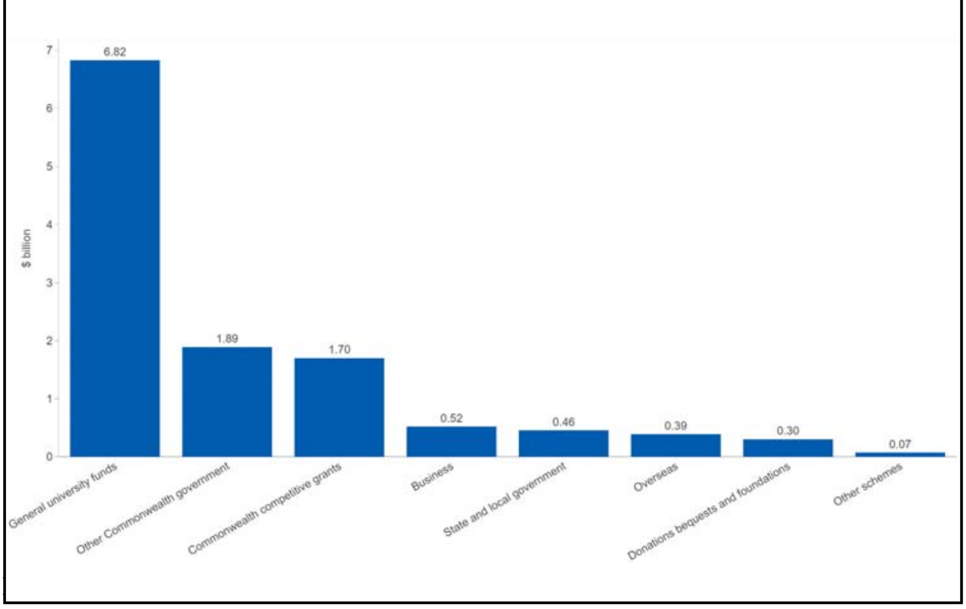

Business Expenditure on R&D
(source: Australian Innovation System Monitor, 2021)

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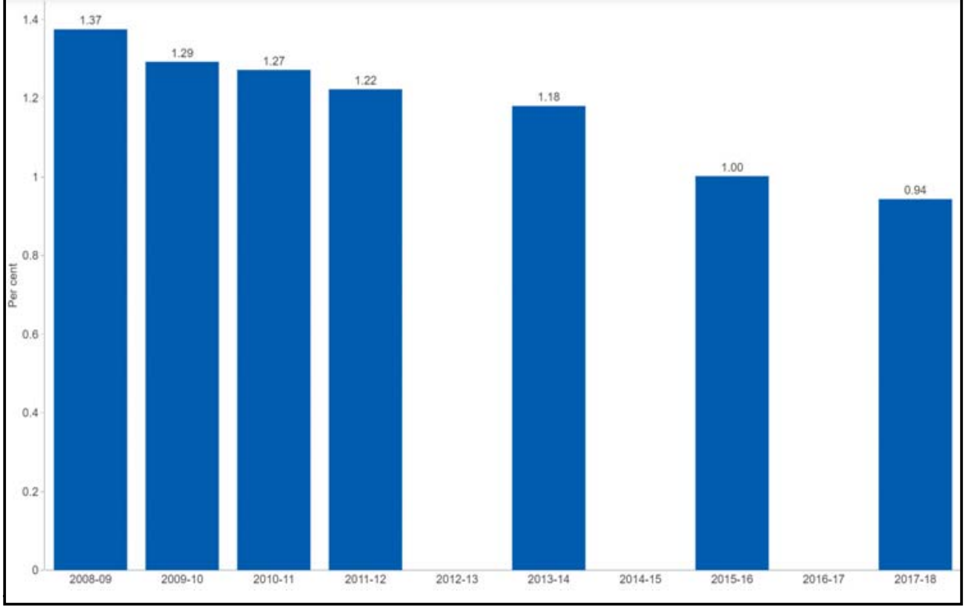

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Current state of collaboration

Business-Business collaboration– 25/32 OECD countries

Collaboration between SMEs with a university (or other non-commercial research organisations) – 29/29 OECD countries

Collaboration between large Australian firms and university – 27/29 OECD countries

King, D.J., Bouazza, A. and Haberfield, C.M. 2021. Geotechnical engineering and knowledge transfer through academic-industry collaboration. Australian Geomechanics Journal (in-press)

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STATISTICS IN CONTRAST

- Economic strength (15th largest economy by GDP)
- Relative strength in research (9th per capita amongst OECD)
- The % of government expenditure on R&D financed by industry (7/32 OECD countries)

The current state of collaboration as evidenced by these statistics should be of concern to our profession.

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WMRR Workshop on R&D in Geosynthetics-Sydney, 8 June 2021

Summary

✓ The geosynthetics discipline has developed around a family of products.

The types have grown extensively

✓ Today, it is almost impossible to practice engineering without using geosynthetics

Applies to infrastructure geotechnical engineering, environmental, mining, Oil and Gas resources. Allow economic and effective constructions.

✓ The use of geosynthetics is associated with challenges.

The efforts made to meet them have led to better understanding of fundamental behaviour and the development of innovative designs.

✓ Time to move products from simply performing a function.

Embrace smart and bio-inspired sensing technologies, new materials that open new opportunities for design and construction of more robust and durable civil structures

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Thanks for attending!

Email me at malek.Bouazza at monash.edu
for further questions or clarifications.