Minimise the risk when integrating underground geocellular stormwater tanks

An engineer’s guide based on real-world structural behaviour

Image source: Wilson, S (2008), The SDMGDT Manual, CIRIA, C680, London (ISBN: 978-0-860127-680-0)

A risky approach to a problem with heavy consequences

Underground stormwater tanks are predominantly used to provide storage for detention (OSDs), reuse (retention) and infiltration.

In Australia, no standards govern the strength of underground plastic geocellular, stormwater tank systems and this is a problem for all stakeholders. Local authorities enforce compliance to regulation by outlining the methods to ensure a development meets the Stormwater Management Plan, however the scope of regulation is limited. For instance, the volume of water a property needs to manage on landscaped, hardstand and roofed areas is regulated but often not the structural integrity of the tank system that stores it.

Property owners, businesses and the general public could experience anything from inconvenience, public liability to litigation caused by the structural failure of an underground tank. Therefore certifying engineers must integrate tanks properly so that they meet a project's strength, durability and serviceability requirements.

In an environment that is not informed by standards, this can involve some guesswork on the part of engineers. It also relies on blind trust in manufacturers, some of whom make claims about strength and design life that are simply not substantiated.

Fortunately, there is a rulebook. It comes in the form of a UK guide called Structural Design of Modular Geocellular Drainage Tanks (SDMGDT)[1], published by the Construction Industry Research and Information Association (CIRIA). This guide is specifically written for geocellular tanks and offers guidance on testing, structural design, construction and installation. Furthermore, it advises on important considerations for engineers when working with underground stormwater tanks, as well as solutions to regulatory and standards-based challenges.

[1]O'Brien, A, Hsu, Y, Lile, C, Pye, S (2016), The SDMGDT Manual, CIRIA, C737, London (ISBN: 978-0-86017-741-8). Go to www.ciria.org

Why plastic tanks?

Traditionally, concrete tanks are constructed using standard blockwork or precast tank designs which come with, as a minimum, heavy panel lifting and unrealistic conventional component lead times. They offer little flexibility to the engineer, are expensive and take a long time to produce and install.

By contrast, plastic geocellular tanks are easily integrated into a Stormwater Management Plan and:

- offer similar storage capacities while reducing the overall footprint
- are light and modular, enabling easy handling, storage, transport, and installation which will save the installer time and money
- are easily adaptable to provide specific stormwater management functions for a number of applications

For many years around the world, plastic geocellular tanks have been utilised under car parks, driveways, public open spaces, landscaped areas, commercial buildings, industrial areas, airports, military bases and more. They can be utilised for stormwater detention or reuse and offer long-term structural stability and serviceability.

What are the load considerations?

A structural design should consider the load-bearing capacity of the tank.

While short-term strength is vital, just as important is long-term strength and durability.

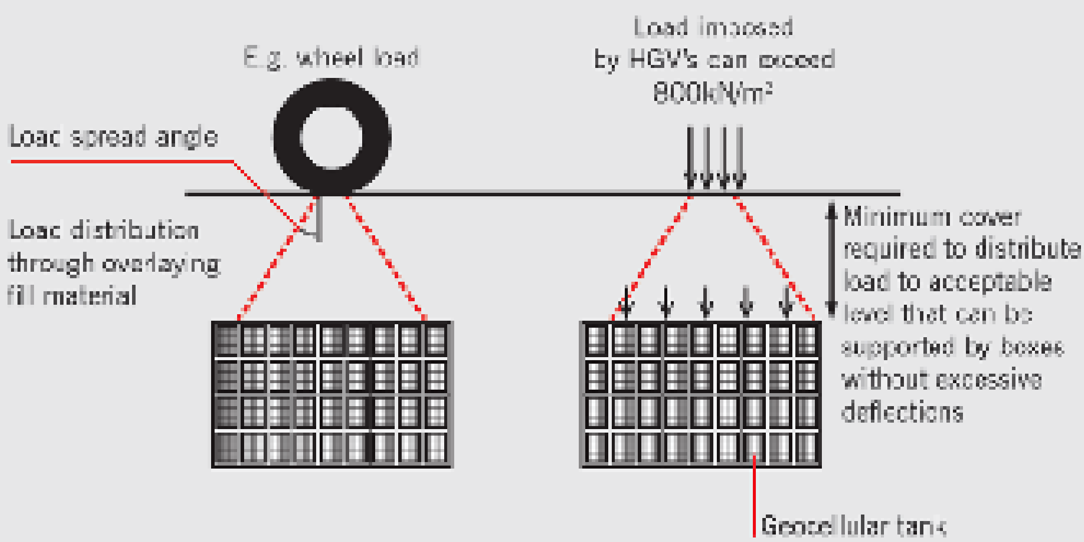
The stronger the tank, the shallower it can be buried, resulting in reduced construction costs and fewer potential collisions with subterranean obstacles such as footings and utilities.

To determine the depth of cover that is required above a tank, engineers must consider:

- **Short-term (dynamic) loads:** including the weight of vehicles traveling overhead
- **Long-term loads:** comprising soil and pavement bearing over the tank for the project's life. Creep is responsible for the gradual deformation of tanks
- **Lateral loads:** relates to soil mechanics, and highly correlated to how deep a tank can be set into the ground
- **Water table depth:** in high water-table areas, poorly designed tank integrations will result in the tank forced upwards and out of the ground by the pressure and movement of groundwater (buoyancy). A high water level also increases the lateral loads on a tank

Further complicating these considerations is the fact that as land use, weather events and water tables change in the future, the tank must be designed for all potential outcomes.

Analysis model for load spread



Short term vertical wheel loads imposed on the geocellular tank.

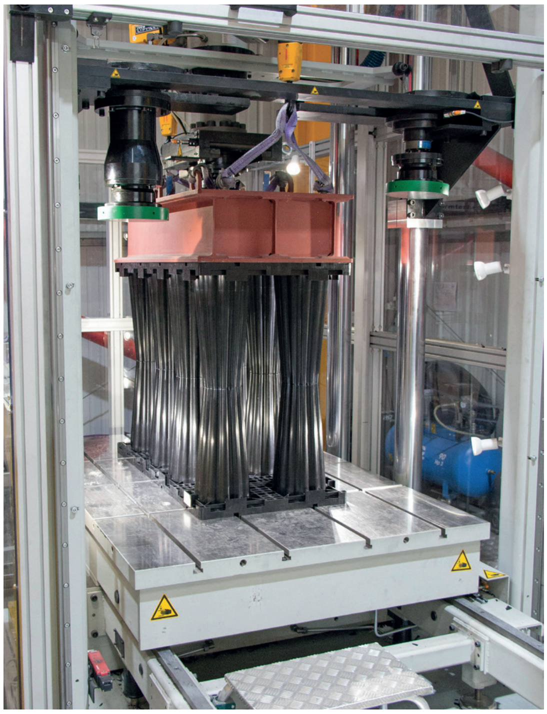
Source: Wilson, S (2008), The SDMGDT Manual, CIRIA, C680, London (ISBN: 978-0-860127-680-0).

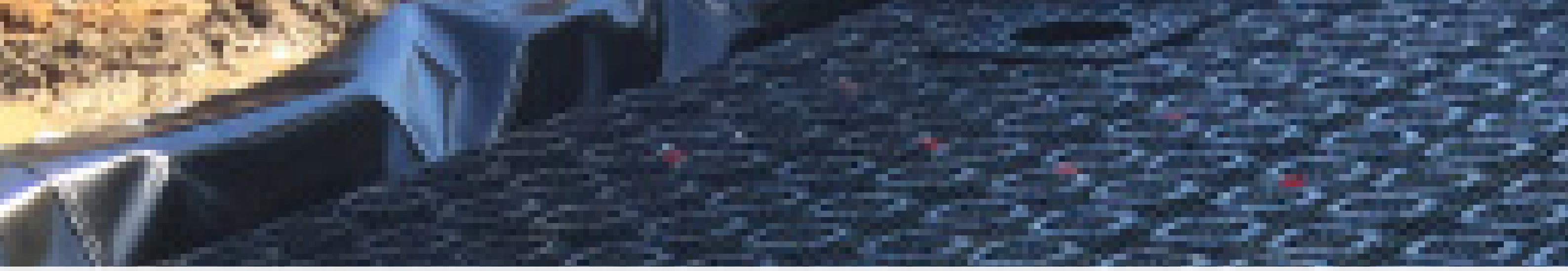
The problem with testing and compliance in Australia

There are no Australian standards governing the structural testing of stormwater geocellular plastic tanks and therefore no industry guidelines for short-term and long-term strength and durability. Some of the main factors identified by CIRIA that contribute to underground stormwater tank failures include:

- insufficient depth of cover
- insufficient pavement thickness
- unaccounted design loads
- high groundwater level
- poor bearing soil
- overstated tank design capacity

To address these, the SDMGDT guide details specific requirements for laboratory strength testing for short-term and long-term vertical and lateral loads.



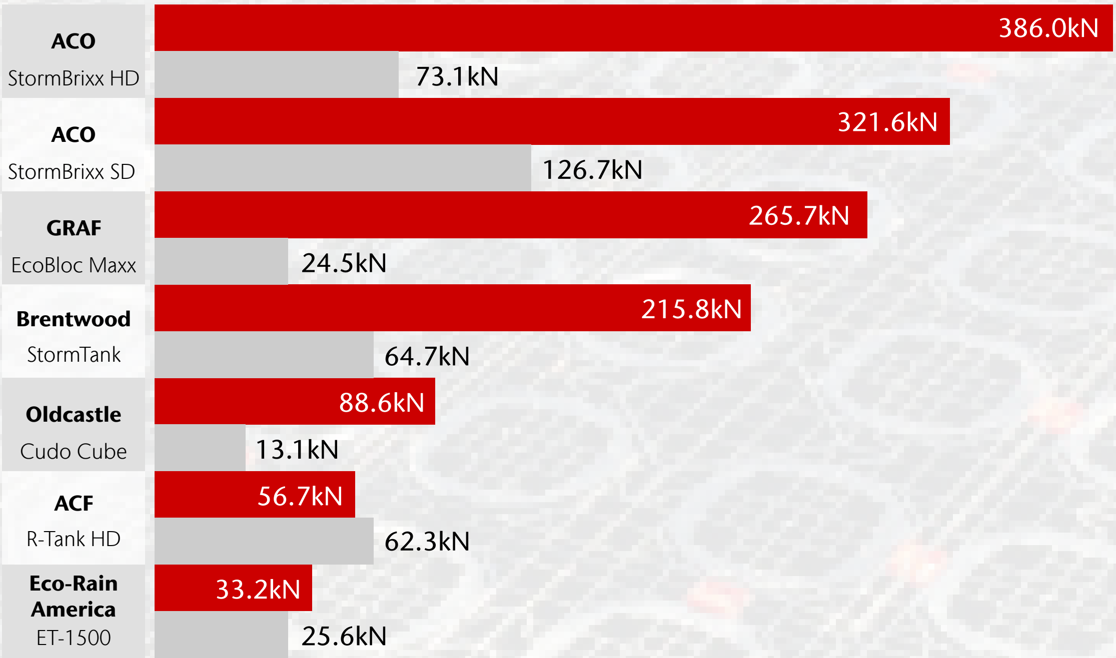


Plastic tanks vary in strength

Some manufacturers only disclose the short-term performance results of their tanks, despite the fact that products must sustainably support loads over their entire design life. Long-term test data contains vital information for a design engineer, so the performance life of the system can be verified. It allows manufacturers to determine and confirm the design life of their tanks, including the tanks' creep resistance capabilities. A lack of information around long-term strength and creep resistance can lead to wrong assumptions during specification.

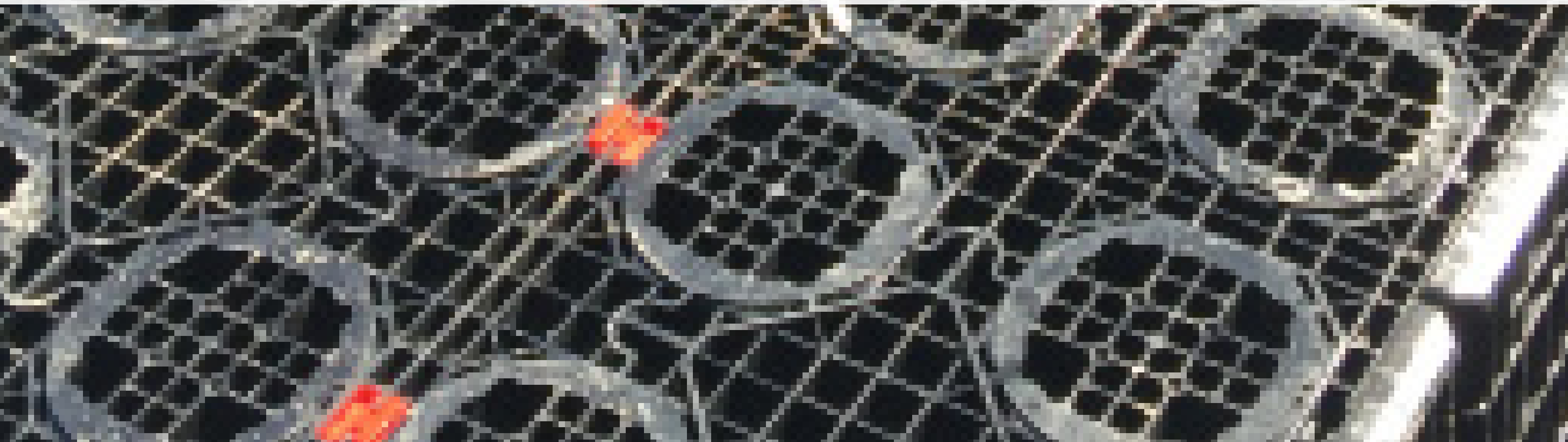
Vertical Maximum Load

Lateral Maximum Load



Relative strength of geocellular plastic tanks under same load conditions.

To view the video, click here



What is CIRIA and how does it work?

For over 60 years, CIRIA has managed and overseen collaborative research to produce information leading to best-practice solutions to problems faced in the construction and engineering space.

The organisation is independent and not for profit. Its vision is "to be a leading enabler and preferred partner for performance improvement, driving collaboration across the built environment and construction sectors for the identification, development and transfer of knowledge".

The SDMGDT is the gold standard for geocellular plastic stormwater products for benchmarking tank performance, one that all manufacturers should qualify their product against. This is the only way to provide some assurance that any product's stated design life can be verified and failures are unlikely.

What is SDMGDT calculation methodology?

SDMGDT addresses the different types of units that are in the industry and offers guidance on manufacturing and the types of testing that must be carried out to determine the strength and deformation characteristics of each type.

SDMGDT also describes for each type of product the geotechnical, structural design and behaviour of the units (and related items) as well as outlining practical issues that should be considered around installation, construction and maintenance.

Recommendations around the design methodology are also offered with case studies and examples.

Understanding what lies beneath the surface.

Why is this important?

Underground stormwater tanks can suffer structural failure. When they do, the failure is often accompanied by the collapse of whatever lies above – soil, pavements, vehicles etc.

According to the SDMGDT guide, failures may not only be caused by problems with materials or quality of manufacture of the tanks, but by:

1. An inadequate design that doesn't take into account ground conditions of a site, or doesn't allow for creep of the units.
2. A lack of understanding of the structural capabilities of the tanks, leading to overloading – for example, the trafficking of very heavy vehicles. Unsuitable backfill (e.g. soil containing boulders) can also contribute to failure.
3. A lack of appreciation of the influence of groundwater levels or the effect of surface water flows into excavations during construction.
4. Inappropriate laboratory testing that overestimates the strength of the units.

When these issues are properly addressed, as the SDMGDT guide[2] outlines, "Plastic geocellular tanks constructed using any of the available units can provide a safe and durable solution for the storage of stormwater below ground."

[2]Wilson, S (2008), The SDMGDT Manual, CIRIA, C680, London, (ISBN: 978-0-86017-680-0). Go to www.ciria.org

Key tank features

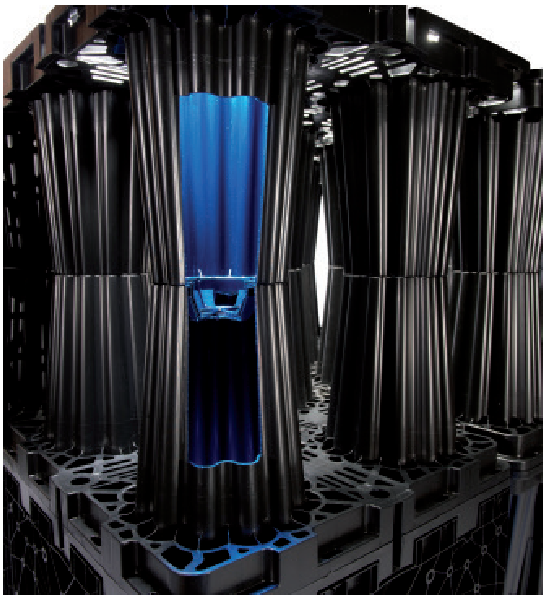
As well as being lightweight, plastics are noted for their structural strength and resilience. They are modern alternatives to concrete and blockwork traditionally used for underground tanks. Polypropylene (PP) is the most commonly used plastic in the manufacture of geocellular drainage tank components as it can be moulded into complex shapes and sizes.

PP is a strong and extremely durable material and does not react with water, acid, or non-oxidising organic compounds. This makes it ideal for underground stormwater tanks ensuring no significant loss of strength throughout a tank's design life.

In recent years, innovative product designs have optimised the structure of geocellular system components to maximise the storage within a tank with a void ratio up to 97%. The inclusion of unique hollow (water storage) pillars act as columns to support vertical loads. This is a giant leap in structural product innovation and acts as an efficient way to transfer the imposed loads from the top of the tank to the foundation beneath.

Structural stability and lateral strength is also important. Modern geocellular components are interlocked together with brickbonding and cross bonding features to provide a rigid tank structure. This results in far greater stability than conventional drainage cells (like crate systems) with nothing connecting or holding the individual cells together, tending to pull them apart once differential settlement occurs.

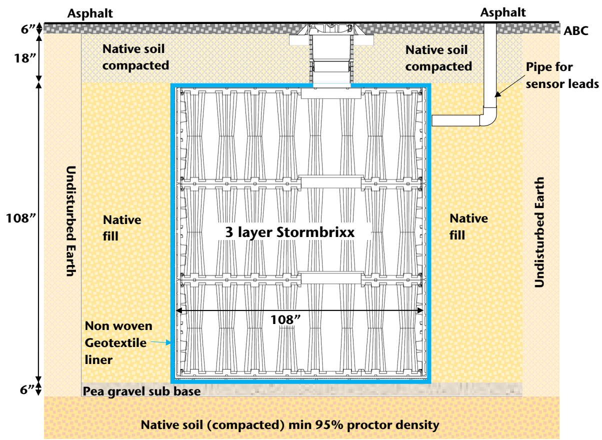
Cross bonding and brickbonding provides a rigid and stable structure.



Innovative product designs - vertical pillars

Full scale empirical testing

ACO has conducted the laboratory tests recommended by SDMGDT as well as real life in-situ tests. Taking a tank out of a controlled environment like a laboratory and measuring behaviour in a typical environment gives all stakeholders a practical indication of performance as well as some assurance.

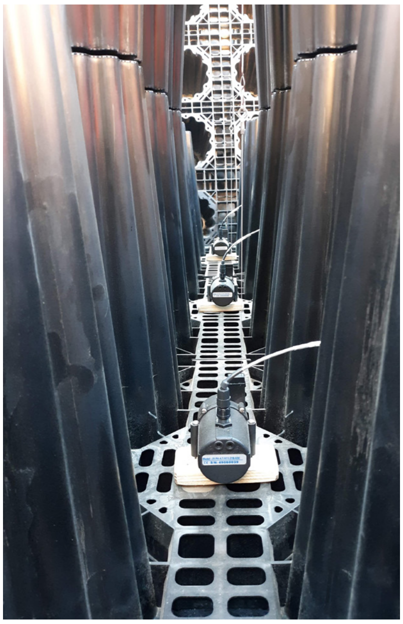


Installation structure of the StormBrixx SD test.

Equipped with sensors to measure vertical deflection and lateral movement, the in-situ tests comprised an installed 3-layer (2.4m x 2.4m x 2.7m deep) StormBrixx SD tank covered with soil and an asphalt layer.

The test data was independently collected and monitored by a leading American university and witnessed by a certified test authority. During the test, a 27.2 tonne water truck was driven numerous times across the tank to simulate dynamic loads. The truck was also parked for a period of time above the tank to ensure static load requirements were met.

The tank met both the vertical and lateral requirements of the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications H-20 load requirement.



In-situ tests used wire potentiometers to measure vertical and lateral pressures.

Fully loaded water truck used in full scale testing of the underground geocellular tank.

To view the video, click here

ACO's simple stormwater tank calculator

To make the structural validation process easier, ACO has designed a simple, online calculator based around the SDMGDT guide.

For individual tanks, engineers can enter the:

- cover depth
- location
- height of water table
- short-term and long-term design loads
- soil type

The calculator's output will include specific solutions to meet the project's requirements, including a checklist of vertical, lateral, hydrostatic loads, and surface deflections.

If any results are over capacity, the design parameter requiring change will be highlighted for revision.

Use the structural calculator for free at
https://askaco.nz/askaco-online/