Maximising the lifespan of plastic geocellular drainage systems

Introduction

Sustainable Drainage Systems (SuDS) have become ever more required in the UK, and worldwide, as a response to climate change and urbanisation. Put simply, SuDS aim to replicate the natural pathways of water (Source: The SuDS Manual[1]). Impermeable surfaces prevent the infiltration of surface water into the soil and so infiltration takes place in other areas, such as soakaways. Where infiltration is not possible or desirable, surface water is 'held back' (attenuated) and discharge controlled to reduce downstream flooding.

Plastic geocellular systems can be used to form an underground structure that creates a void space for the temporary storage of surface water i.e. a tank, for either infiltration or attenuation. They offer advantages for the designer in that they offer high porosity (typically >95%) and are installed underground (i.e. do not take surface area).

Plastic geocellular systems have been used since the late 1980's so there is a lot of experience in designing both the products themselves and their application. CIRIA C737[2] recognises that "*failure of geocellular units are relatively rare." and "The simple guidance given in C680[3] has been shown to be effective and conservative for most applications."* Most of the failures that have been seen are attributable to poor construction and temporary works or poor understanding of ground or groundwater conditions. A few have been attributed to the boxes having inadequate long term strength for the actual site situation.

Geocellular boxes can be manufactured by injection moulding (a variety of box structures, with and without internal support columns), extrusion (typically honeycomb geometries) or by joining thermoformed sheets. Materials most commonly used are polypropylene and polyvinyl chloride and can be 100% virgin material, 100% recyclates or a mix of both.

Testing procedures to achieve design life

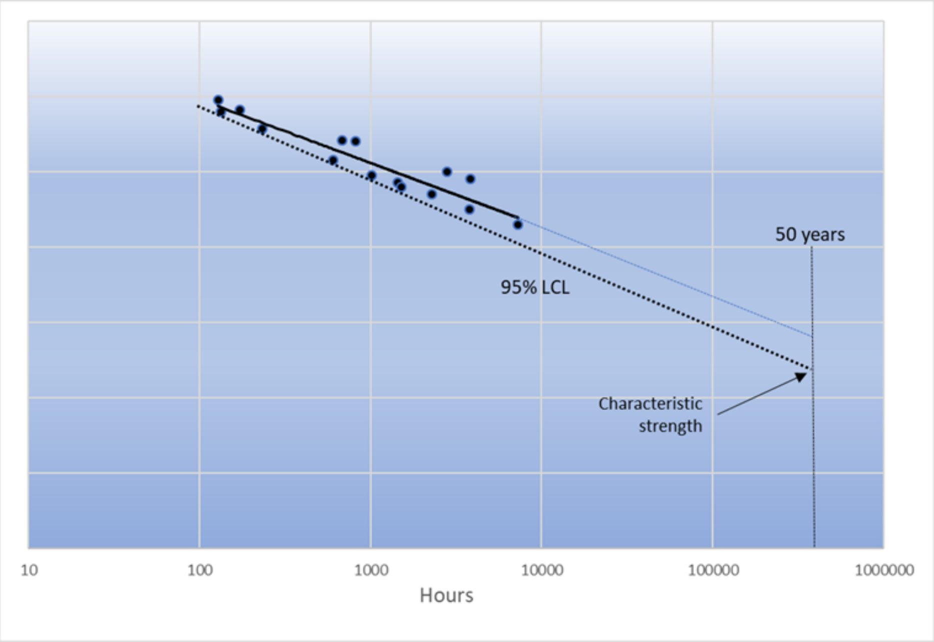
By virtue of being installed underground, geocellular systems can be considered as geotechnical structures. The general principles of designing structures to withstand long-term loads are well established. However, their application is generally for rigid structures such as concrete bridges[4].

The behaviour of thermoplastics is more complex and the reaction to both short term loading (such as vehicular traffic) and long term loading (typically soil surcharge) need to be considered.

BS EN 17152-1 "*Specifications for storm water boxes made of PP and PVC-U*"[5], along with material tests, requires **product** testing to determine characteristic short term strength[6] and characteristic long term strength[7]. In the case of the latter, a series of creep rupture tests is carried out to determine when failure occurs at different loading.

A regression analysis is then carried out to extrapolate the results to 50 years and a 95% Lower Confidence Limit (LCL) is declared as the characteristic strength at 50 years (see Figure 1). This determines the long term load that can be applied **without failure** over the **design life** of the installation. Note that, 50 years is a design point, common across many products, and is not the same as the expected lifespan.

Figure 1 Regression analysis showing characteristic strength at 50 years



A designer can compare the characteristic strengths with the expected loads (with many safety factors included) to ensure that the installation does not fail either by collapse or by deflecting more than allowed at the surface.

Depending on the intended land use above the tank, a box with additional testing outside of the European Standards may be required. A prime example being cyclic or fatigue testing for boxes that are installed under highways or heavily trafficked areas. However, as these types of installations are generally avoided, most boxes are not tested to such a level.

Once the design has been made to ensure no failure within the design life, steps can be taken to maximise the lifespan of the installation.

Design considerations

There are several variables to consider when undertaking the design of geocellular systems. Site characteristics change considerably from site to site. There are different design methods that can be used in the UK, and across Europe. Until Europe-wide guidance for geocellular system design is available, CIRIA C680 is still considered the most reliable design approach in the UK.

The BPF Pipes Group regularly updates a position statement on CIRIA C737 that reflects the views of its members and gives recommendations on guidance designers can follow (https://www.bpfpipesgroup.com/technical-information/position-statements/). Even though structural calculations and testing requirements may vary between design guides, the key considerations remain the same.

Members of the BPF Pipes Group recommend the following is observed during the design process:

- Design to be carried out by competent engineers.
- Use recognised design guidance along with the manufacturer's recommendations.
- Investigate ground conditions on site to determine soil types and groundwater level.
- Use ultimate limit state analysis to check all loads potentially acting vertically and laterally on the tank.
    - Accidental loads from heavy traffic or construction plant.
    - Short term loads caused by traffic movement.
    - Long term loads applied by soil pressure or semi-permanent objects like construction stockpiles and temporary buildings.
- Compare calculated loads against the most current product information from the manufacturer.
- Apply suitable safety factors to the applied loads and product strengths.
- Use serviceability limit state analysis to check tank deflection does not cause unacceptable differential movement to the surface above.

Installation

All geocellular systems should be installed in line with the manufacturer's instructions. By doing so, all the original testing and subsequent design work remains valid. Also, as each system has its own nuances, there may be specific installation instructions that need to be followed. In addition to the boxes, membrane selection is very important. Not only for the tank to attenuate or infiltrate water as intended, but because a leak in the membrane can shift the surrounding backfill and concentrate the loads on the tank.

There are also many other common installation factors that can help reduce the risk of failure:

- Installation to be carried out by capable installers.
- Items handled with care to avoid damage before use.
- Keep components within temperature limits by storing away from direct sunlight and off frozen ground.
- Install on a flat and level surface.
- Use components specified in the design and supplied by the manufacturer (avoid onsite modifications).
- Weld impermeable geomembrane joints and test for water tightness.
- Wrap geomembranes in a protective geotextile fleece.
- Backfill with the specified material and compact in line with the manufacturer's installation instructions.

Maintenance

Maintenance is required to keep the tank operating as intended over its service life. If left unchecked the tank can lose storage volume through siltation and can also be left vulnerable to damage. Due to the different types of tank structures, some are better suited to prevent silt entering the tank, whereas others allow direct access to the tank for CCTV inspection. The product specific O&M Manual from the manufacturer will help ensure maintenance is carried out correctly.

As for all SuDS systems, maintenance should be considered early in the design process, and there are specific maintenance considerations that can help maximise the lifespan of a geocellular system:

- Design tanks off-line rather than on-line.
- A siltation management plan that allows for storage capacity loss in the tank and includes silt treatment upstream.
- Pipe work entering the tank to be accessible for CCTV inspection.
- Do not plant trees and shrubs above the tank without mitigative measures in place such as root barriers.
- Warning signs and barriers to prevent heavy vehicle access if not accounted for in the structural design.
- Location of the tank clearly defined on the maintenance plan, and on site, for easy future identification.

Circular Economy

One of the main ways in which plastic geocellular systems align with circular economy principles is by virtue of their longevity. These are not so-called single use plastics but are engineered systems designed to last more than 50 years. However, should the installed system need to be removed for whatever reason, polypropylene or polyvinyl chloride can be easily recycled and used, either in different products or to make new geocellular boxes, thus ‘closing the loop’.

References

1. The SuDS Manual CIRIA C753, 2015.
2. Structural and geotechnical design of modular geocellular drainage systems, CIRIA C737, 2014.
3. Structural design of modular geocellular drainage tanks, CIRIA C680, 2008.
4. BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design - General rules.
5. BS EN 17152-1:2019 Plastics piping systems for non-pressure underground conveyance and storage of non-potable water – Boxes used for infiltration, attenuation and storage systems; Part 1: Specifications for storm water boxes made of PP and PVC-U.
6. BS EN 17150:2019 Plastics piping systems for non-pressure underground conveyance and storage of non-potable water — Test method for determination of short-term compression strength of boxes.
7. BS EN 17151:2019 Plastics piping systems for non-pressure underground conveyance and storage of non-potable water — Test method for determination of long-term compression strength of boxes.