Comparison of two methods for Hydraulic (Infiltration) Design: BRE Digest 365 and CIRIA156

The background calculations for both methods are the same:

Calculating run-off
Firstly, calculate the run-off volume that will occur from the site during a design storm event, of an intensity that could be expected to occur once in the storm return period.

The greater the soil infiltration rate, the shorter the critical duration will be.

The infiltration system is then designed with sufficient capacity to store this volume of water. This normally involves a layout of AquaCell units with a large surface area adjacent to the soil.

Checking rate of emptying
The rate of emptying must then be checked to ensure that the system empties in a sensible time – normally taken to be at least half-empty within 24 hours.

The purpose of this test is to ensure that the system is empty before the next storm arrives and to avoid problems of water quality caused by storing the water for too long.

Empty rate is a function of the geotechnical properties of the surrounding soil and the wetted area in contact with that soil.

There are significant differences in the methods of calculation between the two methods. Wavin would advise the user to work with whichever method they find to be most acceptable or familiar.

However, to facilitate a decision between the two methods, their key differences are set out as follows:

### The BRE Method
- Only allows the vertical surface areas to be considered as releasing water: assumes the base has been clogged by siltation
- Therefore, favours more linear ‘trench’ layouts with the runs only 1 unit wide to maximise the side surface area in contact with the soil
- Takes a simple approach to the issue of empty-time, assuming a constant outflow rate based upon calculations assuming the tank is half full.

**Overall effect:**
- For shallow tanks: over a given period, the BRE method discharges more water than the CIRIA method
- For deep tanks: over a given period, the BRE method discharges less than the CIRIA method

### The CIRIA Method
- Allows both the sides and the base area to be included in the calculations
- Therefore, tends to generate systems which are more 3D in shape
- To compensate for the risk of the base becoming clogged, includes a factor of safety in the calculations (ranging from 1.5 to 10), the value of which is dependant upon the consequences of failure
- For half emptying time, takes full account of the wetted surface at a particular time instant and thus discharges more water when the tank is full compared to when it is nearly empty.

**Overall effect:**
- For shallow tanks: over a given period, the CIRIA method discharges less water than the BRE method
- For deep tanks: over a given period, the CIRIA method discharges more than the BRE method.

**General conclusion**

The CIRIA calculations are more accurate but involve more complex work that is best carried out by a computer program.

**Further information**

To obtain further information about these methods, please contact the following:
- For BRE Digest 365: www.bre.co.uk or telephone 01923 664000
- For CIRIA 156: www.ciria.org.uk or telephone 0207 222 8891.
EXAMPLE 1: Simplified approximate approach to infiltration

Project details
A new house is to be constructed in an area with blocky fissured chalk soil, into which all stormwater from building and hard surfacing is to be infiltrated. The building has a plan area of 83 m² and surrounding hard surfacing 67 m².

Calculations
Total catchment area = 83 + 67 = 150 m²
Maximum area per box in chalk (Table 2) = 7.9 m²

AquaCell units required
Number of boxes = 150/7.9 = 19 boxes.

EXAMPLE 2: Design of attenuation system

Project details
A factory development of 2000 m² total impermeable areas has had a discharge consent of 3 litres per second placed upon it.

Rainfall levels from the Wallingford Procedure would suggest, in this area for the desired rainfall return period, a run-off volume of 122 m³.

Calculations
Total volume discharged in 2 hour period (Table 5) = 21.6 m³
Volume of storage required = 101 m³
If storage is to be 4 units deep (1.6 m) then volume per layer = 101/4 = 25.25 m³/layer

AquaCell units required

From Table 6, this can be achieved by using either of the following boxes:
- 17 units long, 8 units wide (25.84 m³/layer) (544 boxes)
- 15 units long, 9 units wide (25.65 m³/layer) (540 boxes)
- 19 units long, 7 units wide (25.27 m³/layer) (532 boxes).
19 x 7 provides the most economic solution, but other solutions may fit the site better.
The orifice flow control design equation given in the main text (see Section 2.3.3.1) is derived from the standard equation (from Bernoulli) for a small orifice. It is only valid where the orifice is small when compared with the head above it, and for a sharp edged orifice. The more general equation is given as:

\[ Q = C_d \cdot A_o \cdot \sqrt{2gH} \]

Where:
- \( Q \) = Flow rate (m\(^3\)/s)
- \( C_d \) = Discharge coefficient dependent upon the orifice shape (0.62 typical)
- \( A_o \) = Orifice area
- \( g \) = Acceleration due to gravity, 9.81 m/s\(^2\)
- \( H \) = Head of water (m)
**Design philosophy**

**Structural testing**

The AquaCell units have been tested at Salford University to determine their structural capacity. Direct loading tests were carried out on single units to determine the strength and stiffness parameters. A long-term 90 day creep test was also carried out.

A simplified design procedure has been developed for the AquaCell units. This uses the results of the laboratory testing to directly estimate performance under field conditions.

**Typical results**

Typical results from the laboratory tests to determine short-term compressive strength and deflection rates are shown in Fig. A4.1 for vertical compression, and Fig. A4.2 for lateral compression.

The design limits have been determined following the advice provided in ASTM D-1621 – 00.

**Ultimate compressive strength**

The ultimate compressive strength is determined at the yield point. The short-term vertical deflection of the units under load is obtained from the design line on Fig. A4.1. This value should be used in assessing likely deflections under traffic loads. Design parameters for the AquaCell system are given in Table A.

---

### Table A: Strength and deflection characteristics of AquaCell units

<table>
<thead>
<tr>
<th></th>
<th>Vertical loading on top face</th>
<th>Lateral loading on side face</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultimate compressive strength at yield</strong></td>
<td>560kN/m²</td>
<td>77.5kN/m²</td>
</tr>
<tr>
<td><strong>Short term deflection</strong></td>
<td>1mm per 97.0kN/m² applied load</td>
<td>1mm per 7.0kN/m² applied load</td>
</tr>
<tr>
<td><strong>Long term deflection at up to 10 years, 20°C, 10kN load</strong></td>
<td>Deflection (mm) = 0.4705Ln (time in hours)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Partial factors of safety as appropriate should be applied to these values for design.
Creep

All plastics creep and the design of any structure constructed using polymer materials should take account of it.

Creep testing has been undertaken on the AquaCell units and a typical graph of the results is shown in Fig. A4.3.

The results of the creep tests can be used to estimate settlements up to 20 years. In locations where settlement is not of concern, then designs up to 50 years can be undertaken.

Ultimate and serviceability limit states

Principles

The philosophy of limit state design is used in other structural design applications such as reinforced concrete and steel. The method aims to guarantee that a structure (in this case, the AquaCell system) remains safe and suitable for use at certain limit states.

Limit states

For the AquaCell units, there are two limit states:
- Ultimate limit state: when the structure collapses and is unsafe
- Serviceability limit state: beyond which, although still safe, deflections are excessive and cause cracking or unacceptable movement in the overlying surfacing materials.

Factors of safety

To ensure that the risk of exceeding the limit states is minimal, factors of safety are applied to the ultimate compressive strength and deflection performance of the units and to the applied loads. These are known as partial factors of safety.

Material factors

Variables

The ultimate compressive strength of the units has been obtained from testing on ex-works samples. This may be reduced by factors including:
- Variations during manufacture
- Variability and uncertainties in material strength (e.g. due to extrapolation of data)
- Damage during installation
- Environmental effects.

To take account of these, the design strength is obtained by dividing the ultimate by a material partial factor of safety $F_m$, appropriate to the material and limit state.

Adopted guidance

There is no specific guidance on the choice of material factors for plastic structures such as AquaCell. Therefore the guidance on choice of material factors for thermoplastic geogrids used in earth reinforcement has been adopted.

The partial factors of safety in Table B are appropriate for AquaCell, allowing for extrapolation of creep data, fatigue, etc, and are similar to those used for polymer reinforcement used in reinforced soil applications $^{13,14}$.

Temperature

These factors are only applicable in temperate climate conditions such as the UK.

Although the strength of polypropylene does vary with temperature, this will not be significant for installations in the UK. Here, the temperature in the ground, at the typical depth of installation, remains between $0^\circ$C and $20^\circ$C with a mean value of around $10^\circ$C $^{15,16}$.

Loads and load factors

Loading principles

The loads applied to units can be broken down into separate elements:
- Dead loads are permanent loads applied to the units. They include:
  - The weight of fill placed over the top
  - Lateral earth pressure loads acting on the side of the system.

- Imposed loads are transient loads due to vehicle or pedestrian traffic and construction traffic.

  Traffic wheel loads are normally given as static loads and a factor is applied to allow for dynamic effects $^{17}$.

- Design load

  The design load is obtained by applying a partial factor of safety to the estimated characteristic load. This allows for:
  - Unforeseen variations of loading
  - The severity of the consequences of the limit state occurring.
The loads on the units will be similar to loads applied in the design of structures using conventional materials such as concrete. Accordingly, the partial safety factors for loads that are appropriate to the design of the AquaCell system are taken from British Standard BS 8110 and are provided in Table C.

**Thermal expansion**

Thermal expansion of the units will be negligible because temperature variations that are likely to occur in the ground should not be significant. These loads are not, therefore, considered in design.

**Maximum depth of installation**

**Limiting factors**

The limiting factors that determine the maximum depth of installation are:
- The weight of cover fill and live surcharge loads
- The lateral pressures imposed by the earth and groundwater on the sides of the system.

For all of these cases both the ultimate and serviceability limit states must be considered:

**Weight of cover fill and live surcharge loads**

The pressure on the system due to the weight of cover fill and surcharge \( \sigma_v \) is equal to:

\[
\sigma_v (\text{kN/m}^2) = (d \gamma) + \sigma_{\text{traffic}}
\]

where
- \( d = \) depth of fill material over units, m
- \( \gamma = \) unit weight of fill material, kN/m\(^3\)
- \( \sigma_{\text{traffic}} = \) surcharge load, kN/m\(^2\)

The unit weight of fill material typically lies between 17 kN/m\(^3\) and 21 kN/m\(^3\). No allowance has been made for factors such as dissipation of load through friction with the side of the trench, since this depends on very tight site control over installation which cannot generally be guaranteed.

Where the installation will be subject to traffic loads, such as below a car park, a surcharge of 2.5 kN/m\(^2\) should be applied as defined in British Standard BS 6399: Part 1: 1996. Greater surcharge loads will be applicable for more heavily loaded applications.

**Lateral earth and water pressure**

When the AquaCell units are buried in the ground, the earth around the sides of the excavation will exert a pressure on the units. If the units are wrapped in an impermeable geomembrane and placed below groundwater, there will also be a water pressure (see Fig. A4.4).

The magnitude of the pressure varies with a number of factors including:
- The strength of the soil
- The ground profile
- The extent of any traffic surcharge loading.

### Table C Partial safety factors for loads

<table>
<thead>
<tr>
<th>Limit state</th>
<th>Vertical dead load</th>
<th>Earth pressure (horizontal) dead</th>
<th>Imposed live load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( F_u )</td>
<td>( F_p )</td>
<td>( F_s )</td>
</tr>
<tr>
<td>Ultimate limit state</td>
<td>1.40</td>
<td>1.40</td>
<td>1.60</td>
</tr>
<tr>
<td>Serviceability limit state</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

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Calculating earth pressure

A simplified method of estimating earth pressures is presented to allow an estimation of the maximum installation depth for the units, which should give conservative results. However, care must be taken by designers to ensure that all the assumptions are applicable to a particular site.

For a uniform cohesionless soil the lateral pressure acting on the side of the system (Figure A3.3) at any depth is given by Rankine:

$$\sigma = K_a(h - u) + u + K_d(d_w)$$

where:

- $\sigma$ = Active earth pressure (kN/m²)
- $K_a$ = Coefficient of active earth pressure = \frac{1}{1 + \tan \phi}$
- $u$ = Water pressure (kN/m²)
- $h$ = Depth from ground surface, m
- $\phi$ = Angle of shearing resistance of soil, degrees
- $d_w$ = Depth of penetration below water table, m
- $K_d$ = Coefficient of buoyancy
- $d_m$ = Depth of penetration below ground surface, m

### Total horizontal pressure

$$\text{Total horizontal pressure} = \text{earth pressure} + \text{water pressure} + \text{pressure due to surcharge}$$

$$\sigma = K_a(h - u) + u + K_d(d_w)$$

Where:

- $K_a$ = Coefficient of active earth pressure = \frac{1}{1 + \tan \phi}$
- $u$ = Water pressure (kN/m²)
- $h$ = Depth from ground surface, m
- $\phi$ = Angle of shearing resistance of soil, degrees

### Determining pressure on sides of units

The maximum pressure acting on the sides of the units can then be determined. Earth pressures are dependent on a number of factors.

To allow the determination of the simplified design tables in this manual, certain assumptions have been made:

- Smooth wall – no friction
- Horizontal ground surface
- No cohesion, as it cannot be relied on in infiltration situations where softening may occur
- No sliding or overturning will occur as the units are restrained by the opposite side of the excavation and the weight of the fill over them will prevent upwards buckling.

These may not apply in all site specific designs. Using the preceding theory, the results of the tests on the side faces of the units, and the load and material partial factors, the maximum limiting depth of installation of the system can be determined.

### Flotation

**Preventing uplift**

When the AquaCell units are wrapped in geomembrane and placed below the groundwater table, flotation may occur. To prevent this the weight of the soil over the top of the units must be greater than the uplift force due to buoyancy in the water.

For a unit area the uplift force is given by:

$$\gamma u d_m$$

where:

- $\gamma$ = Unit weight of water, kN/m³
- $u$ = Water pressure (kN/m²)
- $d_m$ = Depth of penetration below water table, m.

The uplift force is resisted by the weight of the soil over the units which is given by:

$$\sigma_u (\text{kN/m}^2) = \gamma d_m$$

where

- $\sigma_u$ = Active earth pressure (kN/m²)
- $d_m$ = Depth of fill material over units, m
- $\gamma$ = Unit weight of fill material, kN/m³

In this instance a partial factor of 0.8 should be applied to the weight of the soil over the units as it is acting in a beneficial manner.

The surcharge due to traffic loads is ignored as this cannot be guaranteed to be present.

For simplicity, the required factors of safety can be achieved with most fill types if the depth of cover fill is equal to or greater than the depth of penetration of the units below groundwater level.

### Minimum depth of cover

**Limiting factors**

The limiting factors to be considered when determining minimum cover depth are:

- Traffic loads
- Construction loads
- Ultimate and serviceability limit states.

### Traffic loads

The AquaCell units must be able safely to support concentrated wheel loads from traffic (ultimate limit state). Undue deflection under traffic loads must also be prevented (serviceability limit state) otherwise the surfacing materials will be damaged (asphalt, concrete or block paving).

This is achieved by spreading the load through the surface and underlying fill to limit settlement to acceptable levels.

The applied pressure on the ground surface from the individual wheel load is given by:

$$\sigma_u (\text{kN/m}^2) = W F_d / A$$

Where:

- $W$ = Wheel load, kN
- $F_d$ = Dynamic factor to allow for the dynamic effects of the moving wheels
- $A$ = Tyre contact area.

The wheel loads and contact area for a car park are given in Table D.

### Heavy loads

For more heavily loaded applications, the precise nature of the wheel loads, types of vehicle and frequency of trafficking will be required.

The resulting pressure that is applied on top of the AquaCell units can be determined (including the weight of the fill material) and thus the deflection of the units can be calculated.

$$\sigma_u (\text{kN/m}^2) = W F_d / A' + \gamma$$

Where:

- $A'$ = Area of applied load on AquaCell unit (see Fig. A4.5).

### Table D Imposed loads for car parks (from BS 6399: Part 1: 1996)

<table>
<thead>
<tr>
<th>Load</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrated wheel load</td>
<td>9kN</td>
</tr>
<tr>
<td>Uniformly distributed load</td>
<td>2.5kN/m²</td>
</tr>
<tr>
<td>Dynamic factor</td>
<td>1.0</td>
</tr>
<tr>
<td>Tyre contact area</td>
<td>200mm by 200mm</td>
</tr>
</tbody>
</table>

Loads in areas used for parking for cars and light vans, not exceeding 2500kg gross mass, except for very occasional refuse collection trucks or similar, typically one per week.
Load spread

The spread of load depends on the type of materials overlying the units.

For well compacted type 1 sub-base a load spread of 45° may be appropriate whereas for poorly compacted selected as dug material a distribution of 27° is more typical.

The effects of traffic loads are transient and only occur in the short term. Therefore short-term load/deflection values are used in design with an appropriate material partial factor to allow for fatigue.
APPENDIX: 5
Specification

5A  Element: AquaCell Attenuation System
Type: Pre-formed Geocellular Tank System

Shall comprise modular geocellular box structures designed specifically for the purpose of subterranean structural storage and distribution of water.

Installation of Geocellular Tank System

The geocellular units shall be installed strictly in accordance with the manufacturer’s recommendations and in a manner that will not cause damage.

The constructed tank shall be surrounded with a robust welded impermeable membrane, overlaid with a heavy-duty geotextile protection fleece prior to carefully backfilling with selected granular material to the approval of the Engineer.

5B  Element: AquaCell Infiltration System
Type: Pre-formed Geocellular Tank System

Shall comprise modular geocellular box structures designed specifically for the purpose of subterranean catchment and soakaway of water.

Installation of Geocellular Tank System

The geocellular units shall be installed strictly in accordance with the manufacturer’s recommendations and in a manner that will not cause damage.

The constructed tank shall be surrounded with a permeable geotextile prior to carefully backfilling with selected granular material to the approval of the Engineer.

Typical Physical Properties of the Geocellular Units shall be:

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Unit Dimensions</td>
<td>1000 x 500 x 400</td>
<td>mm</td>
</tr>
<tr>
<td>Nominal Unit Volume</td>
<td>0.2</td>
<td>m³</td>
</tr>
<tr>
<td>Nominal Storage Volume</td>
<td>0.19</td>
<td>m³</td>
</tr>
<tr>
<td>Porosity (Void Ratio)</td>
<td>95</td>
<td>%</td>
</tr>
<tr>
<td>Ultimate Compressive Strength at Yield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Vertical Loading on Top Face</td>
<td>560</td>
<td>kN/m²</td>
</tr>
<tr>
<td>– Lateral Loading on Side Face</td>
<td>77.5</td>
<td>kN/m²</td>
</tr>
<tr>
<td>Short Term Deflection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Vertical Loading On Side Face</td>
<td>1 per 97</td>
<td>mm per kN/m² (applied load)</td>
</tr>
<tr>
<td>– Lateral Loading On Side Face</td>
<td>1 per 7</td>
<td>mm per kN/m² (applied load)</td>
</tr>
<tr>
<td>Estimated Long Term Deflection (at up to 10 years at 20 °C at 10kN load)</td>
<td>0.4705</td>
<td>Ln (time in hours)</td>
</tr>
</tbody>
</table>
Installation of Domestic Attenuation System Control Chamber

The control chamber shall be installed strictly in accordance with the manufacturer's recommendations and in a manner that will not cause damage.

1m deep domestic attenuation system control chamber would use a sealed, square cover and frame, suitable for use with foot traffic only with a 450mm opening size for use to depths up to 1.2m (e.g. 6D935 Polypropylene cover and frame). When surrounded by a concrete plinth can be used in situations with loading up to 35kN (3.5 Tonnes), i.e. domestic driveways.

1.25m deep domestic attenuation system control chamber would use a sealed, square cover and frame, suitable for use with foot traffic only with a 350mm opening size for use at depths greater than 1.2m (e.g. 6D939 Polypropylene cover and frame). When surrounded by a concrete plinth can be used in situations with loading up to 35kN (3.5 Tonnes), i.e. domestic driveways.

Note: If the 1.25m deep chamber is cut to size to accommodate 0.5m or 0.6m depth of cover AquaCell situations, a 450mm opening size cover and frame should be used (6D935).

Typical Physical Properties of the domestic attenuation system control chamber shall be:

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Unit Size for garage void storage</td>
<td>1000 x 500</td>
<td>mm deep x mm diameter</td>
</tr>
<tr>
<td>Nominal Unit Size for AquaCell storage</td>
<td>1250 x 500</td>
<td>mm deep x mm diameter</td>
</tr>
<tr>
<td>2 Incoming Connections</td>
<td>100</td>
<td>mm diameter</td>
</tr>
<tr>
<td>1 Outgoing Connection</td>
<td>100</td>
<td>mm diameter</td>
</tr>
<tr>
<td>1 Connection to Storage Facility</td>
<td>150</td>
<td>mm diameter</td>
</tr>
<tr>
<td>Discharge Rate at 150mm head</td>
<td>0.8</td>
<td>litres/sec</td>
</tr>
<tr>
<td>Discharge Rate at 225mm head</td>
<td>1</td>
<td>litres/sec</td>
</tr>
<tr>
<td>Discharge Rate at 300mm head</td>
<td>1.16</td>
<td>litres/sec</td>
</tr>
<tr>
<td>Discharge Rate at 400mm head</td>
<td>1.4</td>
<td>litres/sec</td>
</tr>
<tr>
<td>Storage Depth created for garage void type</td>
<td>300</td>
<td>mm</td>
</tr>
<tr>
<td>Storage Depth created for AquaCell type</td>
<td>400</td>
<td>mm</td>
</tr>
</tbody>
</table>
**APPENDIX: 5**

**Specification**

**5D Element: Waterproof Geomembrane**

**Type: Polypropylene**

A single layer loose laid geomembrane suitable for environmental protection to underground structures, containments and cut-off trenches.

Polypropylene combines excellent chemical resistance with low flexural modulus to provide a malleable, flexible membrane suitable for non-smooth surfaces and factory prefabrication to optimise on site installation.

Application temperature of the geomembrane shall be greater than 4°C.

Number of layers: One (1)

Laps – minimum 50mm

Jointing: Shall be formed using fusion (twin wedge) or extrusion bead welding in accordance with manufacturer’s recommendations.

**Workmanship Generally**

Prelaying checks: Surface acceptability. Before laying check that substrate surfaces are:

- a) Structurally sound.
- b) Free from ridges and undulations.
- c) Surface dry.
- d) Cleaned of loose and extraneous material.

Construction Acceptability

Before laying check that construction allows geomembrane continuity to be maintained.

Laying Geomembrane

The Geomembrane is to be installed by qualified operatives recommended by the geomembrane manufacturer and prefabricated into panels where appropriate to suit site requirements.

Laid strictly in accordance with manufacturers recommendations.

When temperature is 4°C and falling, a hot air pre-heat system of welding should be adopted.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness mm +/- 10%</td>
<td>1.0 ASTM D-751</td>
</tr>
<tr>
<td>Density g/cm³ Min</td>
<td>0.9 ASTM D-792</td>
</tr>
<tr>
<td>Tensile Stress @ Break Min N/mm²</td>
<td>18 ASTM D-638</td>
</tr>
<tr>
<td>Elongation @ Break %</td>
<td>&gt;700 ASTM D-638</td>
</tr>
<tr>
<td>Puncture Resistance Min N</td>
<td>150 FTMS 101C Method 2065</td>
</tr>
<tr>
<td>Tear Resistance Min N</td>
<td>60 ASTM D-1004</td>
</tr>
<tr>
<td>Dimensional Stability % Change Max</td>
<td>+/- 2.0 ASTM D-1204</td>
</tr>
<tr>
<td>Stress Crack Resistance</td>
<td>100% ASTM 5397</td>
</tr>
<tr>
<td>Volatile Loss 5%</td>
<td>0.2 ASTM D-1203 Method A</td>
</tr>
<tr>
<td>Loss Max</td>
<td></td>
</tr>
<tr>
<td>Ozone Resistance</td>
<td>No Cracks ASTM D-1149</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>2 – 3% ASTM 1603</td>
</tr>
<tr>
<td>Moisture Vapour g/m²/day</td>
<td>&lt; 0.1 ASTM E96</td>
</tr>
<tr>
<td>Friction Angle</td>
<td>21˚ Shear Box</td>
</tr>
<tr>
<td>(Non Woven Geotextile)</td>
<td></td>
</tr>
<tr>
<td>Methane Permeability</td>
<td>0.11 g/m²/day/atm European Standard</td>
</tr>
<tr>
<td>Methane Transmission Rate</td>
<td>0.8 x 10⁻³ m³/m²/s/atm BRE</td>
</tr>
<tr>
<td>Permeability Coefficient</td>
<td>1.8 x 10⁻¹²</td>
</tr>
</tbody>
</table>

**Protection Generally**

Protect the finished insulation adequately to prevent damage during following works.

Cover the geomembrane with permanent overlying construction as soon as possible.

Immediately prior to covering check for damage and repair as necessary.

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Pre-installation notes:

- Attenuation systems: connect the inflow and outflow pipework level with the base of the AquaCell structure.
- Infiltration systems: connect the inflow pipework into the top of the AquaCell structure.

Order of Works:

1. Excavate hole or trench to required depth, dimensions and levels. Ensure that the plan area is sufficient to allow compaction plant access around sides to compact backfill material (300mm minimum). Ensure base is smooth and level with no sharp drops or humps. Check slopes are cut to a safe angle or adequately supported and that safe access is provided to allow personnel to enter excavation.

2. Inspect base and ensure there are no soft spots in the formation. If any soft spots are present excavate out and replace with compacted granular fill material.

3. Lay 100mm coarse sand bedding layer to base of excavation and level. Lay geotextile protection fleece if required for geomembrane (i.e. attenuation).

4. Lay geomembrane (or geotextile if infiltration) over sand bedding layer and up the sides of the excavation. Inspect geomembrane for damage and test all welds as required.

5. Install the AquaCell units in accordance with installation schedule for correct orientation, i.e. parallel with each other or “brick bond” as required, wherever possible, continuous vertical joints should be avoided. Arrange units so that pre-formed sockets are in correct alignment for inlet and outlet pipes. For single layer applications use the Wavin clips and for multi layers use Wavin clips and shear connectors.

6. Complete geotextile or geomembrane encapsulation to base, sides and top of installation, including protection fleece where required. Geomembrane should be welded with double seams. Inspect geomembrane for damage and test all welds as required.

7. Make drainage connections to installation utilising proprietary adaptors. Ensure pre-formed socket positions for pipe connections are located at correct position for receiving pipework. Alternatively use flange adaptors attached to AquaCell units with adhesive tape and self-tapping screws (note flange adaptors cannot be used at invert of AquaCell units into the pre-formed socket). It is recommended that all connections and air vent installations in attenuation applications are made using a flange adaptor, using adhesive or double sided tape to form a seal. Alternatively seal drainage connections into a pre-formed socket using proprietary seals approved by the geomembrane manufacturer.

8. Backfill around installation with Type 1 or 2 sub base or Class 6P (side fill only) selected granular material in accordance with the Specification for Highway Works. Compact in 150mm layers.

9. Place coarse sand protection layer if required over top of units. Continue to backfill excavation with:

   - Trafficked areas (car parks etc): Type 1 or 2 sub base material compacted in 150mm layers in accordance with Specification for Highway Works. Compaction plant over top of system not to exceed 2300kg per metre width.

   - Landscaped and non-trafficked areas: selected as-dug material with size of pieces less than 75mm compacted to 90% maximum dry density. Compaction plant over top of system not to exceed 2300kg per metre width.

10. Complete pavement construction or landscaping over the AquaCell system.
**Installation of Garastor in conjunction with the undercroft/void of a garage**

**Notes:**

When using Garastor with the undercroft/void of a garage, it is the responsibility of the designer to ensure that the enhancement to the garage undercroft/void and drainage works comply with current prevailing Building Regulations.

Also to prevent softening of the soils below the foundations or loss of fines leading to settlement, the void beneath the garage should be lined as follows:

- Underneath the concrete base of the void area there should be a 1200g polythene damp proof membrane
- Bitumastic paint should be applied to the walls of the void area and to the underside of the reinforced garage floor beams.

Fig. A6.1 shows a typical garastor installation using garage void.

**Order of Works:**

1. Place the Garastor unit (6SC500) on a minimum of 100mm 'as-dug' or granular material. Ensure that the unit is as close to the garage undercroft/void as possible and in a suitable position to allow pipework connection.

   **Note:** it is important to ensure that the Garastor unit is placed in a level position and that the invert of the 150mm pipe connection is level with the base of the concrete undercroft/void.

2. Connect the relevant pipework in accordance with standard pipe installation guidelines.

3. Surround the Garastor unit with 150mm of material similar to that used for the bedding.

4. Fit a 6D935 cover and frame (from the OsmaDrain range) to the top of the Garastor unit.

5. Adequate ventilation must be provided to the undercroft/void area using either air bricks or rainwater downpipes connected directly into the storage area.

   **Note:** when surrounded by a concrete plinth (150mm x 150mm) the cover can be used in situations with a loading up to 35kN (3.5 Tonnes) i.e. domestic driveways.
Installation of Garastor in conjunction with AquaCell units

Notes:

When using Garastor in conjunction with AquaCell units, reference should be made to relevant AquaCell installation details.

The Garastor unit is designed to cover installation depths up to 1.25m deep. In situations where AquaCell cover is 0.5m or 0.6m, cut chamber of unit to suit.

1. Place the garastor unit (6SC501) on a minimum of 100mm ‘as-dug’ or granular material. Ensure that the unit is as close to the AquaCell structure as possible and in a suitable position to allow pipework connection.

   Note: it is important to ensure that the chamber is placed in a level position and that the invert of the 150mm pipe connection is level with the base of the AquaCell units.

2. Connect pipework in accordance with standard pipe installation guidelines.

3. Surround the Garastor unit with 150mm of similar material to that used for the bedding.

4. For installations up to and including 1.2m deep fit a 6D935 cover and frame (from the OsmaDrain range) to the Garastor unit. Alternatively for installations deeper than 1.2m fit a 6D939 cover and frame.

   Note: when surrounded by a concrete plinth (150mm x 150mm) the cover can be used in situations with a loading of up to 35kN (3.5 Tonnes) i.e. domestic driveways.

5. Adequate ventilation must be provided to the AquaCell structure using a Wavin Air Vent. (NB. One air vent is required per 7,500 square metres of impermeable surface to be drained - see Fig.2.12, Section 2.3.6).
Adsorption – The adherence of pollutants or other substances to surfaces.

Aquifer – Layer of rock or soil that holds or transmits water.

Asphalt – A mixture of mineral aggregates and bitumen used in the construction of road and car park surfaces.

Attenuation – Slowing down the rate of flow to prevent flooding erosion, with a consequent increase in the duration of flow.

Block paving – Pre-cast concrete or clay brick-sized flexible modular paving system.

Catchment area – The area contributing flow to a point on a drainage or river system.

Construction Quality Assurance (CQA) – A documented management system designed to provide adequate confidence that items or services:
- Meet contractual requirements
- Will perform adequately in service.

CQA usually includes inspection and testing of installed components, and recording the results.

Controlled Waters – Waters defined and protected under the Water Resources Act 1991, including inland freshwaters (relevant lakes and ponds, rivers and other watercourses), groundwater and coastal waters.

For the full definition refer to the Water Resources Act 1991.

Creep – Long term deformation which continues under a constant load.

Geomembrane – An impermeable plastic sheet, typically manufactured from polypropylene, high density polyethylene or other geosynthetic material.

Geotextile – A plastic fabric which is permeable.

Groundwater Protection Zone (Source Protection Zone) – Areas around public water supply boreholes where groundwater must be protected from pollution.

These are defined by reference to travel times of pollutants within the groundwater.

For specific details, see the Environment Agency’s Policy and Practice for the Protection of Groundwater.

Hydrocarbons – Contaminants derived from petrol, diesel and oil.

Impermeable – Will not allow water to pass through it.

Infiltration – The passage of water through a surface into the underlying ground.

Permeability – A measure of the ease with which a fluid can flow through a porous medium.

This depends on the physical properties of the medium (e.g. grain size, porosity and pore shape).

Return period – How often an event occurs.

Run-off – Water flow over the ground surface to the drainage system. This occurs if the ground is impermeable or is saturated.

Soakaway – A sub-surface structure into which water is conveyed to allow infiltration into the ground.

Source control – The control of run-off at, or near, its source.

Sub-base – The layer of aggregate laid on the soil (or capping layer) to provide a stable foundation for construction of the road pavement.

SuDS – Sustainable Drainage Systems: a sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques.

Type 1 sub-base – Specification for the most commonly used sub-base material in conventional pavements – as prescribed by the Specification for Highway Works.

A 100-year storm refers to a storm event that occurs, on average, once every hundred years. In other terms, the annual likelihood of repetition is 1% (1/100).

A 500-year storm is the storm event expected to occur only once every 500 years. In this case, the annual likelihood of repetition is 0.2% (1/500).
References


xii Construction Industry Research and Information Association (1996). CIRIA Special Publication 124, Barriers, liners and cover systems for containment and control of land contamination.


Further Sources of Information:

