

Polystorm & Polystorm Lite Technical Guide



Water Management Solutions
Design, planning, specification and installation guidelines

Water Management Solutions

Modular Cell Systems

Design, planning, specification and installation guidelines

From the **technical specialists**, Polypipe Water Management Solutions. The Polystorm range of products and solutions for **attenuation and soakaway** applications.

This document describes the products from Polypipe Water Management Solutions for implementing a **stormwater management** system that meets the requirements for **Sustainable Drainage Systems** (SUDS).

Purpose of this document

This document provides full technical details on Polypipe WMS Polystorm products and explains how to:

- select products to provide the best solution for your specific stormwater requirements
- incorporate products into your project's design
- install products on-site

Other relevant documents from Polypipe WMS

- Ridgidrain/Ridgisewer and Polysewer Design and Installation Manuals
- Forms for specifying your requirements for Catchpits and Stormcheck chambers

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Index - how this document is organised



The document is presented in clearly marked sections to help you navigate and find the information you require quickly and easily.

- Section 1 - provides an overview of SUDS.
- Section 2 - provides guidance on drainage design and helps you select which product to use for managing a site's stormwater run-off.
- Section 3 - provides testing and certification information.
- Section 4 & 5 - describe design protocol, installation and maintenance.
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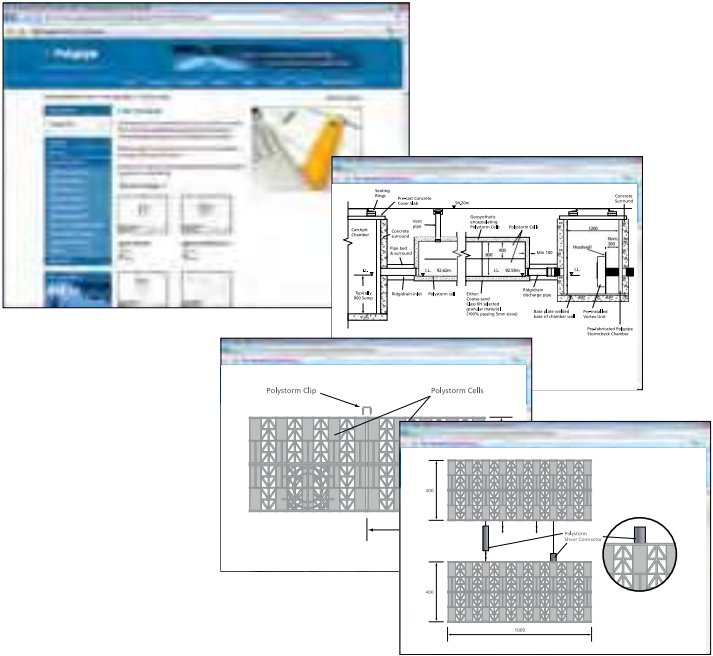
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* Please note:

Illustrations shown within this publication are available as downloadable CAD drawings from www.polypipewms.co.uk



1.0 Overview

Polypipe Water Management Solutions

Part of the overall Polypipe Civils business, the Polypipe Water Management Solutions (WMS) team includes some of the most talented Civil Engineers and Water Management Specialists within the industry to provide dedicated knowledge, support and technical expertise for a wide range of sustainable drainage systems (SUDS) and water management projects.

Today, the concept of sustainable water management is a major driver in the UK construction industry. Planning Policy Statement 25 (PPS25) requires local planning authorities to institute policies that enforce, wherever possible, the use of Sustainable Drainage Systems or SUDS. Combine this with the Floods and Water Management Act and it becomes obvious that specifying the correct sustainable drainage solution is vital.



Polypipe WMS are totally dedicated to focusing on the legislative drivers and industry developments in order to provide innovative, future proof sustainable Water Management Solutions to our customers and the UK construction industry.

Overview

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1.1 SUDS - sustainable drainage best practise and building regulations

Sustainable drainage systems are an alternative to the traditional approach of collecting stormwater in pipes and discharging it into treatment works or watercourses. SUDS best practice limits the flow of rainwater which runs off a site or is piped away, protects local watercourses from the contamination carried in surface run-off, encourages natural groundwater recharge (where appropriate) and reduces the likelihood of downstream flooding.



1.1.1 Building regulations

The Building Regulations Approved Document H3, Rainwater Drainage, which came into effect on 1st April 2002, prioritises drainage requirements. In short, it requires that rainwater from the roof of a building or from a paved area may either be gathered for re-use in a rainwater tank or be discharged into one of the following, listed in order:

- (a) an adequate soakaway or some other adequate infiltration system; or, where that is not reasonably practical,
- (b) a watercourse; or, where that is not reasonably practical,
- (c) a sewer.

In other words, the traditionally preferred method of rainwater disposal, i.e. totally discharging to a sewer, may now only be considered after other forms of re-use or drainage have been considered.

1.1.2 SUDS Best Practice CIRIA C697

The SUDS Manual, published by CIRIA 2007 (CIRIA C697) defines that a sustainable urban drainage system should consider certain basic requirements, including:

- Run-off from a developed area should be no greater than the run-off prior to development
- Run-off from a developed area should not result in any down-grading of downstream watercourses or habitat
- Consideration should be given at the development feasibility stage to water resource management and control in the developed area
- Run-off should replicate as far as possible the natural response of the site to rainfall

SUDS best practice limits the flow of rainwater which runs off a site or is piped away, protects local watercourses from contamination carried in surface run-off, encourages natural groundwater recharge (where appropriate) and reduces the likelihood of downstream flooding.

1.1.3 The Code for Sustainable Homes

The Building Regulations also provide guidance on the construction of rainwater harvesting systems for the first time. The newly published Guidance Document entitled 'The Code for Sustainable Homes' indicates the Government's intentions to further drive developers towards building sustainable homes.

As well as covering energy efficiency, water usage and waste, the Code also proposes a minimum standard for surface water management. This minimum standard will require peak run-off rates or annual run-off volumes of surface water to be no more than the original conditions of the site.

The challenge each developer faces on both greenfield and brownfield developments is what to do with the excess run-off generated by a development which has to be retained in and around the site.

Polypipe WMS

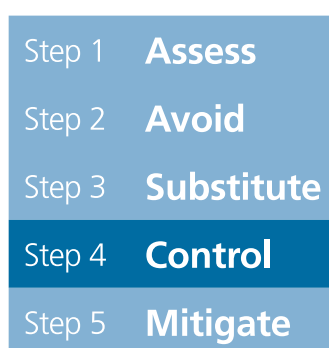
provide the developer, both large and small, with flexible value engineered solutions which cater for almost any site conditions and restraints.



1.2 Drainage design - planning, cost effective techniques, site evaluation, adoption and future maintenance



Many authorities will expect planning applications, whether outline or detailed, to demonstrate how a more sustainable approach to drainage is to be incorporated into development proposals.



Step 4 requires planners to use SUDS as a form of control for surface water.

1.2.1 Key elements of Planning Policy Statement 25 (PPS25)

- Covers all types of flooding
- Flooding considered at all stages of the planning process
- Risk-based sequential approach
- Safe development of sustainable communities

1.2.2 Planning

Planning authorities will set a limit to the rate of stormwater flow from a site via sewers as a condition of planning consent. In recognition of this, Local Planners increasingly state that all applications should, in the first instance, aim to incorporate SUDS into development proposals. SUDS are also considered suitable for mitigating adverse impacts and supporting water conservation objectives.

1.2.3 Cost effective techniques

SUDS incorporate cost-effective techniques that are applicable to a wide range of schemes, from small developments to major residential, leisure, commercial or industrial operations with large roof spaces and large hardstanding areas. They can also be successfully retrofitted to existing developments. Planning policy guidance on development and flood risk emphasises the role of SUDS and introduces a general presumption that they will be used.

1.2.4 Site evaluation

As with other key considerations in the planning process - transport, landscape, heritage and nature conservation - incorporating SUDS needs to be considered early in the site evaluation and planning process, as well as at the detailed design stage.

1.2.5 Floods & Water Management Act

Sir Michael Pitt completed his independent review of the 2007 flooding emergency in June 2008, forming the catalyst for major legislative change. The report proposed 92 recommendations to improve UK surface water management and has called for significant investment from the Government in sustainable drainage techniques and flood management strategy.

The Floods and Water Management Act sets out a more joined-up approach to flood risk prevention and management and has been developed to implement the majority of the recommendations set out in the Pitt Review. It gives local authorities the lead role in managing local flood risk, as well as the responsibility for adopting and maintaining sustainable drainage schemes. This will then enable the Environment Agency to adopt a strategic overview role for all forms of flood risk, including groundwater and surface water.

1.2.6 Adoption and future maintenance

In the early stages of design, consideration should be given to the arrangements for adoption and future maintenance of the system. This is likely to influence the design just as much as technical considerations. For private, or non-adopted systems, maintenance will be the responsibility of the owner and future developments may be affected by covenants. For systems serving more than one residential property it is recommended that maintenance should be the responsibility of a publicly accountable body, which will often necessitate the payment of a commuted sum or a legal agreement, possibly backed by the deposit of a financial bond. The adopting organisation should approve the design before construction.



2.0 Polystorm modular cell system

attenuation and soakaway solutions

Average UK temperatures are expected to rise by up to 3/5°C by 2080, resulting in a dramatic change in the seasonal distribution of rainfall and subsequent weather patterns. The flooding witnessed during recent years is a clear indication that climate change is causing more frequent and extreme weather events and innovative solutions are required to cope with increased pressure on our existing drainage and water management networks.



Planning Policy Statement 25 - Development and flood risk

Planning Policy Statement 25 (PPS25) sets out Government policy on development and flood risk. Its aim is to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding and to direct development away from areas of highest risk. Where new development is exceptionally necessary in such areas, policy aims to make it safe, without increasing flood risk elsewhere and where possible, reducing flood risk overall.

Planning Policy Statement 25: Development and Flood Risk (PPS25), published in June 2008.

Polystorm modular solution

The Polystorm range of modular cells are designed to address the above legislation on minimising flood risk. The cells retain large volumes of water and fit together to create a modular underground water tank. The tank can then be modified to be either an attenuation or soakaway solution.

Products

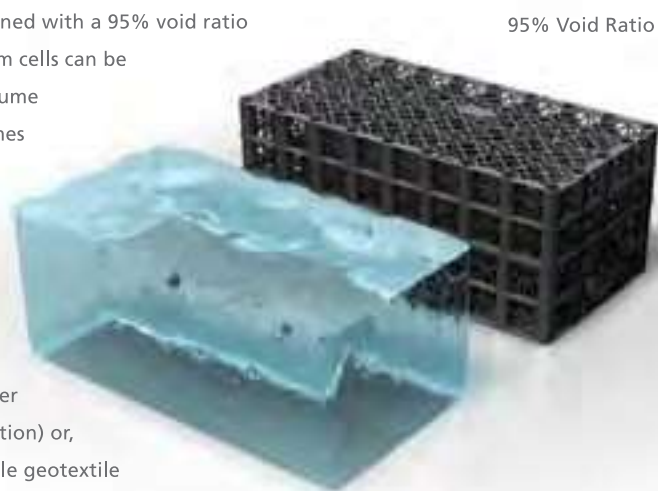
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2.1 Polystorm modular cell system - three types of Polystorm cells

2.1.1 The Polystorm principles

The Polystorm range of modular cell systems are designed with a 95% void ratio to retain large volumes of water run-off. The Polystorm cells can be designed and built to a specific size to a total void volume requirement dependent upon the water run-off volumes required on a particular project (i.e. car park, road or building). The Polystorm range of water storage cells are structurally strong, individual modular cells which can be built up to form a structure of any shape or size. The structure is wrapped in a non permeable, geomembrane which can receive rainwater collected from the roof gutter system or surface drains and either releases the water within set discharge limits (attenuation) or, where soil conditions allow, be wrapped in a permeable geotextile and slowly release the water back into the surrounding soil (soakaway).



Polystorm Lite 20T



Polystorm Lite



Polystorm 40T



Polystorm



Key benefits

- **95% void ratio:** Providing greater water storage capacity and reduced excavation and disposal costs
- **Modular units:** Allow flexibility of shape - ideal for shallow excavation systems, narrow strips or use in restricted areas
- **Light weight yet robust:** Excellent Health and Safety and installation benefits
- **Easy to handle:** Unique rounded corners for ease of handling and reduces likelihood of punctures to membranes
- **Cost effective:** Especially when used as a hybrid, value engineered system
- **Recyclable:** 100% recyclable at the end of its useful life
- **Range:** Spans from 20 tonnes per square metre load bearing capacity up to a maximum of 80 tonnes per square metre load bearing capacity
- The range can be designed for non-trafficked, trafficked or heavy trafficked applications
- Suitable for both attenuation and soakaway systems
- 50 year design life
- BBA Approved
- Hybrid Solutions

There are three different types of Polystorm cells which are Polystorm Lite, Polystorm and Polystorm Xtra. Each Polystorm cell type has a different surface load specification.

- **Polystorm Lite** is designed for use in landscaped pedestrian or other non-loaded applications
- **Polystorm** is designed for use in light trafficked and loaded applications

The Polystorm Technical Manual is available to download at:
www.polypipewms.co.uk/downloads

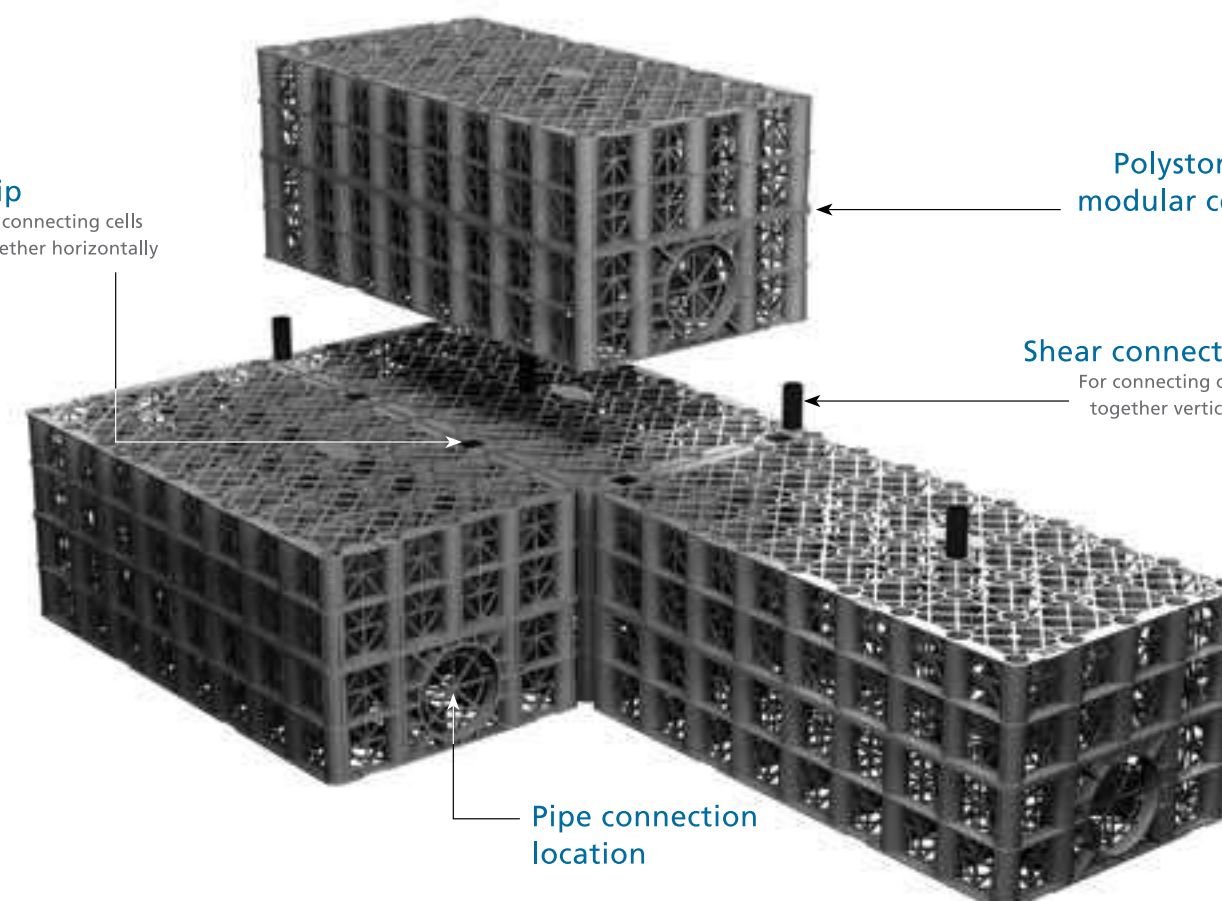
Clip

For connecting cells together horizontally

Polystorm modular cell

Shear connector

For connecting cells together vertically



2.2 Polystorm Lite

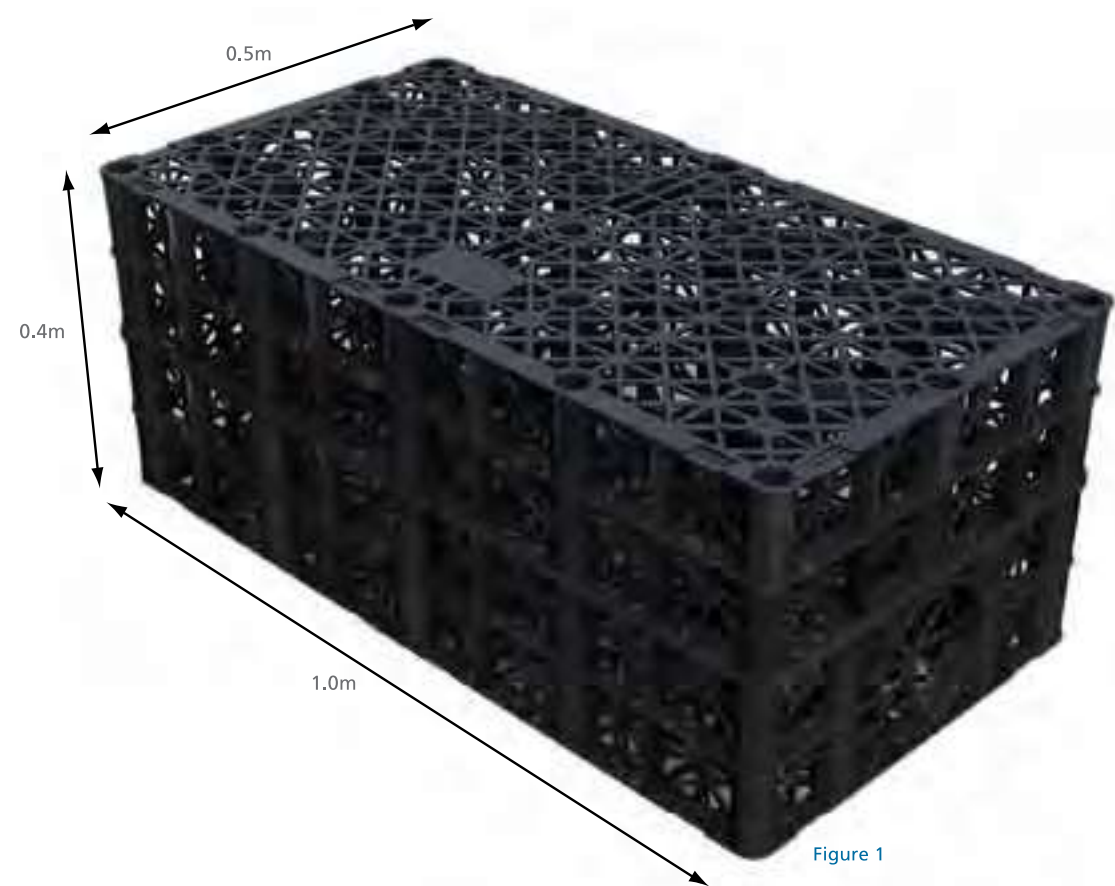


Figure 1

Designed for use in landscaped, pedestrian or other non-loaded applications with a load bearing capacity of:

20 tonnes

Technical specification overview	
Unit type	Polystorm Lite
Product code	PSM2*
Dimensions	1m x 0.5m x 0.4m high
Total volume	0.2m per cube
Unit weight	7kgs**
Cube storage volume	0.19m³ (190 litres)
Surface area	55% perforated
Compressive strength	Maximum 20 tonnes per sq metre
Maximum burial depth	2.5m***

* Each unit includes 4 clips and 2 shear connectors. Please note that brick bond connector may be required at additional cost.

** Pallet weight dependent upon order quantity and transport type.

*** In weak clay soil conditions the maximum burial depth is 1.5 metres. Polystorm Lite should not be installed below the water table.

Table 1

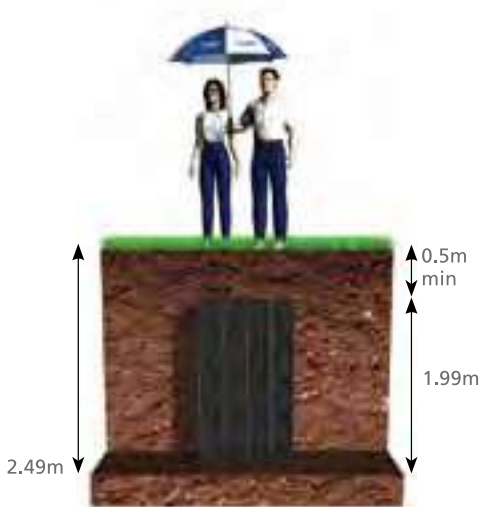


Figure 2

Polystorm Lite has been specifically designed for non-trafficked applications. With a 20 tonne per square metre compressive strength it will however take general maintenance vehicles such as grass cutters. Polystorm Lite can be used for both attenuation and soakaway applications. The modular structure receives rainwater collected from roofs or surface drains ready to release within a set drainage limit. Polystorm Lite can be used typically for landscaped areas, pedestrian or public open spaces such as underneath playgrounds.

Polystorm Lite		
Description	Code	Pack quantity
Polystorm Lite cell 1000 x 500 x 400mm	PSM2	15
Polystorm Lite flow control unit	PSMFC160/30	1
Brick bond shear connector	PSMBBSC	30
Clips	PSMCLIP	60
Shear connector	PSMSC	30
EN1401 flange adaptor - 110mm	PSMFA110	1
Ridgidrain flange adaptor - 150mm	PSMFA150	1
EN1401 flange adaptor - 160mm	PSMFA160	1
Basic silt trap	PSMST160	1
Advanced silt trap - 15 litres/sec	PSMSTA160/15	1
Mini silt trap for Polystorm Lite	PSMST110	1
Cover & frame (round)	UG501	1
Cover & frame (square)	UG502	1
450mm silt trap lid & frame	UG512	1
460mm lockable plastic cover & frame	UG511	1
Polypropylene cover & frame	ICDC1	1
Chamber riser section	ICDR1	1
Silt trap sealing ring	UG488	1

Table 2



Note: Minimum cover and burial depths may vary depending on load and ground conditions. Please contact Polypipe WMS for further information. All grades of Polystorm units may be used in situations outside of those recommended above, through the use of the appropriate protective measures designed to reduce the imposed loading on the proposed Polystorm structures.

2.3 Polystorm

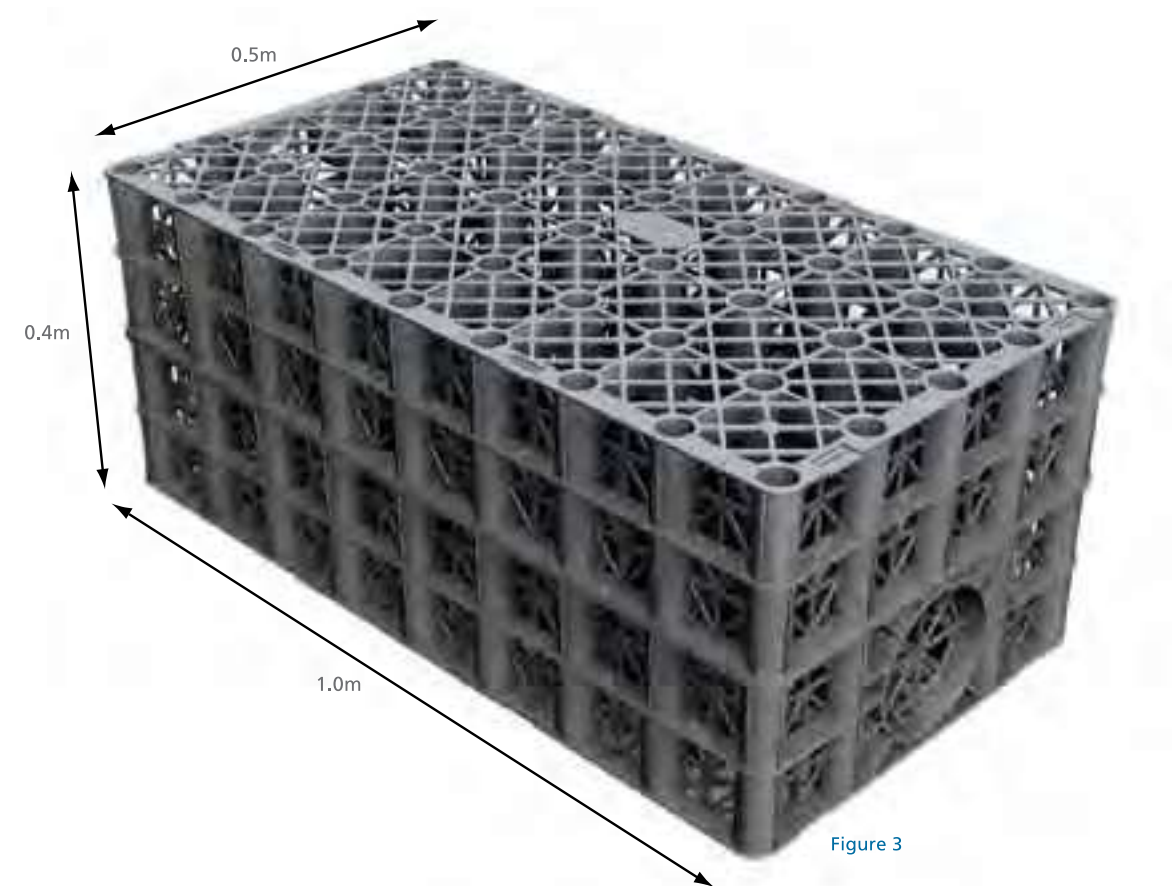


Figure 3

Designed for use in trafficked and loaded applications with a load bearing capacity of:

40 tonnes

Technical specification overview	
Unit type	Polystorm
Product code	PSM1*
Dimensions	1m x 0.5m x 0.4m high
Total volume	0.2m per cube
Unit weight	9kgs**
Cube storage volume	0.19m³ (190 litres)
Surface area	48% perforated
Compressive strength	Maximum 40 tonnes per sq metre
Maximum burial depth	3.7 metres***

* Each unit includes 4 clips and 2 shear connectors. Please note that brick bond connector may be required at additional cost.

** Pallet weight dependent upon order quantity and transport type.

*** In weak clay soil conditions the maximum burial depth is reduced, please consult Polypipe WMS Technical Team on 01509 615100.

Table 3

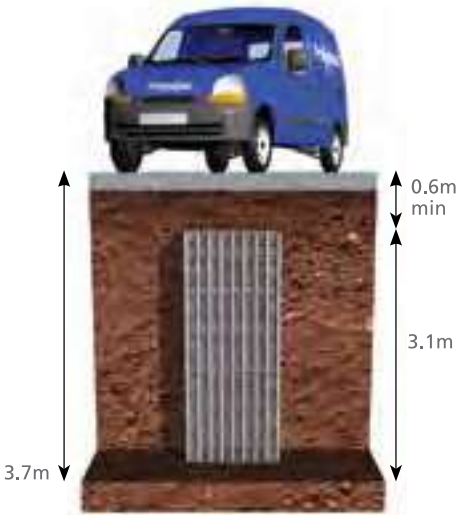


Figure 4

Polystorm features individual modular cells that can be built up to form a load-bearing tank structure of any shape or size to receive rainwater collected from the gutter system or surface drains ready to release within a set discharge limit. Polystorm has a 40 tonne per square metre compressive strength and is ideally suited for light trafficked and loaded applications. Polystorm can be used for both attenuation and soakaway applications and typically for housing developments, small car parks and light commercial developments.

Polystorm		
Description	Code	Pack quantity
Polystorm cell 1000 x 500 x 400mm	PSM1	15
Polystorm cell with 225mm connector	PSMCRD225	1
Polystorm cell with 300mm connector	PSMCRD300	1
Brick bond shear connector	PSMBBSC	30
Clips	PSMCLIP	60
Shear connector	PSMSC	30
EN1401 flange adaptor - 110mm	PSMFA110	1
Ridgidrain flange adaptor - 150mm	PSMFA150	1
EN1401 flange adaptor - 160mm	PSMFA160	1
Basic silt trap	PSMST160	1
Advanced silt trap - 15 litres/sec	PSMSTA160/15	1
Cover & frame (round)	UG501	1
Cover & frame (square)	UG502	1
450mm silt trap lid & frame	UG512	1
460mm lockable plastic cover & frame	UG511	1
Polypropylene cover & frame	ICDC1	1
Chamber riser section	ICDR1	1
Silt trap sealing ring	UG488	1

Table 4

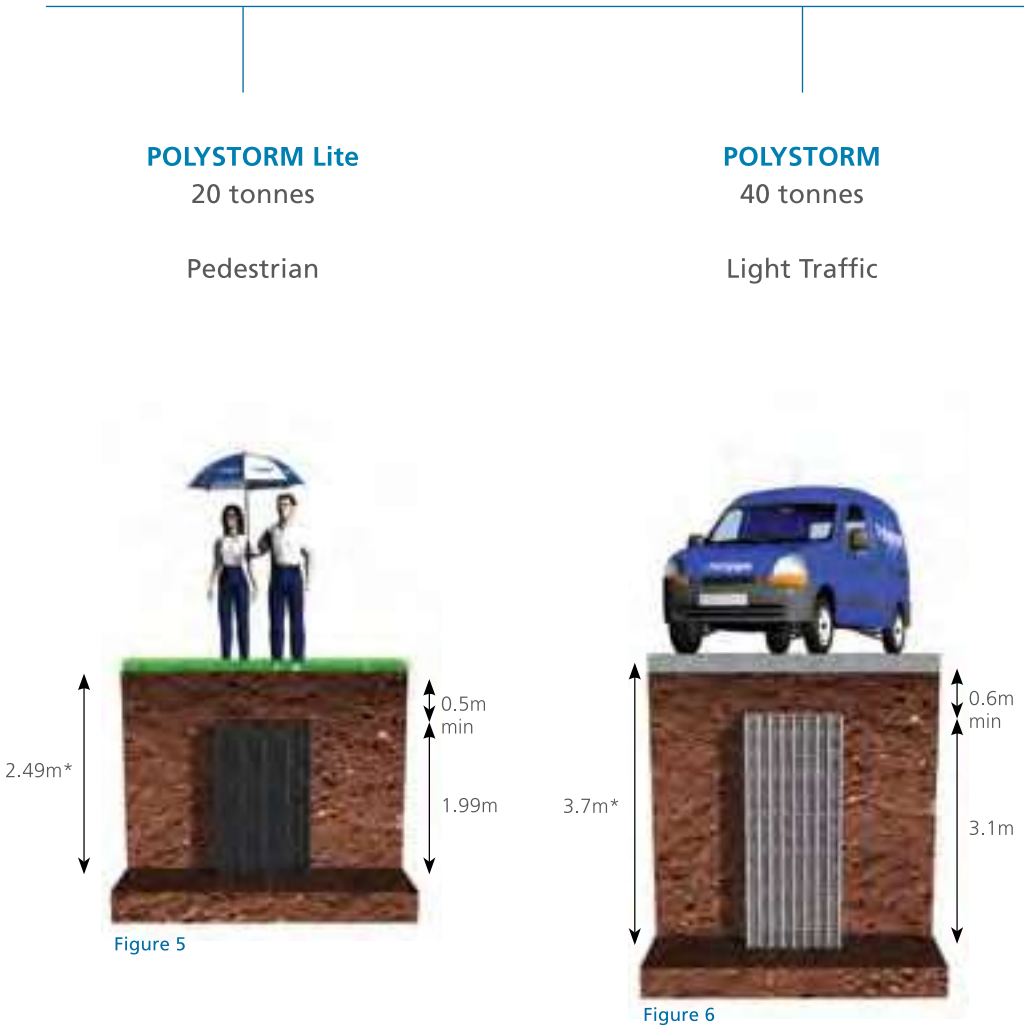


Note: Minimum cover and burial depths may vary depending on load and ground conditions. Please contact Polypipe WMS for further information. All grades of Polystorm units may be used in situations outside of those recommended above, through the use of the appropriate protective measures designed to reduce the imposed loading on the proposed Polystorm structures.

2.4 Hybrid - Polystorm range of modular cells creating a cost-effective hybrid construction

The following illustrations indicate maximum burial depths for Polystorm Lite and Polystorm modular cell systems.

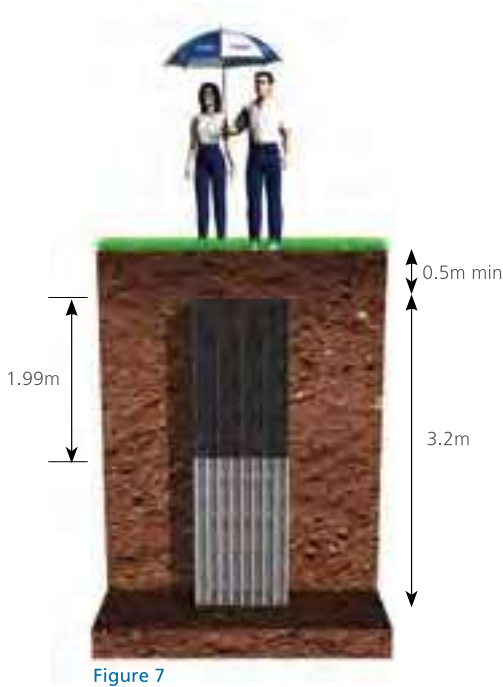
Polystorm Lite and Polystorm



Note: * Based on ground conditions being dense sand and gravel.
Minimum cover and burial depths may vary depending on load and ground conditions.
Please contact Polypipe WMS for further information. All grades of Polystorm units may be used in situations outside of those recommended above, through the use of the appropriate protective measures, designed to reduce the imposed loading on the proposed Polystorm structures.

Hybrid Solution VALUE ENGINEERED STRUCTURES

POLYSTORM Lite
POLYSTORM
Pedestrian



Value engineered structures

Polypipe are the only manufacturer who can offer a complete value engineered hybrid system utilising Polystorm Lite or Polystorm cells to create a bespoke solution based on the load requirements and burial depths for any given project.

When integrated as a hybrid structure, a complete value engineered solution can be adopted for any given project. To reduce costs, it's possible to construct a hybrid tank, which contains all types of cells, the stronger Polystorm cells at the bottom and Polystorm Lite cells at the top. For further details contact Polypipe WMS technical support team. Refer to tables 8, 9 and 10 (page 39) for burial depths in different soil conditions.

3.0 Testing and certification - laboratory testing and protocol

At Polypipe WMS we pride ourselves on providing a consistently high level of product quality. All our products undergo stringent testing and quality control and where possible, are covered by third party certification. Our manufacturing processes are also accredited to ISO 9001:2008. There are two quality control labs in operation 12 hours a day.



Testing and certification

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3.1 Testing and certification

As a manufacturer of plastic below-ground water management products, Polypipe WMS invests heavily in British Board of Agrément (BBA) approval and is a supporter of the criteria used to assess each product. By achieving BBA approval, Polypipe WMS can pass on to our customers confidence in the performance of all our products.



Figure 8 Compression test rig

Increasingly new products are being introduced within the UK water management markets with no independent approvals. This can create potential issues for product specifications unsupported by independent testing and assessment and may not correlate with the performance parameters of the product. BBA approved products offer our customers a safety net and further reassurances that the product will perform in-line with our claims when installed in accordance with the BBA certificate.

3.1.1 Laboratory testing

Laboratory testing to determine the structural performance of the Polystorm cells were carried out in accordance with the laboratory protocol provided by the British Board of Agrément (BBA) for products of this type. Direct compression tests were conducted at Polypipe's research and development laboratory in accordance with ISO 9001:2008 to determine the vertical and lateral strength of the Polystorm cells. Vertical creep tests were undertaken at the UKAS accredited Berry and Hayward laboratory.

3.1.2 Test protocol

Laboratory testing to determine the structural performance of the Polystorm cells has followed the protocol agreed with the British Board of Agrément (BBA). Direct loading tests were carried out on single cells. Individual cells were load tested until failure (i.e. the point at which they could not sustain further load).

Tests were carried out along two axes (Figure 9).

- Vertical compression test; with load applied down the y-axis, via a 300mm ϕ platen, at two positions (Figure 10)
- Vertical compression test; with load applied down the y-axis via a platen covering the full area of the cellular unit (0.5 x 1.0m)
- Lateral compression test; with load applied along the x-axis via a platen covering the full area of cellular unit (0.4 x 1.0m). A simultaneous restraining load, representing the vertical load that may be expected at the units recommended maximum burial depth, was also applied

Creep tests were carried out on single Polystorm cells for a minimum period of 90 days.

- Vertical creep test; with a constant load applied down the y-axis, via a 300mm ϕ platen at position (Figure 9). The applied test load was equivalent to 75% of the vertical compressive design load; with the design load calculated by applying an appropriate material factor of safety (2.75 recommended by CIRIA) to the lowest vertical compressive yield test result

Polystorm cell; direction of applied load and platen location

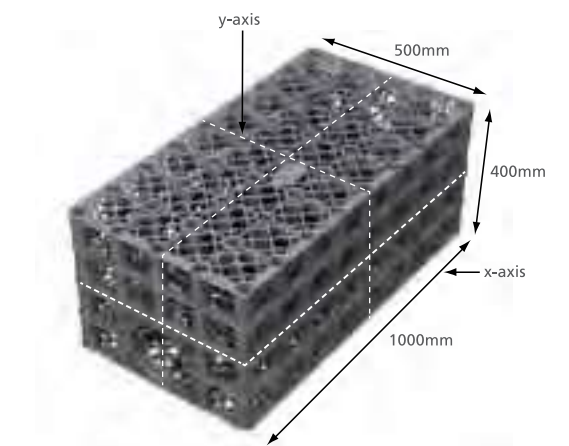


Figure 9 Unit axis; direction of applied load

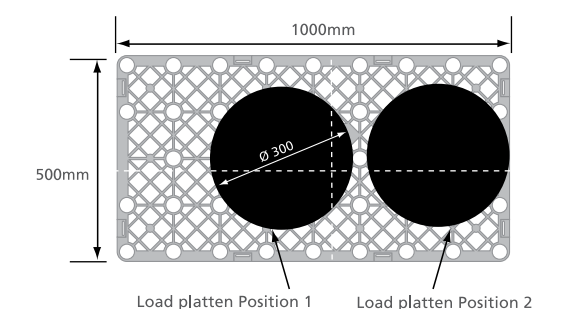


Figure 10 Position of load platens; point load resistance



Figure 11 Creep test rig

3.2 Summary of test results

3.2.1 Unit specifications

Figure 12 shows the dimensions of Polystorm Lite cells.

Figure 13 shows the dimensions of the Polystorm cells.

Table 5 shows the technical data for Polystorm Lite and Polystorm cells.

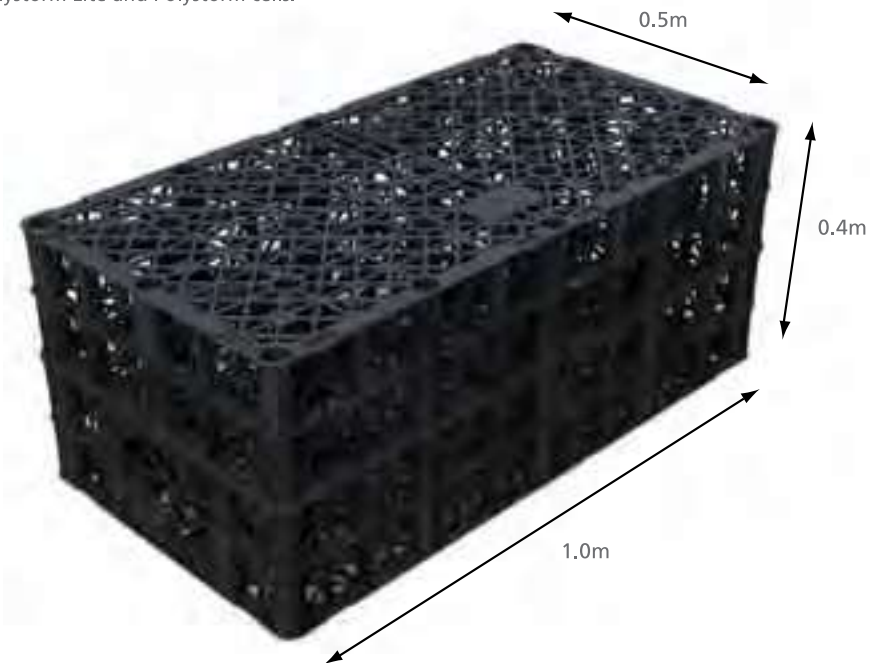


Figure 12 Dimensions of Polystorm Lite cell

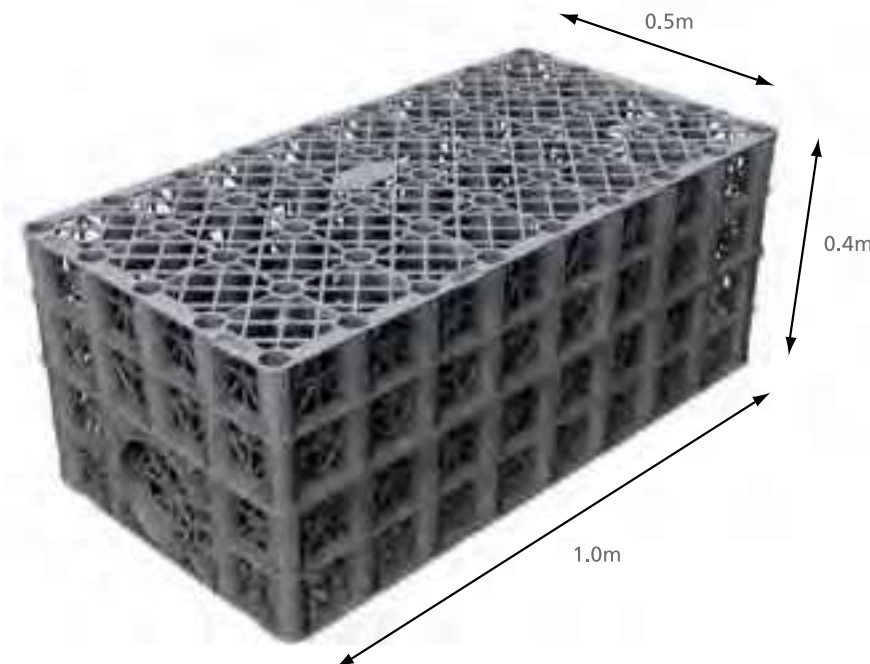


Figure 13 Dimensions of Polystorm cell

Technical data of Polystorm Lite and Polystorm cells		
	Polystorm Lite	Polystorm
Unit dimensions (nom) (mm)	1000 x 500 x 400	1000 x 500 x 400
Unit volume (nom) (m³)	0.2	0.2
Storage volume (nom) (m³)	0.19	0.19
Porosity (void ratio) (%)	95	95
Perforation of surface area (%)	55	48
Weight (kg)	7	9
Ultimate compressive strength at yield (kN/m²) ⁽¹⁾ : Vertical loading on top face	200	440
Lateral loading on side face	40	63
Short vertical loading on top side face (kN/m²)	1 per 43	1 per 83
Estimated long-term deflection ⁽²⁾ (Ln) ⁽³⁾	0.773	0.2796
Max burial depth (m)*	2.5m	3.7m

⁽¹⁾ = Applied load ⁽²⁾ = At up to 20 years @ 20°C @ 127kN/m² load (Polystorm) ⁽³⁾ = Time in hours
⁽²⁾ = At up to 20 years @ 20°C @ 54kN/m² load (Polystorm Lite)
* Maximum burial depth dependant upon soil conditions, see page 39 for further details.

Table 5

3.2.2 Durability

When installed in accordance with Polypipe WMS recommendations, the design life of Polystorm Lite and Polystorm cells exceeds 50 years. Please refer to BBA certificate.

3.2.3 Chemical resistance

Polystorm Lite and Polystorm cells are suitable for use in contact with chemicals likely to be found in rainwater. They are also resistant to all compounds occurring naturally in soils. For guidance on using Polystorm cells in contaminated ground, contact Polypipe WMS technical support team.



4.0 Design protocol



Polypipe WMS provide a full in-house design facility. Upon consultation our team of designers and technical advisors will guide you as to the best solution for your individual situation considering timescales and costs.



Design protocol

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4.1 Detail design protocol

4.1.1 Structural design

4.1.1 Structural design

When designing plastic geocellular structure for soakaway or attenuation tanks care has to be taken to ensure the finished system is safe to carry the loads they will be subject to. The diagram below outlines a safe route to the design and installation of Polystorm modular stormwater tanks.

Applied loads

- Distributed
- Concentrated
- Traffic
- Backfill
- Stockpiles
- Earth pressure
- Construction traffic
- Cranes
- Uplift

Laboratory testing

- Ultimate compressive strength at yield
- Deflection parameters
- Creep



Figure 14

Partial factors of safety

- On material properties
- On loads
- Follow BPF and CIRIA guidance

Analysis

- Failure
- Deflection (movement under load)
- Creep
- Flotation

Listed below are the four main reasons for failure of the system:

- 1 Structural failure or collapse - when the structure cannot support the applied loads.
- 2 Excessive deflection or movement when vehicles passing over the tank cause movement and the surface above may crack or displace.
- 3 Creep - excessive movement or loss of strength over a period of time which can occur under a constant load.
- 4 Flotation: Constructing a tank below the groundwater table can create uplift.

4.1.2 Limit state design, 4.1.3 Industry standards, 4.1.4 Factors of safety

4.1.2 Limit state design

In the design of any load carrying system, there needs to be factors of safety to allow for any variation in either the applied load or cellular unit strength. Limit state design does not use a single overall factor of safety; the method looks at 'limit states' and applies partial factors of safety to the various design parameters depending on the consequences of the limit state being exceeded. In the case of Polystorm drainage tanks the two limit states to be considered are:

• Ultimate limit state (ULS)

This is when the strength of the cell is exceeded by the applied loads and the tank collapses. This is obviously serious and the partial factors of safety used in this assessment are chosen to ensure there is a negligible risk of a collapse occurring.

• Serviceability limit state (SLS)

This considers the operational behaviour of a tank to ensure that the installation remains serviceable. For the structural calculations this means that deflections are not excessive and do not cause damage to overlying surfaces (such as asphalt) or cause a significant reduction in the storage volume of the tank. The Polystorm Lite cell is recommended for use in landscaped areas, where deflections would have a negligible effect. SLS would therefore not play a significant role in Polystorm Lite structural design.

4.1.3 Industry standards

There are currently no design standards or guides specific to generic modular plastic stormwater tanks, with each manufacturer within the marketplace providing their own guidelines that tend to be specific to their own cells. However, a generic design method has been developed that can be applied to most types of cells, using basic structural design theory and relevant British Standards. In particular the loading on plastic tanks may be considered to be the same as a buried concrete or steel tank and so the loads and partial factors of safety for loads have been taken from the following:

1. **British Standards Institution (1997).** British Standard BS8110, Part 1: 1997; Structural use of concrete: Code of practice for design and construction. BSI
2. **British Standards Institution (1996).** British Standard BS 6399: Part 1: 1996: British Standard Loadings for Buildings. Part 1 Code of Practice for dead and imposed loads. BSI

The only available guidance relating to plastic materials in similar situations to buried cellular tanks is that for plastic geosynthetics in soil strengthening and reinforcement. The information in the following British Standard has been used as a guide to the choice of partial material factors used for the design:

1. **British Standards Institution (1995).** British Standard BS8006: 1995; Code of practice for strengthened/reinforced soils and other fills. BSI

4.1.4 Factors of safety

To ensure that the risk of exceeding the limit states is minimal, factors of safety are applied to the cellular unit's ultimate compressive strength and to any applied loads; these are known as partial factors of safety.



4.1.5 Material factors

4.1.5 Material factors

The ultimate compressive strength of the Polystorm cells has been obtained from laboratory testing on samples. To take account of other factors such as variations due to manufacturing processes, variability and uncertainties in material strength (e.g. due to extrapolation of data), damage during installation and environmental effects, a design strength is derived by dividing the cell's characteristic strength by a material partial factor of safety (f_m), appropriate to the material and limit state. There is no guidance on the choice of material factors for plastic storage tanks.

Partial material factors of safety: Polystorm Lite & Polystorm	
Limit state	f_m
Ultimate limit state	2.75
Serviceability limit state	1.5

Table 6

The partial factor f_m is made up of several components:

f_{m11}

This is applied to the characteristic strength of Polystorm. It covers possible reductions in strength from the control test specimens and inaccuracies in the assessment of the resistance of a structural element resulting from modelling errors. For tightly controlled Polystorm production f_{m11} would normally be between 1.05 and 1.1. Because a limited number of compression tests have been undertaken on the Polystorm cells in addition to this property not being measured as part of the quality control program, a conservative value has been adopted. Compression tests were undertaken at points judged by inspection to be the weakest however the cell is a complex three dimensional structure, therefore an allowance must be made for this. In view of the preceding factors and the conservative choice of design parameters already undertaken, a value of $f_{m11} = 1.20$ has been adopted for the ULS and 1.1 for the SLS. This can be reviewed if the compressive strength is measured as part of the manufacturing quality control procedure.

f_{m12}

This is applied to take account of the extrapolation of creep test data. It is also used in the case of the Polystorm cells to allow for the absence of fatigue testing. A suggested value of f_{m12} is given by $\text{Ingoldv} = \text{Log}(t_d/t_t)$ where t_d = design life, t_t is duration of creep test. This gives a value for the ULS, with a design life of 20 years, of $f_{m12} = 1.9$. Although the cells will be under compressive loads and appear to fail in compression at the internal columns, they are complex structures. Some of the elements will be acting in tension and when polypropylene is subject to creep under long term tensile loads it can lose strength over time. Therefore the values taken from reinforced earth applications are considered reasonable. For serviceability, which is not so critical, a value of 1.25 is adopted.

f_{m21}

This is applied to take account of damage during installation. The Polystorm cells are robust and not particularly susceptible to damage and therefore, in the absence of specific damaged strength testing, a factor of 1.1 for the ULS and 1.0 for the SLS has been used.

f_{m22}

This is applied to take account of environmental conditions. The polypropylene used in the manufacture of the Polystorm units is resistant to all contaminants that are naturally found in soil and rainwater. No specific test results are available and so a value of f_{m22} for both ULS and SLS of 1.1 has been adopted; which is the minimum value recommended for reinforced earth applications by Ingoldv. With the total value of $f_m = f_{m11} \times f_{m12} \times f_{m21} \times f_{m22}$

Therefore, for the following limit state, f_m will equate to:

Ultimate limit state:	Serviceability limit state:
$1.2 \times 1.9 \times 1.1 \times 1.1 = 2.75$	$1.1 \times 1.25 \times 1.0 \times 1.1 = 1.5$

The use of conservative factors also allows for synergistic effects (i.e. the combined effect of construction damage, environmental effects and lower than expected cell strength) that may result in a greater combined effect than the three factors acting individually. These factors are only applicable for temperate climate conditions such as in the UK. Although the strength of polypropylene varies with temperature, this will not be significant for installation in the UK where the temperature in the ground (at the typical depth of installation) remains between 0°C and 20°C with a mean value of around 10°C.

4.1.6 Applied loads and load factors



4.1.6 Applied loads and load factors

Loads that may be imposed on a cellular storage structure such as Polystorm, can be broken down into the following types:

- **Dead Loads**

Permanent loads applied to the cells, including the weight of backfill material placed over the top and lateral (horizontal) earth and water pressure loads acting on the side of the system.

- **Live Loads**

Loads due to pedestrian, vehicle and construction traffic that are not permanent. Traffic wheel loads are normally given as static loads, with a factor applied to allow for dynamic effects (a moving wheel will impose more force on the ground than a static one).

A design load is obtained by applying a partial factor of safety to the estimated characteristic load. This allows for unforeseen variations of loading and also the severity of the consequences of the limit state occurring. The loads on cellular units will be similar to loads applied in the design of structures using rigid materials such as concrete and therefore the partial safety factors for loads that are appropriate to the design of plastic storage systems are taken from British Standard BS 8110.

Partial factors of safety for applied loads			
Limit state	Imposed vertical dead load f_m	Imposed earth pressure dead load f_m	Imposed live load f_m
Ultimate limit state	1.40	1.40	1.60
Serviceability limit state (Polystorm only)	1.0	1.0	1.0

Table 7

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

4.2 Distributed loads

4.2.1 Example of calculation methods

The structural design of the cells needs to consider a number of different loads and their effects.

What load is applied to the tank?

1. Dead (permanent) loads such as the weight of soil placed over the top of the cells or long term stockpiles of containers or materials (anything that will be applying load for a lengthy period of time).
2. Surcharge loads. From stored materials or to allow for traffic.

How is this analysed?

The weight of the fill material is calculated from the depth of soil and its cell weight. The traffic loads that are typically used are: Car Parks - 2.5kPa. HGV Loading - 10kPa.

Example: 1.5m cover depth over the top of Polystorm - Car Park.

Design against collapse (ultimate limit state)

Weight of soil = $1.5\text{m} \times 20\text{kN/m}^3$.

Partial factor of safety = 1.4.

Surcharge = 2.5 kPa, Partial factor of safety = 1.6.

Total design load = $(1.5 \times 20 \times 1.4) + (2.5 \times 1.6) = 46\text{kPa}$.

Polystorm ultimate compressive strength at yield = 440kPa.

Partial factor of safety = 2.75.

Design strength of Polystorm = $440/2.75 = 160\text{kPa}$.

Design strength is greater than factored loads so the design is ok.

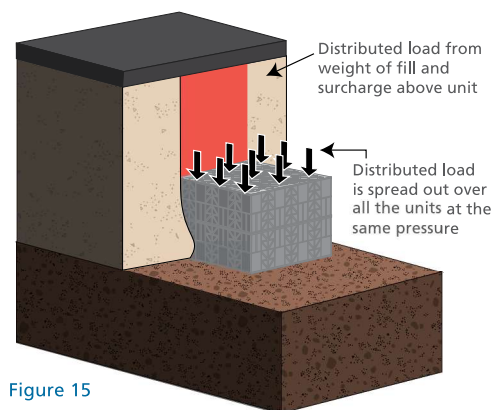


Figure 15

Check deflection (serviceability limit state)

Partial factor on load = 1.0.

Design load = $(1.5 \times 20 \times 1.0) + (2.5 \times 1.0) = 32.5\text{kPa}$.

Deflection of Polystorm = 1mm per 83kPa load.

Partial factor of safety = 1.5.

So elastic deflection of Polystorm = $32.5 \times 1.5/83 = 0.6\text{mm}$.

Most of the deflection is due to the permanent load and so it will be acceptable.

Check creep (serviceability limit state)

Long term creep deflection = 0.2794Ln (design life in hours).

For a load less than 100kPa.

So if design life is 20 years

Creep = $0.2794 \text{Ln} (20 \times 365 \times 24) = 3.4\text{mm}$.

What load is applied to the tank?

3. Concentrated loads for example those from:

- Wheels of cars or trucks
- Container feet
- Construction vehicles
- Crane spreader plates or legs

How is this analysed?

The load from the wheel is spread out through the soil or pavement materials over the top of the tank.

The heavier the load the greater the thickness of material that is required over the top of the tank. However there is a practical minimum of about 0.5m in most cases to avoid damage to the tank during installation and after construction.

Example:

Polystorm is to be used under a car park that may be occasionally crossed by delivery trucks or refuse collection lorries (maximum gross vehicle weight 31,000 kg). Polystorm is covered by 1.2m of Type 1 sub-base and asphalt pavement construction.

Design against collapse (ultimate limit state)

Load from wheel = 35kN.

Assume contact patch is 0.135m by 0.275m.

Trucks will be moving slowly but turning therefore dynamic factor = 1.5.

Cover depth of soil is 1.2m and assume a 26.6° load spread.

Contact area on top of tank is:

$0.275 + 1.2$ by $0.135 + 1.2 = 1.97\text{m}^2$.

Applied pressure from wheel is $35 \times 1.5/1.97 = 26.6\text{kPa}$.

Factor of safety = 1.6

and factored pressure = $26.6 \times 1.6 = 42.6\text{kPa}$.

Pressure from soil is $1.2\text{m} \times 20\text{kN/m}^3 = 24\text{kPa}$.

Factor of safety = 1.4

and factored pressure = $24 \times 1.4 = 33.6\text{kPa}$.

Total pressure = $42.6 + 33.6 = 76.2\text{kPa}$.

As in previous example design strength of

Polystorm = 160Kpa and this is greater than the applied load and so it is acceptable.

4.3 Lateral loading - calculation example

4.3.1 Check deflection (serviceability limit state)

In this case we are interested in the continuous and repeated deflections under wheel loads only.

Partial factor on load = 1.0.

Applied pressure from wheel (above) is **26.6kPa**.

Design pressure = $26.6 \times 1.0 = 26.6\text{kPa}$.

Deflection of Polystorm = 1mm per 83kPa load.

Partial factor of safety = 1.5.

So elastic deflection of Polystorm = $26.6 \times 1.5/83 = 0.5\text{mm}$.

This will be repeated each time a wheel passes over the tank. This is acceptable for an asphalt pavement.

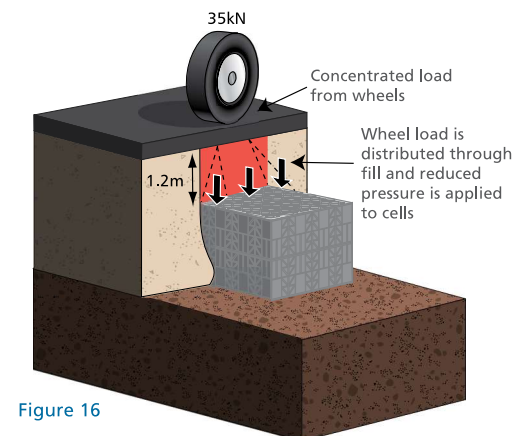


Figure 16

What load is applied to the tank?

4. Earth and groundwater pressure from the surrounding ground. Note that account must be taken of sloping ground, pre-existing shear planes and groundwater. If in doubt obtain expert advice from Polypipe WMS technical support team.

How is this analysed?

The earth pressure applied to the side of the tank by the soil and groundwater. The weaker the soil the greater the pressure it applies to the side of the tank. Water also applies pressure to the side of a tank. The calculations are based on standard earth pressure theory.

Example

The bottom of a modular tank is located 2.5m below ground level. The excavation is surrounded by medium dense sand and gravel with an angle of friction of 34° .

The groundwater is below the base of the tank.

Allow for a 10kN/m^2 surcharge.

To allow for load distribution on the side of the tank, the design uses the earth pressure at a depth of 0.25m above the base of the tank.

Therefore; Design depth = $2.5 - 0.25 = 2.25\text{m}$.

For an angle of friction of 34° the coefficient of active earth pressure is 0.282.

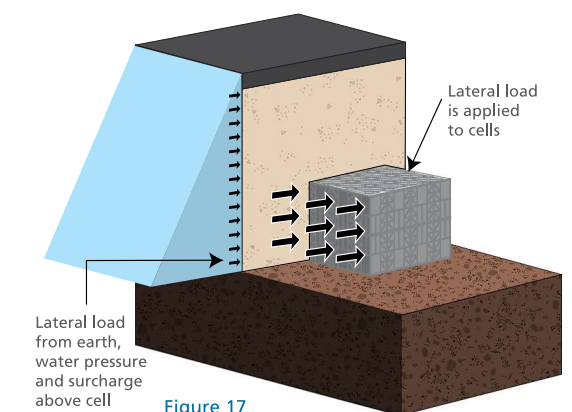


Figure 17

Design against collapse (ultimate limit state)

Partial factor of safety for earth pressure = 1.35.

Partial factor of safety for earth pressure = 1.5.

The applied pressure from the soil is given by;

Applied pressure =

$0.282 \times 2.25\text{m} \times 20\text{kN/m}^3 \times 1.35 + 0.282 \times 10\text{kN/m}^3 \times 1.5$.

Applied pressure = **21.4kN/m^2** .

Polystorm ultimate strength at yield for lateral loading = 63kN/m^2 .

Material partial factor of safety = 2.75.

Design strength = $63/2.75 = 22.9\text{kN/m}^2$.

This is greater than the applied load and so it is acceptable.

Deflections can be estimated using the same approach as for the vertical loads with a partial load factor of 1.0 in all cases.

Note: Where groundwater is present the submerged density must be used to calculate the earth pressure on the side of the tank from the soils below the groundwater table.

4.3 Lateral loading - calculation example



What load is applied to the tank?

5. Uplift pressure from groundwater of the tank is constructed below the groundwater table.

How is this analysed?

A tank is constructed 1m below the groundwater table and has a soil cover over the top of 0.8m.

Will uplift occur?

Design against floatation

Uplift pressure equals weight of water displaced by tank.

Partial factor safety on uplift force = 1.5.

Uplift pressure = 1 x 10 x 1.5 = **15kN/m²**.

Weight of soil resisting uplift

Partial factor of safety = 0.95.

Weight = 0.8 x 20 x 0.95 = **15.2kN/m²**.

The weight of soil is sufficient to present uplift.

Note: An assessment would need to be made of the risk of ground levels being reduced or groundwater levels rising after completion of construction.

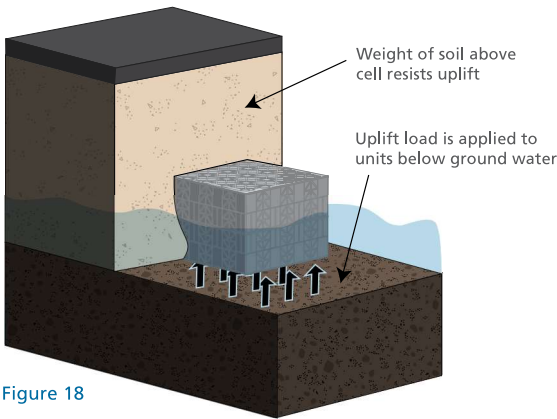


Figure 18

4.4 Maximum burial depths

4.4.1 Recommended maximum installation depths

Polystorm Lite and Polystorm cells can be buried to the maximum depths detailed below. Actual maximum burial depths will depend on soil conditions applicable, however in some circumstances both Polystorm Lite and Polystorm can be buried to greater depths when special measures are carried out. For examples of such measures please refer to page 40.

Polystorm Lite - maximum depth of installation (to base of cells) (m)			
Typical soil type	Typical angle of shearing resistance ϕ	Without groundwater (below base of cells) normal case	With groundwater at 1m below ground level and units wrapped in geomembrane
		Non-trafficked	Non-trafficked
Stiff over consolidated clay e. g. London Clay	24	1.49	1.41
Normally consolidated silty sandy clay e.g. Alluvium, Made Ground	26	1.60	1.48
Loose sand and gravel	30	1.77	1.60
Medium dense sand and gravel	33	2.05	1.69
Dense sand and gravel	38	2.49	1.83

Table 8

Polystorm - maximum depth of installation (to base of cells) (m)					
Typical soil type	Typical angle of shearing resistance ϕ	Without groundwater (below base of cells) normal case		With groundwater at 1m below ground level and units wrapped in geomembrane	
		Trafficked (cars only)	Non-trafficked	Trafficked (cars only)	Non-trafficked
Stiff over consolidated clay e. g. London Clay	24	2.1	2.2	1.5	1.6
Normally consolidated silty sandy clay e.g. Alluvium, Made Ground	26	2.3	2.4	1.5	1.6
Loose sand and gravel	30	2.5	2.7	1.6	1.7
Medium dense sand and gravel	33	3.0	3.1	1.7	1.7
Dense sand and gravel	38	3.7	3.8	1.8	1.8

Table 9

Polystorm Lite & Polystorm - minimum cover levels (to top of cells) (m)			
Live load conditions	Field (Polystorm Lite & Polystorm)	Light trafficking (Polystorm only)	
		Car park with vehicle mass <2500kg	Car park with occasional vehicle mass >2500kg
Minimum cover depth required (m)	0.50	0.60	0.80

Table 10

Please note that the maximum burial depths above are based on the partial factors of safety derived during consultation with the British Board of Agrément (BBA) prior to the publication of CIRIA C680. The BBA has used higher partial factors of safety than CIRIA C680. For further information of the design method detailed in CIRIA C680 please contact our technical support team.