EUROCODE MODELLING STUDY

StormTech SuDS attenuation system

INTRODUCTION

Eurocode structural design principles were used to model the performance of Advanced Drainage System's (ADS's) StormTech below ground SuDS attenuation system, whose original design is based on US Standards. The results show that all the arch shaped StormTech chambers are structurally adequate, at both minimum and maximum cover, when installed as per the manufacturer's guidelines.

ABOUT STORMTECH

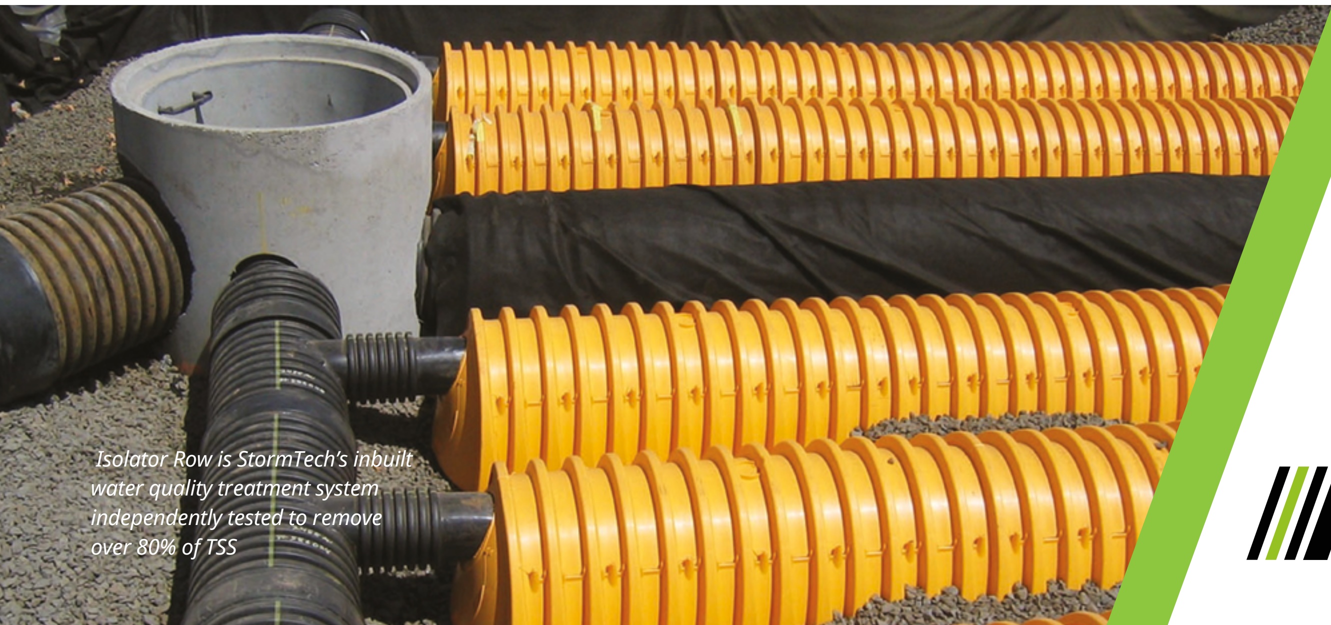
The StormTech system for below ground SuDS attenuation is based on arch-shaped, corrugated thermoplastic chambers. Both the profile of the chambers and material properties contribute to their structural performance. The chambers' elliptical shape forms the embedment material around them into load-bearing structural arches and columns.

StormTech chambers are manufactured using injection moulded thermoplastics. This manufacturing method ensures tight tolerances and full compliance with the AASHTO LRFD design specifications and ASTM F2787, ASTM F2418 and ASTM F2922 (see Reference section at end of document) delivers the best possible combination of safe structural design and product quality.

Chambers are connected to form rows by interlocking the last/first corrugation at each end of the chamber, with an injection molded end cap fitted at either end of the row of chambers. End caps can be cut to accommodate inlet and outlet pipes. The StormTech system incorporates an integral, patented, water quality treatment device known as Isolator Row.

Isolator Row, which is connected to an inlet manhole for easy access, has two treatment stages which can remove sediment (Total Suspended Solids - TSS), hydrocarbons, metals, and nutrients from the runoff. A further two treatment stages can take place downstream of Isolator Row, within the embedment material surrounding the StormTech chambers. This four-stage integral water quality management process can eliminate the need for additional, expensive pre-treatment systems (such as silt separators and hydrocarbon bypass interceptors) that are often required with other proprietary below ground SuDS attenuation systems.

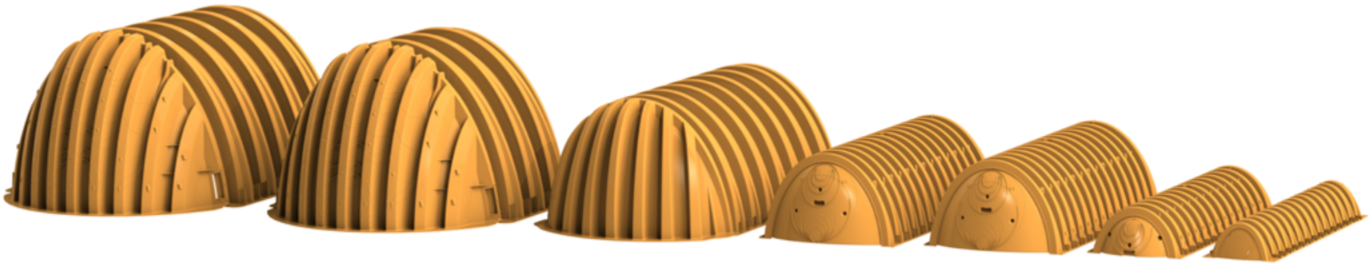
StormTech has been designed for ease and effectiveness of maintenance, since only one row of chambers – the Isolator Row - will require cleaning, using traditional sewer jetting equipment.



Isolator Row is StormTech's inbuilt water quality treatment system independently tested to remove over 80% of TSS

DESIGN FEATURES:

- Lightweight: installation does not normally require mechanical lifting equipment
- Flexible: variety of configurations possible, including shallow inverts, tight footprints and installation around ‘obstacles’, e.g. lighting columns, service corridors
- Strong: exploits ‘load-shedding’ and ‘stone column effect’, so can be installed at shallow or deep cover
- Stackable: deliveries require few truck movements and less storage space required on site
- Four-stage water quality treatment integral to the system at no additional cost
- Ease of maintenance: only Isolator Row will require cleaning, accessed from the inlet manhole



StormTech chambers are available in a range of sizes, providing design flexibility e.g. for shallow installations and tight footprints

TRANSLATING DESIGN STANDARDS

StormTech chambers originated in the US, where they have been used successfully for decades, as well as in many other locations around the world. Their original design was based around North American design philosophy and Standards, namely AASHTO and ASTM International. (See Reference section).

To prove that StormTech chambers are structurally adequate under Eurocode Standards and principles, a study was undertaken to model their performance using limit state Load Model cases based on the standard minimum and maximum cover depths stated in the StormTech product literature.

The standards used, together with related guidance and reports, can be found in the Reference section at the end of this document.

StormTech chambers are tested to extreme conditions, over-and-above standard guidance, to prove structural robustness

LOADS CASES AND ANALYSIS

To investigate the performance of the StormTech system, chambers were evaluated using a finite element analysis (FEA) model, which looked at limit state modes of failure as set out EN 1991-2 – *Eurocode 1 – Actions on Structures – Part 2*.

Engineers may be familiar with CIRIA C737, relating to the design of thermoplastic crates for underground water attenuation, which also suggests Eurocode modelling as a means of demonstrating structural adequacy. Note that, whilst CIRIA C737 design guidance is in the same application field, the structural behaviour of arch-shaped structures is different to cuboid thermoplastic boxes.

Load models for four different stress and fatigue cases were applied, according to EN 1991-2. Cover depths were in accordance with the ADS StormTech Construction Guides and are detailed in the table below.

Maximum and minimum cover per chamber type

Chamber	Minimum cover (mm)	Maximum cover (mm)
SC-160	350	3000
SC-310	450	2400
SC-740	450	2400
DC-780	450	3700
MC-3500	450	2400
MC-4500	600	2100
MC-7200	600	2100

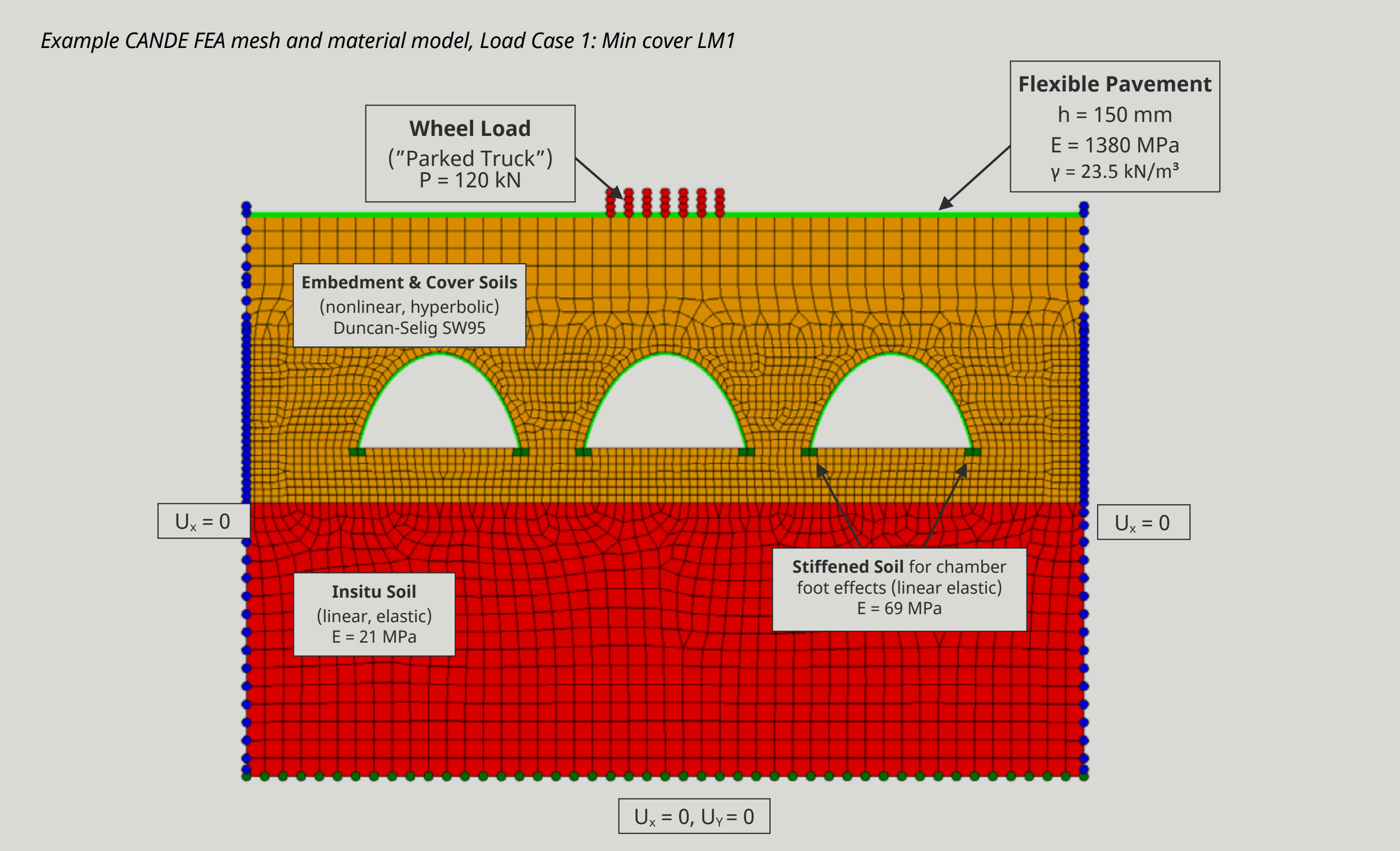
The cover is defined from the top of the chamber crown to the bottom (i.e. underside) of the flexible pavement.

- Load case 1: minimum cover and Load Model 1 (min cover, LM1, subclause 7.2)
- Load case 2: maximum cover and Load Model 1 (max cover, LM1, subclause 7.3)
- Load case 3: minimum cover and Fatigue Load Model 3 (min cover, FLM3, subclause 7.4)
- Load case 4: minimum cover and Load Model 1 with braking forces (min cover, LM1, braking, subclause 7.5)

The strength of the chambers can be drawn directly from testing with minimum requirements for stiffness, bending moment and thrust capacity. The basis for strength of the chambers are flattening test data for moment capacity and stub compression test data for thrust capacity, both performed for the European Technical Assessment (ETA) [see Reference section]. To derive bending moment capacity from the flattening test, a two-dimensional (2D) Finite Element Analysis is completed.

Eurocode principles require that the assessment of structural adequacy must include derating factors to take into account performance over time. Strength reduction factors in accordance with EN 1778 were applied and the elastic modulus of the thermoplastic material was derated, to take into account the long-term performance of the material under loading.

The Culvert ANalysis and DEsign (CANDE) FEA model was used to evaluate the chambers in the most demanding loading scenarios. At shallow depths it is live traffic loads at the surface that are most likely to cause failure. For maximum depths it is the long-term loading of the backfill material which will determine failure.



RESULTS

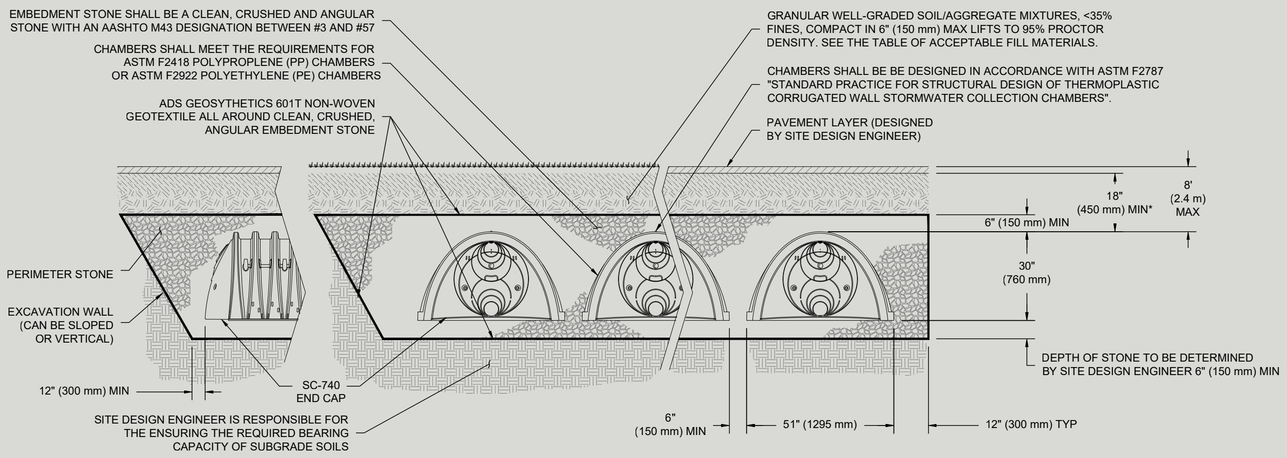
The FEA model was used to calculate the bending moments in the crown and shoulder of each StormTech chamber and the thrust at the foot of the chamber, for the relevant Load Model cases. These were then expressed as a Capacity Factor: the percentage of the chamber's actual strength that was being taken up by the acting loads. Any result below 100% demonstrates structural adequacy.

For all chambers, and in each of the four Load Model cases, the Capacity Factor was below 100%. Generally speaking, Load Case 2, with maximum cover depth had the highest Capacity Factors, although still all comfortably below 100%.

Capacity Factor	Load Case 1	Load Case 2	Load Case 3	Load Case 4
Average for all chambers	56	77	47	50
Range	43-74	52-92	36-63	41-58

For case study details, please click here

The stone arch/columns formed around StormTech chambers and "load shedding" from chambers into the embedment results in extraordinary min/max cover depths



*MINIMUM COVER TO BOTTOM OF FLEXIBLE PAVEMENT. FOR UNPAVED INSTALLATIONS WHERE RUTTING FROM VEHICLES MAY OCCUR, INCREASE COVER TO 24" (600 mm).

REFERENCES

North American standards:
AASHTO LRFD Bridge Design Specifications

ASTM F2787 *Standard Practice for Structural Design of Thermoplastic Corrugated Wall Stormwater Collection Chambers*

ASTM F2418 *Standard Specification for Polypropylene (PP) Corrugated Wall Stormwater Collection Chambers*

ASTM F2922 *Standard Specification for Polyethylene (PE) Corrugated Wall Stormwater Collection Chambers*

European standards:
EN 1778: *Characteristic values for welded thermoplastic constructions – Determination of allowable stresses and moduli for design of thermoplastic equipment; 12-1999*

EN 1990: *Eurocode: Basis of structural design; 10-2021 BD-220177*

EN 1991-2: *Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges and other civil engineering works; 09-2021*

EN 1997: *Eurocode 7: Geotechnical design; 03-2014*

ISO/DIS 4982: *Plastics piping systems for non-pressure underground conveyance and storage of non-potable water – Arch-shaped, corrugated wall chambers made of PE or PP used for retention, detention, transportation and storage of storm water systems – Product specifications and performance criteria; 04-2022*

CIRIA C737: *Structural and geotechnical design of modular geocellular drainage systems; 2016*

BÜV-Empfehlung – *Tragende Kunststoffbauteile im Bauwesen (TKB) – Entwurf, Bemessung und Konstruktion; Bau-Überwachungsverein; 08-2010 (Recommendation – Load-bearing plastic components in building – Design, dimensioning and construction)*

DVS 2205-1: *Berechnungen von Behältern und Apparaten aus Thermoplasten; 09-2013 (Calculations of containers and apparatus made of thermoplastic)*

ISO 12162: *Thermoplastics materials for pipes and fittings for pressure applications – Classification, designation and design coefficient; 11-2009*

Reference documents and software:
BBA Agrément Certificate Product Sheet 07/4480, 2017

European Technical Assessment, ETA-22/0555, Deutsches Institut für Bautechnik (DIBt), 15-08-2022

Culvert ANalysis and DEsign (CANDE) program, Michael G. Katona, Version 2022

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ADS StormTech Construction Guides: Versions relate to chamber type. Available at adspipe.com

Test report PT 19656091: *Zulassungsprüfungen an einem PP- Werkstofftyp 'Formosa, Formolene ® PP 6613N' – 30 Norm-Zugstäbe DIN EN ISO 527-2, Typ 1A; Polytest Ingenieure GmbH; 05.12.2019 (Approval tests on a PP material type 'Formosa, Formolene ® PP 6613N' standard tensile bars DIN EN ISO 527-2, type 1A; Polytest Engineers)*

Test report: Flattening test data, ADS, 06-2022

Test report: Stub Compression Test Report EAD180017-00-0704 Annex D, ADS, 06-2022