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StormTech Chambers designed to meet ASTM and AASHTO performance standards*

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Strategies for successful performance
Apply appropriate engineering principles in design of underground plastic stormwater collection structures.

By Bryan P. Strohman and Phillip A. Sharff

Use of underground stormwater collection systems has increased in recent years because of regulatory mandates to retain, recharge, and/or reuse stormwater onsite. Because of advantages in economics and constructability, the stormwater industry has seen significant growth in the number of available products manufactured from structural plastics. Many of these new, innovative designs offer benefits such as light weight, high corrosion resistance, large storage-to-footprint ratios, and moldability of efficient structural shapes.

However, recent catastrophic failures of some systems have raised concern about the long-term viability of these structures and focused attention on the engineering rigor behind the design of certain products (Figures 1 and 2). Successful structural performance of plastic stormwater collection structures requires understanding and applying engineering principles specific to the behavior of structural plastic materials. It is important for civil engineers to understand the types of plastic stormwater collection structures and strategies for successful performance, including the importance of material selection, structural design, qualification testing, and installation specifications.

Types of structures
Four types of structures currently are available within the plastic stormwater collection industry.

Open-bottom corrugated arched chambers (Figure 3) — Open-bottom corrugated arched chamber stormwater structures consist of arch units placed both in series and parallel, connected by a header pipe, and encapsulated in crushed stone. Both the arches and crushed stone are used to collect, recharge, and/or reuse stormwater. Relevant reference standards for plastic open-bottom corrugated arched chambers include ASTM F2418, ASTM F2787, and ASTM F2922.

Stackable cellular-type units (Figure 4) — Cellular-type units are comprised of a number of pre-assembled modular vertical columns (or cells). The units are manufactured in single-layer panels that comprise an array of interconnected vertical cells. The panels are stacked vertically and placed horizontally to create the stormwater collection system.

Stackable crate-type units (Figure 5) — Crate-type units are comprised of a number of individually assembled crates. Each crate is assembled by joining top, bottom, side, end, and interior plates. The number of interior plates commonly varies by loading (pedestrian, light traffic, and traffic loads). The crates are stacked vertically and placed horizontally to form a modular stormwater collection system.
Corrugated and profile-wall pipe — Corrugated and profile-wall pipe stormwater structures are standard corrugated or profile-wall pipes, which in collection structures can be supplied with perforations to facilitate the percolation of water into the surrounding soil environment. Example reference standards for corrugated or profile-wall plastic pipe include ASTM F949, ASTM F2306, and ASTM F2881.

All stormwater collection structures are commonly embedded in a granular envelope to facilitate structural support and, when required, provide additional water storage capacity. Systems typically are wrapped in a geotextile filter fabric to prevent the migration of fine soils into the system. Structures used for detention/retention and reuse of water are encapsulated in a geomembrane liner. The completed system usually includes maintenance ports or manholes, filtration system, and outlet pipe.

Strategies for success

Most plastic stormwater collection structures are pre-designed by the product manufacturer for “typical” site and installation conditions. However, successful structural performance of plastic stormwater collection structures requires the designer to consider unique site and installation conditions and to understand and apply engineering principles specific to the behavior of structural plastic materials. Components for a designer to evaluate prior to specifying a stormwater collection system for a specific site include material selection, structural design, qualification testing, and installation specifications.

Material selection — A designer needs to ensure that product materials meet applicable consensus standards, such as ASTM, or are otherwise qualified by extensive and properly conducted material and mechanical testing, including resistance to the effects of time and the environment. Common materials used in plastic stormwater collection structures include thermoplastics and fiber-reinforced thermoset plastics.

Thermoplastics are polymers that become moldable above a specific temperature, and then return to a solid state upon cooling. This property allows fabrication of efficient geometries for optimizing structural performance. Examples of thermoplastics used in stormwater systems include polyethylene and polypropylene. These materials exhibit significant time-dependent deformation under sustained loads, a response known as “creep.” When specifying thermoplastic systems, use accepted product standards and material cell classifications.

Thermosets are polymers that begin as malleable materials that are molded into a specific geometry and then cured. Curing is often achieved by the application of heat, radiation, or via a chemical reaction. After curing is complete, the thermoset cannot return to its malleable state. Typical thermoset resins include epoxy and polyesters. Soy-based epoxy resins also are being used in at least one stormwater...
product. Thermoset resins are usually combined with reinforcing fibers such as glass or natural fibers to enhance strength and stiffness. Fiber reinforcement also helps to control creep deformation. For thermosets, designers must rely on manufacturer’s data for material, mechanical, and durability test results.

The use of recycled plastic materials for stormwater collection structures has increased in recent years. These materials present a special challenge in design because of unknown origin and quality control in processing, and variability in basic design properties. The stormwater industry is currently developing specifications for qualifying recycled materials. Designers should use caution when specifying products incorporating recycled materials.

Structural design — Designers of stormwater collection structures must address a number of specific design considerations including the following (Bass et al, 2010):

- Confirm that the system has been pre-designed to meet applicable design standards. Examples are ASTM F2787 for thermoplastic corrugated arched chambers and AASHTO LRFD Bridge Design Specifications for thermoplastic pipe. In the absence of accepted standards, the designer must proceed with caution and conduct a suitability review of the product. This will typically include review of the manufacturer’s material and product tests, quality control program, structural calculations, and survey of the in-service performance history of the product.

- Apply the principles of soil-structure interaction similar to buried flexible pipe. This requires a thorough understanding of soil behavior and how the stormwater structure interacts with the soil envelope. Both the vertical and lateral soil loads on the structure should be considered (Sharff et al, 2011).

- Consider the effects of creep of the plastic materials (i.e., time-dependent reduction in load-carrying capacity under sustained loading conditions) and its impact on the creep stiffness, creep rupture, and ultimately the long-term capacity of the structure. Buried stormwater structures typically are designed using 50-year or longer properties. Creep is non-linear with time, so even short-period loads (for example a parked truck) need to be accounted for in the design by reducing the stiffness of the structure. Reference standards for creep testing of plastic stormwater structures include ASTM D2990, ASTM D6992, and ASTM D7361.

- For corrugated and profile wall structures, take advantage of post-buckling capacity of corrugated elements as detailed in the current AASHTO LRFD Bridge Design Specifications design requirements for thermoplastic pipe. This design approach is now also embodied in ASTM F2787.

- Live load design for these structures is usually based on an AASHTO design truck with 16 kip wheel load. Designers also need to consider the effects of eccentric loadings and the increase in lateral load due to vehicles where appropriate. As noted above, the time-dependent reduction in strength and stiffness must be accounted even for relatively short-duration sustained loads, such as parked trucks over the structure.

Qualification testing — It is essential that structures undergo both laboratory and field testing to qualify their performance. The project designer should verify that laboratory and field testing was performed and incorporated in the product design prior to specifying a stormwater collection system:

- Laboratory tests should address basic material and mechanical properties, as well as tests on the finished product to check strength and stiffness, including confirmation of time-dependent behavior. Tests should include verification of resistance to environmental attack such as oxidation and environmental stress cracking. Reference standards governing environmental resistance include ASTM D3895 and ASTM F2136.

- Because of the complexity in structural behavior of buried plastic structures, full-scale field qualification testing should be conducted to verify structural analysis. These include deep burial tests with consideration for time-dependent response, and shallow burial tests under design vehicle loads. For example, both ASTM F2418 for polypropylene arch-shaped chambers and ASTM F2922 for polyethylene arch-shaped chambers require the chamber manufacturer to “verify the installation requirements and design basis with full-scale installation qualification testing of representative chambers under design earth and live loads” in accordance with ASTM F2787. ASTM F2787 provides specific guidance for field qualification testing, including the need for a minimum three-month test under soil fill equivalent to the factored design load. Experience has shown that well-controlled field qualification testing on prototype structures is essential to verify the structural design and the specified installation requirements.

Installation specifications — Stormwater collection system manufacturers must provide detailed installation requirements to designers to ensure their structures are installed with soil materials and procedures that are consistent with the structural design intent and assumptions. Project designers should incorporate these requirements into the technical specifications for the project, adapting them where appropriate to the site-specific conditions. Prevailing installation standards, such as ASTM D2321 for thermoplastic pipe and ASTM
D3839 for fiberglass pipe, provide benchmark recommendations that can be adapted for plastic stormwater collection structures. Key specifications should include requirements for the following:

- assessing and preparing the soil subgrade and structure foundation
- selection, placement, and compaction of backfill materials
- limiting dimensions of the excavation and soil envelope
- materials and installation of geofabrics, geogrids, and geomembranes
- quality control measurements such as allowable deflection, distortion, and alignment
- minimum and maximum soil cover depths
- basis for determining limiting cover depths, including soil density assumption and design vehicle load

Onsite monitoring of the excavation, installation, and backfill of the system is as important as having detailed installation specifications. A design professional representing the owner should make frequent site visits, and in some cases provide full-time inspection, to monitor conformance to the installation specifications. Identifying non-conformances and taking corrective action during construction goes a long way to preclude costly failures.

Conclusions

Development and application of innovative designs using structural plastic materials provides substantial opportunity for owners and designers to minimize cost and maximize the service life of underground stormwater collection structures. However, successful structural performance of these structures relies on application of engineering principles specific to the behavior of structural plastics materials. Industry standards that embody these principles have been developed for many of the products currently available on the market.

Recent failures of structures using products that have not been vetted by comprehensive industry standards highlight the importance for due diligence on the part of the specifying engineer when selecting candidate systems. As a result, stakeholders in the stormwater industry must push for the development of viable standards that guide designers, installers, and owners or municipalities to the selection of systems that are proven to perform in the long term.

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References

- ASTM F2136 - Standard Test Method for Notched, Constant Ligament Stress (NCLS) Test to Determine Slow Crack Growth Resistance of HDPE Resins or HDPE Corrugated Pipe.
- ASTM F2306 - Standard Specification for 12 to 60 in. (300 to 1500 mm) Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Gravity Flow Storm Sewer and Subsurface Drainage Applications.
- ASTM F2881 - Standard Specification for 12 to 60 in. (300 to 1500 mm) Polypropylene (PP) Dual Wall Pipe and Fittings for Non Pressure Storm Sewer Applications.
SUBSURFACE STORMWATER SYSTEMS ARE NOT ALL CREATED EQUAL

SPECIFYING INDUSTRY STANDARDS PROVIDES CONSULTING ENGINEERS WITH A DEFENSIBLE BASIS OF DESIGN

POLYPROPYLENE CHAMBERS MEET ASTM F 2418 “STANDARD SPECIFICATION FOR POLYPROPYLENE (PP) CORRUGATED WALL STORMWATER COLLECTION CHAMBERS”

POLYETHYLENE CHAMBERS MEET ASTM F 2922 “STANDARD SPECIFICATION FOR POLYETHYLENE (PE) CORRUGATED WALL STORMWATER COLLECTION CHAMBERS”

STORMTECH INSTALLED CHAMBERS PROVIDE THE LOAD FACTORS SPECIFIED IN THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS SECTION 12.12 FOR EARTH AND LIVE LOADS, WITH CONSIDERATION FOR IMPACT AND MULTIPLE PRESENCES. STORMTECH CHAMBERS ARE DESIGNED IN ACCORDANCE WITH CSA B184 “POLYMERIC SUBSURFACE STORMWATER MANAGEMENT STRUCTURES.”

COMPLETE LINE OF STORMTECH CHAMBERS

POLYPROPYLENE CHAMBERS MEET ASTM F 2418 “STANDARD SPECIFICATION FOR POLYPROPYLENE (PP) CORRUGATED WALL STORMWATER COLLECTION CHAMBERS”

STORMTECH CHAMBERS CONFORM TO THE REQUIREMENTS OF ASTM F 2787 “STANDARD PRACTICE FOR STRUCTURAL DESIGN OF THERMOPLASTIC CORRUGATED WALL STORMWATER COLLECTION CHAMBERS”

STORMTECH INSTALLED CHAMBERS PROVIDE THE LOAD FACTORS SPECIFIED IN THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS SECTION 12.12 FOR EARTH AND LIVE LOADS, WITH CONSIDERATION FOR IMPACT AND MULTIPLE PRESENCES. STORMTECH CHAMBERS ARE DESIGNED IN ACCORDANCE WITH CSA B184 “POLYMERIC SUBSURFACE STORMWATER MANAGEMENT STRUCTURES.”

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Rely on ASTM and AASHTO Industry Performance Standards & High Quality Products that meet the Standards: ASTM F 2922, 2418, 2787, AASHTO LRFD and CSA B184...Not Just Questionable Product Claims Alone.

DESIGN REQUIREMENTS FOR THERMOPLASTIC STRUCTURES

- Evaluation of short-term live loads, intermediate-term loads, and long-term soil loads using materials that provide the necessary short, intermediate, and long-term properties
- Verification by experts in the field of soil-structure interaction

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