PROFESSIONAL DEVELOPMENT SERIES

PRECAST CONCRETE: THE STORMWATER MANAGEMENT SOLUTION

National Precast Concrete Assocation

NPCA
Precast ... The Concrete Solution

INTRODUCTION

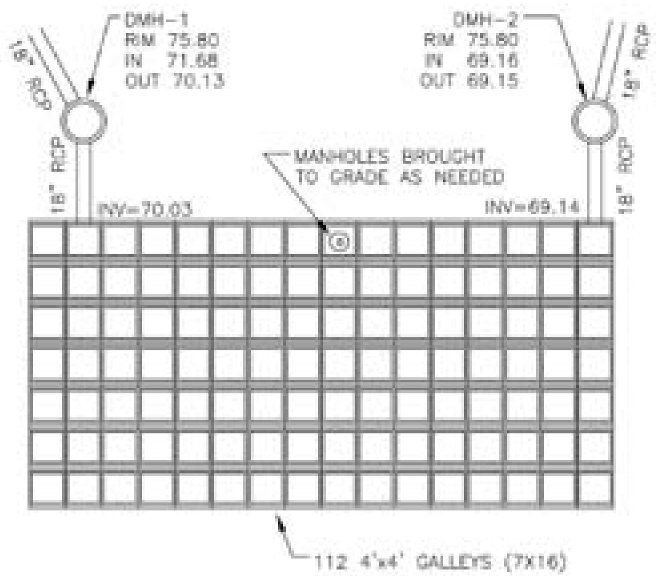
Although it has been a part of the public works landscape since 1972, stormwater management is considered by the Environmental Protection Agency to be an increasingly important component of the EPA strategy to protect the nation's watersheds and waterways. In the public works arena, we typically think of stormwater management as detention ponds, infiltration swales, reservoirs and sand filter beds that are commonly referred to as Best Management Practices (BMPs). However, even with these land-based strategies, the backbone of any stormwater management design is the conveyance system used to move the stormwater from collection system to terminus, whether into a water reservoir or a natural waterway.

Conveyance systems are comprised of a variety of structures that today are often made from precast concrete and include catch basins, manholes, reinforced concrete pipe and other control structures. In the past, conveyance systems were built in the field with a combination of poured concrete and bricks or block. As precast concrete structures evolved into highly customizable, high-quality, watertight products, the advantages of installing precast systems instead of

constructing components on-site have moved precast into the forefront of stormwater management. Drive down any road where construction is underway and you will likely see a collection of precast concrete catch basins, manholes and reinforced concrete pipe ready for installation.

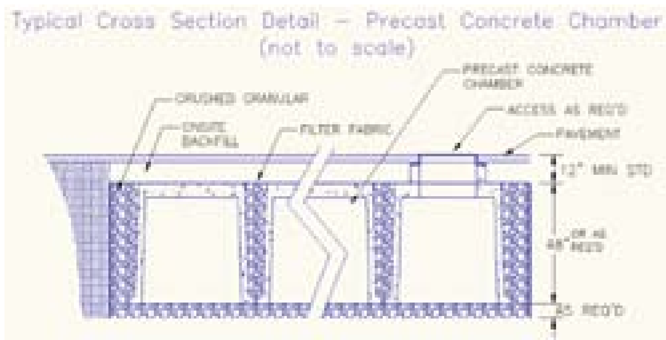
Municipalities have found that there are many benefits to installing precast concrete conveyance systems for stormwater management. The heavy weight of precast concrete makes it resistant to the buoyant forces of water and makes installation quicker and less prone to deflection, for example. Products can be manufactured to custom specifications at extremely fine tolerances and then delivered when needed. And, as with any precast concrete product, the components are manufactured in a controlled off-site environment and trucked to the site. Weather becomes less of a factor at the construction site and there is no formwork waste, less noise and less skilled labor needed at the site.

In addition, precast concrete manufacturers, working in conjunction with trade associations like the National Precast Concrete Association, have developed tools to simplify calculations that engineers typically use in designing stormwater systems. One of these is the Stormwater Detention/Retention Calculator. Here's how it works:



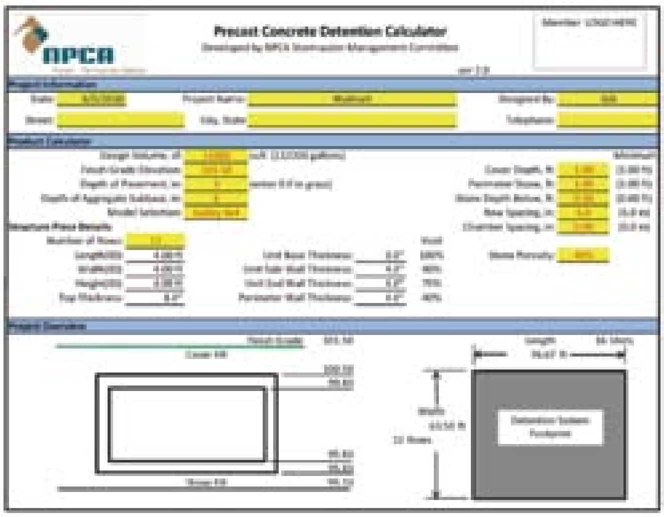
A Precast Solution

Imagine you have a project that requires a very shallow stormwater conveyance system with less than 18 inches of cover in a limited space. One of the key components of the system is a subsurface stormwater detention reservoir to hold the stormwater and enable a controlled discharge from the site at a lower flow rate. However, in reviewing the specs, you find that you are required to have at least 18 inches of cover on the product to meet traffic loading requirements in the parking lot.



Precast manufacturers have developed a solution for exactly this situation. Whether you need a detention or infiltration system for your project, a precast concrete structure can be designed for minimal cover depths and can be designed as an open or closed system.

Once you have chosen precast as the best material for your design, how do you size it for your project specifications, and what standard sizes are available? The NPCA Stormwater Management Committee recognized this as a problem and developed an Excel-based tool for just this situation. The tool is an interactive detention/retention calculator that enables the local manufacturer to add standard products to your spreadsheet for easy use by the design engineer.



Precast Concrete Detention Calculator Data Entry Page

The tool simplifies calculations needed to specify stormwater structures for underground detention/retention systems and is available online at www.precast.org. You can find it by entering the Precast Solutions portal, choosing Products, Sanitary and Stormwater Products, Stormwater Management, and then clicking on Detention Calculator in the Resources section.

This is just one tool engineers and contractors can find on the NPCA website. In addition you will find a variety of other resources for use in stormwater management, including generic product specifications for hydrodynamic separators, sample drawings and pictures of other products commonly used for stormwater controls. With the Clean Water Act in full swing and with municipalities under time constraints to come up with BMP plans and solutions to meet federal mandates, precast concrete stormwater solutions and the new Detention/Retention Calculator can simplify design and help meet those deadlines.

Finding a local precaster is also easy through www.precast.org. Once you enter the Precast Solutions section of the site, simply click the “Find a Precaster” link to locate manufacturers in your region. NPCA manufacturers create products based on ASTM and NPCA standards and best practices. NPCA certified plants provide an even higher level of quality assurance by adhering to the rigorous standards of the certification program. For more information regarding precast concrete Stormwater Management systems, please visit www.precast.org or call NPCA at (800) 366-7731.

Precast Concrete for Stormwater Management: Structural Integrity

Structural integrity is the philosophy behind the engineered design of sound structural components that comply with, or exceed, applicable standards and codes. Structural integrity implies that the strength of the structure will be greater than the maximum anticipated service stresses. If the designed strength of a structure is greater than the expected maximum applied stresses by an appropriate factor of safety, the structure is considered to be adequate to fulfill its function. If not, modification to the design is required. Structural integrity of precast concrete stormwater management structures is essential to provide dependable, long-term serviceability for all stormwater management applications.

Precast concrete stormwater management structures are required to be structurally sound to perform as required in their intended environment. This document will outline the types of precast concrete stormwater management products available, and will examine the proper procedures and design methods necessary to create a product with structural integrity.

I. STRUCTURAL INTEGRITY DEFINITION

Structural integrity can be generally defined as *a structure's uncompromised ability to safely resist all anticipated service loads, while adequately serving its designed function.*

NPCA describes structural integrity in a similar fashion: Precast concrete structures are built according to rigid standards adopted by nationally accredited organizations such as ASTM and ACI. The structural integrity of a precast product makes it capable of supporting service loads independently, without relying significantly on adjacent support materials, soils or minimum depth requirements. With regard to stormwater management products and structures, the structural integrity of precast concrete provides a safer work environment for ongoing maintenance operations. Stormwater management products include hydrodynamic separators, sand filters, water quality units, manholes, catch basins and retention/detention structures.

II. GENERAL CONDITIONS

The following conditions are design parameters that the engineer takes into account when designing precast concrete stormwater management structures to ensure structural integrity: flow conditions, groundwater conditions, adjacent earth conditions, and superimposed loading conditions.

III. LOADING CONDITIONS

The design of an underground stormwater structure requires that the engineer determine all the combined forces acting on the overall structure and those forces acting on each individual component of the structure. Combined lateral forces result primarily from fluid pressures, earth pressures and surcharged loading. The following are loads, methods and coefficients that must be considered in the design of a structurally sound underground stormwater structure: surface loads, adjacent structures and highways, structures in buried parking lots, structures buried in fields or nearby soils, structures buried in or near airport runways, external soil and water loads, internal liquid loads, hydraulic loads (including hydrostatic loads and hydrodynamic loads), earth loads, vertical effective stress, horizontal effective stress (including the three commonly used earth pressure coefficients: at-rest earth pressure coefficient; active earth pressure coefficient, and passive earth pressure coefficient), other methods used to estimate horizontal earth pressures, equivalent fluid pressures, coefficient of friction, bearing capacity values, groundwater loads and superimposed loads.

IV. DISTRIBUTION OF FORCES

The design of precast concrete stormwater management products must include anticipated loading and restraint conditions from initial fabrication to the end-use of the structure, including form removal, storage, transportation and erection. Service load stresses are not the only stresses a precast concrete element experiences. In fact, stresses developed during the period of time leading up to final connection may be more intense than in-service loads. Stresses originate from many different sources, including handling, storage, transport and erection. Precautions should be taken so that the structural performance under service loads and strength under factored loads meets or exceeds code requirements.

Forces and deformations occurring in (and adjacent to) connections must be included in the design of precast concrete stormwater members. Special considerations in precast construction need to be taken into account when designing precast connections in order to minimize or transmit forces due to creep, temperature change, shrinkage, wind, differential settlement and earthquakes.

Distribution of forces perpendicular to the plane of the precast element should be determined by analysis or by testing. Concentrated point and line/uniform loads may be distributed among precast components, provided there is sufficient structural torsional stiffness, so that shear forces can be transferred across joints. The actual distribution of loads depends on many factors, including large openings that cause significant changes in the distribution of forces.

In-plane force paths shall be continuous through both connections and members. A continuous path of steel, steel reinforcement or both (including steel with lap splices, mechanical or welded splices or mechanical connectors) should be provided to carry tension forces, whereas the shear and compression forces may be carried by the adjacent concrete sections.

V. DESIGN: UNDERGROUND STORMWATER STRUCTURES

For an underground precast concrete stormwater structure to be structurally sound, all anticipated loading conditions must be accounted for and the structure must be designed to meet or exceed the requirements of industry standards.

For more technical information, including calculations and formulas on categories V through VI, please send e-mail to technical@precast.org and request complete white paper information.

Underground stormwater structures sustain pressures from live loads, including loads at grade, soil loads and water (internal/external) loads. Pressures exerted on the walls of an underground structure are considered to be uniformly applied in design calculations. It is common to use the term *P*, for pounds of force per square foot (psf), in calculations.

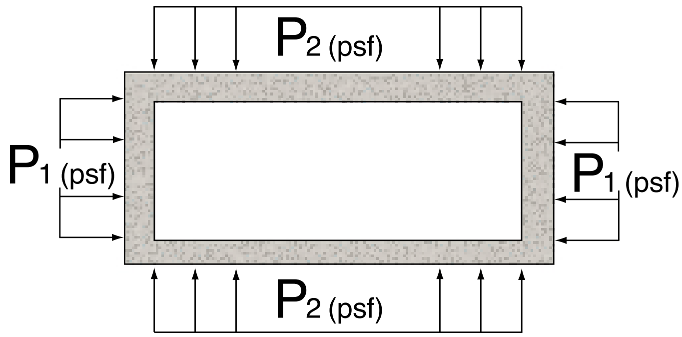


Figure 1: *Uniform load distribution of an underground structure*

In most cases the load pressures will be considered to be uniform on all four walls so that:

$$P = P_1 = P_2 \text{ (as seen in Figure 1)}$$

To simplify calculations, common practice is to use an average pressure over the entire height of a vertical concrete component, or riser. This is acceptable design practice because of the homogeneous nature of the concrete. The lower portions of the wall, when deflected, will distribute the load to the upper portion, enabling the entire structure to act as one unit in resisting loads. **Figure 2** demonstrates this design.

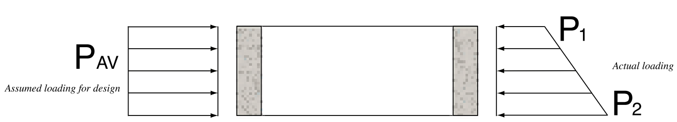


Figure 2: *Accepted design load practice*

Design: Dead Loads

Dead loads are permanent or static loads that need to be included in the design of underground structures. Dead loads include earth backfill, self-weight of the structure, road bed weight and the weight of any other permanent objects above the underground structure. Dead loads will vary depending on the design and location of the underground structure.

Design: Live Loads

Live loads are loads that include all the dynamic forces that are variable with respect to the structure during its service life. Live loads include loads from vehicular traffic, operating machinery, and other temporary loads. These concentrated loads create horizontal and vertical pressures on the components of buried precast structures. Effects of vertical live load pressures decrease as the depth below grade increases due to a corresponding increase in the load distribution area. Vertical surface pressures are distributed over a much larger area at increased depths.

TRAFFIC LOADING

Traffic loading includes loads caused by vehicular and pedestrian traffic. The most common loading occurs when the structure is under or adjacent to a road or highway. Not only must the wheel load from a truck be considered in design, but an allowance must also be made for impact loading caused when the wheel is traveling at high speeds. AASHTO and ASTM C 890 are standard references in choosing the recommended allowance for wheel load and impact loads. The most common wheel load used in underground structure design is the AASHTO HS20 load:

Axle load = 32,000 lbs. + impact **(Equation 1)**

$$\text{Wheel load} = \frac{\text{axle load}}{2}$$ **(Equation 2)**

Other vehicle and pedestrian loads are specified in AASHTO. AASHTO vehicle and load designations are stated in **Table 1.**

Table 1. *Vehicle and Pedestrian Load Designations**

Designation	Load, max	Uses
A-16 (HS20-44)	16,000 lbf (71.2 kN) per wheel	heavy traffic
A-12 (HS15-44)	12,000 lbf (53.4 kN) per wheel	medium traffic
A-8 (H10-44)	8,000 lbf (35.6 kN) per wheel	light traffic
A-0.3	300 lbf/ft² (14,400 N/m2)	walkways

**To determine the arrangement and spacing of wheel loads, refer back to AASHTO or ASTM C 890 standards.*

Design: Hydraulic Loads

Hydraulic loading on structures are categorized in one of two types of loading: hydrodynamic or hydrostatic. Hydrodynamic loads are caused by fluid movement, and hydrostatic loads are caused by fluid pressures. In many applications the hydrostatic forces will represent the dominant hydraulic load on the structure.

Design: Earth Loads

Generally speaking, earth loads on underground precast concrete structures are the sum of the effective soil stresses and the groundwater pressures. Soil stresses consist of the pressure exerted on the structure by the surrounding soil, while groundwater stresses consist of the hydrostatic pressures exerted on the structure by the water in the soil.

Design: Connections

Connection details should be designed to resist the forces of deformation due to shrinkage, creep and thermal effects. Connection details may be selected to accommodate volume changes and rotations caused by temperature gradients and/or long-term deflections. Connections and members should be designed to provide adequate strength and ductility in order to resist these deformation forces.

Adequately designed connections are required for underground precast concrete stormwater management structures to ensure that the structural integrity is not compromised due to weak or poor connections. Nationally recognized codes and standards include design requirements and specifications that underground precast concrete stormwater management structures must meet.

Design: Stability Analysis

To provide a structurally sound underground stormwater structure, the structure must be designed to withstand forces acting against it, and the structure must be able to resist sliding, uplifting and overturning forces.

Design: Top/Bottom/Reducing Slab Design

TOP SLAB DESIGN

Top slabs in precast concrete structures are designed for on- and off-highway loading conditions. Precast concrete stormwater structures may also need to comply with additional design requirements for locations that incur operational airplane or railroad loads. ASTM C 857 and ASTM C 890 specify that underground and monolithic precast structures (for the most part) should be designed to withstand a 16,000 pound wheel load (A16). If the underground precast concrete structure is designed for use near or beneath a highway, the 16,000 pound load is multiplied by a constant to make allowance for vehicular impact loads on the top slab. ASTM C 857 and ASTM C 890 require a constant (safety factor) of 1.3 for structures up to 12 inches below grade, and a constant of 1.0 for structures up to 35 inches below ground level.

LOADS FOR BOTTOM SLAB DESIGN (under highway traffic)

For the most part, bottom slabs do not have openings or access holes. The self-load of the concrete structure, soil on top of the structure, and the live loads experienced at the surface are all transferred to the bottom slab.

LOADS FOR REDUCING SLAB DESIGN

Reducing slabs are designed using the same method as for top slabs.

Design: Total Design, Horizontal, and Vertical Loading Considerations

When designing a structurally sound underground precast concrete stormwater management structure, all potential vertical and horizontal loads must be taken into account.

VI. MATERIALS/CONCRETE/ PRODUCTION PRACTICES/ INSTALLATION METHODS

It is recommended that all materials, concrete mix designs, processes and installation methods used in the design of stormwater management products comply with the requirements stated in the NPCA Quality Control Manual for Precast and Prestressed Concrete Plants, or other nationally recognized guidelines. Compliance with industry recommendations will help to ensure that all materials used are of the highest quality and will help eliminate materials and processes that could jeopardize the structural integrity of the stormwater structure. Follow NPCA's recommendations for materials, production practices, quality control operations and concrete mix design procedures to help ensure that the underground precast concrete stormwater management structure is designed with structural integrity. Structurally sound underground precast concrete stormwater management structure have three key characteristics. They are durable, strong and watertight.

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