PRECAST CONCRETE MANHOLES
WHY PROVIDE GUIDELINES?

Past Problems

• Was tedious to keep track of variables

• Was easy to make mistakes

• Wanted: A design tool to reduce problems
TOPICS

- Overview on Precast Manholes
- Applications
- Design Procedures and Applicable Standards
- Watertight Structures
- Quality
- Installation
PRECAST CONCRETE MANHOLES

Round Structures
• ASTM C478, “Standard Specification for Precast Reinforced Concrete Manhole Sections”
PRECAST CONCRETE MANHOLES

Rectangle / Square Structures

- DO NOT Specify a Box Culvert for a vertical application. Box Culverts are designed for horizontal installations and loading conditions.
- Specify ASTM C913 for square structures.
COMMON SIZES

Round – ASTM C478

- Internal Diameter (I.D.)
- 36” – 144”
- Check with local manufacturer for availability of larger diameter structures. Custom box structures are easily fabricated using universal forming equipment.
COMMON SIZES

Rectangle / Square
ASTM C913
- 24” x 24” to 72” x 72”
- sizes increase by 6” increments
MANUFACTURING METHODS

Wet-Cast

- Cast with an inner and outer form.
- Product cured in the form.
- Blockouts/hole formers can easily be incorporated.
MANUFACTURING METHODS

Wet-Cast

- Cast with conventional concrete or self-consolidating concrete.
- Base sections are typically wet-cast.
- Wet-cast is common for sanitary applications.
MANUFACTURING METHODS

Dry-Cast (Machine Made)

- Product is cast utilizing mechanized equipment.
- Form vibrators consolidate zero-slump concrete between core and jacket.
- The product is immediately stripped and the form is reused.
- Products typically cured in a kiln or a combination of tarps and moisture curing is used.
Dry-Cast (Machine Made)

- Both round and square structures may be dry-cast.
- Hole formers may be incorporated, or coring is done as needed.
- Surface may appear rough due to manufacturing process.
PRECAST ADVANTAGES

• Readily Available (more than 400 NPCA members supply precast concrete manholes)
• Modular Flexible Design
• May be designed to accommodate existing utilities
• Produced in a Quality Controlled Plant Environment
PRECAST ADVANTAGES

• Watertight Structures Easily Achieved
• Resists Buoyant Forces
• Superior Strength
APPLICATIONS

Sanitary and Stormwater Sewer
- Provide access for inspection and maintenance.
- Monolithic drop manholes available.

Stormwater Inlet and Treatment Structures
- Structure for housing stormwater treatment equipment.
- Various proprietary treatment systems available.
APPLICATIONS

Pump/Lift Stations

- Sanitary and stormwater sewer applications.
- Accommodate elevation changes in gravity flow sewer systems.
APPLICATIONS

Utility Manholes

• Provide access to underground utilities and/or vaults.
• Used by electrical, telecommunications, fiber optics, water and gas companies.
• May be referred to as a valve vault.
DESIGN

• Structure Sizing
  • Round Structures
    ▪ ASTM C478
    ▪ ASTM C497
  • Rectangle/Square Structures
    ▪ ASTM C913
    ▪ ASTM C890

• Lifting and Handling

• Corrosion Mitigation
SIZING CONSIDERATIONS

• The structure (round or square) must be large enough to accept the maximum size pipe.

• The structure size is a function of the number, size, elevation and entry angle of pipes connecting to the structure.

• The structural integrity must be maintained by providing a minimum structural leg of concrete between pipe holes. A general rule of thumb is to provide a minimum of 6 inches as measured from the interior of the structure.
SIZING CONSIDERATIONS

• The type of pipe entering the structure and accompanying connection method (boot, compression or mortar) must be known to accurately determine the required hole size and structure size.

• Transition sections may be incorporated above a larger base section to utilize smaller riser sections, which may minimize overall project costs.
SIZING CONSIDERATIONS

• Square and/or rectangular structures are typically used where pipes can intercept at 90 degrees or 180 degrees. Most roadways and some stormwater site drainage systems employ these types of structures.

• Round structures allow more flexibility in the system design and layout. Various sizes of pipes entering at different angles can more easily be accommodated by a round structure, ensuring watertight connections are maintained.
SIZING CONSIDERATIONS

• When possible, avoid pipes entering into structure joints and corners, as this may compromise the structural integrity and watertightness of the structure. However, this practice may be necessary for certain installations and should be left to the discretion of an experienced precast concrete manufacturer.

• Consult your local precast concrete manufacturer and connector supplier for exact design requirements and product specifications.
SIZING CONSIDERATIONS

Hole Sizing for Reinforced Concrete Pipe (ASTM C76)

Relationships between Inside Diameter (I.D.), Wall Thickness (W.T.), Outside Diameter (O.D.) and Hole Size (H.S.)* for concrete pipe.

W.T. (in inches) = I.D./12 + 1
O.D. = I.D. + (W.T. x 2)
H.S. = O.D. + (2” to 4”)

* H.S. may vary depending on type of pipe and connection used. H.S. diameter may be 2-4 inches larger than O.D.

Example: ? Hole Size for 24” RCP
W.T. = 24/12 + 1 = 3”
O.D. = 24 + (3 x 2) = 30”
Hole Size (H.S.) = 30 + 4 = 34”
SIZING CONSIDERATIONS

- Local specifications and design handbooks may include minimum requirements and design tables to assist in the sizing of manhole structures.

- The adjacent table addresses structure sizing when using concrete pipe for storm drains.

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Rectangular</th>
<th>Round</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>Side Dimension</td>
<td>Diameter</td>
</tr>
<tr>
<td>30 in.</td>
<td>3'-6”</td>
<td>4 ft.</td>
</tr>
<tr>
<td>36 in.</td>
<td>4 ft.</td>
<td>5 ft.</td>
</tr>
<tr>
<td>42 in.</td>
<td>5 ft.</td>
<td>6 ft.</td>
</tr>
<tr>
<td>48 in.</td>
<td>6 ft.</td>
<td>6 ft.</td>
</tr>
<tr>
<td>54 in.</td>
<td>6 ft.</td>
<td>8 ft.</td>
</tr>
<tr>
<td>60 in.</td>
<td>7 ft.</td>
<td>8 ft</td>
</tr>
<tr>
<td>66 in.</td>
<td>7 ft.</td>
<td>8 ft</td>
</tr>
<tr>
<td>72 in.</td>
<td>8 ft.</td>
<td>8 ft</td>
</tr>
<tr>
<td>78 in.</td>
<td>9 ft.</td>
<td>10 ft.</td>
</tr>
</tbody>
</table>

Table 4-2

SIZING CONSIDERATIONS

Minimum Angle Between Pipes Entering Round Structures

- Pipe opening (H.S.) is assumed to be:
  - H.S. = I.D. + W.T. + (2” to 4”)

- Recommended minimum structural leg is 6 inches as measured from the interior of the structure.

- Structure #1 would not provide the minimum structural leg.

- Increasing the manhole diameter to the next size (Structure #2) provides the required structural leg.
SIZING CONSIDERATIONS

• Required minimum structural leg has not been achieved.

• A larger diameter manhole base should have been specified.

• Authorities having jurisdiction may require a minimum amount of concrete above openings.
SIZING CONSIDERATIONS

Skewed pipes entering rectangular structures

- Watertight connections may be difficult to achieve.
- Typically done in stormwater structures using mortar joints.
- Consider the use of a round structure and flexible connector when requiring a watertight structure.
SIZING CONSIDERATIONS

Skewed pipes entering rectangular structures

• Authorities having jurisdiction may provide design tables addressing pipe size and maximum allowable skew angles.

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>18&quot;</th>
<th>24&quot;</th>
<th>30&quot;</th>
<th>36&quot;</th>
<th>42&quot;</th>
<th>48&quot;</th>
<th>54&quot;</th>
<th>60&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Skew</td>
<td>19°</td>
<td>17°</td>
<td>16°</td>
<td>16°</td>
<td>15°</td>
<td>14°</td>
<td>14°</td>
<td>13°</td>
</tr>
</tbody>
</table>

These values are based on 2" of construction tolerance, precast structures with 8" walls, and concrete pipe dimensions.
SIZING CONSIDERATIONS

Transition Slabs

- Allow the use of a larger base section to accommodate pipe sizes and entry angles.

- Provides transition to smaller size riser sections.
SIZING CONSIDERATIONS

Transition Slabs

• Slabs must be designed properly to withstand the anticipated loads (riser sections, backfilled soil, surcharge loads, etc.).
DESIGN

• Structure Sizing
  ▪ ASTM C478
  ▪ ASTM C497

• Round Structures
  ▪ ASTM C478
  ▪ ASTM C497

• Rectangle/Square Structures
  ▪ ASTM C913
  ▪ ASTM C890

• Lifting and Handling

• Corrosion Mitigation
ROUND STRUCTURES

Maximum Depth
ASTM C478 and ASTM C497

Products

- Grade Rings
- Flat Slab Tops
- Risers and Conical Tops
- Base Sections
- Steps and Ladders
ROUND STRUCTURES

Maximum Depth
ASTM C478 and ASTM C497

Reinforcement Options
- Conventional Reinforcing Steel
- Welded Wire Reinforcement
- Hoop Steel Reinforcement
- Fiber Reinforcement
• According to the American Concrete Pipe Association (ACPA), the maximum allowable depth of a typical precast concrete round manhole is in excess of 500 feet.

• Let’s check that statement for riser sections with no openings.
Assume the water table is at the same elevation as the ground surface.

Forces Acting on the Manhole Structure Include:

- Lateral Earth Pressure
- Hydrostatic Pressure
Because both loads are uniformly distributed around the periphery of the manhole, no bending moment is experienced by the manhole section. The following equation may be used to calculate the total lateral pressure at a given depth \( (H) \):

\[
p = w_s \cdot H \cdot K_s \cos(i) + w_w \cdot H \cdot K_w
\]

Where:
- \( p \) = total lateral earth and hydrostatic pressure (pounds per square foot)
- \( w_s \) = effective unit weight of the backfill materials (pounds per cubic foot)
- \( H \) = depth of manhole (feet)
- \( K_s \) = conjugate ratio for soil
- \( i \) = angle between backfill surface and the horizontal (degrees)
- \( w_w \) = unit weight of water (62.4 pounds per cubic foot)
- \( K_w \) = conjugate ratio for water (1.0)
ROUND STRUCTURES

\[ p = w_s H K_s \cos(i) + w_w H K_w \]

- Most backfill top surfaces are flat and “i” typically equals 0; therefore, \( \cos(i) = 1 \).
- Using a common angle of internal friction of 30 degrees for the backfill material, \( K_s \) simplifies to 1/3.
- Assuming the saturated unit weight of the backfill material equals 120 pounds per cubic foot, the effective unit weight would be \( 120 - 62.4 = 57.6 \) pounds per cubic foot.
- Using the above information, the equation simplifies to the following:

\[ p = 57.6 \times H \times \frac{1}{3} + 62.4 \times H \]

\[ p = 81.6 \times H \]
ROUND STRUCTURES

In theory the pressure \( p \) acts equally around the periphery of the round manhole section, placing the ring in pure compression without introducing bending moments into the concrete section in the horizontal plane. The compressive stress in any section of the round manhole riser is given by the equation:

\[
s = \frac{(pD)}{(2t)}
\]

Where:
- \( s \) = unit compressive stress in the ring (pounds per square foot)
- \( p \) = total lateral earth and hydrostatic pressure (pounds per square foot)
- \( D \) = diameter of the manhole (feet)
- \( t \) = thickness of the manhole wall (feet)
- \( t \) must be a minimum of 1/12 the largest diameter riser section.
ROUND STRUCTURES

\[ s = \frac{(pD)}{(2t)} \]

Substituting the known values into the above equations yields the following:

\[ s = \frac{81.6H \times D}{144 \times 2 \times \frac{1}{12} \times D} \]

then

\[ s = 3.4H \]
ROUND STRUCTURES

Where:

\[ s = 3.4H \]

- \( s \): unit compressive stress in the ring (pounds per square foot)
- \( H \): depth of manhole, feet

Using an allowable concrete stress of 45% of the minimum specified compressive strength of 4,000 psi, the allowable compressive stress would be 1,800 psi. Substituting this value for \( s \) yields the following:

\[ 1,800 = 3.4H \quad \text{then} \quad H = 530 \text{ feet} \]

The above example illustrates that precast concrete manhole sections may be installed to considerable depths. However, ensure the base sections and/or transition slabs are properly designed to withstand the anticipated loads.
ASTM C478: ROUND STRUCTURES

Standard Specification for Precast Concrete Manhole Sections

• ASTM C478 covers the manufacture and purchase requirements of products used for the assembly and construction of circular precast reinforced concrete manholes used in sewer and water works.

• The standard is divided into two parts.

• Part I covers general requirements on materials, design, reinforcement, manufacturing, acceptance, repair, inspection and product marking.
ASTM C478: ROUND STRUCTURES

Standard Specification for Precast Concrete Manhole Sections

- Part II covers the minimum requirements for the various manhole components.

- The following products are addressed: grade rings, flat slab tops, risers/conical tops, base sections and steps/ladders.

- It should be noted that ASTM Standards are minimum design specifications.
The concrete constituents shall conform to the applicable ASTM Standards.

- Cement – ASTM C150, Aggregates – ASTM C33, etc.

Minimum compressive strength shall be 4,000 psi.

- Maximum water-cementitious ratio of 0.53 specified.
- A typical precast wet-cast mix has a w/c ratio of 0.38 – 0.45.
- A typical precast dry-cast mix has a w/c ratio of 0.24 – 0.30.
Absorption Test Requirements as outlined in ASTM C497.

- Test Method A: Max 9% (specimen shall have max weight of 0.22 lb.)
- Test Method B: Max 8.5%

Repairs to product are allowed.
ASTM C478: OVERVIEW PART I

Products shall be marked w/ ASTM designation, date manufactured and manufacturer’s name or logo.

Reinforcement options will be covered in the following slides.
Conventional Reinforcing Steel

- Typically used in base slabs and flat slab tops.
- Additional bars may be placed around blockouts.
- Conforms to ASTM A615.
- Although not included in ASTM C478, plants may use ASTM A706 reinforcing steel when welding reinforcing mats.
Welded Wire Reinforcing (WWR) Steel

- Commonly used for reinforcing risers and conical sections.
- Available in prefabricated rolls with varying spacing and steel area per foot.
  - Plain WWR - ASTM A185
  - Deformed WWR - ASTM A497
- Cages may be manufactured at the plant with mechanized equipment using steel wire.
  - Plain Wire - ASTM A82
  - Deformed Wire - ASTM A496
REINFORCEMENT

Hoop Steel Reinforcement

• Not allowed for reinforcing base sections.

• Allowed for reinforcing risers and conical tops up to 48 inches in height and 48 inches in diameter.

• Welded splices shall have a min. lap of 2 inches and shall develop 50% of the minimum specified strength of the steel.

• Butt welded splices shall develop at least 75% of the minimum specified strength of the steel.

• Continuity of steel should be maintained.
Secondary Synthetic Fibers

- Fiber reinforcement shall not be used to replace primary reinforcing steel.
- Allowed for use in steel reinforced manholes as secondary reinforcement.
- Helps minimize handling damage (chips and spalls).
- Only fibers designed and manufactured specifically for use in concrete and so certified by the manufacturer shall be accepted.
ASTM C478: OVERVIEW PART II

Part II covers the specific requirements for the various products used to construct a precast concrete manhole system.

Products:
- Grade Rings
- Flat Slab Tops
- Risers and Conical Tops
- Base Sections
- Steps and Ladders
Requirements covered in each product section:

- Design
- Joints
- Reinforcement
GRADE RINGS

- Precast concrete grade rings are used for final adjustment of manholes to grade and available in a range of heights and diameters.

- Grade rings are often supplied in bulk or by the pallet.

- Grade rings are not required to have a male/female joint.

- The minimum wall thickness is 1/12 of the internal diameter of the grade ring or 4 inches, whichever is greater.
GRADE RINGS

Circumferential Reinforcement Requirements

• Minimum steel area of 0.07 square inches per vertical foot, but not less than 0.024 square inches in any one grade ring.

• A minimum of _ inch of concrete cover must be provided.
FLAT SLAB TOPS

Flat slab tops are often used to provide a transition from a larger diameter base to a smaller diameter riser section.

Design

• Flat slab tops must be designed to withstand the anticipated loads from supported riser sections, soil and hydrostatic loads, surcharge loads, live loads and impact loads.

• Tops shall be designed in accordance with ACI 318.

• Acceptance on the basis of Proof-of-Design testing as outlined in ASTM C497.
FLAT SLAB TOPS

Design

• Slab Thickness:
  ▪ For risers 48 inches in diameter and smaller, minimum of 6 inches.
  ▪ For risers larger than 48 inches in diameter, minimum of 8 inches.

• Access opening shall be a minimum of 24 inches in diameter.

• Joints may or may not be designed with a male or female end.

• Shear load testing of joints is not required.
FLAT SLAB TOPS

Reinforcement Requirements

• Tops with a joint or with other indication of a top and bottom side shall have one layer of steel reinforcement placed near the bottom surface so that the protective cover over the reinforcement is 1 inch.

• Tops without a joint or without other indication of a top and bottom side shall have two layers of steel reinforcement, one located near the bottom surface and one near the top surface so that the protective cover over each layer is 1 inch.
FLAT SLAB TOPS

Reinforcement Requirements

• The minimum area of reinforcing steel is 0.12 square inches per linear foot in both directions

• Additional reinforcing steel is required around openings:
  ▪ A minimum of 0.20 square inches of steel at 90 degrees and the length of the reinforcing must be greater than the diameter of the opening plus 2 inches.
FLAT SLAB TOPS

Reinforcement Requirements

• Required concrete cover:
  ▪ A minimum of _ inch is required.
  ▪ 1 inch required above and/or below base slab reinforcement.
RISERS and CONICAL TOPS

Precast concrete manufacturers typically stock a variety of riser sections and conical tops. Conical tops are often referred to as cones and are available in both concentric and eccentric designs.

Design
Minimum Wall Thickness
• 1/12 of the largest internal diameter of the riser or conical top.
RISERS and CONICAL TOPS

Design
Circumferential Reinforcing Steel

• Shall consist of one or two lines of steel.*
• The total area of circumferential reinforcing steel per vertical foot shall be not less than 0.0025 times the internal diameter of the section, in inches.

• Example: minimum circumferential reinforcing steel for a 48-inch-diameter manhole is 48 x 0.0025 = 0.12 in²

*See ASTM C478 for requirements when two lines of steel are used.
RISERS and CONICAL TOPS

Design
Circumferential Reinforcing Steel
• Steel shall be placed in the center third of the wall.
• A minimum of _ inch concrete cover is required.
• The spacing center to center of circumferential reinforcement in a cage shall not exceed 6 inches.
RISERS and CONICAL TOPS

Design

Steel Hoop Reinforcement

- Risers and conical tops ≤ 24 inches in height
  - No fewer than two hoops of steel wire or reinforcing bars.
  - Must have a minimum cross-sectional diameter of 0.250 inches.
  - Must be located in each end quarter of the section and be a minimum of 1 inch from the shoulder of the section.
RISERS and CONICAL TOPS

Steel Hoop Reinforcement
Risers and conical tops > 24 inches and ≤ 48 inches in height
- No less than three hoops of steel wire or reinforcing bars.
- Must have a minimum cross-sectional diameter of 0.250 inches.
- One hoop must be located in each end quarter of the section and be a minimum of 1 inch from the shoulder of the section.
- The third or middle hoop shall be located in the middle of the section as measured from the shoulder, +/- 6 inches.
RISERS and CONICAL TOPS

Steel Hoop Reinforcement
Hoop steel location and cover
  • Placed in the middle third of the wall.
  • A minimum of _ inch of concrete cover must be provided.
RISERS and CONICAL TOPS

Joints
• Sections shall be designed and manufactured with male and female ends.
• The tongue and groove of the joint are not required to contain circumferential reinforcement.
• Joint sealants will be covered in the watertightness section.
BASE SECTIONS

There are three different methods for fabricating precast concrete base sections:

• The riser wall and base slab may be cast monolithically. Such sections are often cast upside down and flipped the following day during the stripping process.
• A base may be cast utilizing a previously cast riser section with a secondary poured base slab, with or without benching.
• A separate precast concrete base slab and riser section may be cast and sealed with a male/female joint between the two pieces.
BASE SECTIONS

Design
Slab Thickness
• For bases 48 inches in diameter and smaller: minimum of 6 inches.
• For bases larger than 48 inches in diameter: minimum of 8 inches.

Slab Thickness: Monolithically Cast Base with Bench Inverts
• Minimum concrete thickness from the invert to bottom of the base slab shall be 4 inches.
BASE SECTIONS

Design
Benched Inverts

• The slope shall be a minimum of _ inch per foot from the channel to the inside diameter (ID) of the riser wall for the benching.

• Channel invert depth shall be a minimum of one-half the pipe ID.

• Secondary poured channels shall have a minimum thickness under the invert of 2 inches.

• The width of the channel at the top of benching shall be at a minimum equal to the pipe ID.
BASE SECTIONS

Design
Benched Inverts
  • Minimum channel centerline radius shall be equal to the pipe ID.

Reinforcement
  • The base riser section shall conform to the same reinforcement requirements for risers and conical tops.

Base Slab Reinforcement
  • A minimum of 0.12 square inches per linear foot in both directions.
**Design**

Base Slab Reinforcement (cont.)

- Shall be placed above the midpoint of the base slab.
- A minimum of 1 inch concrete cover shall be maintained.
- Joints are not required to contain reinforcing steel.
STEPS and LADDERS

• Steps and ladders provide a means of ingress for precast concrete manhole structures. They may be cast, mortared or attached by mechanical means to the manhole components.

• Manhole steps and ladders shall conform to the requirements of the Occupational Safety and Health Standards, U.S. Department of Labor.
STEPS and LADDERS

Step designs are required to be tested in accordance with ASTM C497:

• Horizontal pullout load shall be 400
  • Vertical load shall be 800 lb.
• Spacing of steps shall be limited to a maximum distance of 16 inches.
ASTM C497

Standard Test Methods for Concrete Pipe, Manhole Sections and Tile

- ASTM C497 addresses various test methods used during production and acceptance of concrete pipe, manhole sections and tile.

- AHJ may require one or more of these tests to be performed on a routine basis or that the manufacturer maintain current test result documentation.
The following test methods pertain to testing procedures for precast manholes:

- Flat Slab Top Test Method
- Absorption Test Method
- Hydrostatic Test Method
- Manhole Step Test Methods
- Cylinder Strength Test Method
  (casting dry-cast compression specimens)
DESIGN

Structure Sizing
Round Structures
• ASTM C478
• ASTM C497

Rectangle/Square Structures
• ASTM C913
• ASTM C890

• Lifting and Handling
• Corrosion Mitigation
RECTANGULAR / SQUARE STRUCTURES

ASTM C890, Standard Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures

- ASTM C890 addresses the minimum loads to be applied when designing monolithic or sectional precast concrete water and wastewater structures.

- ASTM C890 does not address:
  - Concrete Pipe
  - Box Culverts
  - Utility Structures
  - Manholes (ASTM C478)
RECTANGULAR / SQUARE STRUCTURES

ASTM C913, Standard Specification for Precast Concrete Water and Wastewater Structures

- ASTM C913 covers the recommended design requirements and manufacturing practices for monolithic or sectional precast concrete water and wastewater structures, excluding the previously mentioned products.
DESIGN LOADS

Dead Loads
Permanent vertical loads to consider:
• Roads
• Walkways
• Earth backfill
• Access opening covers
## DESIGN LOADS

### Weights of common materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight, lb/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (plain or reinforced)</td>
<td>150</td>
</tr>
<tr>
<td>Lightweight concrete (reinforced)</td>
<td>100 to 130</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>450</td>
</tr>
<tr>
<td>Steel</td>
<td>490</td>
</tr>
<tr>
<td>Aluminum</td>
<td>175</td>
</tr>
<tr>
<td>Earth Fill</td>
<td>100 to 150</td>
</tr>
<tr>
<td>Macadam</td>
<td>140</td>
</tr>
</tbody>
</table>
DESIGN LOADS

Traffic Loads

• Vehicle and Pedestrian loads are provided in Table 2 of ASTM C890.

• Table 2 corresponds to the AASHTO load designations (i.e., HS20-44).

• Wheel load distribution area.

  Above ground structures

  \[ A = W \times L \]
DESIGN LOADS

Traffic Loads
Below ground structures
\[ A = (W + 1.75H) \times (L + 1.75H) \]

Where:
\[ A = \text{wheel load area (ft}^2) \]
\[ W = \text{wheel width, ft} \]
\[ L = \text{wheel length, ft} \]
\[ H = \text{height backfill between wheels and structure, ft} \]

Table 2 Wheel Load Increases for Impact (ASTM C890)

<table>
<thead>
<tr>
<th>Height of Backfill Between Wheel and Structure</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 12 in.</td>
<td>30%</td>
</tr>
<tr>
<td>13 to 24 in.</td>
<td>20%</td>
</tr>
<tr>
<td>25 to 35 in.</td>
<td>10%</td>
</tr>
<tr>
<td>36 in or greater</td>
<td>0%</td>
</tr>
</tbody>
</table>
DESIGN LOADS

Hydrostatic Loads

- Water pressure acting on both the interior and exterior of the structure must be taken into consideration.

Lateral Earth Loads

- Ground water levels must be known.

- Backfill soil properties must be known:
  - Unit weight of the earth backfill.
  - Internal friction angle of earth backfill.

- Pressure on walls of buried structures should be calculated using the equations provided in ASTM C890.

- Structures must be designed for all possible loading conditions.
DESIGN LOADS

Surcharge Loads

• When traffic can come within a horizontal distance from the structure equal to one half of the height of the structure, a lateral surcharge pressure will be applied to the wall of the structure. Water pressure acting on both the interior and exterior of the structure must be taken into consideration.

• Lateral surcharge pressures for corresponding vehicle load designations are provided in Table 4 of ASTM C890.
DESIGN LOADS

Surcharge Loads
• Lateral surcharge loads from traffic are considered negligible past a vertical distance of 8 ft below the wheel.

Other loads to consider
• Snow and ice loads when applicable (use local building codes).
• Pedestrian live loads (above ground structures).
• Lifting loads.
• Buoyancy should be checked.
Concrete

- Constituents shall conform to the applicable ASTM Standards.

- Air Entrainment is required when there is a potential for freeze/thaw.
  - 5.5 +/- 1.5% air by volume as measured by ASTM C231.

- Minimum compressive strength of 4,000 psi at 28 days.
ASTM C913: OVERVIEW

Reinforcement

• Wire: A82 or A496
• Wire Fabric: A185 or A497
• Prestressed Wire and Strand: A416 or A421
• Bars: A184, A615, A616 or A617
• Minimum Concrete cover
  ▪ Water retaining structures: 1 inch
  ▪ Other structures: _ inch

Design

• In accordance with ACI 318 and ASTM C890.
• Performance test (Proof-of-Design) is subject to approval of the customer.
ASTM C913: APPENDIXES

The appendixes of ASTM C913 provides designs for standard sized box structures as a convenience for specifying, purchasing and manufacturing.

Structural Analysis
• Analysis based on slope-deflection solution of a frame with nonprismatic members.
• Loads are based on ASTM C890.

Design Calculations
• Concrete strength of f’c = 4,000 psi.
• Reinforcing steel shall be Grade 60.
• Wall thickness is 6 inches.
Design Calculations

• ACI 318 strength design method is used with U.L.F. = 1.7.

• Minimum reinforcement is 0.002 times the gross concrete area of the section.

• Standard designs provided for 2 ft by 2 ft structures up to 6 ft by 6 ft.
  - Dimensions increase by _ foot in either direction.

• If the calculated loads are greater than those provided in the table, an engineer should be engaged to provide the design.
DESIGN

Structure Sizing

Round Structures
  • ASTM C478
  • ASTM C497

Rectangle/Square Structures
  • ASTM C913
  • ASTM C890

Lifting and Handling

Corrosion Mitigation
Lifting devices should be designed with a minimum safety factor of 4.

There are a number of proprietary devices available for lifting and handling precast concrete products.

**Bent reinforcing steel bars should not be used as lifting devices.**
LIFTING and HANDLING DEVICES

Plant-manufactured lifting devices are often fabricated from smooth bars or braided cables.

Plant-manufactured lifting device designs should be evaluated by a Professional Engineer, or proof of design testing should be performed and documented using a safety factor of 4.
CORROSION MITIGATION

Precast Concrete Manholes may be subjected to various corrosive environments.

Sanitary Sewer Applications

- The formation of hydrogen sulfide ($\text{H}_2\text{S}$) gas may increase the potential for Microbial Induced Corrosion (MIC).

- The release of $\text{H}_2\text{S}$ can be controlled by proper hydraulic design of the sanitary sewer system.

CORROSION MITIGATION

Precast Concrete Manholes may be subjected to various corrosive environments.

Light Industrial Applications
- Chemicals and solvents with varying pH levels may have an adverse effect on concrete.
- It is important to know as much information on the intended use of the products so appropriate corrosion mitigation methods may be selected.
CORROSION MITIGATION

Cast-in liners may be used to combat the effects of corrosive agents.

Coatings on both the interior and/or exterior may be specified.
CORROSION MITIGATION

Mix designs can be adjusted to improve the durability of the concrete.
  • Use a low water-to-cementitious ratio
  • Incorporate supplementary cementitious materials.

Corrosion Mitigation Admixtures
  • Various admixtures available on the market.
  • ASTM Subcommittee C13.03 is developing a standard test method to verify the performance of the admixtures.
  • The test method is currently in developmental stage.
WATERTIGHTNESS

Watertight joints and connections should be specified for precast concrete manhole structures used for sanitary and storm sewer applications.

Why?

• 80% of drinking water comes from ground water.

• Exfiltration from both sanitary and stormwater sewers may contaminate local ground water supplies.

• Yes, stormwater contains a number of pollutants, especially during the initial flush, which occurs shortly after the start of a heavy storm.
WATERTIGHTNESS

• Infiltration of water into a sewer may exceed the system’s design capacity.

• Infiltration from contaminated soils increases the concentration of pollutants in a stormwater sewer system, which may flow directly into a local lake or stream.

• Infiltrating water may erode surrounding backfill material, increasing the potential for sinkholes.

• Increased suspended solids and pollutants will disrupt sensitive ecosystems.
WATERTIGHTNESS: MORTAR

- Mortar joints and connections do not ensure a watertight system.

- The quality of the mortar installation varies considerably in the field.

- Breaches to watertightness increase the chances for groundwater contamination and the erosion of surrounding backfill materials.
WATERTIGHTNESS: JOINTS

- May be used for both round and square manholes structures.
WATERTIGHTNESS: JOINTS


- Covers both bitumen and butyl sealants.
- Provides a flexible, watertight joint.
- Maintains both adhesion and cohesion between sections.
- Conforms to a wide variety of joint geometry and can fill slight imperfections.
- Maintains seal even if settlement occurs.
WATERTIGHTNESS: JOINTS


• Typically used for round structures, but may be designed for use with square structures.

• Confined O-ring gaskets.

• Profile gaskets.
WATERTIGHTNESS: JOINTS


- The gasket is designed specifically for each type of joint.
- Prelubricated gaskets.
OTHER JOINT SEALANTS

ASTM C877, “Standard Specification for External Sealing Bands for Concrete Pipe, Manholes and Precast Box Sections”

• May be used for both round and square structures.

• Surface variations and small imperfections may make it difficult to achieve a watertight joint.
OTHER JOINT SEALANTS

ASTM C877, “Standard Specification for External Sealing Bands for Concrete Pipe, Manholes and Precast Box Sections”

ASTM C877 covers three different types of external sealing bands:

- Type I: Rubber and Mastic Bands.
- Type II: Plastic film and mesh reinforced mastic bands.
- Type III: Chemically-bonded adhesive butyl bands.
WATERTIGHTNESS: CONNECTIONS


- Designed to minimize leakage between the pipe and manhole.
- Primarily used in sanitary sewer applications.
- Leakage Test Requirements:
  - Tested to 13 psi (30 ft) for 10 minutes in straight alignment.
  - Tested to 10 psi (23 ft) for 10 minutes when deflected 7 degrees.
WATERTIGHTNESS: CONNECTIONS


Shear and Leakage Test:

• The lateral is loaded with 150 lbs per inch of pipe diameter (Example: For a 36 inch lateral, the load would be 5,400 lbs located 24 inches from the structure).

• Subjected to 10 psi (23 ft) for 10 minutes when loaded.

• Axial movement at connector must be less than 1 inch.

- Similar to ASTM C923, except connectors are designed to prevent soil mitigation.

- Leakage test requirements are reduced to 6 psi (14 ft) for all tests.
WATERTIGHTNESS: CONNECTIONS

Holes for pipes may be cored or cast into a structure.

Cored Hole

Cast In Hole w/Blockout
WATERTIGHTNESS: CONNECTIONS

Compression Type Connectors

- Typically cast into the structure.
- Must provide a minimum structural leg of concrete between pipe openings.
- Should consult the precast manufacturer and connector supplier for exact design requirements.
WATERTIGHTNESS: CONNECTIONS

Flexible Connectors (also known as Boots)

- Both cast-in and mechanical fastener designs are available.
- Must provide a minimum area of concrete cover around the cast-in water stop.
- Should consult the precast manufacturer and connector supplier for exact design requirements.
QUALITY CONTROL

NPCA Plant Certification Program
The voluntary program covers all aspects of a precast operation necessary for production of high-quality precast concrete products and quality assurance. Compliance with the Quality Control Manual is verified with inspections of the plant on an approximately annual basis. The program certifies that plants meeting the requirements set forth in the NPCA Quality Control Manual are capable of producing high-quality products.
QUALITY CONTROL

NPCA Plant Certification Program
Chapter 6 of the NPCA QC Manual covers specific requirements for precast concrete manholes manufactured in accordance with ASTM C478.

- Detailed reinforcing steel inspections.
- Verification of flat slab top designs.
- Absorption testing a minimum of once per year.
- Step testing.
- Detailed post-pour dimensional checks.
- Documented joint designs.
- Gasket quality control.
 Departments of Transportation require precast manufacturers to be enrolled in the NPCA Plant Certification Program in order to supply products to DOT jobs.

QUALITY CONTROL

[Map showing states requiring, pending, reviewing, and inactive certification]

NPCA CERTIFIED PLANT

precast solutions
Lifting Apparatus

• Procedures and equipment should meet or exceed OSHA requirements.

• An approved multiple sling or bridle should be used when lifting product with interior lifting devices.

• An approved or rated spread bar should be used when lifting product with exterior lifting devices.

• Cable or chain lengths should be adequate to minimize contact with the tongue and groove area of the sections; blocking may be used as needed.
INSTALLATION

Bedding

• Minimum depth of 6 inches approved bedding material, extending a minimum of 6 inches beyond the outside radius of the base section.

• Bedding should be compacted to 90% proctor relative density.

• Bedding under connecting pipes should be placed in the same manner.

• Local ground/soil conditions may require additional bedding as determined by the project engineer.
INSTALLATION

Setting Base
• Set the base section according to job specifications.
• Check to make sure the elevation and alignment of connections are correct.
• Level in both directions.

Pipe Connections
Flexible Connectors (Boots):
• Clean pipe surface and inside of connector.
• Insert pipe through connector until flush with interior manhole wall or as specified by the authority having jurisdiction.
INSTALLATION

Pipe Connections
Flexible Connectors (Boots) continued:

• Keep pipe nominally centered and supported with approved bedding.

• Install take-up clamps in grooves of receiving end of connector.

• Tighten clamps with an appropriately rated torque wrench.

• Tighten to torque recommended by the connector supplier.

• If deflection is required, deflect the pipe after the connection has been made.
Pipe Connections
Compression Connectors:
• Cut a _ bevel on the end of the pipe to be inserted into the connector (required bevel and end treatments may vary depending on the type of pipe).
• Using an approved lubricant, clean and lubricate the exterior of the pipe and receiving surface of the connector.
• Insert pipe through connector until flush with interior manhole wall or as specified by the authority having jurisdiction.
INSTALLATION

Pipe Connections
Compression Connectors:
• Center the beveled end of the pipe in the connector and push the pipe through the connector.

• If deflection is required, deflect the pipe or structure after the connection has been made.

• Check the relationship of the pipe to the interior of the wall for compliance with local jurisdiction requirements or project specifications.
INSTALLATION

Pipe Connections
Compression Connectors:
• Ensure the pipe is properly supported with the approved bedding material.

Grouting or placing mortar in and around flexible and compression connectors may inhibit the design and flexibility of the connector and should be avoided.
INSTALLATION

Pipe Connections
Mortar

• The use of mortar is not recommend because of the potential concerns associated with infiltration and/or exfiltration of ground water and/or contaminants from within the system.

• Adjust the pipe within the opening to meet the required elevation.

• Support with approved bedding material.
Pipe Connections
Mortar
• Using a non-shrink mortar mixed in accordance with the manufacturer’s recommendations, fill the voids around the pipe.
• Allow sufficient time for the mortar to cure prior to backfilling.
Pipe Connections
Pipe Stubs
• Pipes stubs are often incorporated into a base structure to allow for future connections.
• In addition to the pipe connector, additional care shall be taken to mechanically restrain the pipe stubs from movement.
INSTALLATION

Joint Installation
Flexible Sealant

• As outlined in ASTM C990, consult the sealant supplier for the recommended size to fill the annular space of the joint design being used.

• Clean and inspect the tongue and groove of the surfaces being joined.

• Surfaces should be free of dust and debris.

• Tongue up manhole – place the sealant next to the vertical surface of the tongue.
INSTALLATION

Joint Installation
Flexible Sealant
  • Bell up manhole – place the sealant next to the vertical surface of the bell.
  • Place the material completely around the unit and knead the ends together to form a uniform splice.
  • Check to make sure ALL the protective paper is removed from the sealant.
  • Lower the connecting section, making sure all steps and/or accessories are in the correct alignment.
Joint Installation
Confined O-Ring Gasket
- Clean, inspect and lubricate the joint surfaces using an approved lubricant.
- Thoroughly lubricate the O-ring and place it in the confined groove space.
- Run a smooth, round object between the O-ring gasket and structure several times around the entire circumference to equalize the gasket. This is an important step that is easily overlooked.
INSTALLATION

Joint Installation
Confined O-Ring Gasket
  • Lower lubricated end of next section onto the structure, making sure steps and/or accessories are in correct alignment with lower section.
  • It is important to keep the sections level/plumb while setting to prevent rolling the gasket and/or breaking the bell.

Profile and Prelubricated Gaskets
  • Install in accordance with the gasket manufacturer’s specifications.
INSTALLATION

Joint Installation
Sealing Lift Holes

• Seal lift holes with a rubber plug or approved material.
• Non-shrink grout may also be used on the interior and exterior.
INSTALLATION

Testing Procedures
Vacuum testing is a quick, safe and practical way to validate manhole system integrity. Manhole sections can be tested at the precast concrete plant prior to delivery or on site prior to backfilling. ASTM has developed a standard vacuum test method to be performed prior to backfill. Both the ASTM test method and vacuum testing after backfill will be addressed.
INSTALLATION

Testing Procedures
ASTM C1244, “Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) test Prior to Backfill” (use most current version)

- Plug all lift holes and temporarily seal and brace all pipes entering the structure.
- A vacuum of 10 inches Hg (-5 psi) is drawn on the manhole.
INSTALLATION

Testing Procedures

• The time is measured for the vacuum to drop to 9 inches Hg. The manhole is accepted if the measured time meets or exceeds the values presented in Table 1 of ASTM C1244.

• If the manhole fails the initial test, it may be repaired using an approved method until a satisfactory test is obtained.

• Repairs are easily made because the structure has not been backfilled.
INSTALLATION

Testing Procedures
Vacuum Testing After Backfill

• No standard test method exists.

• May risk damaging the structure and contaminating the system.

• Difficult to identify, locate and repair leaks

• If you plan to vacuum test a backfilled manhole, keep the following information in mind to properly adjust the testing procedures to minimize the potential for damaging the system.
INSTALLATION

Testing Procedures
Vacuum Testing After Backfill

• Depth to ground water (must know hydrostatic pressure exerted on the lowest critical connector in the system).
• Hydrostatic pressure is roughly 0.433 psi per foot of head.
• Must know the pressure rating of the connectors being used.
• ASTM C923:13 psi straight alignment, 10 psi deflected.
• ASTM C1478:6 psi.
Testing Procedures
Vacuum Testing After Backfill

WARNING: Vacuum testing a manhole system that is already subjected to hydrostatic pressure may exceed the design limits of critical flexible connectors, leading to a system failure.
INSTALLATION

Testing Procedures
Vacuum Testing After Backfill

• For additional information, visit the NPCA Manhole Web site, which contains an entire section on vacuum testing precast concrete manholes.

• The following guidelines should be used when vacuum testing backfilled manholes in the presence of ground water.
INSTALLATION

Testing Procedures
Vacuum Testing After Backfill

• A conservative rule of thumb is to reduce the vacuum by 1 inch Hg for every 1 foot of hydrostatic head greater than 12 feet up to 21 feet. A vacuum test should not be performed when the hydrostatic head is in excess of 22 feet.

<table>
<thead>
<tr>
<th>Hydrostatic Head (ft)*</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Pressure (in Hg)</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>**</td>
</tr>
</tbody>
</table>

* Hydrostatic head above critical connector
** At 22 feet below ground water table, the connector is naturally subjected to 9.5 psi.
INSTALLATION

Backfill Procedure

• Vacuum testing in accordance with ASTM C1244 shall be performed prior to backfill.

• Check to ensure all pipes entering the structure are evenly supported and backfilled.

• Backfill around the structure equally to prevent tipping.

• Compact fill in lifts in accordance with project specifications.

• Backfill shall be clean and free of big rocks.
Advantages of Precast Concrete Manholes

• Readily Available
• Modular Flexible Design
• Produced in a Quality Controlled Plant Environment
• Watertight Structures Easily Achieved
• Resists Buoyant Forces
• Superior Strength
SUMMARY: PRECAST MANHOLES

Applications

• Sanitary Sewers
• Stormwater Sewers
• Stormwater Inlet and Treatment Structures
• Pump / Lift Stations
• Utility Manholes

PRECAST
SUMMARY: APPLICABLE STANDARDS

Structures
• Round: ASTM C478
• Square: ASTM C913

Joints
• Gaskets: ASTM C433
• External Sealing Bands: ASTM C877
• Flexible Sealants: ASTM C990

Connectors
• Flexible: ASTM C923 and C1478

Quality Control
• NPCA Plant Certification Program
• Product Tests: ASTM C497
• Vacuum Testing: ASTM C1244
SUMMARY: APPLICABLE STANDARDS

Resources

• The National Precast Concrete Association
  www.precast.org
• The NPCA Manhole Product Committee
• ASTM International: www.astm.org

The NPCA Annual Volume of ASTM Standards contains more than 90 standards covering the design, production, installation and testing of precast concrete products.
SUMMARY: APPLICABLE STANDARDS

Canadian Standards Association (CSA)

- CSA A257.4-03, “Precast Reinforced Circular Concrete Manhole Sections, Catch Basins, and Fittings”

- CSA A257.3-03, “Joints for Circular Concrete Sewer and Culvert Pipe, Manhole Sections, and Fittings using rubber Gaskets”
SUMMARY: APPLICABLE STANDARDS

AASHTO

• M 198-05, Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants

• M 199M/M 199-05, Precast Reinforced Concrete Manhole Sections

• M 315-05, Joints for Concrete Pipe and Manholes, Using Rubber Gaskets

• M 315M-05, Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets [Metric]

• T 280-05, Concrete Pipe, Manhole Sections, or Tile
SUMMARY: APPLICABLE STANDARDS

Resources

• Canadian Standards Association: www.csa-international.org
• AASHTO: www.transportation.org