

## Circular Precast Concrete Manholes

Circular precast concrete manhole sections are versatile in the construction of buried structures; they may be used as catch basins for stormwater drainage, manholes providing access to buried pipelines, junction chambers at the intersection of sewers lines, and used to construct reservoirs or wetwells for pump stations. The use of precast concrete manhole structures will reduce construction time and labor costs, when compared to cast-in-place or masonry structures.

American Society for Testing Materials (ASTM) C 478, Standard Specification for Precast Manhole Sections, covers the manufacturing of the components used in construction of manhole structures, as well as the purchasing requirements of products used for the assembly of manholes. ASTM C 478 does not include design tables or a method for analysis and design for manhole components, but does permit acceptance of a component by proof-of-design testing. Test methods are found in ASTM C 497, Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile.

The typical precast concrete manhole structure consists of; grade or adjusting rings, a cone or flat slab cover, riser sections, a base section, and frequently a base foundation slab. In other variations of manholes, riser sections are stacked on top of precast tee sections in the pipeline, or on a cover slab of a buried vault or junction chamber. The riser sections are usually 48 inches in diameter, but have been manufactured in nearly every larger pipe size found in ASTM C76 Standard Specifications for Culvert, Storm Drain, and Sewer Pipe.

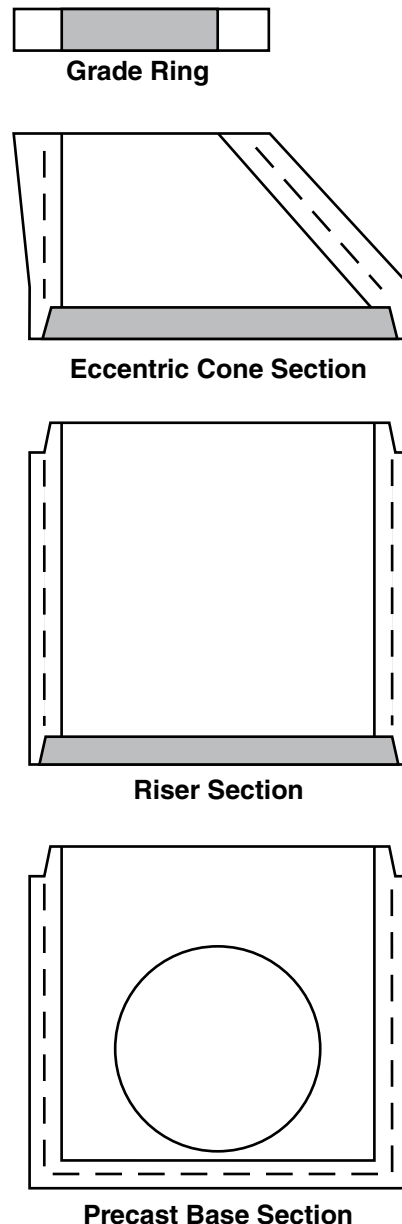
Precast grade rings, or adjusting rings, are stacked on top of the manhole cone or cover slab to provide the correct finished grade for the manhole casting and cover. When manholes are installed in roadways, designers frequently specify a stack of rings at least 6 to 8 inches high so the grade may be easily lowered, if required during future construction.

In most precast manhole structures, the riser sections are topped with either an eccentric or concentric cone. Within the length of a cone section, the diameter of the manhole is reduced from the size of the manhole riser to the diameter of a cast-iron manhole cover and frame. Special shallow cone sections, or flat cover slabs, are used for very shallow manholes. Large diameter

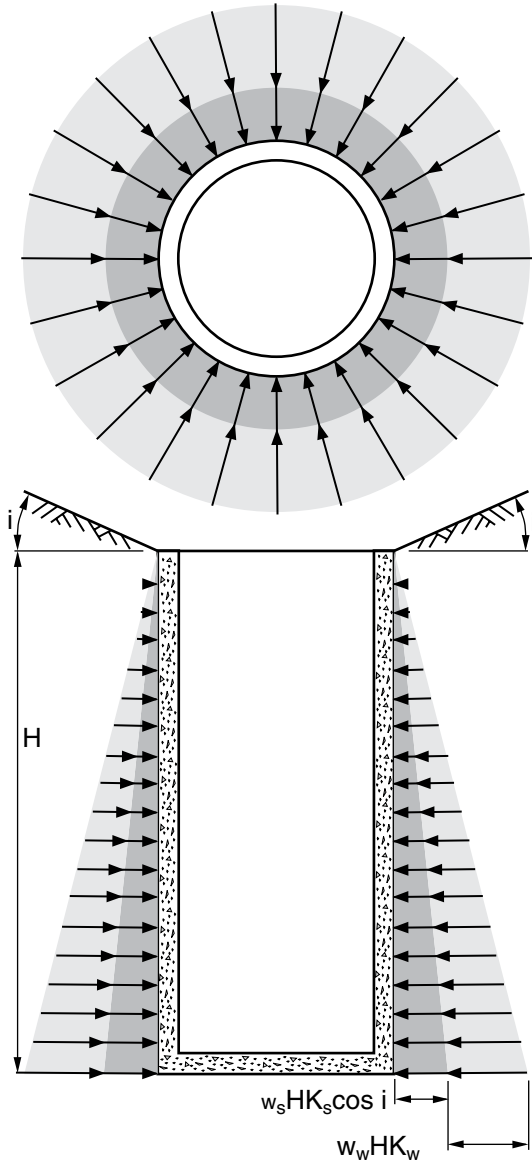
manholes are covered with structural flat slab covers designed to resist the applied dead and live loads.

The riser of a manhole is similar to a straight section of concrete pipe with pipe joints at either end. A riser pipe

**Figure 1 Typical Precast Manhole**



**Figure 2 Forces Acting on Manhole**



or a stack of riser pipes is assembled to obtain the proper height of the structure. Manhole risers are fabricated in standard lengths that are usually increments of the step spacing.

The base section generally has openings through which water or sewer pipes are installed. Base sections may be manufactured with an integral floor, which functions as a foundation, or be placed on a precast or cast-in-place foundation slab. Precast concrete tee pipeline sections serve the same function as a base section.

The manhole structure may be furnished with attached steps or ladders. The dimensions, spacing and test strength of steps are specified by United States

Department of Labor's Occupational Safety and Health (OSHA) Standards, and are published in ASTM C 478 and ASTM C 497.

### FORCES ON CIRCULAR MANHOLE RISER SECTIONS

A circular precast concrete riser is the ideal material for constructing a vertical buried structure. Manhole riser sections have a thick high-strength concrete wall that easily resists the compressive forces caused by lateral earth and hydrostatic pressure. The mass of the concrete gives the structure stability in buoyant installation conditions. See Design Data 22 Flotation of Circular Concrete Pipe, for additional information on the effect of buoyancy on buried structures.

**Lateral earth pressure.** Because manhole risers are manufactured in standard diameters with the minimum wall thickness directly proportional to the riser diameter, a general vertical depth limit for all sizes may be calculated. The most severe loading condition on a riser section occurs when the ground water elevation is the same as the surface of the ground. The forces acting on the riser section are illustrated in Figure 2. The total active force consists of two components; active lateral earth pressure and hydrostatic pressure. Both components of the load act in a radial direction and are distributed uniformly around the periphery of the manhole. Radial forces acting on a circular cross-section result in only compressive forces on the section. There are no bending forces in a riser section unless there is a discontinuity such as a hole for a sewer pipe connection.

Based on the radial load distribution, the lateral earth pressure and hydrostatic pressure at any depth within the soil mass is given by the following equation:

$$p = w_s HK_s \cos i + w_w HK_w \quad (1)$$

where:  $p$  = total earth and hydrostatic pressure, pounds per square foot

$w_s$  = effective unit weight of backfill material, 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, pounds per cubic foot

$K_w$  = conjugate ratio for water

In most cases, the ground surface is level and  $i =$  zero degrees. Therefore  $\cos i = 1.0$  and equation (1) becomes:

$$p = w_s HK_s + 62.4H \quad (2)$$

$K_s$  is further defined as:

$$K = \frac{(1 - \sin\phi)}{(1 + \sin\phi)} \quad (3)$$

Where  $\mu = \tan \phi =$  coefficient of friction for the soil

$\phi =$  angle of internal friction of the soil, degrees

Table 1 lists the normal range of the angle of internal friction for various types of soil.

Table 1 Normal Range of the Angle of Internal Friction for Various Soil Types	
Backfill Material	Angle of Internal Friction $\phi$
Plastic Clay	0 - 10
Wet, Fine Sand	15 - 30
Dry Sand	25 - 40
Gravel	30 - 40
Compact Clay	25 - 45

For design purposes, the average value of  $\phi$  is assumed to be 30 degrees. Since the tangent of 30 degrees is equal to  $\frac{1}{3} \sqrt{3}$ , substitution of this value into equation (3) results in  $K_s = \frac{1}{3}$ .

If the saturated unit weight of soil is 120 pounds per cubic foot, effective or unit weight, because of the buoyant effect of the water, is  $120 - 62.4 = 57.6$  pounds per cubic foot. Substituting the effective unit weight for saturated soil of 57.6 pcf and  $K_s = \frac{1}{3}$  into equation (2):

$$\begin{aligned} p &= 57.6 \times H \times 1/3 + 62.4H \\ p &= 81.6H \end{aligned} \quad (4)$$

The radial pressure,  $p$ , is equally applied around the periphery of the manhole section, placing the cross-section in pure compression unless there is an opening in the section. The compressive stress in any portion of the manhole section is found by using the following equation.

$$s' = pD/2t \quad (5)$$

where:  $s' =$  compressive stress in the concrete cross-section, pounds per square foot

$p =$  total lateral earth and hydrostatic pressure, pounds per square foot

$D =$  inside diameter of manhole, feet

$t =$  thickness of manhole wall, feet

The minimum wall thickness equals one-twelfth the inside diameter of the manhole, when the thinnest wall thickness specified in ASTM C76 is used. Substituting the wall thickness into terms of manhole diameter and,  $p$ , into terms of manhole height, and converting the units to pounds per square inch:

$$\begin{aligned} s &= 81.6H \times D / (144 \times 2 \times D/12) \\ s &= 3.4H \end{aligned} \quad (6)$$

where:  $s =$  compressive stress in the concrete cross-section, pounds per square inch  
 $H =$  depth of manhole, feet

The allowable bearing stress of concrete,  $s$ , equals 45 percent of the minimum required compressive strength of 4000psi for precast manholes or 1800psi. Substituting 1800psi into equation (6) and solving for  $H$ , finds that the maximum depth for a precast manhole riser is in excess of 500 feet.

$$\begin{aligned} 1800 &= 3.4H \\ H &= 540 \text{ feet} \end{aligned}$$

**Vertical dead load.** Two other factors control the maximum depth of a stack of manhole risers; end bearing at the joints and the foundation capacity that will depend on the site conditions. Again, using the allowable bearing stress for concrete of 1800psi, a 48-inch diameter manhole riser, with minimum wall thickness, could theoretically support over 1700 feet of riser sections. The effects of settlement in the adjacent backfilled soils are not easily analyzed and are not included in this analysis. At the joint, only a small portion of the pipe cross-section remains in contact with the adjacent riser section. Assuming that the end bearing area in a joint is only 25 percent of the full cross-section, a stack of risers 450 feet deep could be constructed.

The maximum allowable depth for a buried precast manhole riser is, for all practical purposes, unlimited.

## OTHER PRECAST MANHOLE DESIGN AND ANALYSIS CONSIDERATIONS

**Flat slab covers.** Flat slab covers are frequently used in roadways and are designed to support traffic loads. The method for the analysis and design of manhole cover slabs is not included in ASTM C 478, but the American Association for Highway and Transportation Official's (AASHTO) Standard Specifications for Highway Bridges provides guidance for designing reinforced concrete slabs buried in shallow fills that are capable of supporting highway loads.

AASHTO's Standard H and HS vehicles with specific wheel loads and spacing are commonly accepted as the basis for live load design of highway structures. For buried structures, AASHTO Bridge Specifications distribute the live load as a concentrated force distributed either over a load strip width crossing the span for burial depths less than two feet, or a square or rectangular shaped area on the top of a concrete slab for fills two feet and greater. The dead load due to earth backfilled on top of slabs may be found by multiplying the weight of the soil prism over the slab times a soil structure interaction factor. A factor of 1.15 is adequate for most cases.

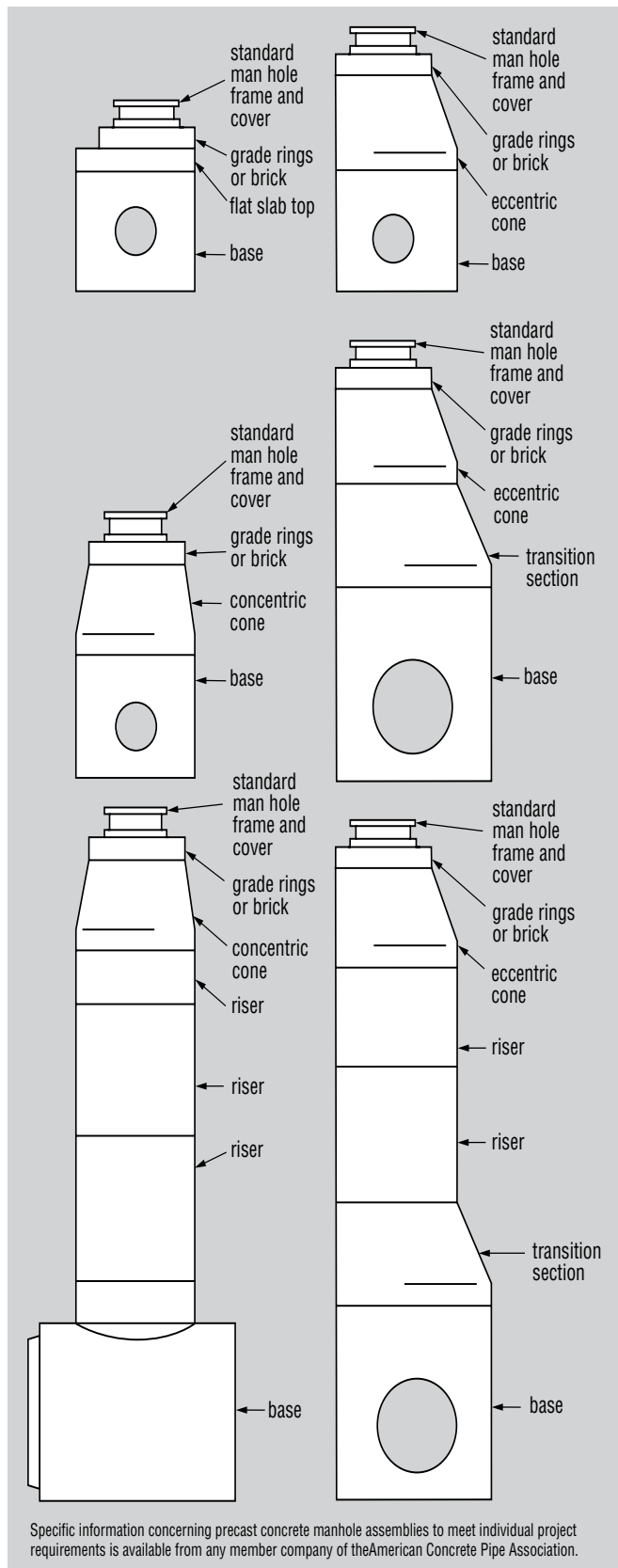
The Specifications provide several simplified formulas that make reasonable approximations of live load bending moments in concrete slabs. Tabulated formulas that recommend minimum slab thickness based on span are found in the Concrete Design section of the Specifications. Impact must be added to the live load for fills less than three feet, and live load may be excluded in the design of slabs that are buried depths greater than eight feet. When slabs have full bearing around the perimeter of a circular manhole riser, such as bedding in fresh Portland cement mortar, they may be designed as a two-way slab with a significant reduction in the flexural requirements. Slabs with less than two feet of cover must have distribution reinforcing placed transverse to the bottom flexural reinforcing.

**Openings.** In conventional installations, only a small fraction of the strength of a manhole section is required to resist lateral and vertical forces. Openings in manhole sections do reduce the strength of that section, and may alter the load paths that carry the vertical loads to the foundation of the structure. When openings are properly positioned, or supplemental reinforcing is provided, there will be no adverse affect on the structural performance of the section. Three common methods of creating an opening in a manhole section are; molded with a circular form attached to the casting equipment, hand-cut or dug-out of freshly placed concrete, and cored with a large diameter circular cutter.

If the openings are large, supplemental reinforcement should be added to the primary reinforcing cage to redistribute the load from the unsupported portion of the section wall to the intact portion. The location of the holes is known during the production process for the first and second methods, so additional reinforcing can be added to the primary reinforcing cage to enclose the opening before the concrete is placed. Cored openings are usually cut into a plain riser section, so the openings occur at random in the primary reinforcing. The diameter of cored openings is usually limited in size, so supplemental reinforcing is not required.

When an opening is made in a slab cover, reinforcing

**Figure 3 Typical Assembly Combinations**



Specific information concerning precast concrete manhole assemblies to meet individual project requirements is available from any member company of the American Concrete Pipe Association.

steel with an area equivalent to one-half the reinforcing interrupted by the opening shall be added to each side of the opening. Many designers enclose the opening with an equal area of reinforcing placed diagonally to the principle reinforcing.

**Diameter of junction manholes.** A junction manhole is installed at the intersection of several sewer lines to form a chamber in which the inflow may be combined and directed to the outlet line. The diameter of the junction manhole must be large enough so that the distances between adjacent openings have enough strength to resist lateral and vertical loads, as well as stresses caused by handling. For non-cored openings, the diameter of the opening should be four inches greater than the outside diameter of the connecting pipe. To insure structural stability of the manhole section, the minimum distance between adjacent openings should be twelve inches. The diameter of a cored opening is generally selected for a proprietary pipe-to-manhole connector, and the minimum distance between openings should be eight inches. The diameter of a junction manhole will greatly depend on the included angle between adjacent pipelines.

**Manhole joints and pipe-to-manhole seals.** Manhole joints usually have a tongue and groove configuration and may be made with or without gasket seals. The single offset and recessed o-ring gasket are the most common type of joint seals. Gasketed joints are popular because most of the labor required to join sections can be done outside the excavation. Gasket joints can greatly reduce the infiltration into the manhole structure. Non-gasketed tongue and groove joints may be sealed with pre-formed mastic cords, external wraps or Portland cement mortar. When low infiltration rates are specified for a pipeline system, pipe-to-manhole connectors may be effective. Connectors may be cast into the manhole wall or attached by an expansion ring in a circular opening formed or cored in the manhole wall.