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design data 12

american concrete pipe association

PRECAST CONCRETE MANHOLES

The proper functioning of a sewer system depends to a large degree on the performance of its appurtenances, with manholes being one of the most important. Precast concrete manholes offer significant savings in labor cost over poured-in-place concrete, masonry or brick manholes and are universally accepted for use in sanitary or storm sewers. Precast reinforced concrete manhole sections are available throughout the United States and Canada, and are generally manufactured in accordance with the provisions of American Society for Testing and Materials Specification C478.

The typical precast concrete manhole consists of riser sections, a top section, grade rings and, in many cases, precast base sections or tee sections. The riser sections are usually 48 inches in diameter, but are also available up to 72 inches and larger. They are of uniform circular cross section, and a number of sections may be jointed vertically on top of the base or junction chamber. Most precast manholes employ an eccentric or concentric cone section instead of a slab top. These reinforced cone sections effect the transition from the inside diameter of the riser sections to the specified size of the top opening. Flat slab tops are normally used for very shallow manholes and consist of a reinforced circular slab at least 6 inches thick for up to 48 inches in diameter and 8 inches thick for larger sizes. The slab which rests on top of the riser sections has an access opening cast into it.

Precast grade rings, which are placed on top of either the cone section or flat slab top, are used for close adjustment of top elevation. Cast iron manhole cover assemblies are normally placed on top of the grade rings.

The entire manhole assembly may be furnished with or without steps inserted into the walls of the sections as specified. Reinforcement required by ASTM Specification C478 is primarily designed to resist handling stresses incurred before and during installation. Such stresses are more severe than those encountered in the vertically installed manhole. In such normal installations, the intensity of the earth loads transmitted to the manhole risers is only a fraction of the intensity of the vertical pressure.

To determine the allowable depth to which precast concrete manholes can be placed, it is necessary to consider the forces acting on the manhole ring. Using the most severe loading condition, where the water table is at the same elevation as the ground surface, the forces acting on the manhole ring are illustrated in *Figure 2*. The total force is comprised of two components: active lateral earth pressure and hydrostatic pressure.

FIGURE 1: Typical Precast Concrete Manhole

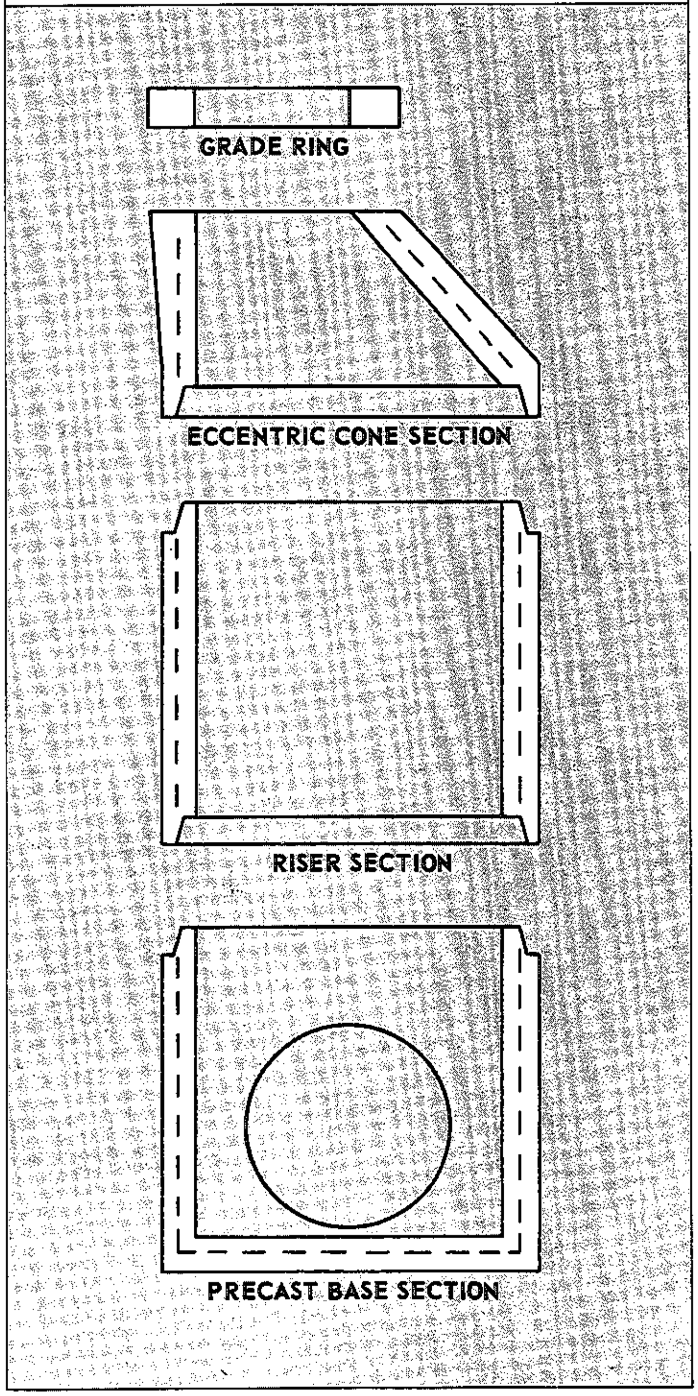
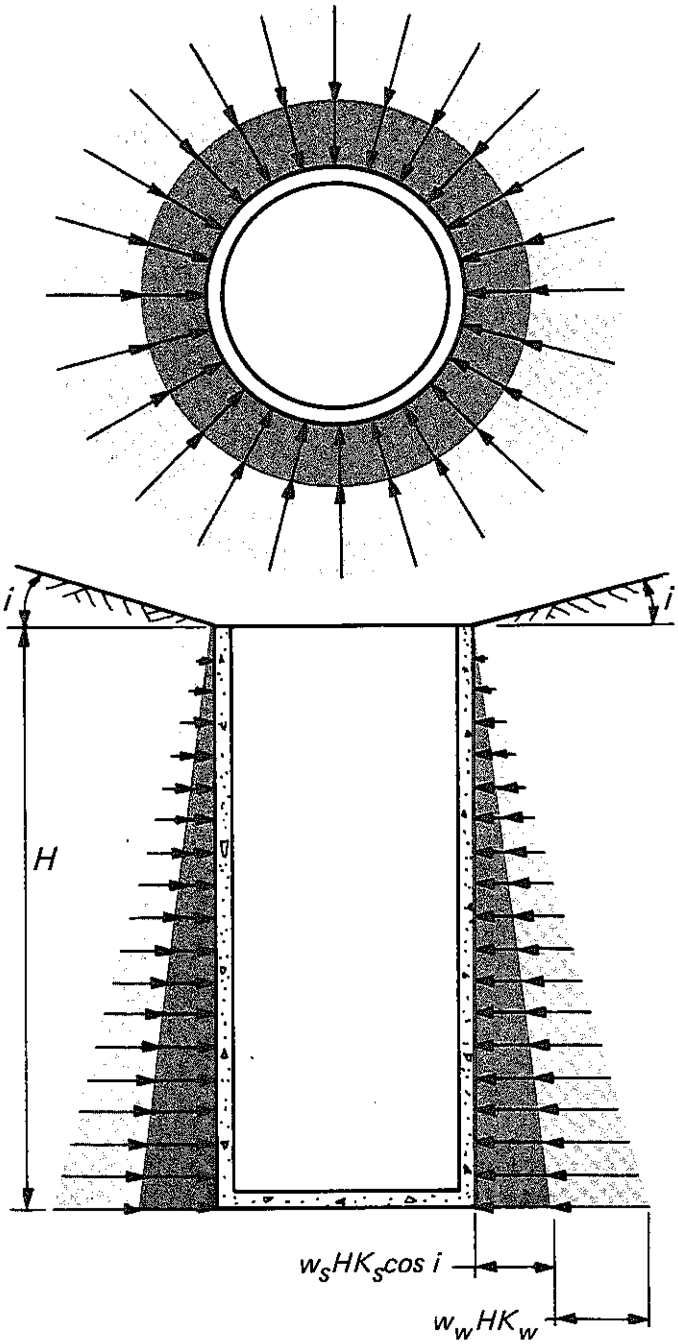


FIGURE 2: Forces Acting on Manhole



Both components are uniformly distributed around the periphery of the manhole with no bending moment imparted to the manhole section. Based on this uniform load distribution, the lateral earth pressure and hydrostatic pressure at any depth within the soil mass is given by the equation:

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

where p = total lateral earth and hydrostatic pressure, pounds per square foot
w_s = effective unit weight of the 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 (62.4 pounds per cubic foot)
K_w = conjugate ratio for water (1.0)

In most cases $i = o$; therefore, $\cos i = 1$ and equation (1) reduces to:

$$p = w_sHK_s + 62.4H \quad (2)$$

K_s is further defined as:

$$K_s = \frac{\sqrt{\mu^2 + 1} - \mu}{\sqrt{\mu^2 + 1} + \mu} \quad (3)$$

where $\mu = \tan\phi$ = coefficient of friction for the soil
ϕ = angle of internal friction of the soil, degrees

Table I lists the normal range of the angle of internal friction for various types of soils.

TABLE I

Backfill Material	Angle of Internal Friction ϕ
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 ϕ is usually assumed to be 30°. Since tan 30° is equal to $\frac{1}{3}\sqrt{3}$, substitution of this value in equation (3) results in K_s equal to $\frac{1}{3}$.

If a saturated unit weight of the backfill is 120 pounds per cubic foot, the effective or submerged unit weight, because of the buoyant effect of water, would be 120 − 62.4 = 57.6 pounds per cubic foot. Substituting the effective unit weight of 57.6 pounds per cubic foot and $K = \frac{1}{3}$ in equation (2):

$$p = 57.6 \times H \times \frac{1}{3} + 62.4\,H$$

$$p = 81.6\,H \quad (4)$$

Except for the section of the manhole where the sewer line is connected, the pressure (p) will act on the manhole ring equally around the periphery of the ring and therefore put the ring section in pure compression without introducing bending moments in the concrete section in the horizontal plane. The compressive stress in any section of the manhole ring is given by the equation:

$$s = \frac{pD}{2t} \qquad (5)$$

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

If the minimum specified wall thickness is used, the wall thickness would be one-twelfth the manhole diameter. Substitution of this wall thickness and the expression for p as given in equation (4) into equation (5) and converting the compressive stress to pounds per square inch:

$$s = \frac{81.6\,H \times D}{144 \times 2 \times \frac{1}{12} D}$$

$$s = 3.4\,H \qquad (6)$$

where s = unit compressive stress in the ring, pounds per square inch
H = depth of manhole, feet

Using an allowable concrete stress of 45 percent* of the minimum specified compressive strength of 4000 psi, the allowable compressive stress would be 1800 psi. Substituting this value in equation (6):

$$1{,}800 = 3.4\,H$$
$$H = 530 \text{ feet}$$

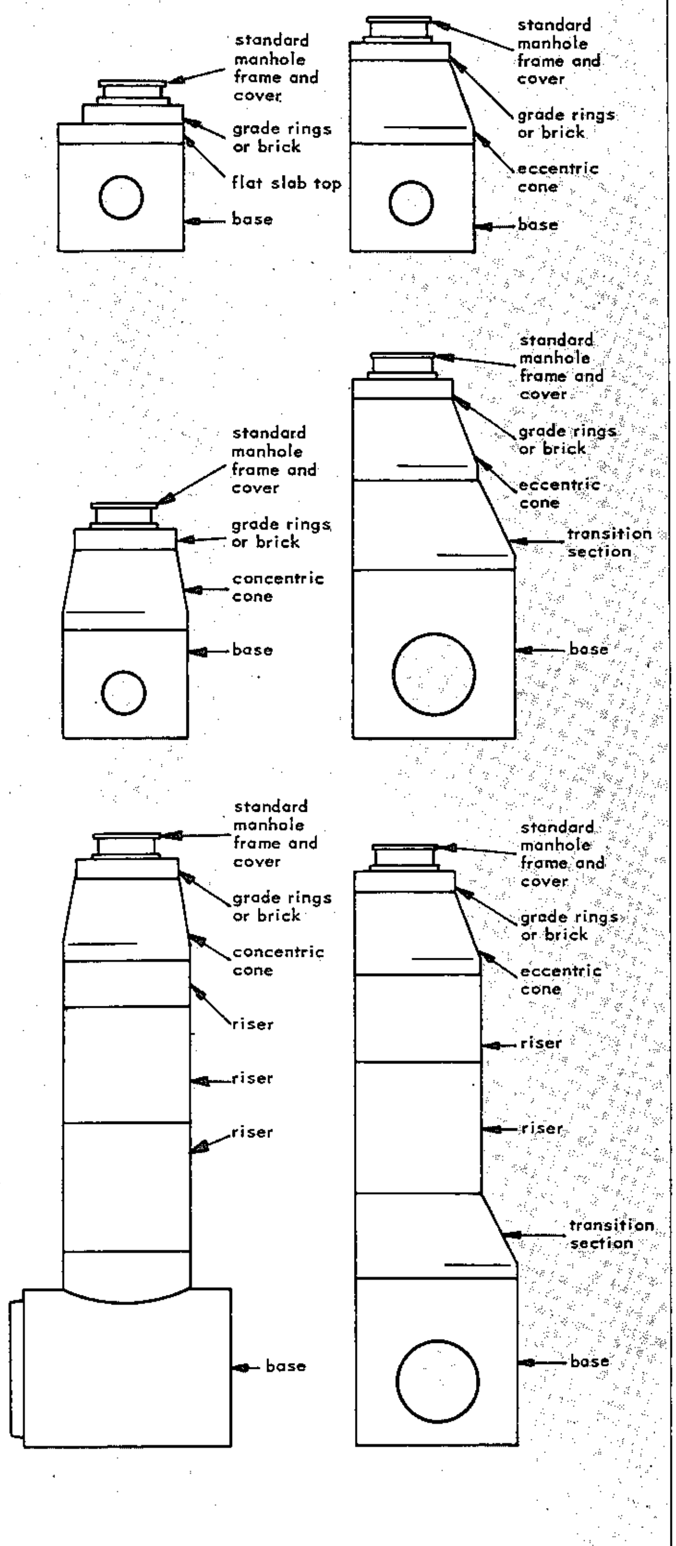
The maximum allowable depth of a typical precast concrete manhole is in excess of 500 feet or, for all practical purposes, unlimited. This indicates that the critical or limiting factor for manhole depth is the supporting strength of the base structure or the resistance to crushing of the ends of the riser sections. This phenomena, being largely dependent on the relative settlement of the adjacent soil mass, does not lend itself to precise analysis. However, if only the weight of the manhole riser and top were considered, with an allowable crushing stress of 1800 psi, a theoretical height of over 1,700 feet could be allowed. Even the most conservative approach would conclude that up to several hundred feet could be safely withstood by the riser sections without end crushing, based on the assumption that provision is made for uniform bearing at the ends of the riser sections and the elimination of localized stress concentrations.

When confronted with manhole depths greater than those previously encountered, there may be a tendency to specify additional circumferential reinforcement in the manhole riser sections. Class III or Class IV reinforcement has been specified for manhole depths as low as 25 to 30 feet. Such requirements are completely unnecessary and only result in increasing the cost of the manhole structure.

A number of joint types are employed for manhole risers and tops using mortar, mastic, rubber gaskets or combinations of these three basic types for sealing purposes. Consideration should be given to manhole depth, the presence of groundwater and the minimum allowable leakage rates in the selection of specific joint requirements.

*The allowable compressive stress of 45 percent of the ultimate compressive concrete strength is based on ACI Code. This design requirement is primarily intended for field-placed concrete and its application to precast and pretested concrete is considered conservative.

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.