



# Standard Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures<sup>1</sup>

This standard is issued under the fixed designation C 890; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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<sup>ε1</sup> NOTE—The ASSHTO standard reference was updated to the 16th edition editorially in June 1999.

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## 1. Scope

1.1 This practice describes the minimum loads to be applied when designing monolithic or sectional precast concrete water and wastewater structures with the exception of concrete pipe, box culverts, utility structures, and material covered in Specification C 478.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

C 478 Specification for Precast Reinforced Concrete Manhole Sections<sup>2</sup>

### 2.2 ASSHTO Standard:

Standard Specifications for Highway Bridges, 16th Edition<sup>3</sup>

### 2.3 ACI Standard:

ACI 318 Building Code Requirements for Reinforced Concrete<sup>4</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *above ground structures*—all structures with their base at or above ground.

3.1.2 *bearing loads*—the foundation pressure reaction to all other loads acting on the structure.

3.1.3 *below ground structures*—all structures other than those with their base at or above ground.

3.1.4 *dead loads*—the mass of the structure and all permanent loads imposed on the structure.

3.1.5 *equipment loads*—loads induced into the structure by equipment installed on mounting devices cast into the structure.

3.1.6 *hydrostatic loads*—all pressures due to the weight of water or other liquids.

3.1.7 *lateral earth loads*—the lateral pressure due to the effective weight of adjacent earth backfill.

3.1.8 *lifting loads*—the forces induced into the structure during handling at the precast plant and the construction site.

3.1.9 *surcharge loads*—the lateral pressure due to vertical loads superimposed on the adjacent earth backfill.

3.1.10 *traffic loads*—all loads superimposed on the structure or adjacent earth backfill due to vehicles or pedestrians.

3.1.11 *water and wastewater structures*—solar heating reservoirs, septic tanks, cisterns, holding tanks, leaching tanks, extended aeration tanks, wet wells, pumping stations, grease traps, distribution boxes, oil-water separators, treatment plants, manure pits, catch basins, drop inlets, and similar structures.

## 4. Significance and Use

4.1 This practice is intended to standardize the minimum loads to be used to structurally design a precast product.

4.2 The user is cautioned that he must properly correlate the anticipated field conditions and requirements with the design loads. Field conditions may dictate loads greater than minimum.

## 5. Design Loads

### 5.1 Dead Loads:

5.1.1 Permanent vertical loads typically include the weight of the road bed, walkways, earth backfill, and access opening covers.

5.1.2 Recommended unit weights of materials for design are shown in Table 1.

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<sup>1</sup> This practice is under the jurisdiction of ASTM Committee C-27 on Precast Concrete Products and is the direct responsibility of Subcommittee C27.30 on Water and Wastewater Containers.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.05.

<sup>3</sup> Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol St., Washington, DC 20001.

<sup>4</sup> Available from the American Concrete Institute, Box 19150, Detroit, MI 48219-0150.

**TABLE 1 Unit Weights of Materials**

Material	Weight, lbf/ft <sup>3</sup> (N/m <sup>3</sup> )
Concrete (plain or reinforced)	150 (23 600)
Lightweight Concrete (reinforced)	100 to 130 (15 700 to 20 400)
Cast Iron	450 (70 700)
Steel	490 (77 000)
Aluminum	175 (27 500)
Earth Fill	100 to 150 (15 700 to 23 600)
Macadam	140 (22 000)

**5.2 Traffic Loads:**

5.2.1 The vehicle and pedestrian loadings are shown in Table 2.

5.2.2 The arrangement and spacing of vehicle wheels are shown in Fig. 1 and Fig. 2.

**5.2.3 Distribution of Wheel Loads through Earth Fills:**

5.2.3.1 For above ground structures where vehicle wheels contact the top surface of the structure, the vehicle wheel loads will be distributed over an area as shown in Fig. 3. The loaded area will be:

$$A = W \times L \tag{1}$$

where:

- A = wheel load area, ft<sup>2</sup> (m<sup>2</sup>),
- W = wheel width, ft (m), and
- L = wheel length, ft (m).

5.2.3.2 For below ground structures where backfill separates the vehicle wheels and the top surface of the structure, the vehicle wheel loads will be distributed as a truncated pyramid as shown in Fig. 4.

The loaded area will be:

$$A = (W + 1.75 H) \times (L + 1.75 H) \tag{2}$$

where:

- A = wheel load area, ft<sup>2</sup> (m<sup>2</sup>),
- W = wheel width, ft (m),
- L = wheel length, ft (m), and
- H = height of backfill between wheels and structure, ft (m).

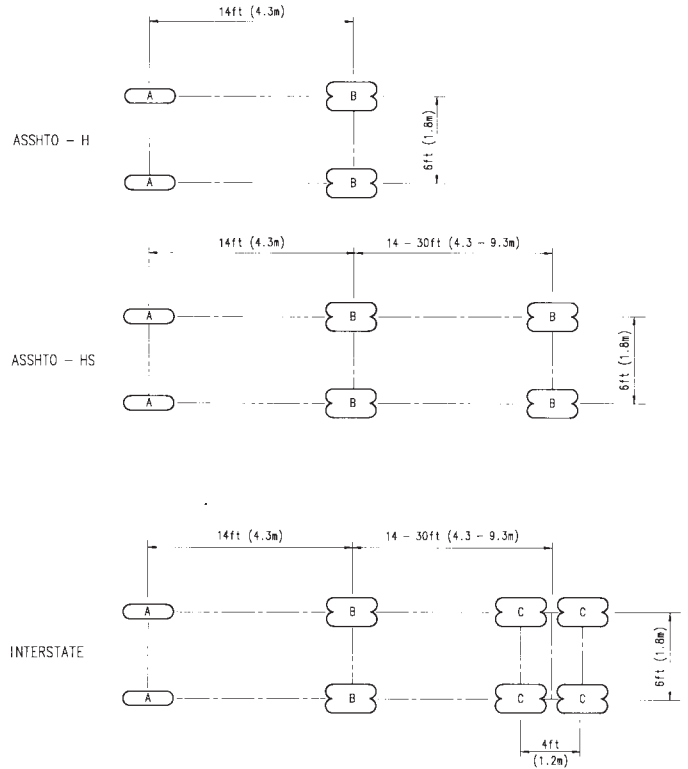
5.2.3.3 When several distributed wheel load areas overlap, the total wheel load will be uniformly distributed over a composite area defined by the outside limits of the individual areas. Such a wheel load distribution is shown in Fig. 5.

5.2.3.4 When the dimensions of the distributed load area or the composite distributed load area exceed the top surface area

**TABLE 2 Vehicle and Pedestrian Load Designations**

Designation	Load, max	Uses
A-16 (HS20-44) <sup>A</sup>	16 000 lbf (71 200 N) per wheel	heavy traffic
A-12 (HS15-44) <sup>A</sup>	12 000 lbf (53 400 N) per wheel	medium traffic
A-8 (H10-44) <sup>A</sup>	8 000 lbf (35 600 N) per wheel	light traffic
A-03	300 lbf/ft <sup>2</sup> (14 400 Pa)	walkways

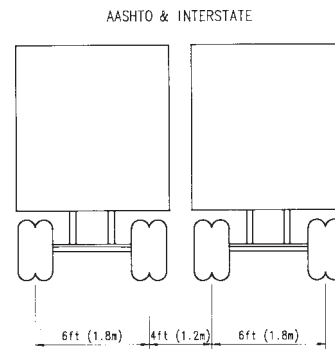
<sup>A</sup> The designations in parentheses are corresponding ASSHTO designations.



Designation	Load at A		Load at B		Load at C	
	lbf	N	lbf	N	lbf	N
A-16 (HS20-44) <sup>A</sup>	4 000	17 800	16 000	71 200	12 000	53 400
A-12 (HS15-44) <sup>A</sup>	3 000	13 300	12 000	53 400	8 000	35 600
A-8 (H10-44) <sup>A</sup>	2 000	8 900	8 000	35 600	6 000	26 700

<sup>A</sup> The designations in parentheses are corresponding ASSHTO designations.

**FIG. 1 Single Vehicle Traffic Loads and Spacing**



**FIG. 2 Multiple Vehicle Spacing**

of the structure, only that portion of the distributed load within the top surface area will be considered in the design.

5.2.4 The effects of impact will increase the live wheel loads designated as A-16, A-12, and A-8 as shown in Table 3.

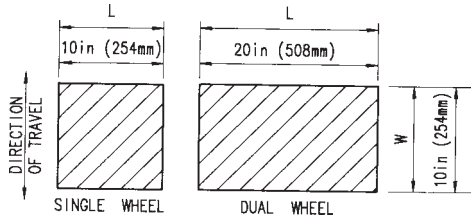


FIG. 3 Wheel Load Area

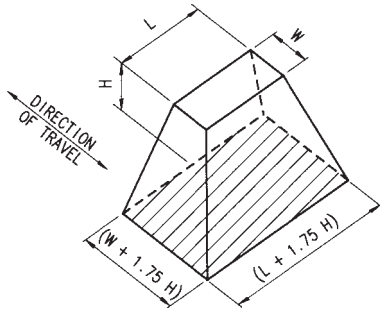


FIG. 4 Distributed Load Area

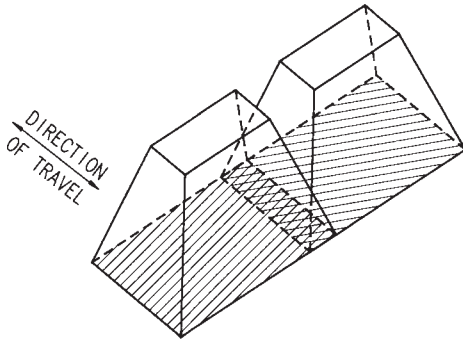


FIG. 5 Composite Distributed Load Area

TABLE 3 Wheel Load Increases for Impact

Height of Backfill Between Wheel and Structure	Increase
0 to 12 in. (0 to 305 mm)	30 %
13 to 24 in. (330 to 610 mm)	20 %
25 to 35 in. (635 to 890 mm)	10 %
36 in. (915 mm) or greater	0 %

5.3 Hydrostatic Loads:

5.3.1 The water pressure acting on any point on the outside surface of the structure is:

$$P_W = W_W \times H_W \quad (3)$$

where:

- $P_W$  = hydrostatic pressure, lbf/ft<sup>2</sup> (Pa),
- $W_W$  = unit weight of water, lbf/ft<sup>3</sup> (N/m<sup>3</sup>), and
- $H_W$  = distance from the ground water surface to the point on the structure under consideration, ft (m).

5.3.2 The liquid pressure acting on any point on the inside surface of the structure is:

$$P_L = W_L \times H_L \quad (4)$$

where:

- $P_L$  = liquid pressure, lbf/ft<sup>2</sup> (Pa),
- $W_L$  = unit weight of the liquid, lbf/ft<sup>3</sup> (N/m<sup>3</sup>), and
- $H_L$  = distance from the liquid surface to the point on the structure under consideration, ft (m).

5.4 Lateral Earth Loads:

5.4.1 The lateral earth pressure on the walls of a buried structure for the portion of the walls above the ground water surface will be:

$$P_E = K \times W_E \times H_E \quad (5)$$

where:

- $P_E$  = lateral earth pressure, lbf/ft<sup>2</sup> (Pa),
- $K$  = coefficient of lateral earth pressure,
- $W_E$  = unit weight of the earth backfill, lbf/ft<sup>3</sup> (N/m<sup>3</sup>), and
- $H_E$  = distance from the surface of the earth backfill to the point on the structure walls under consideration, ft (m).

5.4.2 The lateral earth pressure on the walls of a buried structure for the portion of the walls below the ground water surface will be:

$$P_E = [K \times W_E \times (H_E - H_W)] + [K \times (W_E - W_W) \times H_W] \quad (6)$$

where:

- $P_E$  = lateral earth pressure, lbf/ft<sup>2</sup> (Pa),
- $K$  = lateral earth pressure coefficient,
- $W_E$  = unit weight of the earth backfill, lbf/ft<sup>3</sup> (N/m<sup>3</sup>),
- $H_E$  = distance from the surface of the earth backfill to the point on the structure under consideration, ft (m),
- $W_W$  = unit weight of water, lbf/ft<sup>3</sup> (N/m<sup>3</sup>), and
- $H_W$  = the distance from the surface of the ground water table to the point on the structure under consideration, ft (m).

5.4.3 Laboratory and field testing has shown that the value of the lateral earth pressure coefficient depends on the yielding of the wall of the structure relative to the earth backfill. Walls of sectional precast concrete structures can yield by rotating, translating, or deflecting. Walls of monolithic precast concrete structures can yield by deflecting.

5.4.3.1 The lateral earth pressure on a structure where the walls cannot yield will be considered as the at-rest pressure. The value of the lateral earth pressure coefficient for this condition can be estimated by Jaky's equation of:

$$K_O = 1 - \sin \phi \quad (7)$$

where:

- $K_O$  = at-rest lateral earth pressure coefficient, and
- $\phi$  = internal friction angle of the earth backfill, degrees.

The value of  $K_O$  shall be as computed or 0.50, whichever is greater.

5.4.3.2 The lateral earth pressure on a structure where the walls can yield sufficiently will be considered as the active pressure. The value of the lateral earth pressure coefficient for this condition can be estimated by Coulomb's or Rankine's equation of:

$$K_A = [1 - \sin \phi] / [1 + \sin \phi] \quad (8)$$

where:

- $K_A$  = active earth pressure coefficient, and
- $\phi$  = internal friction angle of the earth backfill, degrees.

The value of  $K_A$  shall be as computed or 0.30, whichever is greater.

5.5 Surchage Loads:

5.5.1 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. Lateral surcharge pressures for the designated vehicle wheel loads are shown in Table 4.

5.5.2 Lateral surcharge loads from traffic will be considered negligible below a vertical distance 8 ft (2.4 m) below the wheel.

5.6 Lifting Loads:

5.6.1 The lifting load induced into the structure will be not less than the total dead weight of the precast unit distributed over not more than three lifting points.

5.7 Cumulative Loadings:

5.7.1 The cumulative vertical loading possible on the top or base of a structure are shown schematically in Fig. 6 and Fig. 7, respectively.

5.7.2 The cumulative horizontal loadings possible on the walls of a structure are shown schematically in Fig. 8.

6. Loading Combinations for Above Ground Structures

6.1 The design load for the top of the structure will consider the cumulative effects of dead loads, snow loads, and either a pedestrian live load if applicable, or a nominal live load of 20 lbf/ft<sup>2</sup> (958 Pa). Local area building codes will be used for snow loads.

6.2 The design load for the walls of the structure will consider both of two individual load cases.

6.2.1 Load Case A— Load Case A will consider a structure full condition and will include only the internal hydrostatic loads.

6.2.2 Load Case B— Load Case B will consider a structure empty condition and will include either the effects of wind load or horizontal vehicle impact if applicable. Local area building codes or a nominal external pressure of 30 lbf/ft<sup>2</sup> (1436 Pa) will be used for wind loads.

6.3 The design load for the base of the structure will consider the applicable individual load case.

6.3.1 Load Case A— Load Case A is an empty structure resting on the ground and will consist of a bearing load uniformly distributed over the base.

6.3.2 Load Case B— Load Case B is a full structure raised above the ground and will include the cumulative effects of dead loads and internal hydrostatic loads.

TABLE 4 Lateral Surchage Pressures

Designation	Lateral Surchage Pressure
A-16 (HS20-44) <sup>A</sup>	80 lbf/ft <sup>2</sup> (3830 Pa) per wheel
A-12 (HS15-44) <sup>A</sup>	60 lbf/ft <sup>2</sup> (2873 Pa) per wheel
A-8 (H10-44) <sup>A</sup>	40 lbf/ft <sup>2</sup> (1915 Pa) per wheel

<sup>A</sup> The designations in parentheses are corresponding ASSHTO designations.

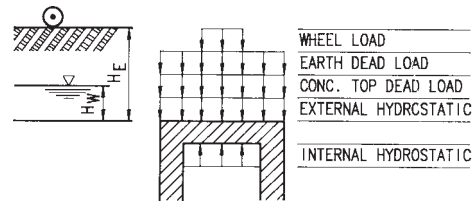


FIG. 6 Cumulative Vertical Top Loads

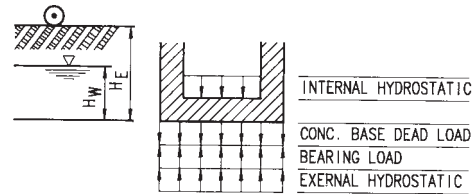


FIG. 7 Cumulative Vertical Base Loads

7. Loading Combinations for Below Ground Structure

7.1 The design load for the top of the structure will consider the cumulative effects of dead loads, snow loads, and traffic loads. Local area building codes will be used for snow loads.

7.2 The design load for the walls of the structure will consider both of two independent load cases.

7.2.1 Load Case A— Load Case A is a structure full condition and will include the cumulative effects of maximum internal hydrostatic loads, minimum external hydrostatic loads, and minimum lateral earth pressure loads.

7.2.2 Load Case B— Load Case B is a structure empty condition and will include the cumulative effects of maximum external hydrostatic loads, maximum lateral earth pressures, and lateral surcharge loads.

7.3 The design load for the base of the structure will consider the cumulative effects of the bearing load and the external hydrostatic load.

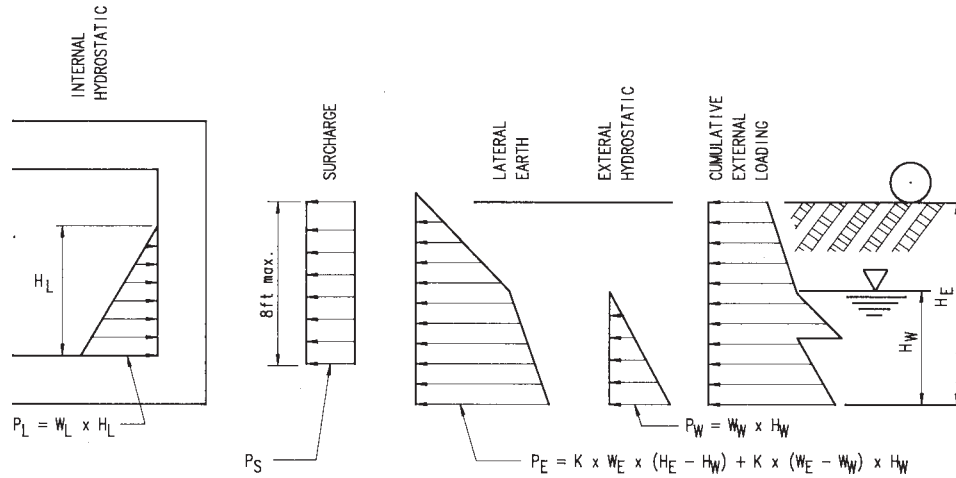
8. Special Loading Considerations

8.1 The structural design loading for unique applications will also consider thrust, vibration, and ice loads applicable.

8.2 The structural design for below ground structures will also consider buoyancy effects, if applicable, and proportion the structure to assure an adequate flotation safety factor.

8.3 The structural design loading will also consider the stresses due to the effects of concrete shrinkage and thermal movement. The reinforcing steel provided in areas of the structure subject to such stresses will equal or exceed the minimum amounts required by the referenced reinforced concrete design standards in Section 4.

8.4 Lifting inserts which are embedded or otherwise attached to the structure will be designed for four times the maximum load transmitted to the inserts.



**FIG. 8 Cumulative Horizontal Wall Loads**

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