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CONCRETE TECHNOLOGY CORPORATION

1/03/17

MANUFACTURERS OF PRESTRESSED CONCRETE • TACOMA, WASHINGTON

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This brochure was developed to describe the use of Hollow Core slabs for storm water detention vault lids. Detention vaults are usually subterranean structures located beneath parking lots or other open spaces. In this regard, the Hollow Core slab lid is typically designed to support vehicular loading in addition to soil cover.

Because of the high magnitude of the loads associated with typical design vehicles, 12½” thick Hollow Core slabs are used for detention vault lids. The following Span-Load charts present preliminary design information on this thickness. It is designed with a thick top flange to provide adequate durability and "punch-through" capacity.

The Hollow Core slab is manufactured in a standard 4'-0" width using a continuous concrete extrusion process. One continuous slab, approximately 600 feet long, is cast and allowed to cure for approximately 16 hours. When the concrete reaches sufficient strength to bond the pretensioned strands, slabs are cut from the continuous extrusion to customer specified lengths. Zero-slump, high strength concrete with a 28-day strength in excess of 8,000 psi and ½" diameter, 270 ksi, low relaxation steel strands are used in this process. The strands are pretensioned and fully bonded to the concrete to support the slab and design loads.

**SPAN-LOAD CHART DESIGN CRITERIA**

**ATTENTION:** The Span-Load Charts are derived from computer-calculated data, are intended as an aid to preliminary sizing, and must be interpreted using sound engineering judgment.

**MODEL CODE** - The 2015 edition of the International Building Code (2015 IBC) was used as the model code. The 2015 IBC references the most-current edition of ACI 318, which at the time this brochure was developed was ACI 318-14.

**LOADING** - With the exception of two contours clearly indicated on the Span-Load Charts, all values shown assume a superimposed soil dead load unit weight of 120 pcf. Each Span-Load Chart has been developed for a very specific Live Load. The reader will find charts for two standard AASHTO vehicles, HS20-44 & HS25-44. Also included are charts for 150 psf and 250 psf uniform Live Load, and finally, a chart for a 45 kip outrigger placed on an 18"x18" pad. Alternate load cases or unique vehicles (such as Vactor type vehicles) must be individually analyzed by CTC's engineering department.
ALLOWABLE STRESSES - The extreme fiber stress under full service load is limited to 0.45$\sigma_c'$ for compression and 7.5 $\sqrt{\sigma_c'}$ for tension in accordance with ACI 318-14, Sections 24.5.4 and 24.5.2. Although ACI 318 allows higher tensile stresses, CTC recommends maintaining the extreme fiber tensile stress to less than the modulus of rupture of concrete = 7.5 $\sqrt{\sigma_c'}$ due to the potentially corrosive environment associated with detention vaults.

FLEXURE - The nominal flexural strength, $\phi M_n$, exceeds the required ultimate strength, $M_u = 1.2M_{DL} + 1.6M_{LL}$ per Sections 5.3.1 & 7.5.1.1(a) of ACI 318-14. The strength reduction factor, $\phi$, is calculated per Sections 21.2.1 through 21.2.3. The stress in the pretensioned reinforcement at nominal flexural strength, $f_{ps}$, is calculated per Sections 25.4.8 and 20.3.2.3.1.

SHEAR - The nominal shear strength, $\phi V_n$, exceeds the required ultimate shear, $V_u = 1.2M_{DL} + 1.6M_{LL}$ per Sections 5.3.1 & 7.5.1.1(b) of ACI 318-14. Web-shear strength, $V_{cw}$, is calculated in accordance with CTA Technical Bulletin 85B1. This method calculates the applied shear which causes a principal tension of 4 $\sqrt{\sigma_c'}$ at the centroid of a prestressed member, as allowed in Section 22.5.8.3.3. Flexure-shear strength, $V_{ci}$, is calculated as set forth in CTA Technical Bulletin 78B1. This method uses a modified version of Equation (22.5.8.3.1a) based on full-scale testing of Hollow Core slabs.

Filling a predetermined number of voids with cast-in-place concrete will result in higher shear strength, particularly in the transfer zone near the ends of the slab. The Span-Load Charts in this brochure use 3,000 psi as the void-fill concrete strength. The capacity of the filled voids is discussed in CTA Technical Bulletin 85B1.

All values in the Span-Load Charts are based on Hollow Core slabs without shear reinforcement. It is not possible to provide shear reinforcement in extruded Hollow Core slabs.

DEFLECTIONS - Hollow Core slab design is usually controlled by allowable tensile stress or ultimate flexural & shear strength. Because detention vaults are typically subterranean structures, deflection is usually not a design concern. Should deflection be of concern for a particular application, deflections may be estimated according to the suggested method described in Section 5.8.4 of the PCI Design Handbook, 7th Edition.
ROUGH OPENINGS - The values in the Span-Load Charts apply to Hollow Core slabs without openings. Rough openings through the voided area of a Hollow Core slab no larger than six inches in diameter have little effect on the load carrying capacity. However, large openings which cut webs and strands have a significant impact on the load carrying capacity of the slab.

Typical features associated with the detention vault are manhole and vent openings. A detail of a 24" diameter manhole and a 12" diameter vent is shown on one of the sample drawings. If the reduced Hollow Core slab cross section is not structurally adequate to support the design loads, additional support from a knee wall is required. Refer to the knee wall detail shown on the sample drawing.

The Knee Wall envelope shown on each Span-Load Chart represents the maximum span under given uniform soil cover allowed without the use of a knee wall. Note that the high shear resulting from the 45 Kip Outrigger load is too great for the reduced section associated with the manhole notch. A knee wall is required at all manhole locations if the Outrigger load is specified.

CONNECTIONS - CTC designs and details the Hollow Core slabs for the gravity loads specified in the contract documents. Connection design for lateral or other loads is not included in the scope of CTC's design.

RELATED PUBLICATIONS AVAILABLE FROM CTC

- Guide Specifications for Precast, Prestressed Hollow Core Slabs
- Field Handling and Erection of Hollow Core Slabs
- Analysis of Wheel Loads on Hollow Core Slabs w/ Soil Cover
- CTA Technical Bulletins:
  - 73B6 Shear Diaphragm Capacity of Precast Floor Systems
  - 74B6 Composite Systems Without Roughness
  - 76B4 Composite Systems Without Ties
  - 78B1 Shear Strength of Hollow Core Members
  - 79B4 Shear Strength of Continuous Hollow Core Systems
  - 80B3 Shear Diaphragm Capacity of Untopped Hollow Core Floor Systems
  - 82B2 Grouting Precast Floor Systems
  - 85B1 Web Shear Strength of Prestressed Concrete Members
a = Length ...........................................± 1 in.
b = Width ................................................± 1/4 in.
c = Depth ..................................................± 1/4 in.
d_{1} = Top of flange thickness
  Top flange area defined by the actual measured
  values of average d_{1} x b shall not be less than
  85% of the nominal area calculated by d_{1} nomi-
  nal x b nominal.
d_{b} = Bottom flange thickness
  Bottom flange area defined by the actual mea-
  sured values of average d_{b} x b shall not be less
  than 85% of the nominal area calculated by
  d_{b} nominal x b nominal.
c = Web thickness
  The total cumulative web thickness defined by
  the actual measured value Σe shall not be less
  than 85% of the nominal cumulative width calcu-
  lated by Σe nominal.
f = Rough Opening ................................. ± 2 in.
g = Flange angle ..... 1/8 in. per 12 in., 1/2 in. max.
h = Variation from specified end
  squareness or skew ................................± 1/2 in.
i = Sweep (variation from straight line
  parallel to centerline of member) ..... ± 3/8 in.
j = Center of gravity of strand group
  The CG of the strand group relative to the top
  of the slab shall be within ± 1/4 in. of the nomi-
  nal strand group CG.

  The position of any individual strand shall be
  within ± 1/2 in. of nominal vertical position and
  ± 3/4 in. of nominal horizontal position and shall
  have a minimum cover of 3/4 in.

k = Local smoothness ....................... ± 1/4 in. in 10 ft.
l = Applications requiring close control of differen-
tial camber between adjacent members of the
same design should be discussed in detail with
the producer to determine applicable tolerances.

Slab Weight
  Excess concrete material in the slab internal
  features is within tolerance as long as the mea-
  sured weight of the individual slab does not
  exceed 110% of the nominal published unit
  weight used in the load capacity calculation.
SECTION PROPERTIES
(with shear keys grouted)

\[ A: \ 313 \text{ in}^2 \]
\[ I: \ 6,136 \text{ in}^4 \]
\[ y_{\text{top}}: \ 6.02 \text{ in} \]
\[ y_{\text{bot}}: \ 6.48 \text{ in} \]
\[ S_{\text{top}}: \ 1,019 \text{ in}^3 \]
\[ S_{\text{bot}}: \ 947 \text{ in}^3 \]
\[ w: \ 84 \text{ psf} \]
GENERAL NOTES:
1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f\(c\) = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2015 & ACI 318-14.
9.) The Vent Notch envelope represents the maximum span and height of soil cover that can be supported by slabs with 6½" standard notches in adjacent slabs to accommodate 12" diameter vents, assuming void fill concrete f\(c\) = 3,000 psi. Refer to Detail 3 on page 13 of this brochure for vent notch details.
GENERAL NOTES:
1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f'c = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
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5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2015 & ACI 318-14.
9.) The Vent Notch envelope represents the maximum span and minimum/maximum height of soil cover that can be supported by slabs with 6½" standard notches in adjacent slabs to accommodate 12" diameter vents, assuming void fill concrete f'c = 3,000 psi. Refer to Detail 3 on page 13 of this brochure for vent notch details.
GENERAL NOTES:

1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f'c = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2015 & ACI 318-14.
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GENERAL NOTES:
1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f'c = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2015 & ACI 318-14.
9.) The Vent Notch envelope represents the maximum span and height of soil cover that can be supported by slabs with 6½" standard notches in adjacent slabs to accommodate 12" diameter vents, assuming void fill concrete f'c = 3,000 psi. Refer to Detail 3 on page 13 of this brochure for vent notch details.
GENERAL NOTES:
1.) A minimum cover depth of nine inches is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) Knee walls are required at all manhole and vent openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2015 & ACI 318-14.
VOID DAMS - Void dams are provided by CTC to restrict the flow of C.I.P. concrete into the slab voids. Typically, the dam is placed six inches from the ends of the slab at voids without pour slots. The dam is placed two feet from the ends of the slab at voids with pour slots. This distance can be modified as required for embedment of reinforcement or to increase the slab end shear strength. To facilitate the placement and consolidation of the concrete fill, CTC recommends and provides blockouts in the top of the voids at locations where endfill length exceeds 1'-6".

BEARING - The recommended design bearing dimension is three inches with a field installation minimum of two inches. CTC recommends and furnishes a 3/8" x 1/4" neoprene end bearing strip to provide uniform bearing during erection. Final bearing is provided when C.I.P. concrete fills the remaining space.

GROUT KEYS - The longitudinal keys between adjacent slabs must be filled with grout to fully develop the concentrated load distribution and shear friction capacity of the Hollow Core slab system. CTC recommends a mix consisting of one (1) part cement to three (3) parts paving or builder's sand by weight, with a maximum water content of five (5) gallons per sack of cement.

RESISTANCE TO LATERAL LOADS - Lateral loads may be transmitted through Hollow Core slabs to resisting elements, such as frames or shear walls, by diaphragm action. When concrete topping is to be installed over the slabs, the diaphragm is normally designed to be in the topping. In this case, shear transfer takes place by shear friction, based on WWF mesh or other reinforcement in the topping. For untopped systems, diaphragm action is developed by means of shear friction reinforcement at the ends of the slabs, as described in CTA Technical Bulletin 80B3. It is important to detail this reinforcement such that it is effectively anchored into the lateral force resisting system, such as by reinforcement hooked into shear walls.

VOID DRAIN HOLES - Void drain holes will be installed in Hollow Core slabs. Cap top holes prior to soil backfill or topping pour to prevent material from washing into void and plugging drains. Drain holes must be cleaned out after end closure concrete pours are complete. The contractor may patch holes, if necessary, once structure is weather proofed.

CONSTRUCTION LOADS - The hollow core slabs for the vault lid are designed to carry the "Design Loads" only after vault construction is complete, all design concrete and grout strengths have been achieved and all cover has been placed over the vault within the limits specified on CTC's production drawings. For contractor's evaluation of construction loads, allowable uniform loads on the bare slabs can be obtained from CTC's website www.concretetech.com.

ASPECT RATIO - A minimum of three each, four-foot nominal width hollow core slabs are required in a bay. Additionally, the ratio of hollow core span length to cumulative width of adjacent slabs in a bay shall be 2.0 or less.