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Precast/Prestressed and Post-Tensioned

Cantilever Precast Concrete Retaining Walls

Proprietary retaining wall system solves Texas' highway expansion dilemma

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It's a familiar scenario—a busy urban highway in need of expansion. The width of the highway, however, is restricted by limited right-of-way, and high land values prohibit increasing the right-of-way. So what choice does the designer have? Going vertical is a logical choice, but elevated lanes require bridges or filled approaches and depressed lanes require earth cuts. In Texas, cantilever precast concrete (CPC) retaining walls have proven a viable option for supporting the lateral loads caused by filled approaches and earth cuts.

TYPICAL CHOICES

Engineers designing structures to resist lateral earth pressure have several structural systems available, such as gravity mass walls, self-supporting cantilever walls, and walls using tie-back anchorage. The particular system chosen can depend on the engineer's familiarity with the system as much as economics,[1] but two of the most common are cast-in-place (CIP) concrete walls and mechanically stabilized earth (MSE) walls.

CPC-retaining walls—developed by Bexar Concrete Works, Inc.—have evolved from the CIP approach. CPC walls use a CIP footing on which a precast panel is installed. The footing and precast panel are then joined with a CIP closure wall. The CPC wall system uses a full moment connection at the base, eliminating the need for the diagonal struts required by precast retaining walls that have been constructed in the past.[2]

The difference in cost of CIP, MSE, and CPC walls (Table 1) primarily depends on the amount of field construction needed, with the least expensive system requiring the least amount of field work. Whereas MSE walls involve minimal footing preparation, CIP and CPC walls require construction of a moment resistant base. MSE and CPC wall panels are prefabricated and transported to the site, providing for efficient manufacturing and quality control of the walls. CIP walls, however, are formed on site and concrete is placed in multiple lifts, requiring many laborers.

Economically, MSE walls appear to be the best choice; however, other considerations may preempt economics.

TABLE 1:
APPROXIMATE COST OF RETAINING WALL SYSTEMS IN TEXAS

Wall type*	Average cost, $/ft^2 ($/m^2)
MSE	18 to 20 (190 to 220)
CPC	23 to 26 (250 to 280)
CIP	35 (380)

*Cast-in-place (CIP), mechanically stabilized earth (MSE), and cantilever precast concrete (CPC)

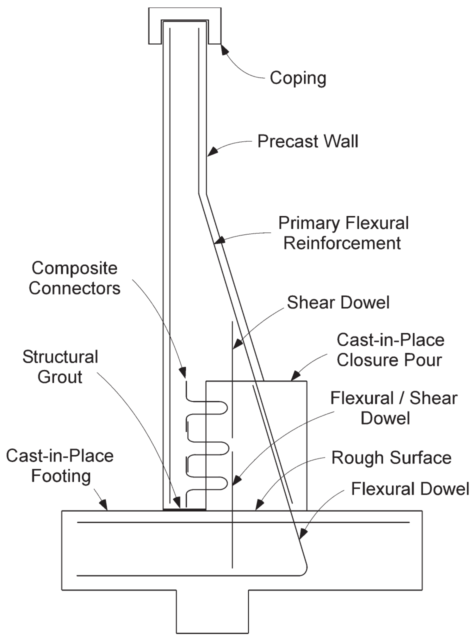

Fig. 1: Major structural components and reinforcement in CPC wall

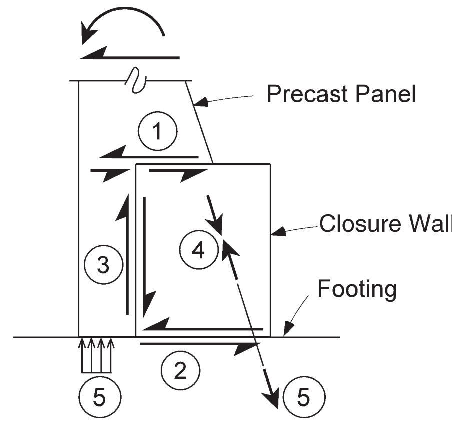

Fig. 2: Major forces and stresses occurring at the base of a CPC wall

In some situations, it may be more aesthetically pleasing to have tall vertical elements forming the face of a wall rather than horizontally jointed components. And CPC retaining walls, which do not require tie-backs, may be advantageous in areas of limited permanent right-of-way.

ANALYSIS AND DESIGN

When designing a CPC retaining wall, one models loads just as for a CIP cantilever retaining wall. When free-draining granular backfill is used, one can assume the lateral earth pressure is equivalent to a horizontal fluid pressure, with the addition of a surcharge to account for slope or traffic loading.[3,4] The design, detailing, and construction of a CPC wall footing is similar to that of a CIP wall. The transfer of moment and shear from the wall to the footing, and the resulting soil pressures felt by the footing, are calculated in the same manner for both systems.

The three principal components of a CPC wall are the precast wall panel, the closure placement (wall), and the CIP footing (Fig. 1). The wall panel is secured to the footing by the closure wall. The inside, or back, face of the panel is sloped so the wall is thicker at the base. The primary flexural reinforcement extends into the closure wall, where it is lap spliced to the flexural dowels extending up from the footing. The front, or exterior, face of the panel extends to the footing, where it can bear on the footing in compression. Composite connectors are cast in the precast panel and dowels are provided in the panel and the footing to transfer load across the construction joints.

Obviously, the strength of a CPC wall depends on how successfully the precast panel, the closure wall, and the footing are connected together. Each of the forces in the precast panel, closure wall, and footing can be evaluated separately. These forces are described in the following list (refer to Fig. 2):

1. Shear at the top of the closure wall is resisted by the concrete strength in the stem of the precast panel and the shear friction at the construction joint. Vertical dowels may be necessary at this joint to engage shear friction when the panel strength is inadequate;[5,6]
2. Shear at the base of the closure wall is also resisted by concrete friction and shear dowels. The shear dowels also provide negative bending strength during the construction phase of the project, before the soil has been backfilled, when wind or accidental loads can push the wall backwards;
3. Shear at the front of the closure wall is resisted by composite connectors. The composite connectors provided connect the precast panel to the closure wall in the same manner in which a deck is compositely connected to a bridge girder. Calculation of the shear flow is based on change in the magnitude of the compression block along the length of the stem;[7]
4. Tension force must be carried from the precast panel reinforcement to the flexural dowels through a lap splice. This is a Class C splice because 100% of the required area is spliced within the closure wall.[7]
   In addition, reinforcement termination occurs within the vicinity of a construction joint, with reduced shear capacity. Extra care must be taken into account in determining whether the theoretical bar cutoff criteria is met; and

Fig. 3: Readying to place concrete in the CPC wall footing along SH 190 in Dallas, TX

Fig. 4: Splicing flexural reinforcement to footing dowels in Dallas, TX

5. Bending moment at the base of the wall is resisted by compression at the grouted end of the precast panel stem and by tension in the inclined flexural reinforcement. Bending capacity is based on the footing's concrete strength and the area of the flexural dowels.

CPC WALLS IN TEXAS

CPC walls have been built at two locations in Texas. The first location is along the President George Bush Turnpike—State Highway (SH) 190—in Dallas. The turnpike is below street level and has retaining walls on either side, supporting its frontage roads and approaches. These walls range in height from 8 to 16 ft (3 to 7 m). Wall construction began with the installation of CIP concrete footings (Fig. 3) followed by placement of the precast wall panels. The panels were braced for stability and the precast panel reinforcement and the footing dowels were lapped (Fig. 4). Formwork was then erected for the closure placement to enclose the lapped reinforcement and concrete was placed, creating a closure wall that secured the precast panel to the footing.

The second use of CPC walls is at the interchange of Military Highway and Interstate Highway (IH) 410 in San Antonio. At this intersection, two linear segments of wall are used to support a five-lane approach embankment (Fig. 5). The walls meet at an acute angle near several drilled shafts (Fig. 6). These walls range in height from 8 to 32 ft (3 to 10 m) and are similar in design to those used on the Dallas turnpike project, but at a much larger scale. The closure walls are about 7 ft (2 m) in height to accommodate higher moments and shears.

In both Texas projects, the choice to use cantilever retaining walls instead of MSE walls was because of the aesthetics of existing highway retaining walls in the vicinity of the projects. Given that cantilever retaining walls were chosen, the choice fell between the CIP and CPC designs, with CPC being the most economical.

Fig. 5: Military Highway overpass at IH 410 in San Antonio, TX

Fig. 6: Installation of CPC adjacent to drilled shafts at IH 410 in San Antonio, TX

CONSTRUCTION ADVANTAGE

CPC walls provide several time, labor, and material advantages over CIP walls. A single 10 ft (3 m) wide x 32 ft (10 m) tall panel can be installed and braced in about 30 min, making it possible for one crew to erect 160 linear ft (50 m) of wall in a day. The closure wall can typically be placed in one lift. Removal of bracing and backfilling can then take place in about 7 days. Overall, there is reduction in field reinforcement, temporary formwork, and volume of concrete placed on site when CPC walls are used. Construction experience has shown that a CPC wall project can be completed in about 3/4 the time a CIP wall project would take. These improvements make CPC walls a less expensive alternative to CIP cantilever walls.

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Selected for reader interest by the editors.

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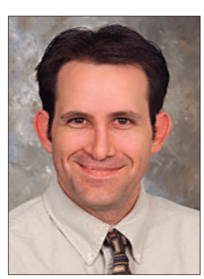

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