Float-In Cofferdam Over 63 Large Pipe Diameter Piles

Float-in cofferdams have been used on several major bridge projects in the U.S. since the concept was first introduced in 1998 on the Bath–Woolwich Bridge in Maine, and then on the new Carquinez Bridge at San Francisco Bay in 2001. For this construction method, all foundation piles are pre-installed and cut-off, and concurrently, a concrete shell is fabricated offsite that acts as both a form and cofferdam for casting of the underwater pile cap. The float-in cofferdam installed in 2009 for the new Port Mann Bridge, southeast of Vancouver, British Columbia, Canada, is distinctive for several reasons:

- **Size of Installation** – It is the largest float-in cofferdam ever installed, 109 ft (33.2 m) by 138 ft (42 m) by 32 ft (9.8 m) high and weighing in excess of 6,000 tons (5,440 tonnes).

- **Number of Piles** – The cofferdam was installed over the top of 63 piles, each 6 ft (1.8 m) diameter pipe pile cut-off 10 ft (3 m) underwater.

- **Pre-Installed Pre-Cast Support Collars for Initial Landing of Cofferdam** – Prior to underwater cut-off, each pile was outfitted with a precast collar hung from the top of the pile driving template and grouted to the outside of the pile.

- **Load Distribution System During Cofferdam Landing on 63 Piles** – To ensure that any single collar was not overloaded by the 6,000 ton (5,440 tonne) cofferdam during landing, a 3 in (7.6 cm) pipe ring with an outside diameter of 9.43 ft (2.9 m) was pre-positioned underwater on top of each precast support collar.

**Design-Build Joint Venture**

A Peter Kiewit Sons Co. and Flatiron Corporation Joint Venture (JV) won the design-build contract for the new Port Mann Bridge in 2008. The bridge crosses the Fraser River at Coquitlam, British Columbia, approximately 10 mi (16 km) southeast of Vancouver. The main in-water tower of the cable-stayed bridge is mid-channel, 45 ft (13.7 m), with tidal variation of about 14 ft (4.3 m). The final foundation design for N-1 Pier consisted of 63 piles, the tops of the piles were embedded in a 24.6 ft (7.5 m) deep, by 138.13 ft (33.2) by 108.6 ft (32 m) pile cap positioned just below the High Water Elevation (HWE) of +9.25 ft (+2.8 m).

The original pre-bid cofferdam design was a conventional cofferdam using AZ-36 sheet piles up to 107 ft (32.6 m) long. The gap between the bottom of the pile cap and the sloping river bottom was to be filled with clean, granular fill and topped with 6.56 ft (2 m) of gravel. After the contract award, the JV evaluated the float-in cofferdam concept and concluded that it offered significant cost savings over the pre-bid conventional cofferdam.

Float-in cofferdams are typically used for underwater foundations that use large-diameter driven piles or large-diameter drilled shafts. Such foundation elements are extremely stiff, which allows the pile caps to be located up off the bottom of the waterway. The tops of the pile caps for these elements are typically located at or just above the HWE for aesthetic reasons.

Float-in cofferdams are characterized by other common features:

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- Use of a precast shell in the shape of a footing that acts as both a cofferdam and a form for the pile cap concrete placement.
- Use of a steel follower cofferdam to extend the cofferdam height and allow the precast pile cap shell to be submerged.
- Use of corrugated pipes or thin-walled steel pipe as pile-top bulkheads for sealing the pile holes in the bottom of the precast pile cap shell.
- Use of a guide system to ensure underwater mating of the floating cofferdam on to the pre-driven piles.
- Floating the precast shell to the job site and positioning over the top of the cut-off piles.
- Ballasting the cofferdam to a pre-set elevation and locking the precast pile cap shell to the piles by underwater placement of grout in the annulus between the precast shell and the pile casing.
- Use of air pockets in the pile top bulkheads to maintain sufficient free-surface to ensure transverse floating stability of the cofferdam during launch, transport and immersion onto the foundation piles. This allows the use of an open-flooding ballast system for adjusting draft and controlled sinking of the floating cofferdam without the need for added transverse bulkheads.
- Use of the bond-shear capacity of the grout closure between the precast bottom slab and the pile casing to resist hydrostatic uplift during the cofferdam dewatering stage prior to placement of the reinforcing steel and pile cap concrete in the dry.

There are several advantages in using a float-in cofferdam. The methodology eliminates the need for extremely long sheet piles typically required for cofferdams in deep water. Float-in cofferdams also eliminate the tremie concrete seal by transferring cofferdam uplift loads directly into the large foundation elements. This aspect results in a significant reduction in pile cap mass, and has significant design and cost benefits by reducing lateral design loads in foundations for structures located in zones of high seismic activity. Another advantage is the potential for schedule reduction due to starting pile cap construction concurrently with pile installation.

**Cofferdam Casting**

The cofferdam was cast on the deck of two cargo barges welded together to form a single casting bed. The two-barge casting bed was placed dock side in the North Vancouver Harbor where it was serviced by land-based cranes for forming, rebar and concrete placement. Following casting, a 16 ft (4.9 m) high steel follower cofferdam constructed of steel plate concrete form panels and internal steel bracing was installed on top of the precast cofferdam shell.

After the JV workers installed the towing attachments and ballast system, they positioned the two barges with the
completed cofferdam inside a floating drydock. The drydock was deballasted up, lifting the two barges and cofferdam clear of the water. Next, they opened the pre-installed valves to allow internal flooding of the barge hulls, and the drydock was ballasted back down. As the drydock was lowered and the two-barge casting deck went underwater, the cofferdam floated free of the drydock and the workers towed it back to dockside for final outfitting.

After the JV workers completed the outfitting, they towed the cofferdam out under the Lions Gate Bridge at the harbor entrance and into the Strait of Georgia. They then towed it south 15 mi (24 km) to the mouth of the Fraser River and finally 36 mi (60 km) up the Fraser River to the bridge site. (See Figure 4)

**Support Collars**

Prior to underwater cut-off, workers outfitted each pile with a 10.27 ft (3.1 m) outer diameter precast support collar. The collars were suspended from the top of the pile driving template with calibrated rigging and threaded rods to provide exact elevation adjustment. The inside diameter of the collars was 6.33 ft (1.92 m), which provided a theoretical annulus of 2 in (5 cm). When a collar reached the required elevation, we sealed the top and bottom of this annulus by inflating rubber tubing embedded in its inside wall. The sealed annulus was then filled with grout through pre-installed grout and vent hoses. Return of high quality grout through the vent hoses ensured complete grouting of the collar and prevented any contaminated discharge from entering the river.

To ensure that no single support collar was overloaded by the 6,000 ton (5,440 tonne) cofferdam during the initial landing stage, the contractor placed a 3 in (7.5 cm) diameter tube ring with an outside diameter of 9.43 ft (2.87 m) at the top of each collar. These rings were pre-attached to each collar prior to installation of the collars.

![Figure 4. Floating cofferdam positioned over 63 foundation piles](image)

**Guide System for Mating**

To land the cofferdam onto the support collars, the JV workers ballasted it from an initial draft of 6.1 ft (1.85 m) to a final draft of about 25 ft (7.6 m). At a draft of about 12 ft (3.6 m), the tops of the foundation piles began to thread up into the bottom of the cofferdam. The inside diameter of the corrugated bulkheads through which the sixty-three 6 ft (1.8 m) diameter foundation piles were threaded during the landing operation was 8 ft (2.4 m). This provided a theoretical annulus clearance of 12 in (30 cm) between the inside face of the pile top bulkheads and the 6 ft (1.8 m) diameter foundation piles. (See Figure 5)

To ensure that the foundation piles cleared the bottom openings and did not punch a hole in the bottom of the cofferdam, workers installed four guide dolphins equipped with guide shims for precise alignment of the floating cofferdam over the tops of the pre-driven piles. The cofferdam was positioned against the four dolphins on a falling tide and ballasting began by opening four 12 in (30 cm) diameter gate valves built into the exterior walls of the precast cofferdam. The four valves were left open until the bottom of the cofferdam reached a position about 4 in (10 cm) above the tops of the 63 cut-off piles. Divers then checked the clearance at each pile location to ensure adequate clearance between piles and the 63 openings in the bottom of the cofferdam. After confirmation, the JV relied on the tide to thread the cofferdam onto the piles.

![Figure 5. 8 ft diameter pile top bulkheads](image)
Stability of the cofferdam was maintained during the ballasting operation by ensuring that each of the 63 pile top bulkheads contained a minimum volume of air at all times. Once the cofferdam landed on the 63 support collars, the workers bled off air in each compartment through vent valves at the top of each corrugated pile top bulkhead.

**Locking Down**

Once the cofferdam had landed, divers removed the pile top bulkheads and the team pumped the tremie concrete into the 36 in (90 cm) deep 12 in (30 cm) annulus between the piles and the 8 ft (2.4 m) diameter holes in the bottom of the cofferdam. After the tremie concrete attained a minimum strength of 3,000 psi (20.7 MPa), workers dewatered the interior of the cofferdam using two each 10 in (25 cm) and 3 each 4 in (10 cm) electrical submersible pumps. Following dewatering, the interior of the 63 piles were excavated to the specified depth and filled with concrete placed in the dry. (See Figure 6)

While the grout was curing, the cofferdam remained vented to the river to maintain a relatively constant load on the collars as the river elevation changed with the tides. However, this created an environmental challenge, because the pH of the water within the cofferdam had to be maintained within tight tolerances stipulated by the project's water discharge permits. After extensive analysis, the JV installed a specialty designed pH monitoring and treatment system to continually remove, test, treat and then return the water to the inside of the cofferdam such that the water inside the cofferdam never exceeded the allowable discharge levels.

![Figure 6. Dewatered cofferdam locked to 6-ft diameter piles](image)

**Pile Cap Casting**

The 24.6 ft (7.5 m) depth of pile cap concrete was placed in two lifts, with the bottom mat, walls, half length hairpins and pylon rebar installed prior to the first lift. The other half of the hairpins, top mat support frame and top mat rebar were installed prior to pouring the second lift. Both lifts were considered mass concrete and required a thermal control plan, cooling tubes, thermal sensors and monitors throughout the entire placement. Total volume of concrete placed was 10,400 cu yds (8,000 m³).

**Summary**

The successful use of the float-in cofferdam system on the Port Mann Bridge has demonstrated again the effectiveness of this method for constructing pile caps in deep water where the caps are located below water but elevated off the bottom.