French Dam Technology Passes the Test

The modular precast system is designed for rapid construction of water impoundment structures

by Peter Drown and Andrew Sanna

The "French Dam" is a technology developed and patented by the French Development Enterprises (FDE), LLC, North Billerica, MA, for construction of small- to medium-sized hydroelectric and water control systems. Designed for new or retrofit projects, the system is based on modular segments manufactured off-site in a controlled environment. After delivery to a dam site, modules will be secured to the riverbed using underpinning (for example, soil nails or rock anchors) and interconnected with adjacent modules to complete a dam. The scalable technology provides high-quality dams but requires minimal construction time and site work. Installation is weather-independent, so project risk is minimized.

Fig. 1: The bottom of an upper-tier module. The relief (darker raised area) will nest inside the walls of the module below. The circular opening will allow workers to access the module below and bolt the two together through holes formed using PVC pipe near the four corners of the face. The reveal near the top of the photo will be fitted with an expansive waterstop immediately before the module is installed in the dam

Prototype Project

The French Dam technology was developed through funding provided by the U.S. Department of Energy (U.S. DOE) to advance the manufacturing and installation of hydroelectric facilities with low environmental impact.[1] Additional support came from the Massachusetts Clean Energy Center (MassCEC), Boston, MA.

In October 2016, FDE; Oldcastle Precast of Littleton, CO; and GEI Consultants, Inc., of Woburn, MA, announced successful fabrication, assembly, and testing of the first French Dam prototype. The prototype was designed by GEI in cooperation with Oldcastle. Modules were cast at Oldcastle's facility in Avon, CT, and they were assembled within a purpose-built concrete tank at FDE's site. The performance testing program included monitoring the system under long-term constant head.

Installation

The six prototype modules were open-top boxes measuring 8 x 8 ft (2.4 x 2.4 m) in plan and 7.67 ft (2.3 m) in height (Fig. 1), with 8 in. (203 mm) thick reinforced concrete walls constructed using a 6000 psi (41.4 MPa) mixture. To accommodate the loads efficiently, the walls of the bottom units included two mats of reinforcement with interconnecting crossties. The walls of the top units had a single mat of reinforcement (Fig. 2). A typical reinforcing mat was fabricated using No. 4 or 5 bars spaced at 12 in. (305 mm) on-center.

Each module weighed about 27,000 lb (12,250 kg)—low enough to allow the modules to be shipped and handled using conventional equipment and methods. After delivery to the project site, modules were stored on timber blocks until they were assembled in the reinforced concrete test tank.

The test tank was constructed of cast-in-place 4000 psi (27.6 MPa) concrete. The tank's base slab measured 28 x 30 ft

(8.5 x 9.1 m) in plan and 18 in. (457 mm) in thickness. Three 12 in. (305 mm) thick walls cantilevered from the base slab. The upstream wall was 17 ft (5.2 m) tall, and two sidewalls stepped down from 17 ft to 14 ft (4.3 m) downstream of the dam (Fig. 3). The walls were reinforced with No. 8 vertical bars and No. 4 horizontal bars spaced at 6 in. (152 mm) on-center each face, and the slab was reinforced with No. 5 bars at 6 in. on-center each way on each face. The slab also contained two embedments designed to provide anchor points for the modules. The embedments comprised welded assemblies of anchor plates, channels, round stock, and internally threaded couplers (Fig. 4).

Fig. 2: A reinforcement cage for an upper-tier module

Fig. 3: The dam was assembled from six precast concrete modules. The completed assembly was tested under a constant head in a reinforced concrete tank constructed at the FDE facility in North Billerica, MA

Modules were positioned in the tank using a 130 ton (118 tonne) crane. Each of the three bottom blocks were anchored to the base slab with four 1-1/4 in. (32 mm) diameter bolts threaded into the couplers on the embedments in the base slab. At each horizontal or vertical interface, modules were interconnected using four 1 in. (25 mm) diameter bolts to form a monolithic structure.

Joints between modules and between the tank slab and the modules were sealed using preformed rubber and paste-type hydrophilic waterstops installed in reveals formed in the modules (Fig. 5). Adeka KM-3030, a 30 x 30 mm (1.2 x 1.2 in.) preformed rubber strip, was used as the primary waterstop, and Adeka Ultraseal P-201, a paste applied with a caulking gun, was used as a secondary waterstop. To complete the test assembly, two abutments fabricated of steel angle, plywood, and rubber were placed between the end modules of the prototype dam and the tank walls at the upstream edge of the end modules (Fig. 6). Sikaflex quick reacting caulking was later applied to the abutments to provide additional waterstop protection. The installation was completed in 3.5 hours in a heavy rainstorm—conditions that would render conventional cast-in-place construction impossible.

Testing

To test the installation of the French Dam prototype, the reservoir created behind the modules was filled up to a 12 ft (3.7 m) head using 30,000 gal. (113,562 L) of water (Fig. 3). Water elevation and leakage were assessed over a period of 4 weeks by project staff, GEI Consultants, and an independent consultant from Knight Piesold. The test successfully demonstrated that the modules met the desired structural and hydraulic integrity and comprised a suitable dam structure for a wide variety of commercial applications.

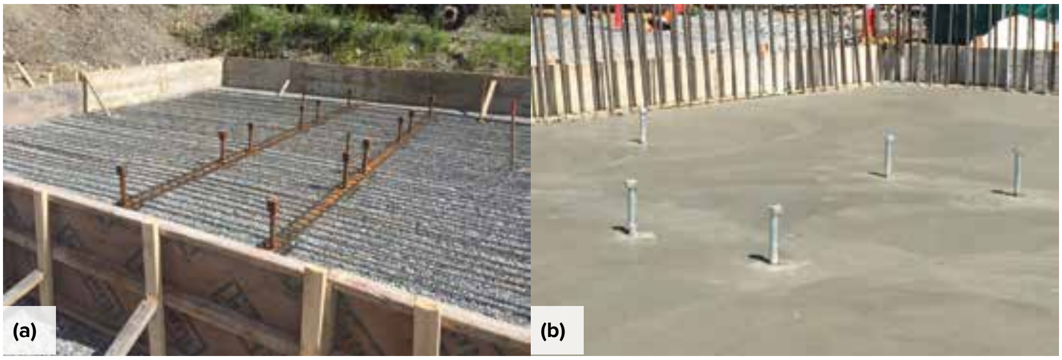

Fig. 4: Concrete modules were anchored to the base slab of the test tank using welded embedments: (a) embedments were placed on the prepared base prior to placement of the bottom mat of reinforcing; and (b) bolts were installed in the couplings prior to concrete placement

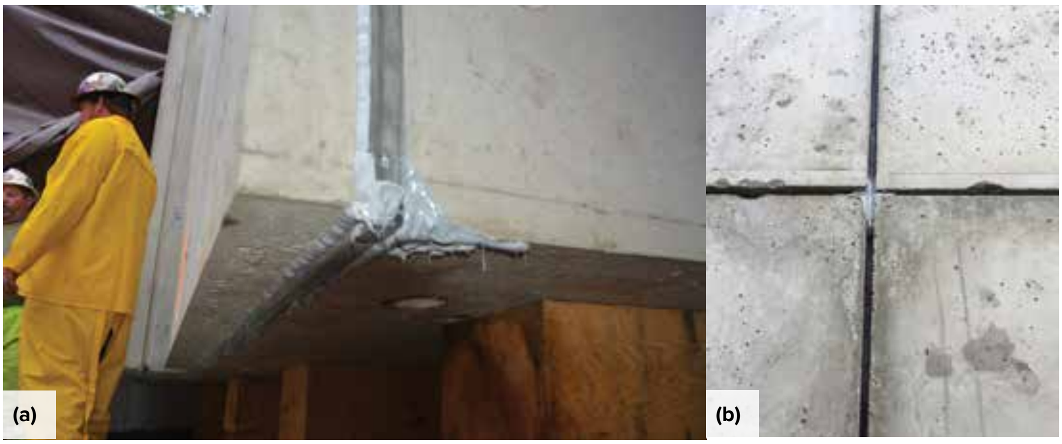

Fig. 5: Expansive waterstops were used to seal the joints between modules and between modules and the test tank base: (a) waterstops were installed in reveals in the modules immediately prior to assembly of the dam; and (b) as the modules were assembled, the waterstops were compressed against adjacent modules

Commercialization

The FDE modules are expected to have broad application, used in both overflow and nonoverflow structures, and for new construction and retrofit/rehabilitation markets. The reduced time to completion brings significant benefits to the dam construction industry, which historically has experienced cost overruns due to weather delays. The FDE prototype construction process and corresponding technical evaluation report demonstrate that this new method of construction can improve the economics and reduce risk for this industry. The technical evaluation report demonstrates a full-scale application of precast modular construction to replace more conventional construction for an actual U.S. dam site and shows the cost- and time-saving potential afforded by the technology.

Following the successful test, the FDE team is now engaging a variety of public and private sector clients to develop a first commercial project. The contacts list includes dam owners, water infrastructure operators, hydroelectric plant developers, and regulatory agencies responsible for dam safety. Several regulators have indicated willingness to include precast concrete as an alternative in project specifications and requests for proposals.

The French Dam patent portfolio covers precast concrete as applied to new dam construction and rehabilitation of existing impoundment structures, and the technology is currently available for licensing to engineering and construction firms and/or precast manufacturers.

Final Remarks

The construction of the French Dam prototype came less than 3 months after the release of the U.S. DOE Hydropower VISION report,[2] which recognized modular components as one of future hydropower technologies "essential to attaining the necessary outcomes of cost reduction, improved performance, and environmental stewardship."

Fig. 6: A downstream view of an abutment used to provide a seal between the tank wall (left) and sides of the precast modules (right)

According to the representatives of three companies that participated in the prototype project:

- "The French Dam will be a game changer for the hydro industry. It simply replaces traditional construction methods with off-site manufacturing and on-site installation, making the entire process just-in-time ready and weather independent." (Bill French Sr., Founder and President of FDE);
- "We believe the 'French Dam' has ultimate flexibility and includes a sophisticated and innovative approach, making it adaptable for almost every type of site conditions for construction of new and retrofit small to medium hydroelectric, water control systems and power houses in the United States." (Varoujan Hagopian, GEI Senior Consultant); and
- "Precast concrete can help to make any project more efficient. It is exciting to see its application as an innovative technology in the construction of hydro dams." (Bob Kramer, Vice President of Marketing and Product Development, Oldcastle Precast).

References

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2. "Hydropower Vision: A New Chapter for America's 1st Renewable Electricity Source," U.S. Department of Energy, Washington, DC, July 2016, 396 pp., http://energy.gov/sites/prod/files/2016/10/f33/Hydropower-Vision-10262016_0.pdf.

Selected for reader interest by the editors.

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