MEGA PROJECT

Raising the Bar on the 'Mighty Mon'

New techniques and carefully designed mixes facilitate dam replacement

By John Weisbarth and Carol Tasillo

With the Port of Pittsburgh looking to double its output over the next 50 years, maintaining and upgrading waterway transportation is vital. The structure known as "Locks and Dam 2," on the Monongahela River in Braddock, Pa., is one of nine navigation structures that provide year-round navigation for 19 million tons of freight between Pittsburgh and Fairmont, W.Va. The U.S. Army Corps of Engineers (USACE) is replacing three lock-and-dam structures with two significantly upgraded $750 million structures.

The landside Braddock lock is 720 feet long by 110 feet wide, with a riverside chamber 360 feet long and 56 feet wide. To allow for increased traffic and to accommodate modern vessels, the USACE is constructing a gated dam to be followed by lock improvements. USACE is applying innovative concrete technologies to the design, sequencing, and construction methods of this structure. This is the first time that "in-the-wet" construction technology has been used on an inland waterway by the USACE. The project required roughly 80,000 cubic yards of concrete and grout using 12 different mix designs.

The two massive dam crest segments were precast 27 miles downstream in Leetsdale, Pa., then floated to the dam site where they were set down and filled with concrete.

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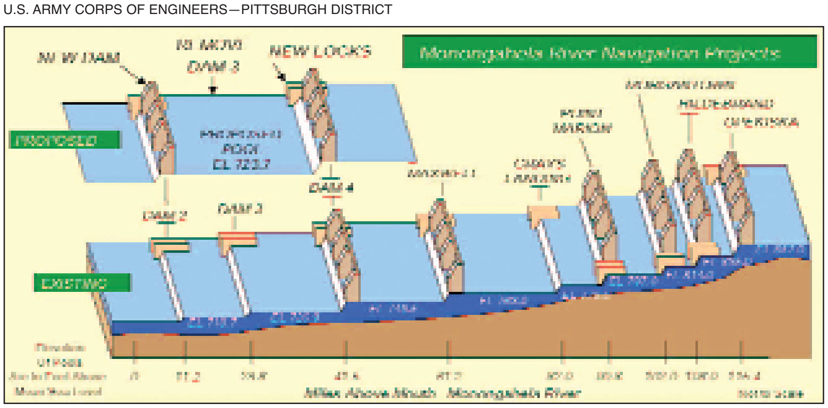

The $750 million Lower Monongahela River Navigation Project will replace the dam at Braddock and locks at Charleroi, raising the pool elevation enough to eliminate the 100-year-old Locks and Dam 3.

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Gate installation on the new Braddock Dam, where precast segments that were floated in, set down, and filled, form the lower third of the pier bases and overflow sections.

Float-in construction

Workers constructed the crest portion of the dam 27 miles down river from the final site in two large precast segments. Once complete, each segment was floated into place, then sunk onto preset pilings. Tremie concrete was used to fill the precast segments to a depth of 10 feet, and the remaining portion of the dam was cast in the dry while the dam bays were dewatered. Mechanical equipment, including the tainter gates, is now being installed and the dam should go into operation in 2004.

High performance concrete (HPC) is saving time and money compared with conventional cofferdam construction (see Table 1).

Unique construction features

Pre-excavation beneath the footprint of the dam ranged from 14 to 32 feet (about 400,000 cubic yards). Upstream and downstream steel sheet pile cutoff walls were constructed to act as retaining walls for work required before workers set the precast segments.

HPC was used in 78 drilled shafts, which act as pilings for the dam foundation, and 12 set-down shafts (6 for each precast segment). For the drilled shafts, permanent steel casing was driven to rock, with a 15-foot rock socket drilled past the tip of the casing. With the casing extending above the waterline, the overburden was removed, steel cage reinforcing set in place, and tremie concrete placed. Workers placed about 18 feet of concrete under water (using Mix #1), requiring the 4000-psi concrete to be a cohesive, uniform mix. Anti-washout and water-reducing admixtures helped to achieve fluid concrete without aggregate segregation.

A two-level casting basin 27 miles downstream of the dam site was used to prepare two large precast segments for the dam crest. Each concrete and steel hollow shell segment, roughly 100 feet long, 300 feet wide, and 42 feet high, weighs more than 10,000 tons. The segments were constructed individually in the dry. Precast wall panels were connected with cast-in-place concrete for closure pours. Exposed portions of the shell are constructed with conventional concrete; the internal walls and bottom slab are constructed with low-density concrete. Once each segment was constructed, the basin was flooded, the segment floated off the casting bed, the water level pumped down, the sheet pile closure to the river removed, and the segment extracted. It was then transported via tug upstream on a 14½-hour trip, through three locks to an outfitting dock.

Additional work at the outfitting site extended the pier height and installed the set-down systems. Then each segment was floated into

Table 1: Concrete mix designs used on the Braddock Dam

	Mix 1 Tremie Infill	Mix 2 In-the-dry Infill	Mix 9 Underbase Grout
w/cm ratio (by volume)	0.38	0.34	0.36
w/cm ratio (by weight)	0.43	0.39	0.47
Cement, Type II	116 lb/cy	191 lb/cy	150 lb/cy
Flyash, Class F	138 lb/cy	122 lb/cy	255 lb/cy
GGBFS, Grade 80	416 lb/cy	451 lb/cy	404 lb/cy
Silica fume (Eucon MSA slurry)	348 fl oz/cy	–	618 fl oz/cy
Water: Monongahela River	280 lb/cy	295 lb/cy	362 lb/cy
Limestone powder	187 lb/cy	52 lb/cy	194 lb/cy
Fine aggregate: natural sand	1308 lb/cy	1214 lb/cy	2257 lb/cy
Coarse aggregate: limestone #57	1455 lb/cy	1414 lb/cy	–
Admixtures:			
- Air entraining (AEA)	–	17 fl oz/cy	–
- WRA, Type A (Eucon WR)	21 fl oz/cy	23 fl oz/cy	25 fl oz/cy
- HRWR, Type F (Eucon 37)	76 fl oz/cy	91 fl oz/cy	59 fl oz/cy
- AWA (Eucon AWA)	48 fl oz/cy	–	118 fl oz/cy
Specified 90-day compressive strength	4000 psi	4000 psi	2000 psi
Slump flow (ASTM C143)	16-20 in.	16-20 in.	18-26 in.
Maximum bleed (ASTM C232)	1%	1%	1%
Maximum Washout Loss (CRD C61)	8%	–	8%

Mix designs courtesy of U.S. Army Corps of Engineers—Pittsburgh District position and sunk onto the set-down pilings. The segments were submerged 36 feet using a ballast system that flooded compartments.

The space between the piles and the precast segments was filled with prepackaged bulk bags of high-flow grout. The grout formed pin connections to lock the precast segments to the foundation piles. The bulk bags were mixed in trucks on a barge, and pumped through a grout line. Evacuation pipes allowed displaced water to be removed from the pin connection.

The upper pier portions of the dam were placed in-the-dry using conventional mass concrete. As a final step, the old dam will be demolished.

Infill concrete and grout

After set-down, the 1-foot void between the precast segment and the river bottom was filled with an underbase grout mix. The process consisted of attaching grout bags to the bottom of the segment, which were then filled after set-down to compartmentalize the area and seal out moving river water. This highly flowable mix included anti-washout and water-reducing admixtures to maintain the flowability and cohesiveness of the mix, and minimize the loss of fines. Workers used about 3000 cubic yards of grout for the underbase (see Table 1, Mix #9).

Once the grout bags were filled, each compartment was filled with grout, approximately 15,000 cubic yards of concrete required to fill the 175 compartments. The first 10 feet of hollow precast shell was filled underwater using an anti-washout tremie infill delivered through 10-inch tremie pipes with evacuation ports (see Table 1, Mix #1). The remaining portion (up to 28 feet) was dewatered and filled with a dry infill mix (see Table 1, Mix #2). Again, four cementitious materials were combined to control the heat of hydration. The underwater infill mix was also used to fill beneath the precast tail-race sections, a process that was completed in two lifts to minimize uplift pressure.

These three mixes provided flowable, self-leveling, washout-resistant concrete. For flowability, the mixes contained additional fines, including limestone powder and silica fume.

Concrete was provided by an on-site batch plant. Because active rail lines are located alongside the river, a conveyor system was used to move concrete 600 feet from the batch plant over the rail lines to a wet hopper on a riverside barge. From the barge, the three mixes were pumped 700 feet through a pump system to the dam segments and gravity fed through tremie pipes for placement. Although the mixes were conveyed and pumped a fair distance, the mixes remained flowable, uniform, and cohesive while surpassing the 90-day strength requirements.

The new structure is expected to be operational in early 2004. More information is available on the USACE Pittsburgh District's Web site, *http://www.lrp.usace.army.mil,* including several webcams. ■

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