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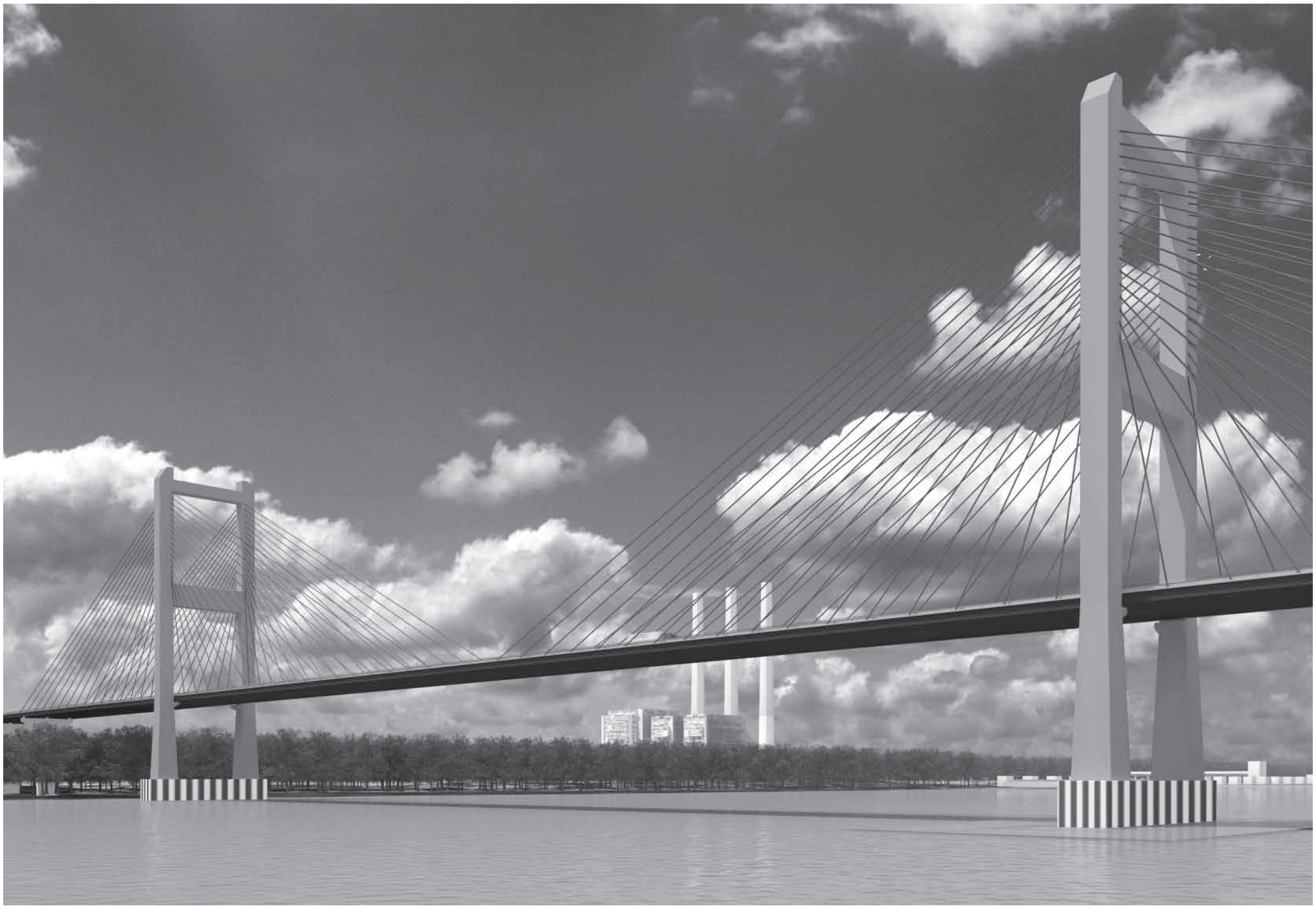

JOHN JAMES AUDUBON BRIDGE PROJECT
Completed Structure Rendering Courtesy of
Louisiana TIMED Managers and Parsons Brinkerhoff

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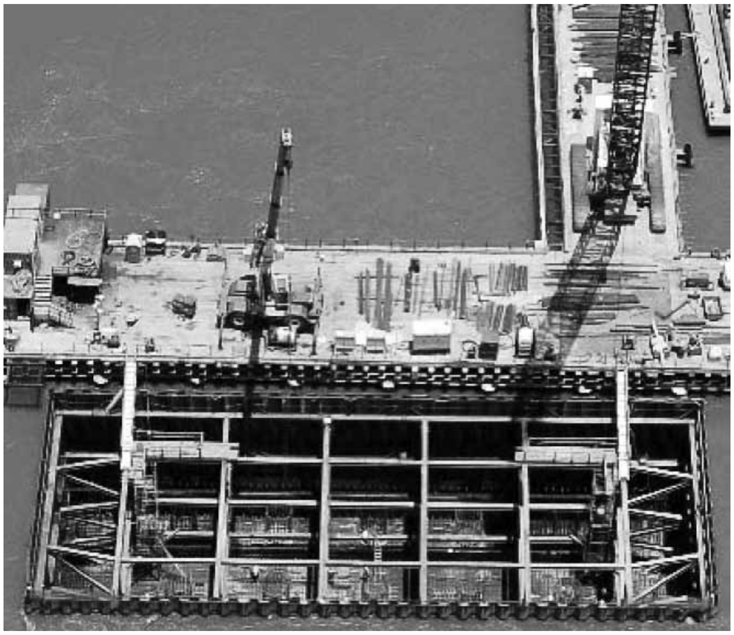
John James Audubon Bridge Project

Cofferdam Construction for the Main Span Pier Foundations

By Sereno Brown, PE, A M ASCE



East Cofferdam Upon Completion of Lowering 47 feet

Sereno Brown, PE, A M ASCE

Background:

The John James Audubon Bridge Project, in Pointe Coupee and West Feliciana parishes, is entering the third year of construction. Once completed, this historic project will serve as many firsts for the state of Louisiana. Some of the most notable include the delivery method, it is the first design-build project for the Louisiana DOTD; the record-breaking 1,583 foot main span length, which will be the longest cable stay span in the United States; and some of the construction methods selected to complete this landmark structure are unique to not only this state, but the heavy civil construction industry.

Project Overview:

The John James Audubon Bridge Project is a $407 million design-build project that will soon link the cities of New Roads on the West and St. Francisville on the East across the Mississippi River. The project is just one part of the larger TIMED Program funded by the $0.04 gasoline tax approved by voters in 1989. The Audubon Project is one of the 16 projects targeted by the $5.2 billion infrastructure funding program. The program is managed on behalf of the LaDOTD by Louisiana TIMED Managers, a Joint Venture of Parsons Brinkerhoff, the LPA Group, Inc and G.E.C., Inc. The design-build contractor for the project is Audubon Bridge Constructors a Joint Venture team of Flatiron Constructors, Inc. of Longmont, Co., Granite Construction Company of Watsonville, Ca., and Parsons Transportation Group, Inc of Washington, D.C. The project is scheduled to complete in the late fall of 2011.

This report will discuss in detail the method of construction utilized to complete the main foundation pier footings.

Foundation Facts:

Each of the two main span pylons were designed to be supported on twenty-one, eight foot (8') diameter drilled shafts. These shafts extended from elevation +5' down to -175' on the west bank pier and to -180' on the east bank pier. The shafts were constructed by means of an oscillator and airlift instead of the Kelly-bar, top down drill method. The shafts each feature a 1" wall steel casing as a scour protection measure along approximately the upper eighty feet (80') of the shaft.

The design called for a fifteen foot (15') thick distribution footing atop each of the twenty-one shafts. The foot print for this footing measures 160' x 64'. Above this, in the splash zone portion of the structure, a pedestal comprised of three foot thick outer walls, with six interior cells each with two foot thick interior walls is designed to support the base of the tower legs and protect against possible barge impact. The exterior of the pedestal and footing is designed

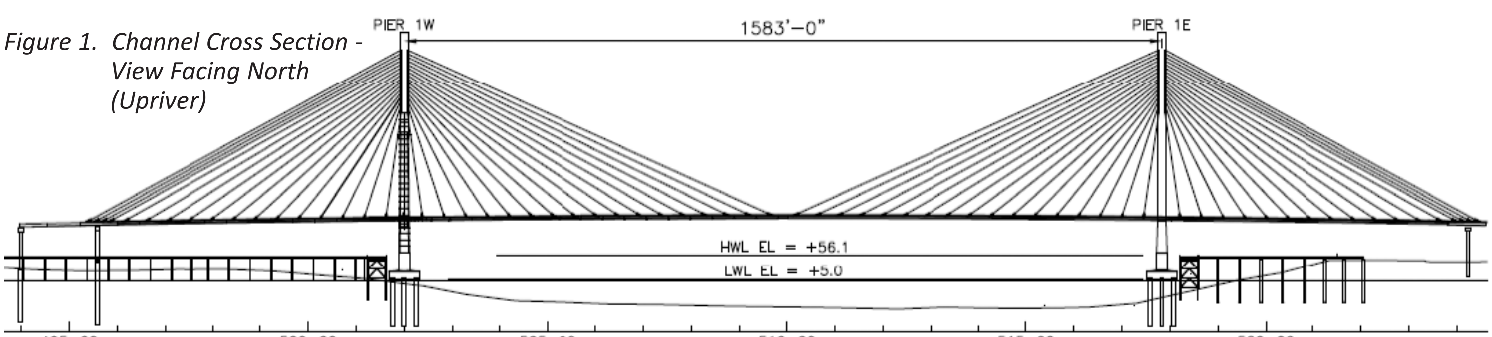


Figure 1. Channel Cross Section - View Facing North (Upriver)

to be clad with a polymer rub strip, the black and yellow feature atop the water in the rendering and as shown in Figures 4 & 5.

Special Challenges to the Design Build Team

The width of the river from top of the levee in Pointe Coupee to top of the bank on the West Feliciana side constituted a distance of nearly 3,300 feet. Acknowledging that the foundations for a conventional cable stayed bridge would not be able to sit outside the influence of the river; the main challenge was to place them as close to the bank and outside the navigational channel as possible. Given the extraordinary fluctuation of the river level in the course of the year and the duration it would take to construct the foundation the design-build team knew their plan would have to work around the high water season. Investigation into the soil properties at West bank revealed a loose silty material for a depth of forty feet (40'). The east bank profile, shown in FIGURE 1, meant a depth of water on the navigation side of the footing greater than eighty feet (80') in high water seasons.

With this information in hand the team concluded that a conventional sheet pile cofferdam would not be a cost effective solution to this problem, nor would it allow the Joint Venture the ability to meet the construction schedule. Instead the team looked toward the idea of a precast concrete cofferdam. Precast concrete cofferdams were successfully used by Flatiron on prior bridge projects which include the Sagadahoc Bridge in Maine and the Alfred Zampa suspension bridge in California.

A significant challenge posed by a precast concrete cofferdam is to design it such that it may be quickly erected with conventional cranes. A modular precast concrete cofferdam solution was developed to meet this challenge. The modular cofferdam allowed precast units to be cast on-site in small, manageable sizes that could be more easily transported and erected. The team developed this approach with the intent that all the pieces could be brought out to the piers and erected from a land based trestle. Once the shell is lowered into place, in order to provide a bond to the shafts and to seal the cofferdam, the team designed an eight foot (8') thick non-reinforced concrete seal slab below the bottom of the structural footing. The lower portions of the cofferdams were designed to act as the finished perimeter wall and soffit forms for the pier footing concrete. The precast concrete walls of the cofferdam were designed to be a permanent part of the footing, while the soffit and concrete seal were not. The plan called for the cofferdam shell (precast soffit and wall panels and structural steel bracing and sheet piling), to be assembled well above the top of the final footing elevation fully out of the water and above the influence of regular river stage fluctuation. Once assembled the cofferdam shell could then be lowered forty-seven feet (47') into the Mississippi River. Once lowered to the final elevation, the combination of an eight foot (8') thick seal slab and the structural steel wale/sheet pile follower act to create a solid, watertight box enabling the team to safely work at forty feet (40') below the top of the river for the construction of the footing and pedestal. The portion of the cofferdam above the finished footing elevation was constructed of temporary steel sheet piling. Upon completion of the footing construction and pedestal and once the level of the river permits, the steel sheet pile walls may be removed.

Design of the precast panels and cofferdam was undertaken by Flatiron Constructors, Inc, the lead partner on the design build project. The design-build team worked closely with the main span foundation structural design team, headed by Parsons Transportation Group, Inc, to integrate the cofferdam plan into the final structure.

The structural design of the cofferdams included many load cases, with the limits being high water at elevation +50, to prevent over-

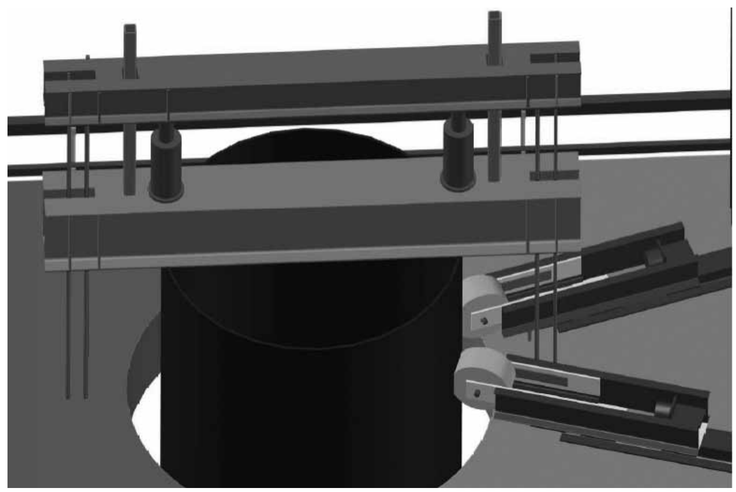


Figure 2. Typical Guide Roller Arrangement

Figure 3. East Pier, Soffit Panels Erected.

topping during high water, and low water at elevation +10. These water level extremes were controlling parameters for a design which considered the stage of construction, stage of dewatering, and river current velocity. Another design challenge was to design a lateral bracing system to resist river current forces during the lowering stage and seal concrete placement. This was accomplished using expendable guide rollers mounted atop the soffit precast panels. These guide rollers could then bear against the face of the vertical drilled shaft caisson extensions as the structure was lowered. A total of six of the shafts were chosen to guide the lowering of the cofferdam by means of the expendable rollers. The rollers were further outfitted with hydraulic jacks to allow remote extension or retraction of the rollers to accommodate any misalignment of the drilled shafts. See FIGURE 2 for a rendering of the guide rollers against a typical shaft.

Sequence of Cofferdam Construction:

The precast elements (soffits and walls) were cast on-site during the drilled shaft construction, off the critical path. Once the drilled shafts were completed, temporary steel casing extensions were spliced to each of the twenty-one shafts in each footing. The shaft extensions brought the top of the casings up to elevation +50'. The precast soffits were then outfitted with temporary support hangers and transported out to the land based access trestles out to the main pier foundations. FIGURE 3 shows placement of the first panel on the temporary hangers. Subsequent panels were placed alongside and adjusted to create a level work surface at elevation +44', and then cross panel bracing was attached via weldment cast into the tops of the slabs.

Following the soffit installation the jacking system and the lower level of structural steel bracing was installed. This was immediately followed by the installation of the precast wall panels, as shown in FIGURE 4. Once the precast was erected and secured the upper structural steel framing and sheet pile follower were installed. FIGURE 5 shows the dam just prior to completion of sheet pile follower.

Figure 4. East Pier, Structural Bracing and Precast Walls Installed

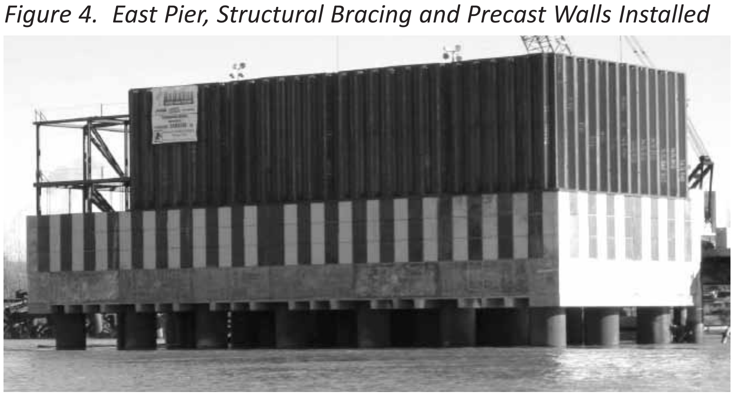


Figure 5. East Pier, Upper Structural Bracing and Sheet Pile Follower Installed

Lowering Design Overview

Support of the cofferdam during initial assembly and final lowering was achieved by means of forty-eight (48) separate 1-3/4" diameter, 150ksi threaded rods, accompanied by 48 redundant auxiliary rods positioned directly adjacent each primary load carrying rod. The team developed a jacking arrangement (see FIGURE 6) whereby these rods, connected to the precast soffit panels and extending up to beams supported on extensions of the drilled shaft steel casings, could be raised or lowered by means of hydraulic jacks atop the steel casing extensions. The jacking system was designed such that the jacks necessary to raise or lower the system were sandwiched between a set of beams. These beams, termed (lower) hanger beam and the (upper) jacking beam are illustrated in FIGURE 7.

To operate the system a portioned amount of hydraulic fluid was sent to the field necessary to raise all the different size jacks an equal displacement. Nuts positioned atop the upper jacking beam were set such that the load would be freely supported by these upper beams when the nuts on the lower hanger beam "lifted off". Once the lower nuts were free they were adjusted up by a set safe clearance and the jacking system would slowly retract the field jacks. The field jacks were all standard double-acting Power Team hydraulic jacks, each with a maximum stroke of 13". For our design, only 11" of stroke was utilized, thus in order to achieve the full

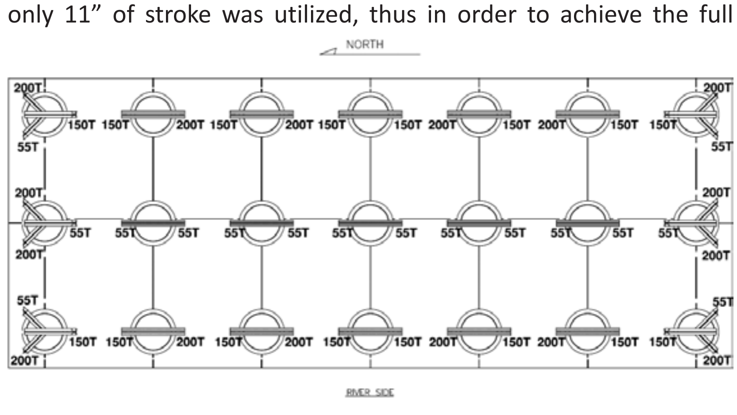


Figure 6. Plan View, Typical Pier Jack Layout

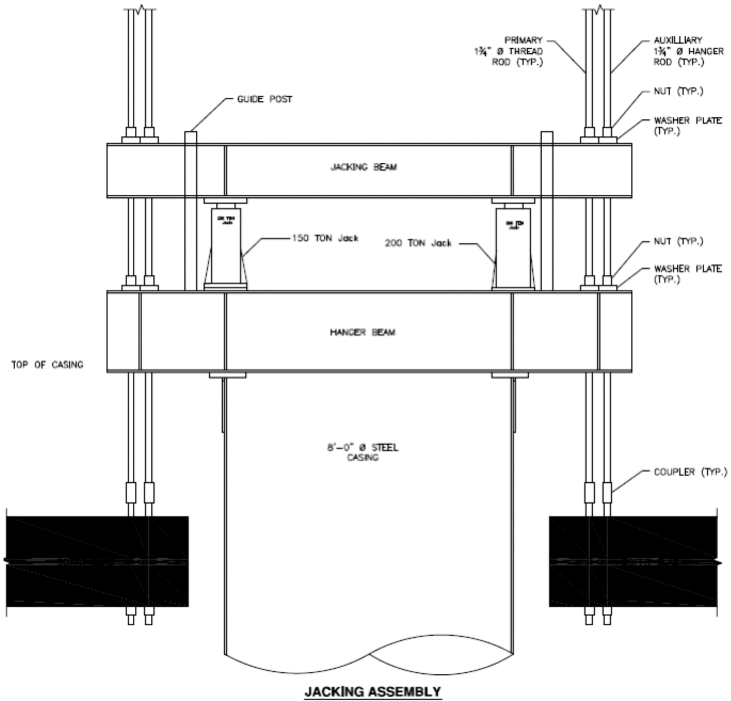


Figure 7. Typical Cofferdam Support Detail

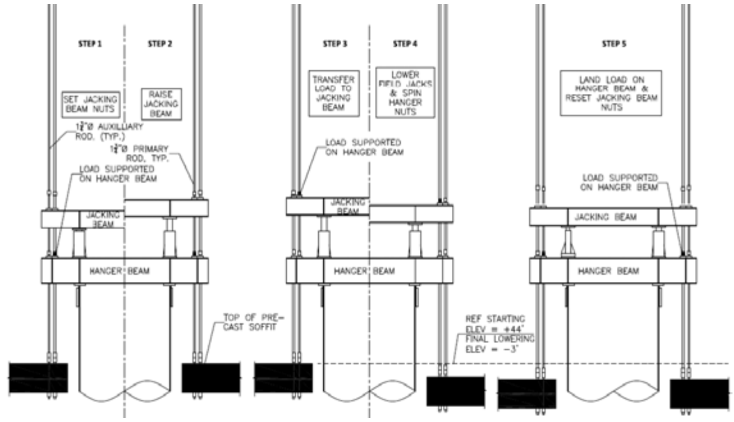


Figure 8. Jacking Operation Illustration

forty-seven feet (47') of lowering required it would take no less than 52 cycles. In order to re-stroke the field jacks the load would be set down on the hanger beams, the nuts atop the jacking beam would be raised up and the field jacks re-extended to pick-up the load and repeat the lowering process. [Reference FIGURE 8]

Safety was a paramount concern throughout the planning of this operation. Specific concerns over how to best mitigate exposure due to a sudden field jack failure or failure of a rod above the hanger beam were chief among these concerns. It was agreed by all parties within the design-build team to make sure that in the event of a sudden change in the support condition that the cofferdam would not be permitted to fall or experience a significant sudden load shift. It was decided that to best guard against this exposure that the lower "hanger" nuts should be kept minimally above their respective washer plates. This required the nuts had to be continuously adjusted up as the load was lowered. Manipulation of the nuts for the 1-3/4" diameter rods would have to be done from inside the cofferdam since the steel frame that braced the steel follower sheeting had to be in place before lowering. Due to access concerns and the importance of not letting a nut accidentally "bottom out" by contacting the lower hanger beam plate washer, it was further agreed that the best option was to staff a dedicated worker at each of the twenty-one shafts. Not surprisingly, these employees came to be known as "Nut Spinners". [FIGURE 9] In order to improve communication and provided continuity of coverage

Figure 9. "Nut Spinner" at Work

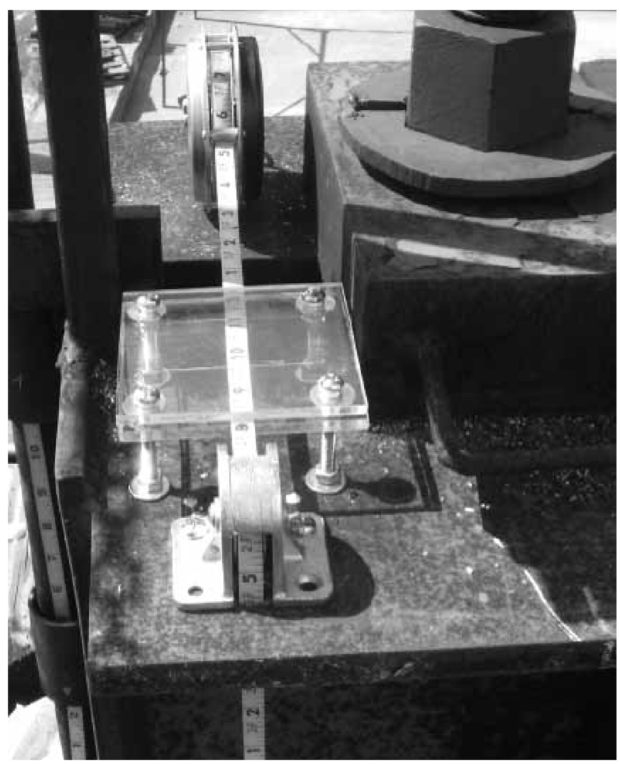


Figure 10. Lowering Measurement Verification System

through the process of lowering across the near quarter acre cofferdam, the twenty-one shafts were broken down into seven, three shaft "zones". Each of these seven zones was manned by supervisors who could double check the progress of the nut spinners, and relieve a nut spinner for periodic breaks as needed.

In order to track the progress of the distance lowered, each shaft was outfitted with a logger tape fastened to the soffit panel and to the hanger beam. The nut spinner at each shaft would record readings periodically through the course of the lowering to double check the lowering and assure there were no global rotations, i.e. one side of the dam progressing down faster than any other area. See FIGURE 10 for a typical tape layout configuration. The tapes were affixed to the beam and from the tape spool passed through a pair of sandwiched plexi-glass plates marked with two indexes. The distance between the indexes was held constant and this created a check on the individual measurements to help guard against any misreading of the tape. As an additional check, digital inclinometers were placed on the soffit panels. These inclinometers gave continuous readings of the attitude of the panel throughout the lowering process. These measurements and the inclinometer data were evaluated along with the loads to confirm the cofferdam lowering was proceeding within the design specified 1/8" tolerance for synchronous movement.

Although the lowering of the cofferdam was mundane and slow, it was anticipated a reliable and steady operation of precise setting of these nuts would prove to be a challenge. To overcome this, a mock up was prepared to train staff on the protocol and diligent setting and manipulation of the nuts, see FIGURE 11. The mock-up was constructed as a four shaft arrangement complete with the actual jacks, hanger beams and pre-cast soffit panels to be used in the actual lowering. The mock-up provided not only a valuable training station, but also served to trouble shoot the system and to refine the process in advance of executing the work.

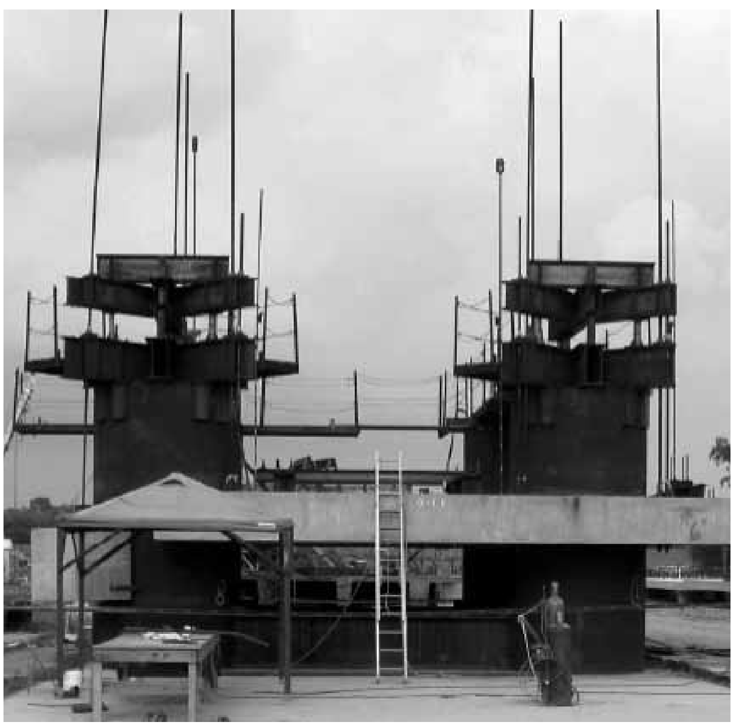


Figure 11. Lowering Training Mock-Up

Due to the size and complexity of the hydraulic operation station we determined it best to locate it outside the cofferdam. This posed an additional challenge in how to best communicate readiness between the team inside the cofferdam to the hydraulic operator outside. In answer to this the team developed a regimen of commands and responses specific for each member of the lowering team. These commands and controls were practiced on the mock-up first to ensure that all team members had a thorough understanding of the protocol and were again reviewed with the crew each day at the start of shift.

<u>Selection of the lowering system and its operation</u>

Through the design process it was determined that the use of hydraulic jacks would be the simplest means of lowering the cofferdam. The specifications developed by the design-build team for this lowering system were, in order of precedence:

1. capacity to lower 5,000Tons with synchronous movement 47' into the river;
2. provide internal safeguards to limit exposure of work force within dam to sudden loss of load;
3. synchronous movement within 1/8" tolerance at any jack;
4. allow real-time individual readouts of jack pressures (loads) at each of the 48 supports*;
5. allow immediate individual jack adjustments to correct for loading/geometry changes;

**Though we were concerned with the actual loads it was only in order that we could compare them against model assumptions. Foremost, the lowering was to be governed by uniform displacement. If the loads varied somewhat from the loads assumed in the structural model, so long as they were within a specified range and the structure was lowered in a level and uniform manner then the loads were secondary to the condition of the lowering.*

The Design-Build team selected Richard Dudgeon, Inc. of Bridgeport, CT to provide the final hydraulic jacking design and furnish the equipment for the lowering. The design provided by Dudgeon worked as a closed hydraulic system. This system consisted of 48 jacks in the field, each directly linked to one of 48 subsidiary jacks located back at the jacking station. The field jacks ranged in capacity based on the load distribution provided by the Design-Build team's model. The jack sizes used in the dam were standard 200Ton, 150Ton and 55Ton jacks. Each jack was independently plumbed to a corresponding smaller, Dudgeon custom fabricated subsidiary jack. For example, the inlet line from a 200Ton field jack was connected directly to the inlet line of a custom 24Ton subsidiary jack. The ratio of the field jack ram area to the subsidiary jack ram area was 0.117. This ratio was maintained throughout the system. Thus, the system was able to produce synchronous movement whereby a set displacement by the subsidiary jack resulted in a unit hydraulic fluid displacement that in turn produced a global, uniform movement of the many different sized field jacks. The design team specified that uniform displacement should serve as the governing criteria, and that loads should be monitored only to determine that no radical load swings were apparent. The system provided by Dudgeon incorporated a digital pressure transducer into each of the field jack lines to allow for real time load verification and monitoring. Load measurement software was provided by Optimation Technologies, Inc. of Rush, N.Y. to record data throughout the lowering in 5 second increments. The data collection station was set-up on-site next to the operator of the jacking system so that any issues arising in the field, detected by the data collection system could be quickly conveyed to the operator and adjustments made accordingly.

The subsidiary jacks were locked into a reaction frame. This frame consisted of a number of "Subsidiary" jacks on one side of a reaction plate and a large 400Ton jack, referred to as the "Primary" jack, on the opposite side. The four load frames are shown in front of the hydraulic operation station in FIGURE 12. This arrangement of one set of jacks directly acting against a single opposing jack allowed that when hydraulic fluid was bled from the main jack back to tank, the main cylinder retracted thus allowing extension of the subsidiary jacks. These, in turn, allowed the field jack cylinders to retract in a synchronous fashion to lower the cofferdam.

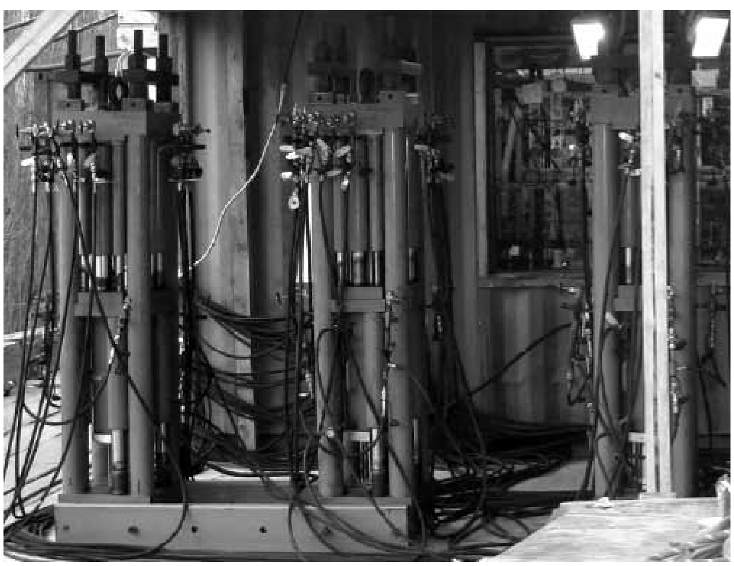


Figure 12. Synchronous Jacking Reaction Frames

Timeline of the work

The design-build team is proud to report that the cofferdam construction was a great success. Construction of the cofferdams commenced with the erection of precast panels in November of 2008 and concluded with the dewatering upon placement of the final 3,000 cubic yard concrete seal slab placement in May of 2009.

Project status

The project is currently well into the construction of the superstructure towers. The towers are nearing the half-way point in construction and once complete each tower will extend up to elevation +520'. Deck construction activities are scheduled to commence in April of this year and extend through to the end of the year. The approach structures leading up to the main span project are near 80% complete, and the roadway and paving are also 40% complete. Progress at the project can be seen at our website www.flatironcorp.oxblue.com/jjab where you can view archive images from the lowering and see real time updates from the project web camera.

Sereno Brown, PE, A M ASCE is the construction team's Project Engineer for the Audubon Bridge Project. An employee of Flatiron Constructors, Inc. for the past 12 years he has been involved with the construction of several notable projects, including the San-Francisco Oakland Bay Bridge "Skyway" Project, Oakland, CA; the Carolina Bays Parkway Design-Build Project, SC; and the Sagadahoc Bridge Design-Build Project, ME. Mr. Brown earned a BSCE from the University of Maine, Orono and is a licensed Professional Engineer in Louisiana.

Norman Kirk, PE, M ASCE – retired Flatiron Constructors, Inc employee, was engineer of record for the design of the cofferdam. Mr. Kirk was has been involved with the design and construction of marine structures which include the precast cofferdams at the Sagadahoc Bridge over the Kennebec River in Maine and the Alfred Zampa bridge over the Carquinez Straits in Calif. Mr. Kirk earned a BSCE at Newark College of Engineering, Newark, NJ and is a licensed Professional Engineer in Colorado, and a licensed Structural Engineer in Massachusetts.

Renato Ravazzolo, PE, M ASCE is a Senior Engineer for Flatiron Constructors, Inc in Lafayette, CO. Mr. Ravazzolo was responsible for the design and modeling of much of the suspended cofferdam structure. As a leading member of Flatiron's in-house design department for the past 12 years, Mr. Ravazzolo has been involved in numerous projects from estimating phases with conceptual design through execution. Mr. Ravazzolo earned a BSCE at the ITR College of Engineering, Rapperswil, Switzerland and is a licensed Professional Engineer in Colorado, Virginia, Maryland and Florida.

The author wishes to thank the contributions of Mark Curtiss, Superintendent and hydraulics expert with Flatiron Constructors, Inc for his review and consultation on the specifics of the hydraulic system described in this report.