Lock and Dam No. 26 R, Lock Cofferdam, Construction Sequencing

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SYNOPSIS: Construction of a new lock and dam to replace existing Locks and Dam No. 26 required construction to be accomplished in three separate stages. Each portion of the new structure would be constructed inside cellular cofferdams. The construction of each cofferdam would require model tests to determine compatibility with design flow requirements relative to constructabiity of coffercells, scour of riverbed material, and navigation of river vessels.

Compatibility of the lock cofferdam geometry was verified using model studies along with sequence for construction of the cofferdam cells. Construction of the second stage cofferdam was successfully completed in December 1985, followed by dewatering and construction of the 1,200 foot lock structure.

INTRODUCTION

Lock and Dam No. 26, Mississippi River Mile 202.9, Alton, Illinois, is part of the inland waterway system on the Upper Mississippi River, comprised of a series of 28 dams and 34 locks. The Upper Mississippi inland waterway system provides for a channel of 9-foot depth and adequate width between the mouth of the Missouri River and Minneapolis, Minnesota, a distance of about 663 miles. The 28 dams in the system are spaced at irregular intervals varying from 9.6 to 46.3 miles, the average length of pools being 25 miles. The sizes of 34 locks vary in width from 56 to 110 feet and in length from 320 to 1,200 feet, the majority being 110 by 660 feet.

The twin locks at Lock and Dam No. 26, which were opened to traffic in 1938, consists of a 110 by 600-foot main lock and a 110 by 360-foot auxiliary lock located adjacent to the Illinois bank. A gated dam, extending from the locks to the Missouri bank, provides a slack water pool on the Mississippi River to Lock and Dam 25, Mile 241.4, and on the Illinois River to LaGrange Lock and Dam, Mile 80.2.

PROJECT DESCRIPTION

The existing facility was designed and constructed during the transition period when packet-type sternwheelers were being phased out and barge-type tows were just beginning to be used on a large scale. During planning and design of the locks, it was believed that these locks would be capable of meeting the requirements of river transportation until 1988.

Since construction of the project, river traffic has increased beyond expectations due to improvements in the inland waterways system, increase in size and power of barge-tows, and the lower cost of water transportation. These locks pass traffic from and to ports on the Gulf of Mexico, the Great Lakes, the upper Mississippi, the Illinois, the Ohio, the lower Mississippi, and the other tributary systems. River traffic at Locks No. 26 has increased beyond expectation since 1938. Presently, the locks at Alton, Illinois, are considered the "bottleneck" for traffic to and from the Upper Mississippi River and its tributaries.

The practical capacity of the existing locks is limited by many factors such as size of lock chambers, lack of up-to-date operating equipment, poor alinement of the approaches, and severe outdraft. The locks reached their practical capacity of 41,500,000 tons per year in 1968, just 30 years after completion of the project. Subsequently, as the volume of traffic has increased over the practical capacity, tows have experienced progressively longer delay times at the locks. The insufficient capacity of the existing facility has created a significant hindrance to navigation.

Several solutions were investigated to provide adequate facilities for existing and anticipated navigation. Traffic projections of all significant commodity groups were made to determine the required capacity of a 50-year economic life of the improvements. Based on capacity analysis, it was concluded that construction of a 1,200-foot and a 600-foot lock would provide the required facilities. Construction of the new facilities would take place at a site two miles downstream of the existing structure.

GENERAL SITE CONDITIONS

Area Topography

The site of the proposed locks and dam is located approximately five miles upstream from the confluence of the Missouri and Mississippi Rivers, at the northern extension of the alluvial valley known as the American and Columbia Bottoms. The area topography is characterized by the broad alluvial valley of these rivers and the wide, flat plains of the uplands. Maximum local relief approximates 200 feet. The floodplain on the Missouri side is a flat, featureless surface used primarily for agriculture and is some five to six miles wide. The Illinois floodplain, on the east bank of the river, is relatively narrow at the site and upstream, while downstream of the site it becomes wider. Along the river channel, the floodplain ranges in average from Elevation 415 in the vicinity of Alton, Illinois to about Elevation 405 near Dupo, Illinois. Although the floodplain relief is low, frequent changes in the course of the Mississippi River during geologic time have produced a complex variety of landforms and channel deposits. South of the site, crescent-shaped (i.e., oxbow) lakes, curved ridges, and swamps mark the location of former meanders abandoned during the process of the Mississippi River channel migration. Also downstream, alluvial fans, which stand 30 to 50 feet higher than the valley bottom, have been developed below the bluffs where tributary streams have entered the main valley.

Subsurface Materials and Conditions

An extensive investigative program was undertaken by the Corps of Engineers, (St. Louis District) consisting of more than 250 land and overwater borings, geophysical surveys, mineralogical studies, and numerous field and laboratory physical tests, to establish the subsurface materials and conditions at the site of the proposed facility. Other studies, including literature searches of geologic and seismic considerations, were also undertaken to provide general information and aid in establishing the type and properties of the subsurface materials and in predicting the service life conditions at the site.

Cofferdam Development

The selection of the cofferdam plan was based on results from physical model studies of navigation conditions, velocities, and scour patterns; historical hydraulic data; theoretical computations of velocities; the results of foundation exploration program; pumping tests to estimate foundation permeabilities; effects of construction sequence on navigation and project completion; and economic considerations.

CONSTRUCTION SEQUENCE

Project Construction Sequence

A three-stage construction sequencing was planned for the locks and dam. The first stage consisted of construction of six ½ gate bays of the main portion of the dam. The second stage is the construction of the river lock and two-½ gate bays of the main portion of the dam. The third stage will be the construction of the remaining portions of the two gate bays and the auxiliary lock. Each stage incorporates the use of a cofferdam to provide the necessary accessibility and protection during construction.

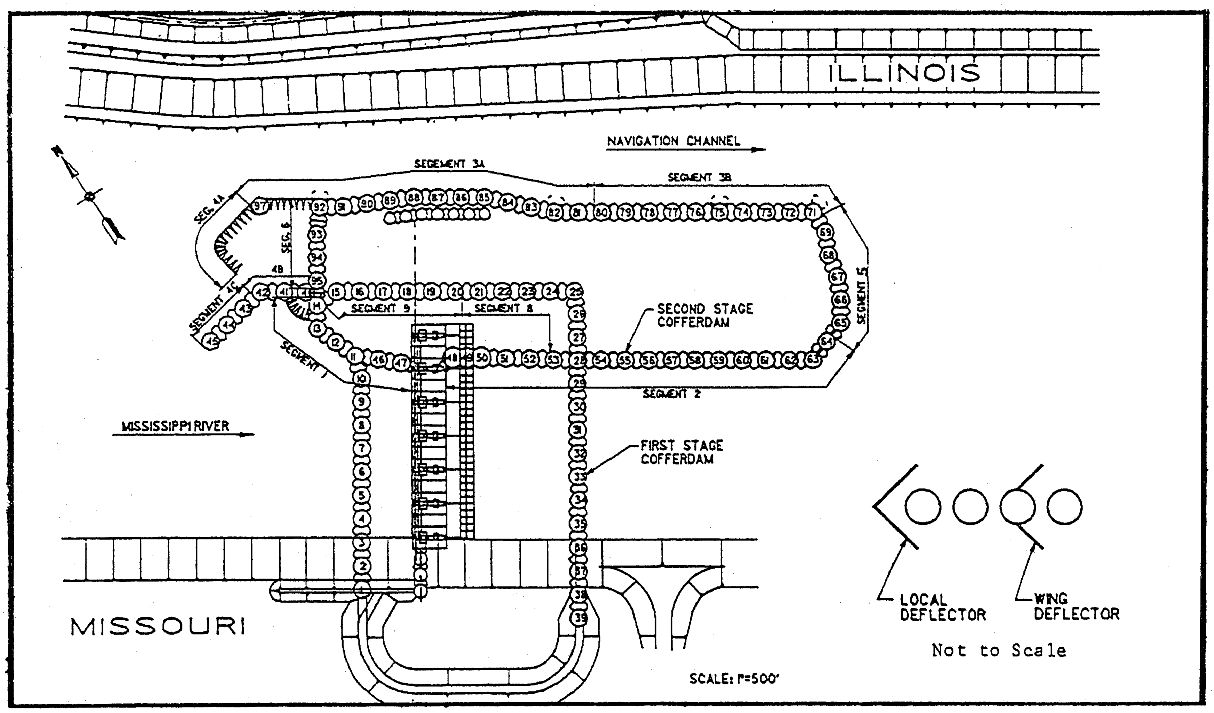

Fig. 1. Plan for Second Stage Cofferdam

The sequence of construction is considered to be the optimum in order to put the first lock in operation at the earliest date and still permit year-round navigation. The channel width provided during the first stage was 620 feet from the cofferdam to the toe of the Illinois bank. During second stage construction, the channel width is reduced to approximately 330 feet. However, during this stage, five gate bays constructed during the first stage will be available for passage of flow.

During third stage cofferdam construction, the tows will lock through the completed 1,200-foot river lock with the completed portion of the dam operable. Model tests have shown that the proposed cofferdams as sequenced provided optimum combinations of low velocities, minimum scour, and favorable navigation conditions.

The plan for the second stage cofferdam is illustrated in Figure 1. The Missouri leg of the cofferdam was constructed as part of the first stage dam contract. The Illinois leg was located at the center of the two dam gatebays on the Illinois side of the lock. This position provided minimal thorough sufficient work space within the cofferdam while providing the widest possible navigation channel between the cofferdam and the Illinois shore. The upstream and downstream closure walls of the cofferdam are located just beyond the ends of the lock guardwall monoliths.

The cofferdam deflector serves to divert the river currents in the navigation channel away from the Illinois leg of the second stage cofferdam, thus keeping the scoured area away from the upstream Illinois leg of the cofferdam. The deflector also served to provide partial closure of the river channel to aid in construction of the upstream arm of the cofferdam.

ORIGINAL CONSTRUCTION SEQUENCE

The second stage cofferdam has been divided into segments for ease of discussion purposes (see Figure 1). Segment 1 was part of the existing first stage cofferdam. Segment 2 was built under the First Stage Dam Contract. Therefore, the Second Stage Lock Contractor was responsible for construction of segments 3A, 3B, 4A, 5 and 6, and removal of segments 8, 9, 4C and 4B of the first stage cofferdam.

The original concept was that no construction could begin in the river channel until the First Stage Dam Contractor removed cells nos. 1 through 10 and nos. 29 through 39. Removal of these cells would allow passage of flow through the five, 110-foot wide gatebays previously built, thus reducing velocities in the navigation channel.

The construction sequence of the second stage cofferdam was of primary concern. A physical movable bed model located at the Waterways Experiment Station (WES) was used to examine the possibility of beginning any work in the navigation channel before passage of flow through the five gatebays. The model indicated that velocities just downstream of cell No. 25 were low enough to allow cell construction of segment 3B before passage of flow through the recently completed dam. Model velocities in the range of 4 to 6 feet per second were used as a limiting criteria for initiating cell construction activities. Velocities in this range would allow construction of a temporary flow deflector which would provide protection for cell construction. The temporary deflectors will be discussed later.

The next planned activity of the original sequence was the construction of the upstream deflector (segment 4A, cell No. 97, and the portion of the deflector between cells No. 97 and 92). This would begin immediately after flow through the five gatebays was achieved. Under this plan, there was a gap of approximately 2,000 feet between cell No. 92 and segment 3B. When a model tow boat was operated under this condition, regardless of flow conditions, there was a very definite draw into the gap. Figure 2 shows this condition. The draw was caused by flow coming around the upstream deflector and trying to expand back through the gap. This condition was considered a potentially dangerous situation, both to tows and to construction workers. Consequently, a new construction sequence was developed.

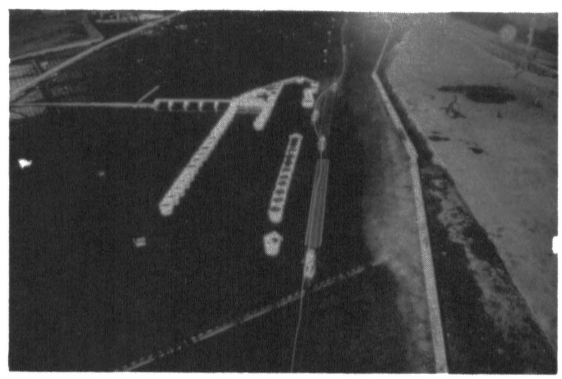

Fig. 2. Navigation Response for Original Construction Sequence

REVISED CONSTRUCTION SEQUENCE

The revised sequence consisted of constructing segments 3A and 3B of the second stage cofferdam prior to construction of the upstream deflector (segment 4A). The model indicated no adverse problems with navigation or scour. Figure 3 shows the model tow headed upstream with segments 3A and 3B complete. Under all flow conditions tested, no problems were identified.

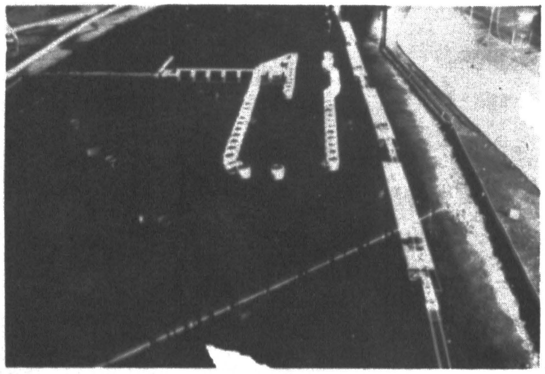

Fig. 3. Navigation Response to Revised Construction Sequence

After the completion of segments 3A and 3B, the remainder of the cofferdam could be completed. The major problem was that a partial river closure would be required in one of three segments. These three segments are segments 5, 6, and 4A (see Figure 1).

Since segments 3A and 3B effectively narrow the navigation channel to approximately 320 feet, segment 5 had to be closed last to provide access to the remaining segments. This would prevent contractor interference with commerical river traffic.

Segment 4A (the upstream deflector) and segment 6 remained as possibilities for partial closure. Originally, the upstream deflector design was to have a continuous flow cutoff to cell No. 42. As Figure 1 depicts, there is a fifty-foot gap between cell No. 42 and the deflector. During model tests to determine the best sequence of construction of the upstream deflector, it was found that velocities would be reduced enough in the area of segment 6 for cell construction if all but fifty feet of the upstream deflector were built. Furthermore, it was determined that the best sequence of constructing segment 6 would be to build cell No. 93, then cell No. 94, followed by cell No. 95 and finally the connecting arcs, starting with the arc between cells Nos. 93 and 92 and continuing on across with the other two arcs. This sequence minimized velocities such that under any flow condition tested, velocities were well within the accepted range for cell construction (4 to 6 feet per second). Therefore, the partial closure was made with segment 6 and the difficulties encountered when trying to close off part of the river were greatly reduced.

MODEL TESTS OF DEFLECTORS

Two other items tested with the model were the local flow deflectors (Figures 1 and 4) and the angle of deflection of the upstream deflector.

Different lengths of the legs of the local flow deflectors were tested to determine their impact on navigation and local scour. The local deflectors have two legs, separated by a 90° angle (see Figure 1). Forty-, sixty-, and eighty-foot legs were tested. The forty-foot legs did not provide sufficient protection to the cell foundation from scour, and the eighty-foot legs produced currents which affected passing navigation. Therefore, a local deflector with sixty-foot legs was decided as best for the given conditions. The sixty-foot legs were long enough to keep the scour away from the cell and thus maintain its stability, and did not affect navigation. The sixty-foot legs provided sufficient protection for three cells immediately downstream. Wing deflectors were then utilized on each side of the third completed cell to provide protection for constructing three more cells. The model revealed that the wing deflectors would be long enough to provide protection similar to the local deflectors (see Figure 1).

Various deflector angles were tested for the upstream deflector. Angles tested ranged from 15° to 60° angled to the direction of the flow. Little differences in results was indicated. The flow separated approximately 500 feet upstream, independent of deflector angles. Therefore, since an angle of 45° to the direction of the flow was used during the first stage without any major problems, it was decided to continue using the same angle.

<u>Prototype Construction</u>

The first local deflector (Fig. 4) was constructed in February of 1985. It was constructed immediately upstream of the location for cell No. 80 (see Figure 2). The construction was accomplished prior to flow through the completed portion of the dam, verifying the model results. Immediately after construction, the river stages began increasing and completely inundated the deflector. In addition, ice began moving down river, subjecting the deflector to ice loads. Normal construction activities did not resume until April 1985, when the template for cell No. 80 was placed. No damage had occurred to the temporary deflector, and the scour patterns which developed correlated well with the model results.

Fig. 4 Local Deflector for Cell Construction

Construction continued throughout the summer of 1985. The sequence of construction followed the specified sequence developed with the aid of the model. By September 1985, the Illinois leg (segments 3A and 3B) and the upsstream deflector (segment 4A) had been completed (see Fig. 5. Visual observations, discussion with towboat pilots, and velocity and flow measurements all indicated very close correlation with the results obtained in the model. The cofferdam was completed in December 1985. During the construction, navigation interference was not a significant factor, and any problems associated with river scour were kept to a minimum. The construction sequence and flow deflectors developed in the model had functioned as designed.

Fig. 5. Illinois Leg and Deflector

CONCLUSIONS

Between April and December of 1985, thirty-one cofferdam cells, the associated arcs between cells, and the upstream flow deflector were constructed in the middle of one of the biggest and busiest rivers in the world. The model tests to develop the construction sequence had lasted well over four years. Much thought and effort went into developing the sequence due to the difficult conditions which would be encountered.

The second stage cofferdam will remain in place until January 1989. Thus far, the cofferdam has functioned as designed. A major flood in October 1986 occurred which required the cofferdam to be completely flooded in anticipation of overtopping. Through all this, actual conditions have reflected those which the model predicted. The model proved to be a very valuable design aid, and has proven its value by the best possible method, prototype performance.