Inner Harbor Navigational Canal Lock Replacement- Shallow Draft GRR

Annex 5: Sector Gate versus Miter Gate Analysis

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1.0 BACKGROUND

1.1 General

The original study, dated March 1997, investigated the feasibility of replacing the existing IHNC Lock with either a 110 foot wide barge lock with a sill elevation (-) 22.0 feet NGVD and a 900 foot usable chamber length or a 110 foot wide ship lock with a sill elevation (-) 40.0 feet NGVD (gate sill at El. –36.0) and a 1200 foot usable chamber length. Both options utilized a conventional miter-gated structure, with two sets of gates (one set having an upstream pair of gates and a downstream pair of gates): one set of direct head gates and one set of reverse head gates. Subsequent to the original study, CEMVN-OD requested the investigation of a sector gate alternative for the 110-foot by 1200-foot ship lock, which is the primary focus of this Annex. The sector gate can operate under a reverse head; therefore, the reverse head gates were eliminated. Furthermore, CEMVN-OD prefers the durability of the sector gate over the slender miter gates.

1.2 Physical Model Study

On 11 April 1997, the Headquarters, U.S. Army Corps of Engineers, at the request of U.S. Army Engineer District, New Orleans (MVN), approved a physical model study of the 110-foot by 1200-foot ship lock, to be performed by ERDC. The main objectives of this study were:

1. To determine the filling and emptying times for various valve speeds for lifts up to 19.6 feet.
2. To determine hawser forces on barges and a ship in the chamber for varying operating conditions.
3. To determine intake and outlet performance.
4. To determine pintle torque loads on the sector gates.
5. To make modifications if necessary to improve hydraulic performance.

While a more detailed discussion of the results of this study and their impacts on the design can be found in the *Inner Harbor Navigation Canal Replacement Lock Filling and Emptying System, Inner Harbor Navigation Canal, Louisiana*, report by John E. Hite, Jr., the results affecting this appendix the most are:

1. The pintle torque results verified that the sector gate and recess designs were satisfactory for a 110-foot wide lock,
2. The side port filling and emptying system were incorporated into the design to assist the end filling system, as the end filling system alone was

inadequate. Ultimately, only the culvert system was considered in the filling and emptying system.

3. The lock geometry was optimized to produce the configuration shown herein.

2.0 DESIGN

2.1 General:

Although there are differences in the gate bay monoliths of a sector-gated structure as compared to a miter-gated structure, the chambers essentially remain the same. Consequently, all design performed as a part of this appendix focuses entirely on the gate bay monoliths, with the exception of some minor adjustments made to the chamber monoliths pile layout and culvert opening dimensions.

2.1.1 Design/Construction Philosophy:

The overall construction of the lock & sector gate monoliths will be via cast-in-place concrete in lieu of the float-in-place methodology. The pros and cons regarding the cast-in-place vs. float-in-place construction methodology are included within Engineering Appendix B, Paragraph titled, *"Cast-In-Place versus Float-In-Construction of the Lock"*. Cellular Cofferdams and dredging of the existing IHNC channel will be required to achieve the in-place concrete pours. The 4 alternatives & cost estimates presented within the General Revaluation Report reflects only the cast-in-place concrete option.

2.2 Structural Design

2.2.1 References:

The EM's, ETL's, technical publications, and material weights referenced in Volume 3 of 9, Appendix B, of the 1997 Evaluation Report were utilized in all computations performed as part of this appendix, with the following exceptions:

1. American Concrete Institute, Building Code Requirements for Reinforced Concrete, (ACI 318R-99).

2. Muckle, W. Muckle's Naval Architecture, Second Edition

2.2.2 Load Cases:

2.2.2.1 Gate Bay Foundation Design Load Cases:

The load cases, as defined in the Evaluation Report, investigated herein for the foundation design are:

Load Case 1: Operation, Maximum Direct Head
Load Case 2: Unusual Operation, Maximum Direct Head Plus Freeboard
Load Case 3: Unusual Hurricane Plus Freeboard
Load Case 4: Maintenance Dewatering

Load Case 5: Unusual Maintenance
Load Case 6: N/A
Load Case 7: Normal Operation

2.2.2.2 Sector Gate Design Load Cases:

As part of the GRR study, the steel sector gates were prorated using the Gate Weight taken from the 2006 CIP evaluation Report. No detailed analysis/load cases were evaluated. More detailed design calculations will be performed during the feasibility portion of this study.

2.2.3 Gate Bay Design:

For cost-comparison purposes, the design philosophy for the gate bay monoliths will be via the cast-in-place construction methodology. ED-T has completed similar designs & construction projects for recent Hurricane Protection Projects. The top of the replacement lock walls will be Elevation 24.5 (NAVD 88) and the lock chamber remains 110 feet in width (for the tentatively selected plan). The lock culvert geometry also varies between the 4 alternatives evaluated, and was chosen as 14.5-ft wide by 14.5-ft high. These dimensions vary from the dimensions proposed within the 1997 report.

2.2.4 Chamber Design:

The overall chamber monolith length for the tentatively selected plan was 900-ft compared to the 1200-ft as proposed within the 1997 Evaluation Report. The pintle to pintle distance is 987.67-ft. To note, the 110-ft wide x 1200-ft option was evaluated and determined to not provide much more benefit to the project, in terms of usable barge length. Refer to the Economics portion of the GRR report for the cost/benefit report.

2.2.5 Sector Gate Design:

The sector gates have a pintle-to-skin plate radius of 52’-6”, an overall height of 62.4 ft, and is composed of three vertical trusses and four horizontal frames. The gate was analyzed with the traditional 2-D approach using C-FRAME. The main members were designed using the C-FRAME results and checked as a 3-dimensional space frame and a 3-dimensional space truss using STAAD. The main members selected were all wide-flanges, however, pipe sections shall be investigated in the next phase of design. The Sector Gate

3.0 COST

3.1 General:

Attached below are the cost estimates for the sector-gated structure and the miter-gated structure respectively. For consistency, the line items in the sector-gated structure’s cost estimate are the same as those for the miter-gated structure. Some quantities were unaffected by changing the structure to a sector –gated lock, and were left unchanged. All others were revised accordingly. The unit costs and lump sum costs were all updated from 1997 prices to 2002 prices.

Worthy of note is the fact that for the sector gate option, CEMVN-OD has authorized the elimination of the emergency crane, which is a $1,350,000 savings.

The overall cost for the miter gate option (2002 prices) is $260,300,000 and the cost for the sector gate option (2002 prices) is $248,800,000.

4.0 SECTOR VS. MITER COMPARISON

4.1 Design Issues:

Considerations that set the two gate types apart are:

- The existence of a reverse head at various times of the year.
- Durability.
- Gate geometry.
- Culvert Maintenance.
- Overall costs.

4.1.1 Reverse Head:

Miter gates are not designed to operate against a reverse head. To deal with this condition, either a second set of gates must be installed or the lock must be shut down for the duration of the reverse head. Since the latter is not an option, a second set of gates must be included along with the appurtenant machinery. To accommodate the second set of gates, the gate bay monolith must be lengthened accordingly.

A single set of sector gates, by design, can handle both a direct head and a reverse head without the need for more gates or more machinery.

4.1.2 Durability:

Miter gates do not stand up to damage as well as sector gates. Additionally, if a miter gate leaf is damaged such that there is a flow of water into the chamber, flooding of the downstream side could occur and/or the undamaged gates cannot be operated. Consequently, a $1.4 million emergency crane must be provided to lift the emergency bulkheads into place to stem the flow.

Sector gates, on the other hand have no problem operating against a flow and can thus temporarily stem the flow until the emergency bulkheads can be placed. Since placement of the emergency bulkheads is no longer imperative, the emergency crane can be eliminated.

4.1.3 Gate Geometry:

Miter gates are routinely built for the rough channel geometry of 110’ wide by 46.5’ tall. Sector gates have also been recently constructed for similar heights and widths as part of the Greater New Orleans Storm Damage and Risk Reduction System.
Additionally, the larger couple (distance between pintle and hinge) distance greatly reduces thrust on the hinge and pintle and large main chords, minimizing deflection. Gate deflection due to dead load is mostly cambered out during fabrication. Wheels and flotation tanks were considered in the preliminary design but discounted.

4.1.6 Culvert Maintenance:

Miter gates cannot operate without culverts to fill and empty the chamber. Sector gates, on the other hand are capable of filling and emptying the chamber in a sufficient time frame when there is a small head differential. Although the sector gate was shown to need the culverts for high head differentials, the gates are capable of operating without them during periods of low differentials. Being able to end-fill during those times would enable the culverts to be dewatered for maintenance without closing the lock to marine traffic.

4.1.7 Costs:

Excluding spare gates for either option, the sector gate option is roughly $12 million cheaper than the miter gate option. Additionally, maintenance costs for the miter gates will be more expensive when maintaining 8 miter gates and machinery compared to 4 sector gates and machinery.

5.0 CONCLUSIONS

5.1 General:

In light of the comparison above, the costs turned out to be roughly comparable and were, therefore, a non-issue. In light of its preference for a sector-gated structure, and the data presented herein, CEMVN-OD elected to pursue the sector gate option and also authorized the elimination of the emergency bulkhead crane.

LIST OF REFERENCES

American Concrete Institute, Building Code Requirements for Reinforced Concrete, (ACI 318R-99).

Inner Harbor Navigation Canal Replacement Lock Filling and Emptying System, Inner Harbor Navigation Canal, Louisiana, Report, John E. Hite, Jr.