DESIGN CRITERIA

SAMPLE CALCULATIONS PERTAIN TO THE 1200 X 110 X 36 SHIP LOCK. TYPICAL CALCULATIONS ARE FOR THE CHAMBER MODULE. THE GATEBAY CALCULATIONS ARE INCLUDED ONLY WHEN THAT MODULE CONTROLS THE DESIGN.

STRUCTURAL DESIGN CRITERIA
3 OCTOBER 96

1. Scope. The analysis and design concepts for the structural components are presented in the following text. A general layout of the structure is presented on Plates B-19 and B-20 for the 1200' Ship Lock and B-29 and B-30 for the Barge Lock.

2. References. The structural components shall be designed according to the applicable portions of the Corps of Engineers (COE) manuals for engineering and design and other reference material.

a. COE Publications:

(1) EM 1110-2-2000, Standard Practice for Concrete (Sep 85).

(2) EM 1110-2-2102, Waterstops and Other Joint Materials (May 93).

(3) EM 1110-2-2104, Strength Design for Reinforced - Concrete Hydraulic Structures (June 92).

(4) EM 1110-2-2105, Design of Hydraulic Steel Structures (May 93).

(5) EM 1110-2-2502, Retaining and Floodwalls (Sep 89).

(6) EM 1110-2-2602, Planning and Design of Navigation Lock (Sep 95).

(7) EM 1110-2-2703, Lock Gates and Operating Equipment (Jun 84).

(8) EM 1110-2-2906, Design of Pile Foundations (Jan 91).

(9) EM 1110-2-8152, Planning and Design of Temporary Cofferdams and Braced Excavations (Aug 94).

(10) ER 1110-2-1806, Earthquake Design and Evaluation for Civil Works Projects (Jul 95).

(11) ETL 1110-2-256, Sliding Stability for Concrete

Structures (Jun 81).

(12) ETL 1110-2-307, Flotation Stability Criteria for Concrete Hydraulic Structures (Aug 97).

(13) ETL 1110-2-338, Barge Impact Analysis (April 93).

(14) ETL 1110-2-355, Structural Analysis and Design of U-Frame Lock Monoliths (Dec 93).

(15) SL-80-4, Strength Report of Reinforced Concrete Hydraulic Structures, Report 3 - T-Wall Design, (Jan 82)

b. Technical Publications.

(1) American Concrete Institute, Building Code Requirements for Reinforced Concrete, (ACI 318-89).

(2) American Concrete Institute, Guide for the Design and Construction of Fixed Offshore Structures, (ACI 357R-84).

(3) American Concrete Institute, State of the Art Report on barge-Like Concrete Structures, (ACI 357.2R-88)

(4) American Institute of Steel Construction (AISC), Manual of Steel Construction 9th Edition, 1989.

(5) American Welding Society, Structural Welding Code, Steel, (AWS-D 1.1-88).

(6) Concrete Reinforcing Steel Institute, CRSI Handbook, (1984).

(7) Precast/Prestressed Concrete Institute, PCI Design Handbook, 4th Edition (1992)

(8) Post-Tensioning Institute, Post Tensioning Manual, 5th Edition, (1990).

(9) American Association of State Highway and Transportation Oficials, Standard Specifications for Highway Bridges, 14 Edition (1992)

c. Computer Programs.

(1) "Pile Group Analysis (CPGA)," WES Program No. X0080.

(2) "Pile Group Graphics Display (CPGG)," WES Program No. X0081.

(3) "Two Dimensional Analysis of U-Frame and W-Frame Structures (CWFRAM)," WES Program No. X0091.

(4) "C-Frame," WES Program No. X0030.

(5) "CWALSHT," WES Program No. X0031.

(6) " GT STRUDL", Georgia Institute of Technology.

(7) "CGSI", WES Program No. X0061.

(8) "CGFAG", WES Program No. X8008.

2. Design Criteria.

a. General. Design criteria shall be according to the referenced EM's, ETL's, and technical publications.

b. Material weights.

Item	PCF	
Water	63.0	
Select Sand	120.0	Ko = 0.50
Semi-Compacted Fill	110.0	Ko = 0.80
Silt	117.0	
Stone	132.0	
Concrete	150.0	
Steel	490.0	

c. Design Stresses.

(1) Concrete. The Strength Design Method is used in the design of conventionally reinforced concrete in accordance with the requirements of the ACI 318R-89R Building Code. Values

contained in the Code shall be modified as required in EM 1110-2-2104. The appropriate Load Factors are stated in para. (8). The transportation and setting load cases shall be analyzed by both the Strength Design Method and Working Strength Design(WSD)as directed in Section 4.4 of ACI 357. The WSD allowables for reinforcing steel are specified in ACI 357. The concrete compressive stress for the temporary loading shall not exceed 0.45 f'c. Crack width is controlled by limiting the stress in the tension reinforcement. In the transverse direction, the tensile stresses do not exceed the values specified in Table 4.1 of ACI 357. Table 4.1 was developed as a method for controlling cracks. The crack widths were calculated in accordance with formulas in ACI para. 10.6.4 Commentary. The Beta Factor for the I-Beam is 1.16. Crack widths were limited to 0.008 inch for normal operation and 0.0012 inch for temporary and extreme load conditions. In that the structure is precast, the dead load of the structure was include in the calculation of flexural stresses at service load. The base section is prestressed in the longitudinal direction; tension is not permitted in the concrete, therefore, concerns for cracks are eliminated. In the lock upper wall the flexural stresses are low, cracking will not be a problem. Although the reinfocement was increased to reduce stress, an upper limit was maintained to assure a ductile failure. The maximum steel ratio does not exceed 0.25pbal. (for members with compression steel pmax = 0.25pbal. + p'X(fs/fy)). Service load deflections and the effects of deformation loads (i.e. temperature) shall be investigated during the FDM. The base concrete shall have a minimum design strength (fc') of 6,000 psi at 28 days, the upper walls shall be constructed of concrete with a minimum 28-day strength of 4000 psi, and the ballast concrete shall have a design strength of 3,000 psi.

(2) Reinforcement. The design strength of conventional reinforcement shall be based on the use of ASTM Grade 60 steel, having a yield strength of 60,000 psi. Development length shall be based on the full yield strength of 60,000 psi.

(3) Prestressed Concrete. Criteria is based on the procedures presented in Section 9 of AASHTO Standard Specifications, the Post-Tensioning Manual and Chapter 18 of ACI 318. Prestressed members and composite members shall be designed to satisfy both strength (Ultimate Strength Design-USD) and serviceability requirements (Working Strength

Design-WSD). Allowable stresses are listed below. The Load Factors required in USD are specified in para. (8) below. The tendon system shall be fully bonded. This Feasibility Design will only consider the threaded bar post-tensioning system. The concrete compressive strength fc' is 6000 psi at 28 days, the concrete compressive strength at the time of transfer fci' is 4500 psi. The ultimate tensile strength fpu of the post-tensioning bar is 160ksi.

Allowable Stresses, Prestressed Concrete.

PRESTRESSING STEEL (Post-Tensioned Members)

Maximum Jacking	0.75 fpu
Maximum at Transfer	0.66 fpu
Effective (After Losses)	0.60 fpu**

** It is recognized that losses due to shrinkage, elastic shortening and creep of concrete as well as steel relaxation and friction should be considered. However, for this level of design an approximate value shall be used in the absence of a detailed analysis.

CONCRETE

AT TRANSFER (Before Losses)

Compression	0.55 f'ci
Tension	0

AT SERVICE LOADS (After Losses)

Compression	0.40 f'c
Tension	0

BEARING (Anchorage)

Compression	3000 psi

4) Structural Steel. For this Feasibility Report all members shall be designed using Allowable Stress Design (ASD). Permissible stresses for structural steel members are specified in Chapter 4 of EM 1110-2-2105. The main steel components are classified by type, in para. 7 below. For Feasibility analysis, the miter gate was analyzed using ASD. The miter gate shall be reanalyzed using LRFD as required in EM 1110-2-2105 during FDM design.

(5) Welds. Allowable stresses for the design of welds shall be according to the latest AWS Welding Code as modified by EM 1110-2-2105.

(6) Steel Pipe Piles. Allowable compressive stresses are given for both the lower and upper regions of the pile.

Axial Compression - Lower Region

Fa = 1/3 X Fy X 5/6

Combined Bending and Axial Compression - Upper Region:

$$\frac{fa}{Fa} \pm \frac{fbx}{Fb} \pm \frac{fby}{Fb} \leq 1.0$$

where:

fa = computed axial unit stress
Fa = 5/6 X 3/5 X Fy
fbx and fby = computed bending unit stress
Fb = 5/6 X 2/3 X Fy

(7) Hydraulic Steel Component Classification. As described in paras. 4.4 and 4.8 of EM 1110-2-2105, the main componemts are classified by Type as follows:

Steel Component	Type
1. Miter Gate	B
2. Culvert Tainter Valves	A
3. Culvert Valve Bulkheads	C
4. Emergency Bulkheads	B
5. Temporary Module Closure Dam	C

(8) Ultimate Strength Design. Load factors for the ultimate strength design of the concrete structure are in accordance with EM 1110-2-2104 for hydraulic structure load conditions. For setting and transportation, the load factors were developed in accordance with ACI 357R-84.

	Loading Condition	Load Factor
1.	Normal Operating	Uh = (1.3) X 1.7(D + L)
2.	Maximum Operating	Uh = (1.3) X 1.7(D + L)
3.	Maintenance Dewatering (Unusual)	Uh = 1.7(D + L)
4.	Hurricane (Unusual)	Uh = 1.7(D + L)
5.	**Setting**	**U = 1.2D + 1.6L + 1.3W** **U = 0.9(D + L) + 1.3W**
6.	**Transportation**	**U = 1.2D + 1.6L + 1.3W** **U = 0.9(D + L) + 1.3W**

D = dead load
L = live load
W = wind plus wave load
(where wind = 50 psf)

4. Loading Conditions.

(1) General. Six load cases shall be investigated. Two uplift conditions shall be applied to the Normal Operation and Maximum Operation, the conditions are described below. Only Uplift A is applied to the Maintenance Dewatering and Hurricane load cases.

(2) Uplift Conditions.

A. Uplift Condition A assumes the headwater sheet pile is fully effective. The uplift pressure is constant and equal to the tailwater pressure head.

B. Uplift Condition B assumes the headwater sheet pile cutoff is ineffective. Uplift pressure varies uniformly between the headwater pressure and the tailwater pressure.

(3) Loadings.

Load Case 1	Normal Operation	
	Riverside Headwater	El. 10.0
	Lakeside Tailwater	El. 1.0
	Chamber	El. 10.0
Load Case 2A	Maximum Operation	
	Riverside Headwater	El. 17.6
	Lakeside Tailwater	El. -2.0
	Chamber	El. 17.6
Load Case 2B	Maximum Operation	
	Riverside Headwater	El. 17.6
	Lakeside Tailwater	El. -2.0
	Chamber	El. -2.0
Load Case 3	Maintenance Dewatering	
	Riverside Headwater	El. 10.0
	Lakeside Tailwater	El. 1.0
	Chamber	El. DRY
Load Case 4	Hurricane	
	Lakeside Headwater	El. 13.0
	Riverside Tailwater	El. 0.0
	Chamber	El. 0.0
Load Case 5	Setting (Construction)	
	Static Head at	El. 3.0
	Chamber	El. DRY
	No Backfill	
	Voids Grouted	
	Flotation F.S. = 1.05	
Load Case 6	Transportation Case	
	Still Water	El. 1.0
	Wave Height	6.0 FT
	Wave Period	400 FT
	Voids Empty w/ short U-Frame	

Additional Factors.

- Sand backfill is assumed throughout the wall height, except for a negligible clay blanket, for all load cases except

Load Case 5.

- The effects of siltation are considered negligible.
- Drag on the outer walls was added when the effects were conservative.

Drag Force = At Rest Lateral earth pressure X 0.5 X (Tangent of the internal angle of friction)

5. PILE FOUNDATION. The pile foundation shall be designed in accordance with EM 1110-2-2906. The minimum factors of safety, based on the results of pile tests, for the loading conditions are as follows:

Loading Condition	Category	Soil Case	Pile Capacity Compression	Factor of Safety Tension
Normal Operation	Usual	S	2.0	2.0
Maximum Operation	Usual	Q	2.0	2.0
Maintenance Dewatering	Unusual	Q	1.5	1.5
Hurricane	Unusual	Q	1.5	1.5
Setting (Constr.)	Unusual	Q	1.5	1.5

6. FLOTATION. Flotation shall be evaluated in accordance with ETL 1110-2-307. For the Maintenance Dewatering Case, the dead weight of the structure alone shall exceed bouyancy by a Factor of Safety equal to 1.05. Tension connections to an adequate number of piles shall be utilized to develop the minimum required Factor of Safety. Drag force is neglected. The minimum factor of safety for load conditions shall be as follows:

Load Condition	Minimum Factor of Safety
Normal Operation	1.5
Maximum Operation	1.5
Maintenance Dewatering	1.05 w/o Tension Piles
	1.30 w/ Tension Piles

Hurricane	1.3
Setting	N/A

7. SLIDING. Since this foundation is grouted to the base a check for sliding is performed. The analysis will conservatively assume no embedment of the piles into the U-Frame base. The shear strength of the pile tension connections is also neglected. The sliding resistance considered is developed by the friction between the concrete base and the tremied 4' pile cap. The factor of safety shall be calculated in accordance with ETL 1110-2-256. A friction factor of 0.60 is used. A minimum factor of safety equal to 2.0 is required for all load conditions.