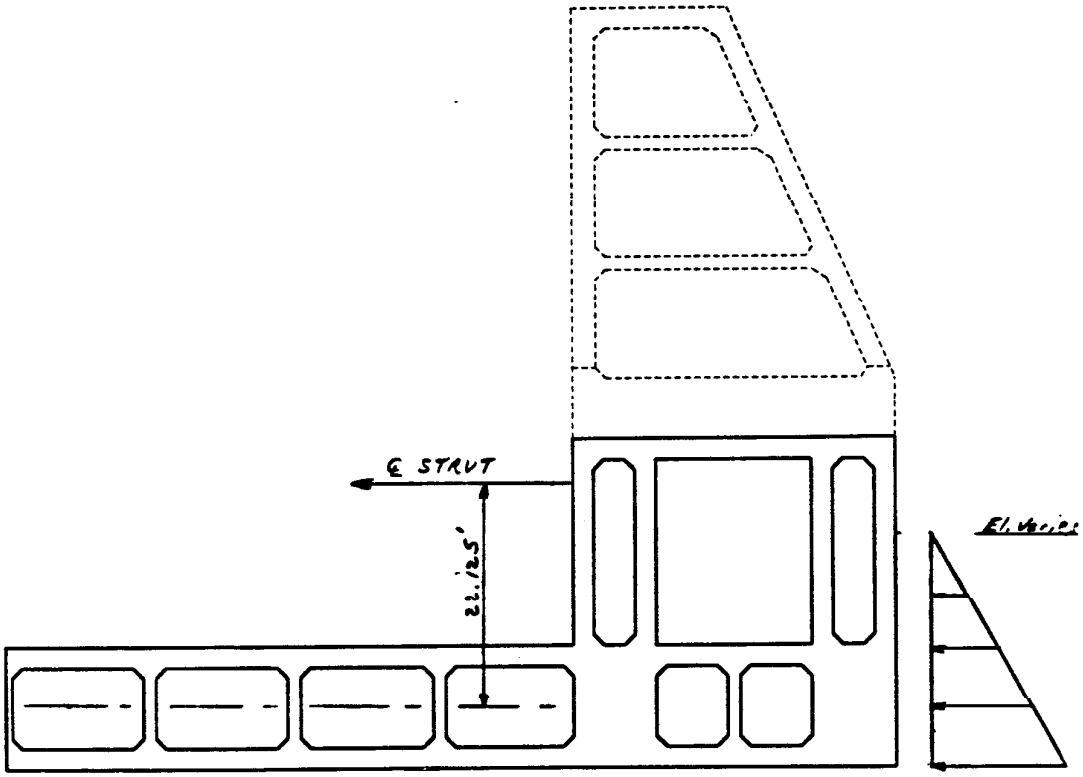
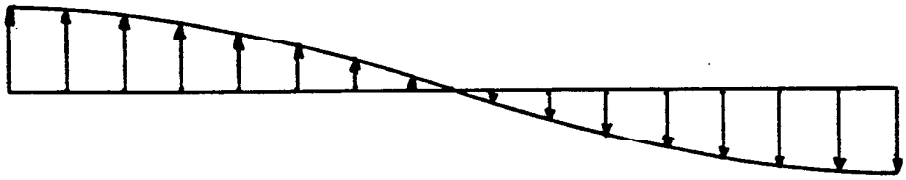
TENSION STRUT DESIGN
CHAMBER SECTION
TRANSPORTATION + WAVE



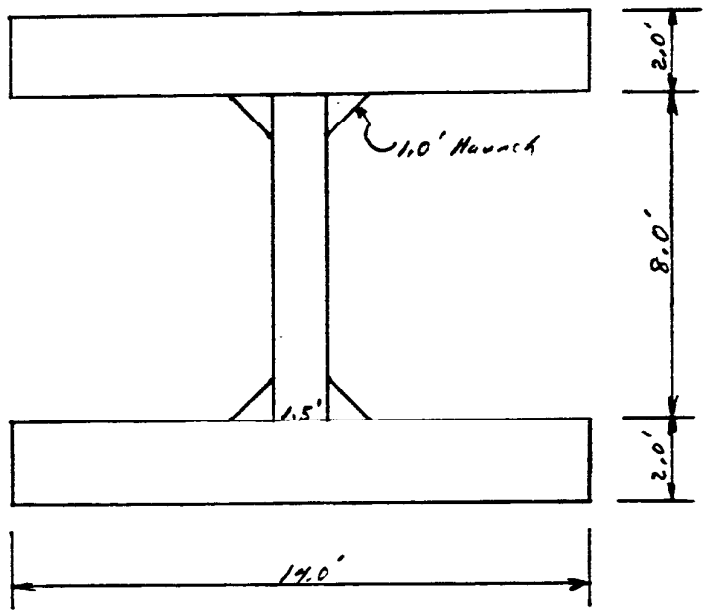


WAVE HOGGING
(Critical Loading)

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 23 OF	COMPUTED BY LCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

Section Properties (14' strip)



$$A_g = 24.0(168.0)(2) + 18.0(96.0) + .5(12.0)(12.0)(4)$$

$$A_g = \underline{10,080.0 \text{ in.}^2}$$

$$I_{xx} = \frac{168.0(144.0)^3}{12} - 2\left(\frac{75.0(96.0)^3}{12}\right) + 4\left(\frac{12.0(12.0)^3}{36}\right) + 4(72.0)(96.0-4.0)^2$$

$$I_{xx} = 41,803,776.0 - 11,059,200.0 + 2,304.0 + 2,437,632.0$$

$$I_{xx} = \underline{33,184,512.0 \text{ in.}^4}$$

$$S_{T\text{-}G} = 33,184,512.0 / 72.0 = \underline{460,896.0 \text{ in.}^3}$$

COMPUTATION SHEET

PROJECT IHNC	PAGE 24 OF	COMPUTED BY DCC	DATE 9/76
SUBJECT Chamber Monolith		CHECKED BY	DATE

TENSION STRUT - TRANSPORTATION (CHAMBER)

Assumptions:

1. Permissible tension in concrete, $6\sqrt{f'_c}$
2. $f'_c = 6000$ psi
3. $1\frac{3}{8}$"ϕ, 160.0 ksi bars
4. Permissible tensile stress in bars, $0.70 f_{pu}$

Design Loads:

Wave load hogging, from calcs by MHG.

$M \approx 4000.0$ '-k

Transport moment from CFRAME.

$M \approx 18,500.0$ '-k

$M_T \approx 22,500.0$ '-k

Allowable slab moment

$M = f_{b_c}(I)/12,000$

$= 6\sqrt{6,000}\,(460,896.0)/12,000$

$\approx 17,850.0$ '-k

Moment to be resisted by tension strut

$M = 22,500.0 - 17,850.0$

$= 4,650.0$ '-k

COMPUTATION SHEET

PROJECT IHNC	PAGE 25 OF	COMPUTED BY OCB	DATE 9/96
SUBJECT Chamber Monolith		CHECKED BY	DATE

Bars Required

$F_T = .70(160.0)(1.58) = 177.0^K/bar$

$T = 4,650.0 / 22.125' = 210.2^K$

$N = 210.2 / 177.0 = 1.2 \Rightarrow 2^*$

* Need 2 bars for transportation, an additional bar will be required in the strut as construction progresses.

COMPUTATION SHEET

PROJECT IHNC Lock	PAGE 26 OF	COMPUTED BY OCB	DATE 7/96
SUBJECT Chamber Monolith		CHECKED BY	DATE

LONGITUDINAL POST-TENSIONING (CHAMBER)

Assumptions:

1. Non-post tensioned reinforcement in the longitudinal direction adds nothing to the flexural strength of the chamber. Flexural strength is essentially supplied by the tendons.

2. The chamber will be post-tensioned in both the top and bottom to resist the moment reversals produced by sagging and hogging.

3. Design load is a 6' wave from stem to stern, during transportation.

4. No combined stresses due to transverse loading is included for this level of design.

5. No tensile stresses are allowed in the concrete.

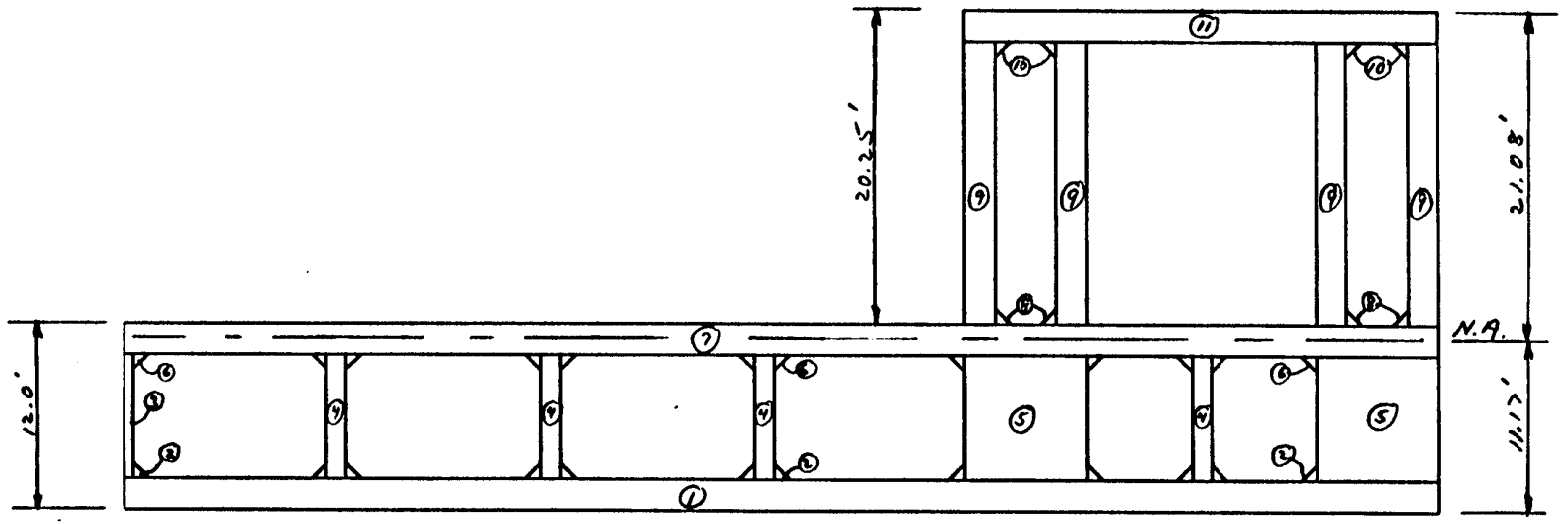
6. $f'_c = 6{,}000$ psi
   $f'_{ci} = 5{,}000$ psi

CHAMBER MONOLITH

FLOAT-IN SECTION

SECTION PROPERTIES

(ADJACENT PORTS)



COMPUTATION SHEET

PROJECT IHNC Lock	PAGE 28 OF	COMPUTED BY OCB	DATE 7/96
SUBJECT Chamber Monolith		CHECKED BY	DATE

Float-In Section (Neutral Axis - Adjacent Parts)

No.		A	$\bar{y}$	$A\bar{y}$
1	2.0(86.0)	172.0	1.0	172.00
2	.5(1.0)(1.0)(12)	6.0	2.33	14.00
3	.63(8.0)	5.0	6.0	30.00
4	1.25(8.0)(4)	40.0	6.0	240.00
5	8.0(8.0)(2)	128.0	6.0	768.00
6	.5(1.0)(1.0)(12)	6.0	9.67	58.00
7	2.0(86.0)	172.0	11.0	1892.00
8	.5(1.0)(1.0)(4)	2.0	12.33	24.67
9	2.0(18.25)(7)	146.0	21.13	3084.25
10	.5(1.0)(1.0)(4)	2.0	29.92	59.83
11	2.0(31.0)	62.0	31.25	1937.5
	TOTALS	741.0		8,280.25

$$N.A. = \frac{8280.25}{741.0} = \underline{11.17'}$$

$$\text{Full Area} = 741.0(2) = 1,482.0 \text{ SF}$$

$$= \underline{213,408.0 \text{ in.}^2}$$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 29 OF	COMPUTED BY DCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

Float-In Section (Moment of Inertia - Adjacent Parts)

No.		I	A	d	Ad^2
1	$86.0(2.0)^3/12$	57.33	172.0	10.17	17,789.77
2	$1.0(1.0)^3/36$ (12)	0.33	6.0	8.84	468.87
3	$.63(8.0)^3/12$	26.67	5.0	5.17	133.64
4	$1.25(8.0)^3/12$ (4)	213.33	40.0	5.17	1069.16
5	$8.0(8.0)^3/12$ (2)	682.67	128.0	5.17	3421.30
6	$1.0(1.0)^3/36$ (12)	0.33	6.0	1.50	13.50
7	$86.0(2.0)^3/12$	57.33	172.0	0.17	4.97
8	$1.0(1.0)^3/36$ (4)	0.11	2.0	1.16	2.69
9	$2.0(18.25)^3/12$ (4)	4,052.26	146.0	9.96	14,483.43
10	$1.0(1.0)^3/36$ (4)	0.11	2.0	18.25	703.13
11	$31.0(2.0)^3/12$	20.67	62.0	20.08	24,998.80
	TOTALS	5,111.14			63,089.26

$$I_{xx} = \Sigma I + Ad^2$$

$$= 5111.14 + 63,089.26 \text{ ft.}^4$$

$$I_{xx} = 68,200.4\ (2) = 136,400.8 \text{ ft.}^4$$

$$S_B = \frac{136,400.8}{11.17} = 12,211.35 \text{ ft.}^3$$

$$= \underline{21,101,212.8 \text{ in.}^3}$$

$$S_T = \frac{136,400.8}{21.08} = 6,470.63 \text{ ft.}^3$$

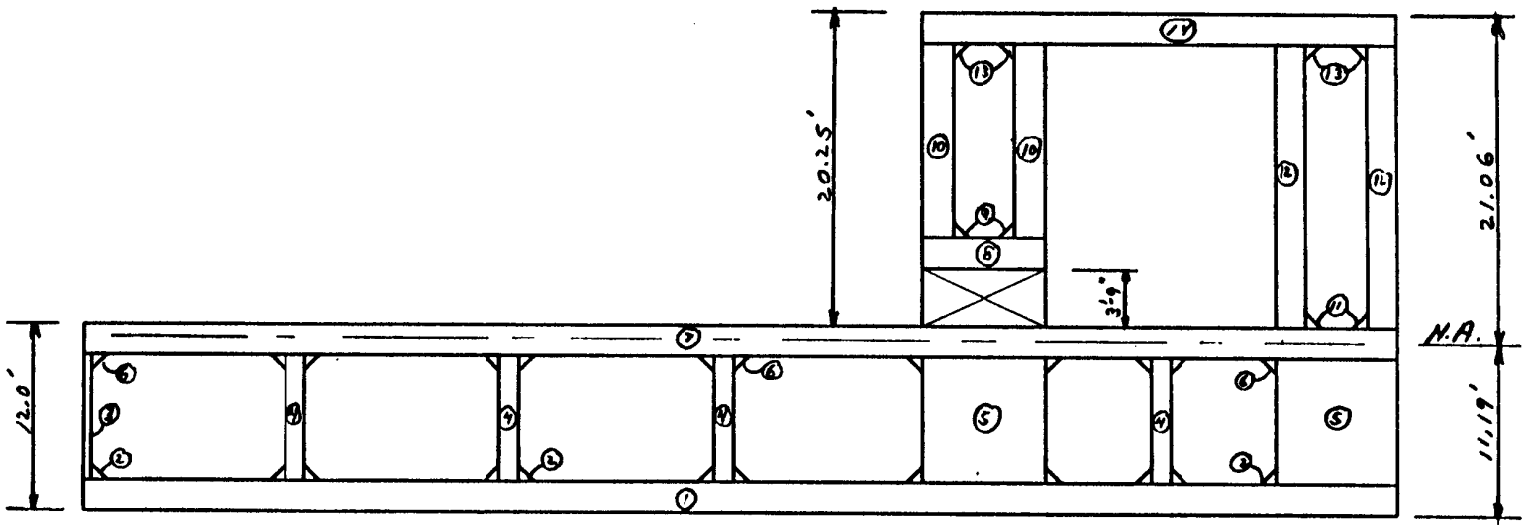
$$= \underline{11,181,248.6 \text{ in.}^3}$$

CHAMBER MONOLITH

FLOAT - IN SECTION

SECTION PROPERTIES

(AT PORT LOCATIONS)



COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 31 OF	COMPUTED BY DCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

Float - In Section (Neutral Axis - At Ports)

No.		A	$\bar{y}$	$A\bar{y}$
1	2.0(86.0)	172.0	1.0	172.00
2	.5(1.0)(1.0)(12)	6.0	2.33	14.00
3	.63(8.0)	5.0	6.0	30.00
4	1.25(8.0)(4)	40.0	6.0	240.00
5	8.0(8.0)(2)	128.0	6.0	768.00
6	.5(1.0)(1.0)(12)	6.0	9.67	58.00
7	2.0(86.0)	172.0	11.0	1892.00
8	2.0(8.0)	16.0	16.75	268.00
9	.5(1.0)(1.0)(2)	1.0	18.08	18.08
10	2.0(12.5)(2)	50.0	24.0	1200.00
11	.5(1.0)(1.0)(2)	1.0	12.33	12.33
12	2.0(18.25)(2)	73.0	21.13	1542.50
13	.5(1.0)(1.0)(4)	2.0	29.92	59.83
14	2.0(31.0)	62.0	31.25	1937.5
		734.0		8,212.24

N.A. = 8,212.24 / 734.0

= 11.19"

Full Area = 734.0 (2) = 1468.0 SF

= 211,392.0 in.²

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 32 OF	COMPUTED BY DCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

Float-In Section (Moment of Inertia - At Rest)

No.		I	A	d	Ad^2
1	$86.0(2.0)^3/12$	57.33	172.0	10.19	17,859.81
2	$1.0(1.0)^3/36$ (12)	0.33	6.0	8.86	471.00
3	$.63(8.0)^3/12$	26.67	5.0	5.19	134.68
4	$1.25(8.0)^3/12$ (4)	213.33	40.0	5.19	1,077.44
5	$8.0(8.0)^3/12$ (2)	682.67	128.0	5.19	3,447.82
6	$1.0(1.0)^3/36$ (12)	0.33	6.0	1.52	13.86
7	$86.0(2.0)^3/12$	57.33	172.0	0.19	6.21
8	$8.0(2.0)^3/12$	5.33	16.0	5.56	494.62
9	$1.0(1.0)^3/36$ (2)	0.06	1.0	6.89	47.47
10	$2.0(12.5)^3/12$ (2)	651.04	50.0	12.81	8,204.81
11	$1.0(1.0)^3/36$ (2)	0.06	1.0	1.14	1.30
12	$2.0(18.25)^3/12$ (2)	2,026.13	73.0	9.94	7,212.66
13	$1.0(1.0)^3/36$ (4)	0.11	2.0	18.73	701.63
14	$31.0(2.0)^3/12$	20.67	62.0	20.06	24,949.02
	TOTALS	3,741.39	737.0		64,622.33

$$I_{xx} = \Sigma I + Ad^2$$

$$= 3,741.39 + 64,622.33$$

$$I_{xx} = 68,363.7\ (2) = 136,727.4\ ft.^4$$

$$S_B = \frac{136,727.4}{11.19} = 12,218.71\ ft.^3$$

$$= \underline{21,113,936.3\ in.^3}$$

$$S_T = \frac{136,727.4}{21.06} = 6,492.28\ ft.^3$$

$$= \underline{11,218,659.8\ in.^3}$$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 33 OF	COMPUTED BY OCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

MIDSPAN STRESSES (Wave Load)

Based on the loading assumptions investigated, a moment of 300,000 1-K will be used for design of the post-tensioning system in the longitudinal direction. Axial compression is neglected. See comps by MHG.

(Hogging - Sagging) - Adjacent Ports

$$\sigma_T = \frac{3,600,000.0}{11,181,248.6} = \underline{\pm 0.322 \text{ ksi}}$$

$$\sigma_B = \frac{3,600,000.0}{21,101,212.8} = \underline{\pm 0.171 \text{ ksi}}$$

(Hogging - Sagging) - At Ports

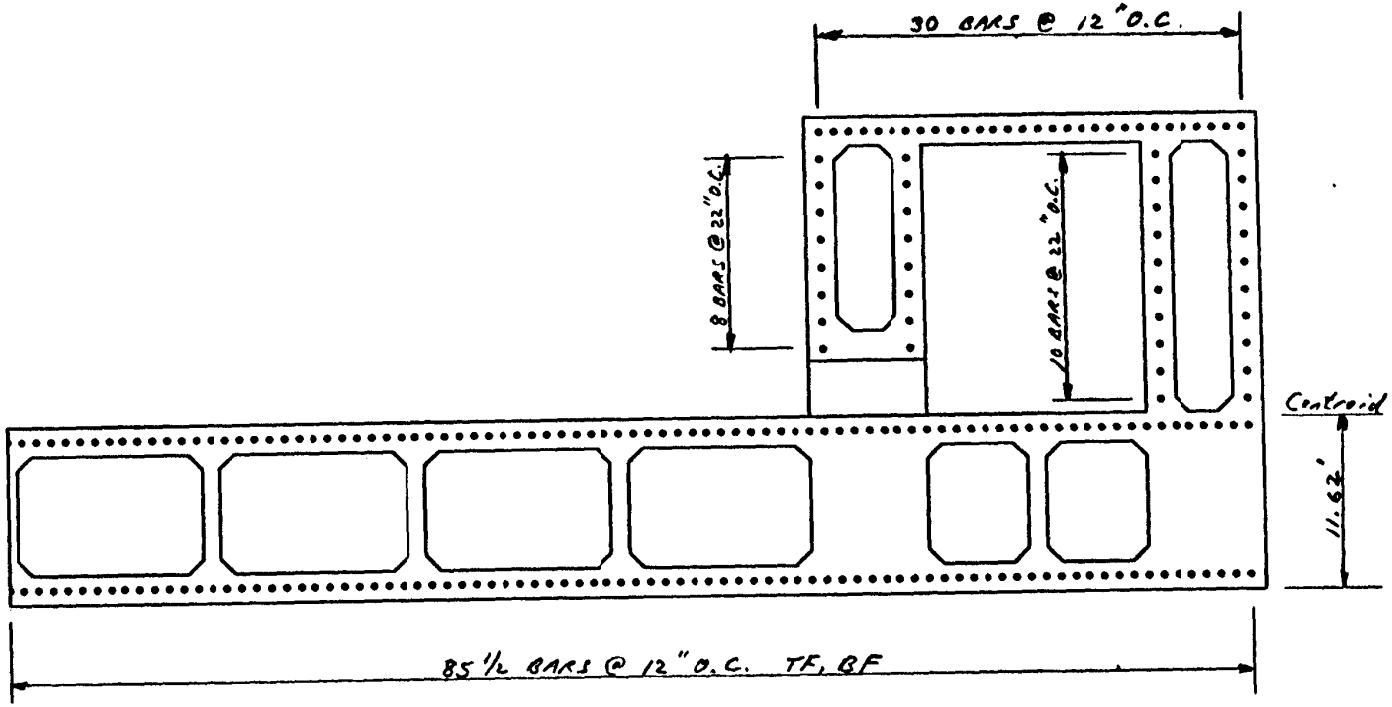
$$\sigma_T = \frac{3,600,000.0}{11,218,659.8} = \underline{\pm 0.321 \text{ ksi}}$$

$$\sigma_B = \frac{3,600,000.0}{21,113,936.3} = \underline{\pm 0.171 \text{ ksi}}$$

CHAMBER MONOLITH

FLOAT-IN SECTION

ASSUMED BAR LAYOUT



COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 35 OF	COMPUTED BY OCB	DATE 2/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

POST-TENSIONING REQUIREMENTS (At Part 1)

Eccentricity of Assumed Bar Layout

$$\bar{y} = \frac{85.5(1.0) + 85.5(11.0) + 16(22.96) + 20(21.13) + 30(31.25)}{237}$$

$$\bar{y} = 11.62' \Rightarrow e = 11.62' - 11.19' = 0.43'$$

$$e = 5.16''$$

Required Post-Tensioning (Wave-Hogging)

$$P_{pe}/A_g + P_{pe}e/S_T - 0.321 = 0$$

$$P_{pe}/211{,}392.0 + P_{pe}(5.16)/11{,}218{,}659.8 - 0.321 = 0$$

$$4.7305 \times 10^{-6} P + 4.5995 \times 10^{-7} P = 0.321$$

$$P_{pe} = 61{,}843.8^{k}$$

$$61{,}843.8 / 474 = 130.5^{k}/\text{Bar}$$

Required Post-Tensioning (Wave-Sagging)

$$P_{pe}/A_g - P_{pe}e/S_B - 0.171 = 0$$

$$P_{pe}/211{,}392.0 - P_{pe}(5.16)/21{,}113{,}936.3 - 0.171 = 0$$

$$4.7305 \times 10^{-6} P - 2.4439 \times 10^{-7} P = 0.171$$

$$P_{pe} = 38{,}117.7^{k}$$

$$38{,}117.7 / 474 = 80.4^{k}/\text{Bar}$$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 36 OF	COMPUTED BY OCB	DATE 2/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

POST-TENSIONING REQUIREMENTS (Adjacent Parts)

Eccentricity of Assumed Bar Layout

$$\bar{y} = \frac{85.5(1.0) + 85.5(11.0) + 16(22.96) + 20(21.13) + 30(31.25)}{237}$$

$$\bar{y} = 11.62' \Rightarrow e = 11.62' - 11.17' = 0.45'$$

$$e = 5.40''$$

Required Post-Tensioning (Wave-Hogging)

$$P_{pe}/A_g + P_{pe}e/S_T - 0.322 = 0$$

$$P_{pe}/213{,}408.0 + P_{pe}(5.40)/11{,}181{,}248.6 - 0.322 = 0$$

$$4.6859 \times 10^{-6} P + 4.8295 \times 10^{-7} P = 0.322$$

$$P_{pe} = 62{,}296.3^{k}$$

$$62{,}296.3/474 = 131.4^{k}/\text{Bar}$$

Required Post-Tensioning (Wave-Sagging)

$$P_{pe}/A_g - P_{pe}e/S_B - 0.171 = 0$$

$$P_{pe}/213{,}408.0 - P_{pe}(5.40)/21{,}101{,}212.8 - 0.171 = 0$$

$$4.6859 \times 10^{-6} P - 2.5591 \times 10^{-7} P = 0.171$$

$$P_{pe} = 38{,}600.5^{k}$$

$$38{,}600.5/474 = 81.4^{k}/\text{Bar}$$

Use 1 3/8" Ø, 160.0 ksi, Threadbar

$$P_{pe} = .60 f_{pu} = 151.7^{k}/\text{Bar}$$

THREADBAR POST-TENSIONING SYSTEM DETAILS

PRETRESSING STEEL PROPERTIES

Nominal Threadbar Diameter (inches)	Ultimate Stress (f_{pu}-ksi)	Cross Section Area (Aps-inches²)	Ultimate Strength (f_{pu} A ps)	Prestressing Force — (kips)			Weight (lbs./ft.)	Minimum Elastic Bending Radius (ft.)	Maximum Threadbar Diameter (inches)
				$0.80 f_{pu} A_{ps}$	$0.70 f_{pu} A_{ps}$	$0.60 f_{pu} A_{ps}$			
⅝	157	0.28	43.5	34.8	30.5	26.1	0.98	26	0.693
1	150	0.85	127.5	102.0	89.3	76.5	3.01	52	1.201
1	160	0.85	136.0	108.8	95.2	81.6	3.01	49	1.201
1¼	150	1.25	187.5	150.0	131.3	112.5	4.39	64	1.457
1¼	160	1.25	200.0	160.0	140.0	120.0	4.39	60	1.457
1⅜	150	1.58	237.0	189.6	165.9	142.2	5.56	72	1.630
1⅜	160	1.58	252.8	202.3	177.0	151.7	5.56	67	1.630

STEEL STRESS LEVELS

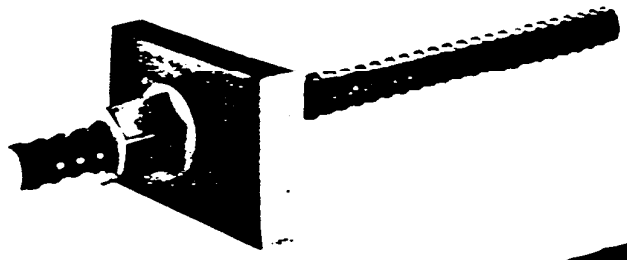
Threadbar and Smooth Bars* may be stressed to the allowable limits of ACI 318. The maximum jacking stress (temporary) may not exceed $0.80 f_{pu}$, and the transfer (lockoff) may not exceed $0.70 f_{pu}$.

ACI 318 does not stipulate the magnitude of prestress losses or the maximum final effective (working) prestress level.

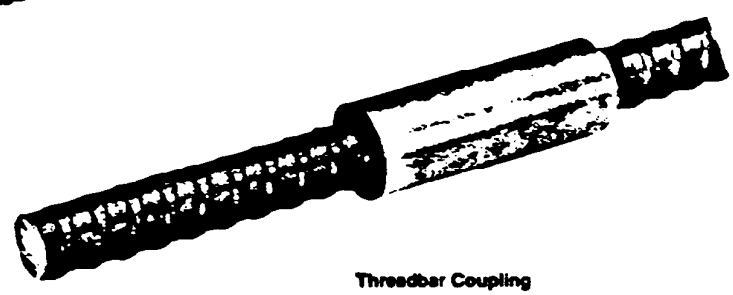
Prestress losses due to shrinkage, elastic shortening and creep of concrete as well as steel relaxation and friction must be considered.

The final effective (working) prestress level depends on the specific application. In the absence of a detailed analysis of the structural system, $0.60 f_{pu}$ may be used as an approximation of the effective (working) prestress level.

Actual loss calculations require structural design information not normally present on contract documents.



Threadbar Plate Anchorage



Threadbar Coupling

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 37 OF	COMPUTED BY DCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

MIDSPAN STRESSES (Comp. = + , Tension = −)

Initial Prestress (Maximum Jacking)

Assumes no stresses due to OL at graving site.

$P_{pi} = 0.75 f_{pu} = 189.6$ k/bar

$$\sigma_T = \frac{474(189.6)}{213,408.0} + \frac{474(189.6)(5.40)}{11,181,248.6} = \underline{+0.465 \text{ ksi}}$$

$$\sigma_B = \frac{474(189.6)}{213,408.0} - \frac{474(189.6)(5.40)}{21,101,212.8} = \underline{+0.398 \text{ ksi}}$$

$$\sigma_{All.} = .55(f'_{ci}) = \underline{2.75 \text{ ksi}} \quad (c)$$

At Transfer

Assumes no stresses due to OL at graving site

$P_{pt} = 0.66 f_{pu} = 166.8$ k/bar

$$\sigma_T = \frac{474(166.8)}{213,408.0} + \frac{474(166.8)(5.40)}{11,181,248.6} = \underline{+0.409 \text{ ksi}}$$

$$\sigma_B = \frac{474(166.8)}{213,408.0} - \frac{474(166.8)(5.40)}{21,101,212.8} = \underline{+0.350 \text{ ksi}}$$

$$\sigma_{All.} = .55(f'_{ci}) = \underline{2.75 \text{ ksi}} \quad (c)$$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 38 OF	COMPUTED BY OCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

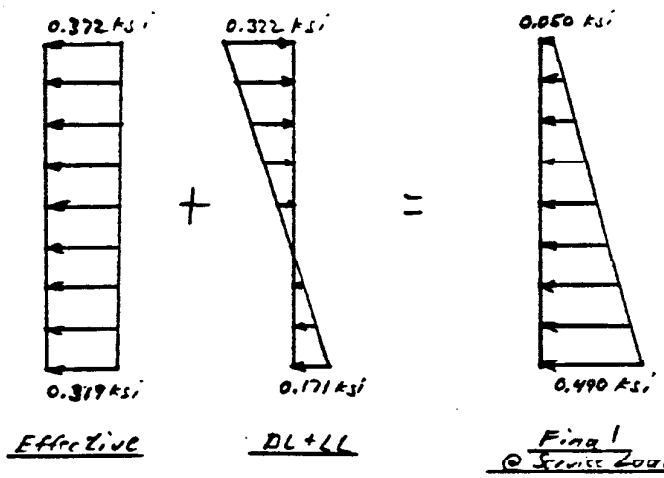
Effective (After Losses)

$$P_{pe} = 0.60\, f_{pu} = 151.7 \text{ K/bar}$$

$$\sigma_T = \frac{474(151.7)}{213,408.0} + \frac{474(151.7)(5.40)}{11,181,248.6} = \underline{+0.372 \text{ ksi}}$$

$$\sigma_B = \frac{474(151.7)}{213,408.0} - \frac{474(151.7)(5.40)}{21,101,212.8} = \underline{+0.319 \text{ ksi}}$$

Service Load (DL + LL, Wave - Hogging)



$$\sigma_T = 0.372 - 0.322 = \underline{+0.050 \text{ ksi}} \quad (c)$$

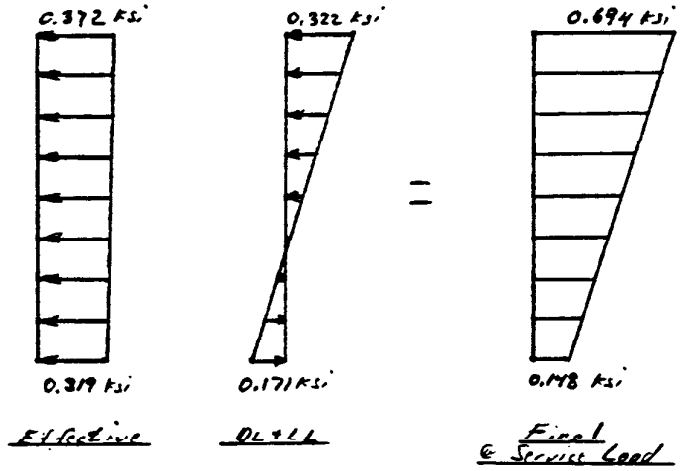
$$\sigma_B = 0.319 + 0.171 = \underline{+0.490 \text{ ksi}} \quad (c)$$

$$\sigma_{All} = 0.40\, f'_c = 2.40 \text{ ksi}$$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 39 OF	COMPUTED BY DCB	DATE 7/96
SUBJECT	Chamber Monolith		CHECKED BY	DATE

Service Load (DL + LL, Wave - Sagging)



$\sigma_T = 0.372 + 0.322 = \underline{+0.694 \text{ ksi}}$ (c)

$\sigma_B = 0.319 - 0.171 = \underline{+0.148 \text{ ksi}}$ (c)

$\sigma_{All.} = 0.40 f'_c = 2.40 \text{ ksi}$

COMPUTATION SHEET

PROJECT	IHNC Lock	PAGE 40 OF	COMPUTED BY OCB	DATE 7/76
SUBJECT	Chamber Monolith - Longitudinal		CHECKED BY	DATE

FLEXURAL CAPACITY (Ultimate Strength)

1. Assume conventional reinforcement in longitudinal direction provides the flexural strength.

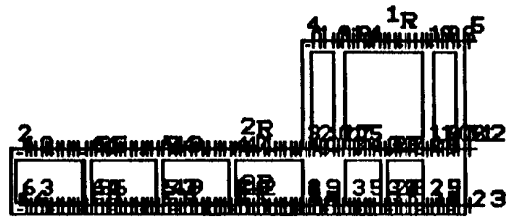
2. Assume #11 @ 12" in flanges, neglect web reinforcement.

3. Due to limitations in the program CGSI (Concrete General Strength Investigation) only half the lock will be modeled.

4. No compatibility analysis will be performed to calculate the flexural strength of the section, combining prestressed and non-prestressed steel. This analysis will be performed in the design memorandum phase.

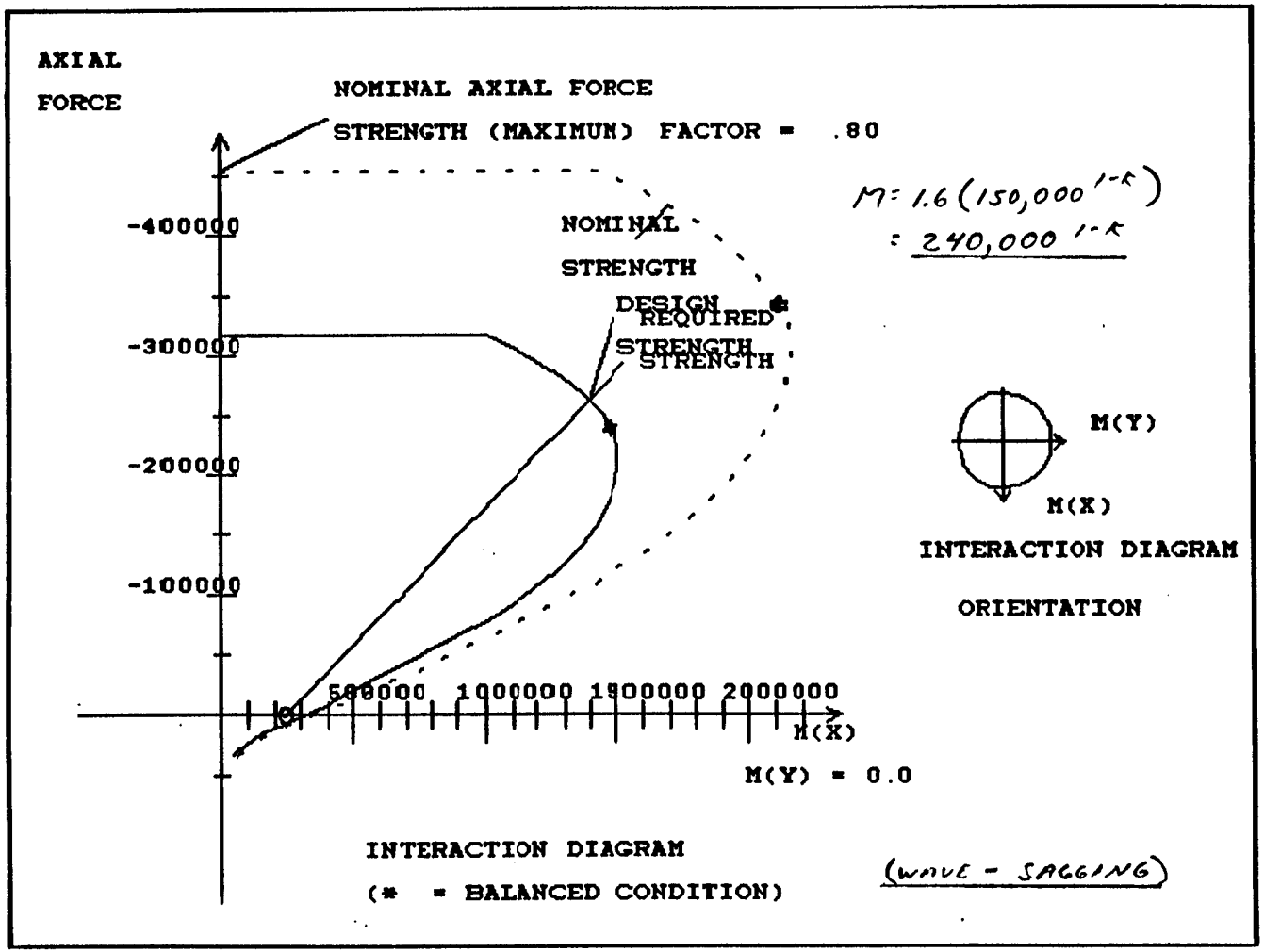
5. Load factors presented in ACI 357 shall be incorporated. Though wave loading is considered an environmental load with a corresponding load factor of 1.3, the Live Load factor of 1.6 shall be conservatively utilized.

FIG. 1. DATA INPUT CHECK



AREA OF REINFORCEMENT / GROSS AREA = .006

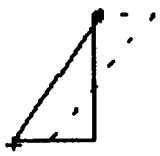
MEMBER CHAMBER SECTION TRANVERSE

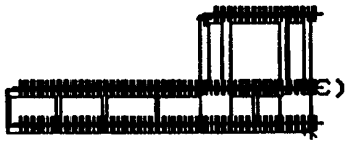


$M = 1.6(150{,}000^{1\text{-}k})$

$= \underline{240{,}000^{1\text{-}k}}$

ACTUAL STRAINS
VS. BALANCED
(BALANCED = ...)





* MAX. CONC. STR.=.00035

\+ MAX. STEEL STR.=.00386

MEMBER CHAMBER SECTION TRANVERSE

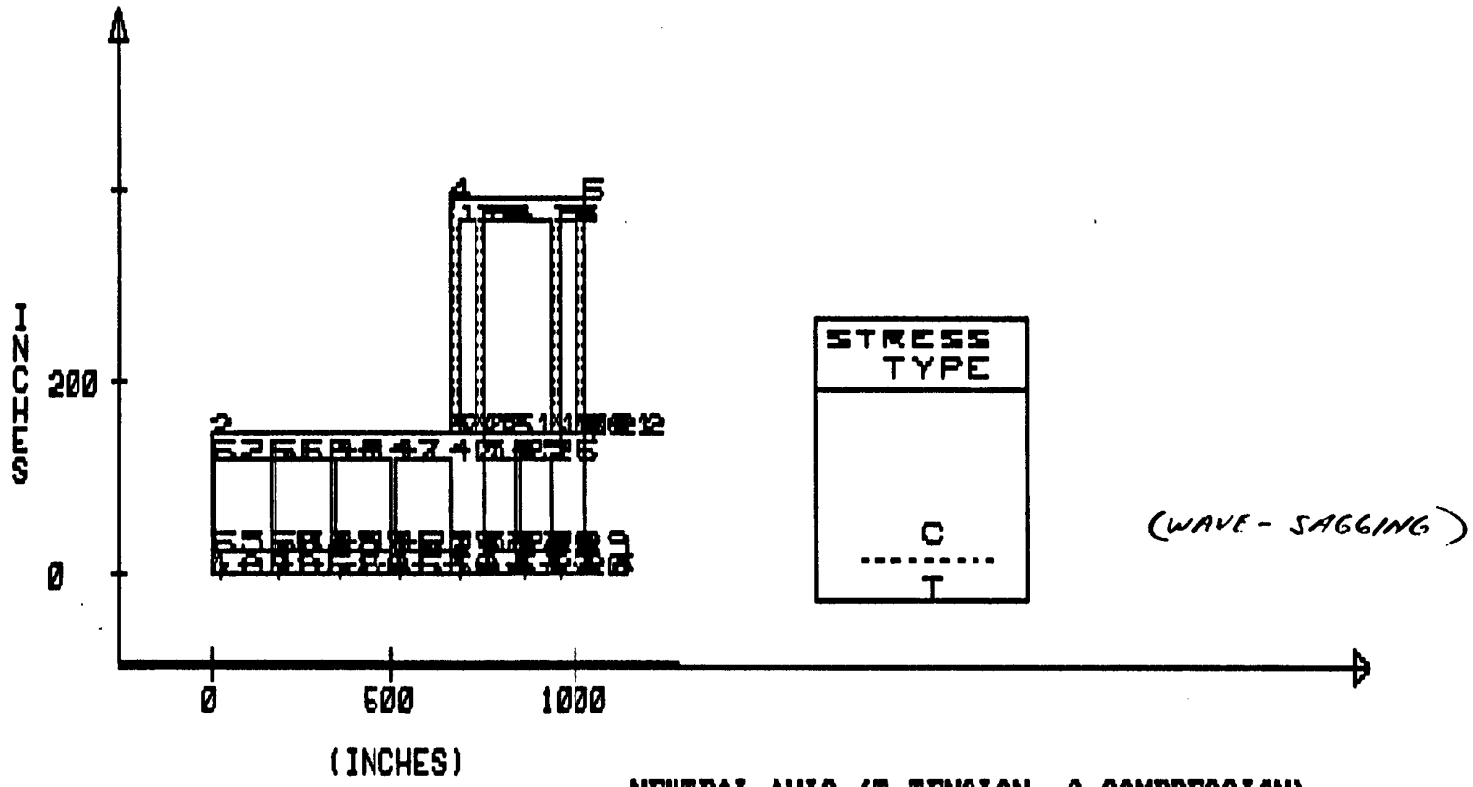
SERVICEABILITY REQUIREMENTS (Allowable Stress)

1. Assume conventional reinforcement in longitudinal direction provides the flexural strength.

2. Assume #11 @ 12" in flanges and at culvert walls. Neglect web reinforcement in the base slab.

3. Due to limitations in the program CGFA (Concrete General Flexure Analysis) only half the lock will be modeled.

4. Allowable stresses for reinforcing steel to control cracking presented in ACI 357 shall be utilized. (f_s = 23.0 ksi)



(WAVE - SAGGING)

----- NEUTRAL AXIS (T=TENSION, C=COMPRESSION)

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PROGRAM CORPS/X8008   CONCRETE GENERAL FLEXURE ANALYSIS  REV 86
SHIP LOCK CHAMBER - TRANSVERSE SECTION
** I N P U T   L O A D I N G   A N D   P A R A M E T E R S **

LD. CASE      P    Y-AXIS MOM. X-AXIS MOM.    N     R    ACCURACY
  301        .00         .00 -1800000.00   9.20  1.00     .010

S T R E S S   E Q U A T I O N   A N D   N E U T R A L   A X I S:

 UNIT STRESS =     .00050 X  +    -.00777 Y  +     .04745

 AT Y = 0, NEUTRAL AXIS CROSSES X-AXIS AT X =   -94.233090
 AT X = 0, NEUTRAL AXIS CROSSES Y-AXIS AT Y =    6.1085330

      MAXIMUM CONCRETE STRESS =      .57 AT POINT23
      MAXIMUM STEEL STRESS    =    23.71 T
                              =     4.76 C
```