Task:

Input
Information
Important

Determine the environmental loads and loading combinations for the analysis of the existing tainter gates.

Notes:

1. Environmental loads and load combinations based on EM 1110-2-2702, *Design of Spillway Tainter Gates,* USACE, 1 January 2000.
2. Structural steel is Federal Specification Q-S-741, type II or ASTM Designation A7 (Original Construction Specifications)
3. Site seismicity provided in Table 2 of the *Ground Motion Hazard Evaluation for Robles Diversion Dam Modification Project* , by AMEC Geomatrix, Inc. Oakland, CA, dated November 12, 2008.
4. OBE - 50% probability of exceedence during the service life. This corresponds to a return period of 144 years for a project with a service life of 100 years. [ER 1110-2-1806]

Calculations:

Loads

Gravity

Selfweight	D	6.25 k	Determined by the finite element modeling.
Mud Weight	M	0.94 k	Based on future silt loading from removal of the Matilija Dam (top of girders filled with silt).

No. Girders	6				
Girder Length	14.58 ft	d	8	b_f	4
γ_m	125 pcf	tw	0.27	t_f	0.425
Gate Length	16 ft				

Ice Weight	C	0.34 k	Iced surface is one side of skin plate, top of girders, and downstream face of girders.

Iced surface area	288 sf		
Skin Plate	152 sf	Ice thickness	0.25 in
Girders	136 sf	γ_{ice}	56 pcf

Hydrostatic

Max that will ever occur	H_1	11.50 ft	Calculate hydrostatic pressure on the skin plate based on depth of water.
Design (10-yr return period)	H_2	11.50 ft	Use H1, river is flashy.
Normal (50% annual exceedance)	H_3	11.50 ft	Use H1, river is flashy.

Existing Sill	755.50 ft	Dam Raise	2.00 ft	γ_w	62.5 pcf
Existing Crest	765.00 ft	New Crest	767.00 ft		

Machinery

Max Downward	Q_1	0.00 k	Wire rope hoist system.
At-Rest Downward	Q_2	0.00 k	Wire rope hoist system.
Max Upward	Q_3	7.50 k	Design drawing 40-D-4331, *Radial Gate Hoist, Capacity - 7500 Pounds, Assembly - List of Parts.*
		0.11 k/in	Contact pressure due to wire rope on gate end girders under gate jammed condition
Ice Impact	I	0.00 klf	Inflow hydrographs show that the reservoir does not sustain a WSEL sufficiently long to establish icing; collaborated by CMWD Staff.

ENGINEERS INC.

		Job Number	08-015H
		Volume/Sheet No.	of
Client/Contract	Tt/Robles Diversion		
Phase/Subject	Tainter Gate Analysis		
Design Topic	Loading Conditions		

Made By PRC/VRG   Date 12/17/2008   Checked By EGL   Date 2/13/2009   Page No.

Side Seal Friction F_s 0.33 k   Eqn. 3-2, EM 2702.

μ_s	0.5	d	3.50 in	
l	12.13 ft	h	11.50 ft	
l_1	12.13 ft	δ	0.25 in	
l_2	0.00 ft	E	900 psi	sealsunlimited.com
S	0.83 plf	I	0.00439 in^3	
γ_w	62.5 pcf			

Trunnion Pin Friction F_t 0.30   EM 2702

Earthquake   E   0.318 g   When gate is open - OBE applied to selfweight, mud and ice.

When gate is closed - disregard inertial forces, use hydrodynamic pressure.

Elevation	y	p
767.00 ft	0.00 ft	0.00 psf
766.00 ft	1.00 ft	58.97 psf
765.00 ft	2.00 ft	83.40 psf
764.00 ft	3.00 ft	102.15 psf
763.00 ft	4.00 ft	117.95 psf
762.00 ft	5.00 ft	131.87 psf
761.00 ft	6.00 ft	144.46 psf
760.00 ft	7.00 ft	156.03 psf
759.00 ft	8.00 ft	166.81 psf
758.00 ft	9.00 ft	176.92 psf
757.00 ft	10.00 ft	186.49 psf
756.00 ft	11.00 ft	195.60 psf
755.50 ft	11.50 ft	199.99 psf

Wave W_A 0.00 ft

Wind   W   3.73 k   ASCE 7-05, Paragraph 6.5.10

q_h	17 psf	A_s	184 sf
G	0.85	I	1.15
C_f	1.4	V	85 mph

ENGINEERS INC.

Job Number	08-015H		
Volume/Sheet No.		of	
Client/Contract	Tt/Robles Diversion		
Phase/Subject	Tainter Gate Analysis		
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	Selfweight	Mud	Ice	Hydrostatic	Hydrostatic	Hydrostatic	Downward	Downward	Upward	Impact	Friction	Friction	Earthquake	Wave	Wind	
Load Cases	D	M	C	H_1	H_2	H_3	Q_1	Q_2	Q_3	I	F_s	F_t	E	W_A	W	
LC 1 - Gate Closed																
Eqn 3-5	1.2	1.6	1.6	1.4				1.2								Extreme Pool
Eqn 3-6A	1.2	1.6	1.6		1.4		1.2									Operating Pool
Eqn 3-6 B	1.2	1.6	1.6		1.4			1.2						1.2		Operating Pool
Eqn 3-6 C	1.2	1.6	1.6		1.4			1.2		k_I						Operating Pool
Eqn 3-7	1.2	1.6	1.6			1.2							1.0			Earthquake
LC 2 - Gate Operating with 2 Hoists																
Eqn 3-8	1.2	1.6	1.6	1.4							1.4	1.0				Extreme Pool
Eqn 3-9 A	1.2	1.6	1.6		1.4						1.4	1.0		1.2		Operating Pool
Eqn 3-9 B	1.2	1.6	1.6		1.4					k_I	1.4	1.0				Operating Pool
LC 3 - Gate Operating with 1 Hoist																
Eqn 3-10	1.2	1.6	1.6		1.4						1.4	1.0				
LC 4 - Gate Jammed																
Eqn 3-11 A	1.2	1.6	1.6		1.4				1.2							
Eqn 3-11 B	1.2	1.6	1.6		1.4		1.2									
LC 5 - Gate Fully Opened																
Eqn 3-12 A	k_d	1.6	1.6												1.3	
Eqn 3-12 B	k_d	1.6	1.6										1.0			
Eqn 3-12 C	k_d	1.6	1.6						1.2							

Gate Opening 0.00 ft

Girder	G-G Spacing	Girder El.	Midheight	Tributary Height	Note
Top El.		767.00 ft			Existing Gate Extended by 2ft
	2.00 ft		766.00 ft		
A		765.00 ft		3.05 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	2.10 ft		763.95 ft		
B		762.90 ft		1.95 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	1.81 ft		762.00 ft		
C		761.09 ft		1.69 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	1.57 ft		760.31 ft		
D		759.52 ft		1.48 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	1.38 ft		758.83 ft		
E		758.14 ft		1.28 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	1.19 ft		757.55 ft		
F		756.96 ft		1.13 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	1.08 ft		756.42 ft		
G		755.88 ft		0.73 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates
	0.38 ft		755.69 ft		
Bottom		755.50 ft		0.19 ft	Sheet 767-D-252, 16'-0" x 9'-0" and 10'-0" x 9'-6" Radial Gates

Client/Contract	Tt/Robles Diversion
Phase/Subject	Tainter Gate Analysis
Design Topic	Loading Conditions
Made By	PRC/VRG Date 12/17/2008 Checked By EGL Date 2/13/2009 Page No.

Location		Elevation	y	H_s	H_s	E	E
Top		767.00 ft	0.00 ft	0 psf		0 psf	
	midheight	766.00 ft	1.00 ft	63 psf		59 psf	
Girder A		765.00 ft	2.00 ft	125 psf	290 plf	83 psf	166 plf
	midheight	763.95 ft	3.05 ft	190 psf		103 psf	
Girder B		762.90 ft	4.10 ft	256 psf	491 plf	119 psf	229 plf
	midheight	762.00 ft	5.00 ft	313 psf		132 psf	
Girder C		761.09 ft	5.91 ft	369 psf	618 plf	143 psf	241 plf
	midheight	760.31 ft	6.69 ft	418 psf		153 psf	
Girder D		759.52 ft	7.48 ft	467 psf	685 plf	161 psf	237 plf
	midheight	758.83 ft	8.17 ft	511 psf		169 psf	
Girder E		758.14 ft	8.86 ft	554 psf	706 plf	176 psf	224 plf
	midheight	757.55 ft	9.45 ft	591 psf		181 psf	
Girder F		756.96 ft	10.04 ft	628 psf	708 plf	187 psf	211 plf
	midheight	756.42 ft	10.58 ft	661 psf		192 psf	
Girder G		755.88 ft	11.12 ft	695 psf	635 plf	197 psf	180 plf
	midheight	755.69 ft	11.31 ft	707 psf		198 psf	
Bottom		755.50 ft	11.50 ft	719 psf		200 psf	

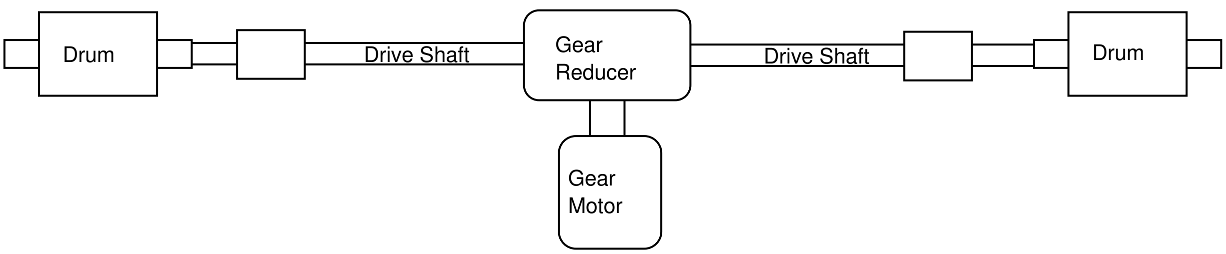
	Load Combinations (w_u)		Bending Moment (M_u)		Shear (V_u)
Location	LC1 (3-5)	LC1(3-7)	LC1 (3-5)	LC1(3-7)	LC1(3-7)
Top					
Girder A	406 plf	514 plf	130 k-in	164 k-in	3.75 K
Girder B	688 plf	819 plf	219 k-in	261 k-in	5.97 K
Girder C	866 plf	684 plf	276 k-in	218 k-in	4.98 K
Girder D	959 plf	1059 plf	306 k-in	338 k-in	7.72 K
Girder E	988 plf	1071 plf	315 k-in	342 k-in	7.81 K
Girder F	992 plf	1061 plf	316 k-in	339 k-in	7.74 K
Girder G	889 plf	942 plf	284 k-in	301 k-in	6.87 K
Bottom					

Unfactored Trunnion Reactions for Lateral Loads

Load Type	Load	Trunnion 1	Trunnion 2
Hydrostatic Load	66.13 kip	33.06 kip	33.06 kip
Earthquake Load (Gate Closed)	23.81 kip	11.91 kip	11.91 kip
Equipment Load (Gate Jammed)	26.51 kip	13.26 kip	13.26 kip
Wind	3.73 kip	1.86 kip	1.86 kip

References

(1) Crane Handbook by Whiting Corporation
(2) CMAA 70, 2004
(3) Drawings Provided by CESPL



Hoist Layout for Existing Tainter Gates

1.0 MOTOR HORSE POWER CALCULATION

The following computations are performed to check the motor HP for the rated capacity of the hoist.

Hoist Rated Capacity, C	=	7500	lb	(Dwg # 40-D-4331)

1.1 Drum

No of Drums, n	=	2		
Drum Pitch Diameter, D	=	11	in	(Dwg 40-D-4332)
Torque at Each Drum, T_d=(C*D)/2n	=	20625	lb-in	

1.2 Gear Reducer

Gear Reducer Type	=	Worm Drive	
Gear Ratio, R_1	=	50	
Efficiency, η_g	=	97	% (Assumed)
Torque at input shaft, $T_g=(T_d*100/R_1/\eta_g)$	=	851	in-lb

1.3 Gear Motor

Rated Speed of o/p shaft, N_1	=	30	rpm	(Dwg # 40-D-4331)
Rated Speed of i/p shaft, N_2	=	1730	rpm	(From Motor Capacity Marking)
Ratio of Gear Motor,N= N_2/N_1	=	57.67		
Gear Mesh	=	3	(Assumed)	

Efficiency/Mesh, η_m	=	0.97	(Assumed)	
Combined Efficiency, $\eta_c = \eta_m^3$	=	0.913		
Torque at input shaft of motor, $T_i = T_g/\eta_c/N$	=	16.16	in-lb	
Required Motor HP=$T_i * N_2/63000$	=	0.44	HP	
Available Motor HP	=	1.5	HP	(Dwg # 40-D-4331)

MOTOR CAPACITY IS SUFFICIENT

References
(1) Crane Handbook by Whiting Corporation
(2) Drawings Provided by CESPL
(3) CMAA 70, 2004

2.0 WIRE ROPE CHECK

The following computations are performed to check the wire rope breaking strength against rated load.

2.1 Rope Specification

Wire Rope Type	=	6 X 19		
Wire Rope Diameter, D	=	0.5625	in	(Dwg 40-D-4332)
Wire Rope Breaking Strength, P	=	14.5	ton	(Dwg 40-D-4332)

2.2 Rope Load

Hoist Capacity, C	=	7500	lb
No. of Reeving Parts, N	=	1	
No. of Drums, n	=	2	
Tension in the rope, F_t	=	3750	lb
	=	1.875	ton

2.3 Rope Strength Check

Per Section 4.4.1 of CMAA 70, 2004, for hoisting rope, "The rated capacity load plus the load block weight divided by the number of rope shall not exceed 20 percent plus the load block divided by the number of rope parts shall not exceed the 20 percent of the published breaking strength of the rope."

20% of the rope breaking strength	=	2.9	ton
Rope Tension	=	1.875	ton
Safety Factor	=	7.73	

ROPE MEETS THE RATED LOAD CRITERIA

References

(1) Drawings Provided by CESPL, Dwg # 40-D-4332
(2) CMAA 70, 2004

3.0 DRIVE SHAFT

The following computations are performed to check the drive shaft for torsional and bending stresses.

3.1 Drive Shaft Stress Analysis

Material	=	SAE1040	(Ref#1)
Yield strength, σ_{yp}	=	71	ksi
Ultimate tensile strength, σ_u	=	85	ksi
Permissible bending stress, $\sigma_u/5$	=	17.0	ksi
Permissible torsional shear stress, $\sigma_u/5\sqrt{3}$	=	9.47	ksi
Shaft diameter, D	=	2.4375	in
Torque at drive shaft, T	=	20625	lb-in

(a)Check for torsional shear stress

Per CMAA 4.11.4.1-C,

$$\tau_T = \frac{T \times (d/2)}{J} = T \times \frac{16}{\pi d^3} \le \sigma_u / (5\sqrt{3})$$

= 7.25 ksi < 9.47 ksi
OK

where

T = Torque
d = Shaft diameter
J = Polar moment of inertia

(b) Check for Bending

Per CMAA 4.11.4.1-B,

$$\sigma_B = Mr / I = \frac{32\ M}{\pi d^3} \le \sigma_u / 5$$

Length of the shaft,l	=	60	in	(Approx.)	
Weight of the shaft,w	=	79	lbs		
Maximum bending moment, wl/4	=	1190	in-lb		
σ_B	=	0.84	ksi	<	17.00 ksi OK

(c) Combined bending and torsional shear

Per CMAA 4.11.4.1-E,

$$\sigma_{COMB} = \sqrt{(\sigma_B)^2 + 3(\tau_T)^2} \le \sigma_u / 5$$

= 12.59 ksi < 17.00 ksi
OK

References

(1) Crane Handbook by Whiting Corporation
(2) CMAA 70, 2004
(3) Drawings Provided by CESPL
(4) EM 1110-2-2702, Design of Spillway Tainter Gates

4.0 FORCES FROM HOIST TO GATE UNDER JAMMED CONDITION

The following computations are performed to find the forces on the tainter gate due to hoist system when the gate is jammed. This computations are performed at 200% motor torque.

4.1 Motor Torque (200%)

Gear motor input speed	=	1730	rpm
Ratio of Gear Motor	=	57.67	
Rated Motor HP	=	1.5	HP
200% Motor Torque	=	109.29	in-lb
Gear Mesh	=	3	(Assumed)
Efficiency/Mesh, η_m	=	0.97	(Assumed)
200% Torque at o/p Shaft of Gear Motor	=	5752	in-lb

4.2 Gear Reducer Output Torque

Gear Reducer Type	=	Worm Drive	
Gear Ratio, R_1	=	50	
Efficiency, η_g	=	97	% (Assumed)
Torque at o/p Shaft	=	278973	in-lb

4.3 Torque at Each Drum

Drum Diameter	=	11	in
No of Drum	=	2	
Torque at Each Drum	=	139487	in-lb
Wire Rope Tension at Each Drum,F	=	25361	lb

4.4 Contact Pressure on Gate Elements

Gate Radius,r	=	228	in	(Dwg # 767-D-252)
Contact Pressure Force, Q_3=F/r	=	111	lb/in	

References
(1) EM 1110-2-2702, Design of Spillway Tainter Gates
(2) Drawings Provided by CESPL
(3) SAP 2000 Analysis Results for Existing Tainter Gates

1.0 TRUNNION BEARING

The following computations are performed to find maximumbearing pressure at the existing tainter gates trunnions.

1.1 Material

SAE 64 Bronze bushing

1.2 Bushing Size

Bore diameter, d	=	3.26 in	(Dwg#767-D-252, Ref#2)
Bushing length, l	=	6.00 in	(Dwg#767-D-252, Ref#2)
Area, A= l x d	=	19.56 in^2	

1.3 Trunnion Reaction

Maximum reaction at the trunnion developes under a combination of dead, mud, ice, hydrostatic and earthquake load under gate closed condition. Reactions shown below are for unfactored loads.

X	Y	Resultant Reaction , R
46.79 k	5.49 k	47.11 k

(Ref#3)

1.4 Bearing Pressure

Allowable bearing pressure	=	5000 psi	(Section 4-3(b), Ref # 1)	
Induced bearing pressure, R/A	=	2409 psi	<	5000 psi **OK**

SAP2000

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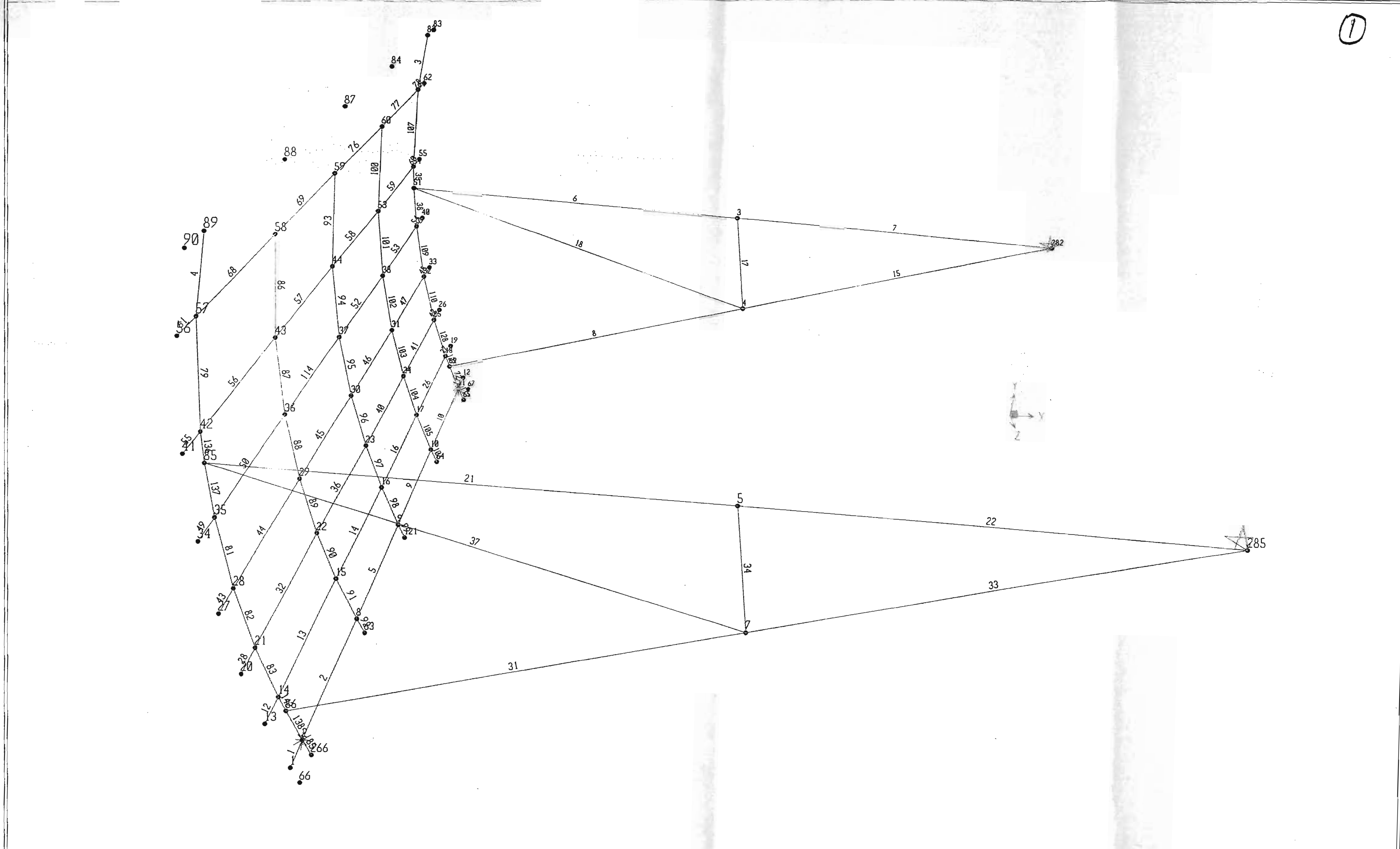

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SAP2000

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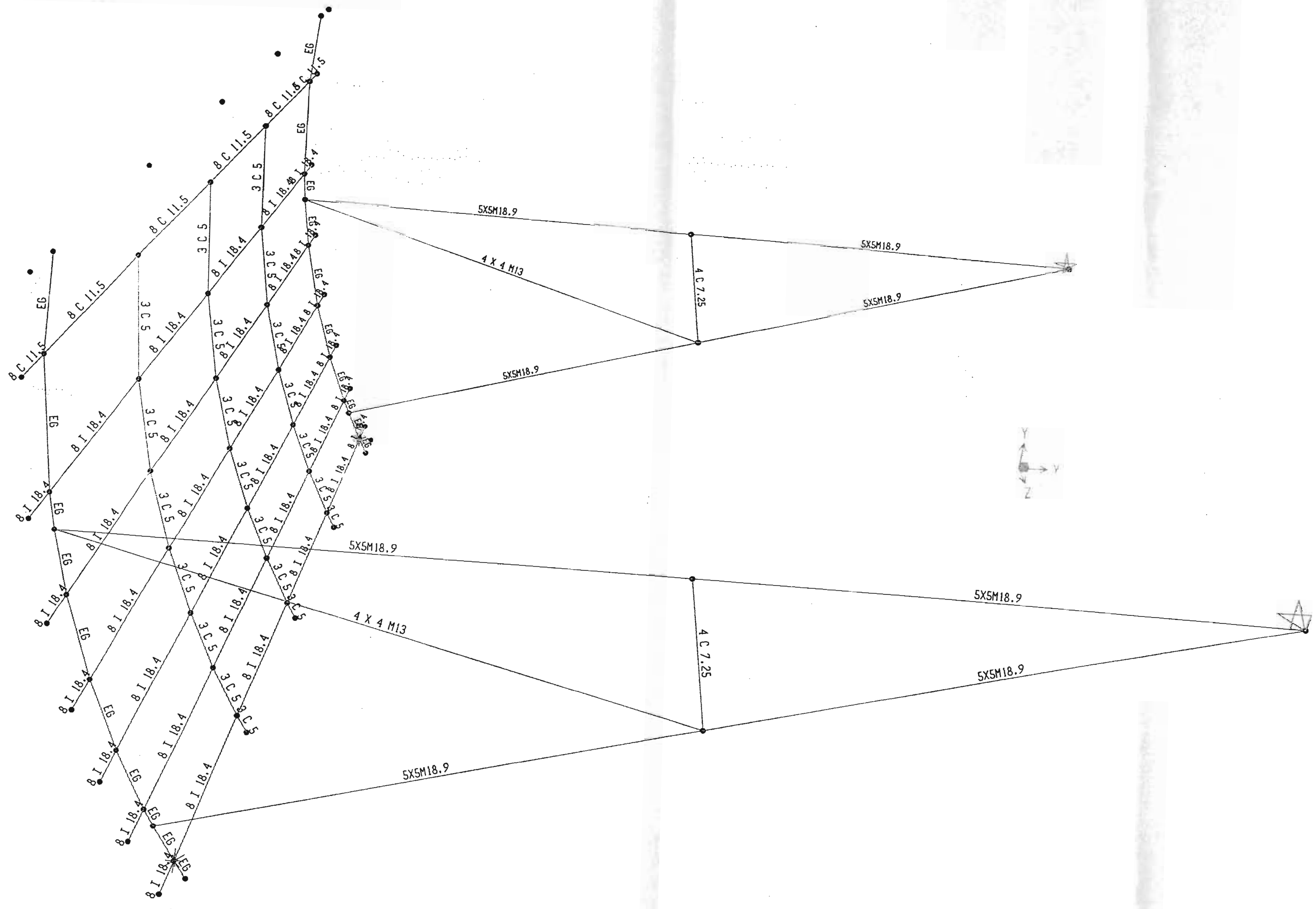
(2)



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SAP2000

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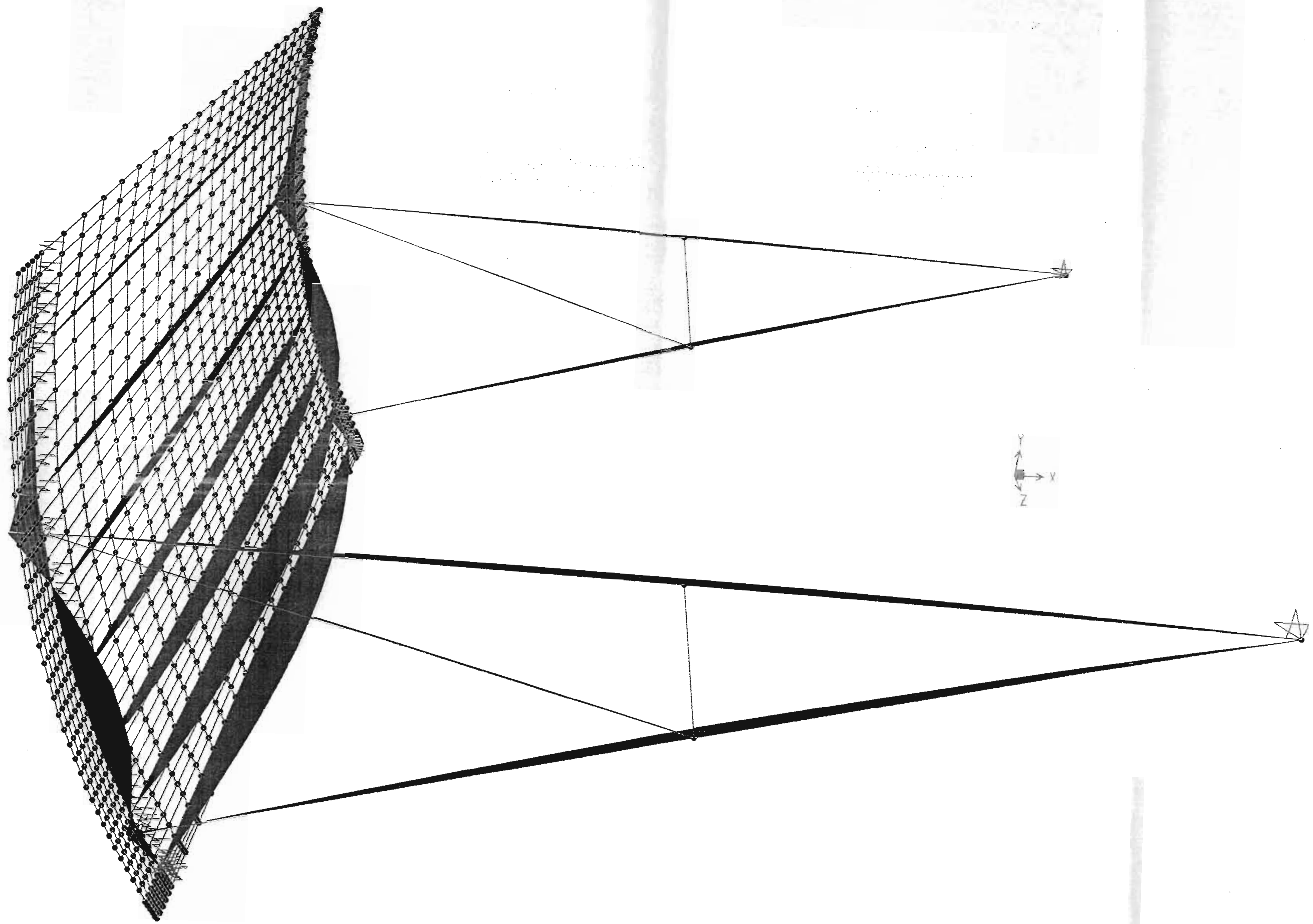
3



SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Moment 3-3 Diagram (1.2D+1.6M+1.6C+1.4H1+1.2Q3 (Gate Jammed)) - Kip, in, F Units

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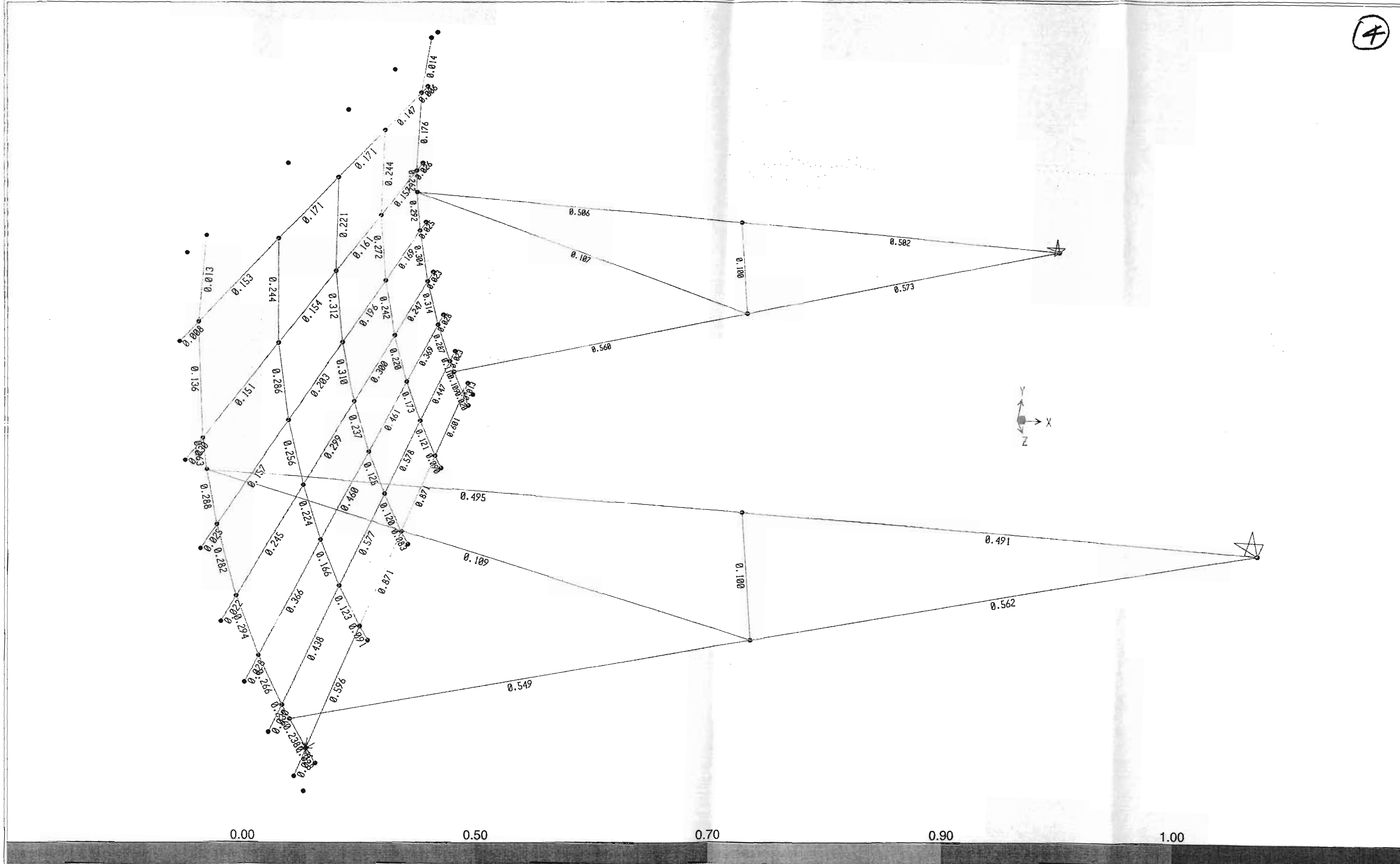
(4)



SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Steel P-M Interaction Ratios (AISC360-05/IBC2006) - Kip, in, F Units

(1.2D + 1.6H + 1.6C + 1.4H, +1.2 Φ) (Gate Jammed)

SAP2000

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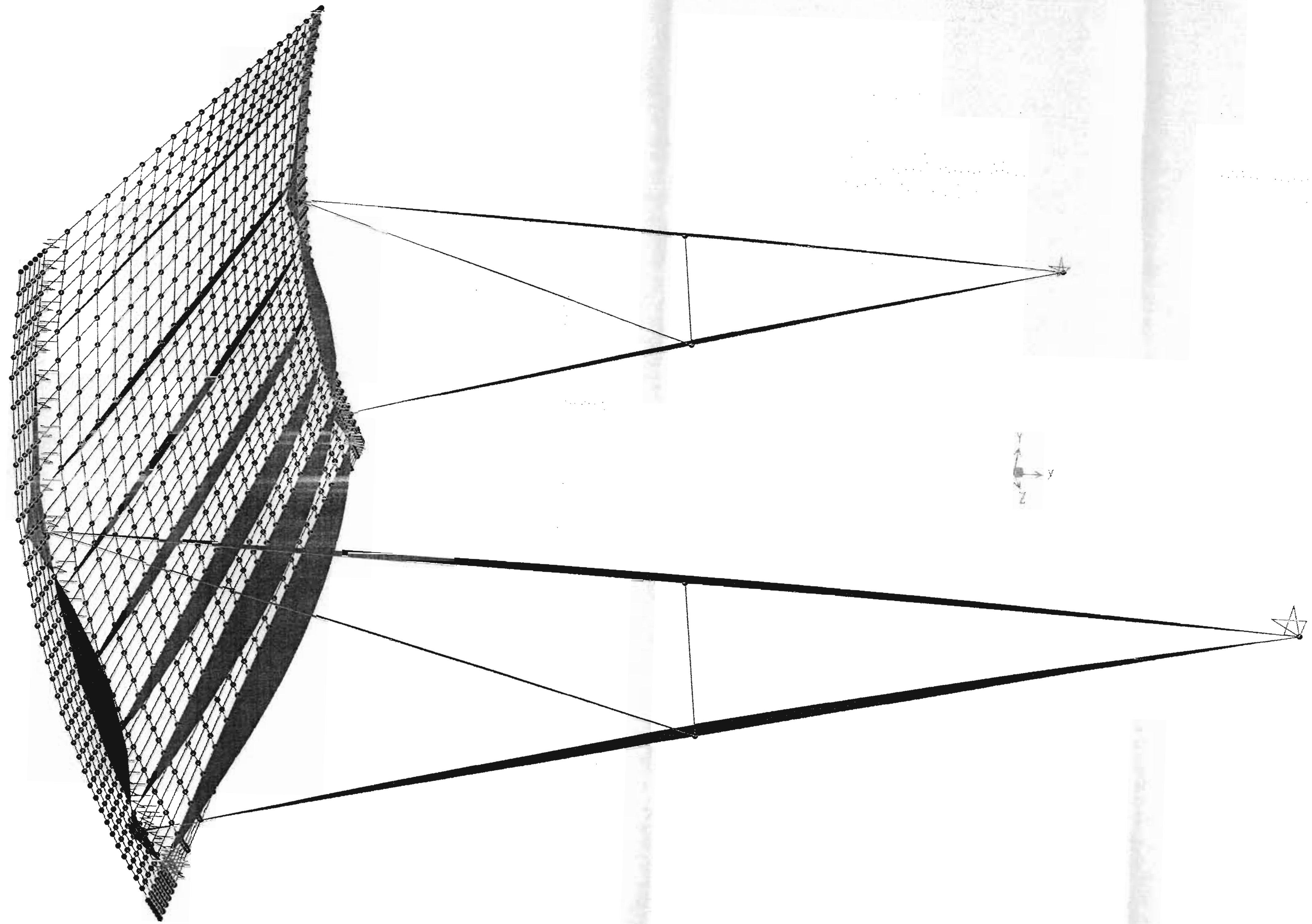
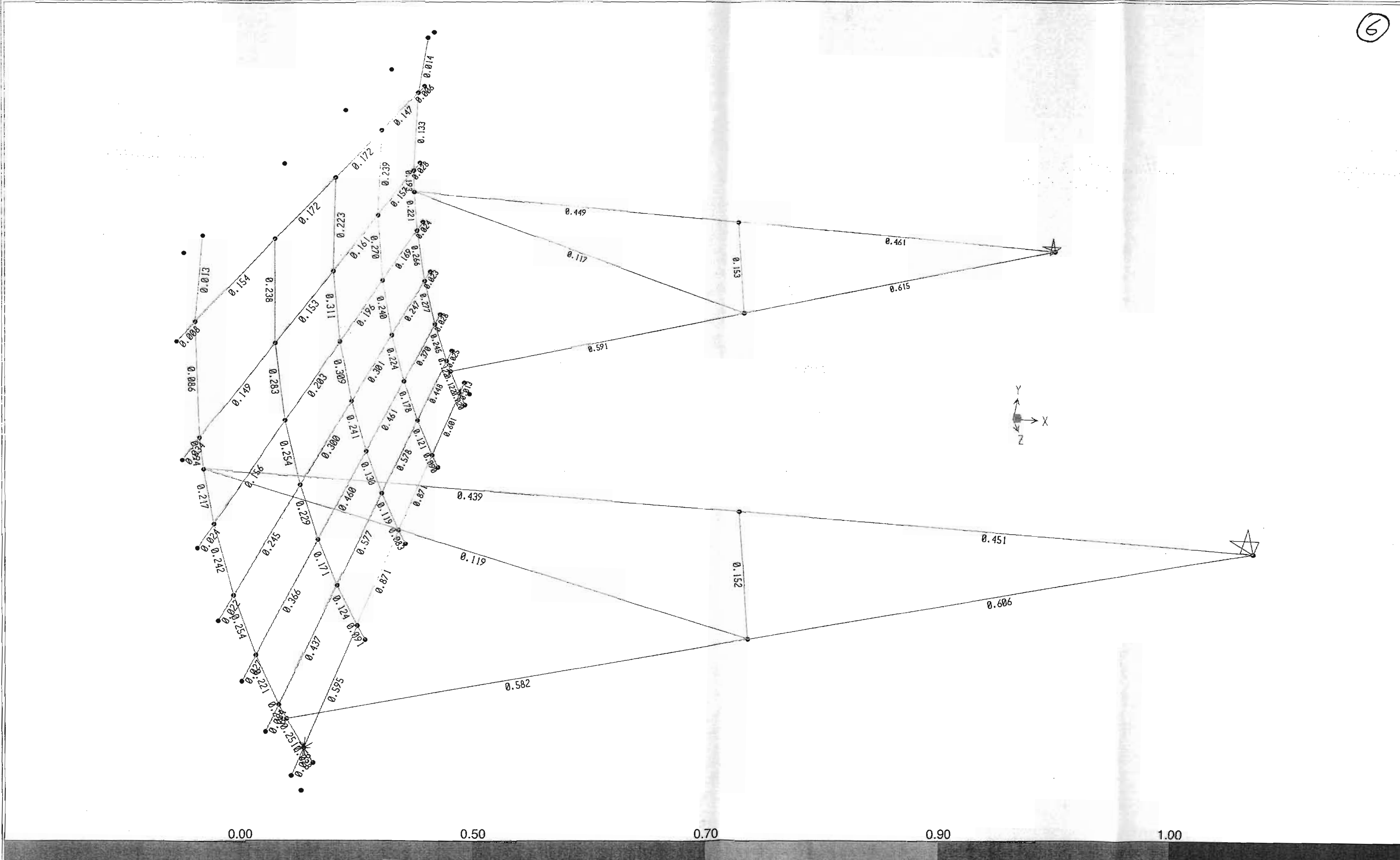


SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Moment 3-3 Diagram (1.2D+1.6M+1.6C+1.4H1+1.4Fs+1.0Ft) - Kip, in, F Units

SAP2000 1/15/09 8:01:02

(6)



SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Steel P-M Interaction Ratios (AISC360-05/IBC2006) - Kip, in, F Units (1.2D+1.6M +1.6C +1.4H, +1.4Fs +1.0Ft)

SAP2000

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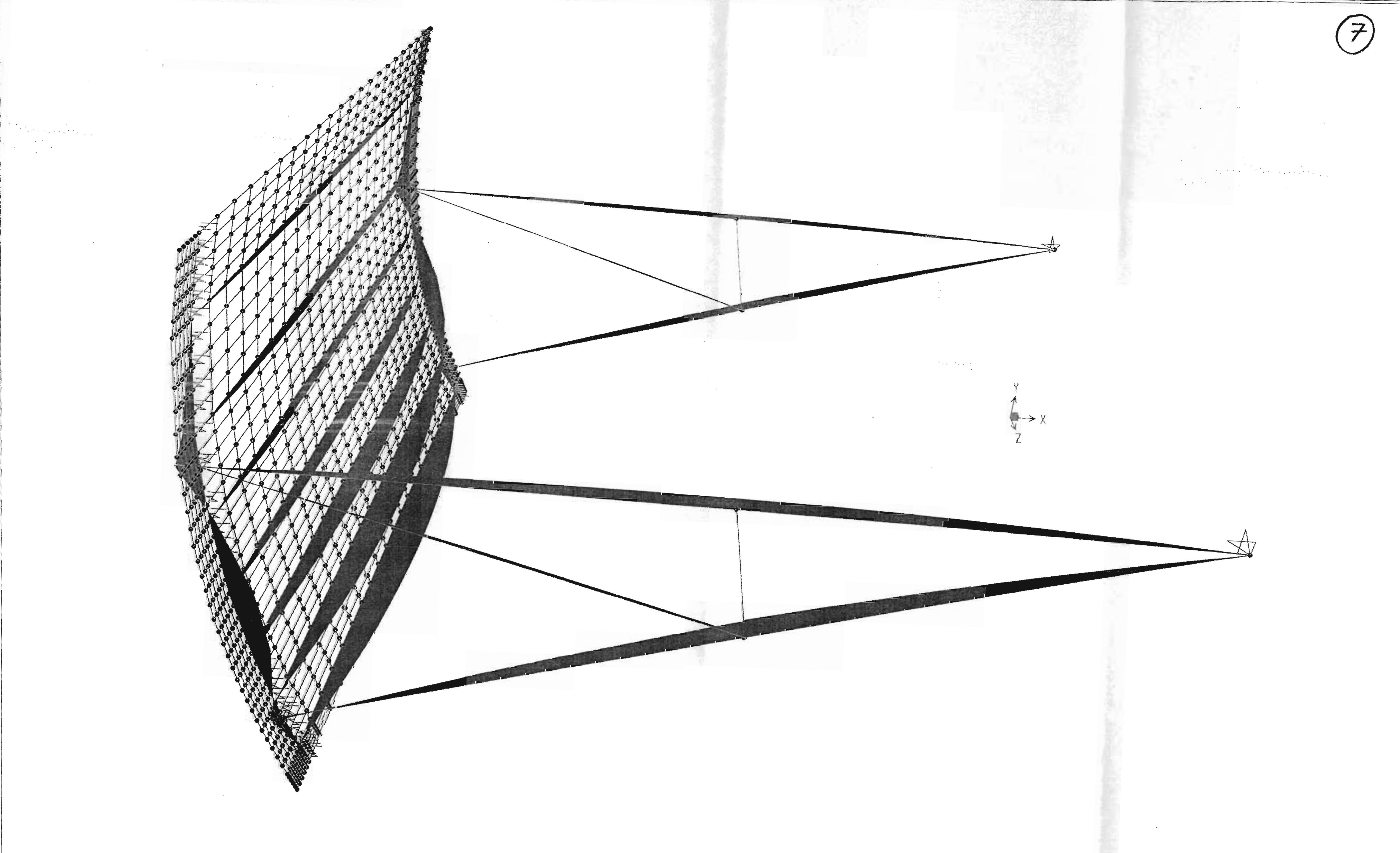
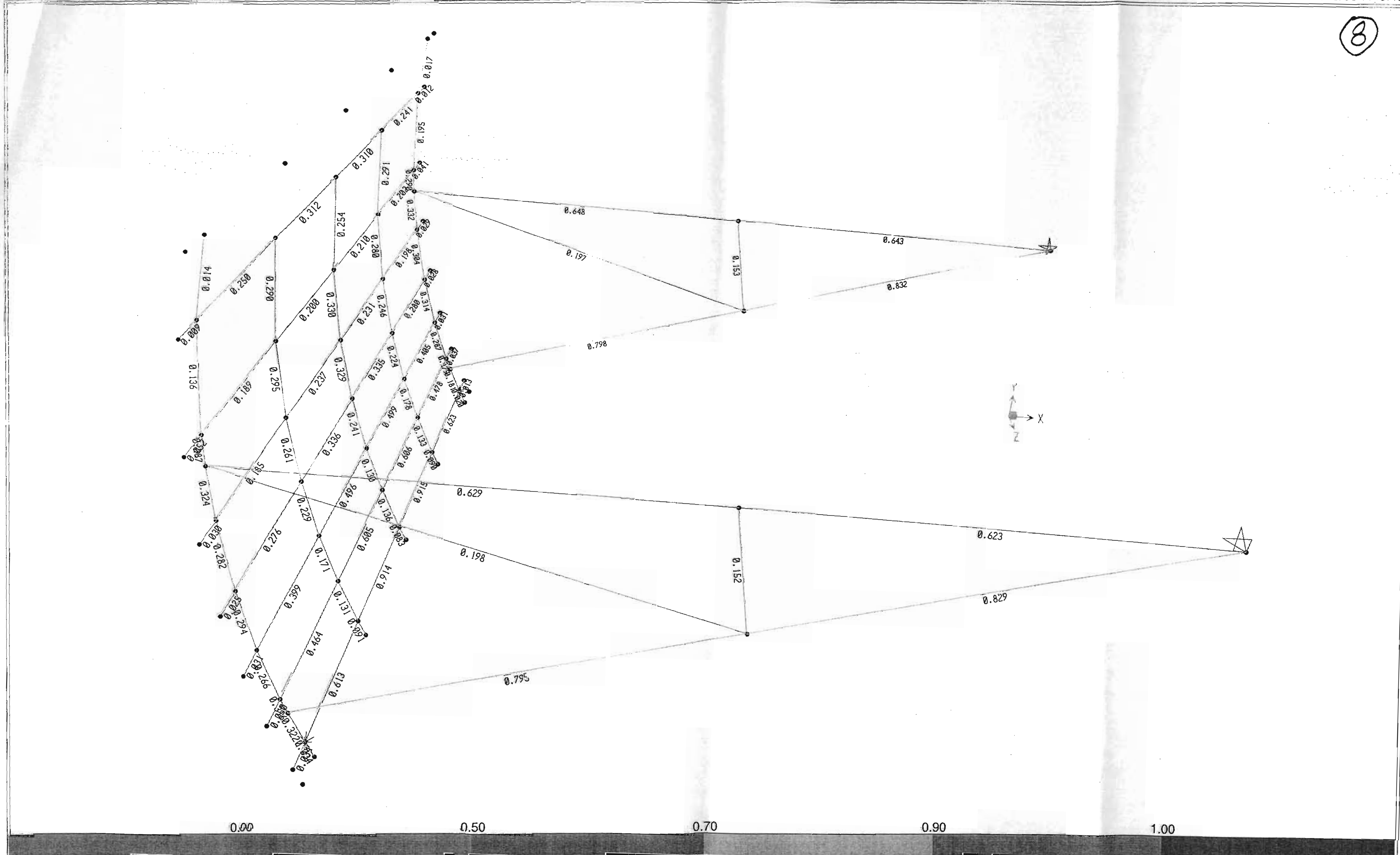


SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Moment 3-3 Diagram (1.2D+1.6M+1.6C+1.2H1+1.0E) - Kip, in, F Units

(8)



SAP2000 v12.0.0 - File:16 ft gate with 2ft extension - Steel P-M Interaction Ratios (AISC360-05/IBC2006) - Kip, in, F Units

(1.2D + 1.6M + 1.6C + 1.2H, + 1.0E)

ENGINEERS INC.

Job Number	08-015H		
Volume/Sheet No.		of	

Client/Contract	Tt/Robles Diversion
Phase/Subject	30 ft Tainter Gate Analysis
Design Topic	Loading Conditions and DCRs

Made By VRG Date 1/16/2008 Checked By SVL Date 3/16/2009 Page No.

Task:

Input
Information
Important

Determine the environmental loads and load combinations for the analysis of the 30 ft tainter gates.

Notes:

1. Environmental loads and load combinations based on EM 1110-2-2702, *Design of Spillway Tainter Gates*, USACE, 1 January 2000.
2. Structural steel is Federal Specification Q-S-741, type II or ASTM Designation A7 (Original Construction Specifications)
3. Site seismicity provided in Table 2 of the *Ground Motion Hazard Evaluation for Robles Diversion Dam Modification Project*, by AMEC Geomatrix, Inc. Oakland, CA, dated November 12, 2008.
4. OBE - 50% probability of exceedence during the service life. This corresponds to a return period of 144 years for a project with a service life of 100 years. [ER 1110-2-1806]
5. AISC Steel Construction Manual, 13th Edition

Calculations:

Loads

Gravity

Selfweight	D	22.50 k	Determined by the finite element modeling.
Mud Weight	M	1.98 k	Based on future silt loading from removal of the Matilija Dam (Upper half of the girders, half filled with silt).

No. Girders	7				
Girder Length	28.58 ft	d	18	b_f	6
γ_m	125 pcf	tw	0.3125	t_f	0.5
Gate Length	30 ft				

Ice Weight	C	0.43 k	Iced surface is one side of skin plate, top of girders, and downstream face of girders.

Iced surface area	741 sf		
Skin Plate	360 sf	Ice thickness	0.13 in
Girders	381 sf	γ_{ice}	56 pcf

Hydrostatic

Max that will ever occur	H_1	12.00 ft	El. for H1	769.75 ft		
Design (10-yr return period)	H_2	12.00 ft	El. for H2	769.75 ft		
Normal (50% annual exceedance)	H_3	12.00 ft	El. for H3	769.75 ft		
			Proposed Sill	757.75 ft	γ_w	62.5 pcf
			Proposed Crest	769.75 ft		

Machinery

Max Downward	Q_1	0.00 k	Wire rope hoist system.
At-Rest Downward	Q_2	0.00 k	Wire rope hoist system.
Max Upward	Q_3	22.50 k	Under gate fully open condition
		0.11 k/in	Contact pressure due to wire rope on gate end girders under gate jammed condition (Maximum Wire Rope Tension/Gate Radius))

Ice Impact	I	0.00 klf	Inflow hydrographs show that the reservoir does not sustain a WSEL sufficiently long to establish icing; collaborated by CMWD Staff.

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Side Seal Friction F_s 0.34 k Eqn. 3-2, EM 2702.

μ_s	0.5	d	3.50 in
l	12.13 ft	h	12.00 ft
l_1	12.13 ft	δ	0.25 in
l_2	0.00 ft	E	900 psi sealsunlimited.com
S	0.83 plf	I	0.0044 in^3
γ_w	62.5 pcf		

Trunnion Pin Friction F_t 0.30 EM 2702

Earthquake E 0.318 g When gate is open - OBE applied to selfweight, mud and ice.

When gate is closed - disregard inertial forces, use hydrodynamic pressure.

Elevation	y	p
769.75 ft	0.00 ft	0.00 psf
768.75 ft	1.00 ft	60.24 psf
767.75 ft	2.00 ft	85.20 psf
766.75 ft	3.00 ft	104.34 psf
765.75 ft	4.00 ft	120.49 psf
764.75 ft	5.00 ft	134.71 psf
763.75 ft	6.00 ft	147.56 psf
762.75 ft	7.00 ft	159.39 psf
761.75 ft	8.00 ft	170.39 psf
760.75 ft	9.00 ft	180.73 psf
759.75 ft	10.00 ft	190.50 psf
758.75 ft	11.00 ft	199.80 psf
757.75 ft	12.00 ft	208.69 psf

Wave W_A 0.00 ft

Wind W 7.29 k ASCE 7-05, Paragraph 6.5.10

q_h	17 psf	A_s	360 sf
G	0.85	I	1.15
C_f	1.4	V	85 mph

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	Load Factors															
	Selfweight	Mud	Ice	Hydrostatic	Hydrostatic	Hydrostatic	Downward	Downward	Upward	Impact	Friction	Friction	Earthquake	Wave	Wind	
Load Cases	D	M	C	H_1	H_2	H_3	Q_1	Q_2	Q_3	I	F_s	F_t	E	W_A	W	
LC 1 - Gate Closed																
Eqn 3-5	1.2	1.6	1.6	1.4				1.2								Extreme Pool
Eqn 3-6A	1.2	1.6	1.6		1.4		1.2									Operating Pool
Eqn 3-6 B	1.2	1.6	1.6		1.4			1.2						1.2		Operating Pool
Eqn 3-6 C	1.2	1.6	1.6		1.4			1.2		k_I						Operating Pool
Eqn 3-7	1.2	1.6	1.6			1.2							1.0			Earthquake
LC 2 - Gate Operating with 2 Hoists																
Eqn 3-8	1.2	1.6	1.6	1.4							1.4	1.0				Extreme Pool
Eqn 3-9 A	1.2	1.6	1.6		1.4						1.4	1.0		1.2		Operating Pool
Eqn 3-9 B	1.2	1.6	1.6		1.4					k_I	1.4	1.0				Operating Pool
LC 3 - Gate Operating with 1 Hoist																
Eqn 3-10	1.2	1.6	1.6		1.4						1.4	1.0				
LC 4 - Gate Jammed																
Eqn 3-11 A	1.2	1.6	1.6		1.4				1.2							
Eqn 3-11 B	1.2	1.6	1.6		1.4		1.2									
LC 5 - Gate Fully Opened																
Eqn 3-12 A	k_d	1.6	1.6												1.3	
Eqn 3-12 B	k_d	1.6	1.6										1.0			
Eqn 3-12 C	k_d	1.6	1.6						1.2							

Gate Opening 0.00 ft

Girder	G-G Linear Spacing	Girder El.	G-G Circular Spacing	Midheight	Tributary Height	Note
A		769.75 ft			0.00 ft	Built Up C
	2.28 ft		2.29 ft	768.61 ft		
B		767.47 ft			2.14 ft	W 18 X 40
	2.00 ft		2.00 ft	766.47 ft		
C		765.47 ft			1.91 ft	W 18 X 40
	1.81 ft		1.83 ft	764.56 ft		
D		763.66 ft			1.76 ft	W 18 X 40
	1.70 ft		1.75 ft	762.81 ft		
E		761.96 ft			1.60 ft	W 18 X 40
	1.50 ft		1.58 ft	761.21 ft		
F		760.46 ft			1.36 ft	W 18 X 40
	1.23 ft		1.33 ft	759.84 ft		
G		759.23 ft			1.17 ft	W 18 X 40
	1.12 ft		1.25 ft	758.67 ft		
H		758.11 ft			0.92 ft	W 18 X 40
	0.36 ft		0.42 ft	757.93 ft		
Bottom		757.75 ft				
	12.00 ft		12.45 ft			

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Location	Elevation	y for H_1	H_{s1}	H_{s1}	E for H_1	E for H_1	y for H_2	H_{s2}	H_{s2}	E for H_2	E for H_2	y for H_3	H_{s3}	H_{s3}	E for H_3	E for H_3
Girder A	769.75 ft	0.00 ft	0 psf	41 plf	0 psf	37 plf	0.00 ft	0.00 psf	41 plf	0 psf	37 plf	0.00 ft	0.00 psf	41 plf	0 psf	37 plf
midheight	768.61 ft	1.14 ft	71 psf		64 psf		1.14 ft	71.28 psf		64 psf		1.14 ft	71.28 psf		64 psf	
Girder B	767.47 ft	2.28 ft	143 psf	295 plf	91 psf	185 plf	2.28 ft	142.55 psf	295 plf	91 psf	185 plf	2.28 ft	142.55 psf	295 plf	91 psf	185 plf
midheight	766.47 ft	3.28 ft	205 psf		109 psf		3.28 ft	204.97 psf		109 psf		3.28 ft	204.97 psf		109 psf	
Girder C	765.47 ft	4.28 ft	267 psf	504 plf	125 psf	235 plf	4.28 ft	267.40 psf	504 plf	125 psf	235 plf	4.28 ft	267.40 psf	504 plf	125 psf	235 plf
midheight	764.56 ft	5.19 ft	324 psf		137 psf		5.19 ft	324.09 psf		137 psf		5.19 ft	324.09 psf		137 psf	
Girder D	763.66 ft	6.09 ft	381 psf	666 plf	149 psf	260 plf	6.09 ft	380.79 psf	666 plf	149 psf	260 plf	6.09 ft	380.79 psf	666 plf	149 psf	260 plf
midheight	762.81 ft	6.94 ft	434 psf		159 psf		6.94 ft	433.94 psf		159 psf		6.94 ft	433.94 psf		159 psf	
Girder E	761.96 ft	7.79 ft	487 psf	775 plf	168 psf	268 plf	7.79 ft	487.09 psf	775 plf	168 psf	268 plf	7.79 ft	487.09 psf	775 plf	168 psf	268 plf
midheight	761.21 ft	8.54 ft	534 psf		176 psf		8.54 ft	533.99 psf		176 psf		8.54 ft	533.99 psf		176 psf	
Girder F	760.46 ft	9.29 ft	581 psf	787 plf	184 psf	249 plf	9.29 ft	580.89 psf	787 plf	184 psf	249 plf	9.29 ft	580.89 psf	787 plf	184 psf	249 plf
midheight	759.84 ft	9.91 ft	619 psf		190 psf		9.91 ft	619.25 psf		190 psf		9.91 ft	619.25 psf		190 psf	
Girder G	759.23 ft	10.52 ft	658 psf	768 plf	195 psf	228 plf	10.52 ft	657.61 psf	768 plf	195 psf	228 plf	10.52 ft	657.61 psf	768 plf	195 psf	228 plf
midheight	758.67 ft	11.08 ft	692 psf		201 psf		11.08 ft	692.45 psf		201 psf		11.08 ft	692.45 psf		201 psf	
Girder H	758.11 ft	11.64 ft	727 psf	529 plf	206 psf	151 plf	11.64 ft	727.30 psf	529 plf	206 psf	151 plf	11.64 ft	727.30 psf	529 plf	206 psf	151 plf
midheight	757.93 ft	11.82 ft	739 psf		207 psf		11.82 ft	738.65 psf		207 psf		11.82 ft	738.65 psf		207 psf	
Bottom	757.75 ft	12.00 ft	750 psf		209 psf		12.00 ft	750.01 psf		209 psf		12.00 ft	750.01 psf		209 psf	

	Load Combinations (w_u)			Bending Moment (M_u)			Shear (V_u)		
Location	(3-5)	(3-6 A,B,C)	(3-7)	(3-5)	(3-6 A,B,C)	(3-7)	(3-5)	(3-6 A,B,C)	(3-7)
Top									
Girder A	57 plf	57 plf	85 plf	70 k-in	70 k-in	105 k-in	0.81 K	0.81 K	1.22 K
Girder B	414 plf	414 plf	540 plf	507 k-in	507 k-in	662 k-in	5.91 K	5.91 K	7.72 K
Girder C	706 plf	706 plf	840 plf	865 k-in	865 k-in	1029 k-in	10.09 K	10.09 K	12.00 K
Girder D	933 plf	933 plf	1059 plf	1143 k-in	1143 k-in	1298 k-in	13.33 K	13.33 K	15.14 K
Girder E	1085 plf	1085 plf	1198 plf	1329 k-in	1329 k-in	1467 k-in	15.50 K	15.50 K	17.12 K
Girder F	1101 plf	1101 plf	1193 plf	1349 k-in	1349 k-in	1462 k-in	15.74 K	15.74 K	17.05 K
Girder G	1075 plf	1075 plf	1150 plf	1318 k-in	1318 k-in	1409 k-in	15.37 K	15.37 K	16.44 K
Girder H	740 plf	740 plf	785 plf	907 k-in	907 k-in	962 k-in	10.58 K	10.58 K	11.22 K
Bottom									

Unfactored Trunnion Reactions for Lateral Loads

Load Type	Load	Trunnion 1	Trunnion 2
Hydrostatic Load	135.00 kip	67.50 kip	67.50 kip
Earthquake Load (Gate Closed)	48.40 kip	24.20 kip	24.20 kip
Equipment Load (Gate Jammed)	24.54 kip	12.27 kip	12.27 kip
Wind	7.29 kip	3.64 kip	3.64 kip
Overtopping	270.00 kip	135.00 kip	135.00 kip

(Checked by PD)

Girder A Section Modulus (Built up Channel)

Element	b (in)	h (in)	t (in)	A (in^2)	X (in)	AX (in^3)	d (in)	I_0 (in^4)	Ad^2 (in^4)
D/S Flange	4.000		0.250	1.00	17.88	17.88	8.88	0.01	78.77
Web		17.500	0.250	4.38	9.00	39.38	0.00	111.65	0.00
U/S Flange	4.000		0.250	1.00	0.13	0.13	8.88	0.01	78.77
SUM				6.38		57.38		111.66	157.53

X_{bar}	9.0 in
I_{xx}	269.2 in^4
Sxc	29.9 in^3
Sxt	29.9 in^3

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Span 28.58 ft F_y 50 ksi α 0.85 Φ_b 0.90 E 29000 ksi

Location	Section Modulus	Flexural Capacity	Flexural Demand to Capacity Ratio (3-5)	(3-6 A,B,C)	(3-7)	Moment of Inertia Ixx	Deflection H_{s1}
Top							
Girder A	29.9 in^3	1144.1 kip-in	0.06	0.06	0.09	269 in^4	0.08 in
Girder B	68.4 in^3	2616.3 kip-in	0.19	0.19	0.25	612 in^4	0.25 in
Girder C	68.4 in^3	2616.3 kip-in	0.33	0.33	0.39	612 in^4	0.43 in
Girder D	68.4 in^3	2616.3 kip-in	0.44	0.44	0.50	612 in^4	0.56 in
Girder E	68.4 in^3	2616.3 kip-in	0.51	0.51	0.56	612 in^4	0.66 in
Girder F	68.4 in^3	2616.3 kip-in	0.52	0.52	0.56	612 in^4	0.67 in
Girder G	68.4 in^3	2616.3 kip-in	0.50	0.50	0.54	612 in^4	0.65 in
Girder H	68.4 in^3	2616.3 kip-in	0.35	0.35	0.37	612 in^4	0.45 in
Bottom							

Girder	Lateral Torsional Buckling		Flange Local Buckling		Compression Flange Yielding		Flexural Capacity	
Girder A (Built up Channel)	Property		Property		Property		Property	
	Ix	269.20 in^4	Compact?	No	Zx	36.89 in^3	Φb	0.90
	A	6.38 in^2	Check Applies?	Yes	Rpc	1.23	Mn	1845 kip-in
	r_y	6.50 in	h/t_w	70	Mn	1845 kip-in	αΦbMn	1411 kip-in
	Check Applies?	No	K_c	0.48	λpw	90.55	Mu	70 kip-in
	Lb	42.88 in	λp	9.15	λrw	137.27	DCR	0.05
	Lp	275.44 in	λr	18.91	Mp	1845 kip-in	Okay?	Yes
			λ	16.00	Myc	1496 kip-in		
Girders B to H (W 18 x 40)	Property		Property		Check Not Required		Check Not Required	
	Ix	612.00 in^4	Compact?	Yes				
	A	11.80 in^2	Check Applies?	No				
	r_y	7.20 in	λp	9.15				
	Check Applies?	No	λr	24.08				
	Lb	42.88 in	λ	6.00				
	Lp	305.25 in						

References

(1) EM 1110-2-2702, Design of Spillway Tainter Gates
(2) 30 ft x 12 ft Tainter Gate Design Spreadsheet
(3) Joint Reactions from SAP Analysis

1.0 TAINTER GATE HOIST SELECTION

The following computations are performed to find the required capacity of 30 ft x 12 ft tainter gate hoist.

1.1 Capacity

Trunnion Moment Mz	=	71	kip-in	(for μ=0.3, Unfactored Hydrostatic Load)
Lift Radius, r	=	233	in	

Load Type	Load		
30 ft x 12 ft Tainter Gate Lifted Load (Based on CG)	19.00	kip	
Mud Load	1.98	kip	(Ref#2)
Ice Load	0.43	kip	(Ref#2)
Side Seal Friction Load	0.34	kip	(Ref#2)
Force to Overcome Trunnion Friction Load	0.61	kip	(2*Mz/r)
Total	22.36	kip	
	11.18	ton	(Assume
	13.97	ton	25% overload)

Choose 15 ton hoist.

1.2 Lifting Speed

Lifting speed requirement for the tainter gate is 1.75 fpm.

1.3 Lift

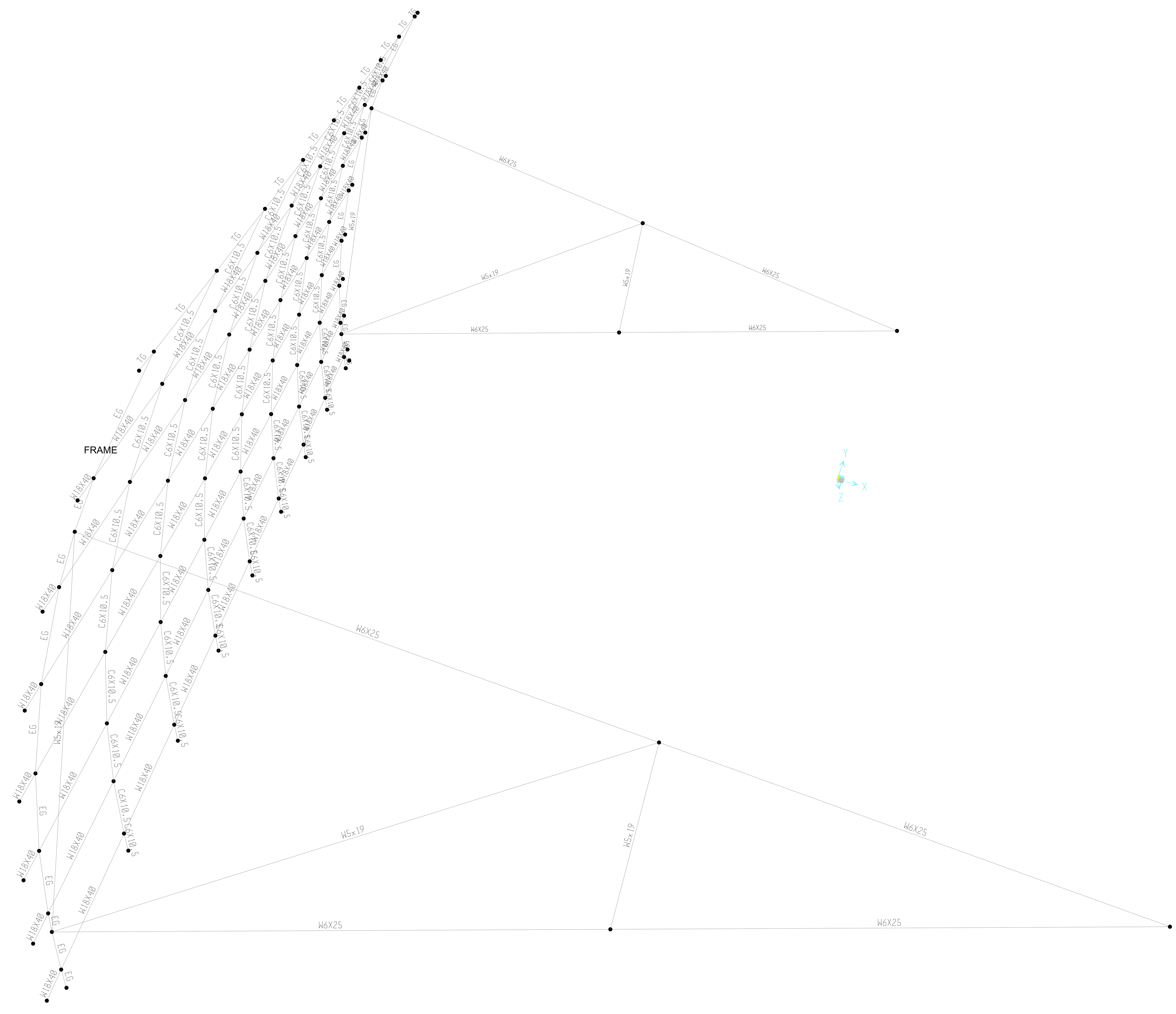
Gate Sill El.	=	757.75	ft	(Proposed)
Hoist Deck El.	=	780.80	ft	(Proposed)
Lift	=	23.05	ft	(Minimum)
		25.00	ft	(Selection)

1.4 Wire Rope Pick Point Distance

Wire rope pick point distance for 30 ft tainter gate is 343 in.

1.5 Hoist Type

Floor mounted hoist with structural steel base.



SAP2000 v15.0.1 - File:30FTX1~1 - 3-D View - Kip, in, F Units

Frame Sections

SAP2000

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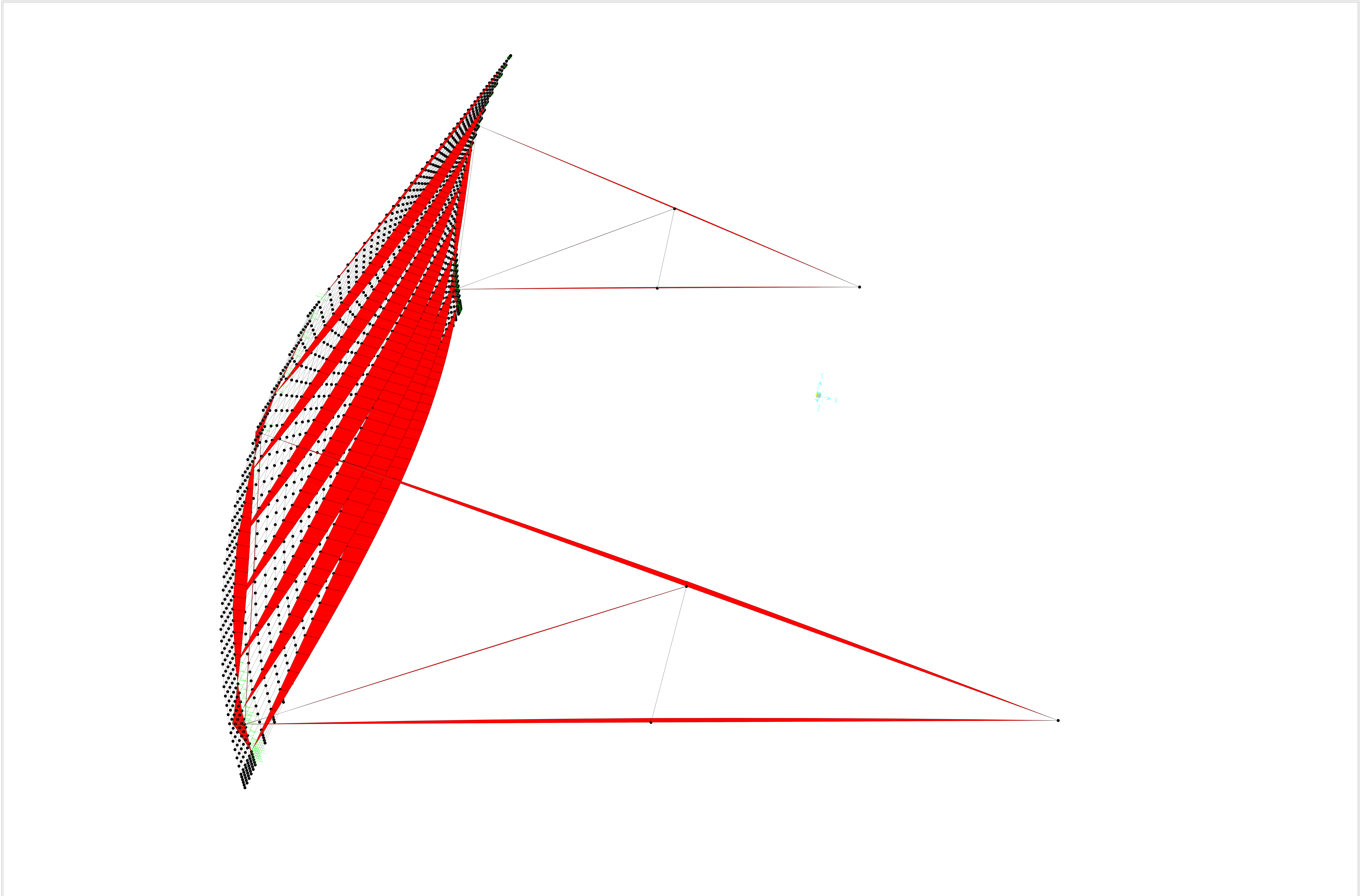
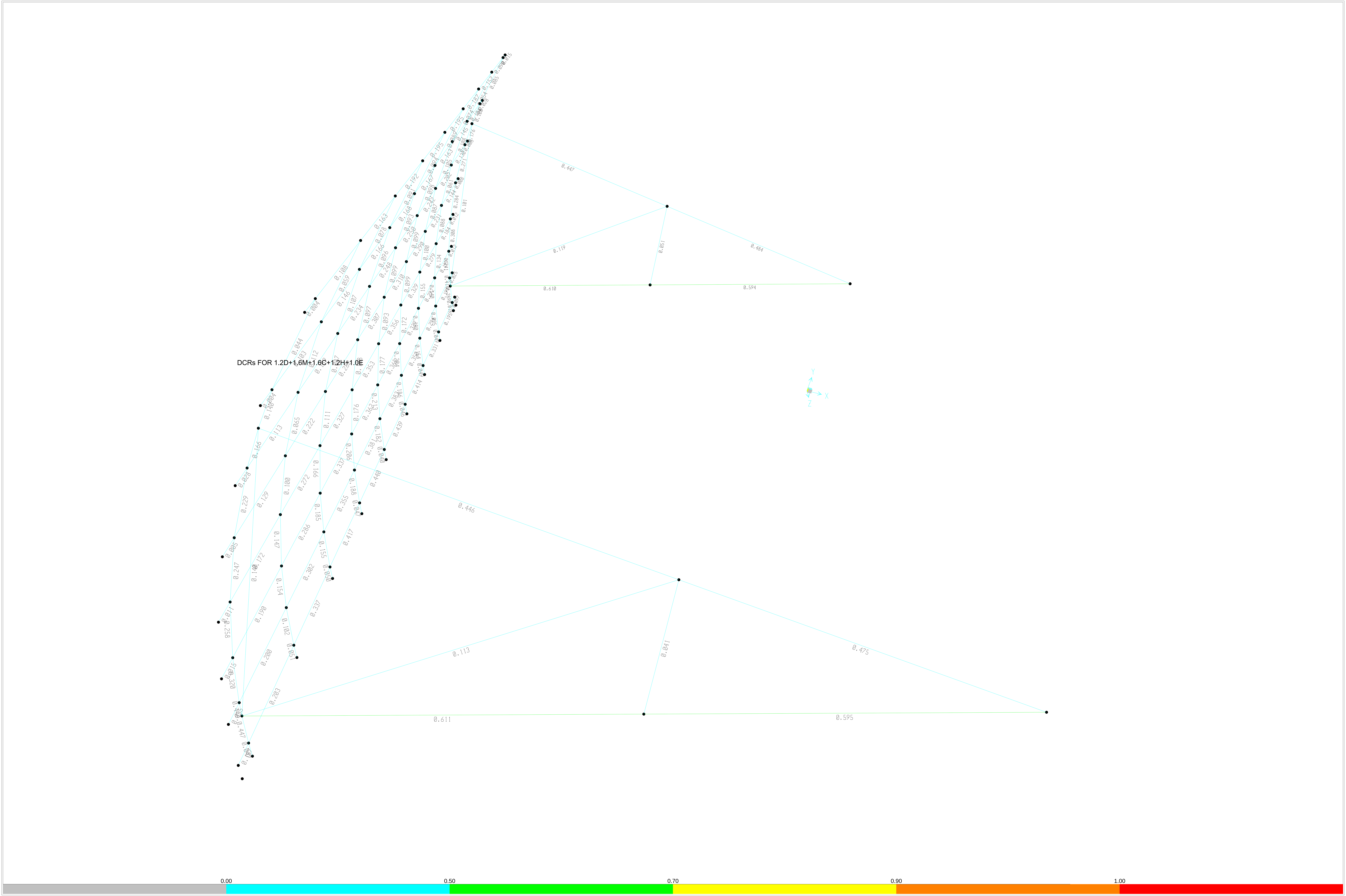


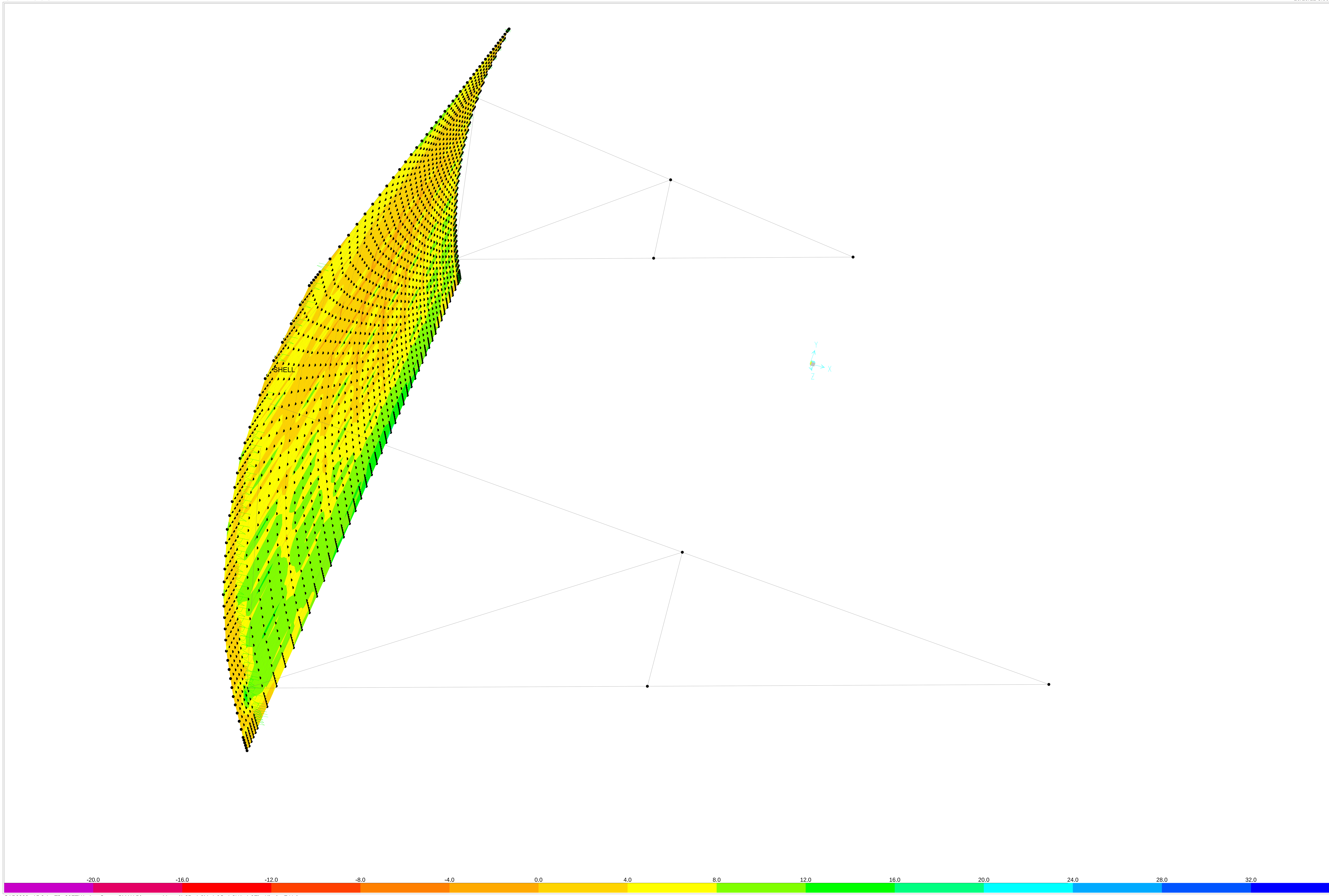
SAP2000 v15.0.1 - File:30FTX1~1 - Moment 3-3 Diagram (1.2D+1.6M+1.6C+1.2H1+1.0E) - Kip, in, F Units

Load Combination 5 Frame Moment

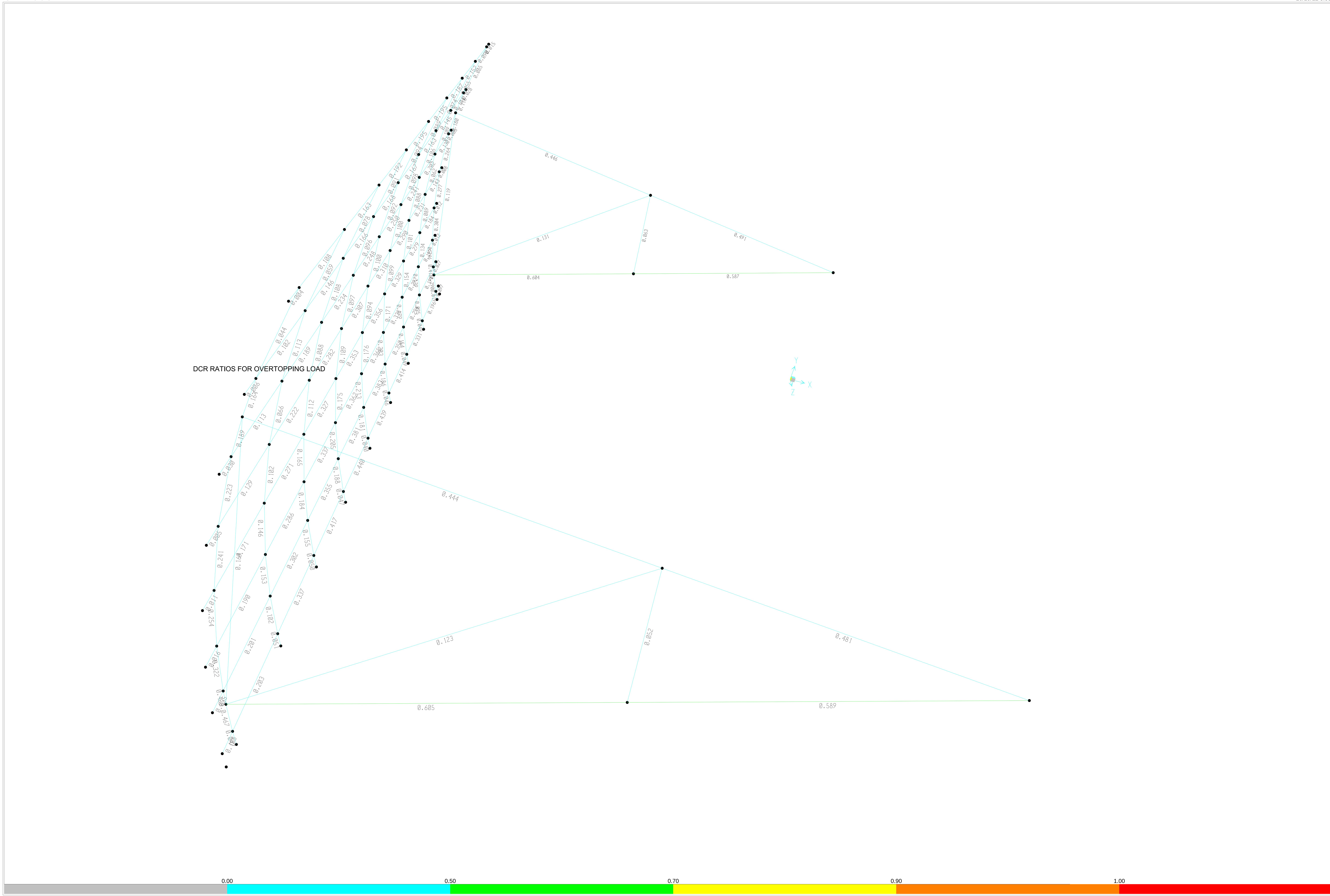


SAP2000 v15.0.1 - File:30FTX1~1 - Steel P-M Interaction Ratios (AISC360-05/IBC2006) - Kip, in, F Units

Load Combination5 DCR Ratios



Shell Stresses Load Combination 5



SAP2000 v15.0.1 - File:30FTX1~1 - Steel P-M Interaction Ratios (AISC360-05/IBC2006) - Kip, in, F Units

DCR Ratios Overtopping Case

SAP2000

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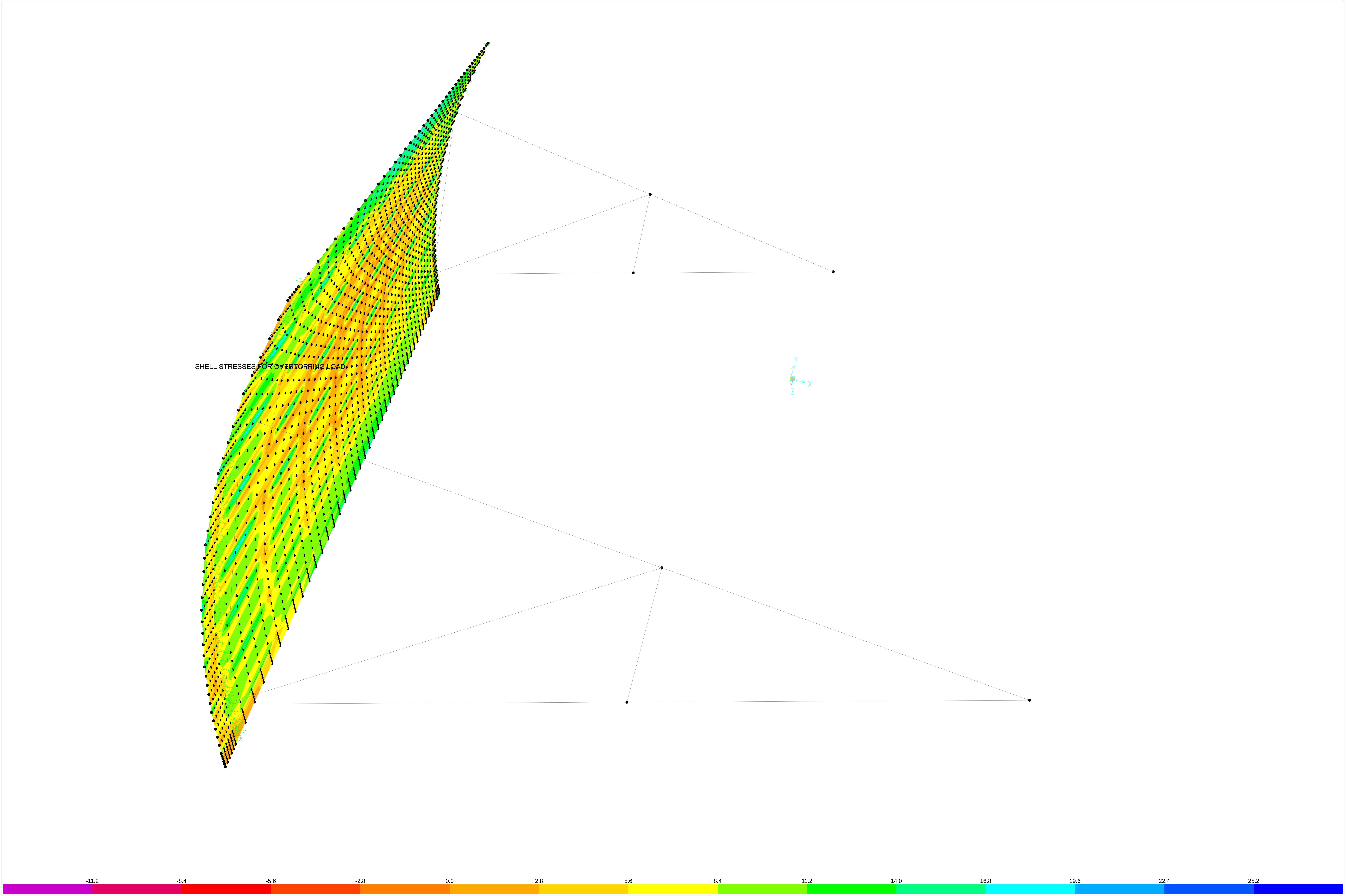

SAP2000 v15.0.1 - File:30FTX1~1 - Stress SMAX Diagram - Max (Overtopping) - Kip, in, F Units

Shell Stresses Overtopping Case

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References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009

2. Design Criteria

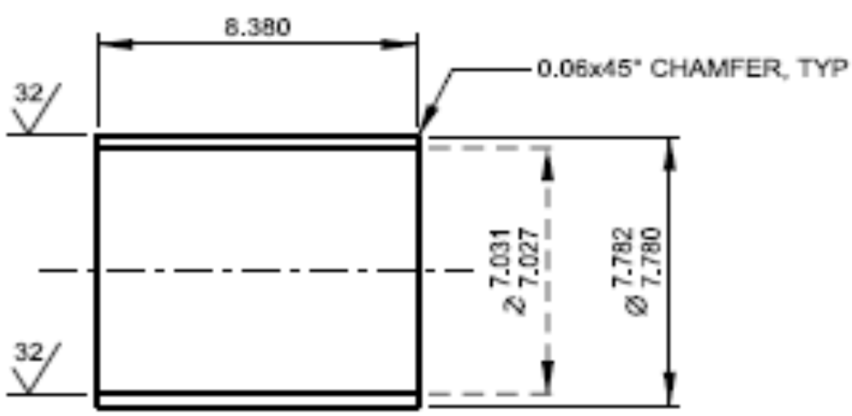
3. Design Drawing, M-11

4. EM 1110-2-2702 Design of Spillway Tainter Gates

5. Lubron Self Lubricating Bearings Catalog

6. Manual of Steel Construction, AISC, ASD, 9th Edition

1.Trunnion Bearing Selection



Trunnion Bearing Basic Geometry

D_o	=	7.78 in
L	=	8.38 in
Di	=	7.02 in

1.1 Maximum Load

As per SAP analysis performed by INCA Engineers, Inc. on March 16, 2009. The load case with the combination of Self Weight , Mud, Ice, Max. Hydrostatic and Seismic loads results in a maximum reaction at the Trunnion.

Load Combination	=	Self Weight + Mud + Ice + Max. Hydrostatic + Seismic	
Horizontal Reaction, Fx	=	-94 kip	(Un-factored Load)
Vertical Reaction, Fy	=	-11 kip	(Un- factored Load)
Resultant Reaction, R	=	95 kip	

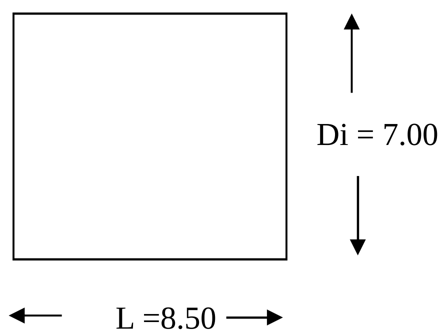
Adding an additional 5 kip to the resultant reaction to account for the inaccuracies in computation.

Maximum Bearing Design Load	=	100 kip

1.2 Allowable Bearing Pressure

Material	=	Orkot C378	
Ultimate Stress, Fu	=	40 ksi	(Compressive Stress)
Allowable Stress,	=	5000 psi	

1.3 Trunnion Bearing Pressure Calculation



Bearing Projected Surface

Bearing Inner Diameter, Di	=	7.02 in	
Bearing Effective Length, L	=	8.38 in	
Bearing Projected Area, A =0.7*Di*L *(30 % reduction is accounted for, as a result of embedded self lubricating plugs)*	=	41.2 in^2	
Maximum Bearing Load, F	=	100 kip	*(Refer Sec 1.1)*
Bearing Pressure, P = F/A	=	2428 psi	< 5000 psi OK

1.4 Bearing Dimensional Specifications

Bearing Inner Diameter, Di	=	7.020 in
Bearing Outer Diameter, Do	=	7.780 in
Bearing Thickness, t	=	0.380 in
Bearing Length, L	=	8.380 in

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Mechanical Properties

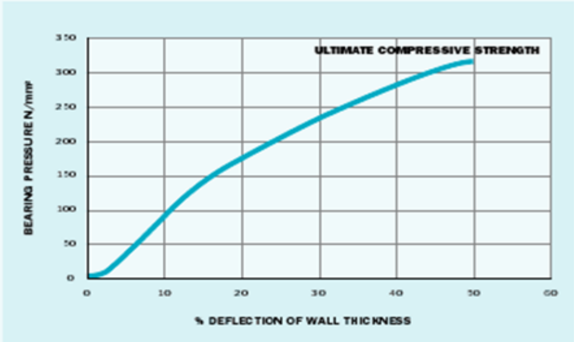
Under compressive load, standard Orkot® grades behave in an elastic manner up to a yield point. Beyond this, permanent deformation may occur. The yield point relates to the shape of the part and to some extent to the operating temperature.

To keep a safe distance from the yield point when designing a bearing, our general recommendation is for most static applications a maximum design load of 80 N/mm², with 40 N/mm² maximum for dynamic applications. However, dynamic application is also dependant on the PV (pressure x velocity) value (see page 12).

These values are with fully supported bearing surfaces and forces perpendicular to the laminations. For forces applied parallel to the laminations, such as on the end face of a flanged bush, only light loads should be used, typically to a maximum of 40 N/mm² for static loading and 20 N/mm² for dynamic. Higher loads may require the use of, for example, separate thrust washers made from a flat laminate sheet.

Higher load values than those indicated above have been used for specific applications.

Please contact TSS Product Management for assistance if your applications exceeds these values.



Typical deflection under load for a cylindrical bearing

As with all composite bearings, the effective Elastic Modulus in an application for Orkot® materials is very dependent upon the shape of the component and the support provided for it. Modulus values for Orkot® standard grades range from 800 N/mm² to 3000 N/mm². Thus, calculating the deformation of a pad or the degree by which a shaft moves off the center line when under load is complex and depends on the wall thickness, any shaft misalignment and the bearing clearance.

Please contact TSS Product Management for assistance if bearing deflection is important in your application.

Wall Thickness

To allow the correct balance of wall pressure and hoop stress with an interference fit, a minimum wall thickness is required for bushes. The minimum wall thickness indicated below should also be used where possible since excessive wall thickness can result in increased clearance requirements to accommodate thermal expansion and swell if used in water. Also, the lower wall thickness allows more accurate control of final fitted bush size.

Thinner wall sections can be used depending on the application details. Please inquire if a thinner wall thickness is required to fit existing hardware. Alternatively, thin walled bushes can be fitted using adhesive or designed as a split ring mounted in a closed groove.

Shaft Diameter (mm)	Minimum Wall Thickness (mm)
6 – 25	1.5
26 – 50	2.5
51 – 75	3.5
76 – 100	5.0
101 – 150	6.5
151 – 200	8.0
201 – 280	10.0
280 – 400	12.0
400 +	Consult TSS

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Design Topic	Trunnion Yoke Calculation							
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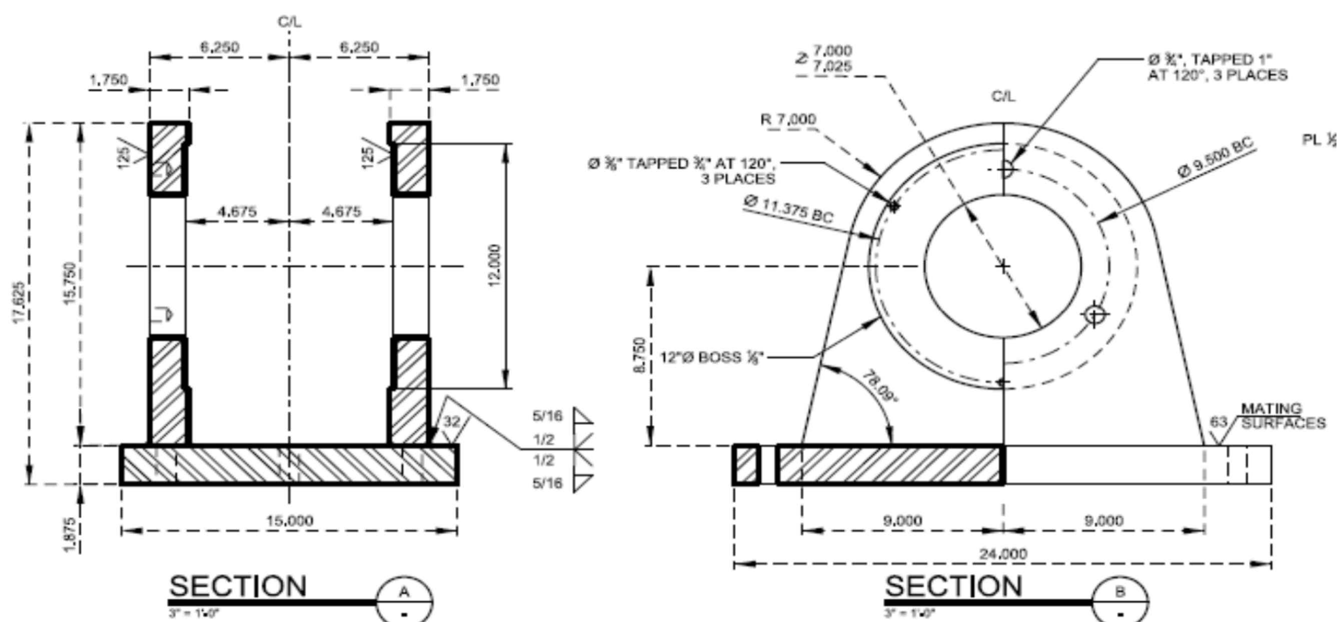
References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009
2. Design Criteria
3. Roark's Formulas for Stress and Strain, 7th Edition
4. EM 1110-2-2702 Design of Spillway Tainter Gates
5. Manual of Steel Construction, AISC, ASD, 9th Edition
6. SolidWorks and COSMOSWorks, 2009 3D Modelling and Analysis Software

2. Trunnion Yoke Stress Calculation



TRUNNION YOKE

Contract/Client	Tt/Robles Diversion		
Phase/Subject	Robles Diversion Tainter Gates		
Design Topic	Trunnion Yoke Calculation		

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2.1 Trunnion Yoke Material and Allowable Stress Calculation

Material	=	ASTM A709	
Yield Strength, Fy	=	50	ksi
Ultimate Strength, Fu	=	65	ksi
Allowable Stress, 0.33*Fy	=	16.5	ksi

2.2 Trunnion Yoke Bearing Stress Calculation

Diameter of the Yoke Hole, D_1	=	7.00	in	
Thickness of the Yoke plate,t	=	1.75	in	
Effective Bearing Area, $A = 2*D_1*t$	=	25	in^2	
Maximum load, F	=	100	kip	*(See. Sec 1.1)*
Bearing Stress = F/A	=	4.1	ksi	< 16.5 ksi OK

2.3 Trunnion Yoke Contact Stress Calculation

Material	=	ASTM A709
Yield Strength, Fy	=	50 ksi
Ultimate Strength, Fu	=	65 ksi
Allowable Stress, 0.33*Fy	=	16.5 ksi
Elatic Modulus, E	=	29000 ksi

Diameter of the Yoke Hole, D_1	=	7.025 in	
Diameter of the Trunnion Pin, D_2	=	7.000 in	
Thickness of the Yoke Plate, t	=	1.75 in	
Maximum Load, F	=	100 kip	*(See. Sec 1.1)*
Load on each Yoke Plate, L =F/2	=	50 kip	
Load per unit length, P = L/t	=	29 kip/in	
$K_D = \dfrac{D_1 D_2}{D_1 - D_2}$	=	1967	*(Ref 3. Case 2c. Pg. 703)*

Maximum Compressive Stress,

$(\sigma_c)_{\max} = 0.591\sqrt{\dfrac{PE}{K_D}}$	=	12.1 ksi	< 16.5 ksi OK

2.4 Trunnion Yoke Finite Element Analysis

Summary

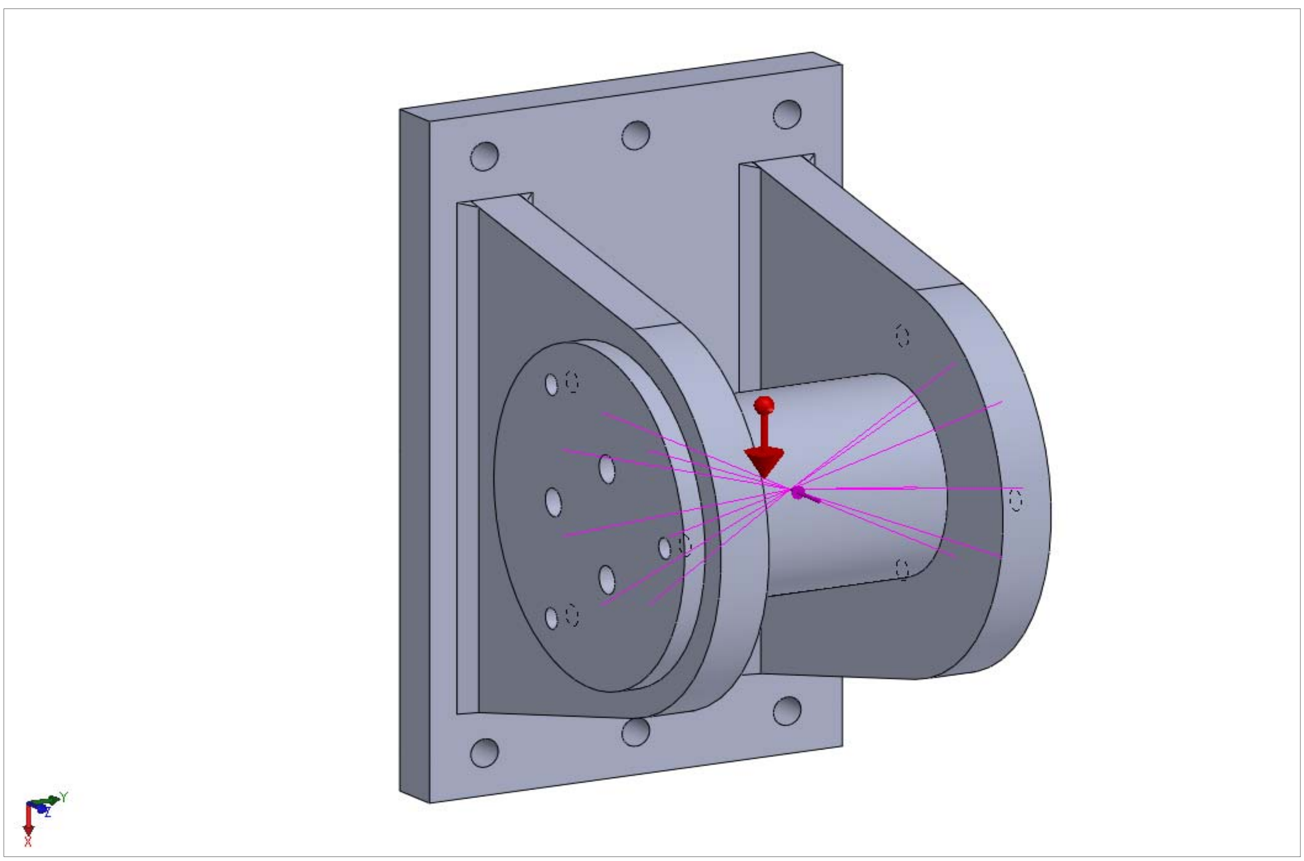
Stresses observed in the Trunnion Yoke are all with in the allowable range. The Maximum Von Mises stress was observed at the Trunnion yoke bearing area edge. The deflection plot showed very minimal deflection. The table below summarizes the stresses observed in the Trunnion Yoke.

Stress	Maximum (ksi)	Allowable (ksi)	Location
1.Von Mises	12.6	16.5	Trunnion Yoke
2. Sx	3.0	16.5	Trunnion Yoke
3. Sy	2.5	16.5	Trunnion Yoke Weld
4. Sz	11.4	16.5	Trunnion Yoke

2.4.1 Analysis Approach

(a) Model Type

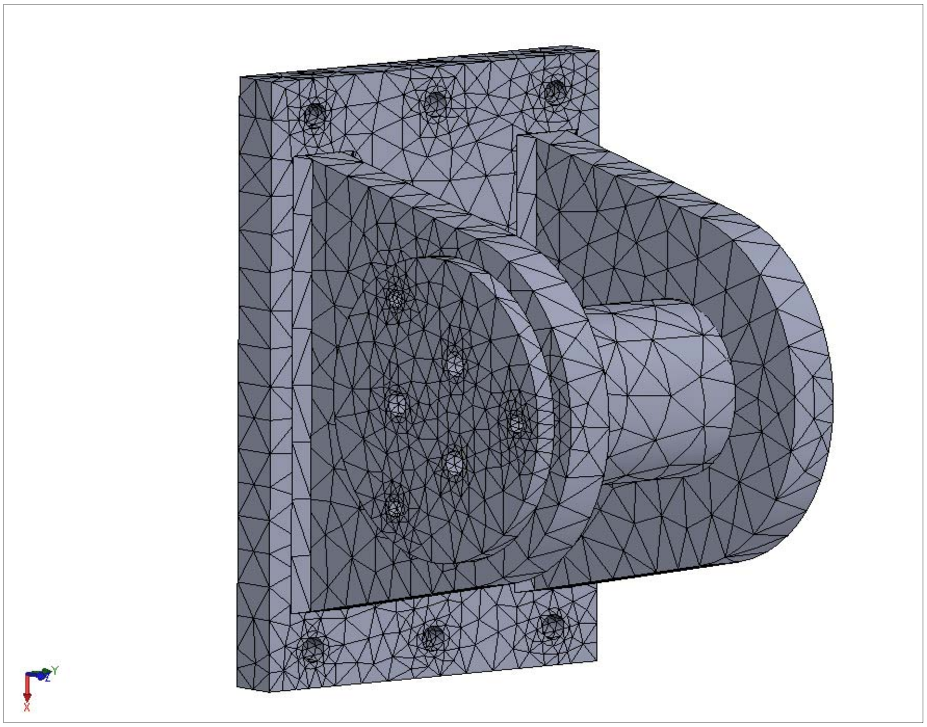
The Trunnion Yoke is analyzed using 3D solid, FEA model. The 3D model of the assembly is created using SolidWorks 2009 and analyzed using COSMOSWorks 2009. (See design drawings for the detailed dimensions and geometry of the trunnion yoke model.)



Trunnion Yoke Model

(b) Mesh

The model consists of curvature based mesh

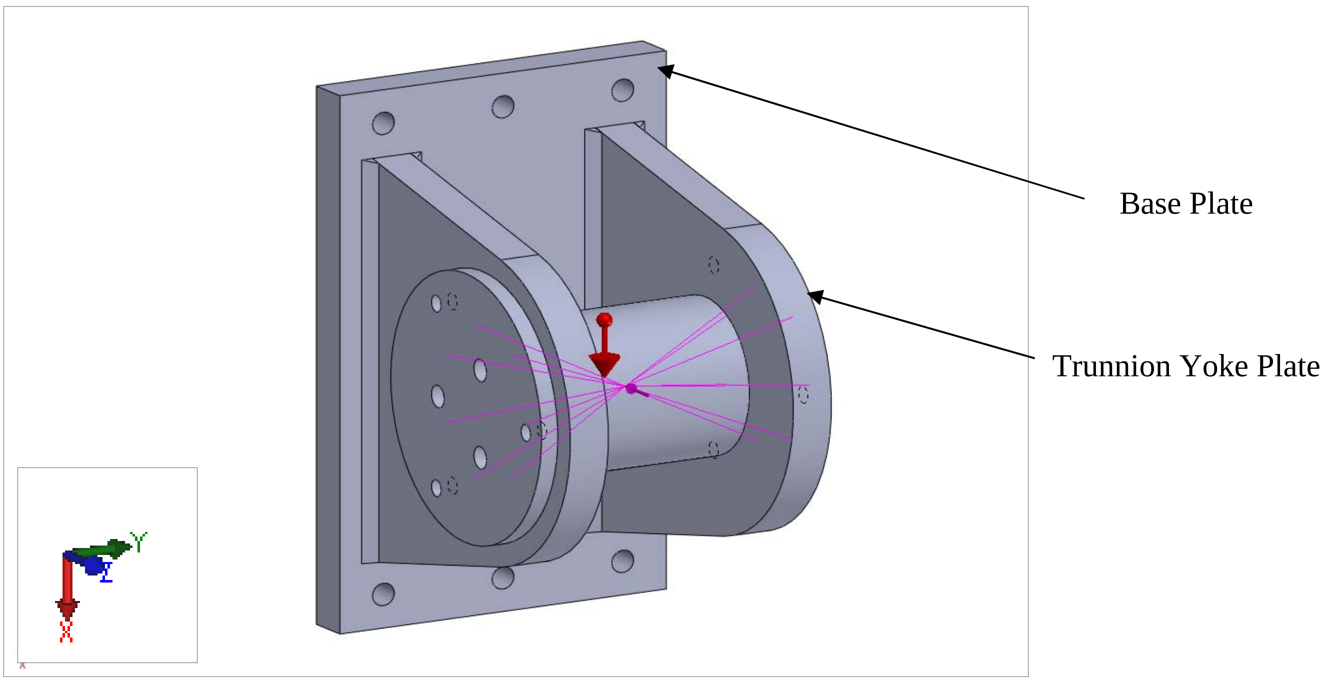


Trunnion Yoke Mesh Plot

Component	Material	Yield Strength, Fy (ksi)	Allowable Stress 0.33*Fy (ksi)
Trunnion Yoke	ASTM A709	50	16.5

(c) Loads

The force is applied along the negative z direction acing on the Trunnion Pin.



Trunnion Yoke Force and Restraint

Force acting on the Trunnion Yoke is taken from SAP analyis performed by INCA Engineers, Inc. as on March 16, 2009

Applied Force, Fz = -105 kip-in

Gravity, g = 9.8 m/s^2

(d) Restraints

Anchor Bolt Restraints are applied at the bolt hole locations

Bolt Connection is used to attach the cover plate with the Trunnion Pin and Trunnion Yoke

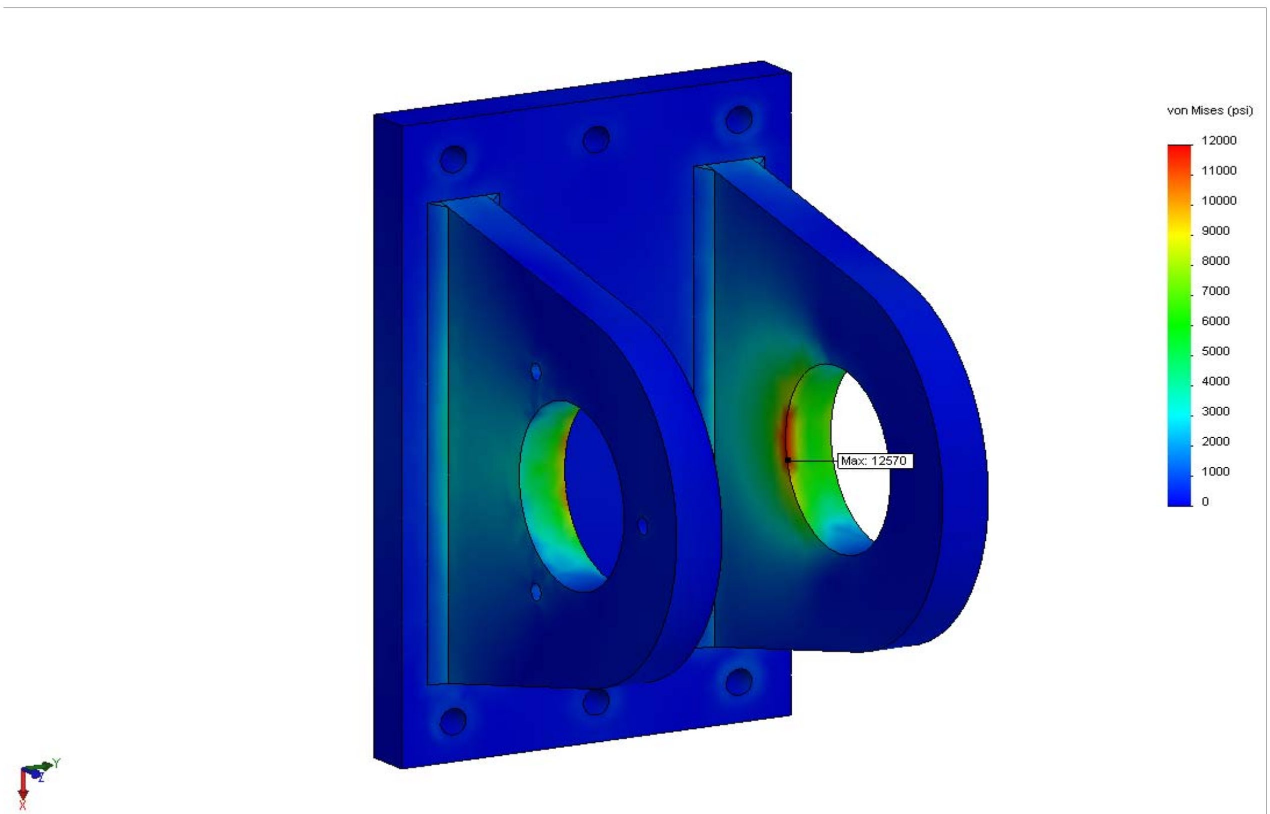
No- Penentration contact set is established between,
1. Trunnion Yoke and Trunnion Pin
2. Cover Plate and Trunnion Yoke
3. Cover Plate and Truniion Pin

Rigid wall restraint is used to restraint the back plate in the negative z direction

2.4.2 Analysis Results

The following plots show the Von Mises stresses in Trunnion Yoke as well as stress plots in X,Y and Z direction and deflection.

Plot 1: Von Mises Stresses



Trunnion Yoke Von Mises Stress Plot

Maximum stress = 12.6 ksi < 16.5 ksi

Maximum stress location = Trunnion Yoke

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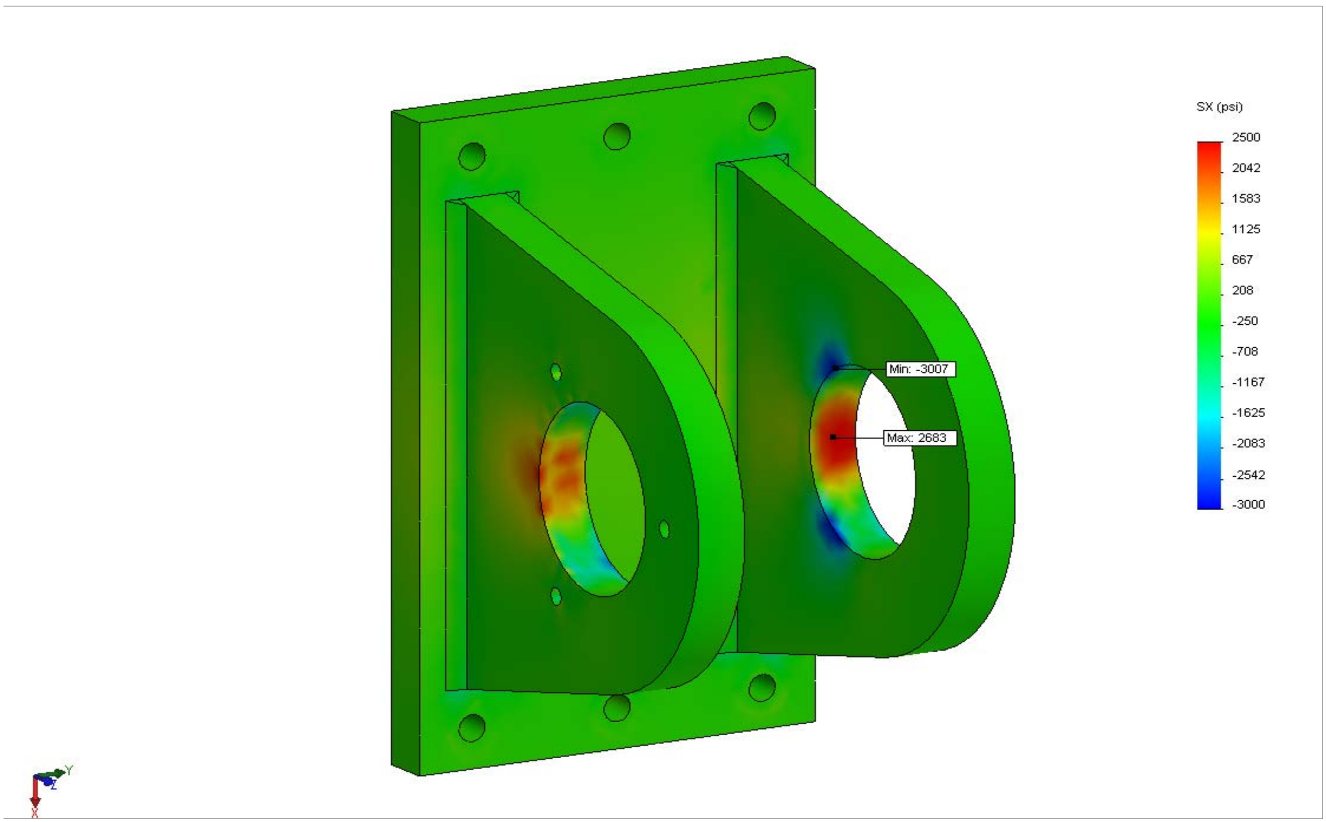
Plot 2: Axial Stresses in X-Direction, Sx



Trunnion Yoke Sx, Stress Plot

(a) Tension

Maximum stress	=	2.7 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke		

(b) Compression

Maximum stress	=	3.0 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke		

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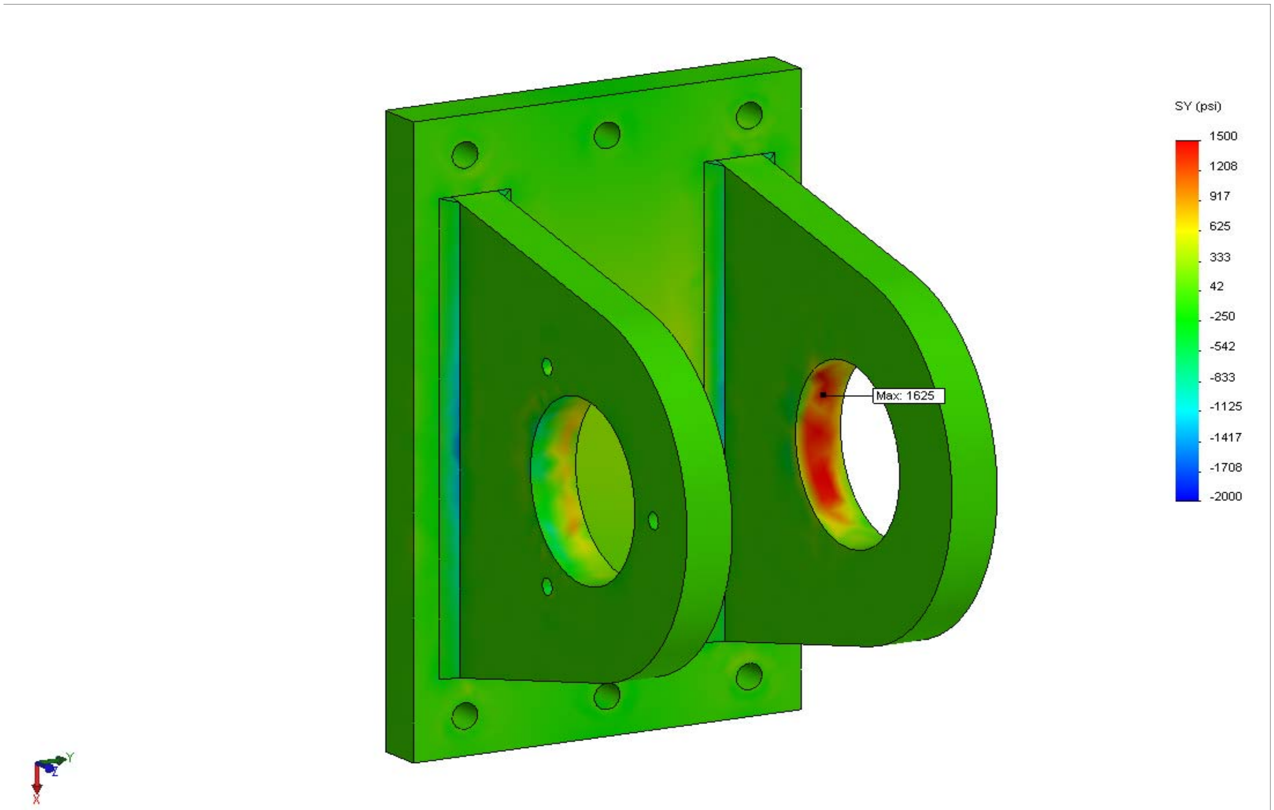
Plot 3: Axial Stresses in Y-Direction , Sy



Trunnion Yoke Sy, Stress Plot

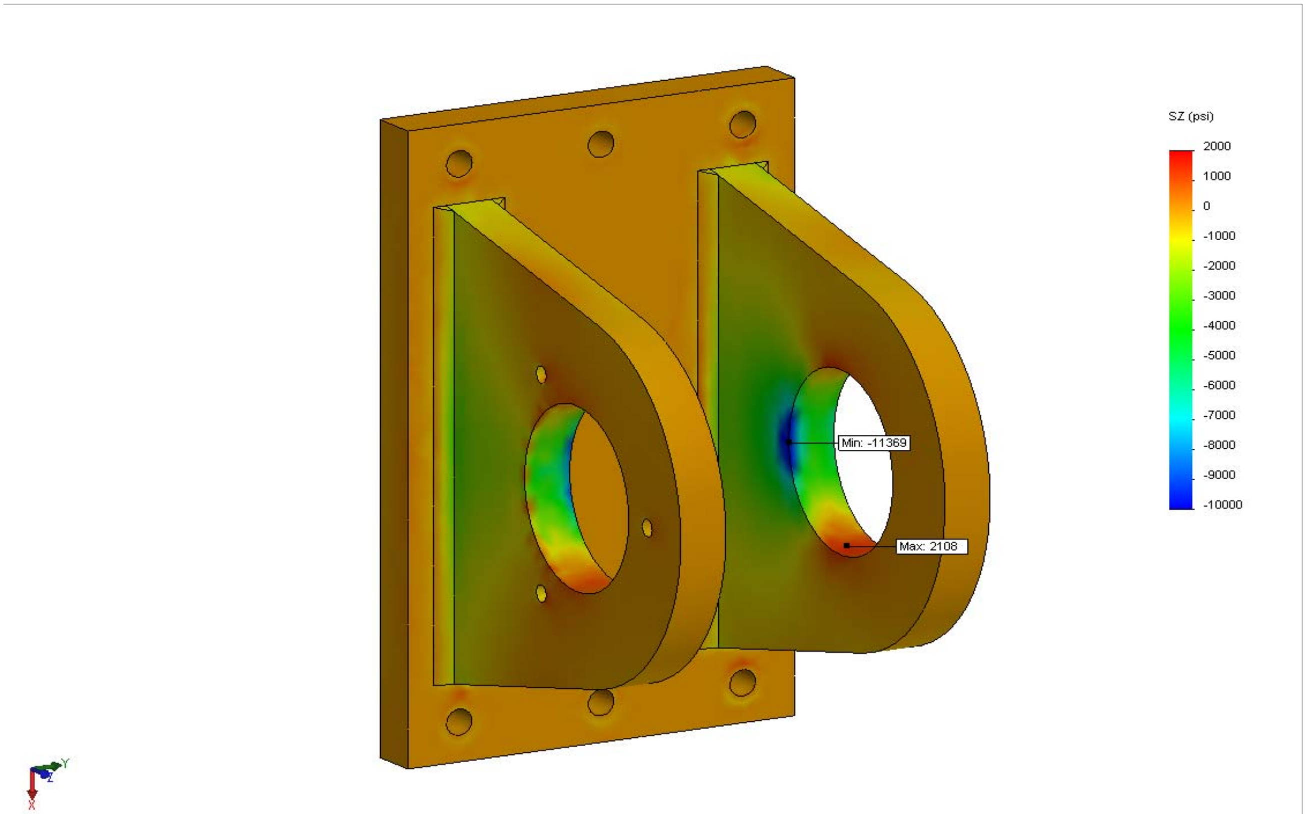
(a) Tension

Maximum stress	=	1.6 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke		

(b) Compression

Maximum stress	=	2.5 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke Weld		

Plot 4: Axial Stresses in Z-Direction Plot, Sz



Trunnion Yoke Sz, Stress Plot

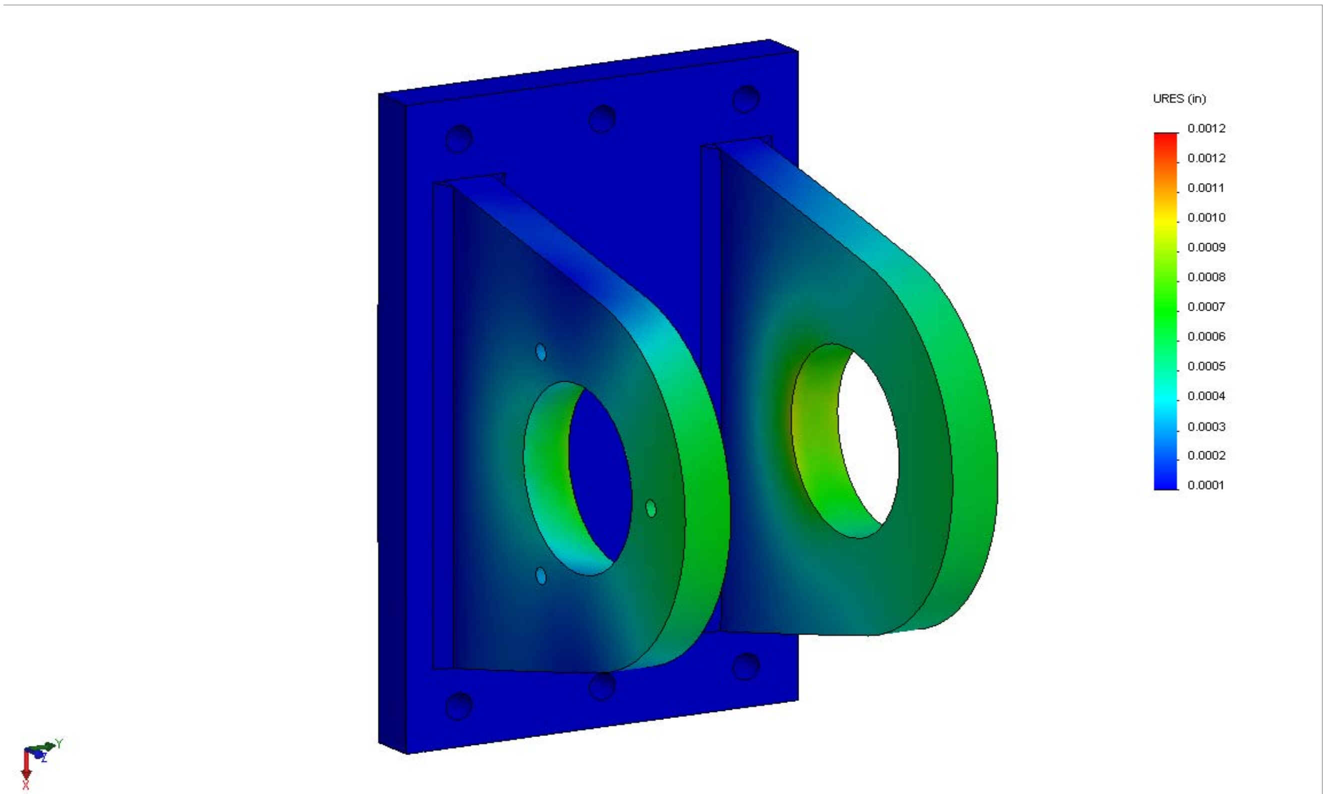
(a) Tension

Maximum stress	=	2.1 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke		

(b) Compression

Maximum stress	=	11.4 ksi	<	16.5 ksi
Maximum stress location	=	Trunnion Yoke		

Plot 5: Trunnion Yoke Deflection Plot



Trunnion Yoke Deflection Plot

Maximum Resultant Deflection = 0.002 in

Note: Deflection plots are for general representation only

2.5 Yoke Weld Size Calculation

Vertical Force on Trunnion Yoke,	=	11.5 kip	(See Sec. 1.1)
Weight of the Trunnion, W	=	1 kip	
Combined Vertical Force, Fv	=	12.5 kip	
Distance from point of force to weld, aL	=	8.75 in	
Weld Length, L	=	18 in	
Weld Size	=	1/2 in	

Allowable Load, $P = CC_1DL$ (Ref. 5. Pg. 4-75, Special Case)

aL	=	8.75	
a	=	0.5	
C	=	0.78	(For a = 0.5 & k =0)
C_1	=	1	(Electrode E70XX)
D	=	8	(No of sixteenth-of-an-inch in a fillet weld size)

Allowable Load, P = 112 kip > 12.5 kip

OK

References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009

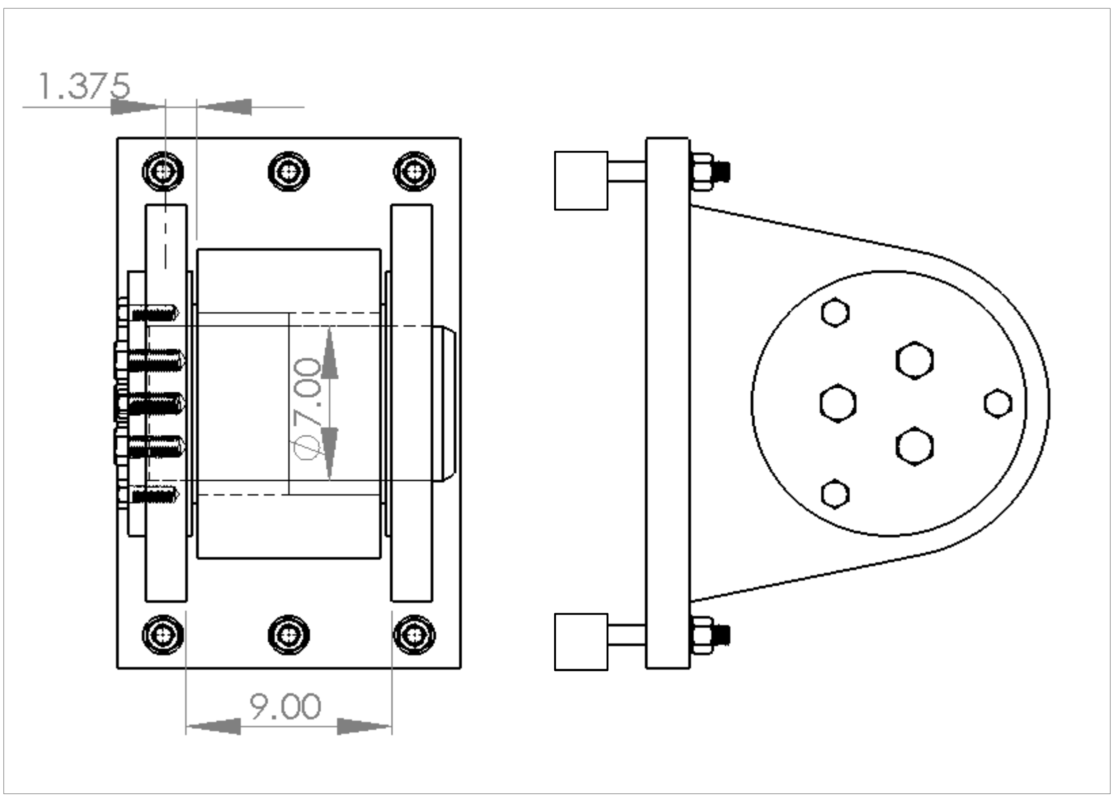
2. Design Criteria

3. EM 1110-2-2702 Design of Spillway Tainter Gates

4.Manual of Steel Construction, AISC, ASD, 9th Edition

5. ASTM Standards in Building Codes 37th Edition

3. Trunnion Pin Stress Calculation



Trunnion Pin and Yoke Basic Geometry

3.1 Trunnion Pin Bending

Max Static Load , W_s	=	100 kip	*(See Sec. 1.1)*
Momemt arm length, a	=	1.375 in	
Trunnion Pin diameter, d_{Pin}	=	7.0 in	
Section Modulus,S	=	33.7 in^3	
Area, A	=	38.5 in^2	
Bending Moment, M = (Ws/2)*a	=	68750 lb-in	

3.2 Trunnion Pin Combined Stress Calculation

Trunnion Pin material		=	ASTM A 705,Type 630, UNS S17400, Condition 1150	
Yield Strength, Fy		=	105.0 ksi	
Ultimate Strength, Fu		=	135.0 ksi	
Allowable Stress,	Min (0.2*Fu, 0.33*Fy)	=	27.0 ksi	
Bending Moment,	M = (Ws/2)*a	=	68750 lb-in	
Bending Stress,	σ_b = M/S	=	2.0 ksi	
Shear Stress,	τ =1.33*(Ws/2)/A	=	1.7 ksi	
Combined Stress	$\tau_{combined} = \sqrt{\sigma^2{}_b + 3\tau^2}$	=	3.6 ksi OK	< 27 ksi

3.3 Trunnion Pin Bearing Stress (Pin-Yoke) Calculation

Trunnion Pin material	=	ASTM A 705,Type 630, UNS S17400, Condition 1150		
Yield Strength, Fy	=	105.0 ksi		
Ultimate Strength, Fu	=	135.0 ksi		
Allowable Stress, Min (0.2*Fu, 0.33*Fy)	=	27.0 ksi		
Diameter of Trunnion Pin, d_{Pin}	=	7.0 in		
Effective length of Trunnion Pin, b_{Pin}	=	2.5 in		
Projected Area, $A_{Pin} = d_{Pin}*b_{Pin}$	=	17.5 in^2		
Max Static Load, F_s *(See Sec 1.1)*	=	100 kip		
Bearing Pressure due to Max Static Load, F_s/A_{Pin}	=	5.7 ksi	<	27.0 ksi
		OK		

References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009

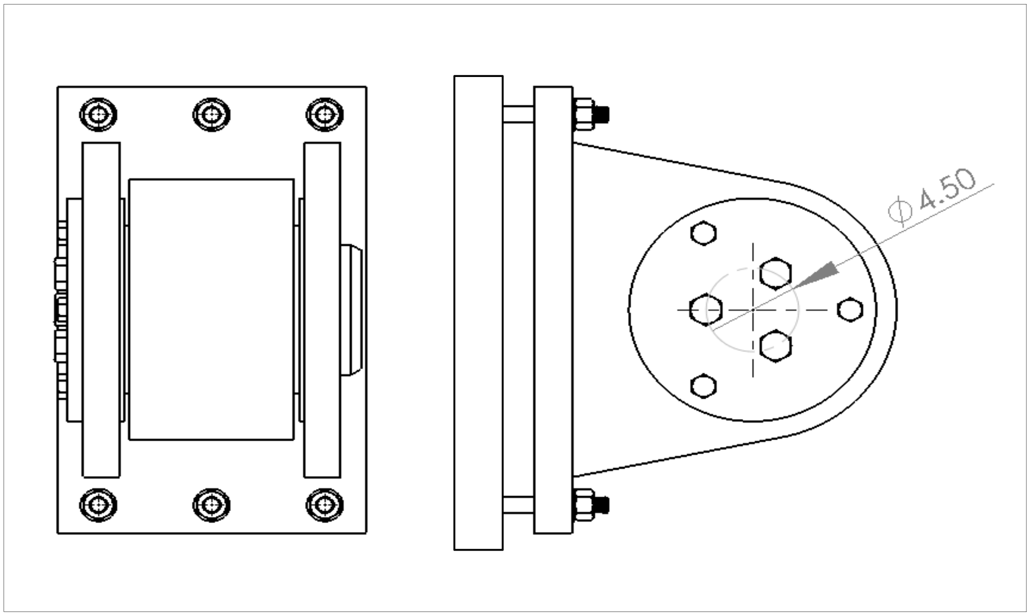
2. Design Criteria

3. Design Drawing, M-11

4. EM 1110-2-2702 Design of Spillway Tainter Gates

5.Manual of Steel Construction, AISC, ASD, 9th Edition

4. Shear Pin Stress Calculation



Trunnion Pin Basic Geometry

Maximum load on Trunnion, F	=	100 kip	*(See. Sec 1.1)*
Diameter of the Pin, D_p	=	7 in	
Coefficient of Friction, μ_1	=	0.3	*(After Bearing Wear Out)*
Coefficient of Friction, μ_2	=	0.1	*(Normal operating condition)*

Max Torque at Trunnion, $T_{Max} = F * \mu_1 * D_p/2$	=	105 kip-in
Normal Torque at Trunnion, $T_{Nor} = F * \mu_2 * D_p/2$	=	35 kip-in

4.1 Shear Pin Allowable Stress

Material	=	ASTM F 593 ,Alloy Group 5 (410), Cond. H
		(Hardened & Tempered at 1050 ^{o}F Min)
Bolt Diameter	=	0.75 in
Yield Strength, Fy	=	90 ksi
Ultimate Strength, Fu	=	110 ksi
Allowable Stress, 0.2*Fu	=	22 ksi
Allowable Stress[1], 0.75*Fy	=	68 ksi

([1] Allowable stress for bearing failed condition)

4.2 Shear Pin Stress Calculation

Max Torque at Trunnion, T_{Max}		=	105 kip-in	
Normal Torque at Trunnion, T_{nor}		=	35 kip-in	
Shear Pin Bolt Circle Diameter, D		=	4.5 in	
Maximum Force on the Shear Pin, $F_{Max}=T_{Max}/(D/2)$		=	47 kip	
Normal Force on the Shear Pin, $F_{Nor}=T_{Nor}/(D/2)$		=	16 kip	
Shear Pin Diameter, d		=	1.00 in	
Shear Pin Area, A		=	0.79 in^2	
Shear Pin Stress Area, As		=	0.61 in^2	
Number of Shear Pins, N		=	3	*(Bolts on one side)*
Maximum Shear Stress, τ_{Max}	(F_{max}/NA)	=	25.7 ksi	< 68 ksi
Normal Shear Stress, τ_{Nor}	(F_{Nor}/NA)	=	8.6 ksi	< 22 ksi

4.3 Surface Pressure on Cover Plate due to Torque

Material	=	ASTM A572		
Yield Stress, Fy	=	50 ksi		
Ultimate Stress, Fu	=	65 ksi		
Allowable Stress, 0.33*Fy	=	16.5 ksi		
Allowable Stress[1], 0.75*Fy	=	37.5 ksi		

([1] Allowable stress for bearing failed condition)

Maximum Force on the Shear Pin, $F_{Max}=T_{Max}/(D/2)$	=	47 kip		
Normal Force on the Shear Pin, $F_{Nor}=T_{Nor}/(D/2)$	=	16 kip		
Bolt Hole Diameter, d	=	1.00 in		
Bolt Hole Length, L	=	0.75 in		
Projected area, A	=	0.8 in^2		
Number of Bolt Holes.N	=	3	*(Bolts on one side)*	
Max Surface Pressure, $P_{max} = (F_{max}/NA)$	=	20.7 ksi		< 38 ksi
Max Surface Pressure, $P_{max} = (F_{Nor}/NA)$	=	6.9 ksi		< 17 ksi

4.4 Trunnion Assembly Finite Element Analysis

Summary

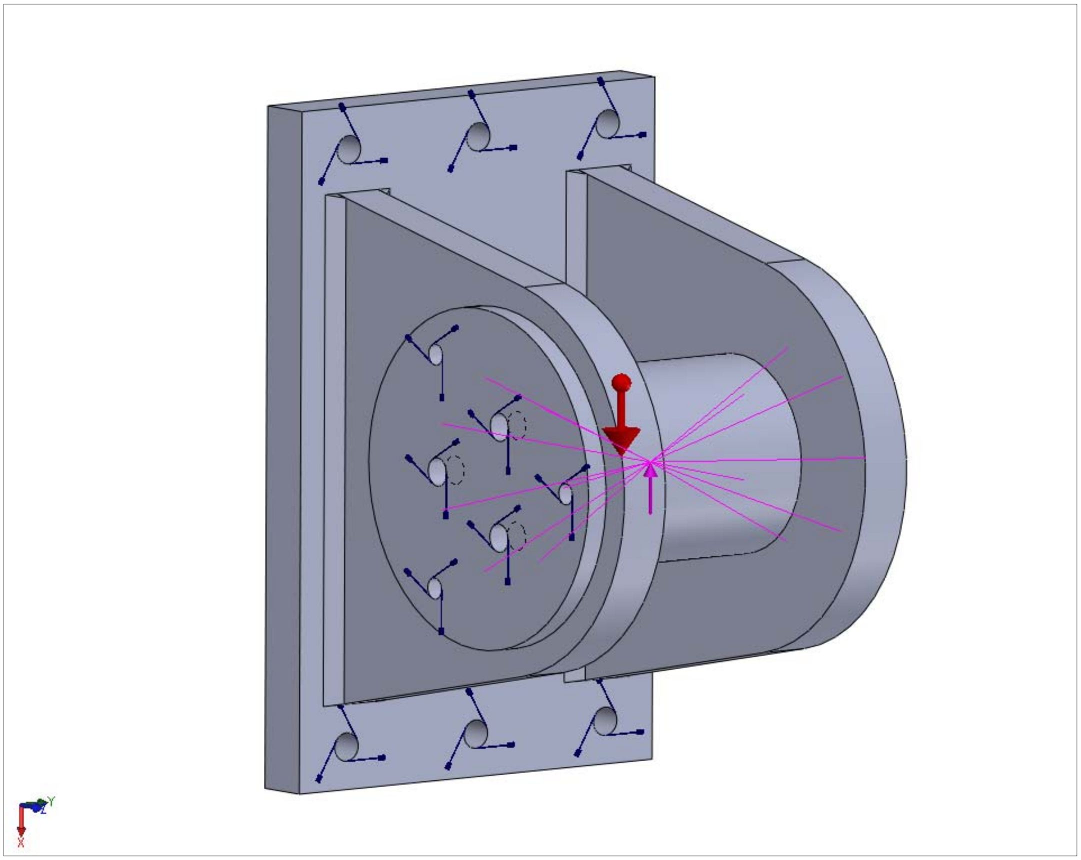
Stresses observed in the Trunnion Assembly are all with in the allowable range. The Maximum Von Mises stress was observed at the Trunnion Cover Plate. The table below summarizes the stresses observed in the Trunnion Assembly as a result of the bearing/bushing wear torque.

Stress	Maximu (ksi)	Allowable (ksi)	Location
1.Von Mises	26.0	37.5	Trunnion Cover Plate
2. Sx	17.6	78.8	Trunnion Pin
3. Sy	27.6	37.5	Trunnion Cover Plate
4. Sz	16.6	78.8	Trunnion Pin

4.4.1 Analysis Approach

(a) Model Type

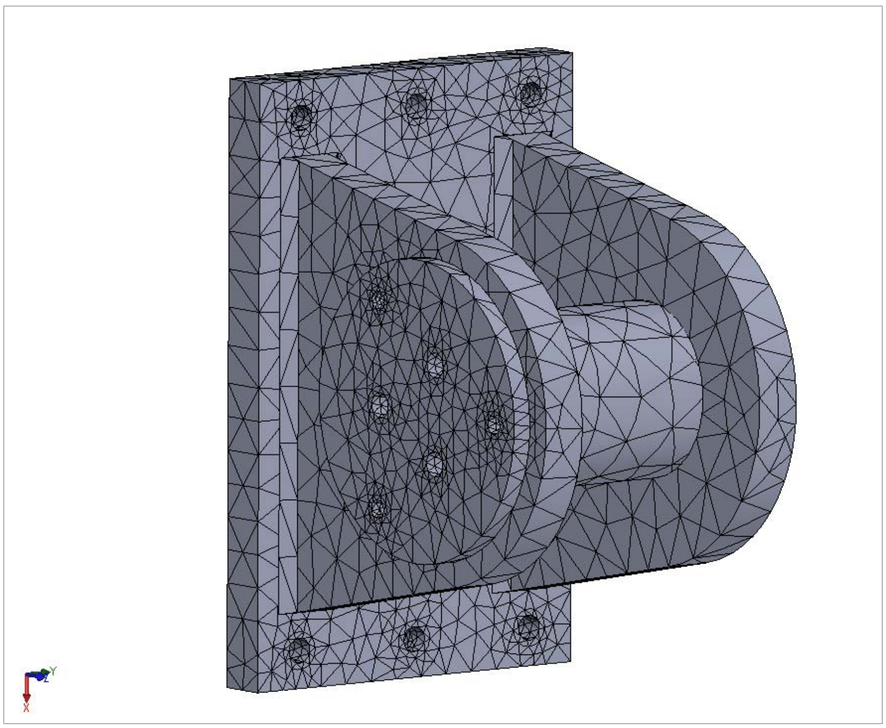
The Trunnion Yoke is analyzed using 3D solid, FEA model. The 3D model of the assembly is created using SolidWorks 2009 and analyzed using COSMOSWorks 2009. (See design drawings for the detailed dimensions and geometry of the trunnion yoke model.)



Trunnion Yoke Model

(b) Mesh

The model consists of curvature based mesh

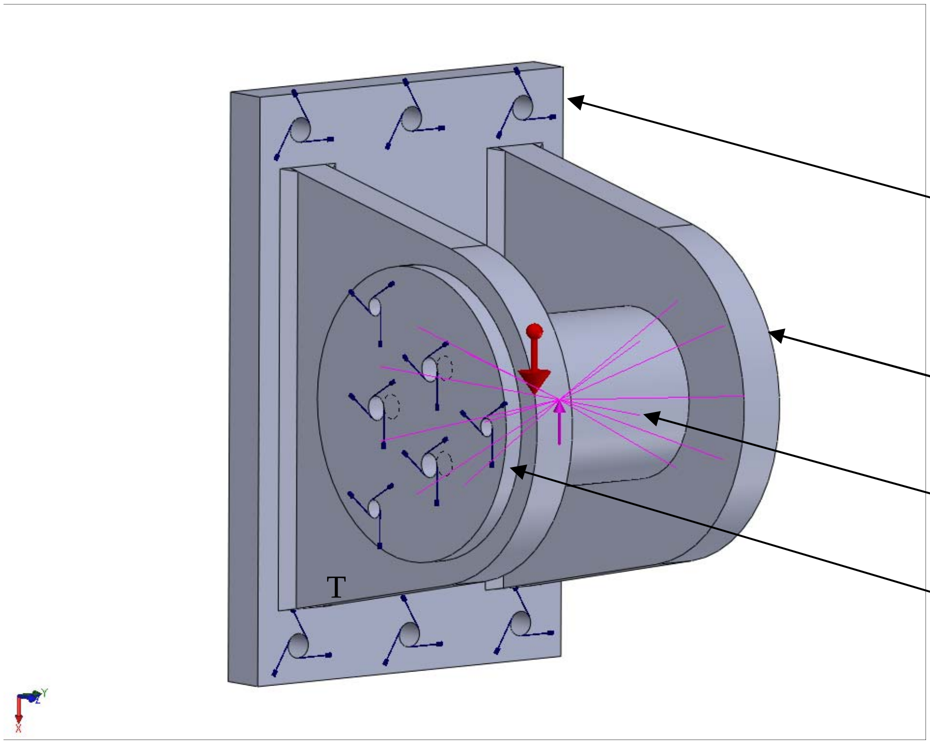


Trunnion Yoke Mesh Plot

Component	Material	Yield Strength, Fy (ksi)	Allowable Stress 0.75*Fy (ksi)
Trunnion Yoke	ASTM A709	50	37.5
Trunnion Pin	ASTM A705	105	78.8
Cover Plate	ASTM A709	50	37.5

(c) Loads

The force is applied as Torque acing on the Trunnion Pin. The applied torque is a result of bearing wear, with a coefficient of friction, $\mu = 0.3$



Trunnion Yoke Force and Restraint

Force acting on the Trunnion Yoke is taken from SAP analyis performed by INCA Engineers, Inc. as on March 16, 2009

Applied Torque, T = 105 kip-in

Gravity, $g = 9.8\ m/s^2$

Force, Fx = -12 kip

(d) Restraints

Anchor Bolt Restraints are applied at the bolt hole locations

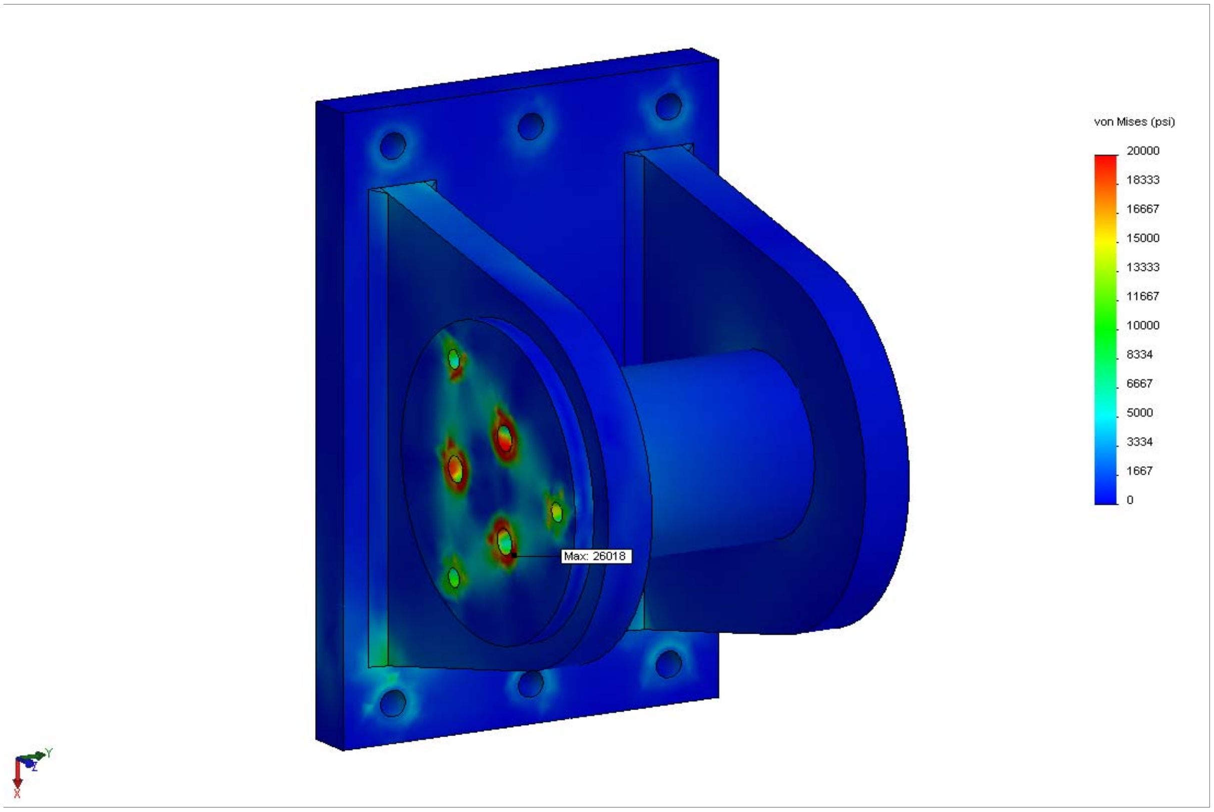
Bolt Connector are use to attach the cover plate with the Trunnion Pin and Trunnion Yoke
The assumption is made that friction between the cover plate and yoke does not assist in transferring the load, hence no torque is applied to bolts.

No- Penentration contact set is established between,
1. Trunnion Yoke and Trunnion Pin
2. Cover Plate and Trunnion Yoke
3. Cover Plate and Truniion Pin

4.4.2 Analysis Results

The following plots show the Von Mises stresses in Trunnion Yoke as well as stress plots in X,Y and Z direction and deflection.

Plot 1: Von Mises Stresses



Trunnion Yoke Von Mises Stress Plot

Maximum stress = 26.0 ksi < 37.5 ksi

Maximum stress location = Trunnion Cover Plate

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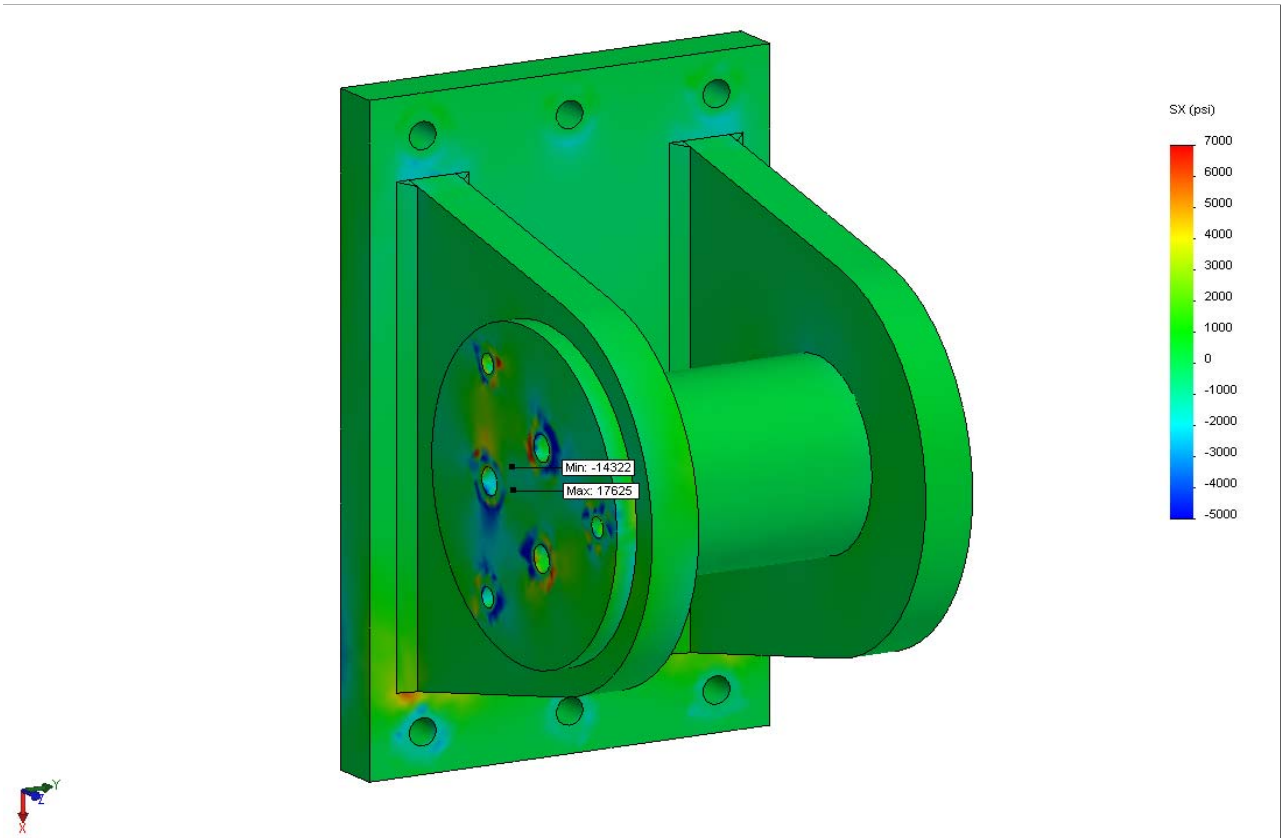
Plot 2: Axial Stresses in X-Direction, Sx



Trunnion Yoke Sx, Stress Plot

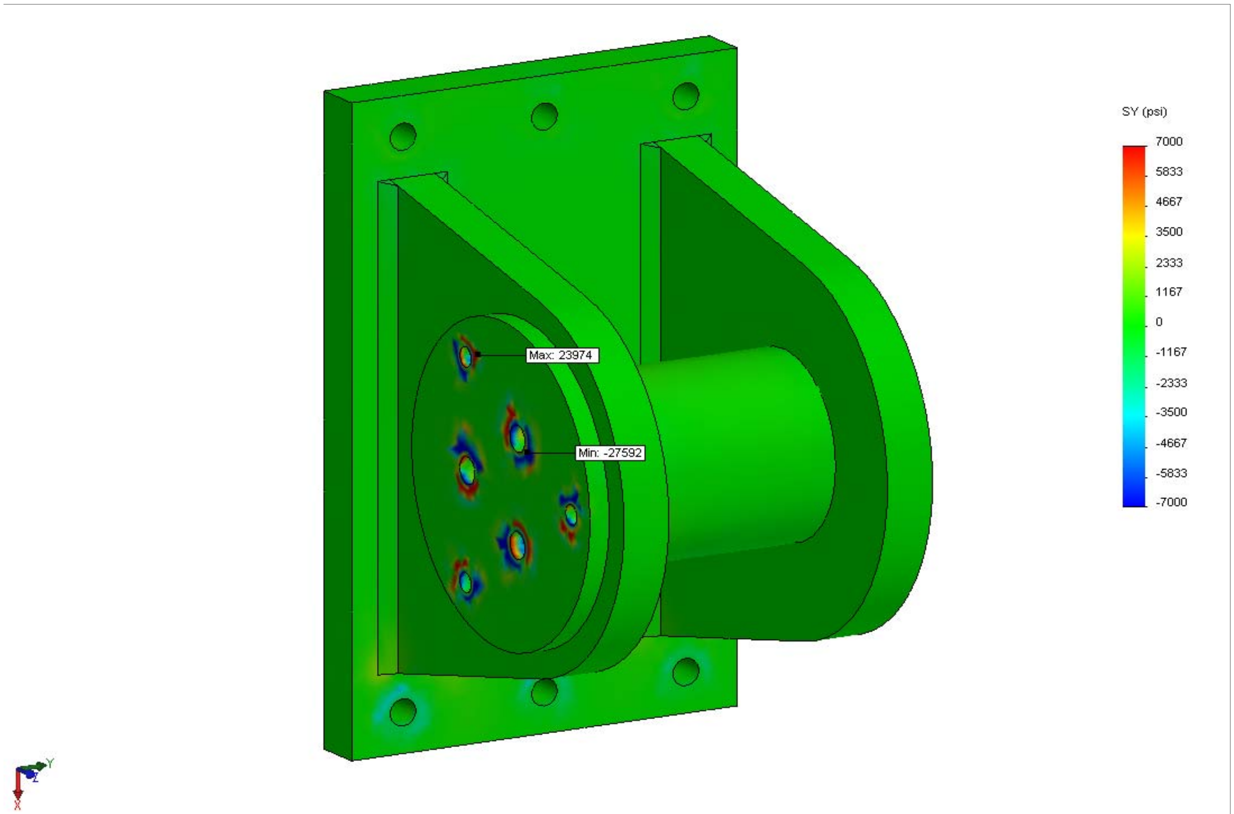
(a) Tension

Maximum stress	=	17.6 ksi <	78.8 ksi
Maximum stress location	=	Trunnion Pin	

(b) Compression

Maximum stress	=	14.3 ksi <	78.8 ksi
Maximum stress location	=	Trunnion Pin	

Plot 3: Axial Stresses in Y-Direction , Sy



Trunnion Yoke Sy, Stress Plot

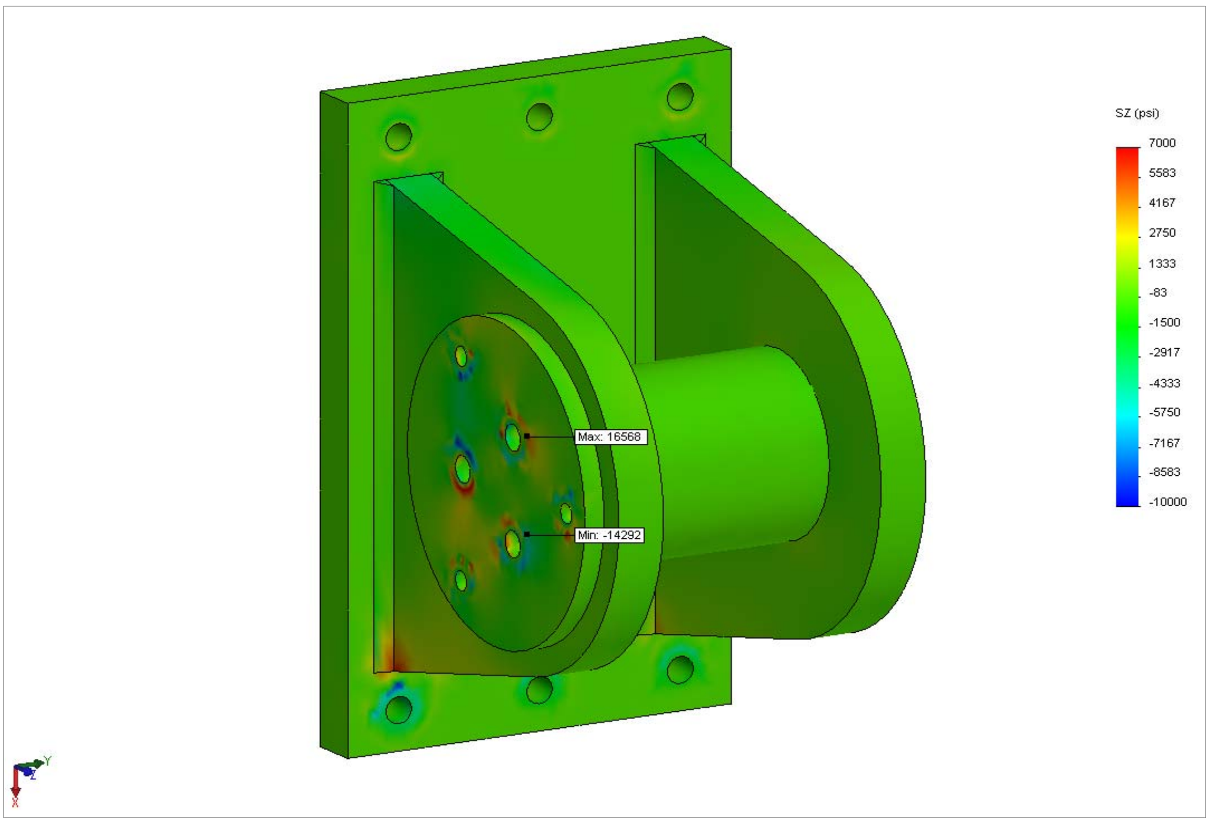
(a) Tension

Maximum stress	=	23.9 ksi	<	37.5 ksi
Maximum stress location	=	Trunnion Cover Plate		

(b) Compression

Maximum stress	=	27.6 ksi	<	37.5 ksi
Maximum stress location	=	Trunnion Cover Plate		

Plot 4: Axial Stresses in Z-Direction Plot, Sz



Trunnion Yoke Sz, Stress Plot

(a) Tension

Maximum stress	=	16.6 ksi	<	78.8 ksi
Maximum stress location	=	Trunnion Pin		

(b) Compression

Maximum stress	=	14.3 ksi	<	78.8 ksi
Maximum stress location	=	Trunnion Pin		

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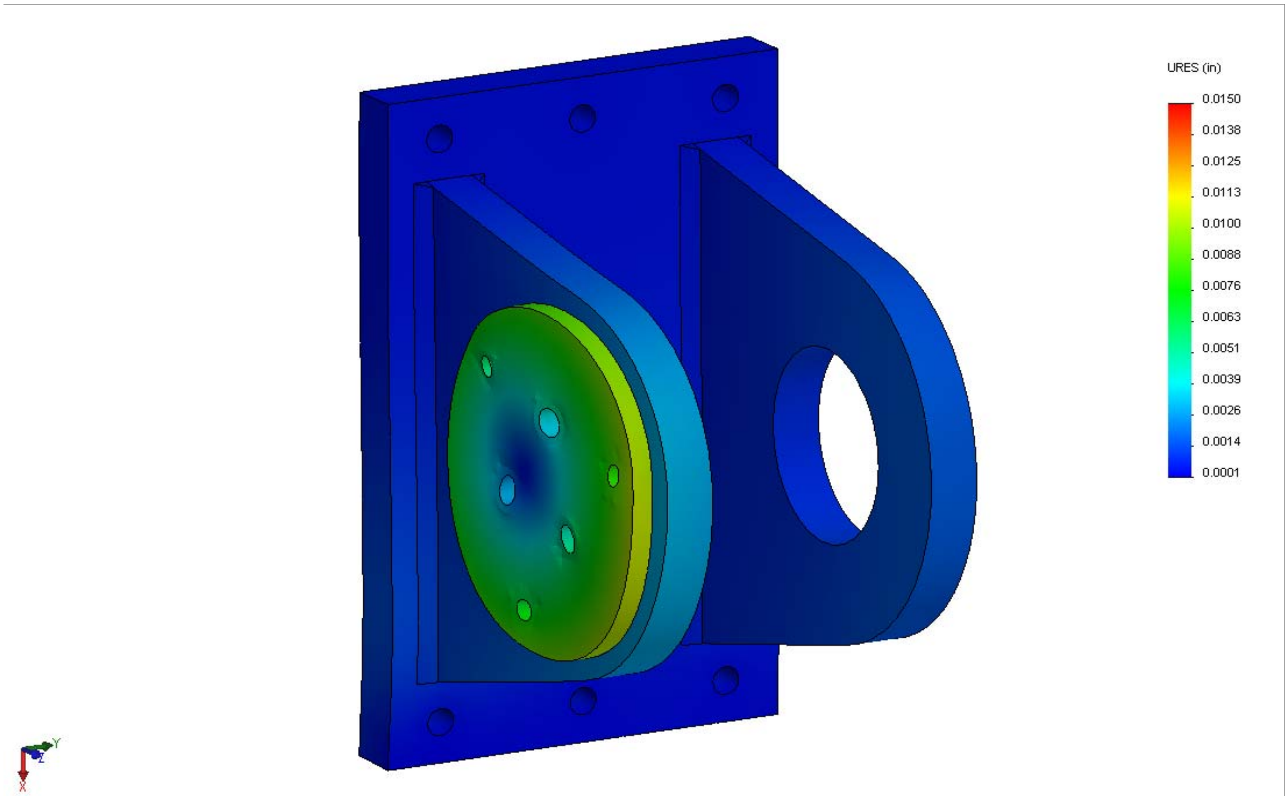
Plot 5: Trunnion Yoke Deflection Plot



Trunnion Yoke Deflection Plot

Maximum Resultant Deflectioı = 0.015 in

Note: Deflection plots are for general representation only

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Design Topic Trunnion Hub Compressive Load

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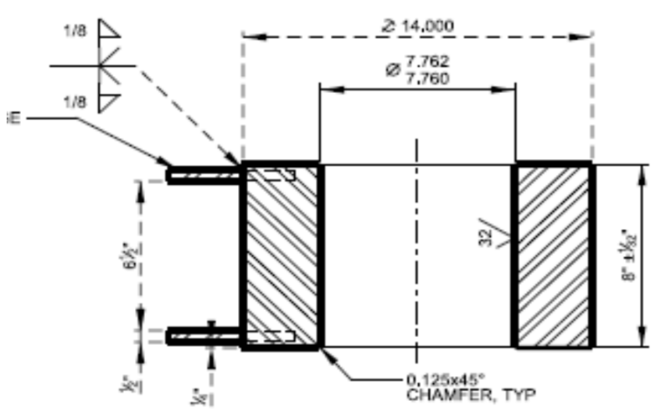
References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009
2. Design Criteria, DDR 60% Submittal
3. Design Drawing, M-7
4. EM 1110-2-2702 Design of Spillway Tainter Gates
5. ASTM Standards in Building Codes 37th Edition
6.Manual of Steel Construction, AISC, ASD, 9th Edition

5. Trunnion Hub Compressive Load

Material	=	ASTM A 668, Class D, Grade X1			
Yield Stress, Fy	=	37.5 ksi			
Ultimate Stress, Fu	=	75 ksi			
Allowable Stress, 0.33*Fy	=	12.4 psi			
Maximum Vertical Design Load, F	=	100 kip			
Projected Area of Strut Arm on to Trunnion Hub, A	=	11.52 in^2			
Pressure on Trunnion Hub = F/A	=	8.7 ksi	<	12.4 ksi	
			OK		



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Design Topic	Trunnion Hub Weld		

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References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009
2. Design Criteria
3. Design Drawing, M-7
4. EM 1110-2-2702 Design of Spillway Tainter Gates
5.Manual of Steel Construction, AISC, ASD, 9th Edition

6. Strut Arm Trunion Weld Size

Vertical Force on Trunnion, = 11.5 kip

Distance from point of force to weld, aL = 7 in

Weld Length, L = 18.6 in

Weld Size = 5/16 in

Allowable Load, $P = CC_1DL$ (Ref. 5. Pg. 4-75, Special Case)

aL = 7

a = 0.4

C = 0.939 (For a = 0.4 & k =0)

C_1 = 1 (Electrode E70XX)

D = 5 (No of sixteenth-of-an-inch in a fillet weld size)

Allowable Load, P = 87 kip > 11.5 kip
OK

References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009
2. ACI 318-05, Appendix D
3. Design Drawing, M-11
4. EM 1110-2-2702 Design of Spillway Tainter Gates
5. ASTM Standards in Building Codes 37th Edition
5.Manual of Steel Construction, AISC, ASD, 9th Edition

7. Trunnion Yoke Assembly Anchor Bolt Calculation

7.1 Trunnion Yoke Assembly Anchor Bolt Allowable Load in Tension

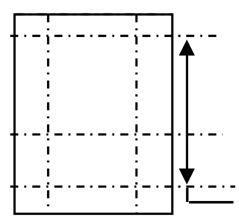
Force on Trunnion Yoke assembly = 11.5 kip *(See Sec. 1.1, Fy)*

Torque at Trunnion, T = F * μ * D_p/2 = 105 kip-in *(See Sec. 4)*
(After Bearing Wear Out)

Distance from Yoke Center to Bolt, e = 10.625 in

Number of bolts below neutral axis to take tensile load ,n' = 2

Moment arm between resultant tensile force and compressive force, d_m = 21 in



3/4", F1554 Gr. 36 Anchor, Fy = 36 ksi

Allowable Tensile Stress Ft = 0.35*Fy = 12.6 kip (Ref 4. p 4-3)

Tensile force per bolt, $r_{at} = \dfrac{P_a e + T}{n' d_m}$ = 5.4 kip

Ase = 0.44 in^2 *(For 3/4" OD)*

Tensile Stress = 12.3 ksi < 12.6 ksi
OK

7.2 Shear Force Calculation

Maximum Force, F'		=	11.5 kip	(Ref 1.)	
Number of bolts in shear,N		=	6		
Allowable Shear Stress	Fv = 0.17*Fy	=	6.1 ksi		
Shear Stress per bolt, F'/(N* Ase)		=	4.4 kip	< OK	6.12 ksi

Assumption:

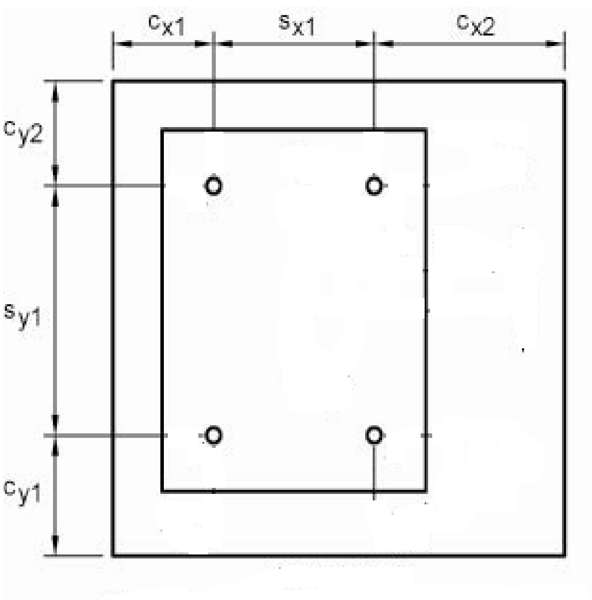
The Tension Force ia assumed to be carried by the lower two bolts

The shear Force is assumed to be carried by all six bolts

Anchor Material	=	=	ASTM F1554 Gr. 36
Anchor Diameter	=	=	0.75 in
Anchor Length	=	=	12 in
Anchor Type	=	=	Heavy Hex Bolt
			Cast-in Anchors

Steel Strength of Anchor in Tension [Sec. D.5.1]

Nsa	=	$nA_{se}f_{uta}$		*[Ref. 2, Eq. D-3]*
Ase	=	0.44	in^2	*(For 3/4" OD)*
A_{bgr}	=	0.79	in^2	*(For head dia 1.25 in)*
F_{uta}	=	58	ksi	
Number of anchors acting in tension,n	=	2		*(Assumed two bolts will take the load)*
Nsa	=	25520	lbs	
ϕ	=	0.8		*[Ref. 2, D.4.5]*
ϕNsa	=	12.76	kip/bolt	



Cx1	=	3	in
Sx1	=	11	in
Cx2	=	4.5	in
Cy2	=	4.5	in
Sy1	=	21	in
Cy1	=	4.5	in
Anchor Length	=	12	in

Concrete Breakout Strength of Anchor Group in Tension

Ncbg =		(ANc/Anco)* ec,N *ed,N* c,N cp,N*Nb		*[Ref. 2, Eq. D-5]*
Number of influencing edges = 4				
hef =	=	7	in	*[Ref. 2, D.5.2.3]*
Anco	=	441	in^2	*[Ref. 2, Eq. D-6]*
Anc	=	600	in^2	
ec,N	=	1		
ed,N	=	0.785714		*[Ref. 2, Eq. D-11]*
c,N	=	1.25		*[Ref. 2, Sec. D.5.2.6]*
cp,N	=	1		*[Ref. 2, Eq. D-12]*
Kc	=	17		*[Ref. 2, Sec. D.5.2.6]*
fc'	=	4000	psi	
Nb = kc * √f 'c *$hef^{1.5}$	=	19913	lb	*[Ref. 2, Eq. D-7]*
Ncbg	=	26608	lb	
ϕ	=	0.75		*[Ref. 2, D.4.5]*
ϕ Ncbg	=	20.0	kip	
ϕ Ncbg	=	10.0	kip /bolt	> 5.4 kip

Pullout Strength of Anchor in Tension

$Np = 8A_{brg}f\ 'c$	=	25280	*[Ref. 2, Eq. D-15]*
c,p = 1.4	=	1.4	*[Ref. 2, D.5.3.6]*
Npn = c,pNp [Eq. D-14]	=	35392 lb	
ϕ		0.75	*[Ref. 2, D.4.5]*
ϕ Npn	=	27 kip >	10.8 kip

Concrete Breakout Strength of Anchor Group in Shear

$V_{bx} = 7(le/do)^{0.2}$ √do √f'c(ca1)$^{1.5}$ *[Ref. 2, Eq. D-24]*

le = h_{ef}	=	7		
ha	=	12	in	*(Length of Anchor Assumed)*
V_{bx}	=	3114	lb	
A_{vco}	=	41	in^2	
A_{vc}	=	240	in^2	
V_{cbg} = $(A_{vc}/A_{vco})\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}V_{bx}$	=	20230	lbs	*[Ref. 2, Eq. D-22]*
ϕ = 0.75	=	0.75		
V_{cbg} =	=	15.2	kip	> 11.5 kip

References

1. Proposal # HR090209-2 by Ace world companies (Attached)

2. EM-1110-2-2702 Design of Spillway Tainter Gates

8. Lifting Bracket Load Calculation

Motor Horse Power	=	2 HP	(Reference 1)
Motor Speed, S_1	=	1200 RPM	(Reference 1)
Motor Efficiency, N_m	=	0.97	(Assumed)
No. of Mesh	=	4	(Assumed)
Total Efficiency, $N_e = N_m^4$	=	0.89	
Required Lifting Speed, S_2	=	1.75 ft/min	(Specified)
Drum Diameter, D	=	26 in	(Reference 1)

Drum Speed, $S_3 = (12 * S_2)/(\pi * D)$ = 0.26 RPM

Gear Ratio, GR = S_1/S_3 = 4668 : 1 (Estimated)

Motor Torque, $T_i = \dfrac{HP * 5252 * 12}{RPM}$ = 105 in-lb

Gear box Output Torque, $T_o = \dfrac{T * N_e * GR}{1000}$ = 434 kip- in

Torque at each Drum, $T_D = T_o/2$ = 217 kip-in

Wire Rope Tension on each Side, $F_t = Td/(D/2)$ = 17 kip

Maximum Lifting Bracket design Force , F = 2.00 * F_t,(Wire Rope Tension @ 200% Torque (T_i)) = 67 kip (Reference 2)

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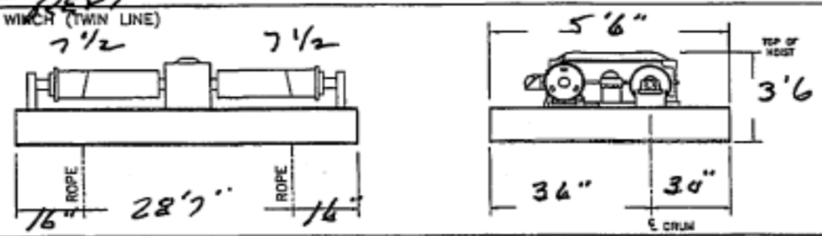
Contract/Client	Tt/Robles								
Phase/Subject	Robles Diversion Tainter Gates								
Design Topic	Maximum Wire Rope Tension								
Made By	PD	Date	06/22/09	Checked By	EOF	Date	09/16/09	Page No.	
Revised By	EOF	Date	08/13/12	Checked By	VRG	Date	10/19/12	Rev No.	2

ACE-ENGINEERING
AN ACE WORLD COMPANY LIMITED PARTNERSHIP
10200 Jacksboro Hwy – Ft Worth, TX 76135
PHONE: (817) 237-7700 • FAX: (817) 237-2777

TO: INCA Engineers Inc
Ph 425-732-6701
ATTN.: Poovaiah Devenira

QTY.(1) CAP.: 15 TONS. CLASS SERV.: A1 ☐ INDOOR ☑ OUTDOOR
PROP. NO.: AL110504/ Rev 1 DATE: 5-4-11 CUST. REF.: GATE HOIST

BASE MOUNTED WINCH (TWIN LINE)



WT.: 16350 #. M.W.L. (Act.) — #. ASCE RAIL: — #. WHEEL DIA.: —
LIFT: Main 25' Aux. — BUMPER: — POWER: 460-3-60 CRTL: 120-1-60

	MAIN HOIST	AUX. HOIST	TROLLEY
SPEED	2 FPM		
NO. OF SPEED STEP	VF		
H.P. – R.P.M.	2 HP-1200		
MOTOR MAKE & TYPE	VECTOR		
HOLD. BRK. SIZE & QTY.	75 FT LB		
HOLD. BRK. MAKE&TYPE	Disc		
CRTL. BRK. MAKE&SIZE	Dynamic		
GEAR LIMIT SWITCH	ROTARY		
UPPER LIMIT SWITCH	Control Type		
DRUM DIAMETER	26"		
RUNNING SHEAVE DIA.	—		
W.R. & REEVING	7/8 GALV		
REDUCER	Helical		

COMMENTS
SSPC-SP6 Com. Blast, Epoxy primer, paint
30 To 1 Rope Ratio
Space Heater in Mtrs
Panel Strip Heater
Wire Conduit To Junction Box
Nema 4 Enclosure
Ace control To ship loose

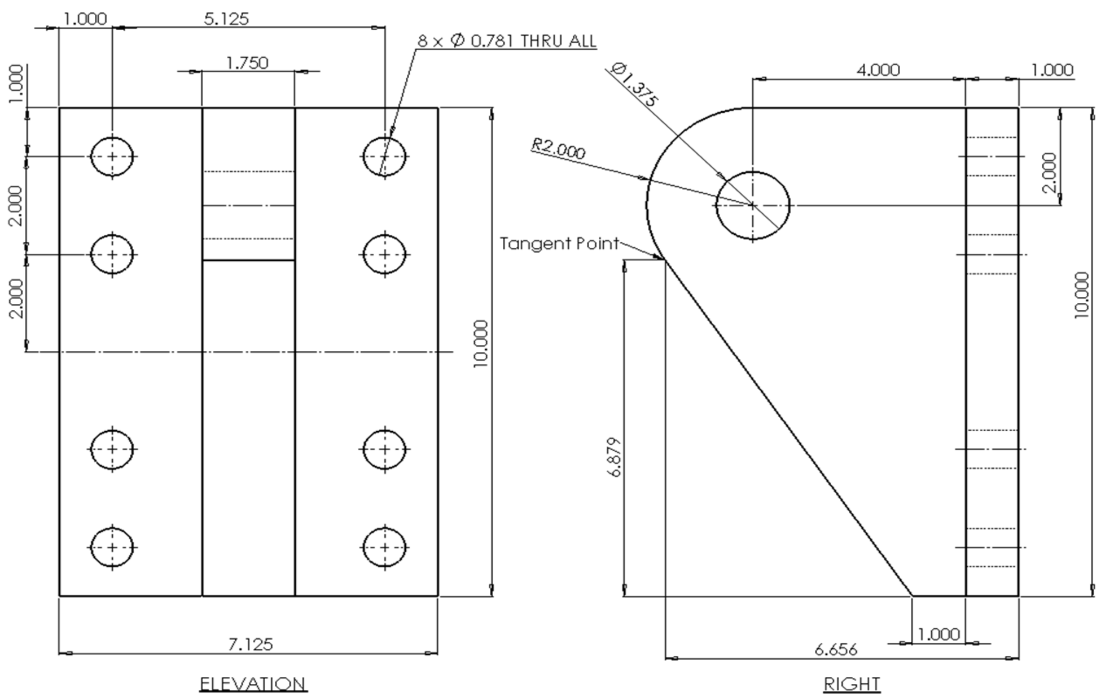
NET PRICE: # 133,910 – F.O.B.: Ft. Worth, TX DELIVERY: 14-16 WEEKS (A.R.A.)
TERMS: 10% Dn, 40% Before Ship, 50% Net 30

OPTIONS
1.75 FPM Same HP, Rope
VFD Control only
Rotor Torque 22 LBS.
Second Encoder #1200 –

References

1. *Manual of Steel Construction, AISC, 13th Edition*
2. *Mechanical Engineering Design, 6th Edition, J.E. Shigley, L.D. Mitchell*
3. *Lifting Bracket Load Calculation, by INCA Engineers Inc.*
4. *EM-1110-2-2702 Design of Spillway Tainter Gates*

9. Lifting Bracket Weldment



Lifting Bracket Weldment Geometry

Material	=	ASTM A572 Grade 50
Yield Strength, Fy	=	50 ksi
Ultimate Strength, Fu	=	65 ksi
Allowable Stress[1],(0.75*Fy)	=	37.5 ksi

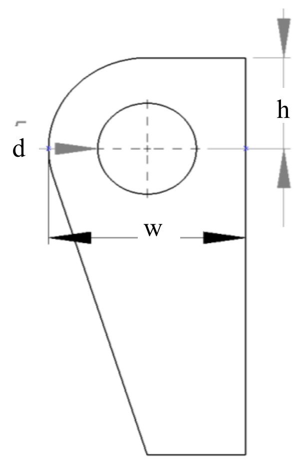
[1] *Gate Jammed Condition*

9.1 Lifting Bracket Bearing Pressure

Diameter of the Lifting Bracket Hole, D	=	1.38 in	
Thickness of the Bracket Plate,t	=	1.75 in	
Effective Projected Area, A	=	2.41 in^2	
Maximum Load[2], L	=	66.8 kip	(See Ref. 3)
Bearing Stress, σ = L/A	=	27.8 ksi	< 38 ksi OK

9.2 Lifting Bracket Nominal Stress

Distance, w	=	4.00 in
Distance, h	=	2.00 in
Diameter, d	=	1.38 in
Thickness of the Plate,t	=	1.75 in
a = (w-h)/2	=	1.00 in
Area on the shear failure path, A_{sf}=2t(a+d/2)	=	5.91 in^2
Allowable Strength, P_n=0.6FuA_{sf}/Ω	=	115.2 kip

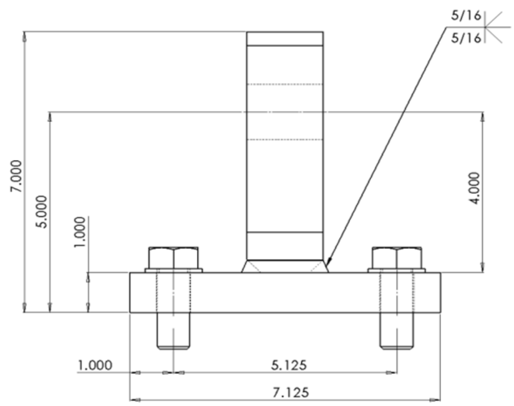


[2] *Per section 3-7b of EM 1110-2-2702, the force in the attachment due to the machinery's operating at maximum stall pull normally governs the design rather than normal operating forces*

9.3 Lifting Bracket Shear Tear Out Stress

Diameter of Lifting Bracket Hole, d	=	1.38 in		
Plate Thickness, t	=	1.75 in		
Width of the Bracket, w	=	4.00 in		
Distance from the Hole Centre to Outer Radius, c	=	2.00 in		
Effective Shear Length ,L= sqrt(c^2-$(d/2)^2$)	=	1.88 in		
Shear Area, A = L * t	=	3.29 in^2		
Maximum Force, F	=	67 kip		
Shear Tear Out Stress, = F/2A	=	10 ksi	<	38 ksi
			OK	

9.4 Lifting Bracket Weld Size Calculation



Lifting Bracket Weldment Basic Geometry

Vertical Force on Bracket, F = 67 kip (See Ref. 3)

Distance from Point of Force to Weld, aL = 4 in

Weld Length, l = 10 in

Weld Size = 5/16 in

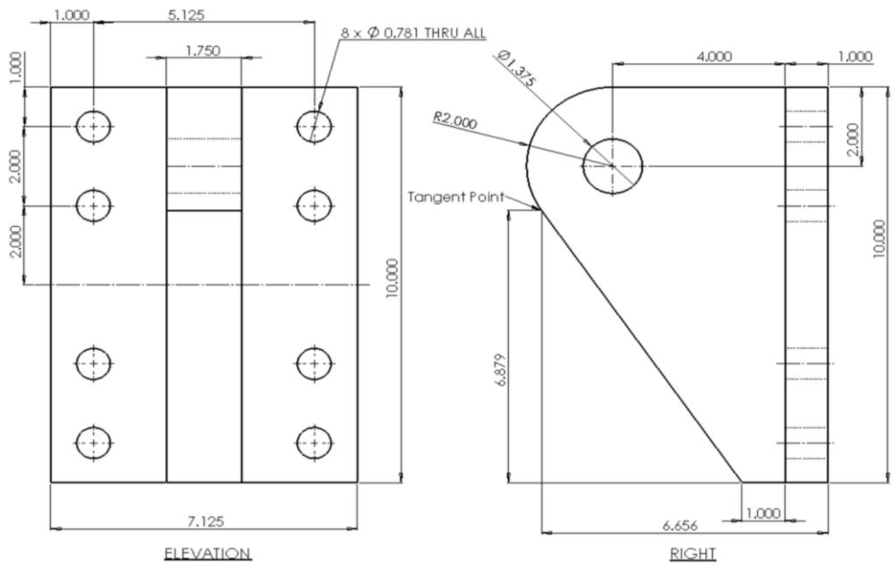
Allowable Load, P =CC_1Dl (Ref. 1. Tb. 8-4 Coefficients C, Pg. 8-66, Special Case)

Distance, al	=	4.00 in	
a	=	0.40	
C	=	2.66	(for a= 0.40 & k = 0)
C_1	=	1	(Filler material same as base material))
D	=	5	(Number of sixteenth-of-an-inch in a fillet weld size)
Ω	=	2	

Allowable Load, P/Ω = 67 kip > 66.8 kip

OK

9.5 Lifting Bracket Bolt Size Calculation



Bolt Specification

Material	=	ASTM A325		
Allowable Tensile Load	=	29.8 kips	(Tensile)	(See Ref. 1)
Allowable Shear Strength,	=	17.9 ksi	(Shear)	(See Ref. 1)
Bolt Nominal Dia. D	=	3/4 in		
Number of Bolts, N	=	8		

9.5.1 Shear Force on Each Bolt

Shear Force on the Bracket, F = 67 kip (See Ref. 3)

Shear Force on each Bolt, F/N = 8.35 kip/bolt < 18 kips
OK

9.5.2 Tension Force on Each Bolt

Force on the Bracket, P_a	=	67	kip		(See Ref. 3)
Length of the Moment Arm,e	=	5	in		
Center Line Distance b/w Bolt Groups, d_m	=	3	in		
No. of Bolts Below Neutral Axis, n'	=	4			
Tension Load, $r_{at} = \dfrac{P_a e}{n' d_m}$	=	27.8	kip/bolt	< OK	30 kips

9.5.3 Bearing Stress on the Flange

Material	=	ASTM A709	
Yield Strength, Fy	=	50	ksi
Ultimate Strength, Fu	=	65	ksi
Allowable Stress, (0.9 * Fy)	=	45	ksi

Bolt Nominal Dia. D	=	3/4	in		
Flange thickness, t	=	0.375	in		
Bearing Area, A	=	0.28	in^2		
Bearing Stress	=	29.7	ksi	<	45 ksi

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Phase/Subject	Robles Diversion Tainter Gates						
Design Topic	Turnbuckle Specification						
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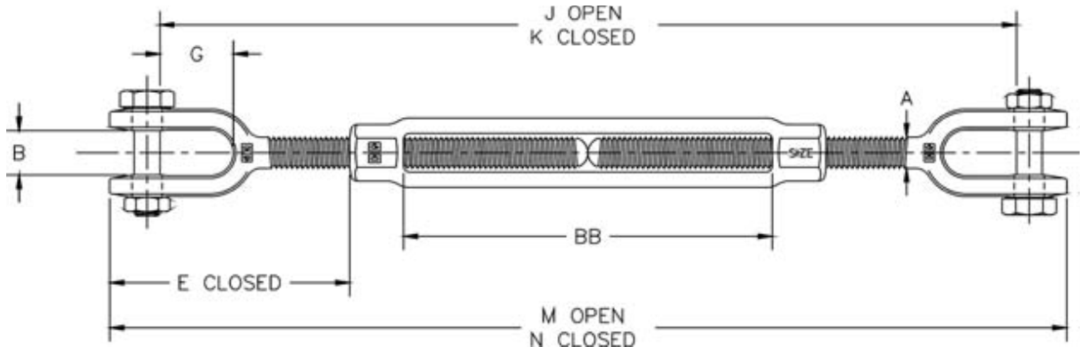
Revised By	EOF	Date	08/13/12	Checked By	MJC	Date	09/26/12	Rev No.	1

References

1. The Cosby Group 2011 General Catalog, Page 173

10. Turnbuckle



10.1 Turnbuckle Specifications

Working Load = 17 kip *(See Sec 8.)*

Maximum Load, 2* L = 67 kip *(See Sec 8.)*

Turnbuckle Catalog # = HG-228 Jaw & Jaw 1 1/2 x 12
1032938

Specifications are as per Ref. 1, Rigging Accessories, Turnbuckles, Pg. 165

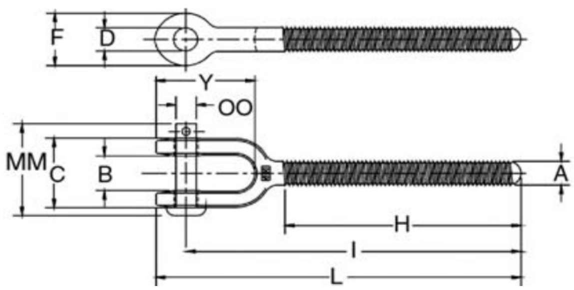
J = 40.76 in
K = 28.76 in
M = 45.66 in
N = 33.68 in

Working load limit = 21.4 kip > 16.7 kip
OK

Ultimate Load = 5(Working Load) = 107 kip > 67 kip
OK

10.2 Jaw End Fitting Basic Dimensions

Specifications are as per Ref. 1, Rigging Accessories, Turnbuckles, Pg. 168



F	=	3.12 in
D	=	1.47 in
MM	=	5.13 in
C	=	4.16 in
B	=	2.06 in
OO	=	1.38 in
Y	=	5.27 in

References

1. The Cosby Group 2011 General Catalog

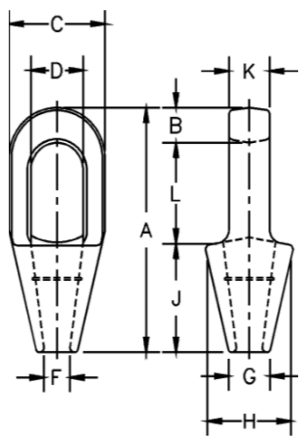
2. Proposal # HR090209-2 by Ace world companies (See Sec. 6.)

11. Clevis

Maximum Load, F	=	67 kip	*(See Sec. 6.)*
Wire Rope Diameter	=	7/8 in	(Reference 2)

Specifications are as per Ref. 1, Wire Rope End Terminations Pg. 43

A	=	8.75 in
B	=	1.25 in
C	=	3.63 in
D	=	1.94 in
F	=	1.00 in
G	=	1.50 in
H	=	3.25 in
J	=	4.00 in
K	=	1.50 in
L	=	3.50 in



Clevis Catalog # = G-417 / S-417
Closed Spelter Sockets
1039995 (S. C.)
1040000 (Galv.)

Ultimate Load Limit	=	65.3 ton		
	=	130.6 kip	>	67 kip
			OK	

Spelter socket terminations have an efficiency rating of 100%,
based on the catalog strength of wire rope.

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Design Topic	Gate Guide							
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Revised By	EOF	Date	08/13/12	Checked By	MJC	Date	09/27/12	Rev No. 1

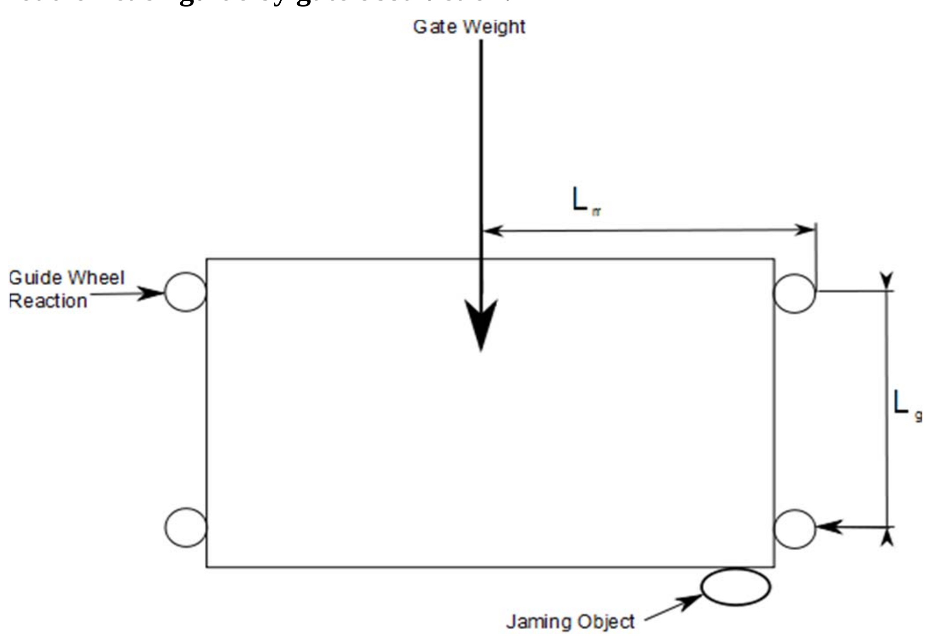
References

1. SAP Analysis by INCA Engineers, Inc. Dated : March 16, 2009
2. Design Criteria
3. ASTM Standards in Building Codes 43rd Edition
4. Roark's Formulas For Stress and Strain, 7th Edition
5. Maximum wire rope tension by INCA Engineers

12. Guide Wheel Axil

12.1 Load Calculation

12.1.1 Load on each guide by gate obstruction.



Weight of the gate, Wg = 24.3 kip

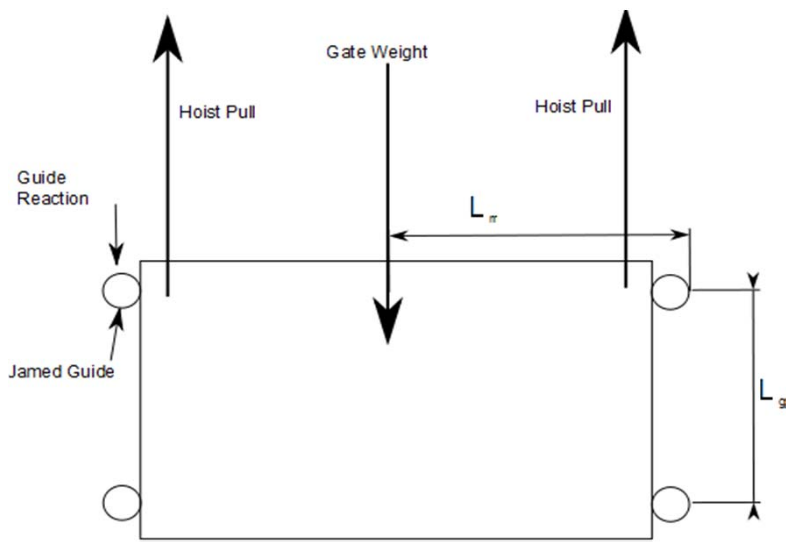
Lm = 180 in

Lg = 86 in

Moment from gate weight. Mg=Wg*Lm = 4370 kip-in

Guide wheel reaction W_s =Mg/Lg/2 = 25.4 kip

12.1.2 Load on each guide by jamed guide.



Hoist pulling force at motor stall torque, Wh = 133.5 kip (see Ref. 5)

Guide wheel reaction Wv =Wh-Wg = 108.1 kip

12.2 Guide Wheel Contact Stress

Width of wheel, Lw	=	2.0 in
Diameter of wheel	=	6.0 in
Modulous of elsaticity of Wheel and Track	=	36.0E+6 psi
Max contact stress	=	163 ksi

Based on Max contact stress a guide wheel is not ideal for this instalation.

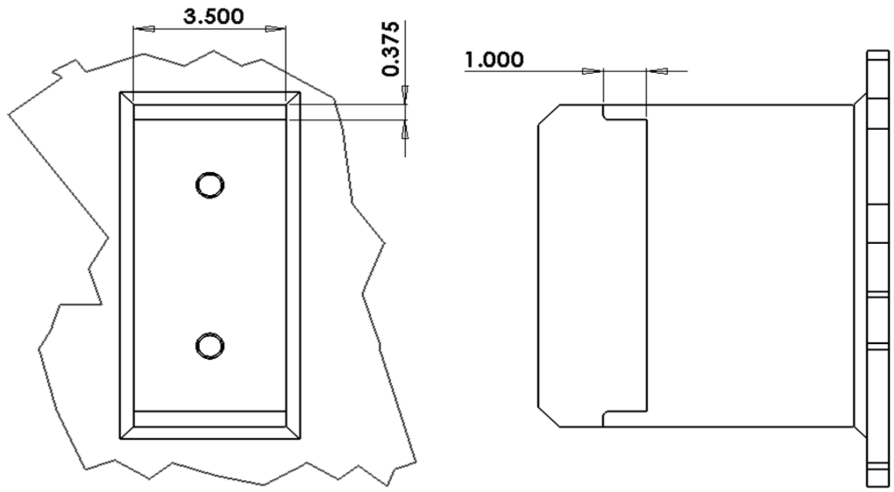
12.3 Orkot Guide Shoe

Orkot Grade SL Compressive strength	=	34000 psi
Shear strength	=	8700 psi
Allowable compressive syrength 0.33* compressive strength	=	11220 psi

12.3.1 Guide Shoe Contact Stress

Guide shoe length	=	7.0 in
Guide shoe width	=	3.5 in
Guide shoe contact area	=	24.50 in^2
Guide shoe contact stress	=	1.04 ksi

12.4 Guide Shoe Shear Key



Guide shoe base material = ASTM A36

Yield Strength, Fy = 36 ksi

Allowable Stress[1], Fa =(0.75*Fy) = 27.0 ksi

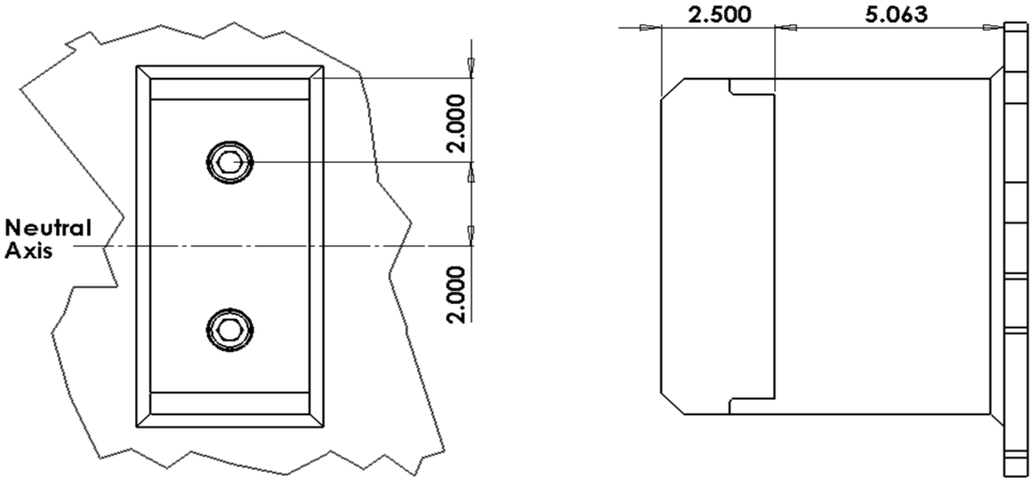
[1] *Gate Jammed Condition*

Shear key length, l = 3.5 in

Min. required shear key thickness, $t = \frac{3}{2}\frac{W_V}{F_a l}$ = 0.11 in

Min. required sheat key width, $w = \frac{W_V}{F_a l}$ = 2.75 in

12.4 Guide Shoe Bolts



Bolt Specification

Material	=	ASTM F837, SS 316.
Tensile Strength, Fu	=	28.49 kip
Allowable Strength, 0.75 * Fu	=	21 kip (Tensile)
Allowable Strength, 0.45 * Fu	=	13 kip (Shear)
Bolt Nominal Dia. D	=	3/4 in
Threads per inch, n	=	10
Bolt Stress Area, A	=	0.33 in^2
A =0.7854[D-(0.9743/n)] ^{2}		
Number of Bolts, N	=	2

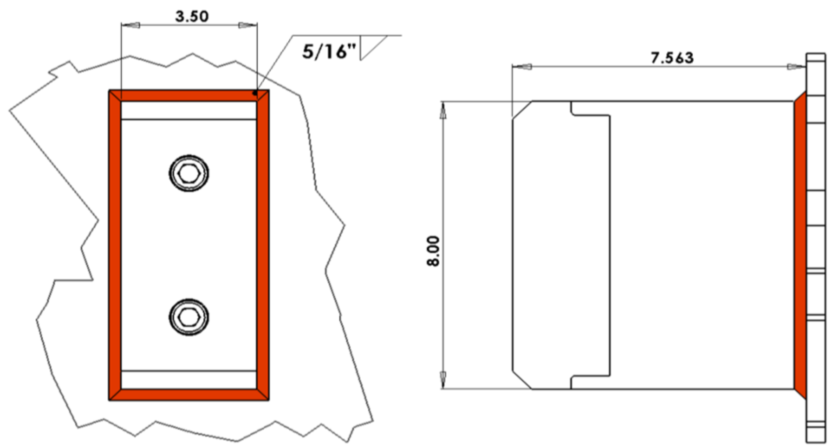
12.4.2 Tension Force on Each Bolt

Force on the Bracket, P_a	=	108 kip		(See Ref. 3)
Length of the Moment Arm,e	=	2.5 in		
Center Line Distance b/w Bolt Groups, d_m	=	2 in		
No. of Bolts Below Neutral Axis, n'	=	1		
Tension Load, $r_{at} = \dfrac{P_a e}{n' d_m}$	=	135.2 kip/bolt		
Tensile Stress on Each Bolt	=	67.6 ksi	< OK	21 ksi

12.4.3 Guide Shoe Shear Tear Out Stress

Diameter of bolt Hole, d	=	0.75 in	
Pad Thickness at the holes, t	=	1.50 in	
Width of Pad, w	=	3.50 in	
Distance from the Hole Centre to Outer Radius, c	=	1.75 in	
Effective Shear Length ,L= sqrt(c^2-$(d/2)^2$)	=	1.71 in	
Shear Area, A = L * t	=	2.56 in^2	
Maximum Force per bolt hole, F	=	54.07 kip	
Shear Tear Out Stress, = F/2A	=	10.54 ksi	< 12 ksi OK

12.5 Guide shoe base weld



Vertical Force on Base, F = 108 kip (See Ref. 3)

Distance from Point of Force to Weld, aL = 7.563 in

Weld Length, l = 8 in

Weld Size = 5/16 in

Allowable Load, P $=CC_1Dl\phi$ (Ref. 1. Tb. 8-4 Coefficients C, Pg. 8-66, Special Case)

Distance, al = 7.56 in

a = 0.95

C (for a= 0.9 & k = 0) = 1.14

C_1 (Filler material same as base material)) = 1

D (Number of sixteenth-of-an-inch in a fillet = 5

ϕ = 0.75

Allowable Load, P/Ω = 34 kip > 108 kip

OK

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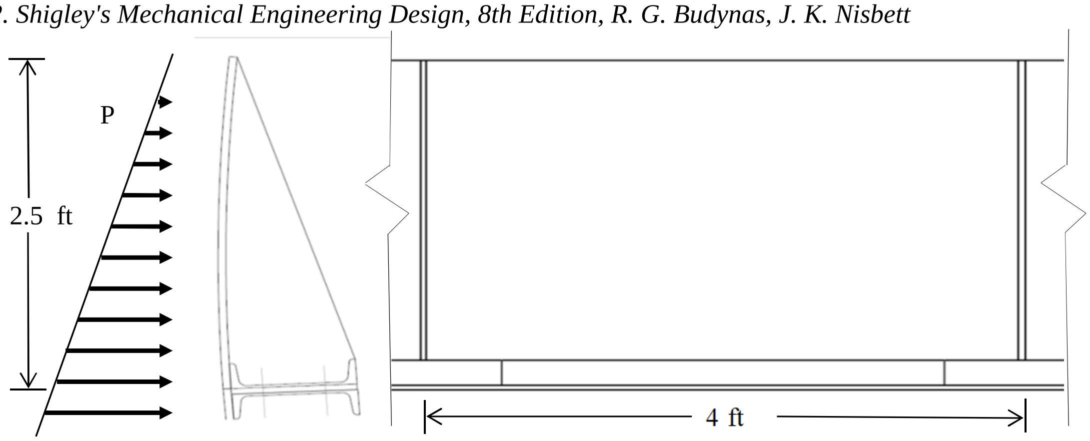
Contract/Client	Tt / Robles Diversion
Phase/Subject	Robles Diversion Tainter Gates
Design Topic	Existing Gate Extension

Made By EF Date 9/12/09 Checked By VRG Date 02/11/10 Page No. ___

References

1. AISC, Steel Construction Manual, 13th Edition

2. Shigley's Mechanical Engineering Design, 8th Edition, R. G. Budynas, J. K. Nisbett



13. Existing Gate Extension

13.1 Extension Dimensions and Properties

Addition Dimensions

Height	=	2.5	ft
Stiffener Plate c/c	=	4	ft
Skin Plate Thickness	=	0.25	in
Gusset Thickness	=	0.5	in
Gusset Length	=	28.3	in
Gusset Width at base	=	8.0	in

Unit weight of water		62.50	lb/ft^3
Modulus of elasticity of steel, E	=	29000	ksi
Maximum yield strength of steel, F_y	=	50	ksi
Ultimate strength of steel, F_u	=	65	ksi
Allowable Stress	=	16.5	ksi

13.2 Skin Plate Stress

Moment of Inertia, I		=	0.3255	in^4		
Distributed Force on Section, P		=	195.31	lbf - ft		
M_{MAX}	$M_{MAX} = \frac{PL}{12}$	=	65.104	in-lb		
Skin Plate Stress	$\sigma_{MAX} = \frac{M_{MAX}\, t/2}{I}$	=	0.03	ksi	< OK	16.5 ksi

13.3 Stiffener Plate Buckling

Hydrostatic force per section		=	781.25	lbf		
Average Stiffener Width		=	4.0	in		
Moment of Inertia, I		=	0.04167	in^4		
F_{CR} Stiffener	$F_{CR} = \frac{1.2\pi^2 EI}{L^2}$	=	18	kip	> OK	781 lbf

13.4 Joint Bolt

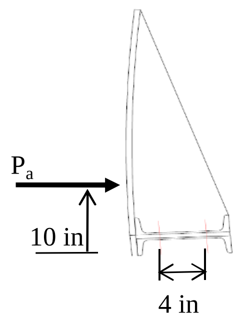
13.4.1 Bolt Specification

Material	=	ASTM A 325				
Yield Strength, Fy	=	92	ksi			
Ultimate Strength, Fu	=	120	ksi			
Allowable Stress, (0.75 * Fy)	=	69	ksi			
Bolt Nominal Dia. D	=	3/4	in			
Threads per inch, n	=	10				
Bolt Stress Area, A	=	0.33	in^2			
A =0.7854[D-(0.9743/n)] ^{2}						
Number of bolts per section, N	=	4				

13.4.2 Shear Force on Each Bolt

Shear Force on the Bracket, F	=	781	lbf			
Shear Force on each Bolt, F/N	=	195.31	lbf/bolt			
Shear Stress on Each Bolt	=	0.58	ksi	<	69.00	ksi
				OK		

13.4.3 Tension Force on Each Bolt



Force on the Bracket, P_a	=	781	lbf
Length of the Moment Arm,e	=	10	in
Center Line Distance b/w Bolt Groups, d_m	=	4	in
No. of Bolts Below Neutral Axis, n'	=	2	
Tension Load, $r_{at} = \dfrac{P_a e}{n' d_m}$	=	1.0	kip/bolt
Tensile Stress on Each Bolt	=	2.9	ksi < 69.0 ksi OK