Sound Ocean Systems Inc.

P.O. Box 2978 , Redmond WA. 98073-2978 (425)869-1834(p) (425)869-5554(f) **SOSI**

Project Number	S70031				
Project Name	OSMO Winch	**Eng'd By**	PGH	**Date**	7/2/08
Client	Monterey Bay Aquarium Research Institute	**Chk'd by**		**Date**	
Design Item	CFR Winch Stress Analysis	**Page**	1	**of**	11

Ref.

Sound Ocean Systems (SOSI) was contracted in March, 2007, to design and fabricate a winch for the Monterey Bay Aquarium Research Institute (MBARI). This winch is to be used primarily for recovering osmotic sensor packages from sea floor bore holes, and may be installed on vessels belonging to both MBARI and to the UNOLS fleet.

As required for all lifting equipment to be placed on board ships in the UNOLS fleet, the winch has been designed to meet the requirements of 46CFR189.35.
The requirements of 46CFR189.35 stipulate that any "Wet Weight Handling Gear", including this winch, be designed with a minimum safety factor of 1.5 times the allowable load, as determined by the weakest portion of the line or rope used on the winch.
In addtion, the winch should be tested to 1.25 times the allowable working load.

In this case, the winch has been designed for the specific job of retrieving sensor packages from sea floor bore holes. As specified by MBARI, the dynamic working load for the winch is 5000 lbs. A secondary portion of the proposed use for the winch is dislodging the sensor packages from the bore holes. It has been estimated by MBARI that this can take up to 8000 lbs line pull. However, the winch is designed for this level of pull only when the manual brake is engaged, and not by using the winch drive.

Therefore, the winch frame, bearings, and mounting have been designed to withstand a static load of at least 12000 lbs (1.5 x 8000). The drive components are designed for a minimum live load of at least 7500 lbs (1.5 x 5000).

The winch is constructed primarily of aluminum, with mostly stainless steel hardware. A few select components are made of steel as needed to provide extra strength.

The winch is driven by a 20 Hp hydraulic power unit, driving a hydrostatic pump and motor combination. The winch has two (2) speed modes, High and Low. In the High Speed mode, the winch will operate at approximately 100 rpm at the drum. In the Low Speed mode, the speed is reduced to aproximately 25 rpm at the drum.

Refer to drawings:

351-100-001	Winch Assembly
351-100-004	Winch Frame Weldment
351-100-005	Drum Weldment

The major portions of the winch, the drum and frame, are fabricated
from 6061-T6 aluminum, with a yield stress of $S_y =$ 39.9 ksi

Then for the required safety factor $\eta =$ 1.5

the allowable stress is $S_a =$ 26.6 ksi

EXPIRES: 7/24/07

Ref.

For shear, the max allowable stress is commonly 0.6 times S_a

Therefore $\tau_a =$ 16.0 ksi

There are two (2) primary load cases:

Case 1	8000 lb	maximum line pull at empty drum
Case 2	5000 lb	maximum line pull at full drum

Drum Dimensions

Core Diameter	d =	12 5/8	in	12" Sched 40 Pipe			
Flange Diameter	D =	54	in	Thickness	t =	3/8	in
Between Flanges	B =	32	in				
Between Bearings	L =	48	in				
Shaft Diameter	d_s =	2 15/16	in	I =	3.6549	in^4	

<u>**Case 1**</u> F = 8000 lbs pull at bare drum

Worst case is at near horizontal pull.

Torque at bare drum: T = P x d/2 = 50500.0 in lbs

The drive sprocket is 72 tooth, R(100

Its pitch diameter is PD = 28.657 in

The chain loading is then T_{chain} = 3524.4 lbs

The published breaking strength of the chain is L_{allow} = 26460 lbs ***OKAY***

Per the layout drawings, the chain angle is approximately 22.5 degrees below the horizontal. then the components of the chain load are:

Horizontal	T_{horiz} =	3256.2	lbs
Vertical	T_{vert} =	1348.7	lbs

The weight of the drum W_{drum} = 670 lbs

The weight of the rope is estimated at W_{rope} = 783 lbs (5000 m)

Then the total weight of the drum assembly is W_{total} = 1453 lbs

The net loads are then:

P_{horiz} =	11256	lbs
P_{vert} =	2802	lbs

With the resultant load being P = 11600 lbs

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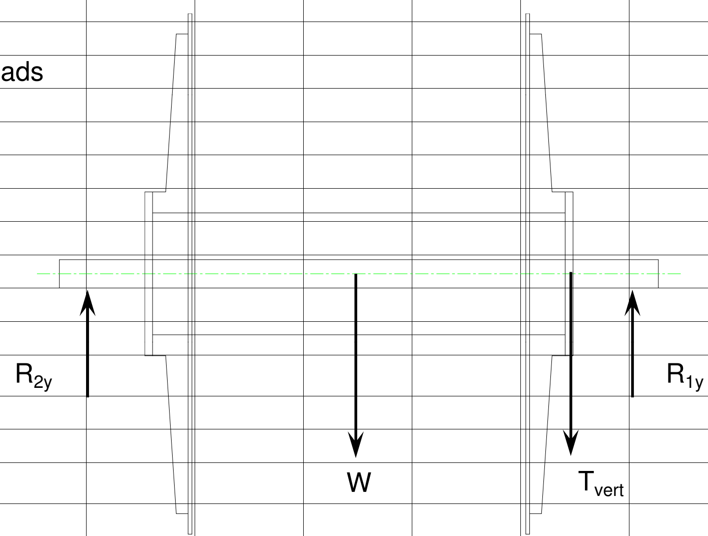
Ref.

Vertical Loads



Using the dimensions from drawing 351-100-005, and summig the moments about R_2 yields

$M = 0 = 24 \times W + 44.5 \times T_{vert} - 48 \times R_{1y}$

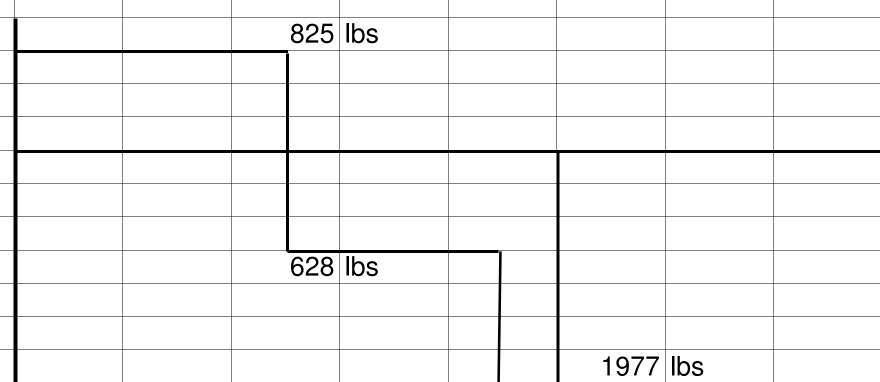
and solving for R_{1y}: $R_{1y} =$ 1977.1 lbs

and summing the vertical forces:

$R_{2y} = W + T_{vert} - R_{1y}$

$R_{2y} =$ 825 lbs

Shear Diagram



Moment Diagram

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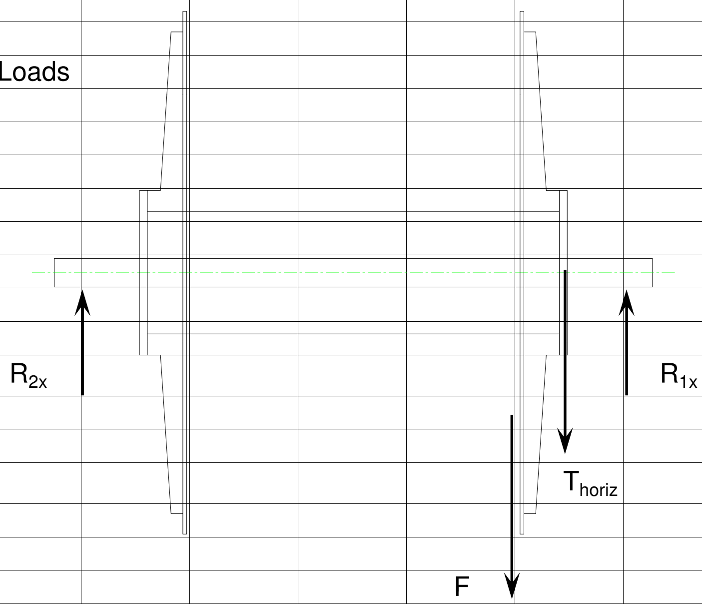
Design Item CFR Winch Stress Analysis

Ref.

Horizontal Loads



Using the dimensions from drawing 351-100-005, and summig the moments about R_2 yields

$M = 0 = 39.75 \times F + 44.5 \times T_{horiz} - 48 \times R_{1x}$

and solving for R_{1x}: $R_{1x} =$ 9643.7 lbs

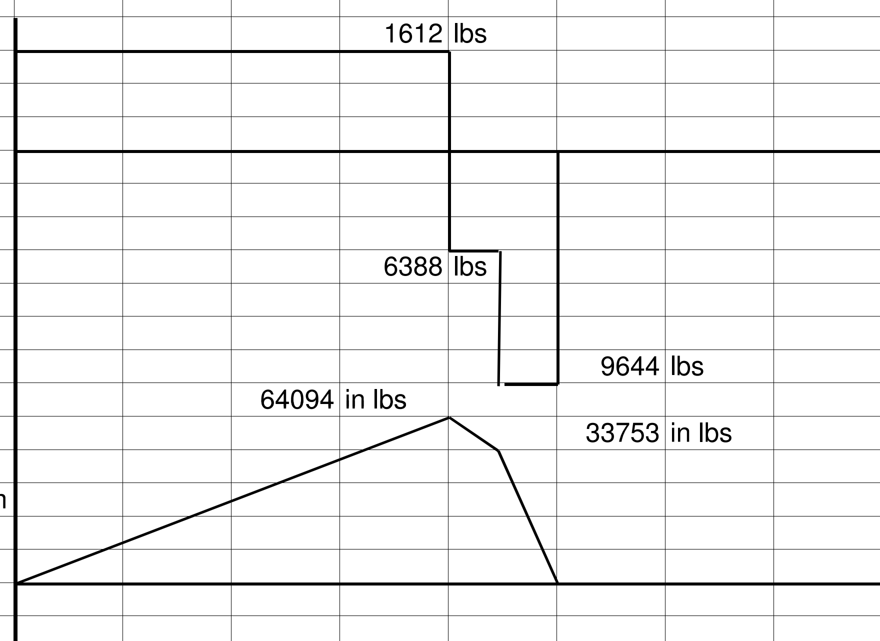
and summing the vertical forces:

$R_{2x} = F + T_{horiz} - R_{1x}$

$R_{2x} =$ 1612 lbs

Shear Diagram

Moment Diagram



Ref.

Summing the moment diagrams above, $M = (M_H^2 + M_V^2)^{1/2}$

Then the maximum moment load in the shaft is $M_{max} =$ 64854 in lbs
located at the drum flange closest to the drive sprocket (x = 39.75")

At that location the shear load in the shaft is V = 6418.4 lbs
The shear stress is then $\mathrm{T} =$ 947.1 psi

The stresses imposed by the bending moment are $\sigma =$ Mc/I
$\sigma =$ 26061.5 psi

By Mohr's circle analysis, the principal stresses are
$\sigma_1 = 0.5\sigma + ((0.5\sigma)^2 + \mathrm{T}^2)^{1/2}$ $\sigma_1 =$ 26096 ***OKAY***

$\mathrm{T}_1 = ((0.5\sigma)^2 + \mathrm{T}^2)^{1/2}$ $\mathrm{T}_1 =$ 13065 psi ***OKAY***

The maximum bearing load is at R_1: $R_1 = (R_{1x}^2 + R_{1y}^2)^{1/2} =$ 9844.3 lbs

The published allowable load for the bearings is 14872 lbs ***OKAY***

Loads on the drum and shaft for Case 1 are within acceptable limits.

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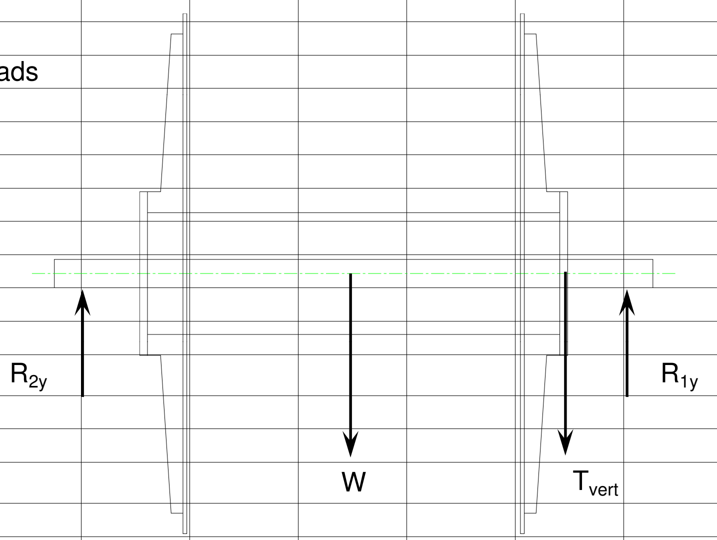
													Ref.
	Case 2	F =	5000	lbs pull at full drum			d =	52	in				
				Worst case is at near horizontal pull.									
		Torque at bare drum:			T = P x d/2 =		130000	in lbs					
		The drive sprocket is			72	tooth, R(	100						
			Its pitch diameter is			PD =	28.657	in					
			The chain loading is then			T_{chain} =	9073	lbs					
			The published breaking strength of the chain is						L_{allow} =	26460	lbs		***OKAY***
		Per the layout drawings, the chain angle is approximately								22.5	degrees below		
			the horizontal. then the components of the chain load are:										
				Horizontal		T_{horiz} =	8382	lbs					
				Vertical		T_{vert} =	3472	lbs					
		The weight of the drum					W_{drum} =	670	lbs				
		The weight of the rope is estimated at					W_{rope} =	783	lbs	(5000 m)			
		Then the total weight of the drum assembly is						W_{total} =	1453	lbs			
	The net loads are then:												
				P_{horiz} =	13382	lbs							
				P_{vert} =	4925	lbs							
		With the resultant load being				P =	14260	lbs					

Ref.

Vertical Loads



Using the dimensions from drawing 351-100-005, and summig the moments about R_2 yields

$M = 0 = 24 \times W + 44.5 \times T_{vert} - 48 \times R_{1y}$

and solving for R_{1y}: R_{1y} = 3945.5 lbs

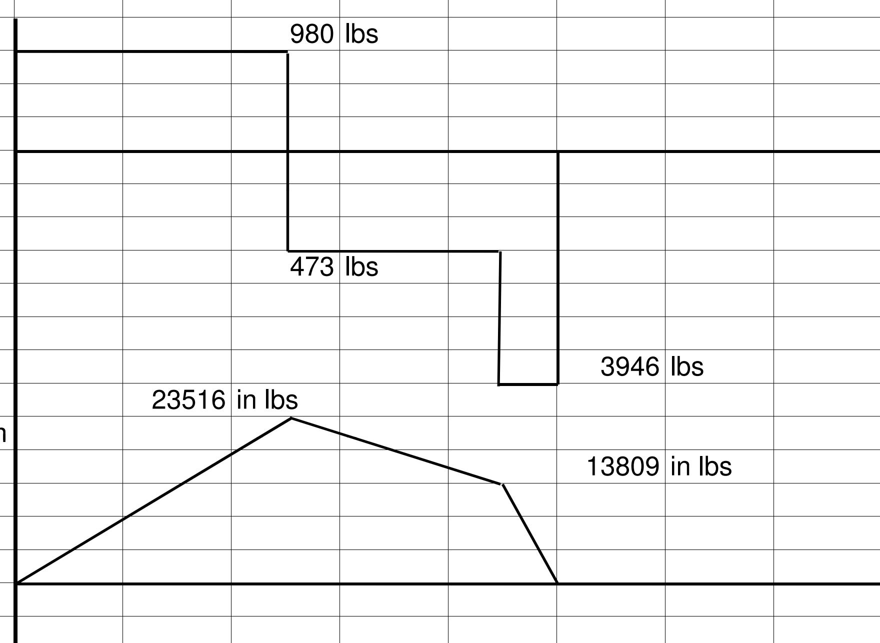
and summing the vertical forces:

$R_{2y} = W + T_{vert} - R_{1y}$

R_{2y} = 980 lbs

Shear Diagram

Moment Diagram



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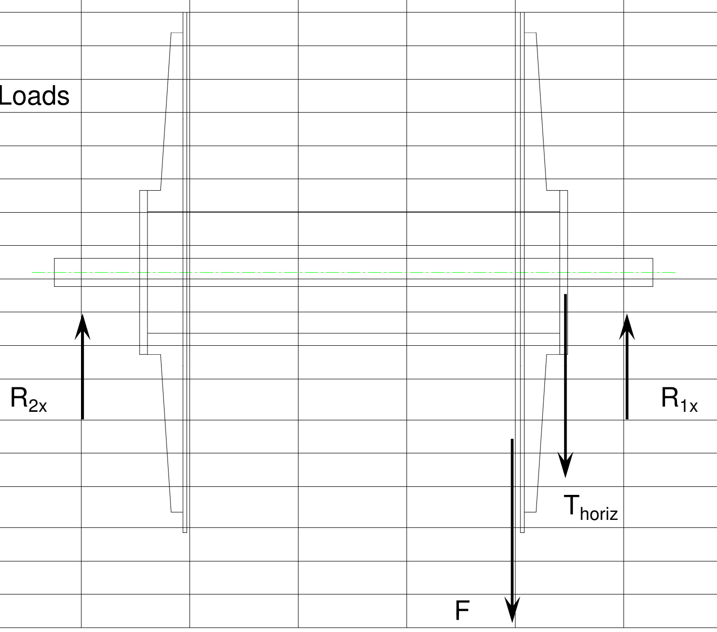
Horizontal Loads



Using the dimensions from drawing 351-100-005, and summig the moments about R_2 yields

$M = 0 = 39.75 \times F + 44.5 \times T_{horiz} - 48 \times R_{1x}$

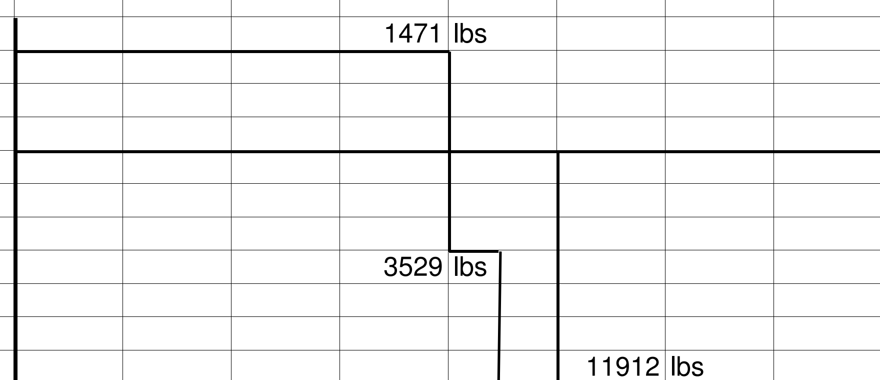
and solving for R_{1x}: $R_{1x} =$ 11912 lbs

and summing the vertical forces:

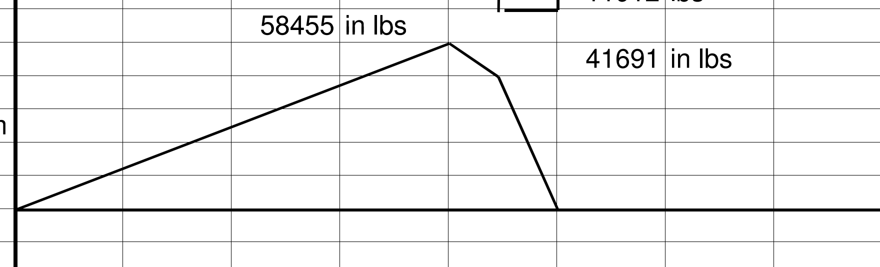
$R_{2x} = F + T_{horiz} - R_{1x}$

$R_{2x} =$ 1471 lbs

Shear Diagram



Moment Diagram



Ref.

Summing the moment diagrams above, $M = (M_H^2 + M_V^2)^{1/2}$

Then the maximum moment load in the shaft is $M_{max} =$ 58929 in lbs
located at the drum flange closest to the drive sprocket (x = 39.75")

At that location the shear load in the shaft is V = 3561 lbs
The shear stress is then $\tau =$ 525.5 psi

The stresses imposed by the bending moment are $\sigma =$ Mc/I
$\sigma =$ 23680.9 psi

By Mohr's circle analysis, the principal stresses are

$\sigma_1 = 0.5\sigma + ((0.5\sigma)^2 + \tau^2)^{1/2}$ $\sigma_1 =$ 23693 ***OKAY***

$\tau_1 = ((0.5\sigma)^2 + \tau^2)^{1/2}$ $\tau_1 =$ 11852 psi ***OKAY***

The maximum bearing load is at R_1: $R_1 = (R_{1x}^2 + R_{1y}^2)^{1/2} =$ 12548 lbs

The published allowable load for the bearings is 14872 lbs ***OKAY***

Loads on the drum and shaft for Case 2 are within acceptable limits.

<u>Torque on Drum</u>
The maximum torque on the drum is applied in Load Case 2 T = 130000 in lbs

The torque is resisted by either the brake disc or the sprocket. In either case, the disc and sprocket are connected by a flange welded to the drum. Therefore, the torque is transmitted through the drum.

Drum OD	D =	12.625	in		
Drum ID	d =	11.875	in		
Polar Moment	J =	$\pi (D^4 - d^4)/32 =$	541.92	in^4	
Torsional Stress	τ =	T x D / 2J =	1514.3	psi	
Moment of Inertia	I =	$\pi (D^4 - d^4)/64 =$	270.96	in^4	
Bending Moment	M =	64854	in lbs		***From Case 1***
Bending Stress	σ =	M c / I =	1510.9	psi	

Stresses are well below allowable ***OKAY***

Ref.

The analysis of the frame begins with the points of contact from the shaft. There is a vertical and a horizontal force acting through the bearing. It is assumed that the vertical load is acting only on the center support. For ease in calculation, it is assumed that the horizontal member is rigid and has no compressive deflection. However bending is taken into consideration. The deflection at points A, B, and C are assumed equal.

The members AC and BE are examined first. The ends are assumed to be rigid mounted. The horizontal force is placed 4.25" above the frame, creating a moment on member AC. Setting the deflection of each member equal at point B, the forces acting on each can be determined.

F_x=	0	lbs	δ=	$F_B*L_{BE}/(E*A)$	=	$(F_y-F_B)*L_{AB}^2*(3*L_{AC}-4*L_{AB})/(48*E*I)$
F_y=	3302.3	lbs	F_B=	3230.1	lbs	
M_{AC}=	0	lb-in				
I=	2.6	in^4	F_B is the compressive force acting on member BE, F_y - F_B			
A=	2.02	in^2	is the bending force acting on member AC.			
L_{AC}=	69	in				
L_{AB}=	31.5	in				
L_{BE}=	29.1	in				
y=	1.5	in	The reaction forces on member AC are then determined			
			to find the maximum moment.			
F_C=	32.986	lbs				
F_A=	39.269	lbs	The negative sign means is pointing the opposite direction from F_C			
			Shear stress is assumed negligible.			
M_{ACmax}=	1237	lb-in				

σ_{AC}=	$M_{max}*y/I$		σ_{AC}=	713.63	psi
S_y=	40000	psi			
η=	S_y/σ		η_{AC}=	56.051	

The deflections at point A, B, & C are equal. There are 5 member that will deflect at these points. Members AD, BE, & CF will see mostly bending, while members AE & CE will see bending and compression/tension.

For members AD, BE, and CF the deflection is equal to: δ_{xAD}= $F_{XA}*L_{AD}^3/(3*I*E)$

For members AE & CE the deflection is assumed to be in the horizontal direction only. The forces acting on these members are broken up into horizontal and vertical components relative to the member. This allows for the bending and compression/tension deflections to be found separately. The two deflections can be found relative to the force in that direction and then can be used to solve for the total deflection in the horizontal. Subscript h stands for horizontal relative to the member and v stands for vertical.

Ref.

θ_{AE}= the angle between the member and horizontal plane
L_{AE}= length of the member from point A to point E

θ_{CE}= 0.7732 θ_{AE}= 0.8983 L_{AE}= 37.2 in L_{CE}= 41.68 in

δ_{xAE}= δ_b/sin(51.47)= δ_c/cos(51.47)
δ_{xAE}= $F_{vA}*L_{AE}/(A*E)*\cos(\theta_{AE})+F_{hA}*L_{AE}^3/(3*I*E)*\sin(\theta_{AE})$

Combining the two above equations allows for a relation between the forces.

F_{vA}= 410.69*F_{hA} F_{vC}= 449.82*F_{hC}

The horizontal component of each force must add up to horizontal force applied to the frame.

F_x= $F_{AD}+F_{BE}+F_{CF}+F_{hA}*\sin(51.47)+F_{vA}*\cos(51.47)+F_{hC}*\sin(44.3)+F_{vC}*\cos(44.3)$= 12276.69lbs

δ_{xAD}= δ_{xBE}= δ_{xCF}= 3159.3 *F_{AD}/E lbs

δ_{xAE}= 5915.69*F_{hA}/E+11.47(410.69)*F_{hA}/E=10626.3*F_{hA}/E F_{hA}= .2973*F_{AD}
δ_{xCE}= 6483.39*F_{hC}/E+14.77(449.82)*F_{hC}/E=13127.23*F_{hC}/E F_{hC}= .2407*F_{AD}

F_{AD}=	0	lbs
F_{hA}=	0	lbs
F_{hC}=	0	lbs
F_{vA}=	0	lbs
F_{vC}=	0	lbs
F_{BE}=	78.224	lbs
F_{CF}=	78.224	lbs

For members AD, BE, and CF the bending stress will be the same. Member BE will also have a compressive stress.

σ_{AD}/σ_{CF}=	0	psi	η=	######	***OKAY***
σ_{AE}=	0	psi	η=	######	***OKAY***
σ_{CE}=	0	psi	η=	######	***OKAY***
σ_{BE}=	1599	psi	η=	######	***OKAY***