HydraSafe

4” Structural Steel Crosshead FEA

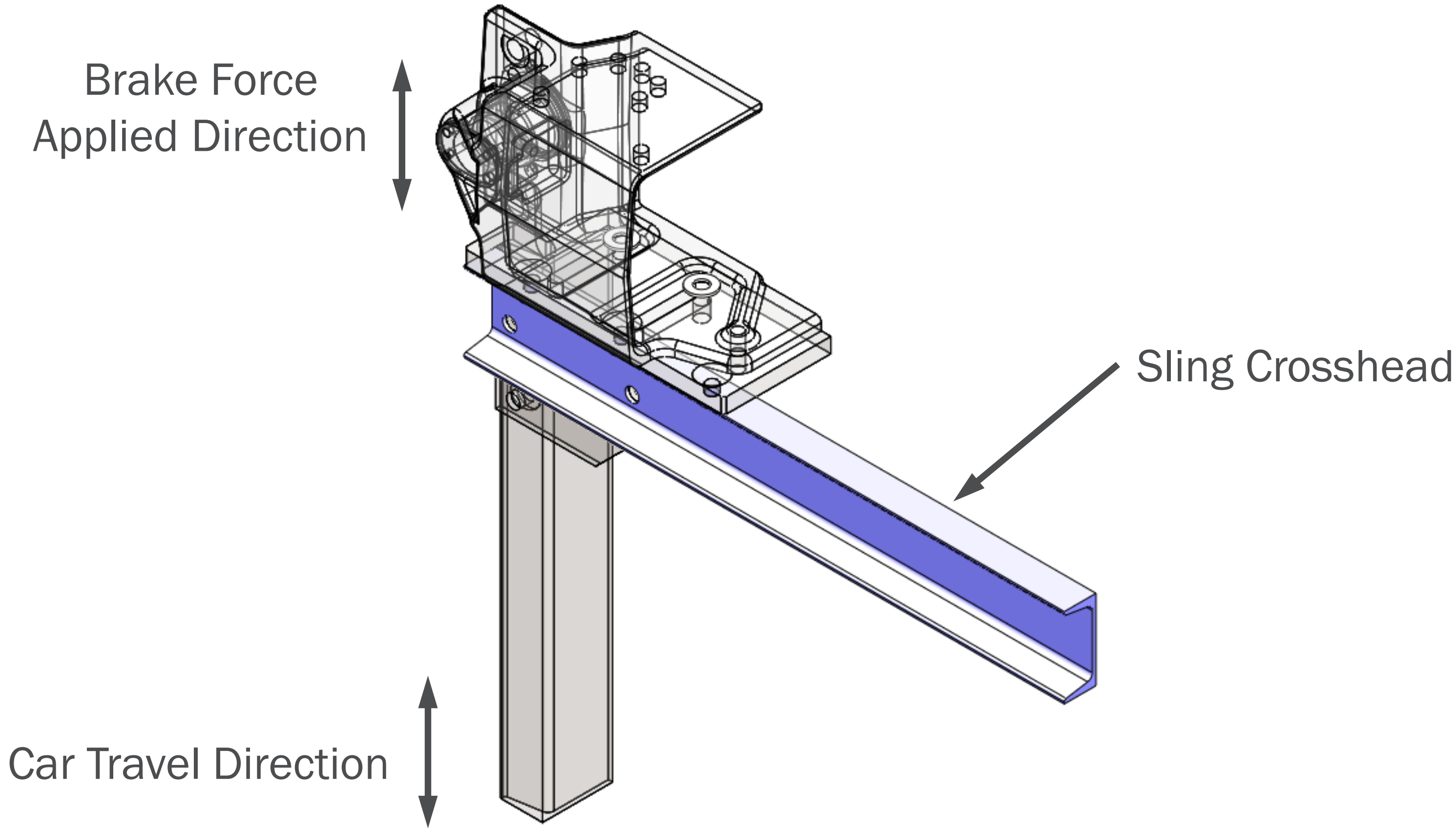
2024/03/25

Purpose of Sling Crosshead FEA

The purpose of the FEA is to show the Stress, Displacement and FOS for the structural steel crosshead.

When the car is travelling in the upward direction, a downward force is applied at the caliper housing.

When the car is travelling in a downward direction, and upward force is applied at the caliper housing.



Required FOS for crosshead

Per ASME A17.1-2016/CSA B44-16 2.24.3

FOS for the brake and its components is 3.5x

Required max stress for the crosshead is 27,500 psi (~1.3x FOS)

2.19.3 Emergency Brake (See Nonmandatory Appendix F)

2.19.3.1 Where Required

2.19.3.2 Requirements. The emergency brake is permitted to consist of one or more devices and shall

(i) be designed so that the factors of safety based on the maximum stresses developed in the parts subject to load during the operation of the emergency brake shall comply with the following:

(1) Where an emergency brake is applied only when protecting against either an ascending car overspeed condition or unintended car movement with the car and hoistway doors open, the minimum factors of safety, when applied during the retardation phase of emergency braking, shall be not less than those specified in 2.17.12.1.

2.17.12 Minimum Factors of Safety and Stresses of Safety Parts and Rope Connections

2.17.12.1 Parts of safeties, except springs, safety-rope drums, leading sheaves, and their supporting brackets and safety-jaw gibs, shall have a factor of safety of not less than 3.5, and the materials used shall have an elongation of not less than 15% in a length of 50 mm (2 in.) when tested in accordance with ASTM E8. Forged, cast, or welded parts shall be stress relieved.

2.19.4 Emergency Brake Supports

All components and structural members, including their fastenings, subjected to forces due to the application of the emergency brake shall be designed to withstand the maximum forces developed during the retardation phase of the emergency braking so that the resulting stresses shall not exceed those permitted for the applicable type of equipment as follows:

(a) machinery and sheave beams (see 2.9.6)
(b) guide rails and their supports (see 2.23.5.3)
(c) counterweight frames (see 2.21.2.3.3)
(d) car frames (see 2.15.10.2)
(e) machines, sheaves, and bedplates (see 2.24.3.2)

2.15.10.2 Car frame members, brackets, and their connections subject to forces due to the application of the emergency brake (see 2.19.4) shall be designed to withstand the maximum forces developed during the retardation phase of the emergency braking so that the resulting stresses due to the emergency braking and all other loading acting simultaneously, if applicable, shall not exceed 190 MPa (27,500 psi).

Structural steel and caliper casting materials

Channel and Beam Materials are made from hot roll material. These materials are most commonly A572, A588 and A36 steel. For this FEA, A36 steel was chosen as it has the lowest yield strength.
The caliper casting is made from A352 LC2-1 steel.

Different Steel Compositions

In addition to choosing the right shape for your steel beams, it's important to consider the material itself. Most commonly, steel beams come in A572, A588, and A36.

Source: www.bushwickmetals.com

Structural Steel Components

A36 Yield Strength: 36,000psi

Caliper Casting Component

A352 LC2-1 Yield Strength: 105,000psi

Source: www.makeitfrom.com

Bolt Material, Strength and Torque

For the purposes of fastener strength simulations, the tensile strength is used.

Grade 8 Bolts

A **grade 8 bolt** is the highest grade SAE bolt. Grade 8 bolts have a minimum tensile strength of 150,000 PSI. As a comparison, the ASTM A325 bolt is roughly equivalent to the SAE grade 5. A grade 8 bolt would be one that meets ASTM A490 standards.

Source: www.tfgusa.com

US Bolts					
Head Marking	Grade and Material	Nominal Size Range (inches)	Mechanical Properties		
			Proof Load (psi)	Min. Yield Strength (psi)	Min. Tensile Strength (psi)
6 Radial Lines	**Grade 8** Medium carbon alloy steel, quenched and tempered	1/4" thru 1-1/2"	120,000	130,000	150,000

Source: www.boltdepot.com

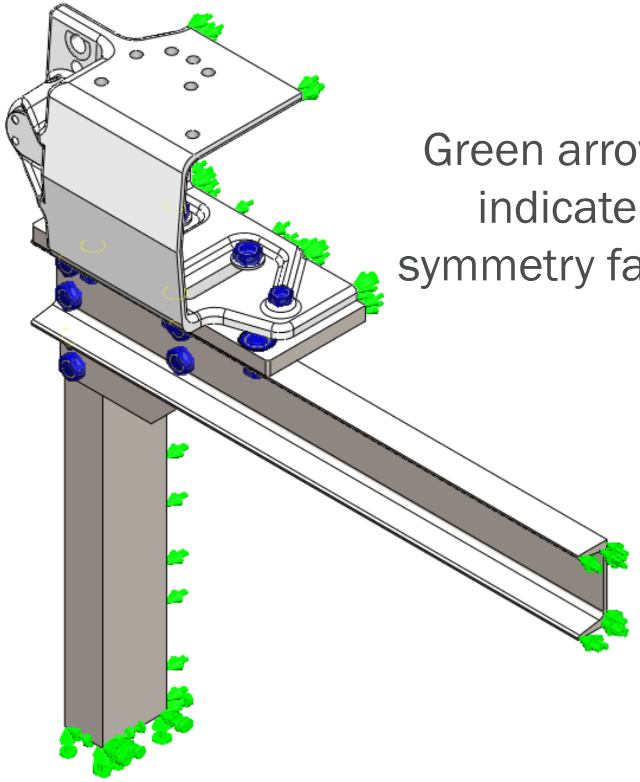
This is not an installation torque spec. This is the highest expected torque spec used to confirm our bolt tension is safe.

GRADE 8 Coarse Thread			
Size	Clamp Load	Plain (ft. lbs.)	Plated (ft. lbs.)
1/4-20 (.250)	2850	12	9
5/16-18 (.3125)	4725	25	18
3/8-16 (.375)	6975	44	33
7/16-14 (.4375)	9600	70	52
1/2-13 (.500)	12750	106	80
9/16-12 (.5625)	16350	153	115
5/8-11 (.625)	20325	212	159
3/4-10 (.750)	30075	376	282
7/8-9 (.875)	41550	606	454
1-8 (1.000)	54525	909	682
1 1/8-7 (1.125)	68700	1288	966
1 1/4-7 (1.250)	87225	1817	1363
1 3/8-6 (1.375)	103950	2382	1787
1 1/2-6 (1.500)	126450	3161	2371

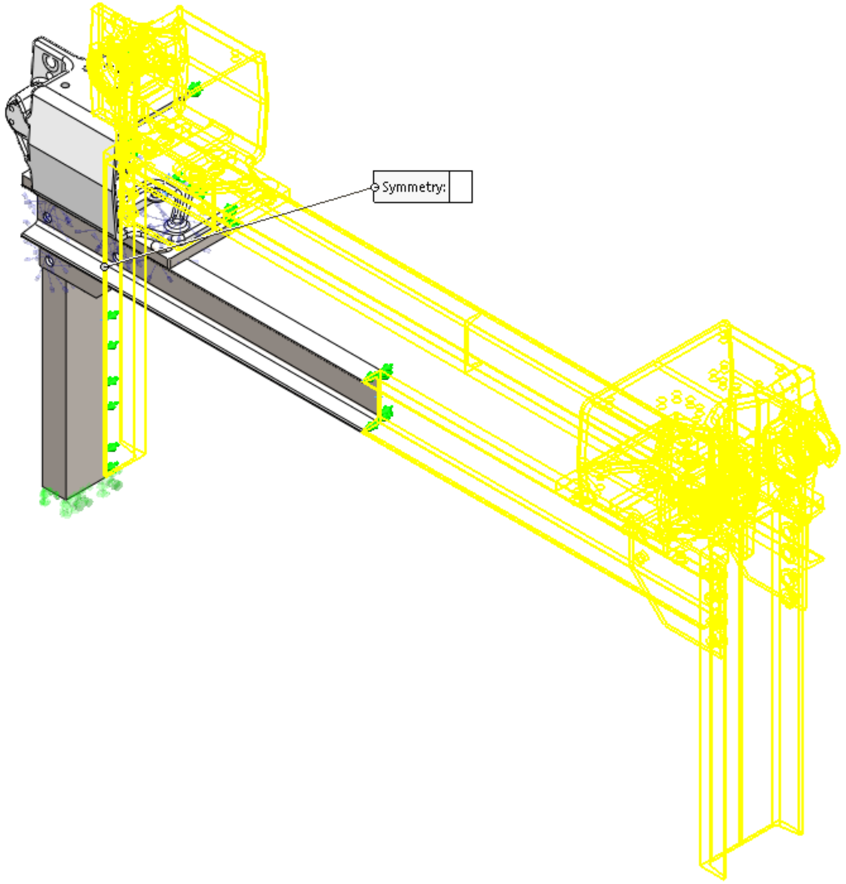
Source: www.almabolt.com

FEA Setup - Model

The FEA model was set up using ¼ of the actual assembly, and then applying symmetry fixtures in the front and right planes.

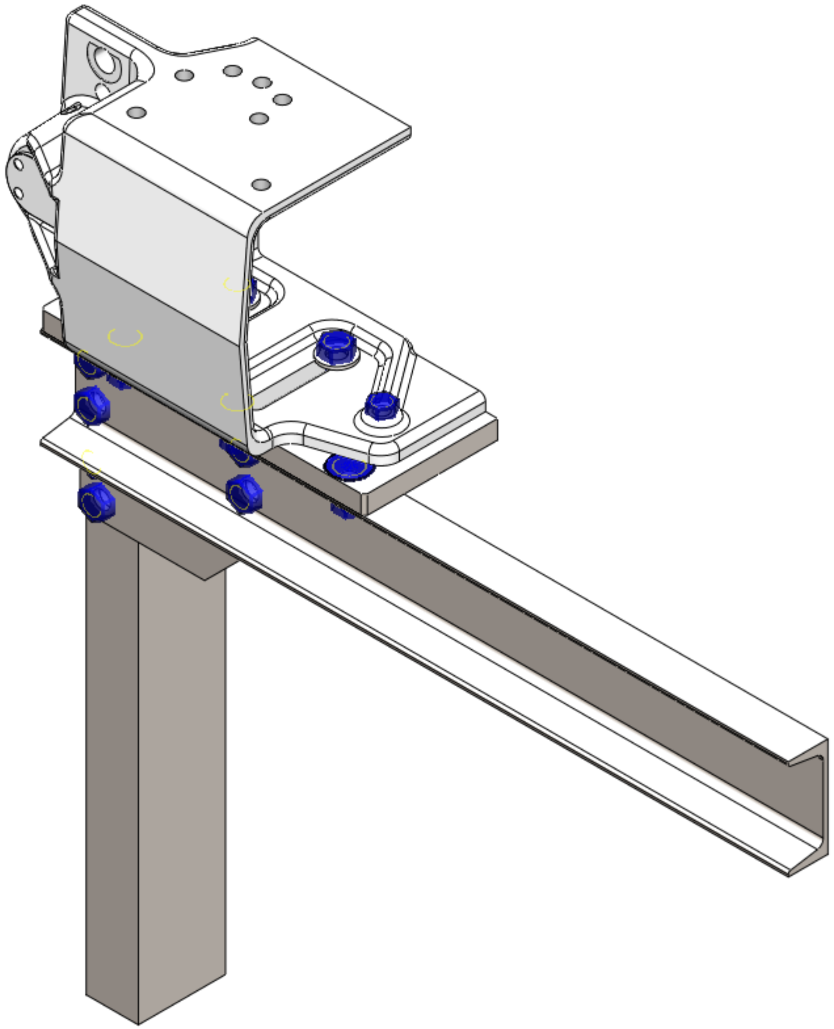


Green arrows indicate symmetry faces



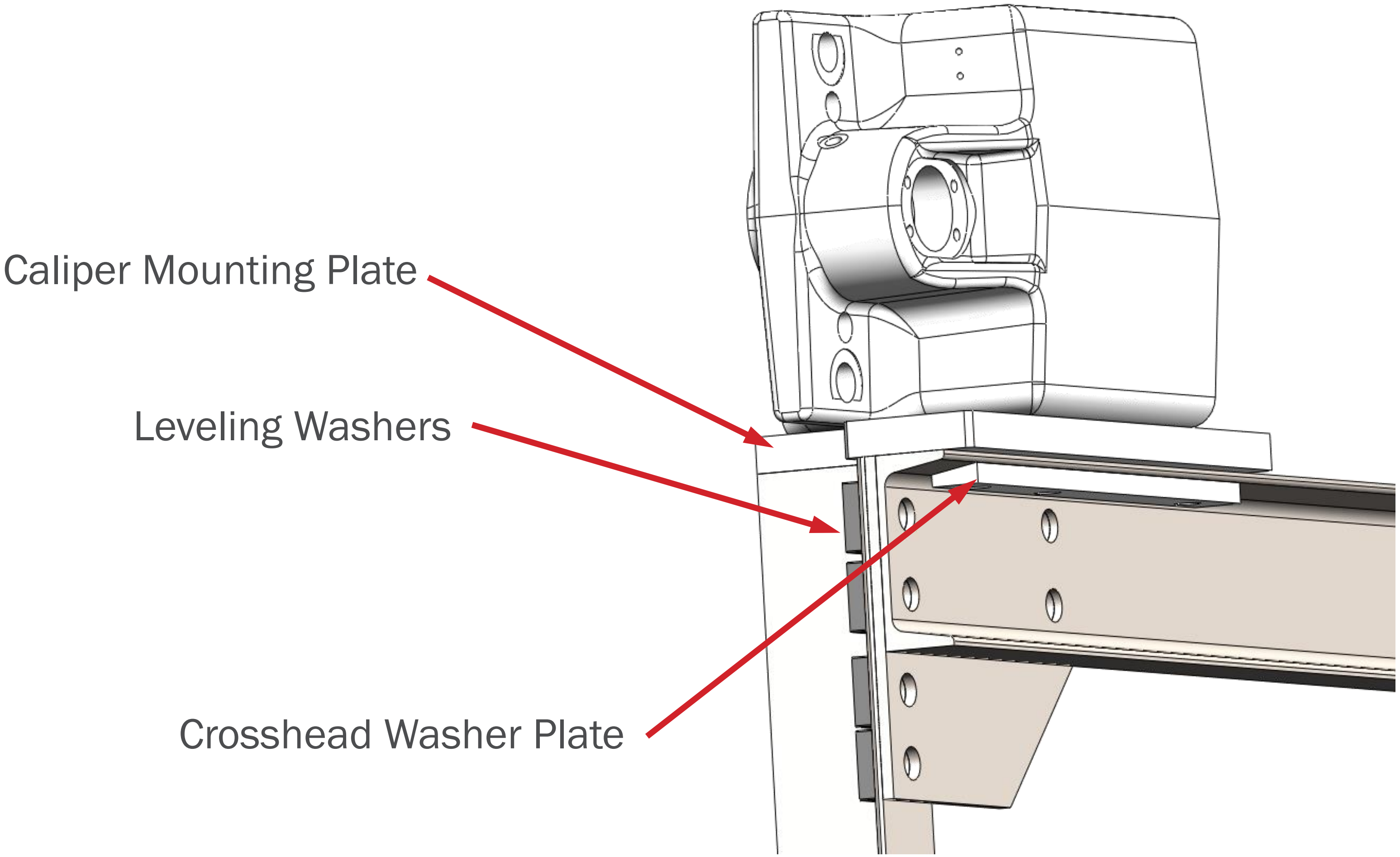
FEA Setup - Connectors

Grade 8 fasteners are used at all bolt locations.



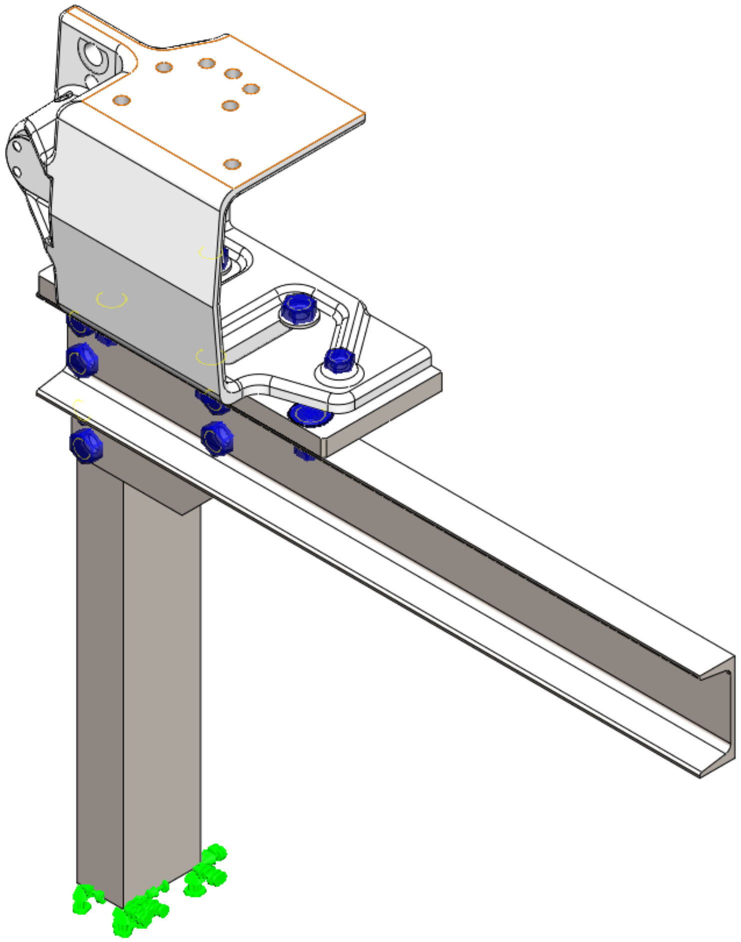
Updated Mounting Components

An update to the FEA was made to strengthen areas of stress.
Leveling washers were added and are made from ductile iron.
A crosshead washer plate was added and is made from A36 steel.



FEA Setup – Fixed Component

The stile was cut at 3' from the top and fixed at the base surface.



Green arrows indicate fixed face

This report represents data as a result of Finite Element Analysis studies run by DiMonte Group Inc. for its client. This data is accurate to the best of our knowledge, based on parameters calculated and supplied by our client. None of the data in this report can be interpreted as a guarantee or warranty of the product design analyzed.

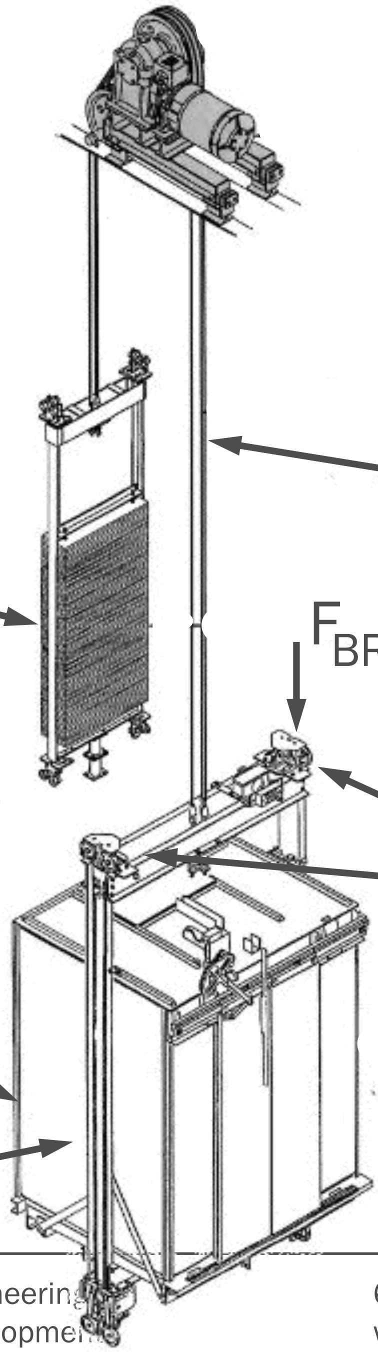
FEA Masses 4" Crosshead Car Travelling Upward (Downward Brake Force)

NOTE: Guide-rails not shown

Braking load:

Car and Sling Empty Weight
+ Load Inside Car
+ Counterweight
+ Ropes & Cables
= 8,162 lbs

0.5g Stopping Force
Used For FEA = 8,162 lbs X 0.5
= 4,081 lbs



Counterweight
3,187 lbs

Counterweight Travel

Car and Sling Empty weight
2,050 lbs

Load Inside Car
2,625(125%) lbs
(either 0 or 125% of capacity)

Elevator Ropes 150 lbs
Travel Cables 150 lbs

F_{BRAKE}

HydraSafe Brake Locations (Top or Bottom)

Car Moving Up

Sling Crosshead FEA Brake Downward Forces

The 4,081 lb mass used in the FEA was calculated using an 8,162 lb moving mass and a 0.5 stopping reaction force.

Speed (ft/min)	Stopping distance (ft) at acceleration (g) 0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
50	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.9	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
200	3.5	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.2
500	21.6	10.8	5.4	3.6	2.7	2.2	1.8	1.5	1.3	1.2	1.1
1000	86.3	43.1	21.6	14.4	10.8	8.6	7.2	6.2	5.4	4.8	4.3
1500	194.1	97.0	48.5	32.3	24.3	19.4	16.2	13.9	12.1	10.8	9.7
2000	345.1	172.5	86.3	57.5	43.1	34.5	28.8	24.6	21.6	19.2	17.3

$$v^2 = u^2 + 2as$$

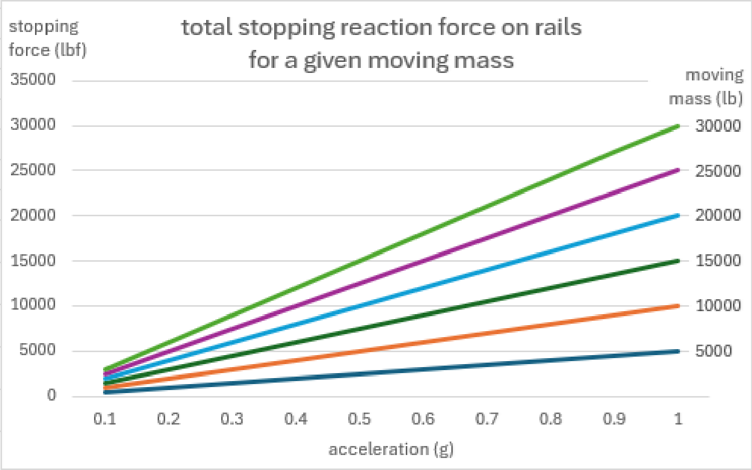
where:

- v is the final velocity,
- u is the initial velocity,
- a is the acceleration,
- s is the displacement.

"Total Gross Load"

F = ma mass = 8162 lb

Moving Mass (lb)	Stopping reaction force (lbf) at acceleration (g) 0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5000	250	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
10000	500	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
15000	750	1500	3000	4500	6000	7500	9000	10500	12000	13500	15000
20000	1000	2000	4000	6000	8000	10000	12000	14000	16000	18000	20000
25000	1250	2500	5000	7500	10000	12500	15000	17500	20000	22500	25000
30000	1500	3000	6000	9000	12000	15000	18000	21000	24000	27000	30000
8162	408.1	816.2	1632.4	2448.6	3264.8	4081	4897.2	5713.4	6529.6	7345.8	8162



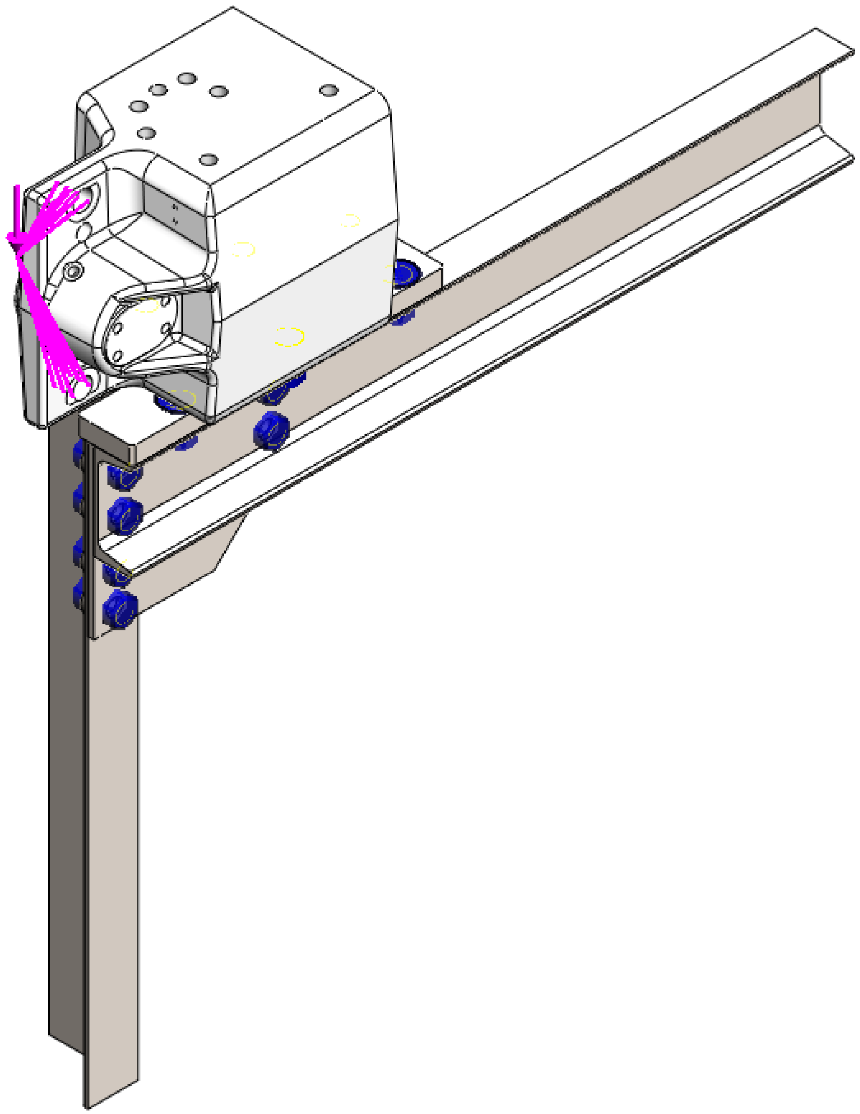
Setup – Downward Load

A braking load of 8,162 lb is used. A multiplier for 0.5g was added for an FEA load of 4,081 lbs.

Since the model is in a ¼ section, ¼ of the 4,081 lb was used.

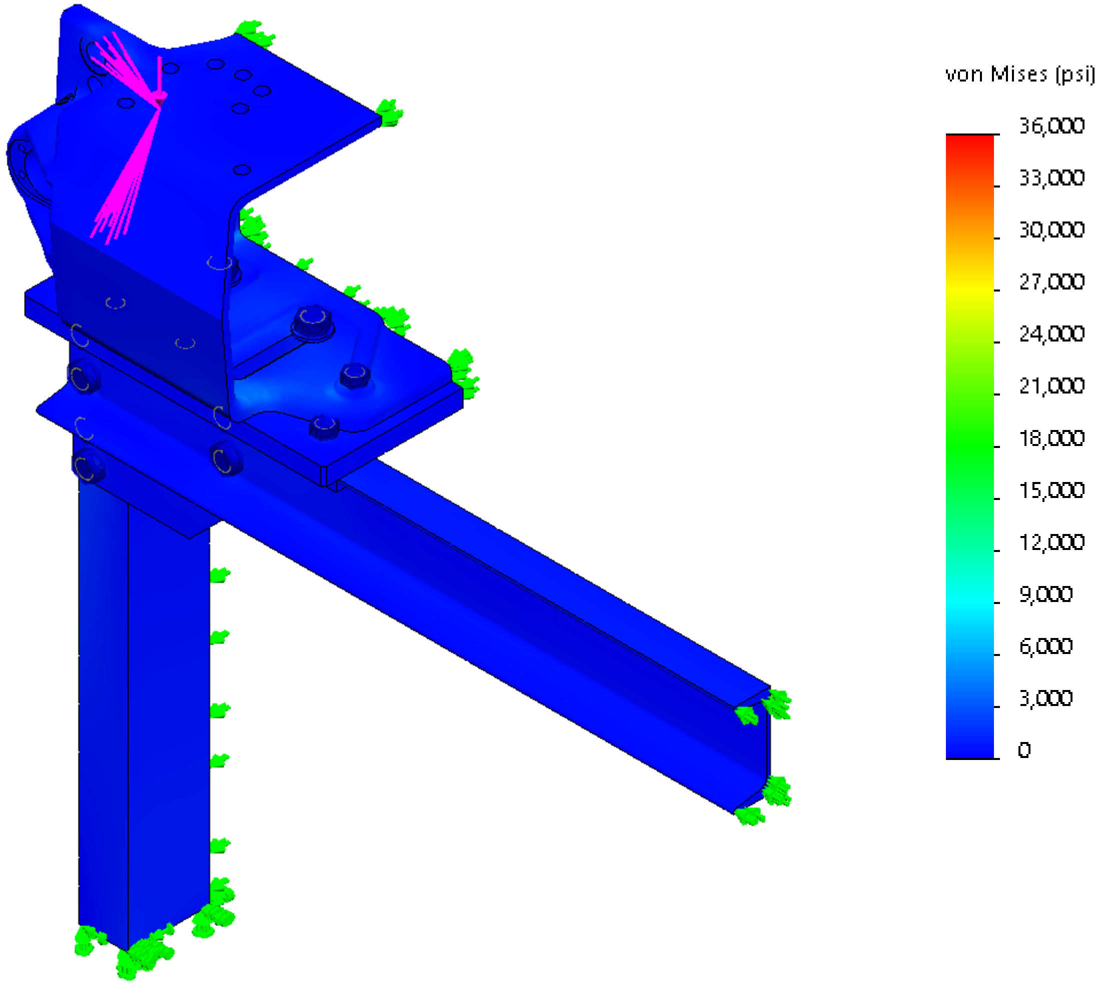
A 1,020 lb load was applied in a Downward direction at the brake pad clamping location and transferred to the brake pad bolt holes in the caliper casting.

The Downward force is used to simulate the car travelling in an Upward direction.



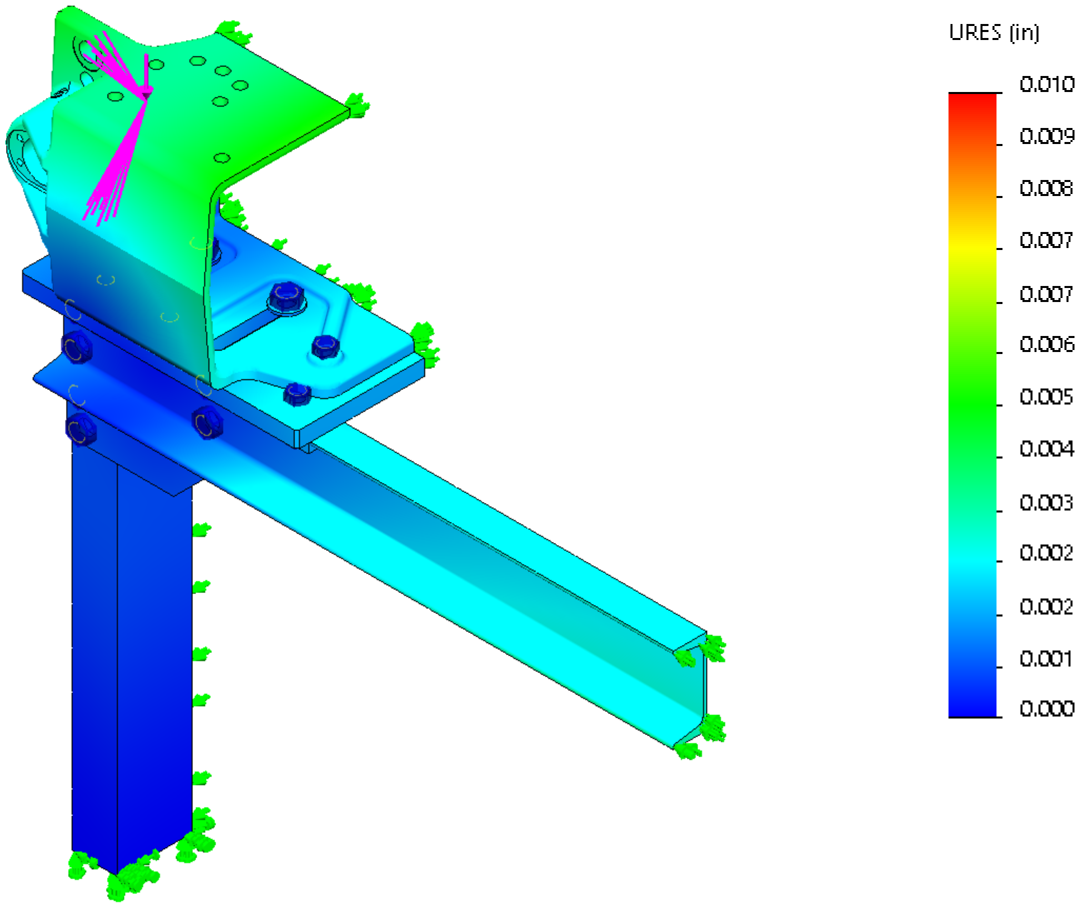
Stress Results – Crosshead Downward Load

Crosshead stress is ~3,000psi.



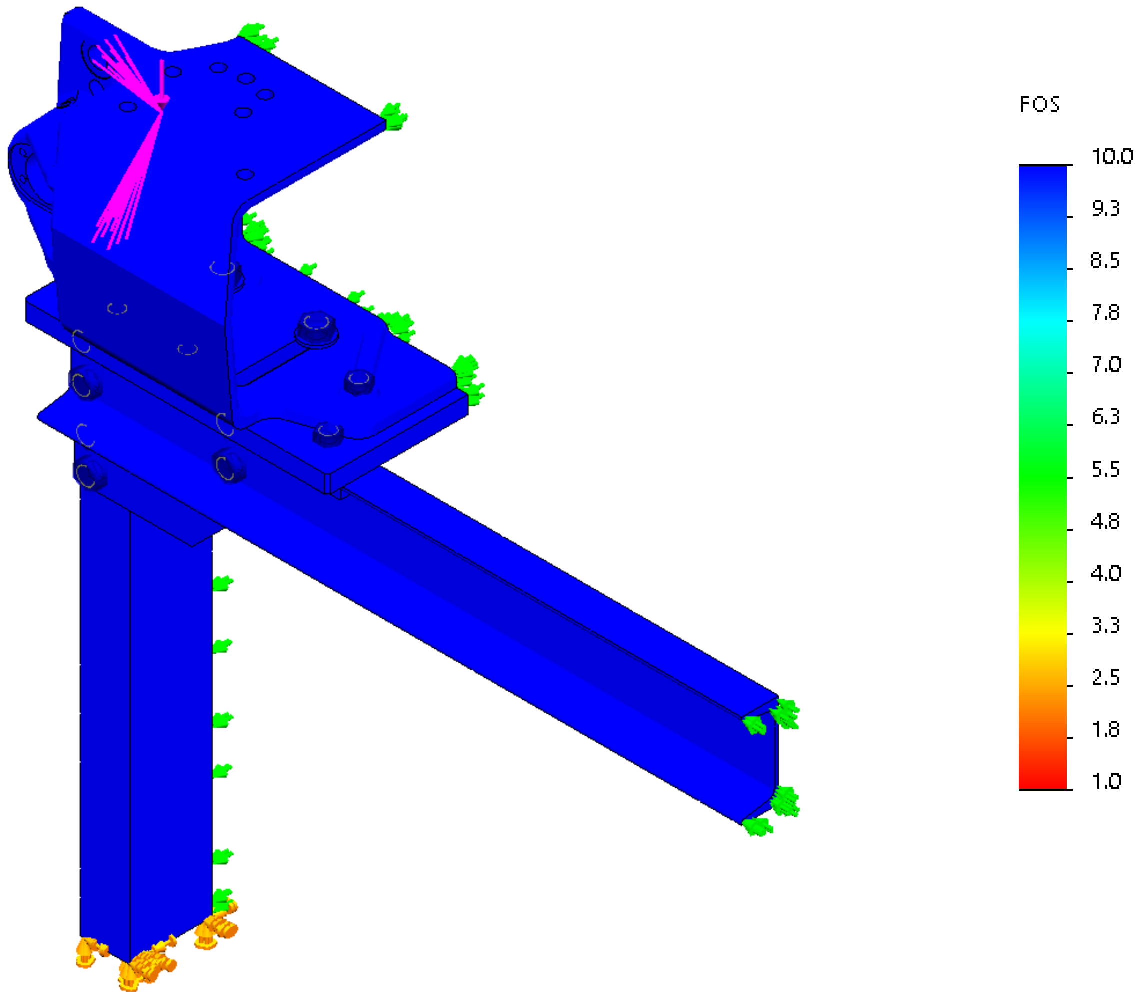
Displacement Results – Crosshead Downward Load

Crosshead displacement is ~0.002"



Factor of Safety Results – Crosshead Downward Load

Crosshead FOS is over 3.5X.



Factor of Safety Results – Bolts Downward Load

Applied appropriate preload to all bolts (e.g. 212 ft-lbs torque for 5/8”)
Increase load to 3.5x (3570 lbs downward) since we need a 3.5x FOS

- We’re increasing load because factor-of-safety plots would incorrectly show an unloaded bolt failing due to installation torque alone

No bolts yield with 3.5x applied load

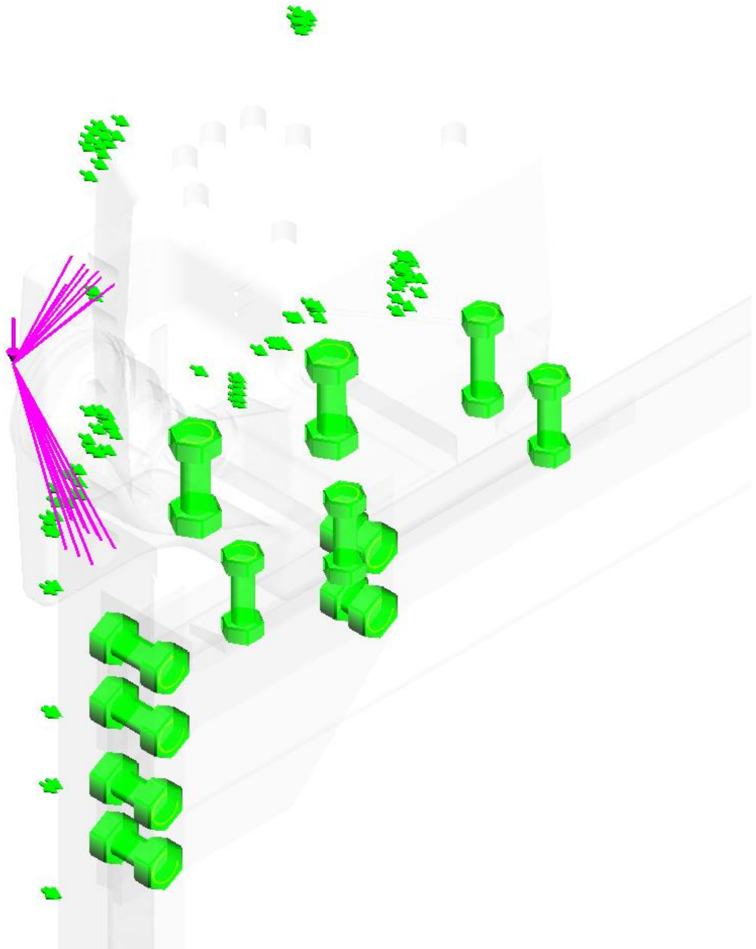
Highest load thru any bolt is 19,428 lbs (73,038 psi) which is well below the yield strength of 130,000 psi for a grade 8 bolt

Study name: DOWNWARD FORCE ON CALIPER - PRELOAD

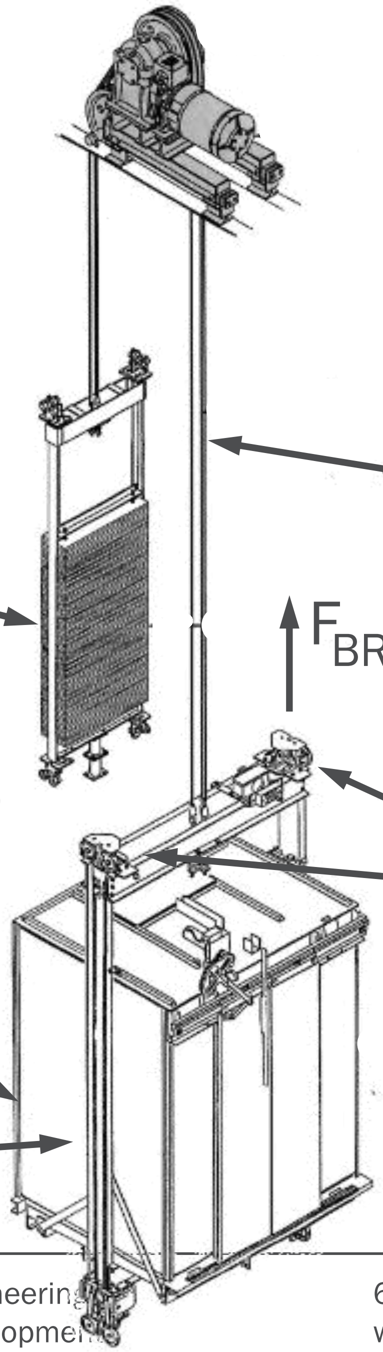
Connector: All bolts   Units: English (IPS)

Connector type: Bolt   <--   -->

Type	X-Component	Y-Component	Z-Component	Resultant	Connector
Axial Force (lbf)	0	19,428	0	19,428	Counterbore with Nut-17
Axial Force (lbf)	0	19,242	0	19,242	Counterbore with Nut-18
Axial Force (lbf)	18,817	0	0	18,817	Counterbore with Nut-15
Axial Force (lbf)	18,806	0	0	18,806	Counterbore with Nut-14
Axial Force (lbf)	18,728	0	0	18,728	Counterbore with Nut-16
Axial Force (lbf)	18,723	0	0	18,723	Counterbore with Nut-13
Axial Force (lbf)	18,474	0	0	18,474	Counterbore with Nut-12
Axial Force (lbf)	18,298	0	0	18,298	Counterbore with Nut-1
Axial Force (lbf)	0	12,643	0	12,643	Counterbore with Nut-19
Axial Force (lbf)	0	12,338	0	12,338	Counterbore with Nut-21
Axial Force (lbf)	0	12,274	0	12,274	Counterbore with Nut-20
Axial Force (lbf)	0	12,273	0	12,273	Counterbore with Nut-22
Shear Force (lbf)	0	-705.29	-344.83	785.07	Counterbore with Nut-16
Shear Force (lbf)	0	688.66	89.434	694.44	Counterbore with Nut-12



FEA Masses 4” Crosshead Car Travelling Downward (Upward Brake Force)



Braking load:

Car and Sling Empty Weight
+ Load Inside Car
+ Ropes & Cables
= 4,975 lbs

0.5g Stopping Force

Used For FEA = 4,975 lbs X 0.5

= 2,487.5 lbs

Sling Crosshead FEA Brake Upward Forces

The 2,487.5 lb mass used in the FEA was calculated using an 4,975 lb moving mass and a 0.5 stopping reaction force.

Speed (ft/min)	Stopping distance (ft) at acceleration (g) 0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
50	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.9	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
200	3.5	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.2
500	21.6	10.8	5.4	3.6	2.7	2.2	1.8	1.5	1.3	1.2	1.1
1000	86.3	43.1	21.6	14.4	10.8	8.6	7.2	6.2	5.4	4.8	4.3
1500	194.1	97.0	48.5	32.3	24.3	19.4	16.2	13.9	12.1	10.8	9.7
2000	345.1	172.5	86.3	57.5	43.1	34.5	28.8	24.6	21.6	19.2	17.3

$$v^2 = u^2 + 2as$$

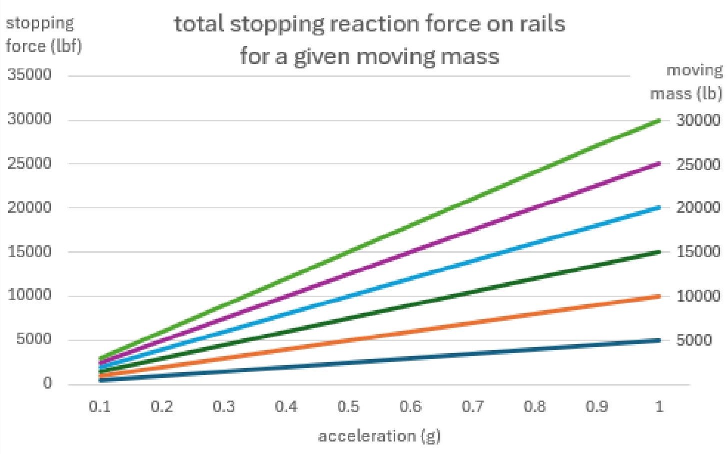
where:

- v is the final velocity,
- u is the initial velocity,
- a is the acceleration,
- s is the displacement.

"Total Gross Load"

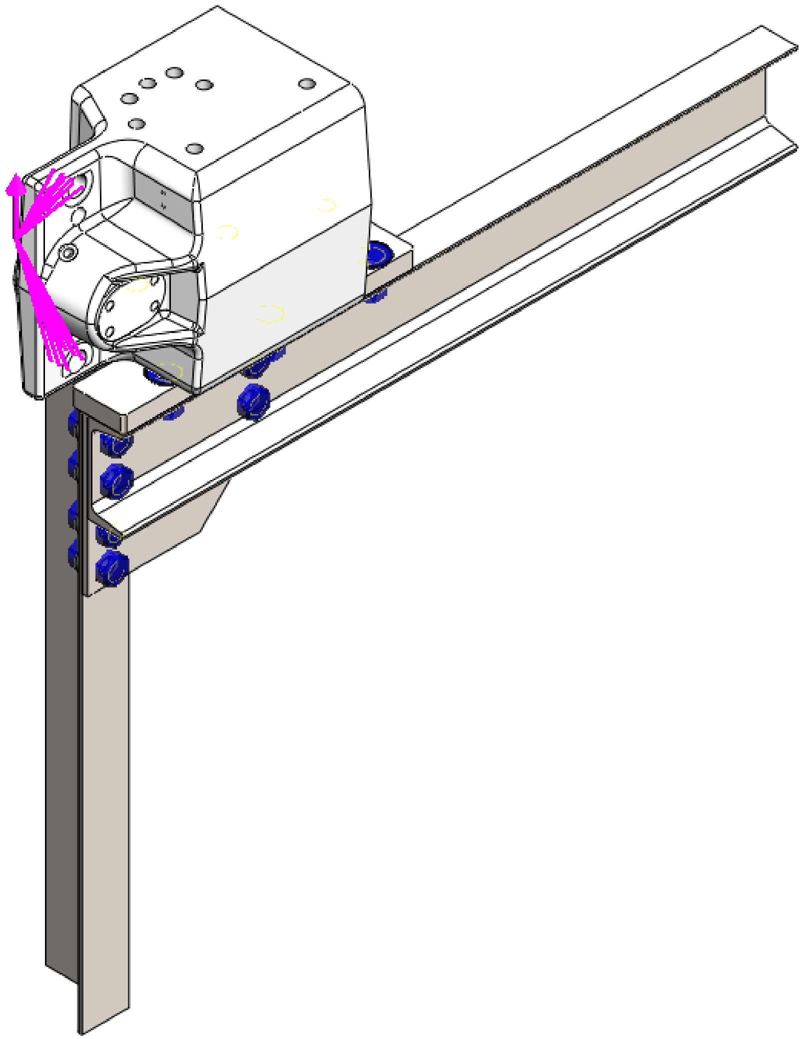
F = ma — mass = 8162 lb

Moving Mass (lb)	Stopping reaction force (lbf) at acceleration (g) 0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5000	250	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
10000	500	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
15000	750	1500	3000	4500	6000	7500	9000	10500	12000	13500	15000
20000	1000	2000	4000	6000	8000	10000	12000	14000	16000	18000	20000
25000	1250	2500	5000	7500	10000	12500	15000	17500	20000	22500	25000
30000	1500	3000	6000	9000	12000	15000	18000	21000	24000	27000	30000
4975	248.75	497.5	995	1492.5	199	2487.5	2985	3482.5	3980	4477.5	4975



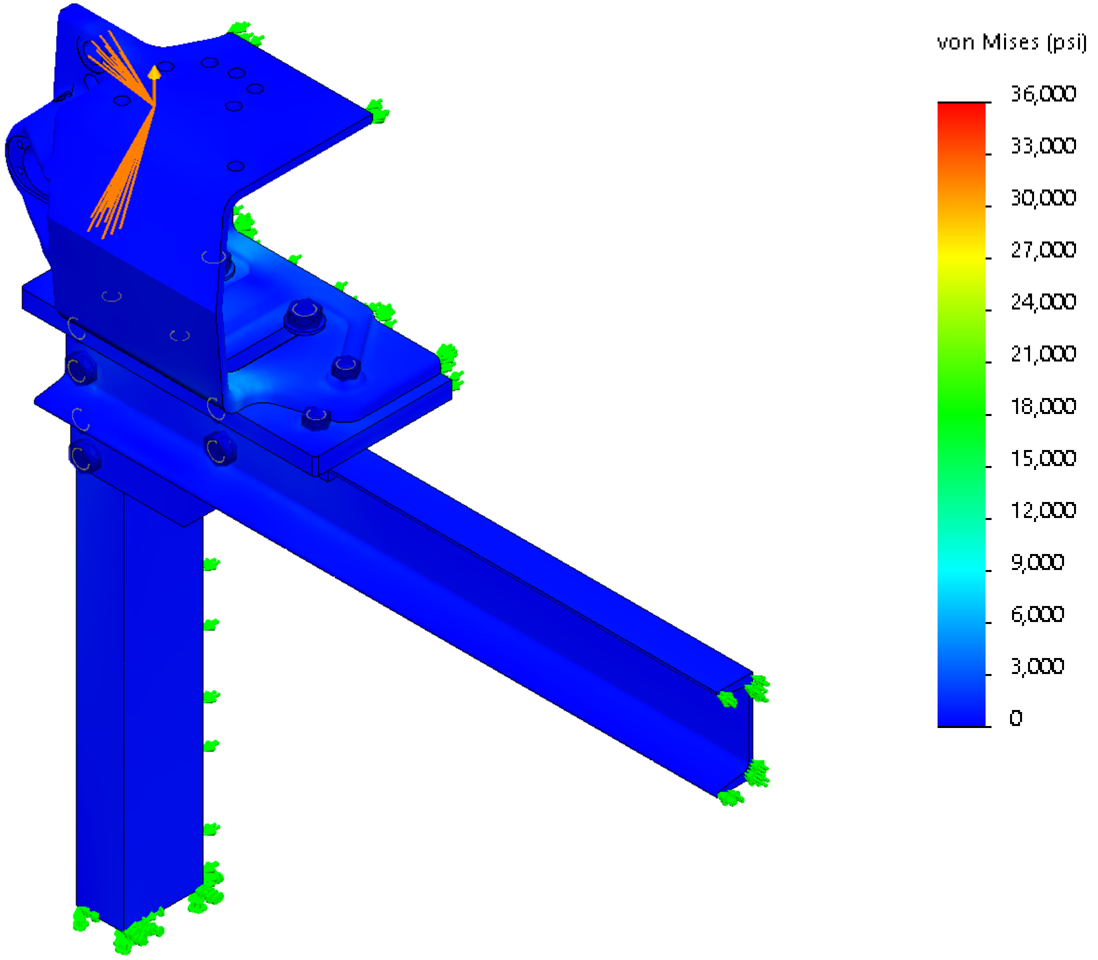
Setup – Upward Load

A braking load of 4,795 lb is used. A multiplier for 0.5g was added for an FEA load of 2,487.5 lbs.
Since the model is in a ¼ section, ¼ of the 2,487.5 lb was used.
A 622 lb load was applied in an Upward direction at the brake pad clamping location and transferred to the brake pad bolt holes in the caliper casting.
The Upward force is used to simulate the car travelling in a Downward direction.



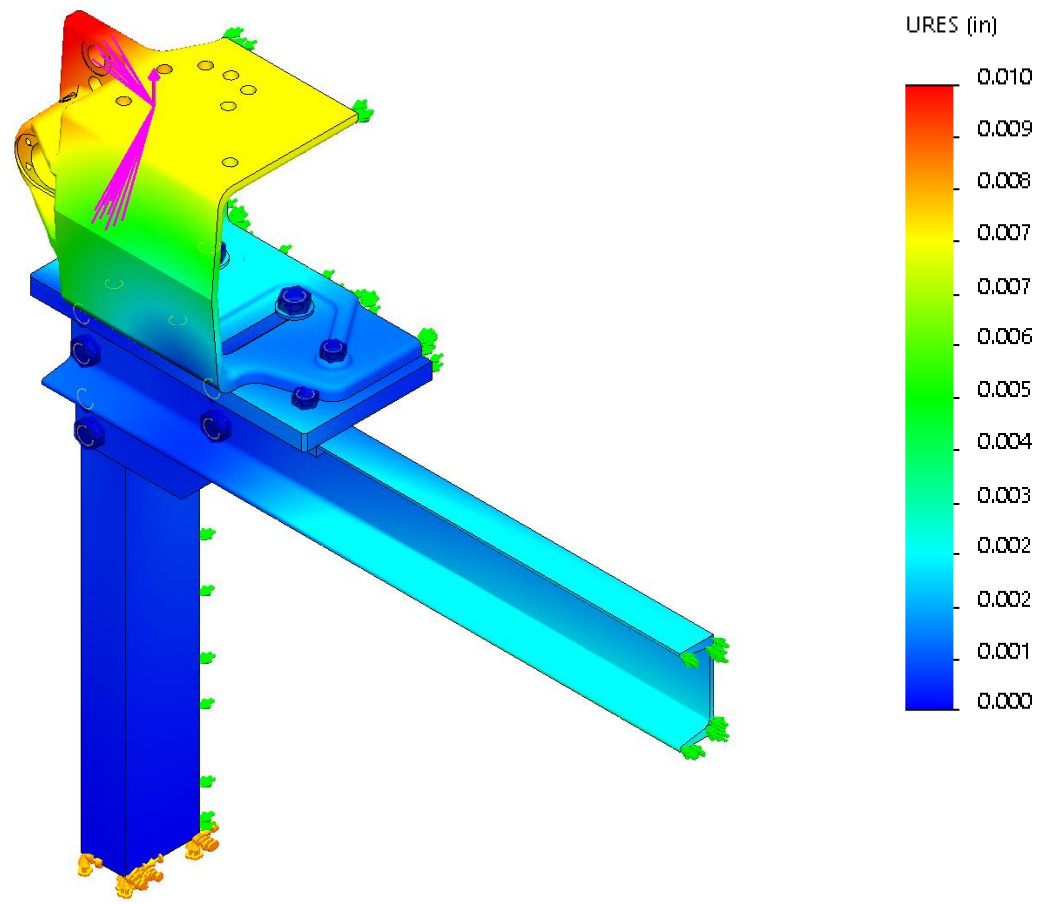
Stress Results – Crosshead Upward Load

Crosshead stress is ~5,000psi.



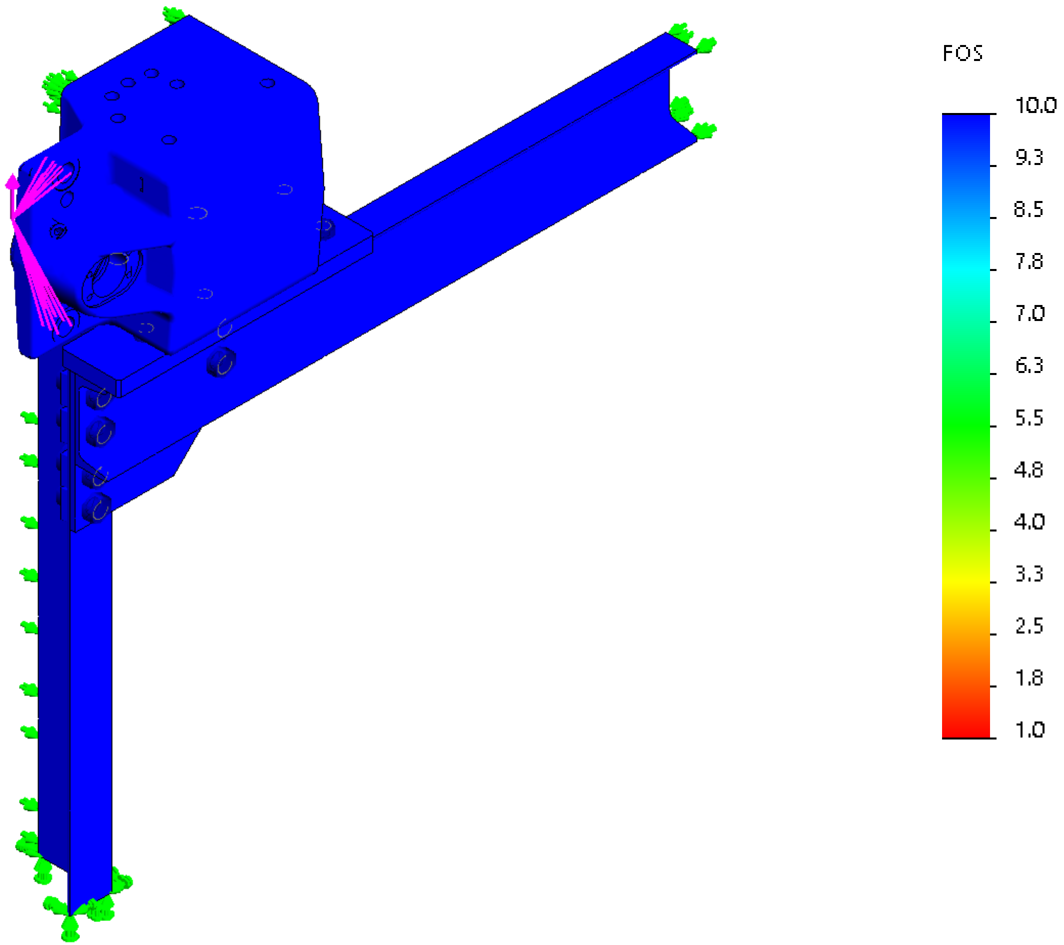
Displacement Results – Crosshead Upward Load

Crosshead displacement is ~0.002”



Factor of Safety Results – Crosshead Upward Load

Crosshead FOS is over 3.5X.



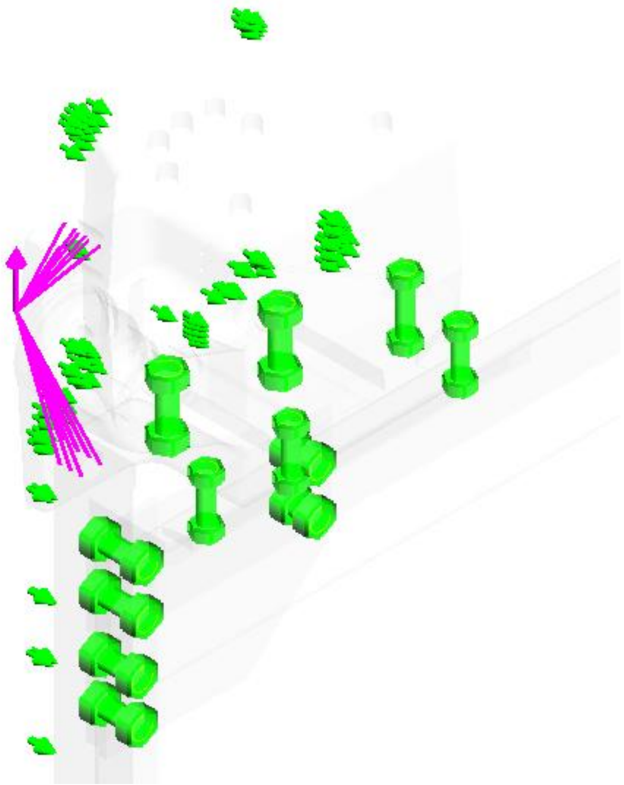
Factor of Safety Results – Bolts Upward Load

Applied appropriate preload to all bolts (e.g. 212 ft-lbs torque for 5/8”)
Increase load to 3.5x (2177 lbs upward) since we need a 3.5x FOS

- We’re increasing load because factor-of-safety plots would incorrectly show an unloaded bolt failing due to installation torque alone

No bolts yield with 3.5x applied load

Highest load thru any bolt is 19,443 lbs (73,094 psi) which is well below the yield strength of 130,000 psi for a grade 8 bolt



Study name: UPWARD FORCE ON CALIPER - PRELOAD

Connector: All bolts   Units: English (IPS)

Connector type: Bolt   <--   -->

Type	X-Component	Y-Component	Z-Component	Resultant	Connector
Axial Force (lbf)	0	19,443	0	19,443	Counterbore with Nut-17
Axial Force (lbf)	0	19,288	0	19,288	Counterbore with Nut-18
Axial Force (lbf)	18,859	0	0	18,859	Counterbore with Nut-14
Axial Force (lbf)	18,727	0	0	18,727	Counterbore with Nut-13
Axial Force (lbf)	18,709	0	0	18,709	Counterbore with Nut-15
Axial Force (lbf)	18,640	0	0	18,640	Counterbore with Nut-16
Axial Force (lbf)	18,389	0	0	18,389	Counterbore with Nut-12
Axial Force (lbf)	18,268	0	0	18,268	Counterbore with Nut-1
Axial Force (lbf)	0	12,622	0	12,622	Counterbore with Nut-19
Axial Force (lbf)	0	12,399	0	12,399	Counterbore with Nut-20
Axial Force (lbf)	0	12,339	0	12,339	Counterbore with Nut-21
Axial Force (lbf)	0	12,291	0	12,291	Counterbore with Nut-22
Shear Force (lbf)	0	1,310.2	87.736	1,313.2	Counterbore with Nut-1
Shear Force (lbf)	0	711.46	-108.51	719.69	Counterbore with Nut-12