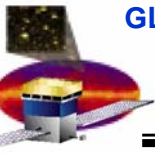


**Stress Analysis Summary for
GSE
Rotation Stand, Grid Perimeter
Ring, and Lift Spreader Bar**

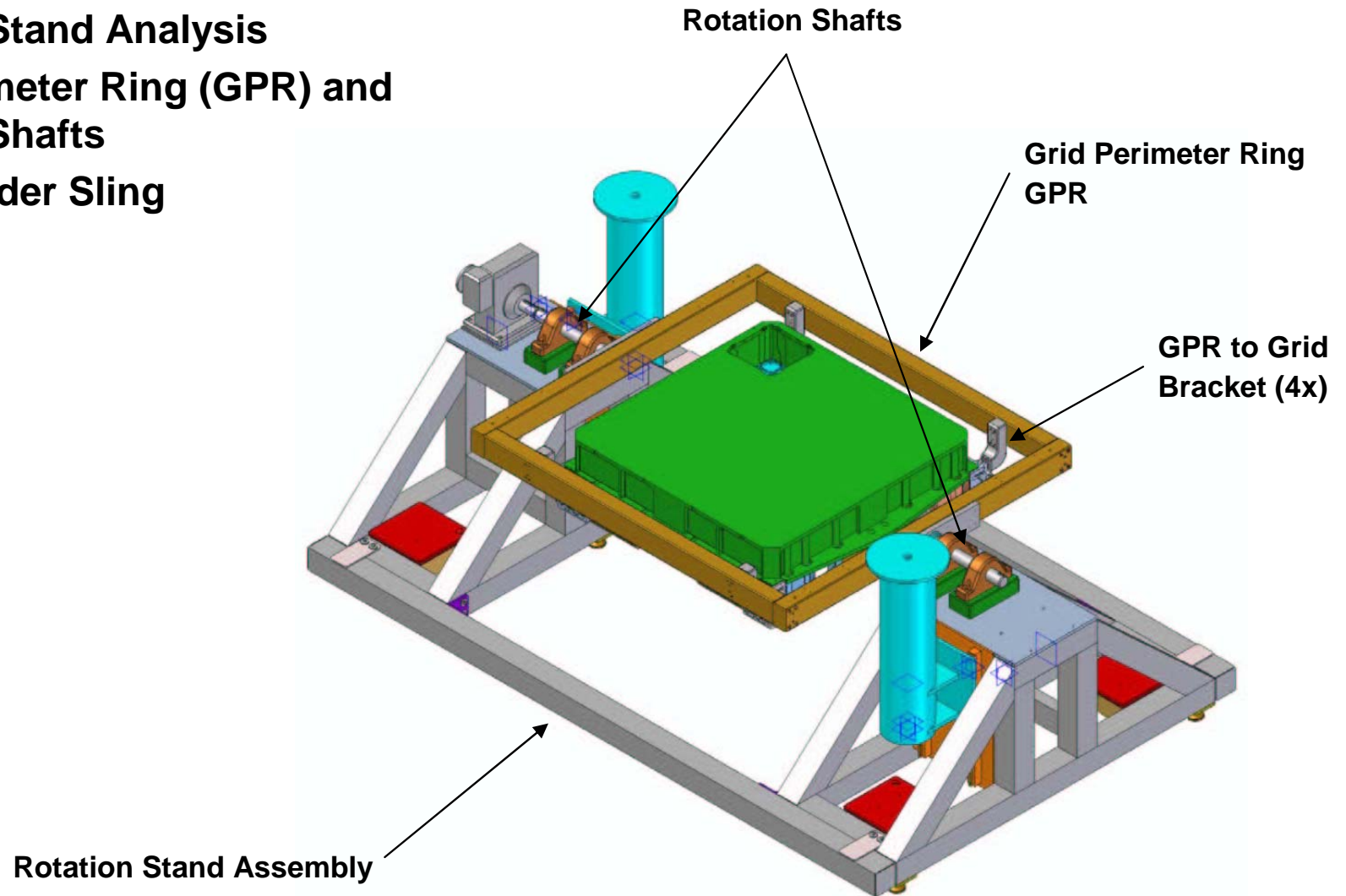
Eric J. Roulo

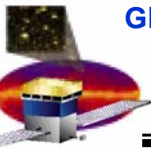
2/24/2004



Contents

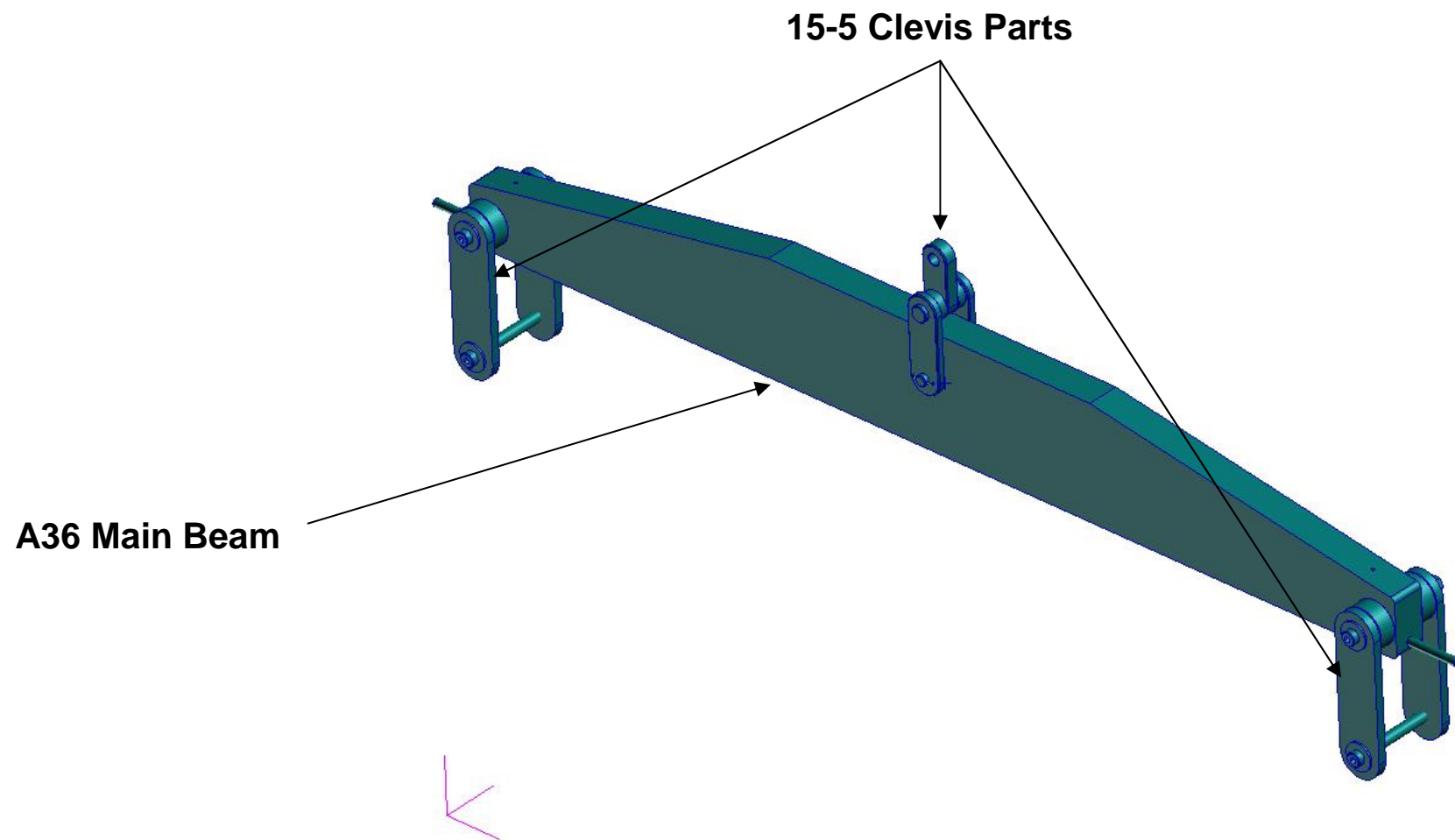
- **Rotation Stand Analysis**
- **Grid Perimeter Ring (GPR) and Rotation Shafts**
- **Lift Spreader Sling**

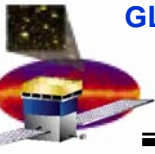




Contents (cont.)

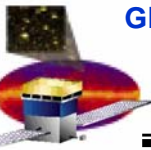
- **Lift Spreader Sling**





Component Design Description

- **Drawing number and revision**
 - Preliminary design models
- **Details of component (material, special conditions)**
 - Rotation Stand - Welded A36 (or better)
 - GPR - Aluminum 6061-T6 (bolted assembly)
 - Rotation Shafts – 15-5PH Stainless Steel
 - Lift Spreader Sling - A36



Loads and Load Cases

- Design loads are based on earthquake and operational requirements
- EWR 127.1 specified required SF

Load Case	X	Y	Z	SF _y Required	SF _u Required	Configuration/Comments
Earthquake						
Earthquake 1	1.9 g		1 g	-	1.00	Rotation Stand on wheels
Earthquake 2		1.9 g	1 g	-	1.00	Rotation Stand on wheels
Earthquake 3			2.9 g	-	1.00	Rotation Stand on wheels
Earthquake 4	1.9 g		1 g	-	1.00	Rotation Stand on feet supports
Earthquake 5		1.9 g	1 g	-	1.00	Rotation Stand on feet supports
Earthquake 6			2.9 g	-	1.00	Rotation Stand on feet supports
Assembly, Integration (Operation)						
				SF_y Required	SF_u Required	
Integration 1			-1 g	3	-	Rotation Stand on wheels
Integration 2			-1 g	3	-	Rotation Stand on feet supports
GPR Horizontal Lift			-1 g	3		GPR Crane Lift (Horizontal)
GPR 1			-1 g	3	-	Grid Perimeter Ring at 0 degrees in Rotation Stand
GPR 2			-1 g	3		Grid Perimeter Ring at 45 degrees in Rotation Stand
GPR 3			-1 g	3		Grid Perimeter Ring at 90 degrees in Rotation Stand
Personnel Access Platform			300 lbf	3	-	Static Load

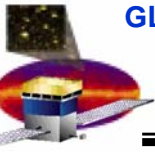
$$MS = \frac{F_{all}}{SF_{required} \cdot F_{ind}} - 1$$

where :

F_{all} = allowable stress or load

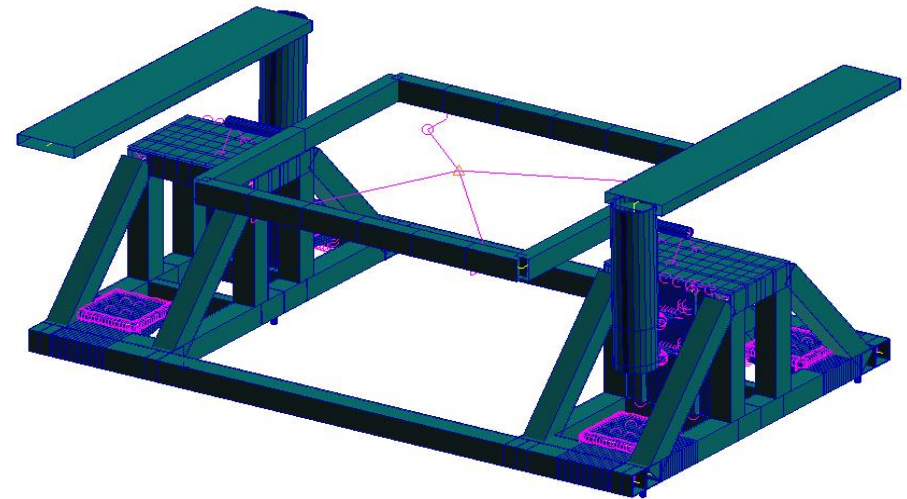
F_{ind} = induced stress or load

$SF_{required}$ = required safety factor

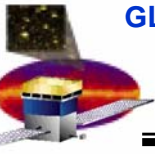


Analysis Model Configuration

- **Description of FEA/other models**
 - An FE model was generated of the Rotation Stand and GPR
 - Hand calculations were done for the Lift Sling
- **Model metrics**
 - 5062 element model
 - CBAR and CQUAD4 elements
 - 13000 lbm (total mass)
- **Comparison of FEA model with actual design**
 - Mass was 7056 lbm for the lumped mass LAT
 - All other masses were model derived from density
 - Bolt calculations were done with forces extracted from the NASTRAN model

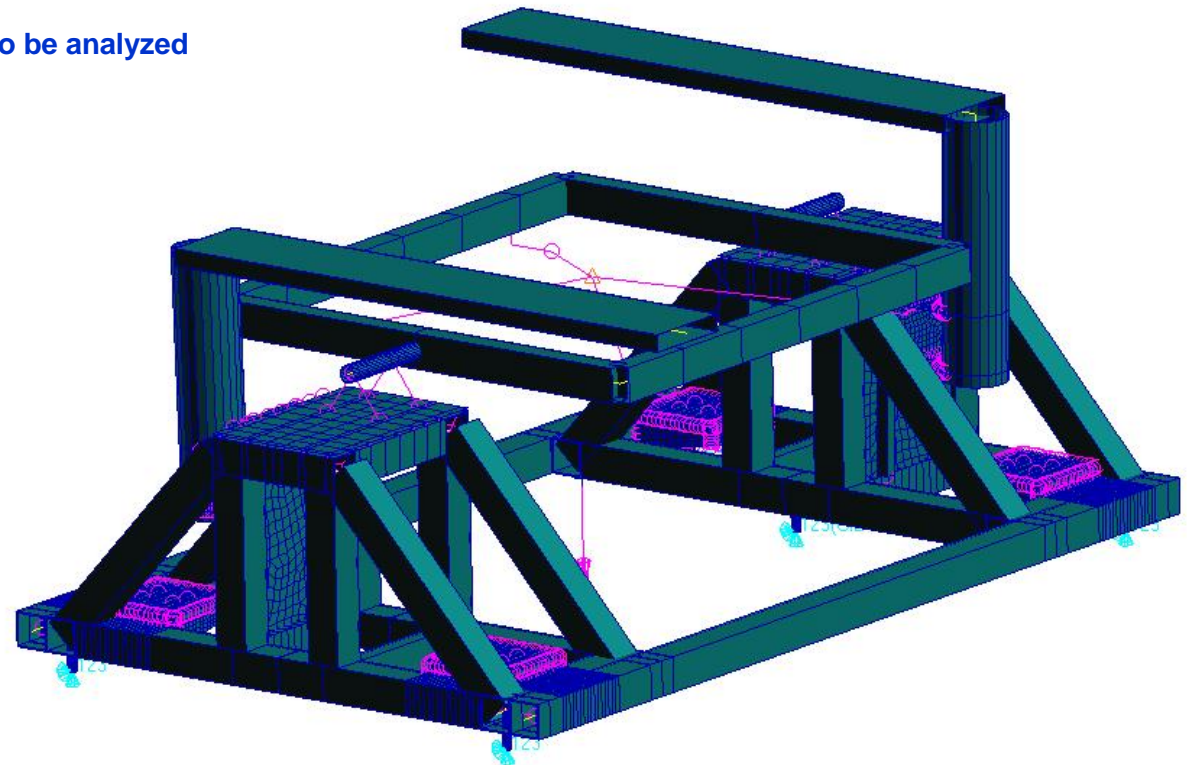


Finite Element Model of Rotation Stand

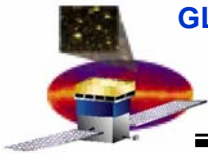


Boundary Conditions

- How is model constrained
 - Translational constraints are at the 4 wheels or 6 feet points (close to anchor points)
- How valid are boundary conditions compared to as-installed boundary
 - Excellent
 - Anchor bolt case still needs to be analyzed

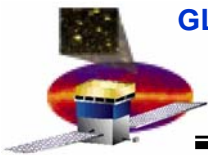


Finite Element Model with Boundary Conditions



Material Properties and Allowables

- **Material properties, including allowable stresses**
 - **A36 for box sections and plate**
 - 36ksi yield, 58ksi ultimate
 - **Aluminum 6061-T6 bar**
 - 35ksi yield, 42ksi ultimate
 - **15-5PH Stainless Steel**
 - 115ksi yield, 140ksi ultimate
- **Joint allowables, or any special conditions that limit stresses**
 - **Welds have been specified as 80% penetration groove weld with additional fillet. The weld region is therefore stronger than the base material**
 - **Fastener analysis assumes shear is taken in fastener and all bolts are active**
 - Fasteners are assumed to be Grade 8 or better strength (e.g. Unbrako fasteners)
 - Joint efficiencies are calculated to account for joint preload

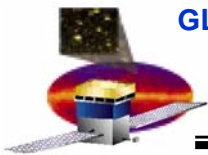


Grid Perimeter Ring (GPR) Operational Results

Grid Perimeter Ring (operational load) Result Type	Max Value	Units	Load Case	Allowable	Units	Required SF		Actual	
						SFy	SFu	MSy	MSu
Beam Stress	3.93	ksi	GPR 2	35	ksi	3	-	1.97	
Rotation Shafts	13.65	ksi	Integration 2	115	ksi	3	-	1.81	
Fastener Loads (Beam to Beam)			Integration 2			-	5	-	1.22
Grid to GPR Bracket (normal stress)	4.56	ksi	Integration 2	35	ksi	3		1.56	
Grid to GPR Bracket (shear stress)	3.221	ksi	Integration 2	19.25	ksi	3	-	0.99	
Grid to GRP Bracket fasteners			Integration 2			-	5		0.056

Note: Some results account for plastic bending and their results are not simply a ratio of the allowable strength over the calculated stress

- **Lowest Margin = 0.056 for combined fastener loading**
 - **These results are effected by bolt preload and are conservative**

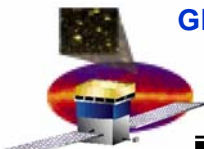


Grid Perimeter Ring (GPR) Earthquake Results

Grid Perimeter Ring earthquake load)						Required	Actual
Result Type	Max Value	Units	Load Case	Allowable	Units	SFu	MSu
Beam Stress	9.27	ksi	Earthquake 6	42	ksi	1	3.53
Rotation Shafts	94.48	ksi	Earthquake 4	140	ksi	1	1.52
Fastener Loads (Beam to Beam)			Earthquake 6			1	10.07
Grid to GPR Bracket (normal stress)	13.21	ksi	Earthquake 6	42	ksi	1	3.77
Grid to GPR Bracket (shear stress)	6.12	ksi	Earthquake 5	23.1	ksi	1	4.66
Grid to GRP Bracket fasteners			Earthquake 6			1	5.34

Note: Some results account for plastic bending and their results are not simply a ratio of the allowable strength over the calculated stress

- **Margins are higher than operational loads due to the reduced requirement of only survival at earthquake loads**

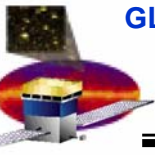


Horizontal Lift Spreader Operational Results

4 x 4 Horizontal Lift Spreader (operational)

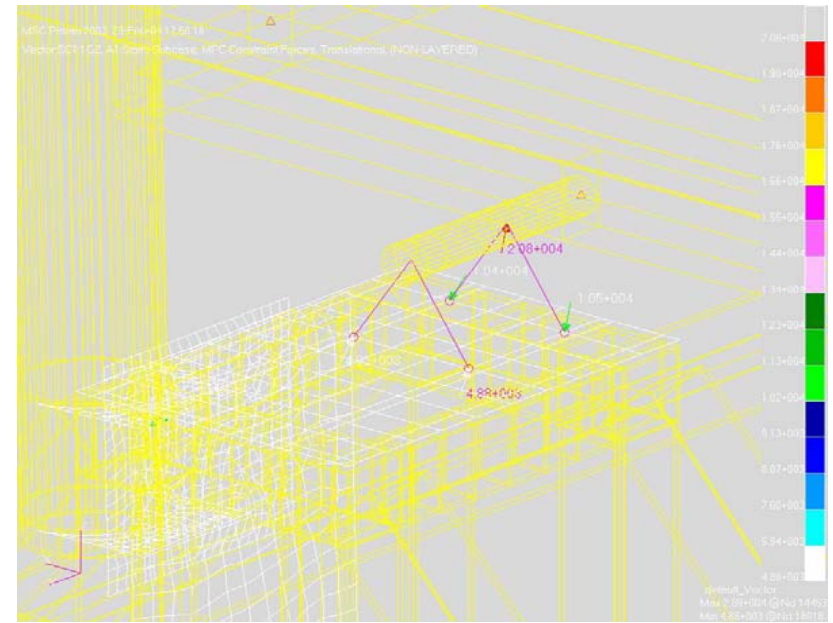
Result Type	Max Value	Units	Load Case	Allowable	Units	Required SF		Actual	
						SFy	SFu	MSy	MSu
Beam Stress	10.7	ksi	GPR horizontal lift	36	ksi	3.00	-	0.12	-
Beam Lateral Buckling	8.2	kips	GPR horizontal lift	726	lbf	3.00		28.51	
Pin Shear Stress	6.2	ksi	GPR horizontal lift	63.25	ksi	3.00		2.40	
Pin Bending Stress (worst case possible)	25.35	ksi	GPR horizontal lift	115	ksi	3.00		0.51	

- Only operational results are investigated because:
 - The assembly hangs from cables and therefore has limited lateral load carrying ability
 - The operational case envelopes the earthquake case for the lift direction



Bolt Loads and Displacements

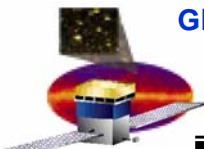
- Bearing loads are taken directly from MPC forces and scaled for new GPR geometry
- Bearing block bolt forces are actually much lower than MPC forces because the bolted flange takes the majority of the load
- Displacements of the GRP under 1gz loading are ~ .100 inch



Bearing Block Bolt Loads



Displacements under 1gz



Preliminary Rotation Stand Results

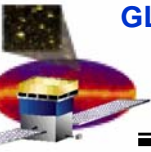
Rotation Stand (earthquake load)

Result Type	Max Value	Units	Load Case	Allowable	Units	Required	Actual
						SFu	MSu
Beam Stress	9.18	ksi	Earthquake 4	58	ksi	1.00	5.32
Weld Stress	9.18	ksi	Earthquake 4	58	ksi	1.00	5.32
Plate Stress	12.7	ksi	Earthquake 4	58	ksi	1.00	3.57
Bearing Load	22.25	kips	Earthquake 6	39.9	kips	1.00	0.79
Bolt Loads	TBD	lbf					

Rotation Stand (operational load)

Result Type	Max Value	Units	Load Case	Allowable	Units	Required SF		Actual	
						SFy	SFu	MSy	MSu
Beam Stress	1.86	ksi	Integration 2	36	ksi	3.00	-	5.45	-
Weld Stress	1.86	ksi	Integration 2	36	ksi	3.00	-	5.45	-
Plate Stress	2.27	ksi	Integration 2	36	ksi	3.00		4.29	
Bearing Load	7.03	kips	Integration 2	39.9	kips	-	5.00	-	0.14

- **Bearing Load Allowable is from Vendor**
- **All margins are high**



Conclusions

- **Current design meets all strength requirements**
- **Configuration has been mostly finalized**
 - **No expected need for major modifications due to strength considerations**
- **Final sizing (diameters, thicknesses, etc)**
 - **Initial results indicate size reduction possible based on strength considerations**
- **Special requirements**
 - **Bolt torques will have to be specified on the assembly drawings (this effects margins)**
 - **Heat treatment on 15-5PH will need to be specified and verified for rotation shafts**
- **Analyses still to do**
 - **Review anchor bolt final design**
 - **Personnel Access Platform strength analysis**
 - **Write formal analysis report for the GSE analyzed**