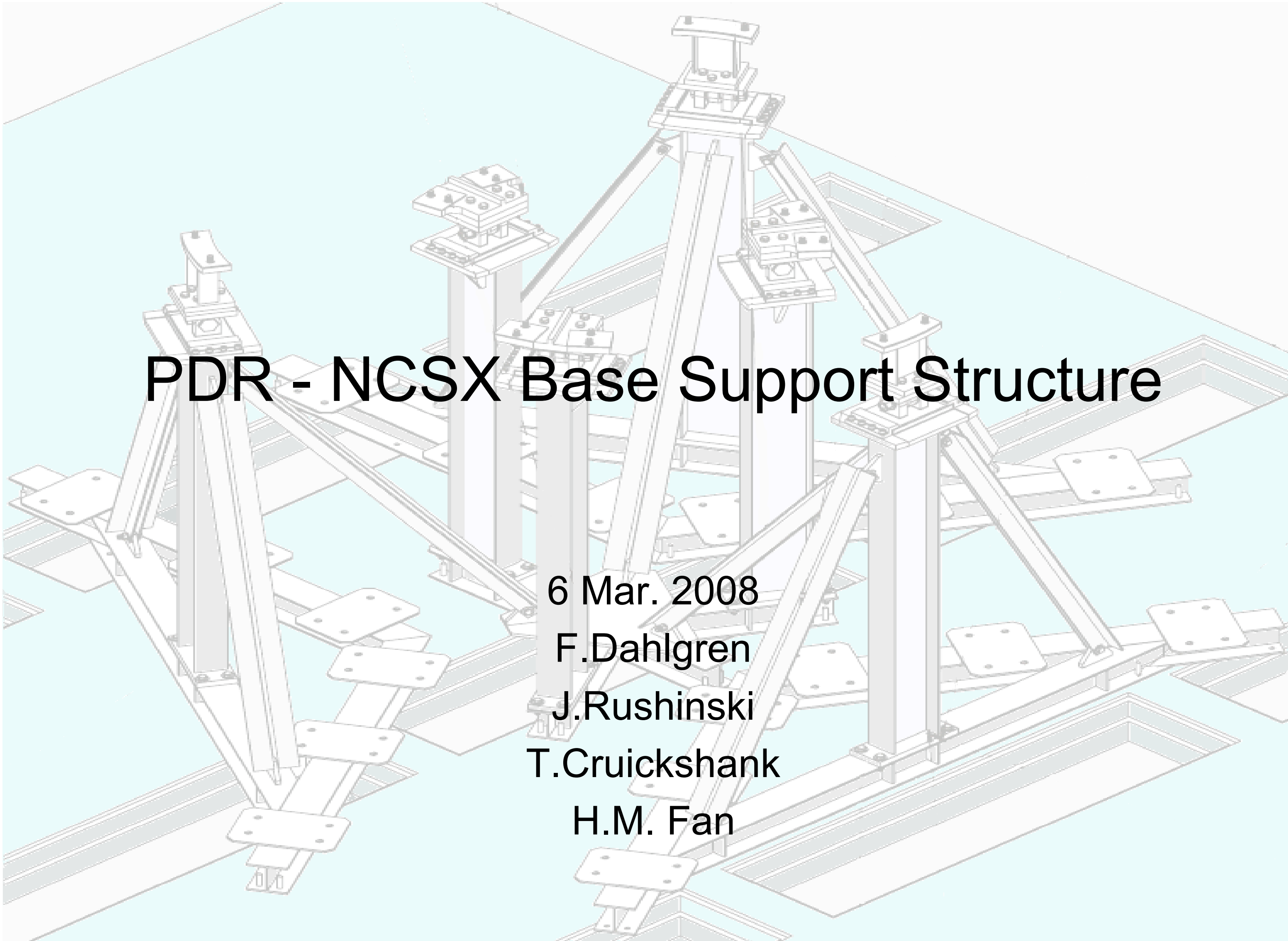


PDR - NCSX Base Support Structure

6 Mar. 2008

F.Dahlgren
J.Rushinski
T.Cruickshank
H.M. Fan

The charge to the review committee is as follows:

1) Has the Systems Requirement Document been prepared? Are interfaces adequately defined in it?

2) Does the design meet the requirements?

3) Are the critical calculations necessary to confirm the design basis sound? Has a Failure Modes and Effects Analysis been started?

4) Have the constructability, assembly and installation plans been adequately addressed?

5) Have the drawings and models been promoted to Preliminary Design release level?

6) Have the CDR chits been addressed?

NCSX
National Compact Stellarator Experiment

Functional (SRD) requirements:

- It must provide the gravity load path from the machine core to the test cell floor at EL 98’ - 6”
- It must have a relative magnetic permeability less than 1.05 (ref.GRD para.3.3.1.1.b)
- It must meet the NCSX Structural Design Criteria (NCSX-CRIT-CRYO-00).
- It must meet the NCSX Seismic Design Criteria (NCSX-CRIT-SEIS-00).
- It must provide clearance to accommodate the three period assembly tooling.
- It must not exceed the maximum test cell floor loading of 4,500 lbs/sq.ft.

Main Project GRD Design Requirements:

3.2.4.2 Design Life

a. The facility shall have a design life of >10 years when operated per the reference scenarios defined in Section 3.2.1.5.3.3.1.

b. The facility shall be designed for the following maximum number of pulses when operated per the reference scenarios defined in Section 3.2.1.5.3.3.1 and based on the factors for fatigue life specified in the NCSX Structural and Cryogenic Design Criteria Document:

- 100 per day;
- 13,000 per year; and
- 130,000 lifetime.

Base Beams:
Laser Welded 304 ss - 8WF-35
(0.5” thick flg., 0.31” thick web)

Columns:
Laser Welded 304 ss - 12WF-35 (50?)
(0.52” thick flg., 0.30” thick web)

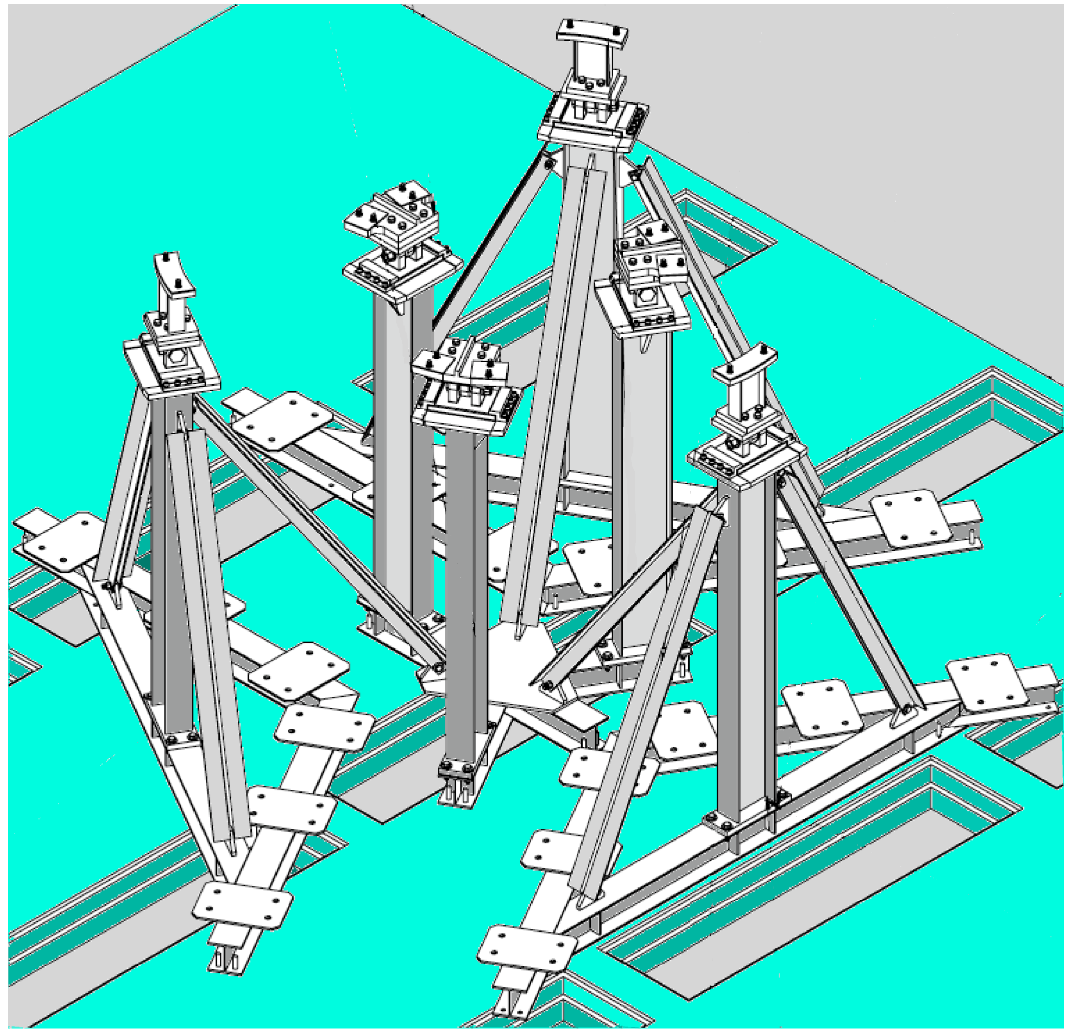
Lateral Bracing:
316 ss Rolled angles - 4” x 4” x 3/8”

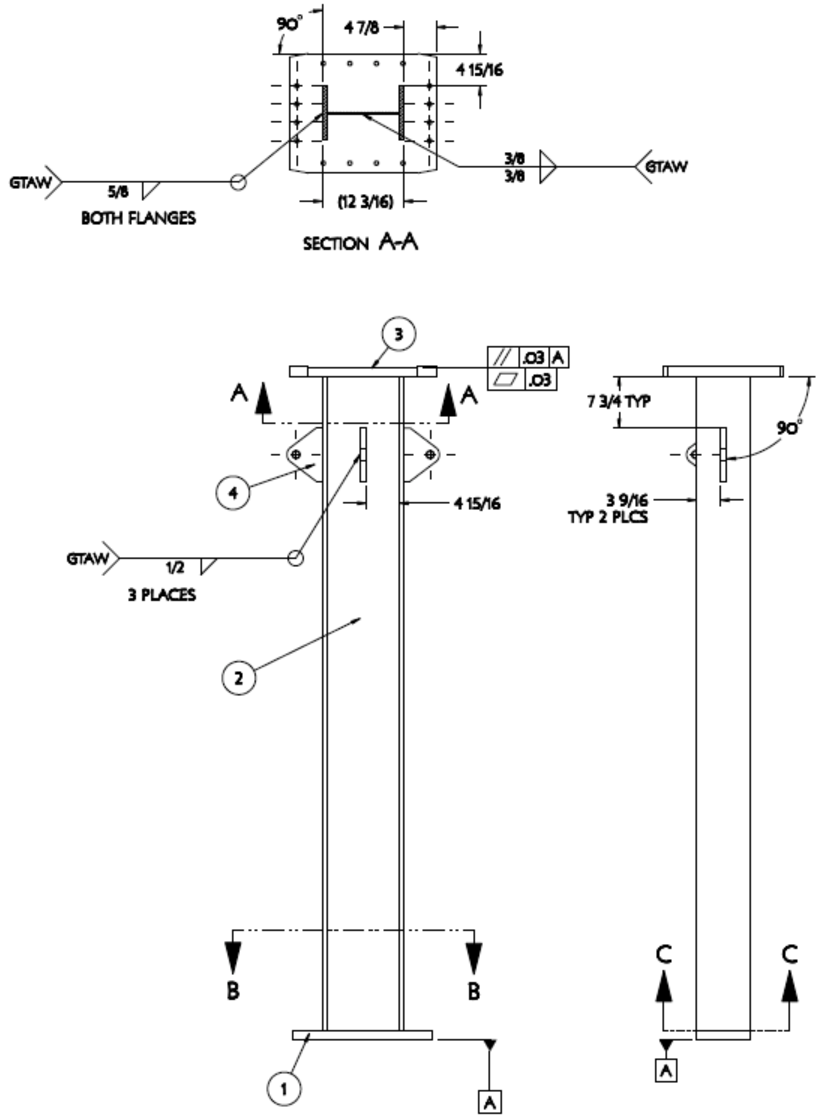
Base & Top plates:
304L 1.5” thk. Solution annealed plate

Gussets:
304L 0.5” thk. Solution annealed plate

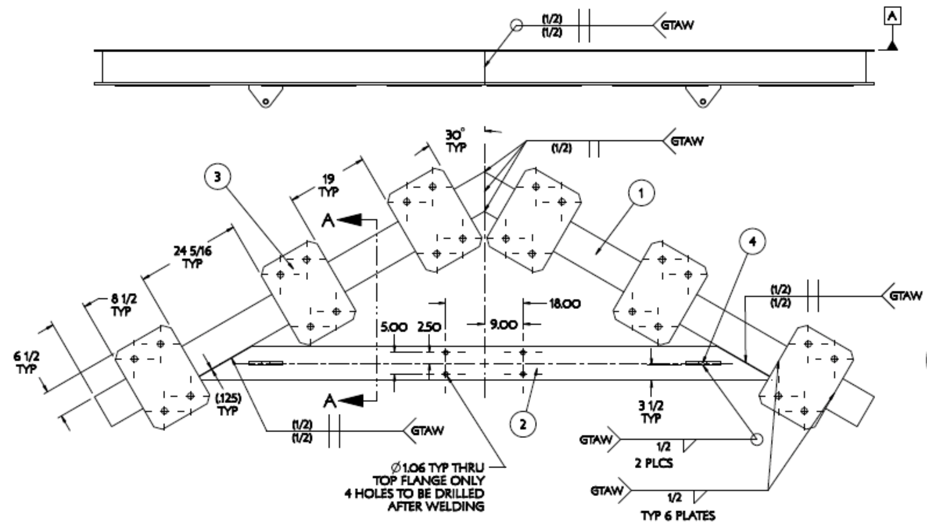
Anchors:
1-8 x 9” 316ss Wedge-Stud Anchors,
McMaster-Carr #97799A730

Weld filler:
ER316L-Mn (Stellalloy weld alloy)





Typical column detail



Typical base weldment detail

Installation will require pre-assembly in the test cell to shim and/or grout level the base frames with surface A & top pedestals, and to locate exact positions of wedge anchors.

Stainless Structurals,LLC is the preferred vendor
For the laser welded beams and rolled angles.

About Concrete Anchors

Wedge anchors provide a threaded stud in concrete. Once installed, they are not removable.

Sleeve anchors hold better in softer masonry materials. The sleeve is permanent. They're available with a permanent threaded stud or a removable bolt.

Concrete bolts and ***concrete screws*** are one-piece anchors that can be removed.

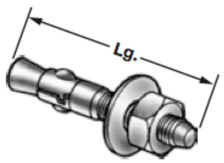
Drive anchors are good for light duty applications in both concrete and softer masonry materials. They're available in permanent and removable styles.

Consider the following when selecting a concrete anchor:

- ***Minimum embedment depth*** is the distance from the surface of the base material to the bottom of the anchor.
- ***Tension strength*** is the ultimate parallel load an anchor can withstand before pulling out of the base material.
- ***Shear strength*** is the ultimate perpendicular load an anchor can withstand before breaking.

Wedge Stud Anchors

Wedge Stud Anchors—For Concrete



Leave a threaded stud in concrete. Drive through a fixture, into a hole, and tighten the nut. Stud is chamfered to prevent thread damage during installation. Not reusable.

Stainless steel and ***zinc-plated steel*** anchors are UL listed and FM approved. Type 316 stainless steel is more corrosion resistant than 18-8. Zinc-plated anchors are C1018 steel (¼″ to ¾″ diameters in lengths up to 7″) or C1030 or 12L14 steel (⅞″ to 1¼″ diameters in all lengths and all lengths over 7″).

Galvanized steel anchors are C1018/C1022 steel (¼″ to ¾″ diameters in lengths up to 7″) or 12L14 steel (⅞″ to 1¼″ diameters in all lengths and all lengths over 7″). They're more corrosion resistant than zinc-plated steel anchors. Great for outdoor use.

Grade 5 steel anchors have a Grade 5 steel body for higher strength than zinc-plated steel and stainless steel. Plated with zinc yellow-chromate. ⅜″ to ¾″ diameters are UL listed and FM approved.

Ultimate Tension and Shear Strength in 4,000 psi Concrete

Diameter	¼″	⅜″	½″	⅝″	¾″	⅞″	1″	1¼″
Min. Embed. Dp.	1¼″	1¾″	2¼″	2¾″	3⅜″	4″	4½″	6½″
Tension, lbs.	860	2,367	4,760	5,556	8,960	9,640	13,000	22,280
Shear, lbs.	1,060	2,280	6,260	8,720	11,360	15,820	22,920	32,370

1″ Diameter—*Thread: 1″-8; Washer OD: 2″ to 2½″ (Drill Size 1″)*

			Type 316 SS				18-8 SS				Galvanized Steel				Zinc-Plated Steel		
6″	4½″	2¼″	4	97799A720	49.74	43.68	92188A601	27.80	24.70	4	97110A700	10.41	8.33	4	91578A700	8.55	7.35
9″	4½″	2¼″	4	97799A730	67.00	57.95	92188A602	35.34	30.04	4	97110A701	13.14	10.51	4	91578A701	10.49	9.01
12″	4½″	2¼″	4	97799A740	78.06	67.51	92188A605	45.65	38.81	4	97110A702	14.95	13.60	4	91578A702	11.06	9.95

Alternate: Hilti HSLG-R - M20:

HSLG-R Stainless Steel with Thread Rod

FEA Analysis:

Loads and modeling considerations:

Gravity Loads with 1g static vertical downward, B.C.: Symmetry at the floor perimeter & attached @ the test-cell anchor points. Fixed support at basement column bases. Contact elements at the base beam/test-cell floor interface.

Horizontal seismic loading using static 0.15g acceleration per the NCSX/IBC2000 criteria (h~15.3ft, Fp=0.108 x 1.376 = 0.149 ~ 0.15g)*.
B.C.: Same as static gravity.

Various static load distributions (inner to outer supports) based on load shifting due to cooldown and EM loading of the MCWF.

* Para 3.1 - NCSX-CRIT-SEIS-(Rev. 0)

Model Features:

Beams, columns, & plates modeled with 8-node brick element (solid45).

Lateral braces are beam188 elements with 4" angle sections.

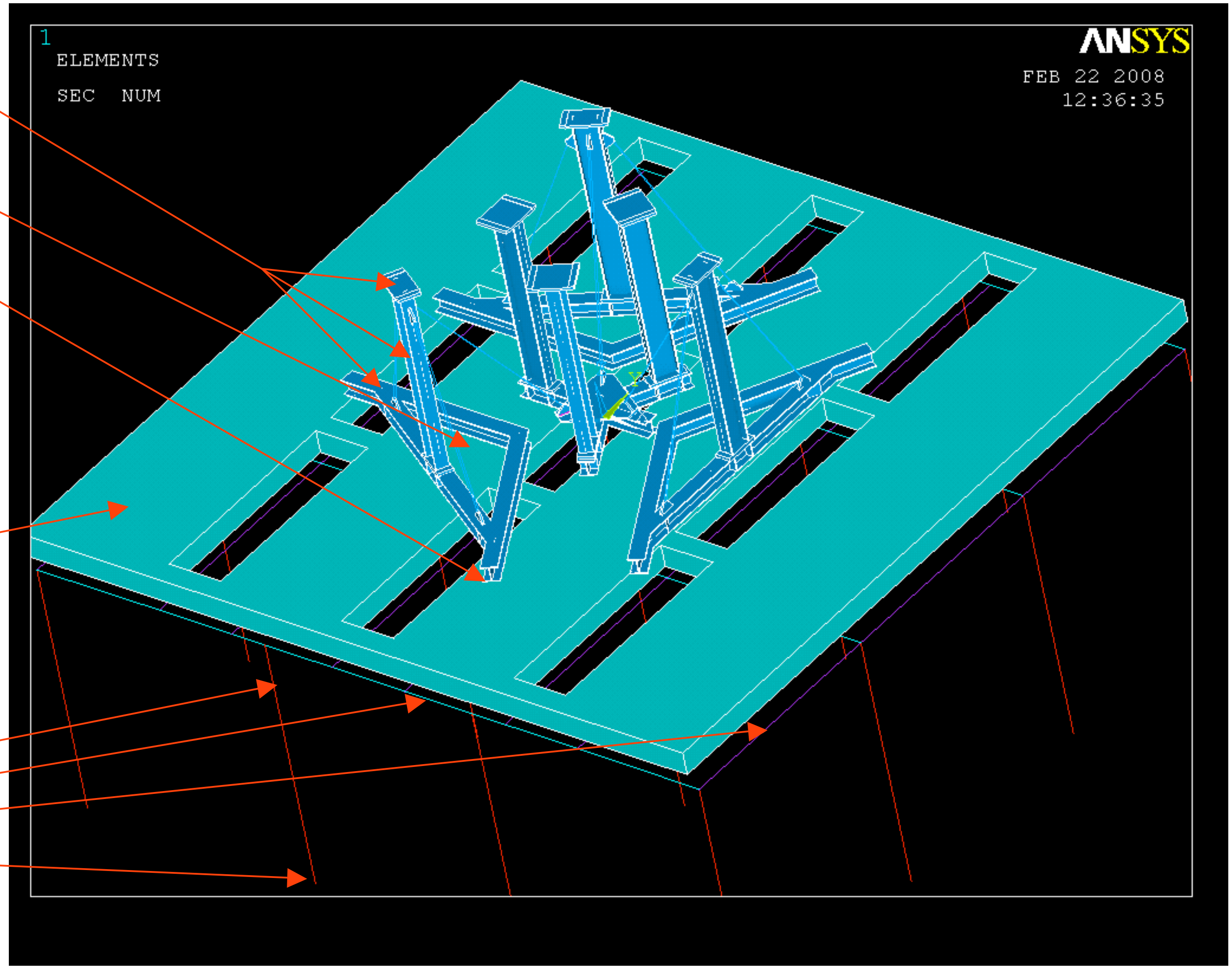
Floor anchor points modeled with coupled nodes.

Base beam-floor interface modeled with standard contact elements (μ = 0.2)

Test cell floor 12" R.C. modeled with 20 node bricks (solid186).

Building Steel modeled with beam188 beam elements
Sections:
P3-columns 14WF-127
G1-girders 27WF-124
S1-stringers 12WF-106

Bldg. columns are fixed at the basement floor level and rot. symmetry boundary conditions are employed around the reinforced concrete test cell floor perimeter to approximate the full building structure.



ANSYS FEA Model of the base support structure

Most severe loadings selected from H.M. Fans' integrated model results:

Loads	Items	Unit	Model 1R	Remarks	Comments
Dead load	D max	mm	3.02E-01	w/o support block	Dmax at PF6
• w/o Wt. increase	DZ	mm	(-0.292 to 0.0314)	w/o support block	
• stellalloy E=199GPa	Seqv	Pa	1.10E+08	PowerGraphics OFF	Max.Seqv at sup. Block
	Seqv	ksi	1.60E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.53E+05		
	OB reaction	kip	3.43E+01	**Total weight**	
	IB reaction	N	1.60E+05	3.122E+05	**G10 shim on cantilever sup.**
	IB reaction	kip	3.59E+01	7.018E+01	Calculated weight
Dead load	D max	mm	3.33E-01	w/o support block	Dmax at PF6
• DL Factor = 1.14	DZ	mm	(-0.323 to 0.0314)	w/o support block	
• stellalloy E=145GPa	Seqv	Pa	9.68E+07	PowerGraphics OFF	Max.Seqv at sup. Block
• Regular PF shim	Seqv	ksi	1.40E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.74E+05		
	OB reaction	kip	3.92E+01	**Total weight**	
	IB reaction	N	1.82E+05	3.561E+05	**SS shim on cantilever sup.**
	IB reaction	kip	4.09E+01	8.005E+01	
Dead load	D max	mm	3.34E-01	w/o support block	Dmax at PF6
• DL Factor = 1.14	DZ	mm	(-0.324 - 0.0310)	w/o support block	
• stellalloy E=199GPa	Seqv	Pa	9.68E+07	PowerGraphics OFF	Max.Seqv at sup. Block
	Seqv	ksi	1.40E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.82E+05		
	OB reaction	kip	4.09E+01	**Total weight**	
	IB reaction	N	1.74E+05	3.559E+05	**G10 shim on cantilever sup.**
	IB reaction	kip	3.91E+01	8.001E+01	
EM load	D max	mm	2.793	w/o support block	Type C modular coil
• stellalloy E=145GPa	DZ	mm	(-0.993 - 1.359)	w/o support block	
• Regular PF shim	Seqv	Pa	4.05E+08	PowerGraphics OFF	MCWF flange shim
	Seqv	ksi	5.87E+01	PowerGraphics OFF	
	OB reaction	N	6.61E+04		
	OB reaction	kip	1.49E+01	**Total weight**	
	IB reaction	N	-6.62E+04	-9.900E+01	**ss shim on cantilever sup.**
	IB reaction	kip	-1.49E+01	-2.226E-02	
DL & EM	D max	mm	2.766	w/o support block	Dmax at MC type C
• DL Factor = 1.14	DZ	mm	(-1.152 - 1.199)	w/o support block	
• stellalloy E=145GPa	Seqv	Pa	4.05E+08	PowerGraphics OFF	at TF shim?, others 2.51E8
	Seqv	ksi	5.87E+01	PowerGraphics OFF	
	OB reaction	N	2.40E+05		
	OB reaction	kip	5.40E+01	**Total weight**	
	IB reaction	N	1.16E+05	3.558E+05	**G10 shim on cantilever sup.**
	IB reaction	kip	2.60E+01	7.999E+01	

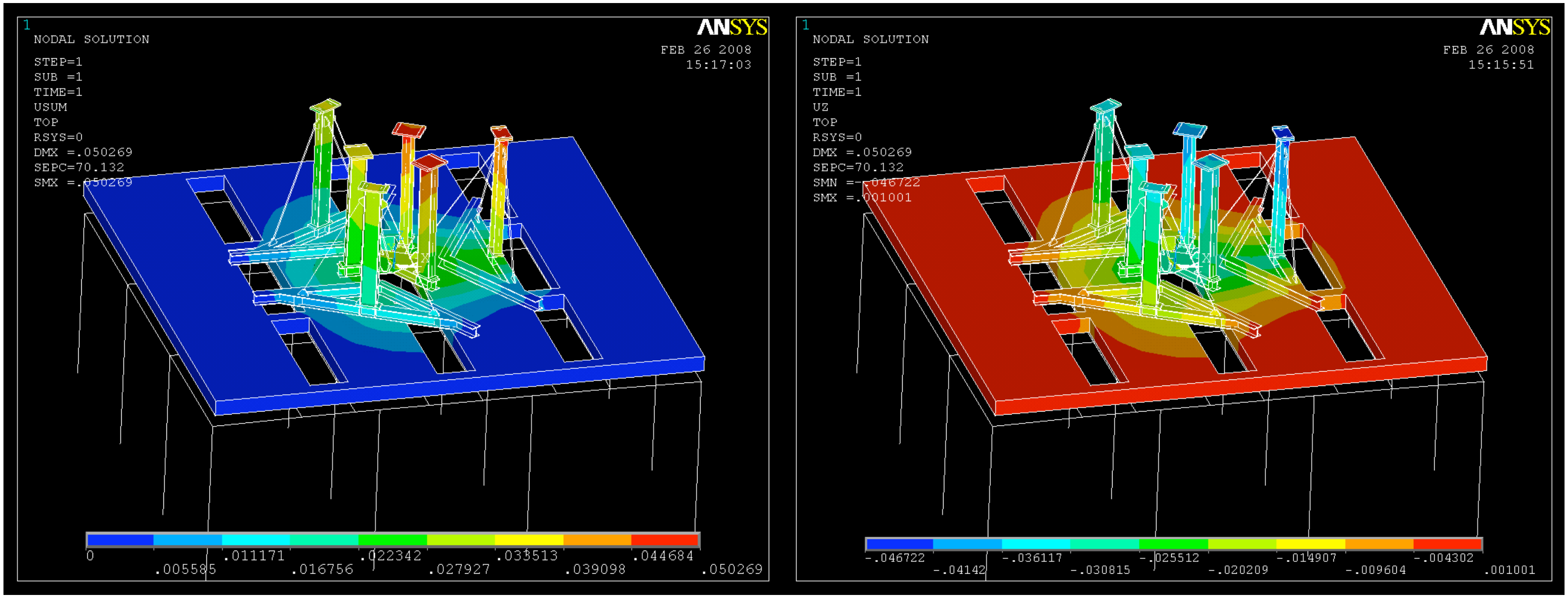
Loads	Items	Unit	Model 1R	Remarks	Comments
Change alpx for shim					
Cooldown	D max	mm	4.692	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.932 - 1.180)	w/o support block	
• Regular PF shim	Seqv	Pa	4.71E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.83E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.08E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	4.67E+00	**Total weight**	
Run: co-h3a	IB reaction	N	-2.08E+04	0.000E+00	**SS shim on PF6 sup.**
	IB reaction	kip	-4.67E+00	0.000E+00	
Cooldown	D max	mm	4.667	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.823 - 0.877)	w/o support block	
• Regular PF shim	Seqv	Pa	4.69E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.80E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	8.29E+03		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	1.86E+00	**Total weight**	
Run: co-h4	IB reaction	N	-8.29E+03	0.000E+00	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-1.86E+00	0.000E+00	
Dead load	D max	mm	5.39	w/o support block	Dmax at PF6
• stellalloy E=145GPa	DZ	mm	(-5.37 - 0)	w/o support block	
• Regular PF shim	Seqv	Pa	9.51E+07	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	1.38E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.79E+05		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	4.02E+01	**Total weight**	
Run: dl-h4	IB reaction	N	1.78E+05	3.571E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	4.01E+01	8.028E+01	**add wt. from PF6 links**
EM load	D max	mm	2.794	w/o support block	Type C modular coil
• stellalloy E=145GPa	DZ	mm	(-0.998 - 1.323)	w/o support block	
• Regular PF shim	Seqv	Pa	4.05E+08	PowerGraphics OFF	MCWF flange shim
• PF shim COF effect	Seqv	ksi	5.87E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.36E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	5.30E+00	**Total weight**	
Run: em-h4	IB reaction	N	-2.37E+04	-9.900E+01	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-5.32E+00	-2.226E-02	
Cooldown	D max	mm	4.062	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.942 - 0.896)	w/o support block	
• Regular PF shim	Seqv	Pa	4.64E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.73E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	4.42E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	9.93E+00	**Total weight**	
Run: co-h4a	IB reaction	N	-4.42E+04	0.000E+00	**SS shim on PF6 sup.**
w/PF6 link & bonded TF shim	IB reaction	kip	-9.93E+00	0.000E+00	

EM load	D max	mm	2.756	w/o support block	Type C modular coil
• stellalloy E=145GPa	DZ	mm	(-1.02 - 1.322)	w/o support block	
• Regular PF shim	Seqv	Pa	4.03E+08	PowerGraphics OFF	MCWF flange shim
• PF shim COF effect	Seqv	ksi	5.85E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.95E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	6.63E+00	**Total weight**	
Run: em-h4a	IB reaction	N	-2.96E+04	-1.000E+02	**SS shim on PF6 sup.**
w/PF6 link & bonded TF shim	IB reaction	kip	-6.65E+00	-2.248E-02	

Static Load Summary:

Loading	Outboard Z load (kips)	Inboard Z load (kips)
Gravity Only	-40.01	-40.02
EM unbonded (w/link, corrected Alpha, etc.)	-5.3	+5.3
Cooldown. unbonded(w/link, corrected Alpha, etc.)	-1.86	+1.86
EM bonded (w/link, corrected Alpha, etc.)	-6.63	+6.63
Cooldown. bonded (w/link, corrected Alpha, etc.)	-9.93	+9.93

FEA Results (normal EM ops. unbonded case):



Peak vector sum displacement 0.050”

Peak vertical displacement -0.046”

Note Test Cell floor deflects ~ 0.025” (node 6274)

SRSS & Vertical Displacements for Gravity + Cooldown + EM-N

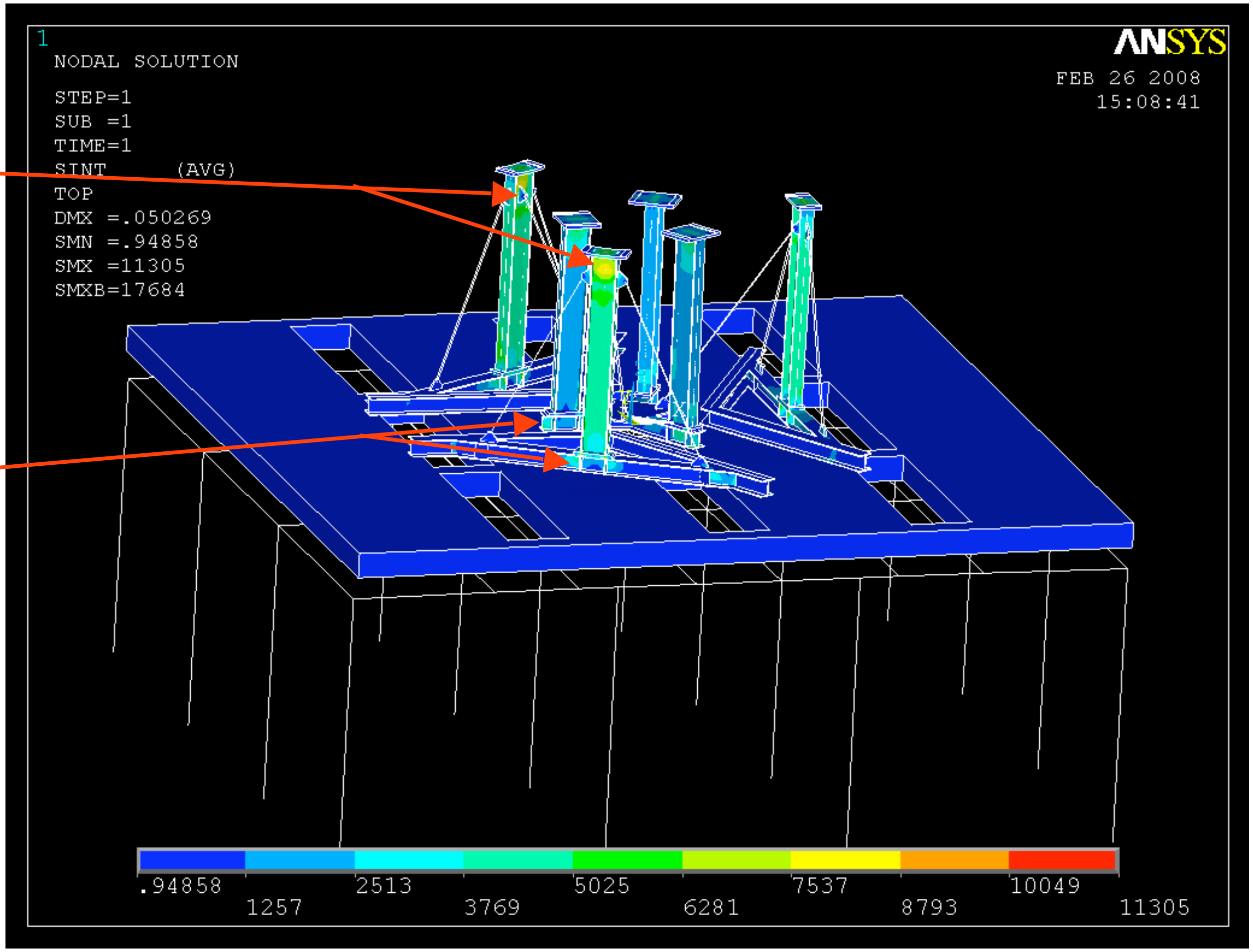
FEA Results (normal EM ops. unbonded case):

Peak Stress @ Lateral support mounting brackets 11.3 ksi

Average Stress in columns is 4 - 5 ksi

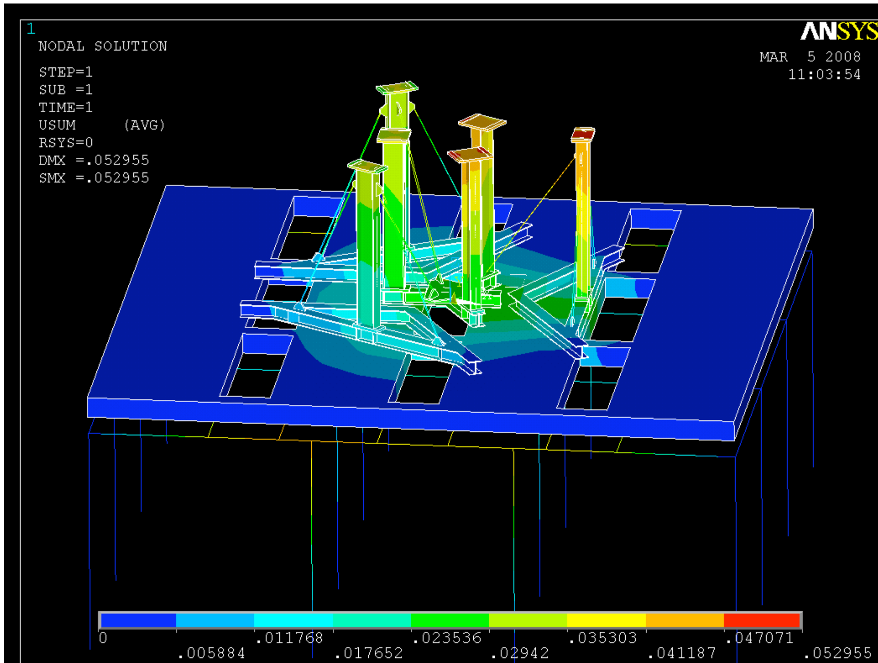
Peak Stress in the base frame is 4 ksi at gussets

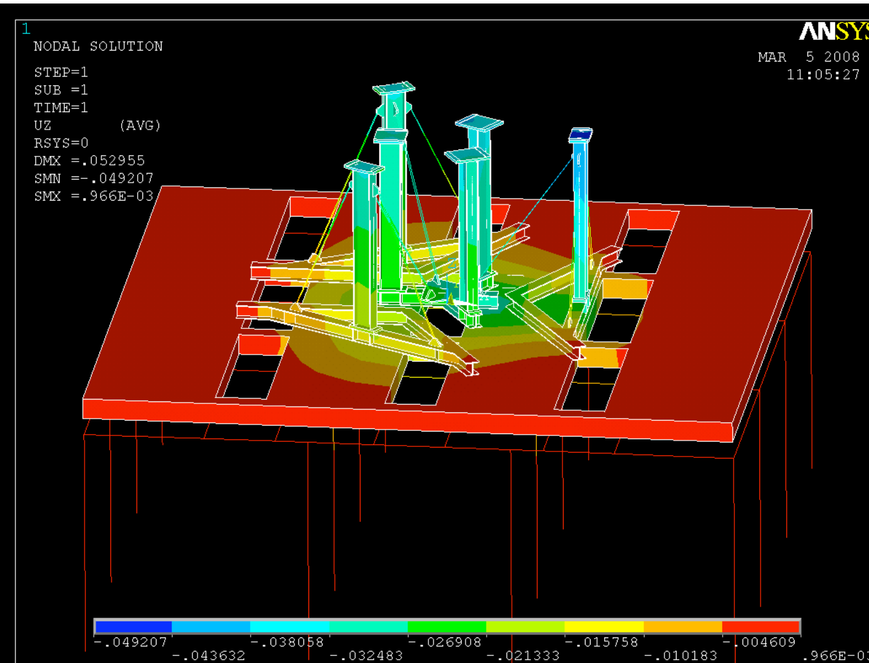
Calc. Stress in anchor studs is 4 - 5 ksi



Tresca Stress contours for Gravity + Cooldown + EM-N

FEA Results (normal EM ops. bonded case):





Peak vector sum displacement 0.052”

Peak vertical displacement -0.049”

Note Test Cell floor deflects ~ 0.028” (node 6274)

SRSS & Vertical Displacements for Gravity + Cooldown + EM-N

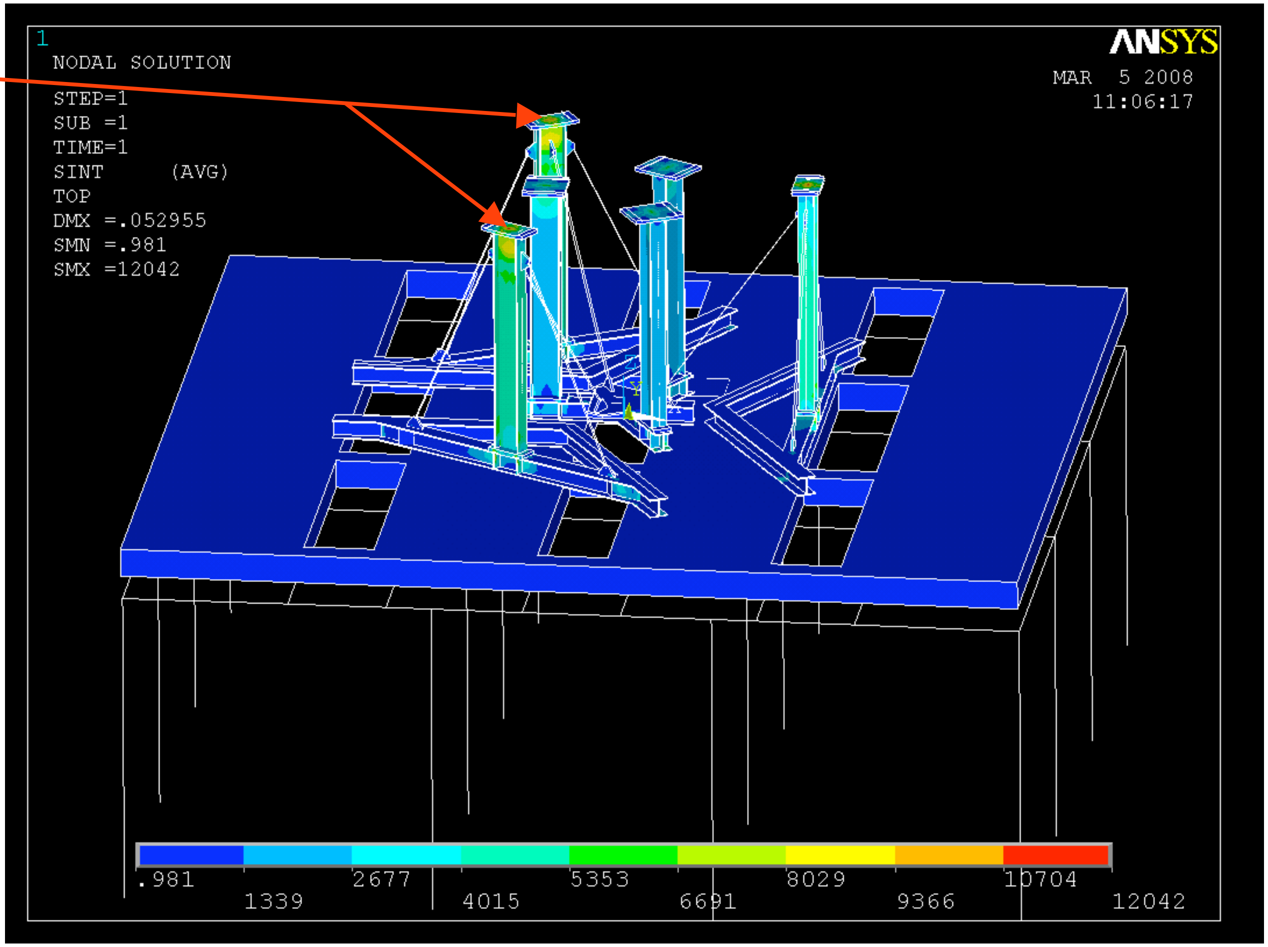
FEA Results (normal EM ops. bonded case):

Peak Stress @ pedestal 12.0 ksi (slightly higher bending there due to increased load)

Average Stress in columns is 4 - 5 ksi

Peak Stress in the base frame is 4.5 ksi at gussets

Calc. Stress in anchor studs is still ~4 - 6 ksi



Tresca Stress contours for Gravity + Cooldown + EM-N

FEA Model for seismic runs:

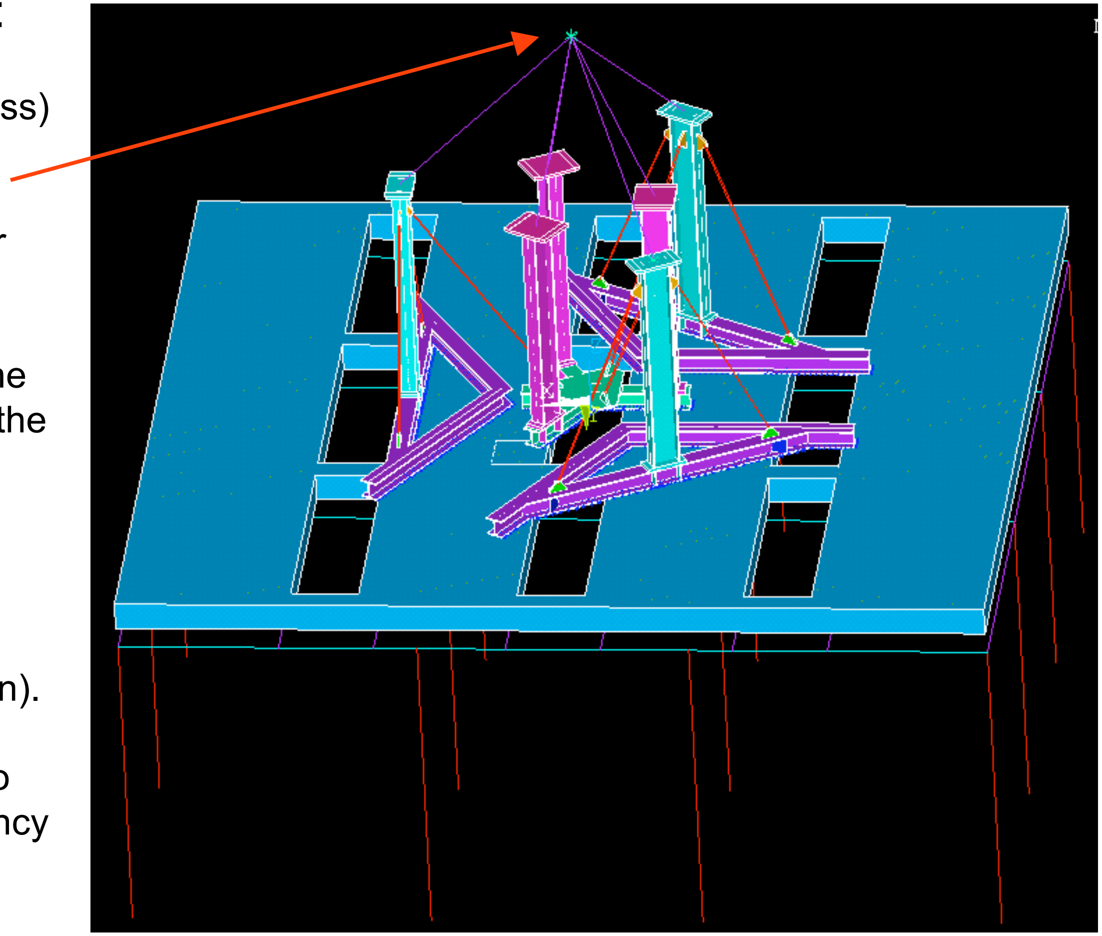
•Concentrated 240 kip (231 slug mass) located at the Stellarator core C.G.

•Static loading 0.15g horizontal, (per the NCSX/IBC2000 criteria).

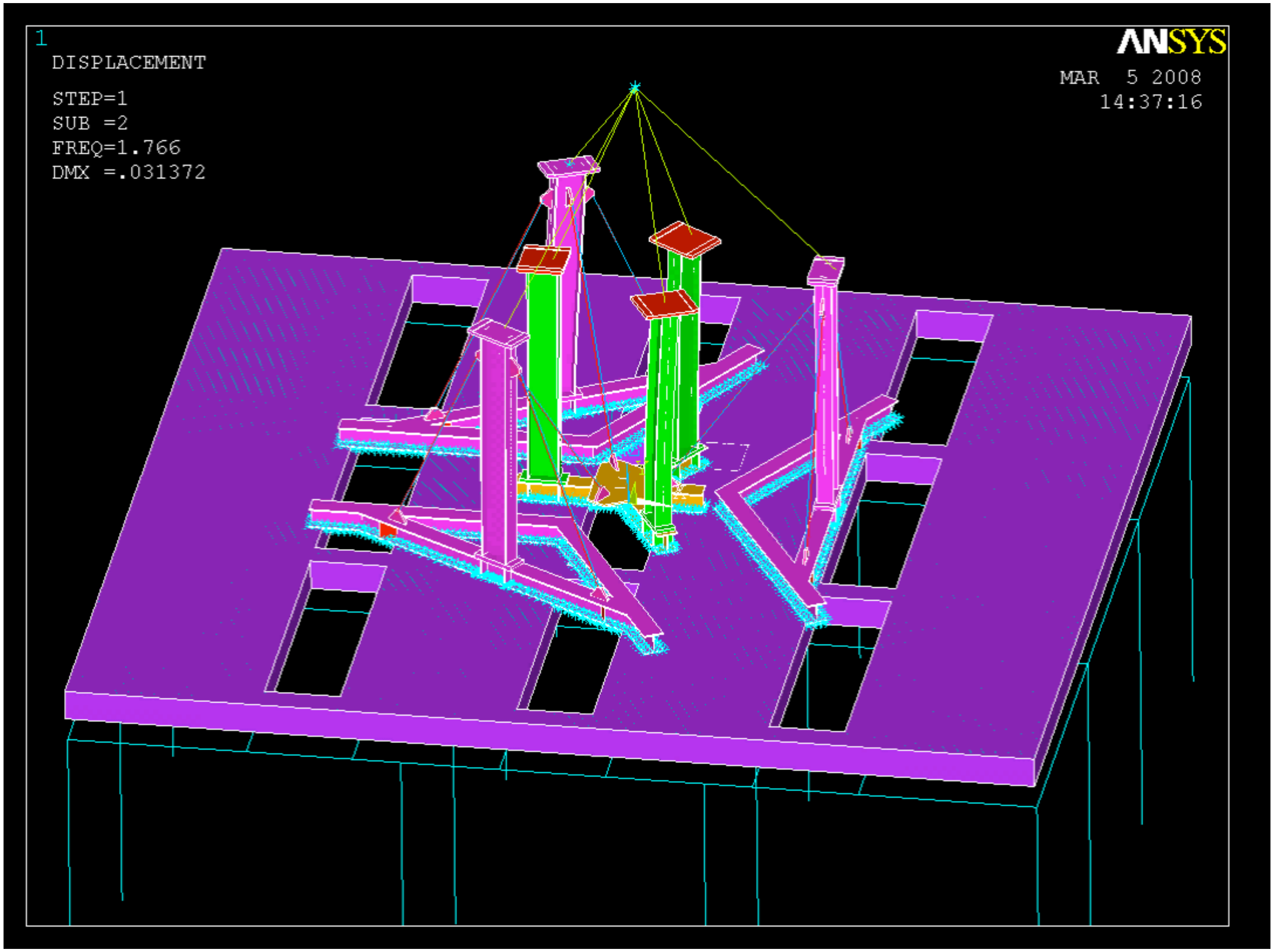
•Stiff (nearly rigid) beams connect the mass to 6 master nodes just above the support column pedestal level.

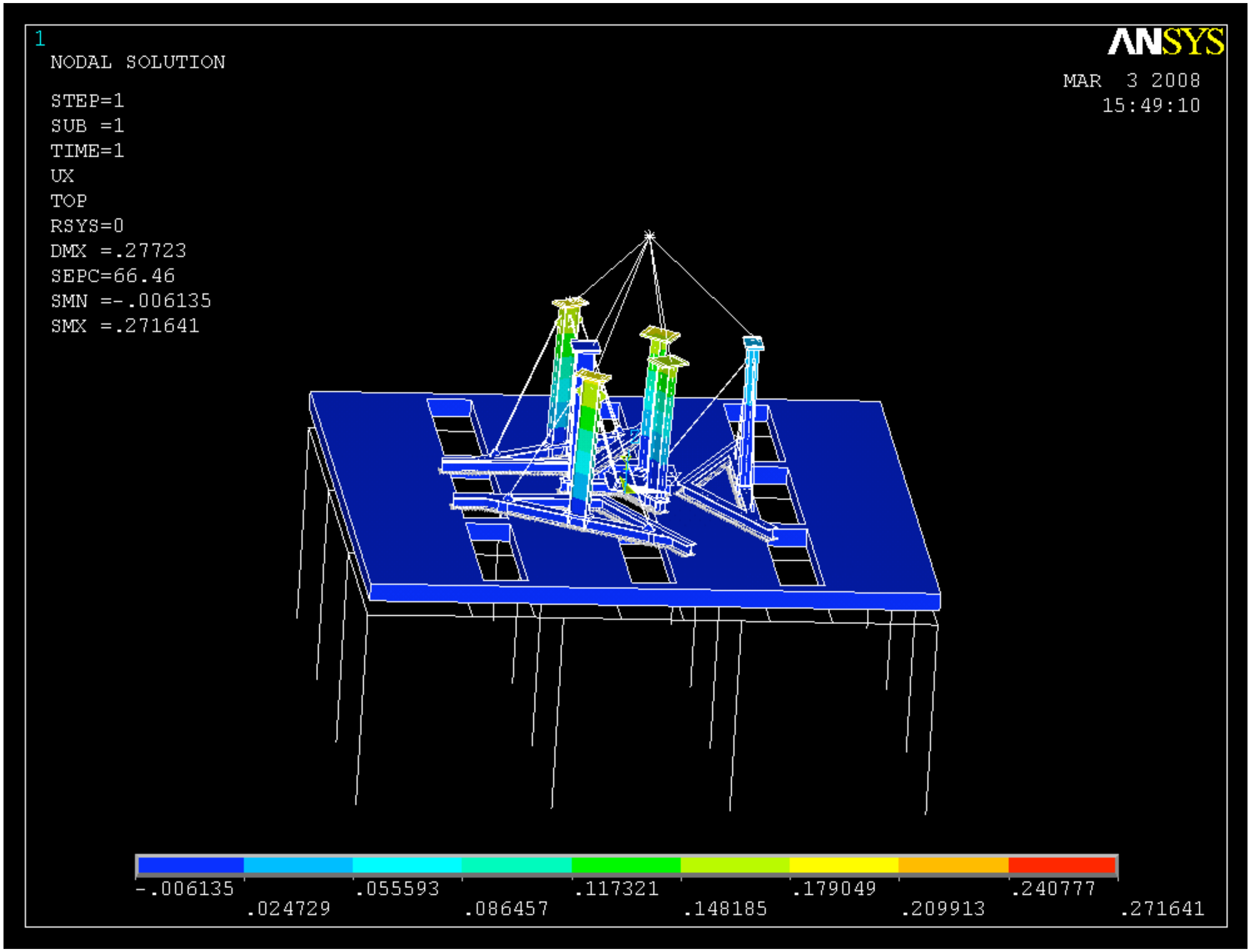
•Utilized coupled nodes to master nodes at the sliding low friction surfaces (with the radial DOF uncoupled to simulate the low friction).

• A model analysis was performed to determine the lowest nutural frequency of the structure.

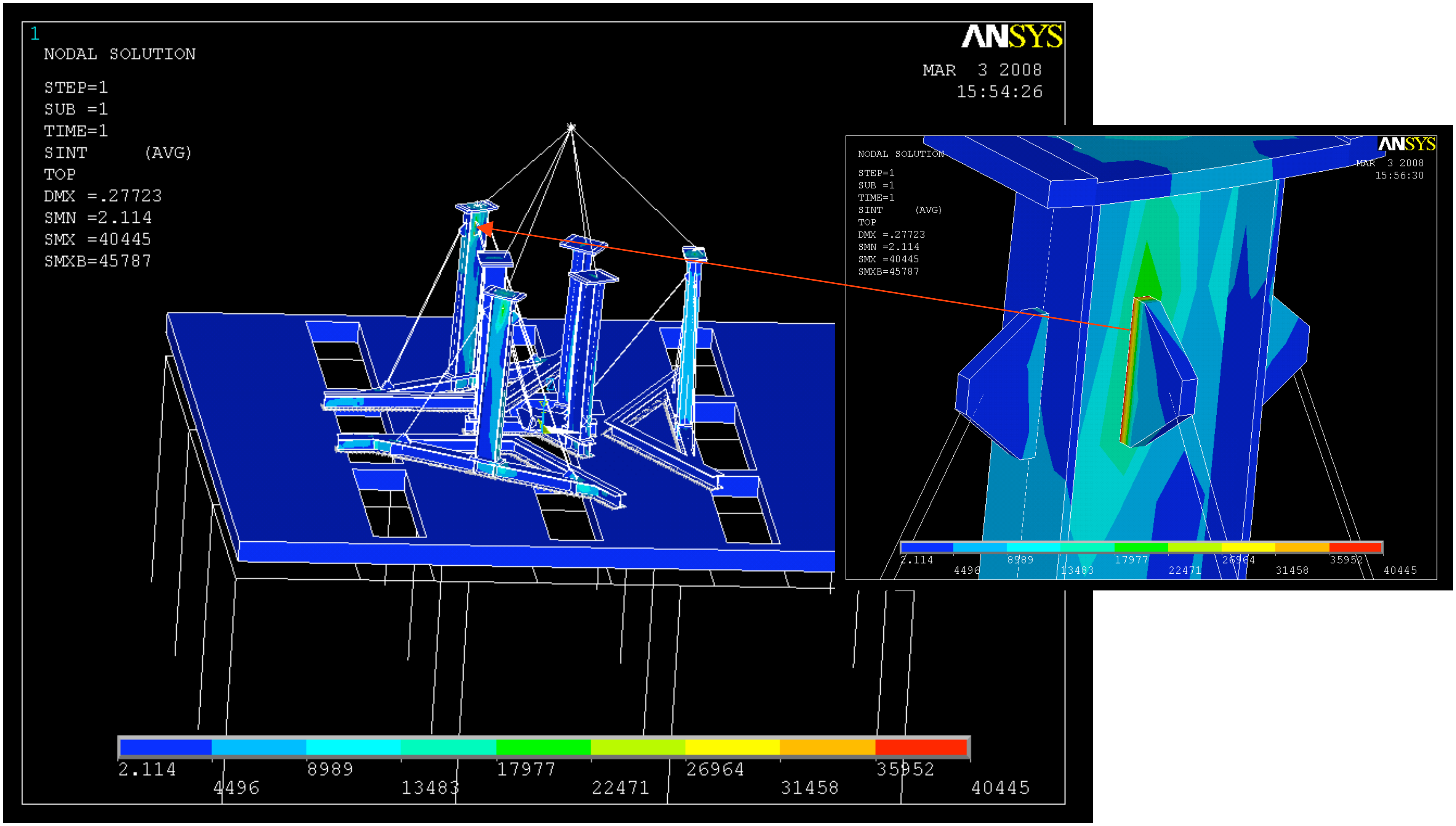


Modal Analysis Result: 1st flexible mode @ ~1.7 Hz NE-SW (30 deg.)

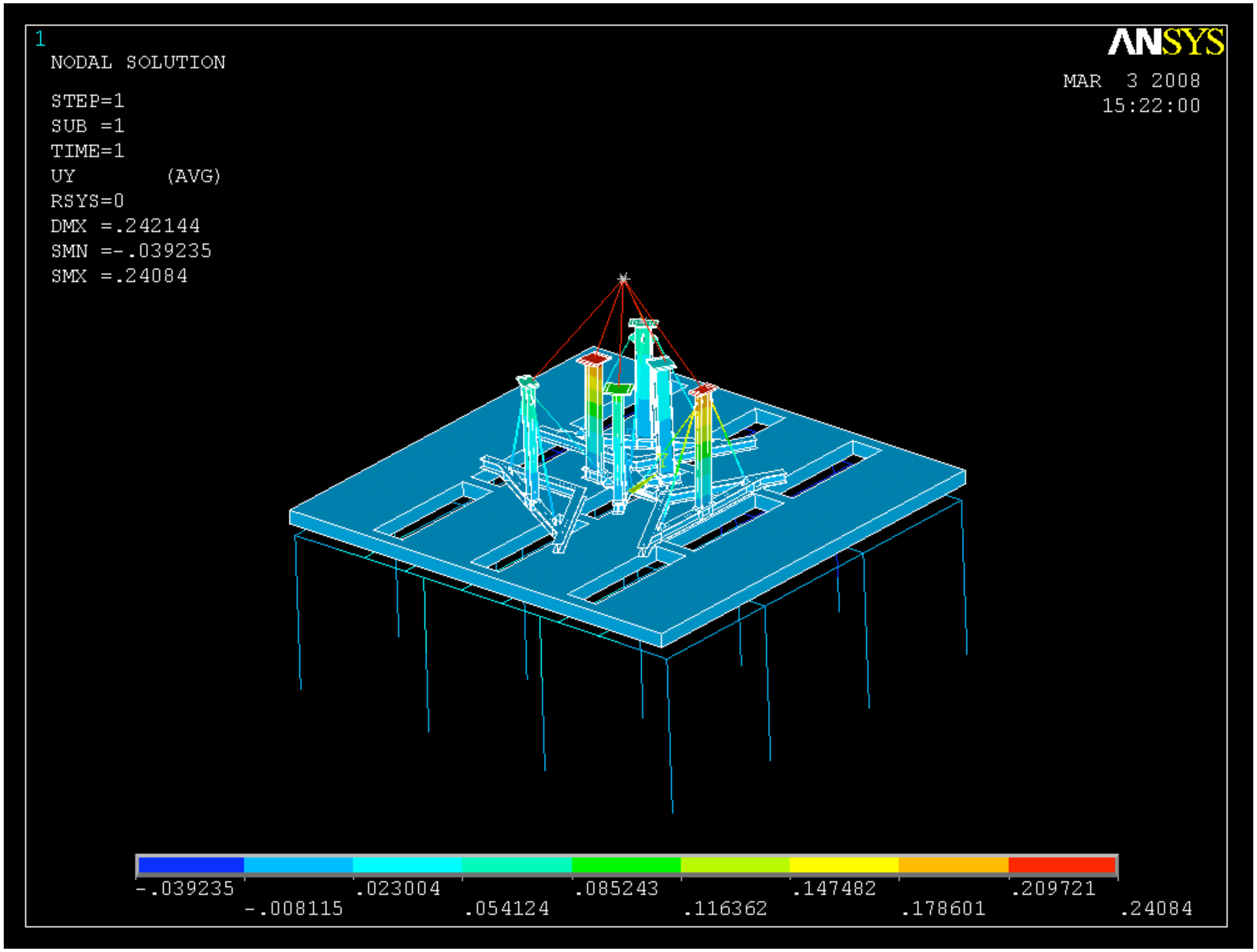




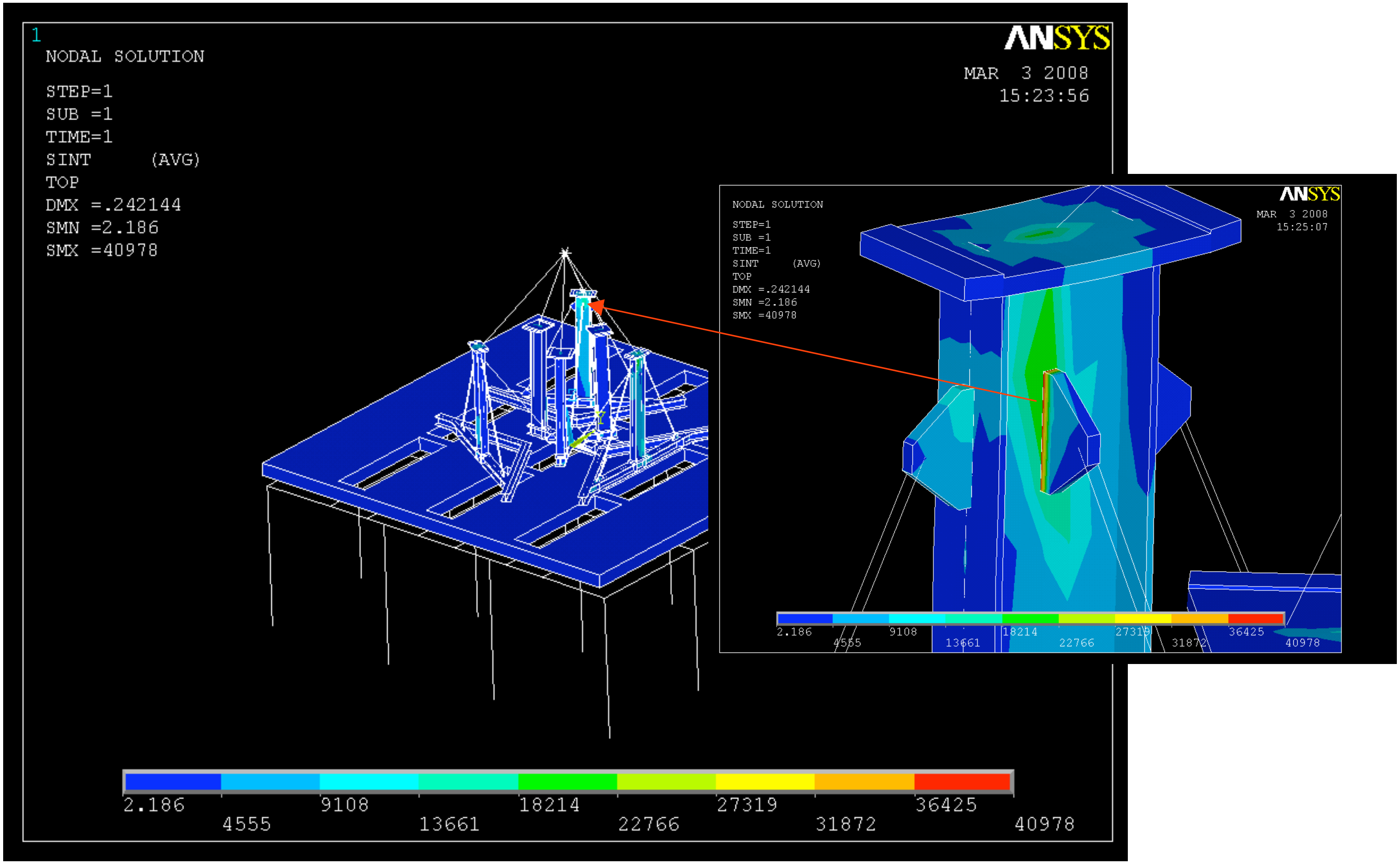
Results from E-W static lateral loading (0.15g): Peak displacement of C.G. 0.27”



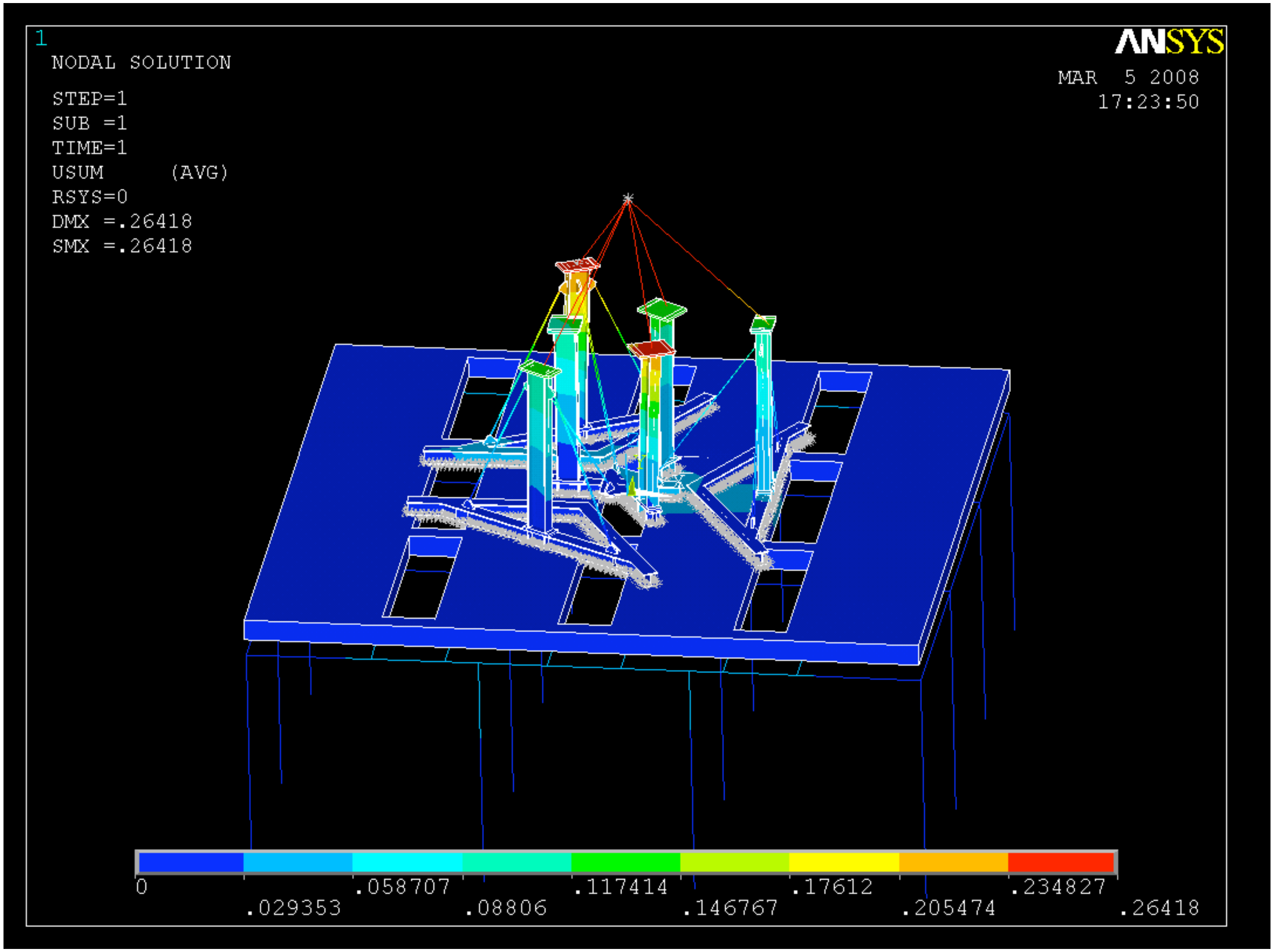
Results from E-W static lateral loading (0.15g): Peak Tresca Stress 40.4 ksi
Location: Bending stress @ the base of lateral brace brackets



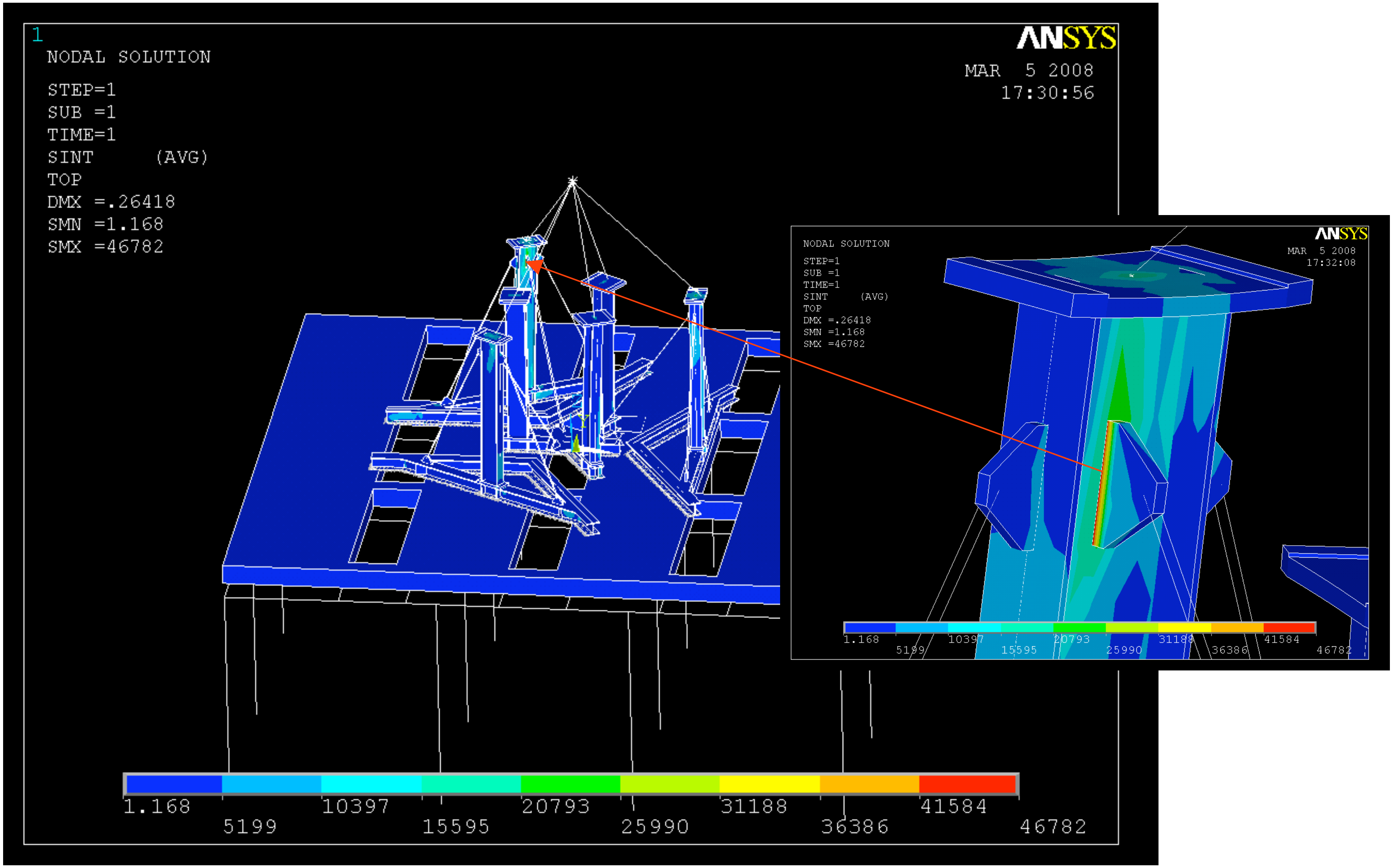
Results from N-S static lateral loading (0.15g): Peak displacement of C.G. 0.24”



Results from N-S static lateral loading (0.15g): Peak Tresca Stress 40.9 ksi
Location: Bending stress @ the base of lateral brace brackets - Modeling issue

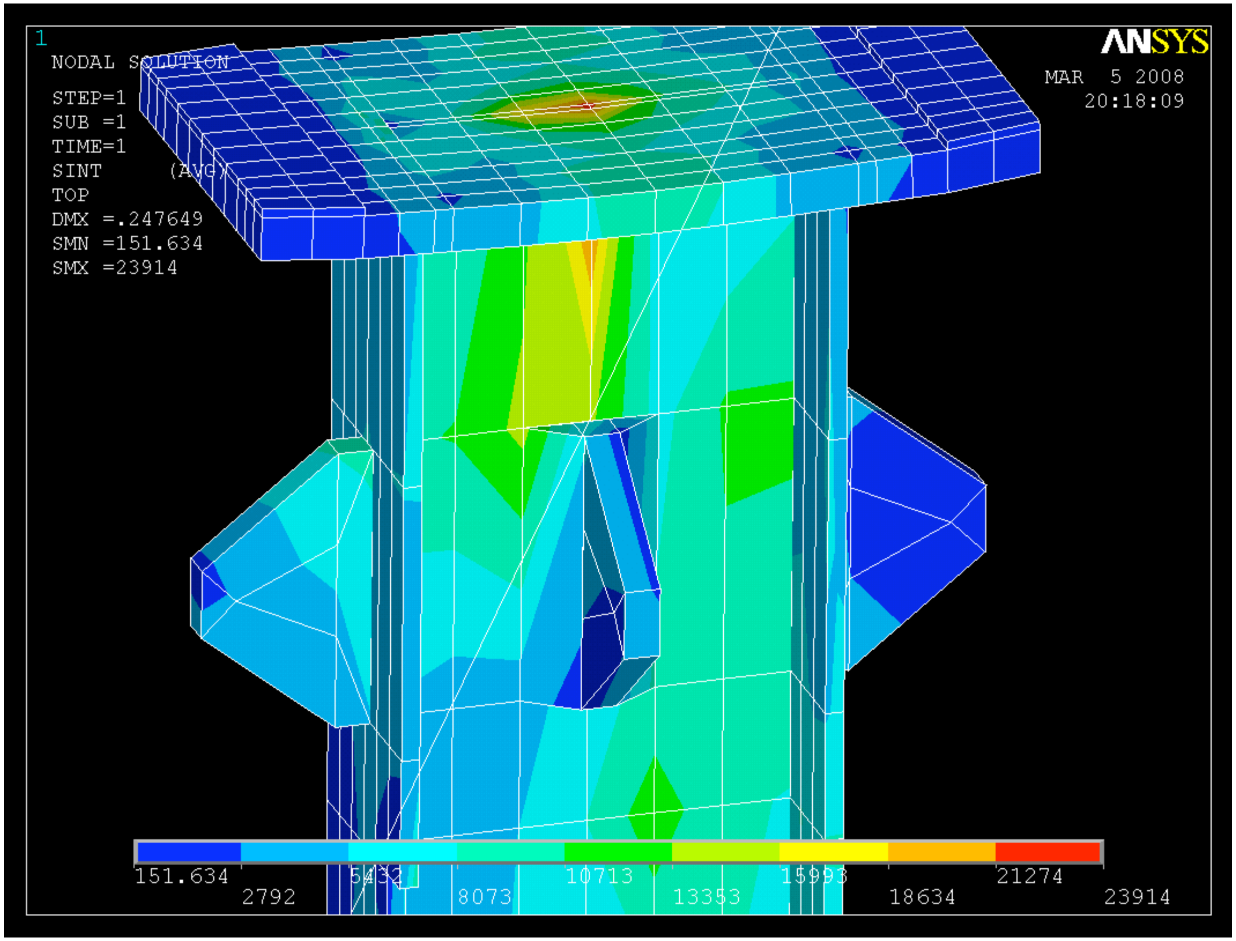


Results from NE-SW static lateral loading (0.15g): Peak displacement of C.G. 0.26”



Results from NE-SW static lateral loading (0.15g): Peak Tresca Stress 46.8 ksi
Location: Bending stress @ the base of lateral brace brackets - Modeling issue

National Compact Stellarator Experiment



Fixed modeling issue:

Added fillet to model weld - reduced stress in the bracket region to ~ 11 ksi peak tresca.

Peak, 24 ksi, now at the pedestal center over - estimated due to lateral seismic load transfer to localized points near the center

Enhanced model which includes spherical bearing housing is being prepared.

Results from re-modeled NE-SW static lateral loading (0.15g): Peak Tresca Stress 24 ksi
Location: Bending stress @ the center of pedestal plate

NCSX National Compact Stellarator Experiment

Seismic Loading on Anchors:

Forces on concrete wedge studs:

NODE	FX	FY	FZ
16560	398.70	-2210.4	4315.8
16612	4552.2	-3412.6	-3288.6
17234	826.51	5147.6	-1534.6
17286	-492.71	667.62	52.423
19454	-3423.9	3347.4	340.46
19467	-2536.8	-3199.8	-955.54
21988	444.46	-2947.8	674.77
22070	-136.47	-3393.3	2775.4
22698	-799.82	6116.4	1872.8
27352	-3.9376	446.26	2409.3
27434	1713.6	-1165.6	2378.7
27982	5766.0	-5069.0	-450.61
28064	-687.22	618.00	-962.14
32724	-424.18	186.34	-697.50
32806	8688.9	7165.1	-462.25
33354	7462.7	4044.8	6025.2
33436	-1419.8	-1271.9	5776.6

For minimum embedment 4.5” in 4,000 lb R.C.

Shear area of stud	.78 sq.in.
Max. Shear force	11,262 lbs (node 32806)
Max. Shear in stud	14.4 ksi
Max. pullout load	6.03 kip (node 33354)
Stud capacity	13,000 lbs pullout
Shear	22,920 lbs

For recommended stud spacing:

Margin on shear load	~2x
Margin on pullout	~2x

Reduction for stud less spacing 75% of rated values:

Margin on shear	~1.1x
Margin on pullout	~1.6x

Loading & stress on the anchors for all operating conditions are substantially less (~50%) than this DBE seismic loading

Design Load Requirements[1]:

Normal ops.: D + P + L + T + EM-N + IR
Off-Normal: D + P + L + T + EM-F + IR
Seismic: D + P + L + T + F_{DBE}+ IR

D = 240,000lbs, -40kip per support (nominal)
T = -9.93 kip (on O.B. columns), +9.93 kip (I.B. columns)
P = 0
L = 0 (exception for anchor pre-loading)
EM-N = -6.63 (on O.B. columns), + 6.63 kip (I.B. columns)
F_{DBE} = 36 kip (for 0.15g static horizontal load)[2]
vertical acceleration not given in ref.2 (seismic requirements)
but 10% used should exceed requirements
IR = 0

Definitions

D - Dead Loads (gravity)
P - Pressure
L - Pre-loads
T - Thermal loads
EM-N Electro-Magnetic Normal Ops.
EM-F " " Fault conditions
IR - Interaction Loads
F_{DBE} - Design Basis Earthquake Load
D_T - Peak column loading

Comparison with project allowable stresses:

Normal ops. Max stress = 12 ksi - S_m is 16.6 ksi 2/3 25ksi (min.spec yield at R.T.)
Seismic Max stress = 24 ksi < Allowable 1.5xS_m = 25 ksi for local bending
Off-Normal stress: EM-F not yet defined by project but based on most severe normal EM-N case ± 6.6 ksi and >2 margins on allowable, structure should be capable of handling fault conditions (Project needs to define credible EM-F conditions and stresses to be confirmed by the FDR).

1. NCSX-CRIT-CRYO-00
2. NCSX-CRIT-SEIS-00

Stainless Structurals L.L.C.
590 Beautyrest Avenue | Jacksonville, Florida 32254
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DATA SHEET FOR STAINLESS STEEL LASER CHANNELS, TEES, BEAMS AND ANGLE BAR
DUAL GRADES 304 / 304L AND 316 / 316L

Applicable standards		Rev.	Grade: AISI – 304/304L, UNS – S30400, UNS – S30400	Grade: AISI – 316/316L, UNS – S31600, UNS – S31603
ASTM	A484/A484M	2003a	X	X
	A276	2004	X	X
	A370-03a	2003	X	X
	A479/A479M	2004	X	X

Chemical values (1)

Grade	C	Si	Mn	Ni	Cr	Mo	S	P	N	Cu	Co
304/304L	0.03	1.0	2.0	8-10.5	18-20	1.0	0.030	0.040	0.10	1	Report
316/316L (2)	0.03	1.0	1-2	10-14	16-18	2-3	0.030	0.040	0.10	0.75	Report

(1) Maximum values if not specified differently
(2) Ti is allowable in amounts up to 0.5%

Mechanical properties of parent materials

Grade	TS [KSI]	YS (1) [KSI]	EL (1) [%]	RA (1) [%]	HB
304/304L 316/316L	75-115	30	30	50	140-241

(1) Minimum values

- Condition: as welded; parent materials are solution annealed and quenched.
- Intergranular corrosion test according to ASTM A262 practices A, C & E (where applicable).
- Mechanical properties of fusion zone might differ from parent material.
- Material free of contamination from mercury or metals liquid at ambient temperature.
- Tag marking: P.O. #, heat nr., nr. of bars, grade, weight, length, shape and size.
- Shape tolerance according to ASTM A484 Table 16.
- 100% laser fusion inspected to ISO 13919-1 class D.
- Antimixing performed

Base materials of Structurals meet or exceed ASME BPV code requirements for minimum specified yield at 70 deg.F

ASME ASTM-A240 316L $S_{y\text{-min.}}$ > 25 ksi (assume 25 ksi)

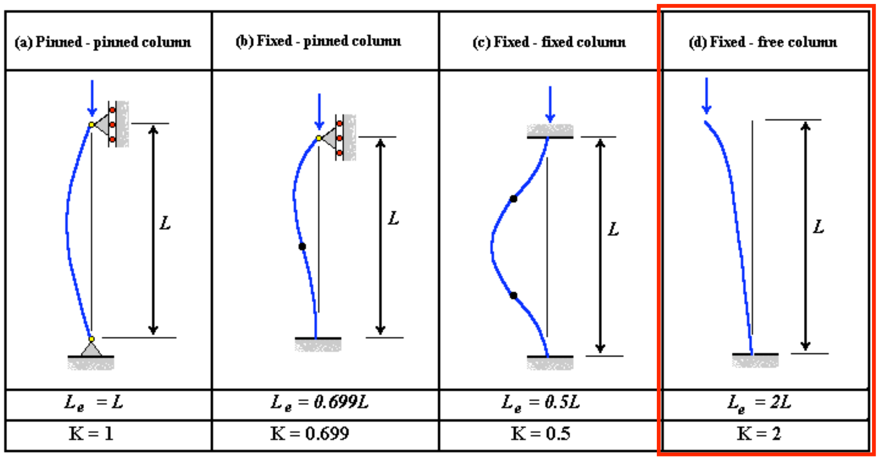
Per NCSX-CRIT-CRYO-00, the stress allowable is the lesser of:

1/3 $S_{ult,}$ or 2/3rd $S_{y\text{-min.}}$

For all materials specified this will be:

S_m = 16.6 ksi (110 Gpa) @T = 70 ^{o}F

Column buckling:



Eulers formula:
for end condition (d): $F_{cr} = \pi^2 EI / 4L^2$

WF12 x 35	WF12 x 50
L = 98 in	L = 98 in
I_{yy} = 24.5 in^4	I_{yy} = 56.3 in^4
E = 29e6 psi	E = 29e6 psi
A = 10.3 in^2	A = 14.4 in^2
F_{cr} = 182,537 lbs	F_{cr} = 419,463 lbs

(Note these values are for columns with no lateral bracing)

Buckling Margins:

For 80 kip loading:

WF12x35 margin = 2.27

WF12x50 margin = 5.2

For 25 ksi min. yield, the buckling stress for a WF12x50 column:
29.1 ksi
Probable failure mode is yielding

Cost & Schedule:

Purchased parts:	(ft.)	lbs./ft.	$/lb. (or per pkg.)	cost
4 - W12 x 35 x 24' - 316L stainless steel (LW)	96	35	$9.20	$30,912.00
4 - W8 x 35 x 24' - 316L stainless steel (LW)	96	35	$9.20	$30,912.00
4 - W12 x 35 x 24' - 316L stainless steel (LW)	96	35	$9.20	$30,912.00
5 - 4" x 4" x 3/8" thk. Tee sections - 316L	120	9.2	$9.20	$10,156.80
3/4" - 316L plate 36" x 48" base hub plate	4	95	$7.50	$2,850.00
3/4" - 316L plate 36" x 48" top & bottom base column bases	4	95	$7.50	$2,850.00
Weld rod & roto-bores				$3,000.00
12 - Inconel 718 hex bolts 1-8 x 2.5" @ $55 ea.				$660.00
12 - Inconel 718 hex nuts 1-8 @ $38 ea.				$456.00
24 - 316 SS flat washers 1.03" ID @$4.26 ea.				$102.24
1 x 9" 316ss Hilti concrete anchors - 4 packs (Part#97799A730)		$231.80	24	$5,563.20
Sub-Total:				**$118,374.24**
G& A on Materials @25%				$29,593.56
Total Materials				**$147,967.80**
	EMTB			
Labor - PPPL:	**hrs.**			
Welding *(4hrs @ 48 places)*	192			
Welding *(4hrs @ 24 places)*	96			
Cut & Drill plates	75			
	363			

17 - Cryostat and Base Support Structure

Job: 1702 - Base Support Struct Design-DAHLGREN

1702-510	Base support structure prel. design & analysis	120*		03SEP07A	29FEB08	303	21,459.40	DAHLGREN =178hr ; CRUIKSHANK =224 ;
1702-515	Base support - PDR	5	R	25FEB08	29FEB08	303	3,582.60	DAHLGREN =04hr ;
1702-516	Disposition PDR chits	5	R	03MAR08	07MAR08	303	2,895.04	DAHLGREN =04hr ;
1702-520	Final design. Assy dwgs, fab dwgs, BOMs,specs/SO	46*		01JAN08A	05MAR08	305	2,388.40	DAHLGREN =178hr ; CRUIKSHANK =224 ;
1702-525M	Base Support Structure FDR	0			07MAR08	303	0.00	
1702-530	Resolve chits, issue dwgs for fab,Issue requisit	10		10MAR08	21MAR08	303	10,277.36	DAHLGREN=36;CRUIKSHANK=32
Subtotal		135		03SEP07A	21MAR08	303	40,602.80	

Relevant chits from 1/17/07 peer review:

Coil Structure Peer Review Dahlgren/Reiersen/Dudek	1/17/07	1	Coil structure rests on cover plate for an existing building penetration. A structure will be needed to carry loads to the building structure [Perry]	Concur	Base Structure spans floor opening and distributes the load to the test cell floor.
Coil Structure Peer Review Dahlgren/Reiersen/Dudek	1/17/07	3	Interface with base support structure (p13) should have sliding joints at tops of columns. Columns pinned top and bottom will change elevation when lateral motion occurs. [Perry]	Concur	A sliding interface between the top pedestal and spherical bearing housing has been implemented.
Coil Structure Peer Review Dahlgren/Reiersen/Dudek	1/17/07	17	Consider coil fault conditions in the design of the structure. [Dudek]	Concur	Fault conditions and loads are still TBD

Fatigue Considerations:

The facility shall be designed for the following maximum number of pulses when operated per the reference scenarios defined in Section 3.2.1.5.3.3.1 and based on the factors for fatigue life specified in the NCSX Structural and Cryogenic Design Criteria Document:

- 100 per day;
- 13,000 per year; and
- 130,000 lifetime.

Max. operational load O.B. columns: 40.1 + 9.93 = 49.94

S max = 14.2 ksi, S min = 12.0 ksi

S mean = 13.1 ksi

Seq. = 2.67 ksi

20x life = 2.6e6 cycles

---> 26 ksi limit >> max stress intensity

Conclusion:
Fatigue life not a limiting
Factor in design

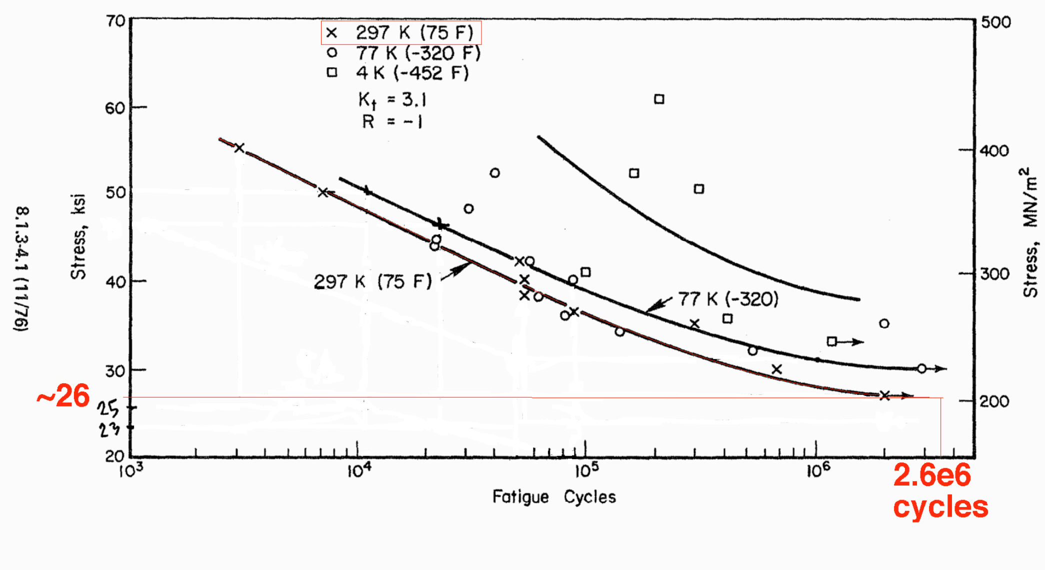


FIGURE 8.1.3-ME2.1. AXIAL FATIGUE LIFE CURVES FOR NOTCHED ANNEALED 304L STAINLESS STEEL BAR [95168]
[Up to 2.540 cm (1.000 in.) diameter]

The charge to the review committee is as follows:

1) Has the Systems Requirement Document been prepared? Are interfaces adequately defined in it?

2) Does the design meet the requirements?

3) Are the critical calculations necessary to confirm the design basis sound? Has a Failure Modes and Effects Analysis been started?

4) Have the constructability, assembly and installation plans been adequately addressed?

5) Have the drawings and models been promoted to Preliminary Design release level?

6) Have the CDR chits been addressed?

Seismic Static Load Requirements:

For hazardous equipment when Ip > 1 use the following
Fp = .4*a.p*Sds*Wp*(1 + 2*z/h) / (Rp / Ip) Equation 16-67
Fp = the seismic force centered at the center of gravity of the component
Wp = component operating weight
a.p = component amplification select from table 1621.2 or 1621.3

For rigid structures whose natural frequency (Fn) is greater than 16.7 hz use a.p = 1
(ref. commentary Figure 1621.1.4)
For non rigid structures use a.p = 2.5
Fn = 1 / (2*p(W.p / K.p *g)^.5) Component Natural Frequency (1621.3.2)
g = Acceleration of gravity
K.p = Stiffnes of the component and attachment in terms of load per unit deflection at the center of gravity

Rp = Component response modification factor select from table 1621.2 or 1621.3,

Represents the ability of a component to sustain permanent deformations without losing strength (= 2.5 for most components includes steel and copper , = 1.25 for low deformability elements such as ceramic, glass, or plain concrete)

z = Height in structure above base at point of attachment of component (height above grade)
h = Average roof height of structure relative to the base elevation
Ip = 1 for non hazardous equipment and 1.5 for hazardous equipment or life safety equipment required to function after an earthquake, from section 1621.1.6

For NCSX we simplify the equation to :

Fp = .096*a.p*Wp*(1 + 2*z/h)*Ip / Rp
With Basement Elevation = 0'
Test Cell Elevation = 13'3"
Top of Steel = 55'
For the Test Cell Floor z/h = .24
For C.G. of machine z/h = 28.5/55 = 0.519
a.p. = 1.0 (rigid structure)
Ip = 1.5
Rp = 2.5

Fp = (.096*(1.0)*(1 + 2*0.519)*1.5/2.5) * Wp = 0.1174 * Wp
If a.p. = 2.5 (non-rigid): Fp = (.096*(2.5.0)*(1 + 2*0.519)*1.5/2.5) * Wp = 0.293 * Wp