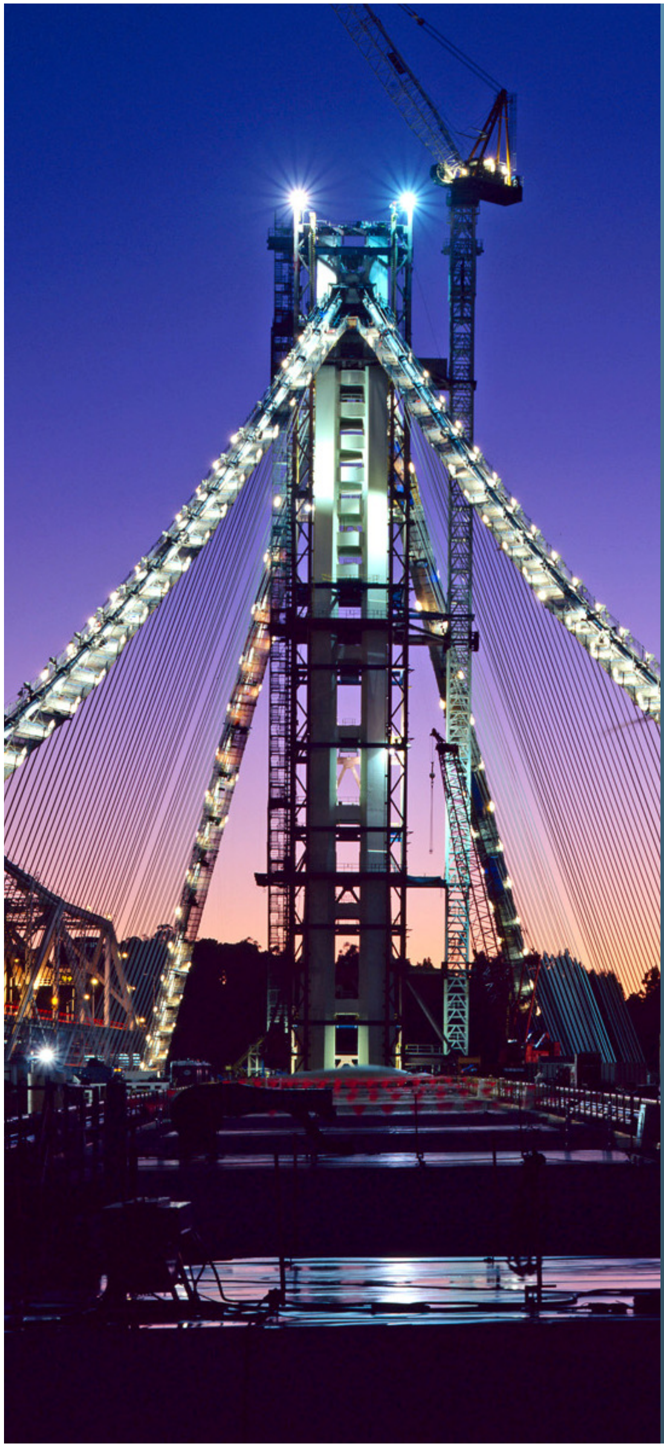


Shear Key S1 & S2 Design Alternatives and Testing of A354BD

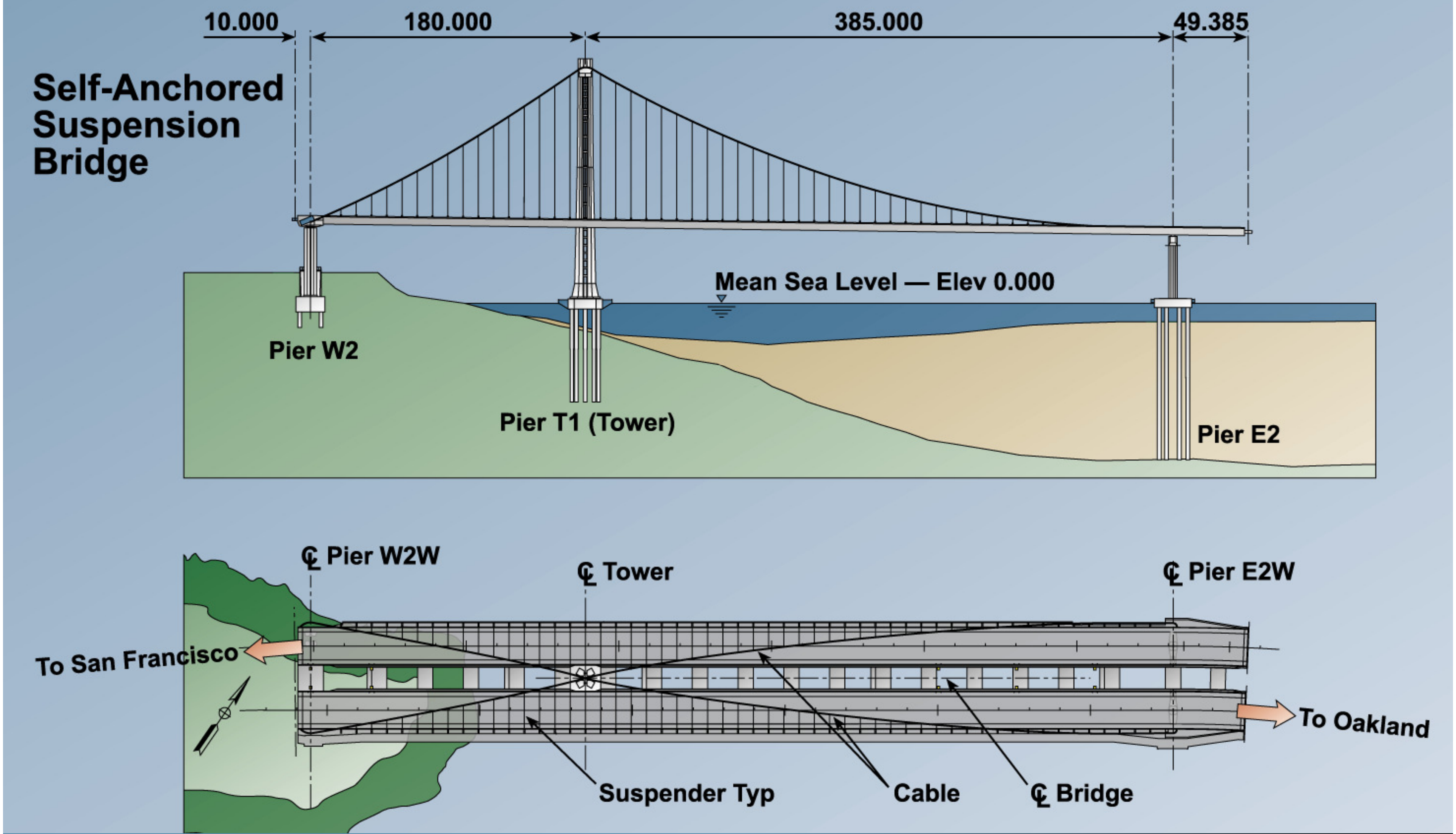
Seismic Safety Peer Review Panel

May 6, 2013

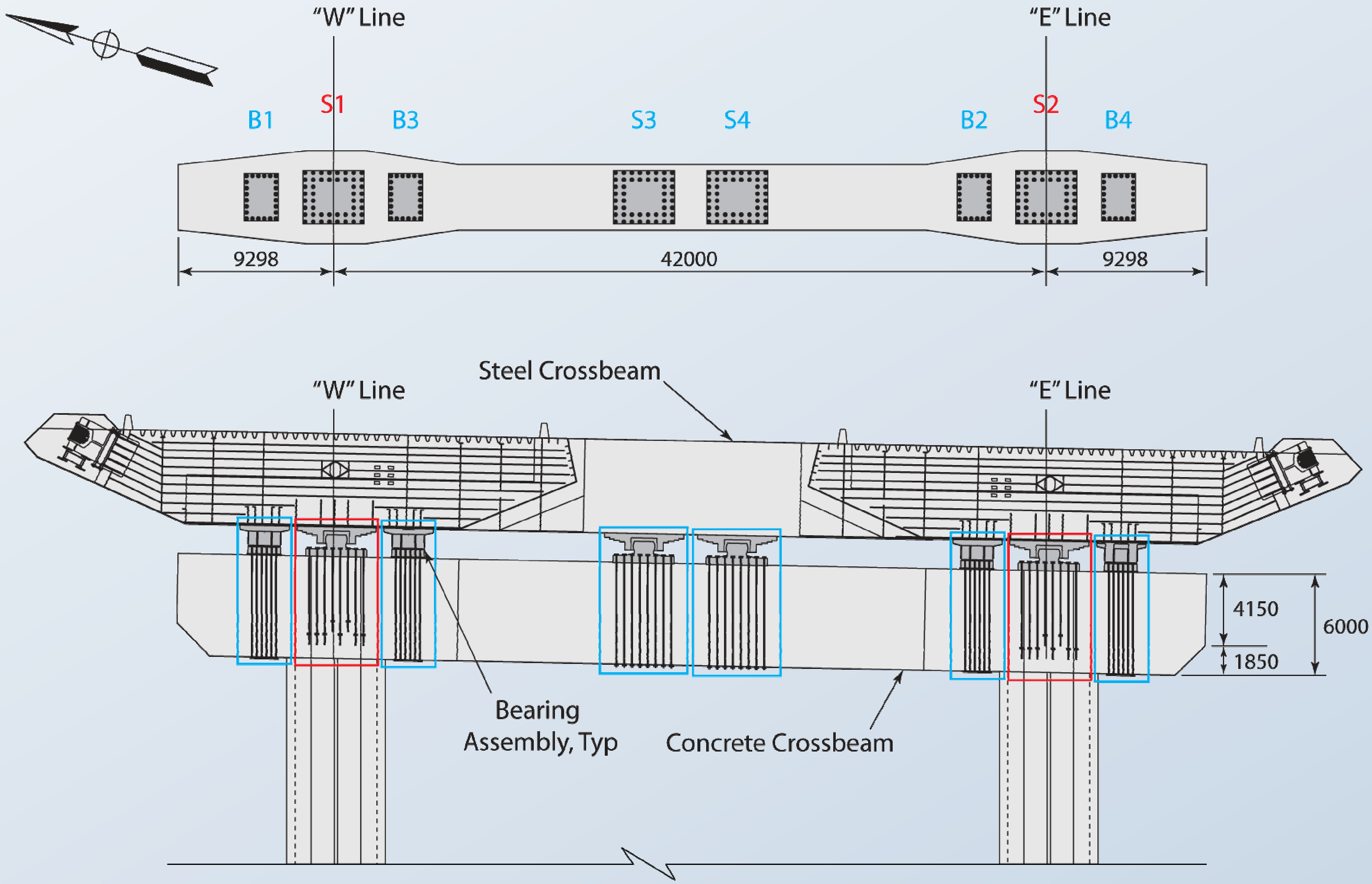
THE SAN FRANCISCO-OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECTS

CALTRANS BAY AREA TOLL AUTHORITY CALIFORNIA TRANSPORTATION COMMISSION

Self Anchored Suspension Bridge

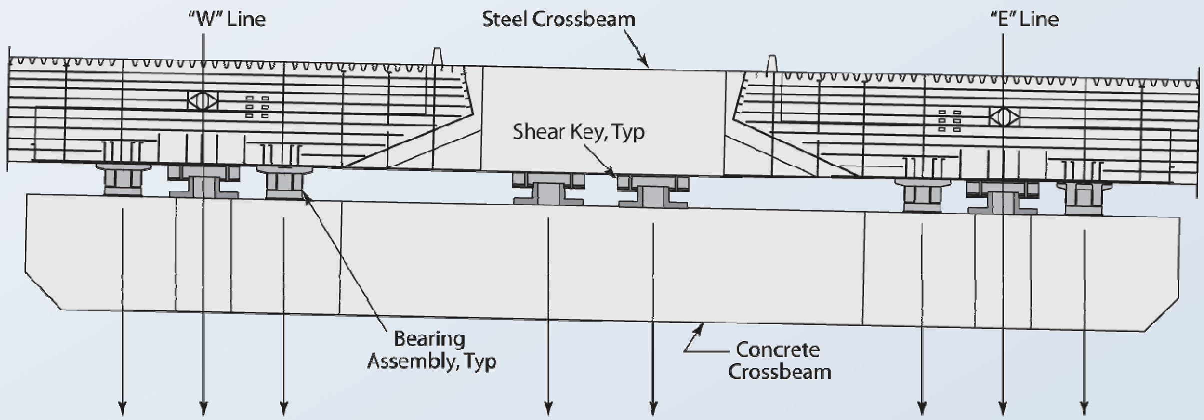


East Bent Elevation



Summary Of Shear Key Design Forces

- **Shear key design forces are determined based on the larger of:**
- **1.4 x Safety Evaluation Earthquake (Envelope from 6SEE Time-History Analysis)**
- **1.15 x Push-Over Analysis using maximum feasible material strengths:**
  - Concrete: f'ce = 1.7 f'c
  - Rebar: fye = 1.3 fy



PRIMARY FUNCTION

	Component →	B1	S1	B3		S3	S4		B2	S3	B4
Force	VERTICAL	X		X					X		X
	LONGITUDINAL*										
	TRANSVERSE*					X	X				

ALL BEARINGS AND SHEAR KETS ARE FUNCTIONAL
*LOAD FACTOR FOR DEMAND = 1.4

BACK-UP (REDUNDANCY) FUNCTION

	Component →	B1	S1	B3		S3	S4		B2	S3	B4
Force	VERTICAL	X		X					X		X
	LONGITUDINAL**	X		X					X		X
	TRANSVERSE**	X		X					X		X

ALL BEARINGS AND SHEAR KETS ARE FUNCTIONAL/ SHEAR KEYS ARE ASSUMED NON-FUNCTIONAL
**LOAD FACTOR FOR DEMAND = 1.0

E2 Bearing and Shear Key

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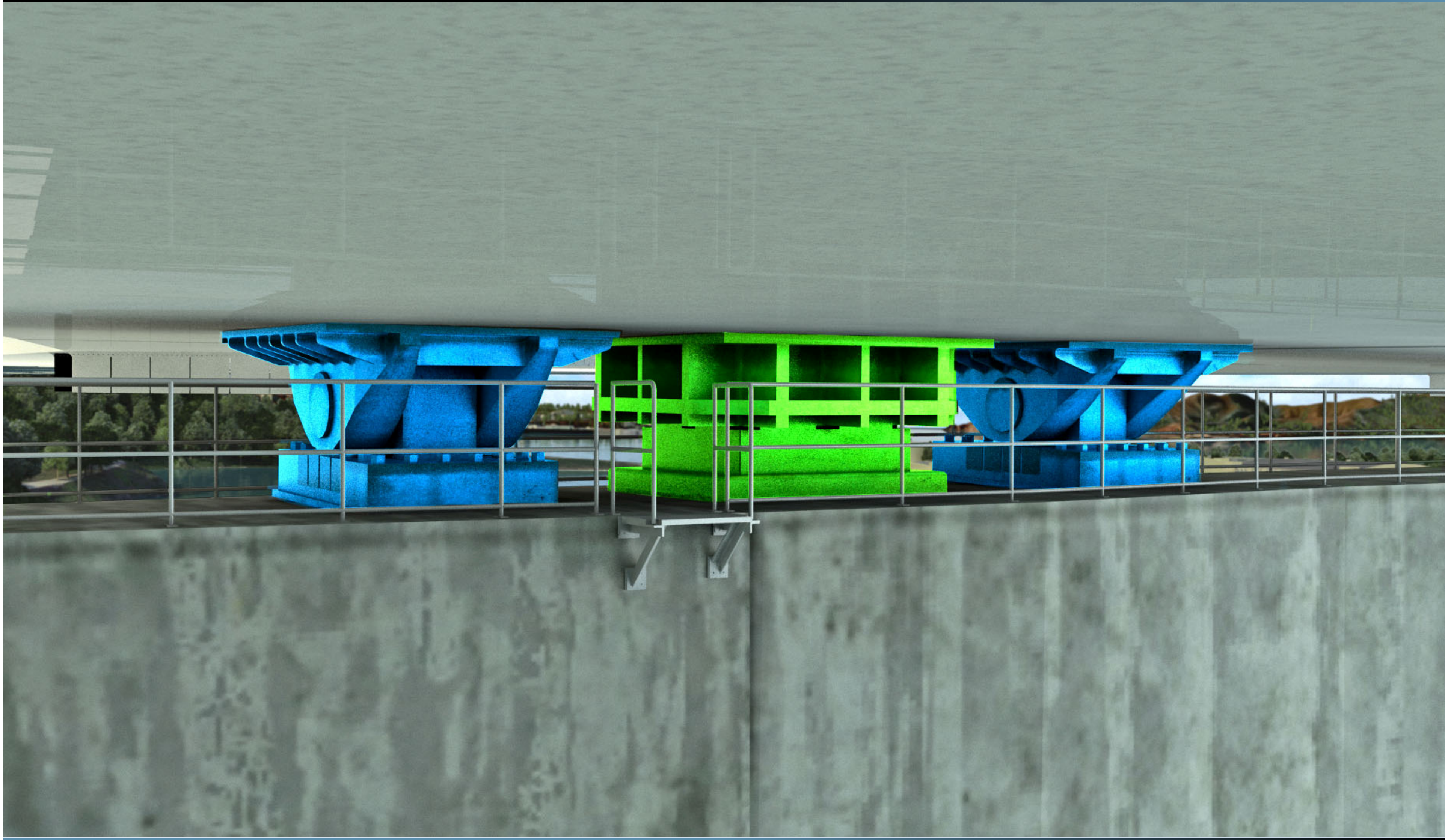
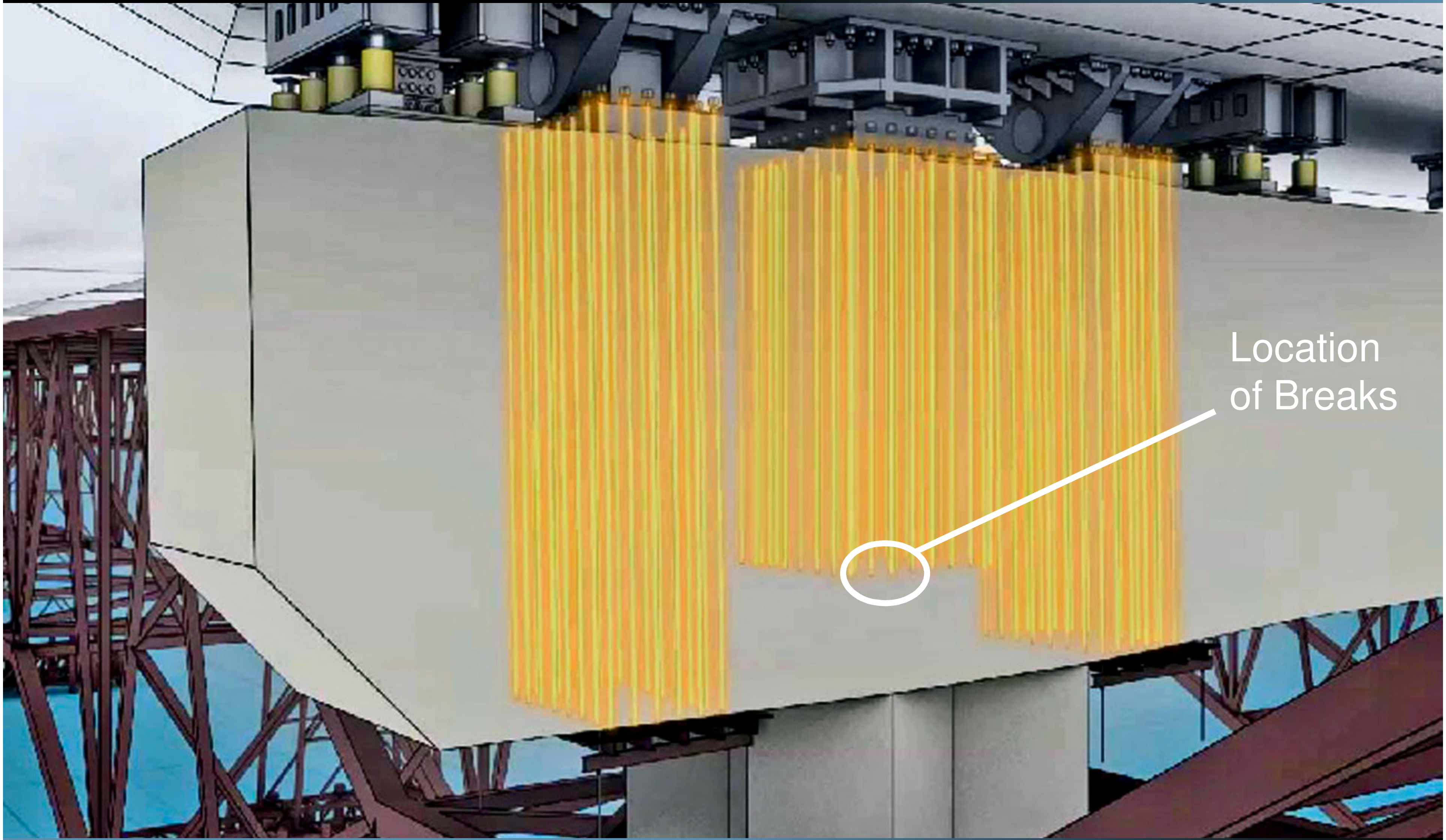


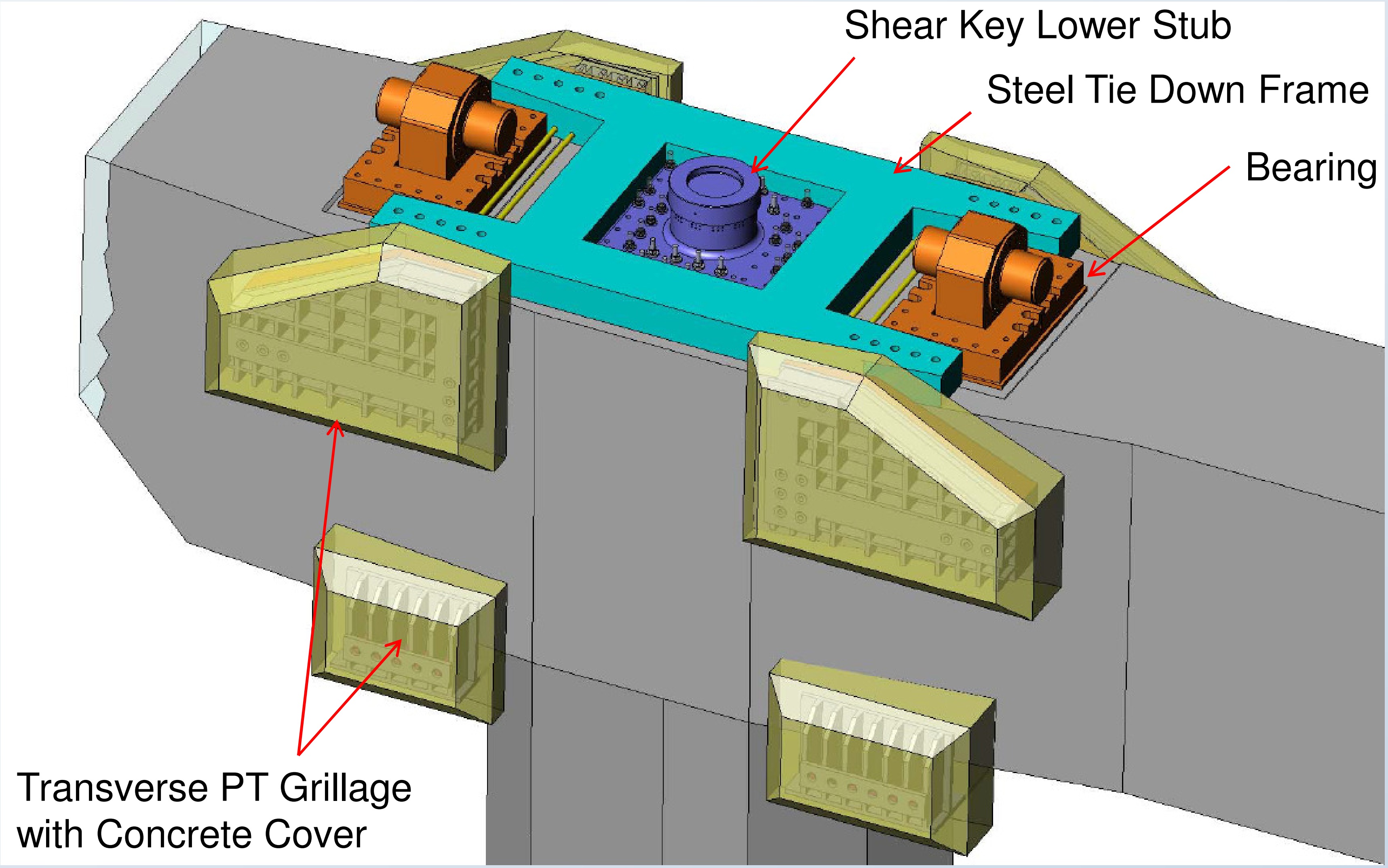
Broken Bolt Location



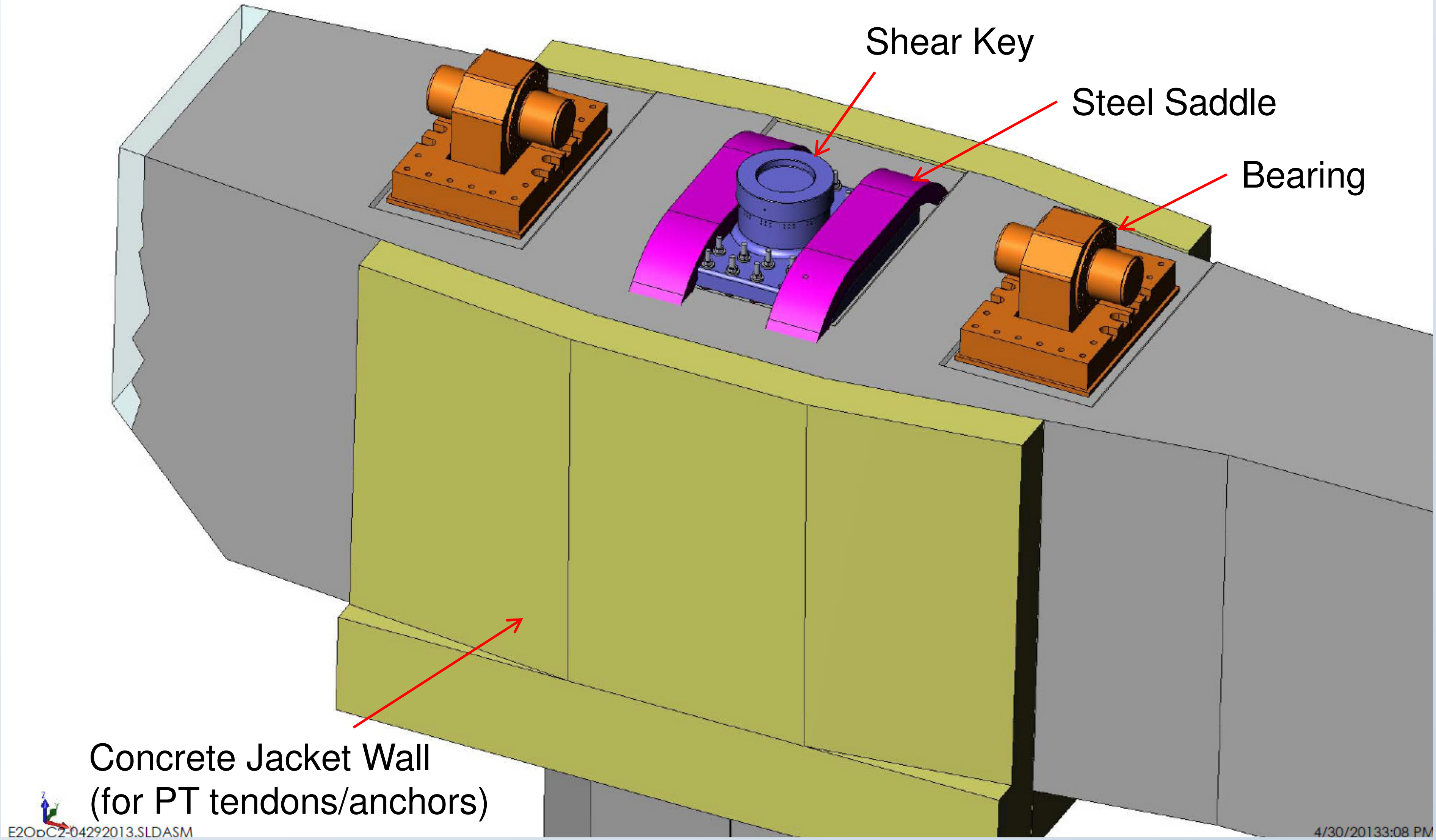
Shear Key S1 & S2: Alternatives Considered

- Alternative A: Replace Rods in Kind
- Alternative B: Dowel Option
- Alternative C1: Concrete Jacket (Single Layer PT)
- Alternative C2: Concrete Jacket (Double Layer PT)
- Alternative BD1: Dowel / Steel Collar Option
- Alternative BD2: Diaphragm Option

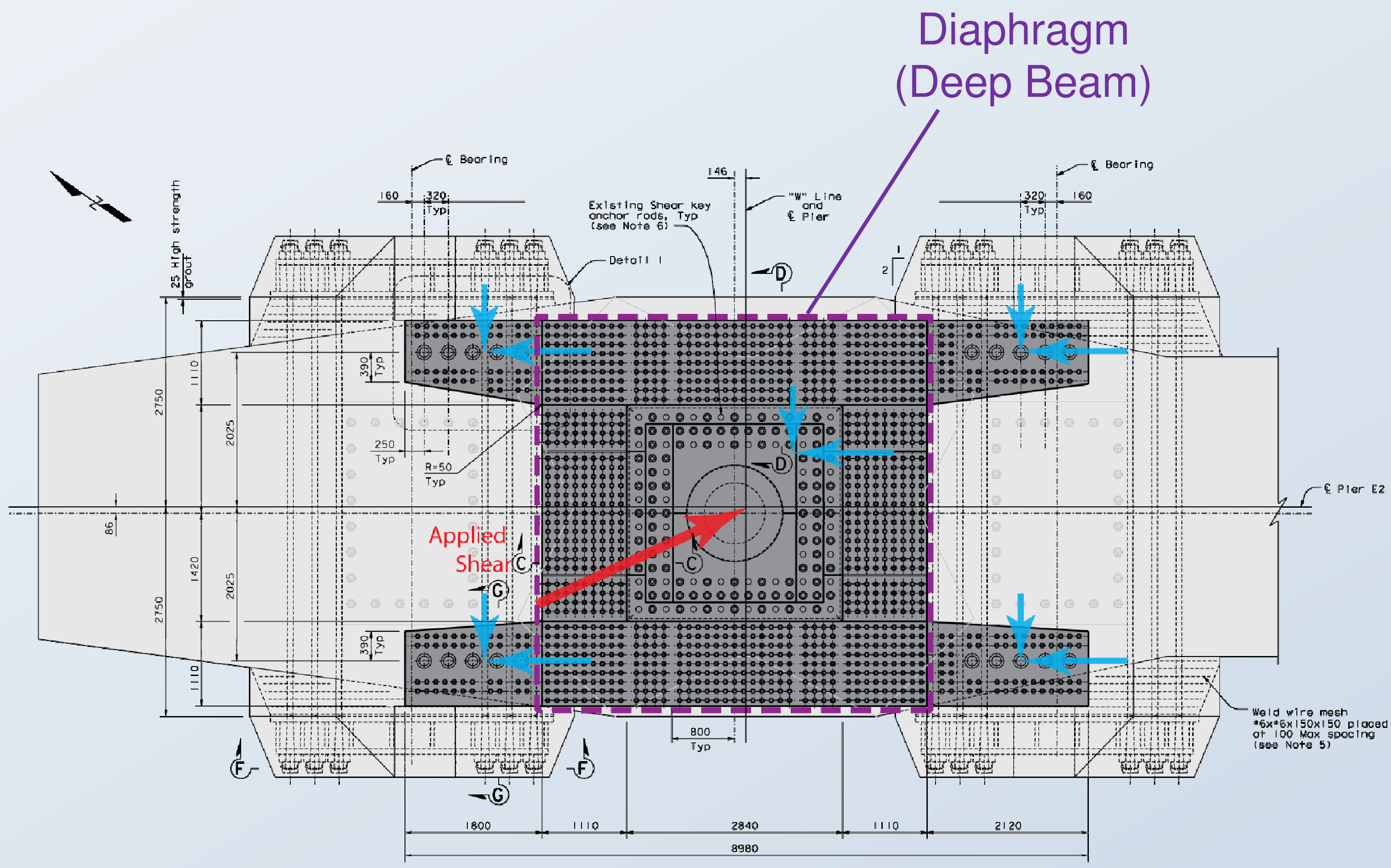
Alternative BD2 Overview



Alternative C2 Overview



Alternative BD2



TOP PLAN OF CAP BEAM

Applied Shear:

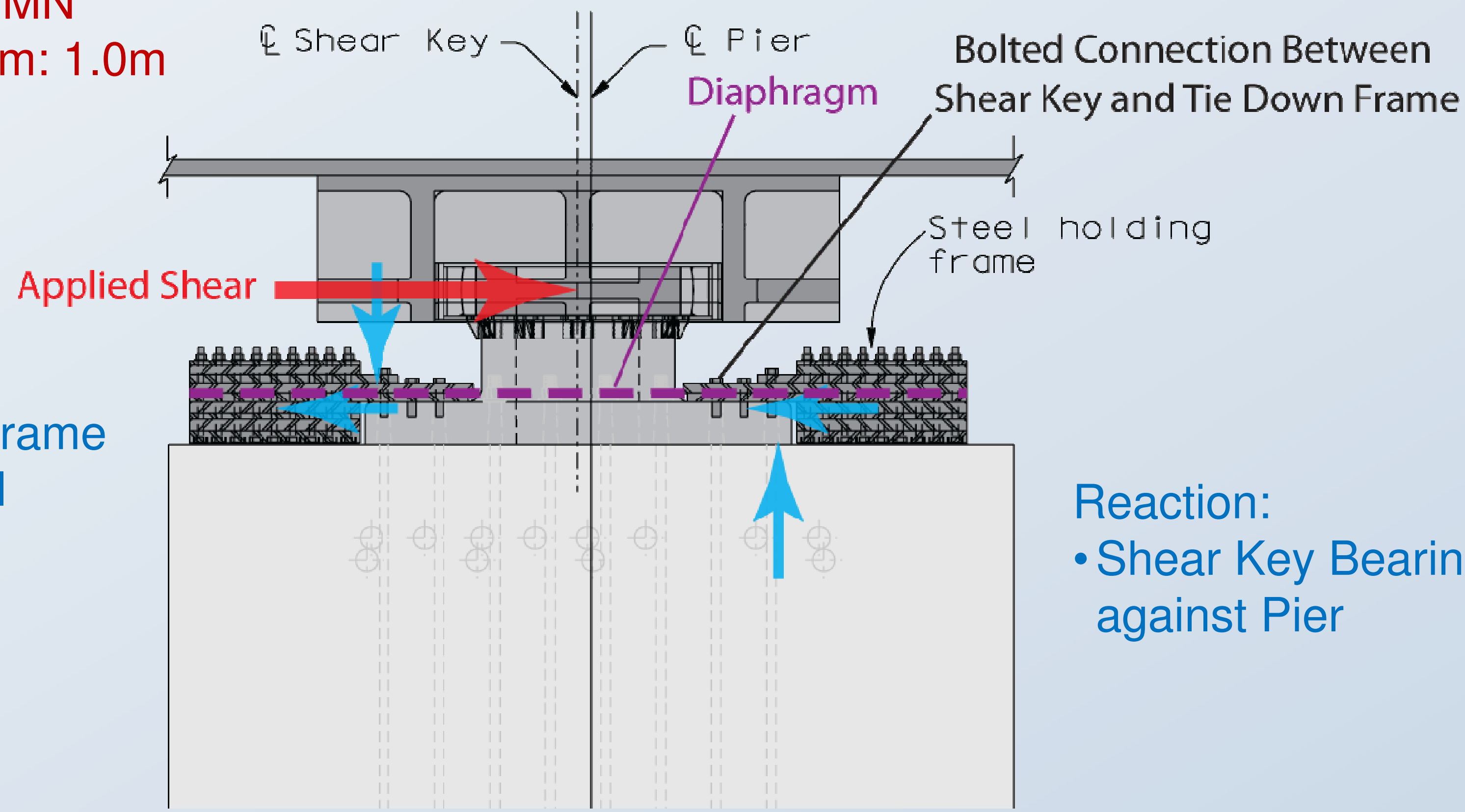
- Trans: 42.5MN
- Longi: 19.0MN

Reaction:

- Friction due to Vertical PT
- Friction at the bottom of Shearkey (not counted in design)

Alternative BD2

Applied Shear:
- Trans: 42.5MN
- Longi: 19.0MN
- Moment Arm: 1.0m

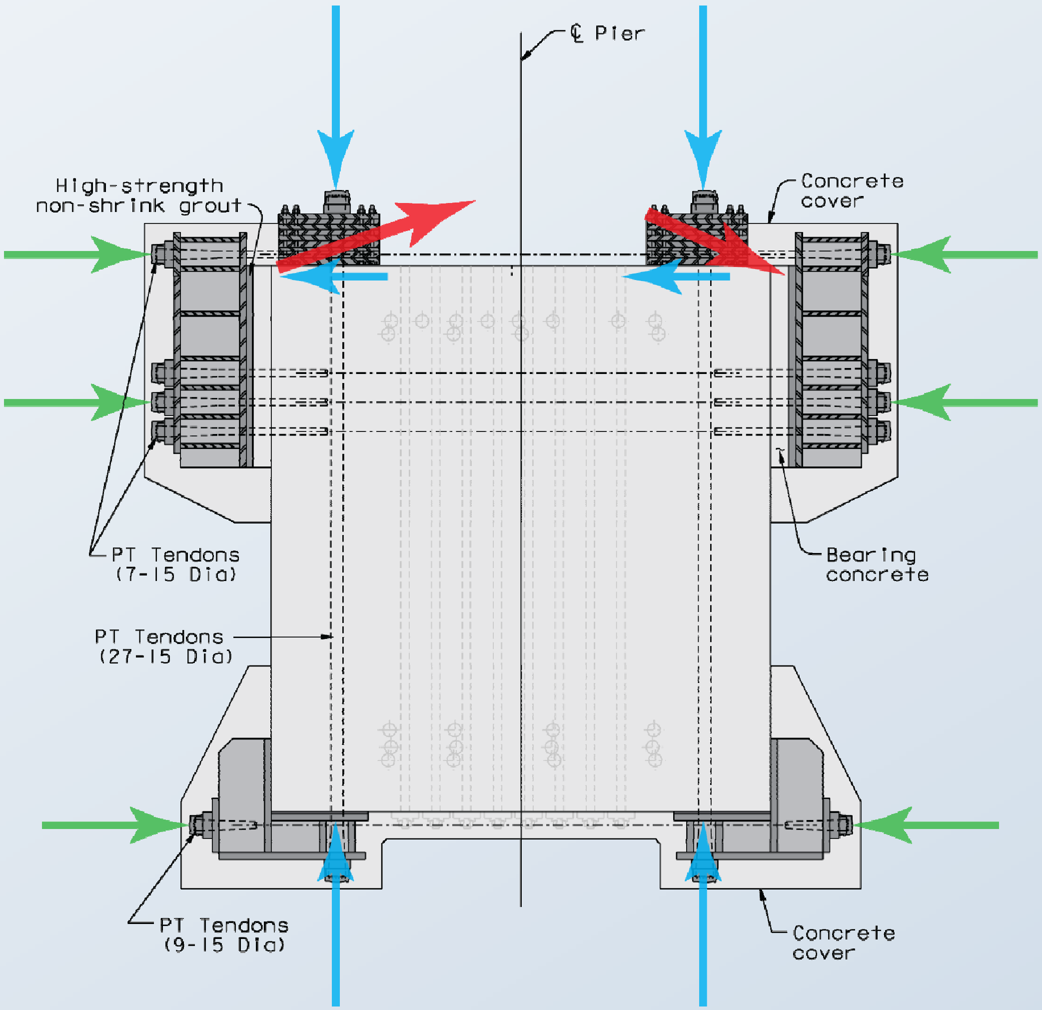


Reaction:
- Tie Down Frame Vertical and Horizontal Restraint

Reaction:
- Shear Key Bearing against Pier

CROSS SECTION AT SHEAR KEY

Alternative BD2

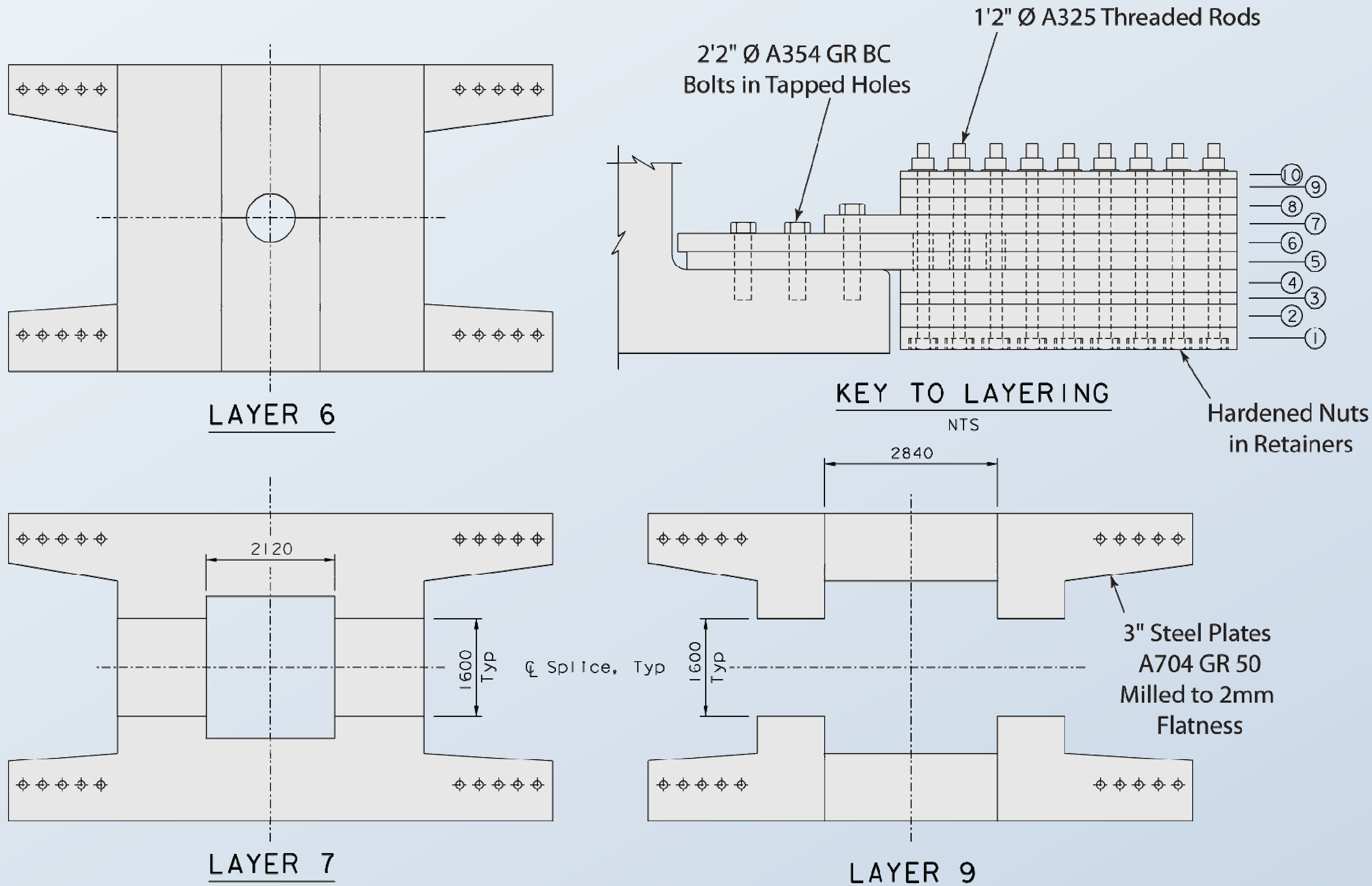


CROSS SECTION BETWEEN SHEAR KEY AND BEARING

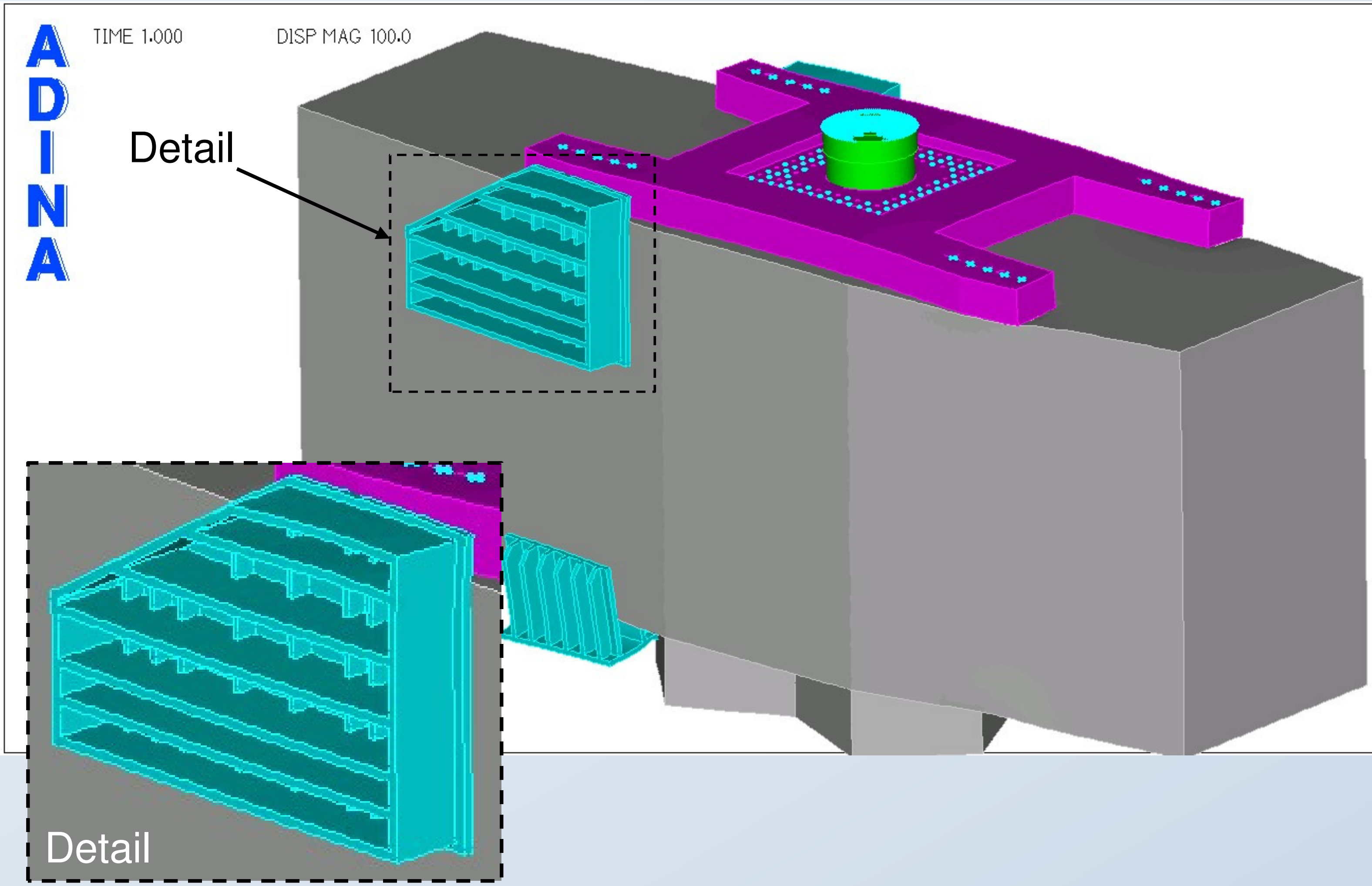
At Each Anchorage Zone:

- **Vertical PT:**
  - –5 Tendons
  - –27-0.6 in Strand
  - –Stressed to: 0.7 fpu
  - –PT Force: 5.0 MN
- **Top Transverse PT:**
  - –3 Tendons per group
  - –3 groups
  - –7-0.6 in Strand
  - –Stressed to: 0.7 fpu
  - –PT Force:1.3 MN/group
- **Bottom Transverse PT:**
  - –5 Tendons
  - –9-0.6in Strand
  - –Stressed to: 0.7 fpu
  - –PT Force: 1.6MN

Alternative BD2



Alternative BD2: Analysis Model



Maximum Displacements

- **Top Grillage:**
  - x: 1 mm
  - y: 0 mm
  - z: 0 mm
- **Bottom Grillage:**
  - x: 1 mm
  - y: 2 mm
  - z: 0 mm

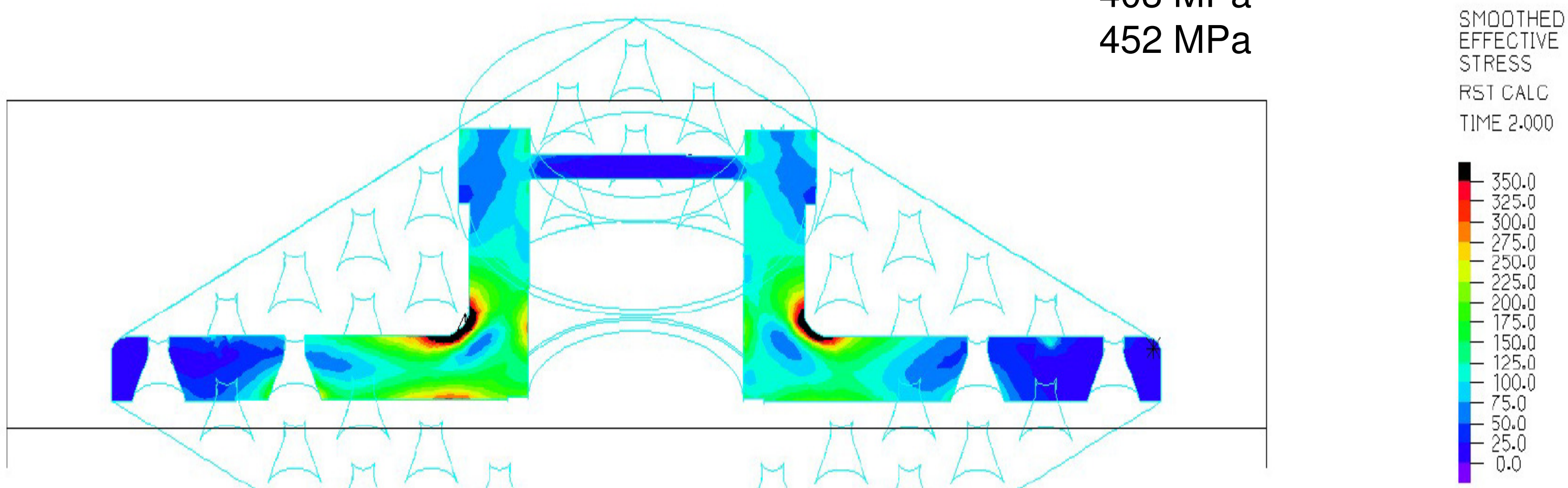
Alternative BD2:
Shear Key Von Mises Stress

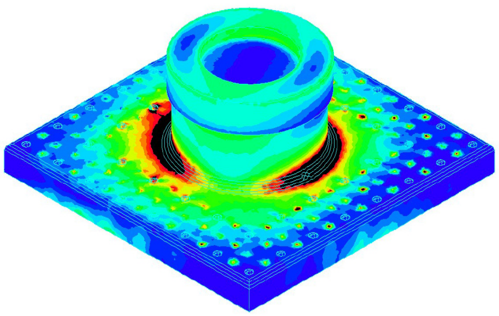
ADINA

TIME 2.000

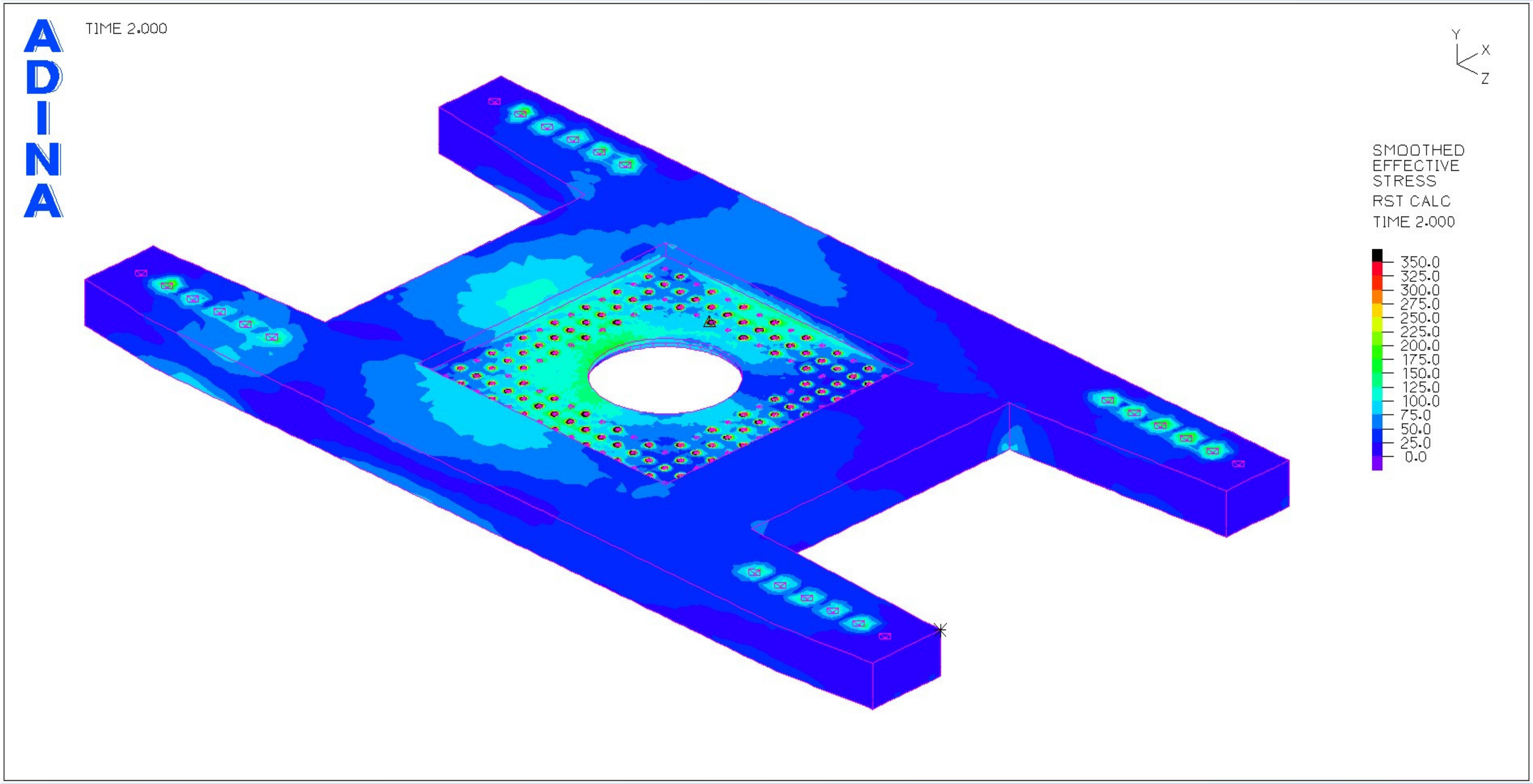
Black Denotes
Stress > 345 MPa

Coupon Test Yield Stress Values
380 MPa
391 MPa
403 MPa
452 MPa

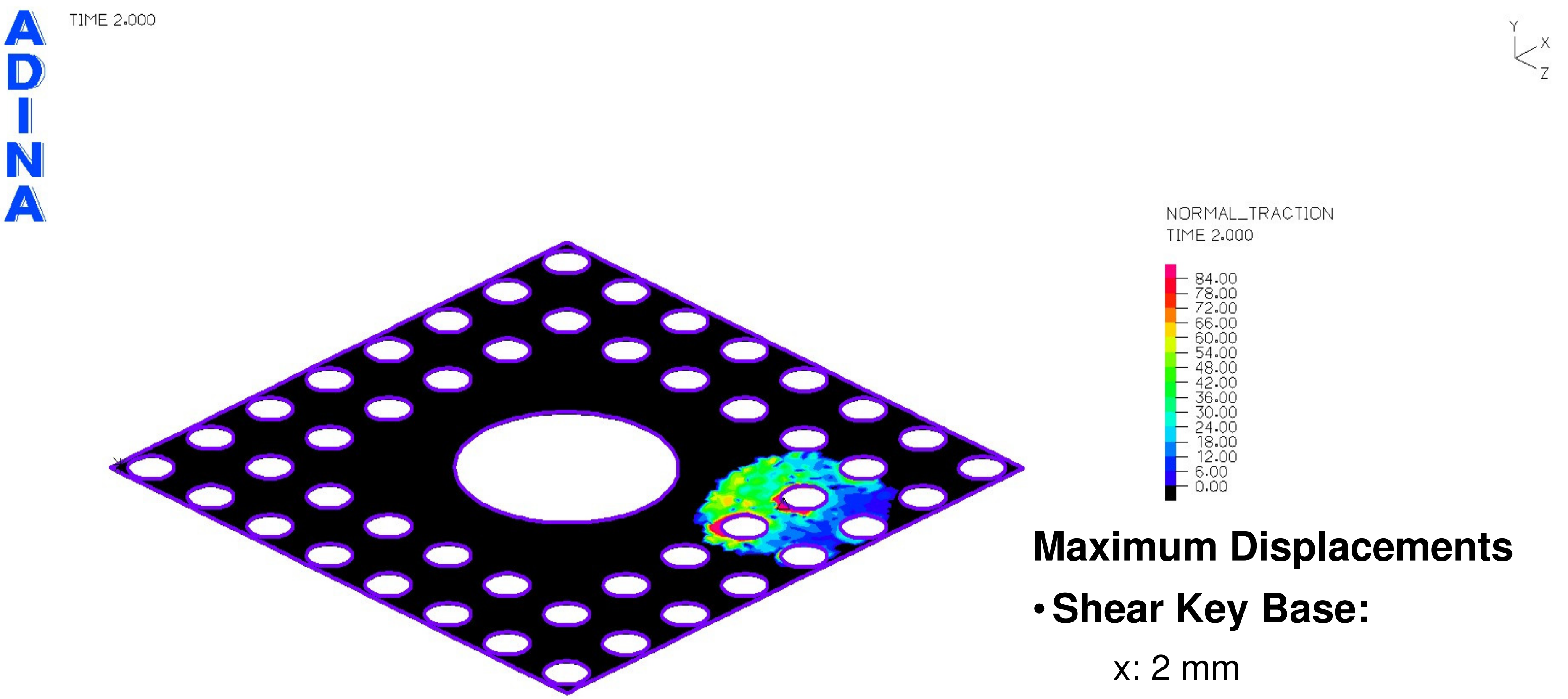




Alternative BD2:
Tie Down Frame Von Mises Stress



Alternative BD2:
Contact Btw Shear Key and Pier Cap



Contact Between Shear Key and Pier Cap
Black = No Contact

Maximum Displacements

- **Shear Key Base:**

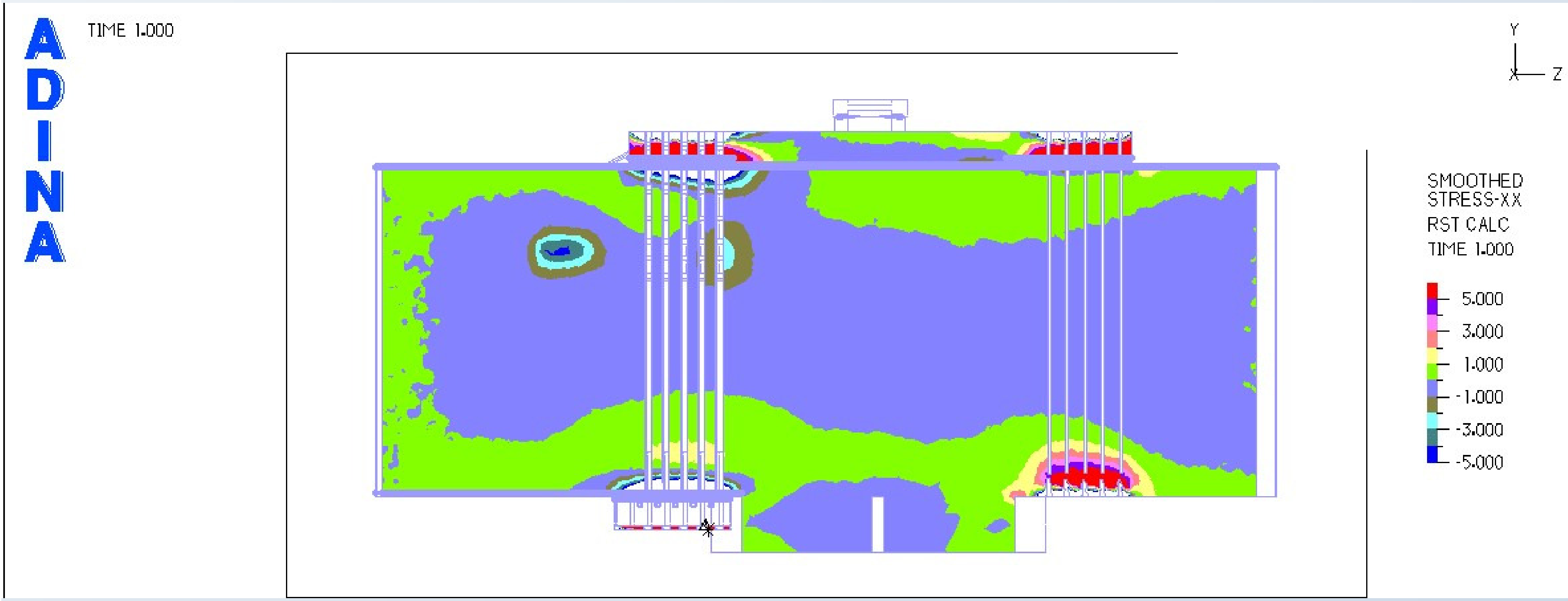
  x: 2 mm

  y: 6 mm

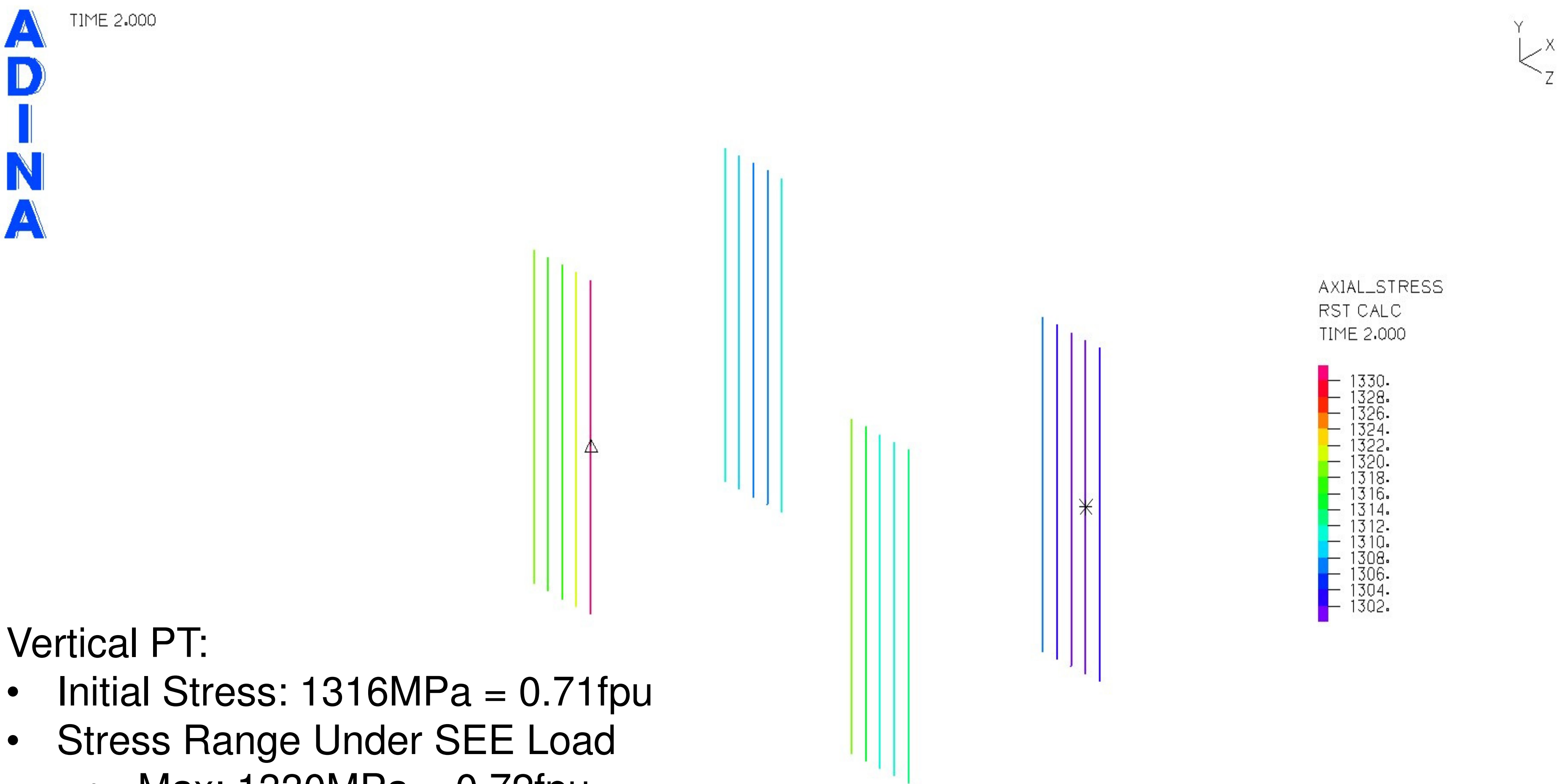
  z: 2 mm

Alternative BD2: : Anchorage Zone Concrete

Vertical Section Cut at CL of Vertical Tendon



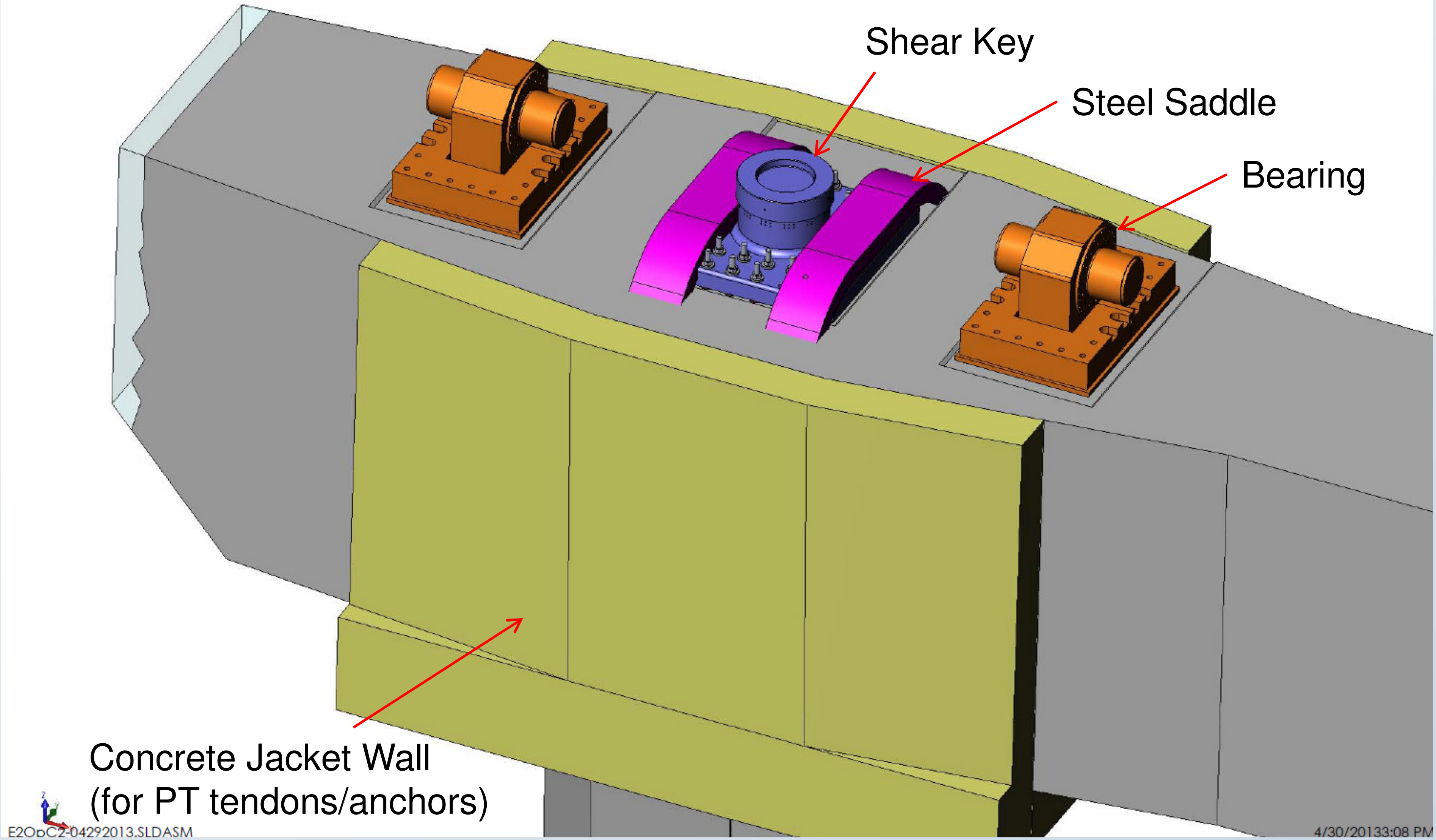
Alternative BD2: Vertical Tendon Stress



Vertical PT:

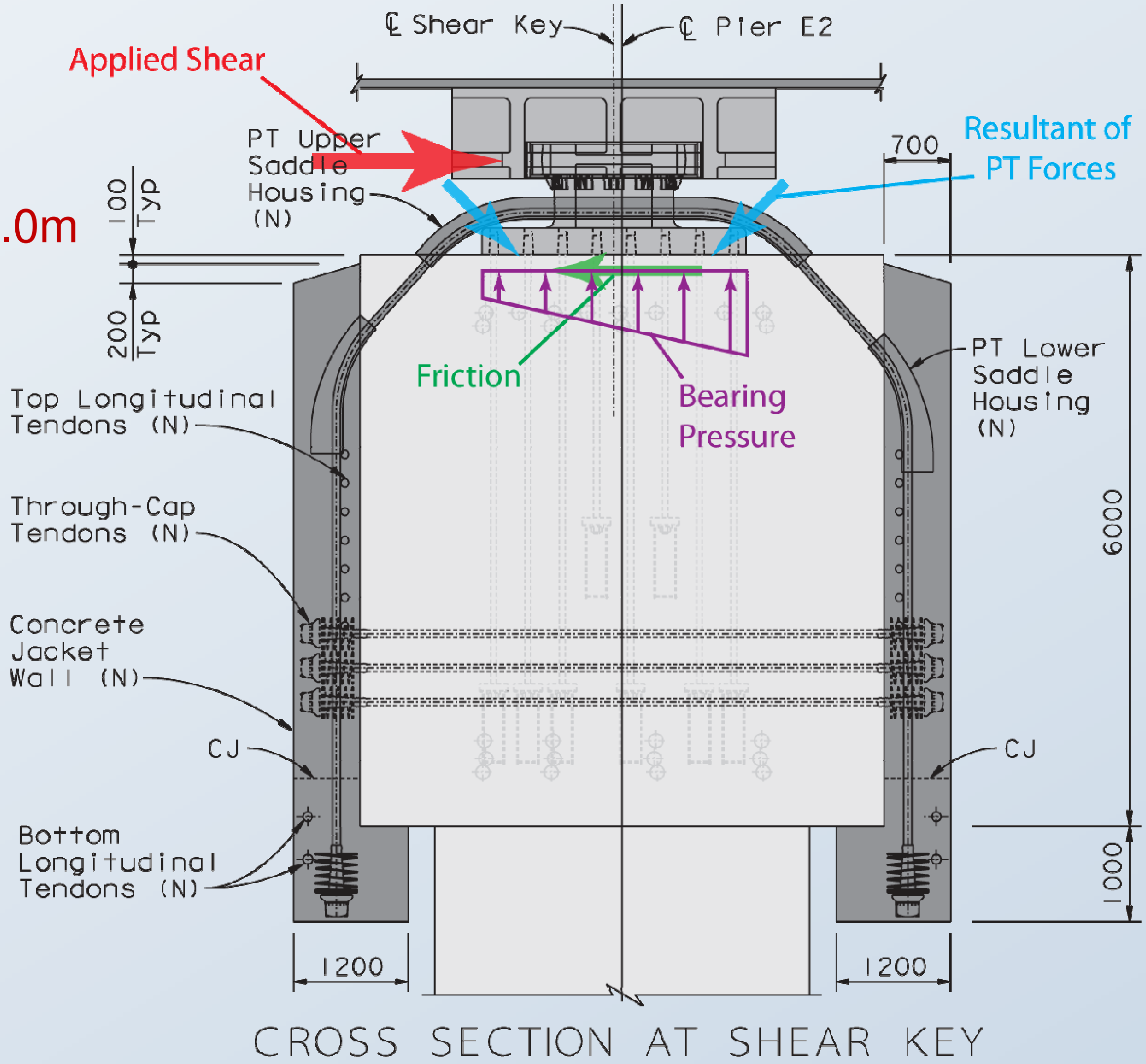
- Initial Stress: 1316MPa = 0.71fpu
- Stress Range Under SEE Load
  - Max: 1330MPa = 0.72fpu
  - Min: 1300MPa=0.70fpu

Alternative C2 Overview

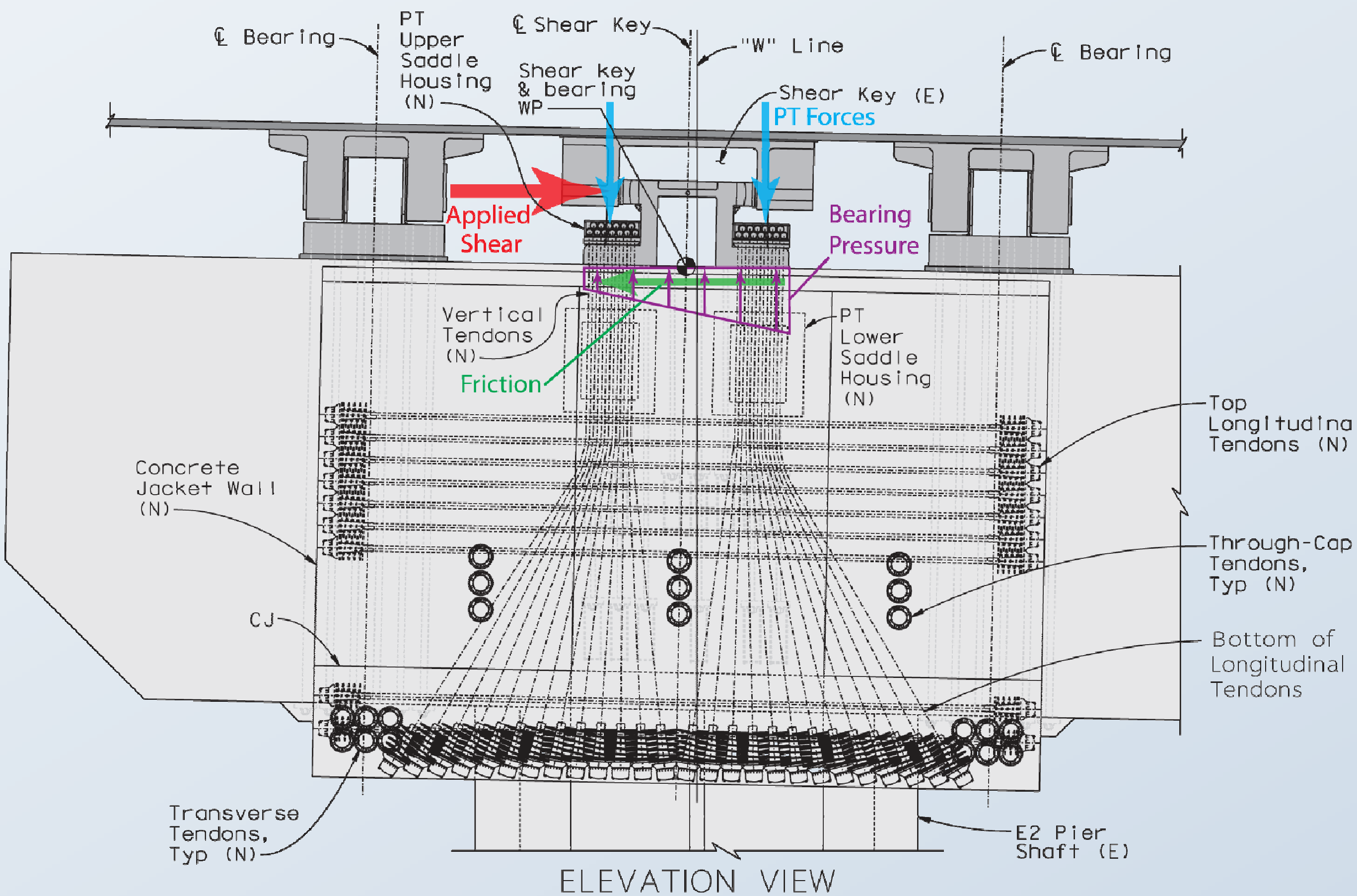


Alternative C2

Applied Shear:
- Trans: 42.5MN
- Longi: 19.0MN
- Moment Arm: 1.0m

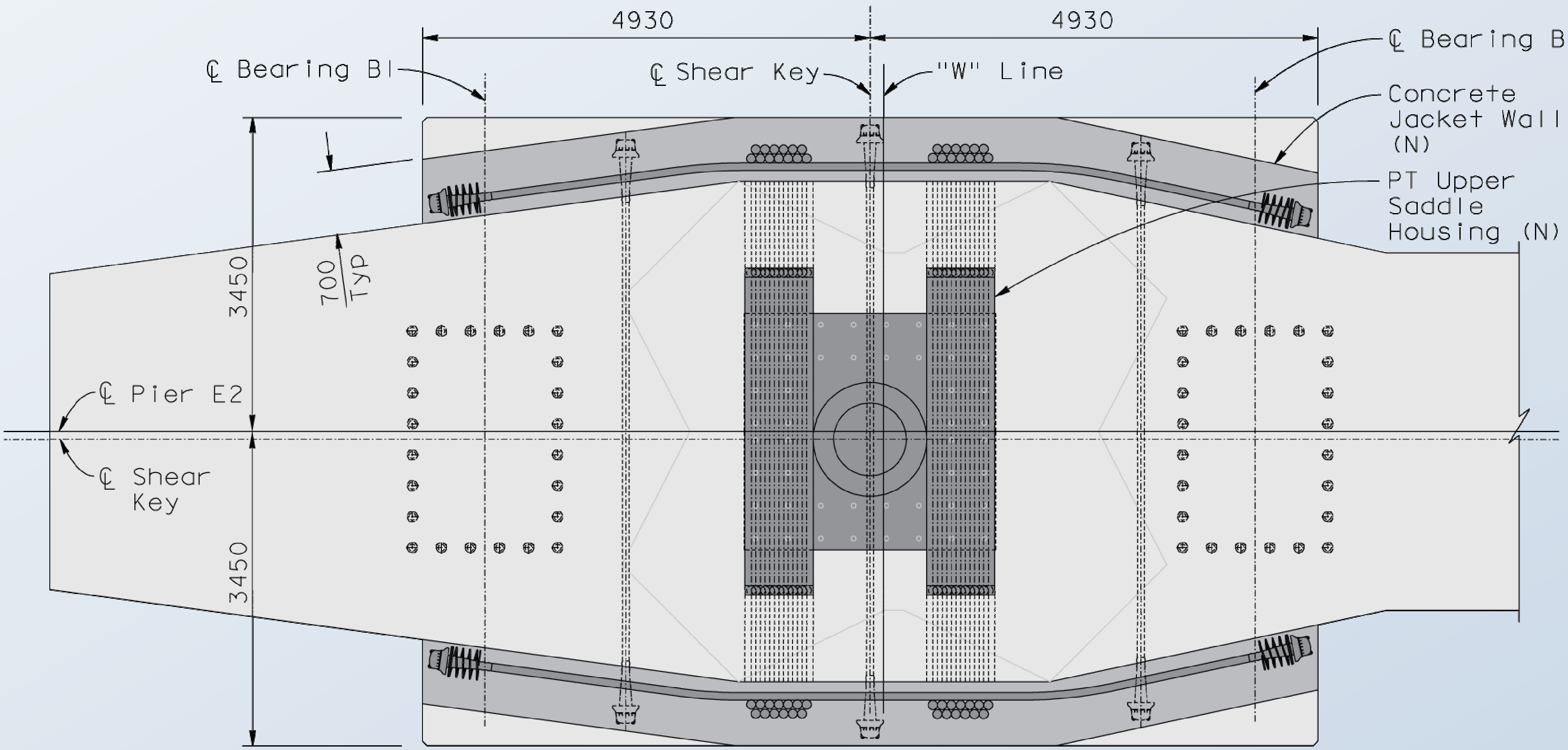


Alternative C2



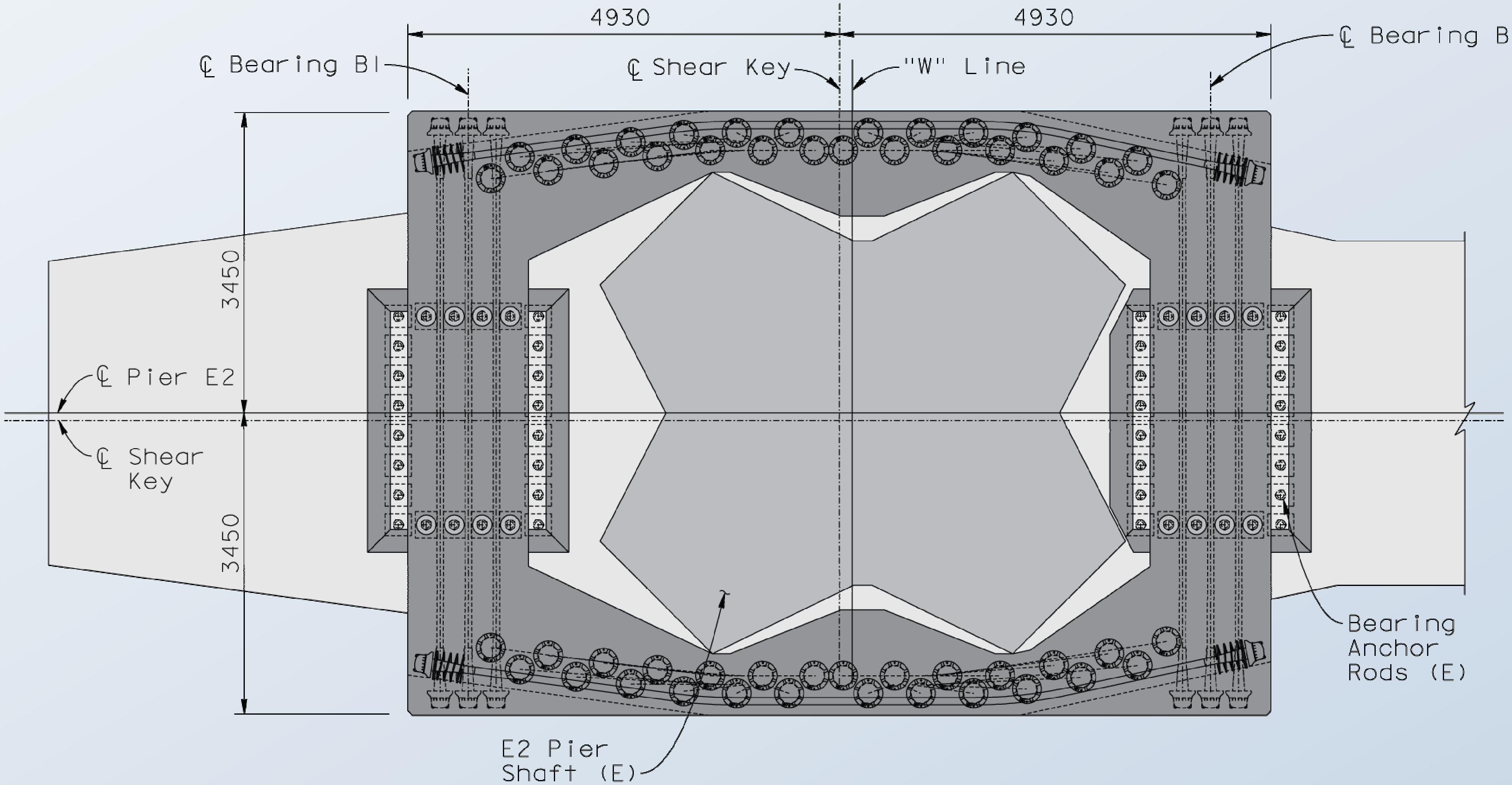
- Vertical PT:
  13x19-0.6 Dia Tendons
  (each side of shear key base)
- Top Longitudinal Tendons:
  7x9-0.6 Dia Tendons
  (each side of cap beam)
- Bottom Longitudinal Tendons:
  4x9-0.6 Dia Tendons
  (each side of cap beam)
- Transverse Tendons:
  6x12-0.6 Dia Tendons
  (each side of pier)
- Through-cap Tendons:
  9x12-0.6 Dia Tendons
  (as shown)

Alternative C2



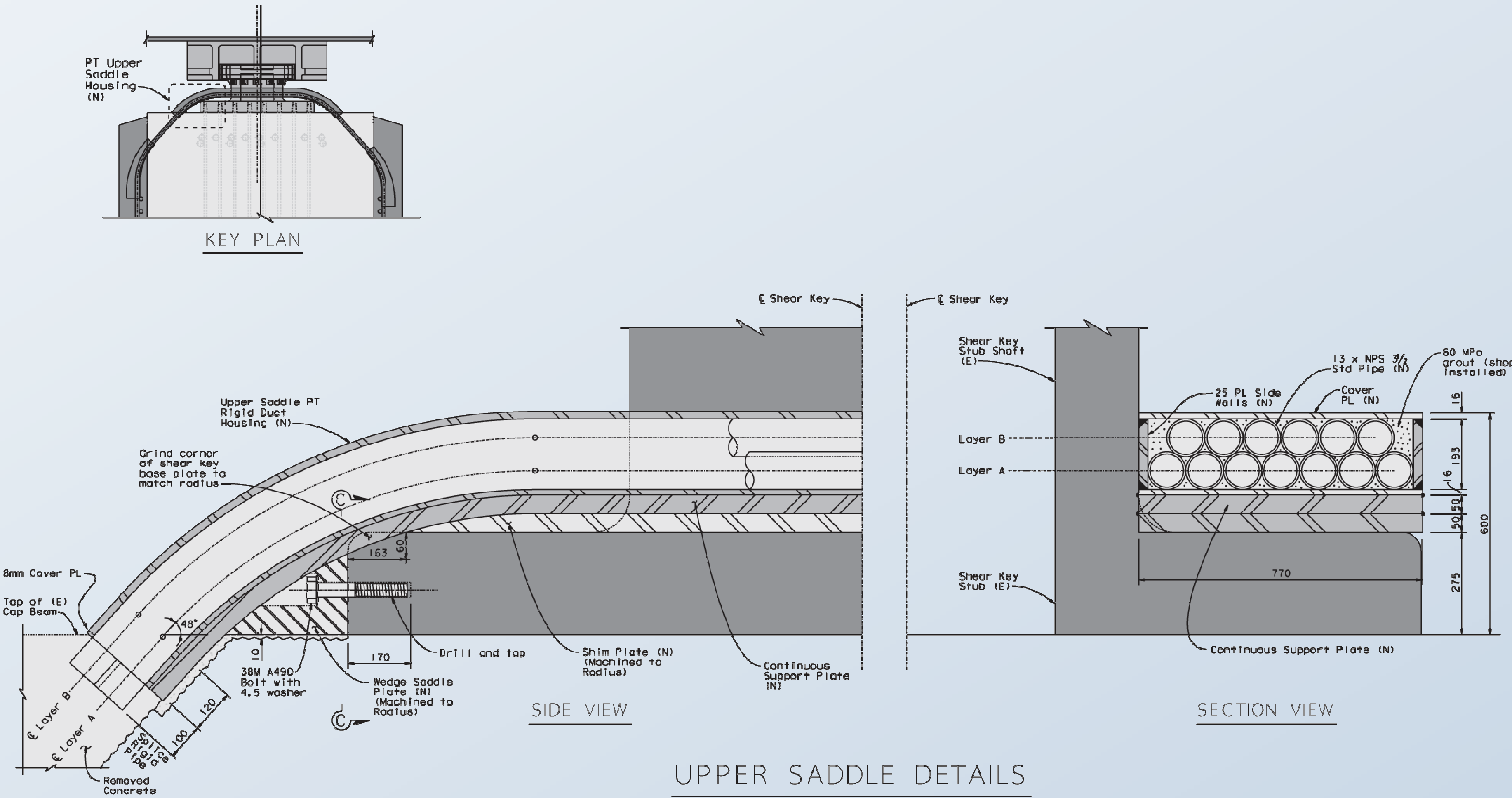
TOP PLAN OF CAP BEAM

Alternative C2

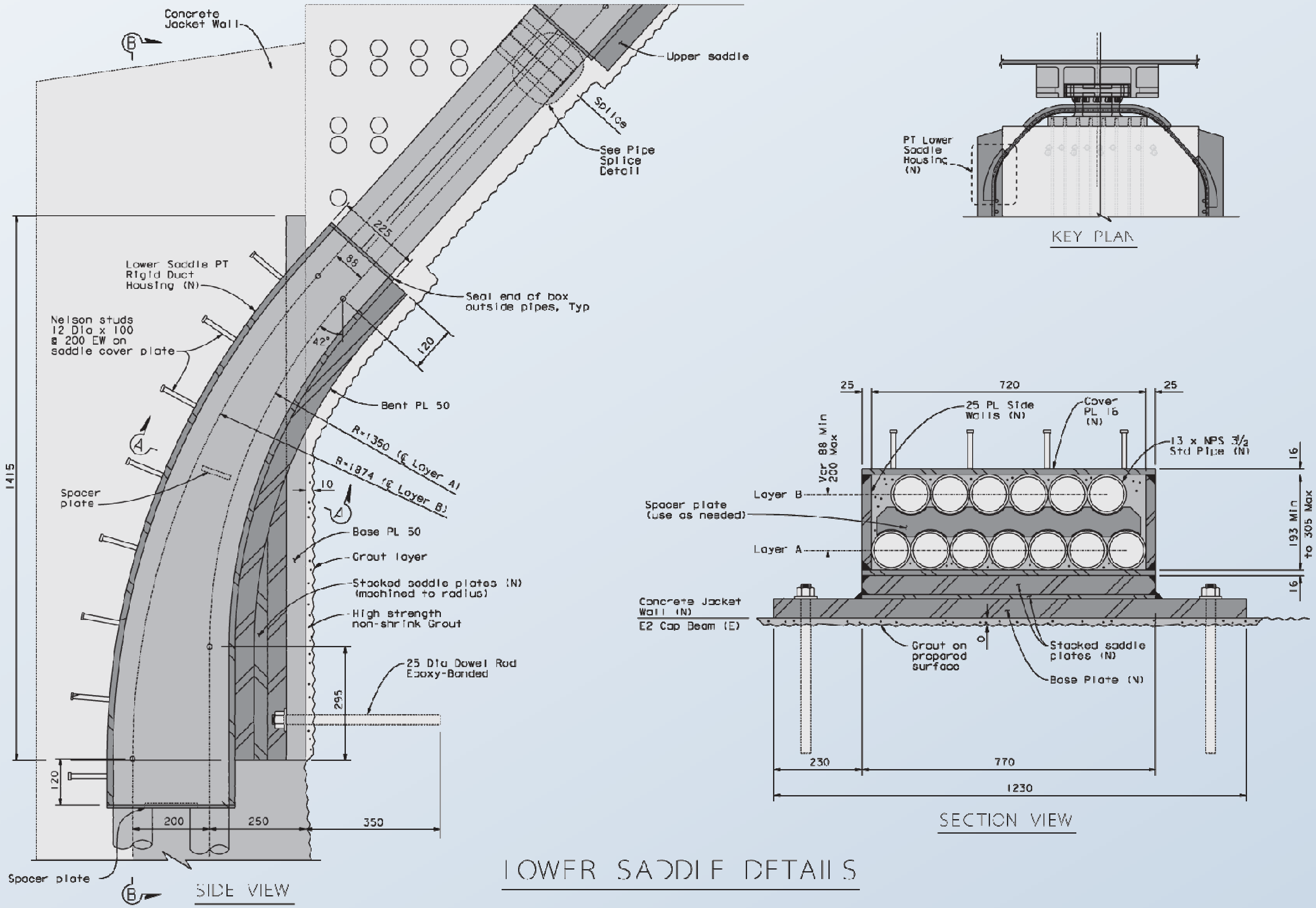


BOTTOM PLAN OF CAP BEAM

Alternative C2



Alternative C2



Alternative C2: Analysis Model

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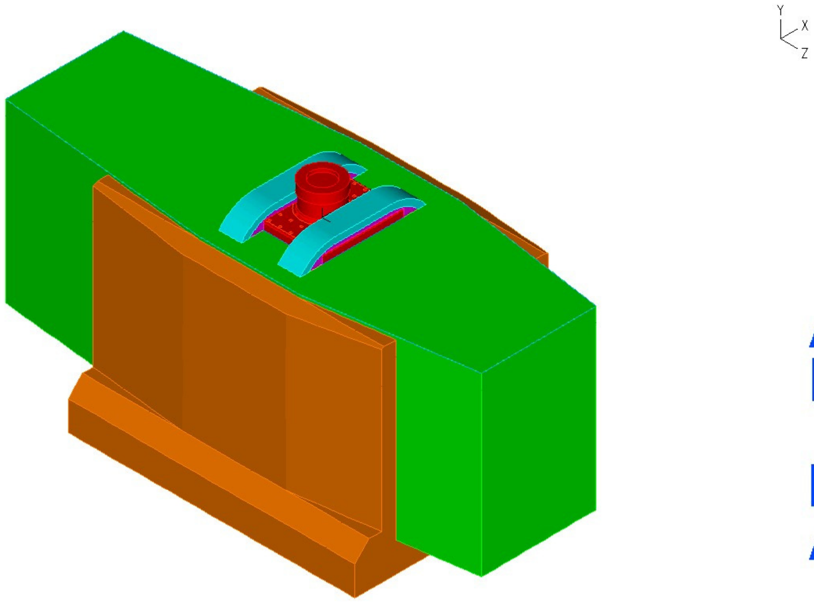
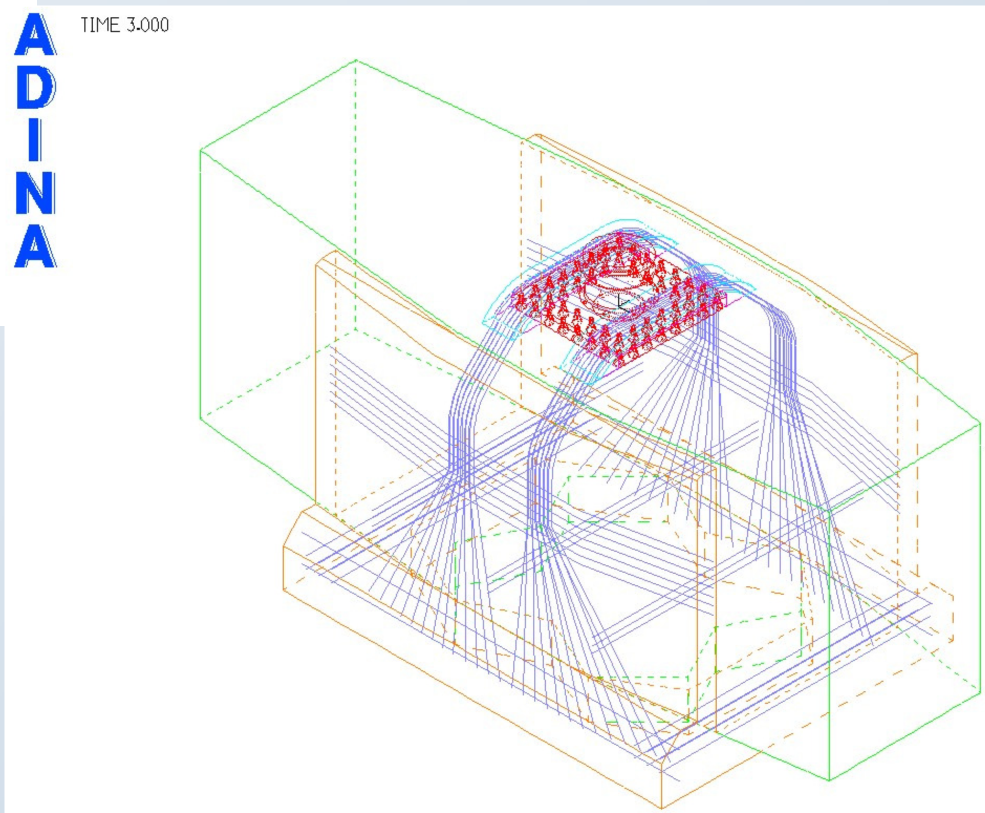
CALTRANS BAY AREA TOLL AUTHORITY CALIFORNIA TRANSPORTATION COMMISSION



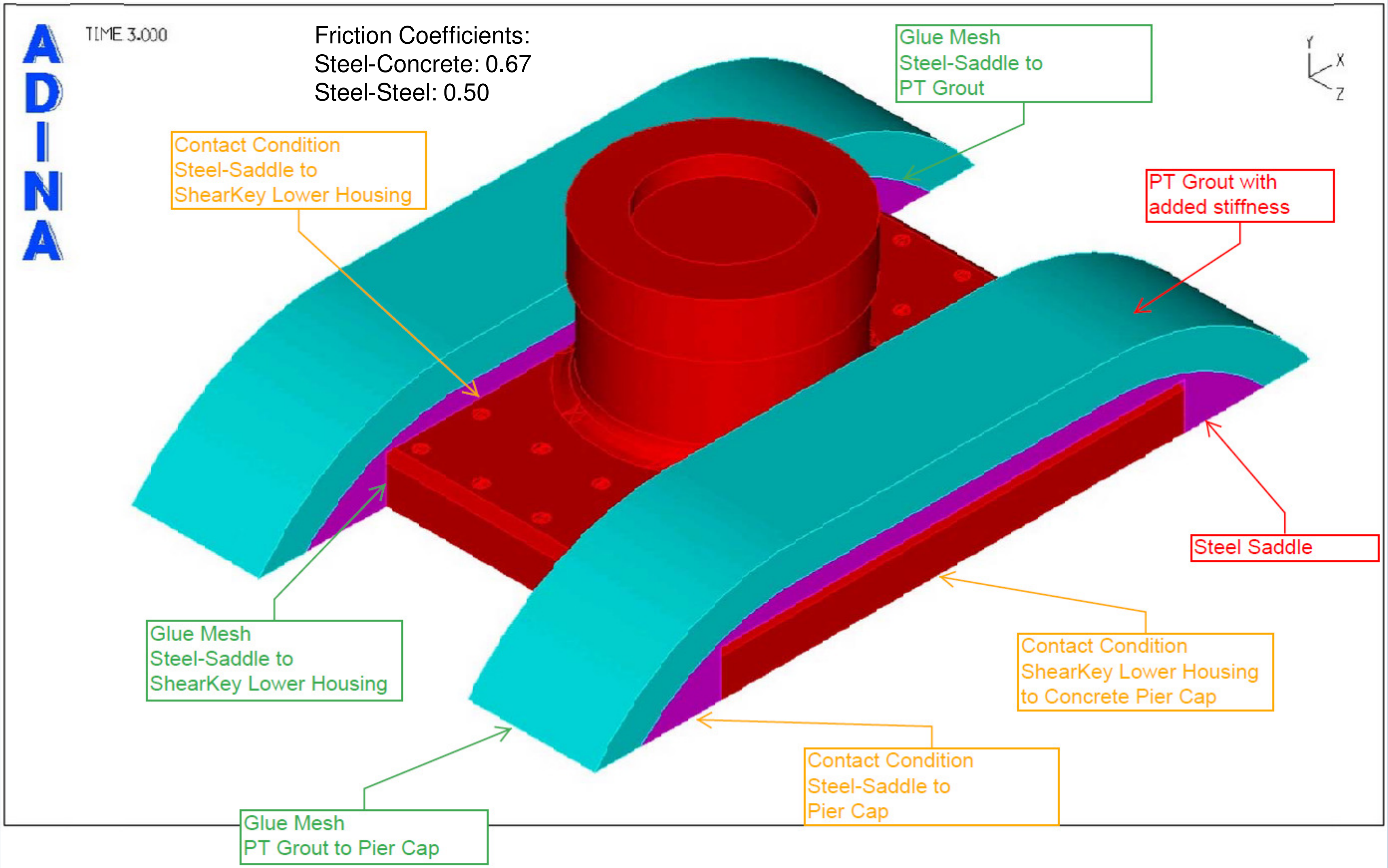
3D solid elements
Linear Materials
-E_{steel} = 200,000 Mpa
-$E_{concrete}$ = 37,400 Mpa
-E_{grout} = 67,700 Mpa (composite w/saddle)



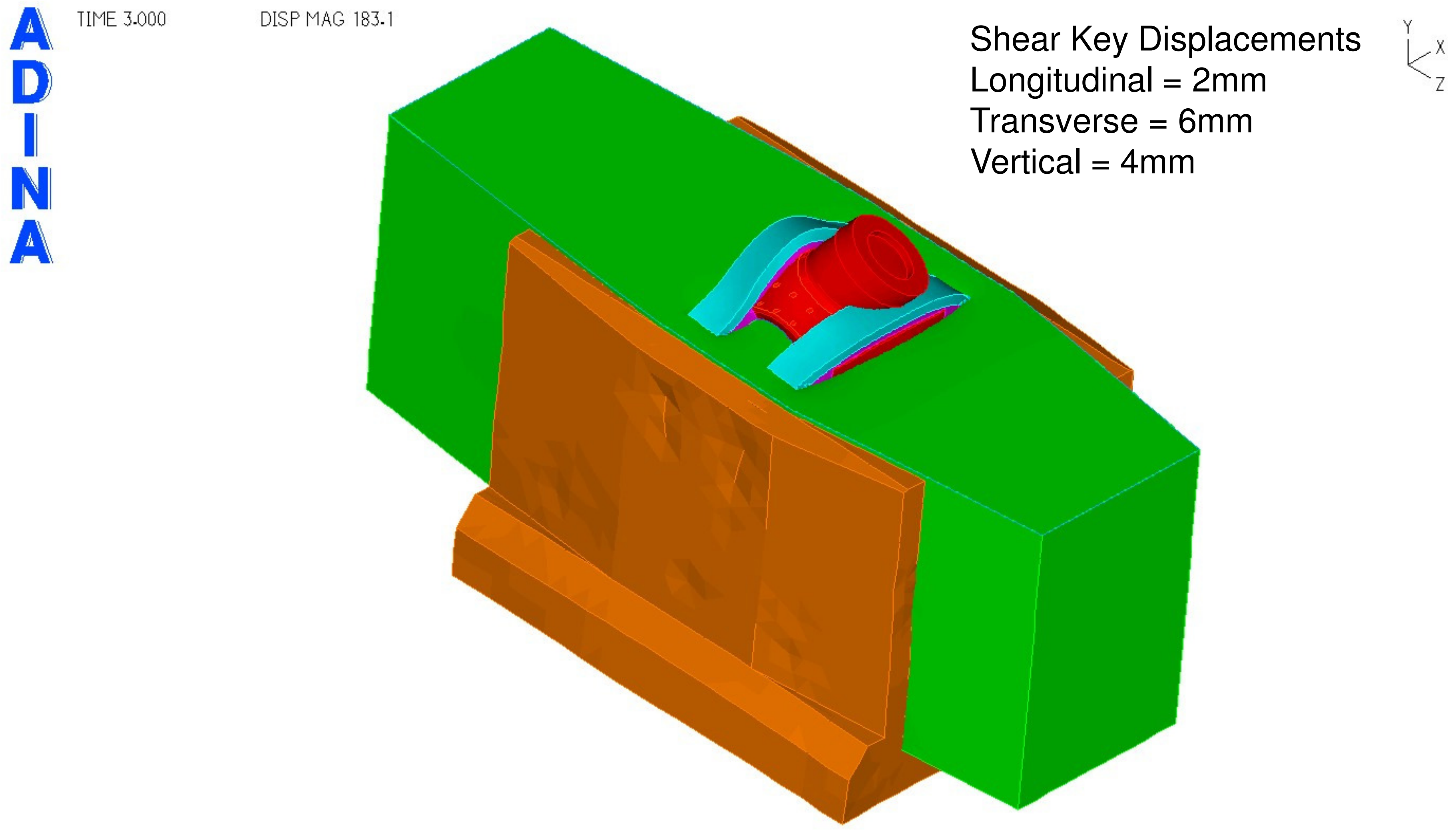
Controlling Seismic Load
= 1.4 x Concurrent SEE Loads
= 42.5 MN Transv. + 19 MN Long.

PT considered to be grouted.
Constraints of PT to solid elements hidden for clarity

Alternative C2:
Shear Key Contact Conditions

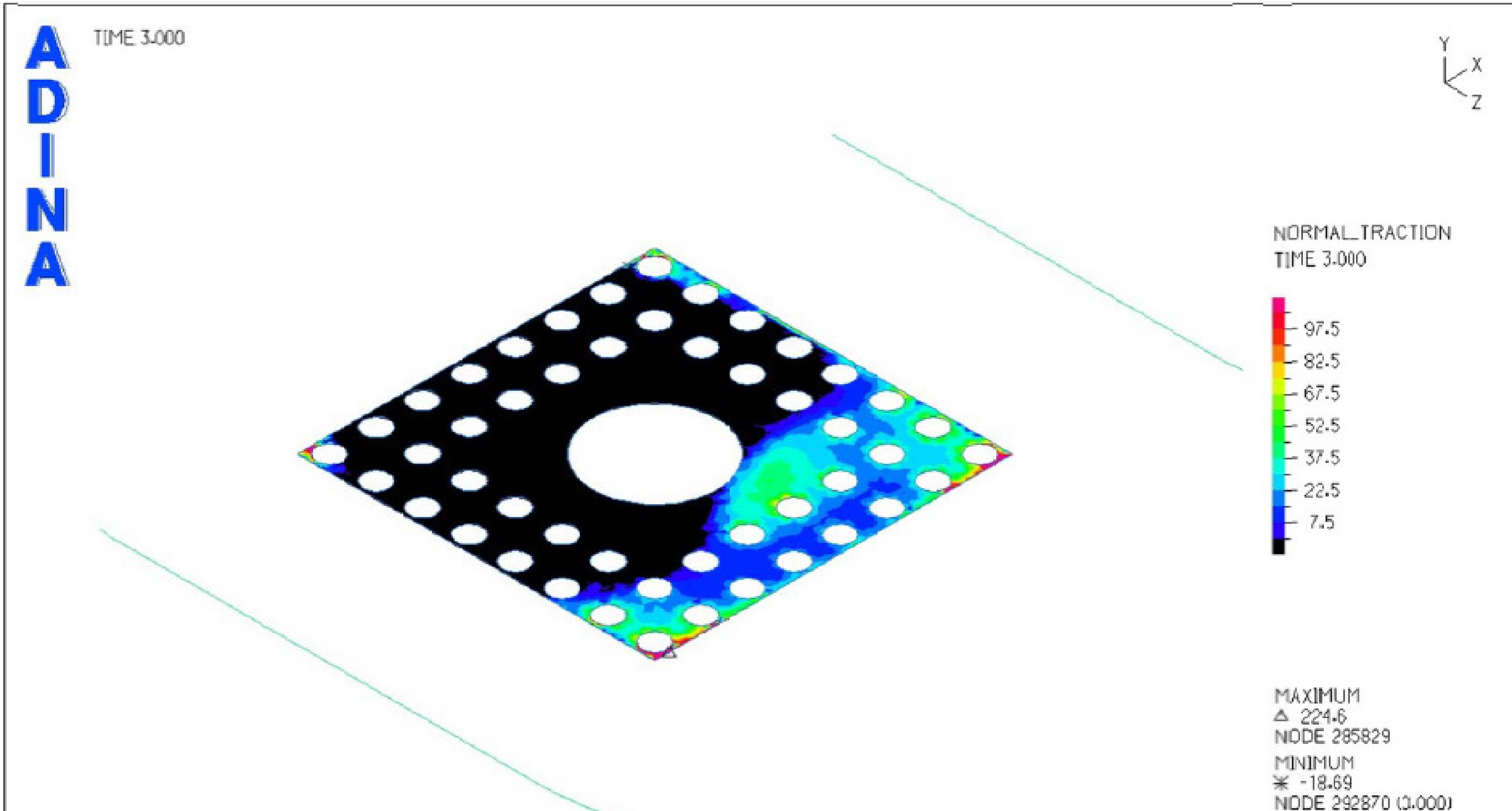


Alternative C2: Deformed Shape



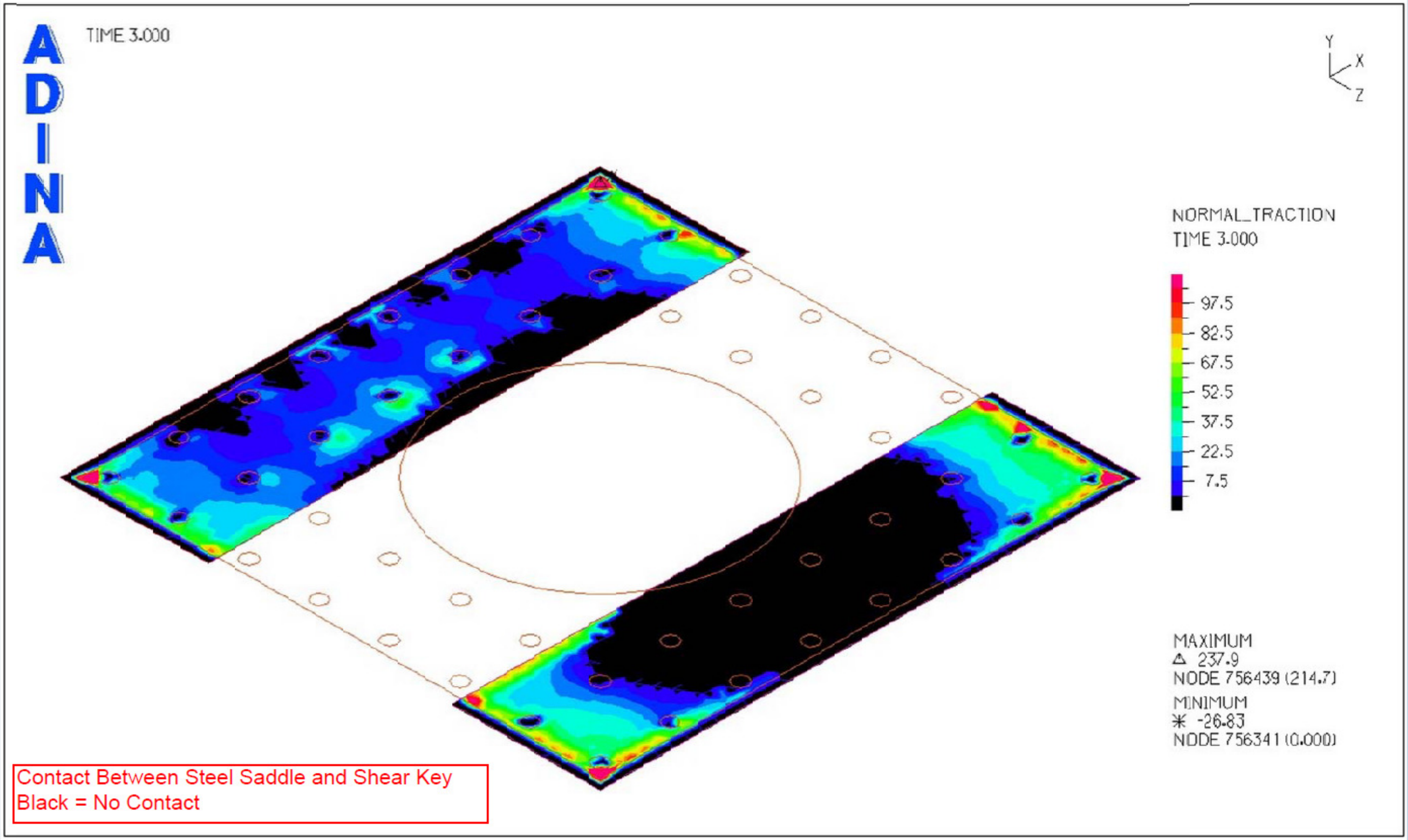
Shear Key Displacements
Longitudinal = 2mm
Transverse = 6mm
Vertical = 4mm

Alternative C2: Contact of Shear Key/Pier Cap



Contact Between Shear Key and Pier Cap
Black = No Contact
Maximum Separation 3mm

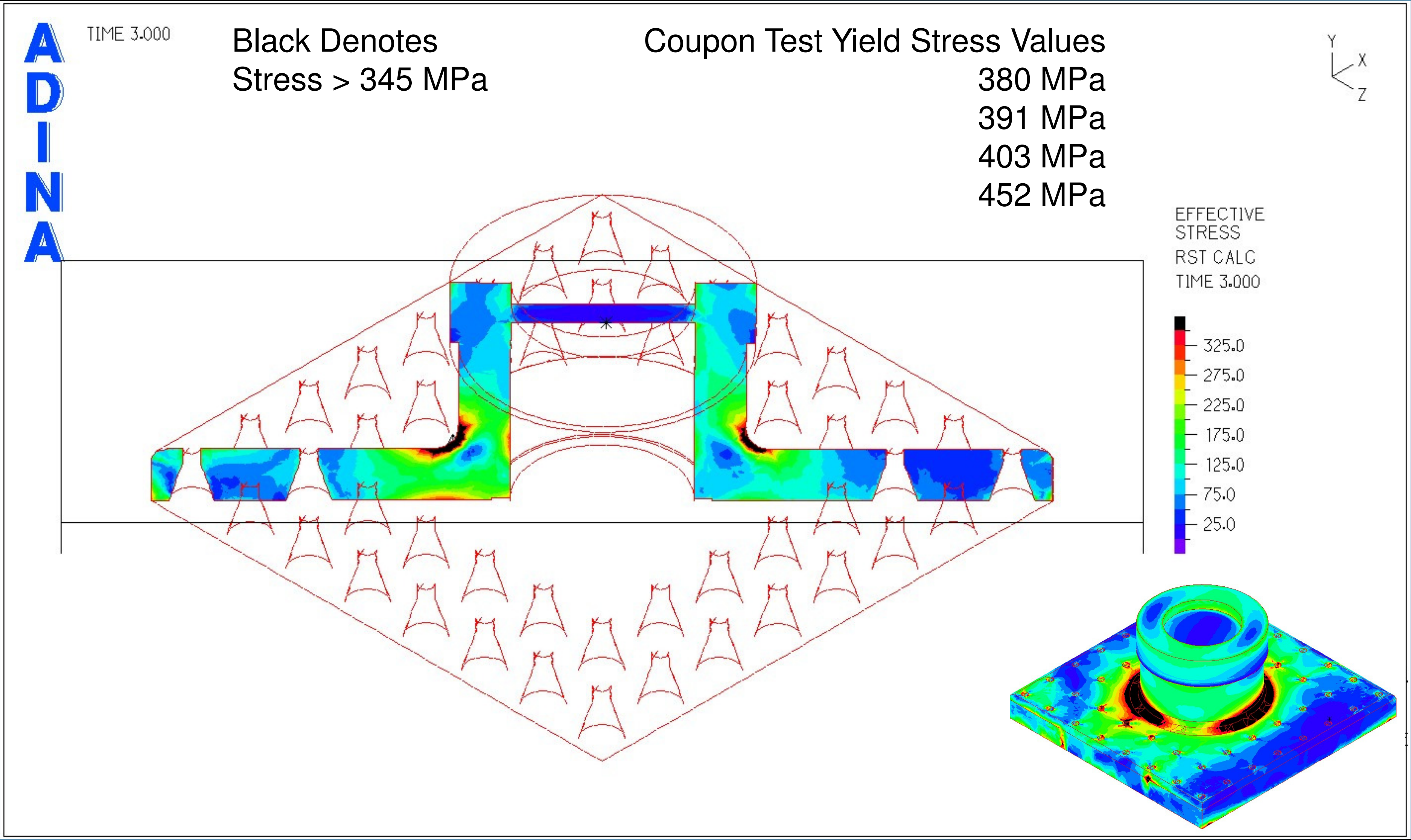
Alternative C2: Contact of Steel Saddle/Shear Key



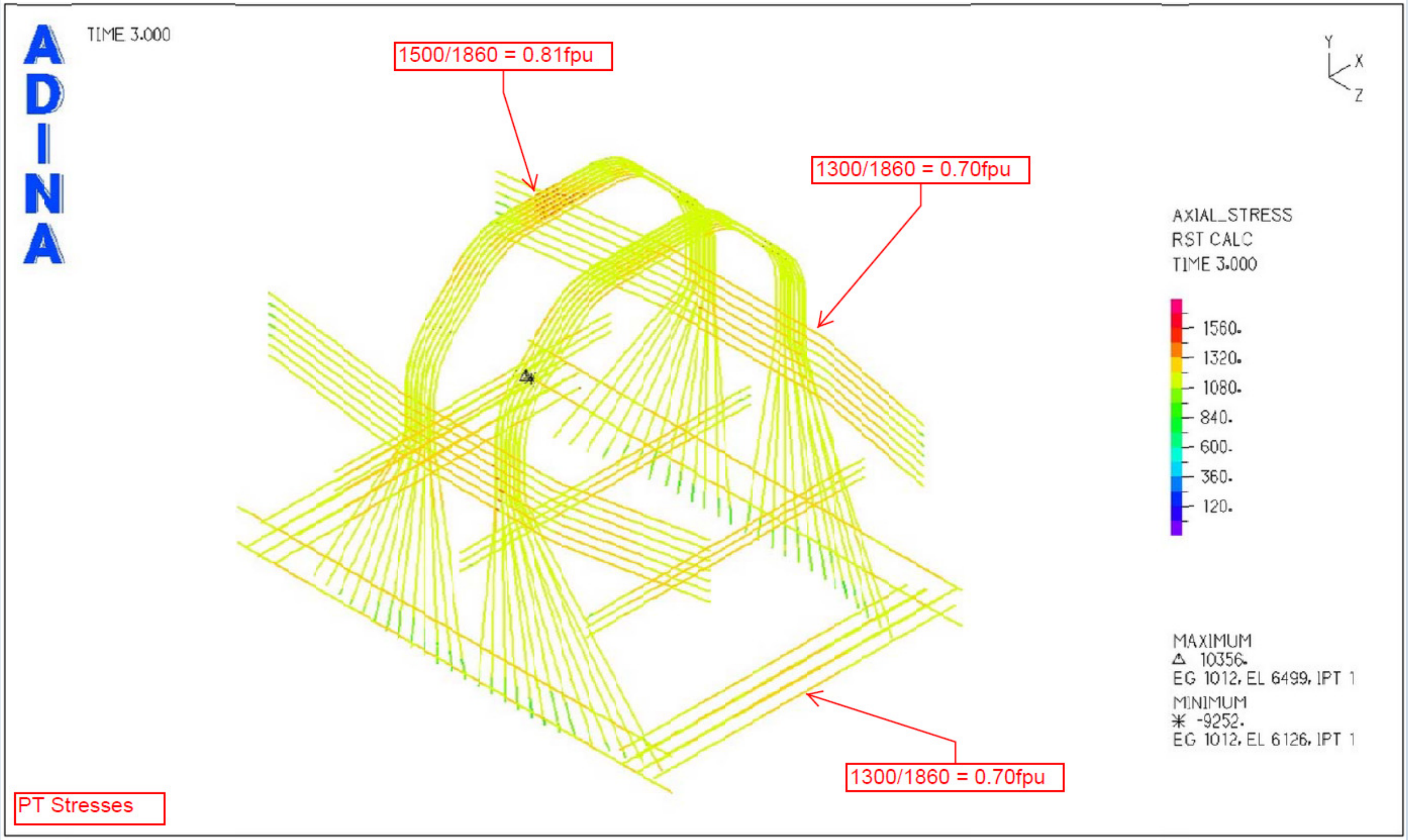
Alternative C2:
Shear Key Von Mises Stress

Black Denotes
Stress > 345 MPa

Coupon Test Yield Stress Values
380 MPa
391 MPa
403 MPa
452 MPa



Alternative C2: PT Stresses



PT_Stress_017

OptionC Steel Saddle Continuous Glued Dual Layer Stiff Grout Summary_017.pdf

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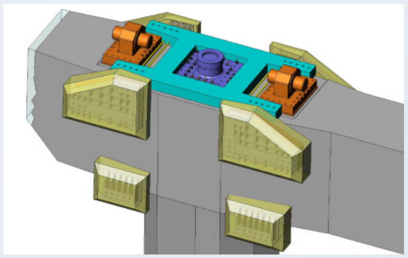
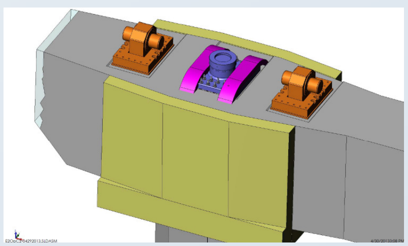
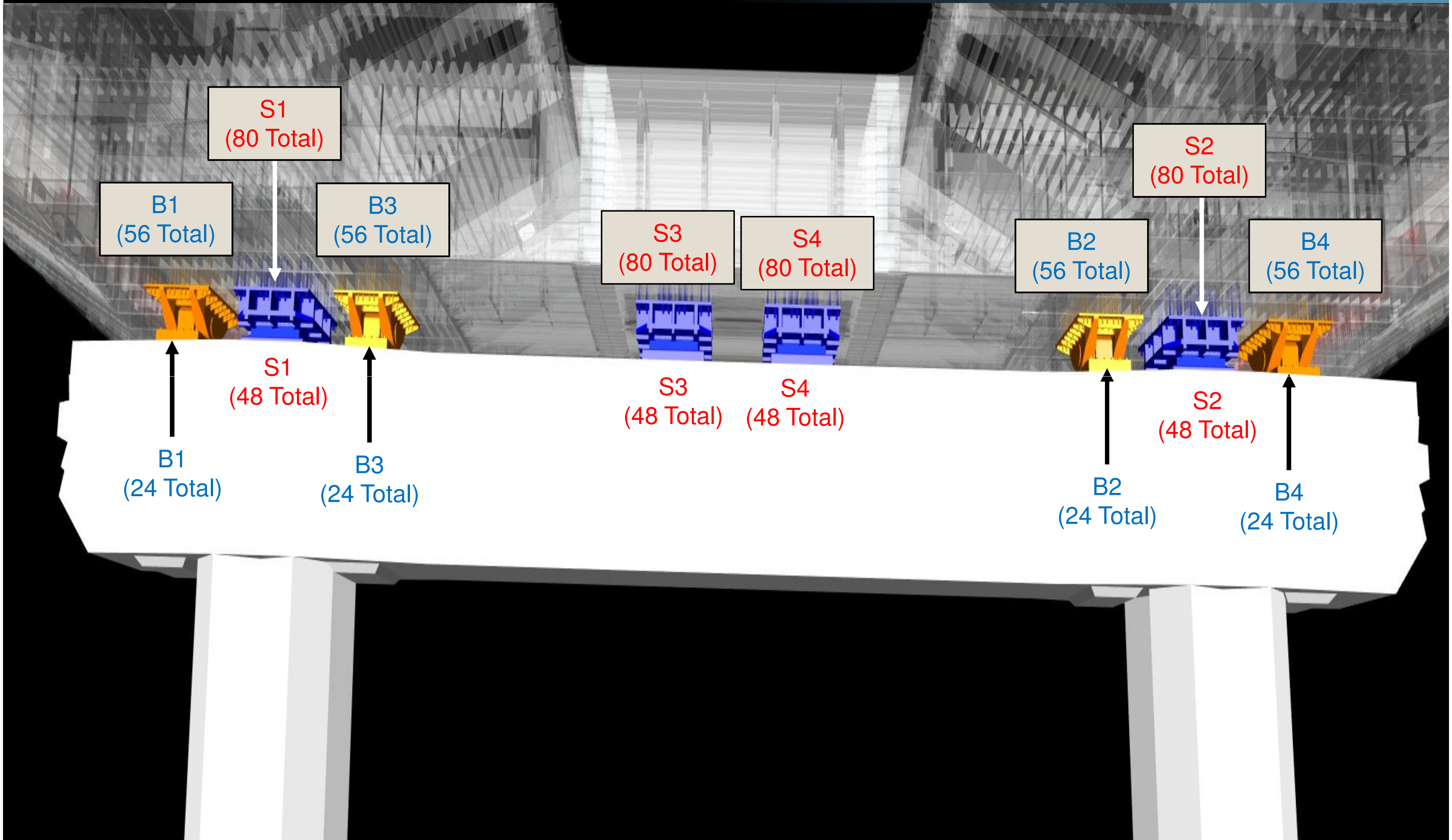
Design Alternatives For Shear Keys S1 and S2

ID Tag	ID Text Label	Image	Major Steps	Major Pros	Major Cons
BD(2)	Steel Collars		1) Procure material (PT strands/ steel plate/ bolts) 2) Fabricate steel frame/ transverse steel grillage 3) Tap holes in existing lower housing and prepare surface 4) Core existing concrete and cast supplemental concrete 5) Install steel frame and grillages 6) Grout under steel frame and grillages 7) Tension PT and grout 8) Cast cover concrete	• Provide full expected earthquake safety (1500 years of recurrence interval) • Shear keys do not need to be removed • Does not require splitting the bushing	• Requires more steel fabrication (milling/ welded steel grillages/ bolted steel frame) • Requires multiple vertical and horizontal cores • Requires an alternative procedure for future bearing replacement
C(2)	Prestressed Collars		1) Procure material (PT strands/ steel plate) 2) Fabricate steel frame/ saddle 3) Concrete surface preparation/ drill and bond 4) Core existing concrete 5) Cast concrete jacket 6) Install steel frame/ saddle 7) Grout under saddle 8) Tension PT and grout	• Provide full expected earthquake safety (1500 years of recurrence interval) • Shear keys do not need to be removed • Requires fewer horizontal cores and no vertical cores • More economical to build • Less maintenance	• Requires concrete jacket • Requires complex saddle fabrication • Requires splitting of the bushing

Design Recommends Alternative C(2)

SFOBB-SAS Pier E2: Bearings and Shear Keys



Testing Program

GOAL: Determine acceptable levels for sustained pre-tension loads for existing A354 BD. This goal will be reached through a combination of:

- In-Situ Hardness test of representative sample (%)
- Laboratory hardness test of representative sample (%)
- Destructive testing/chemical analysis/metalurgical analysis of a representative sample (%)
- Wet test of a representative sample (%)

In addition, the 2008 bolts are being tested (same as above)

Based on the testing program results:

- Conclude that existing A354 BD at current sustained stress levels are acceptable
- Consider reducing Pre-tension (this will require a fit-for-purpose analysis)
- Replace Rods

E2 Shear Keys (S3 & S4) and Bearings Connection To E2 Capbeam

THE SAN FRANCISCO-OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECTS

CALTRANS BAY AREA TOLL AUTHORITY CALIFORNIA TRANSPORTATION COMMISSION

Equivalent Substitution
192 Rod Replacement Alternatives (2010)

(To be considered in the event that test results indicate that change of existing rods is advisable)

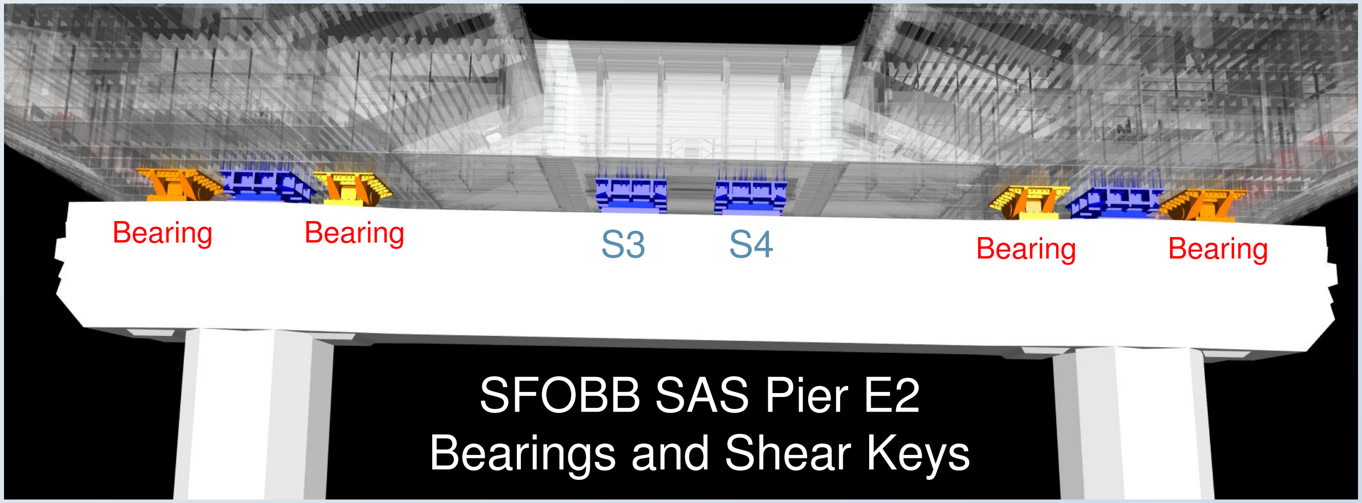
ID Tag	ID Text Label	Nominal Diameter [inch]	Minimum Strength (Fu) [ksi]	Prestress [ratio of Fu]	Pre-Tension Load per Bolt [kips]	Major Pros	Major Cons	Lead Time
1	ASTM A354 BD Rods w/ Supplementary Requirements	3	140	0.7 Fu	585	- Does not require fit-for-purpose evaluation - Size of components (rods, spherical washer, spherical nut) works with existing condition	- Additional requirements above ASTM standards - May require removal of grout in pipe sleeve for rod replacement	- Estimated at 3-4 months
2	ASTM A354 BC Rods	3.5	115	0.61 Fu	585	- Avoids use of high strength material	- Requires machining of bearing bottom housing for larger spherical washer and nut assembly (32 locations) - Requires re-evaluation of the bearing bottom housing by FEM analysis to confirm if it is fit-for-purpose - Requires reaming of holes of the bearing bottom housing and the shear key bottom housing by 12mm for larger rod diameter (192 locations) - Larger diameter bolt removes 12mm of the available tolerance for fit-up - Requires removal of grout pipe sleeve for larger diameter rod. Requires modifications to jacking equipment	- Estimated at 3-4 months
3	DYWIDAG Bars	3" (3.15" max)	150	0.57 Fu	585	- Proprietary alloy and chemistry (strength meets ASTM A722; however, 3" rods are not covered under ASTM A722)	- Sole-source - No standard spherical nuts, washers, and dished plate; but can be designed and manufactured - Requires machining of bearing bottom housing for higher spherical washer and nut assembly (32 out of 96 locations) - Requires re-evaluation of the bearing bottom housing by FEM analysis to confirm if it is fit-for-purpose - Requires reaming of holes of the bearing bottom housing and the shear key bottom housing by 4mm to for larger rod diameter (192 locations) - Requires removal of grout in pipe sleeve for larger diameter rod. Require modifications to jacking equipment	- Estimated at 3 to 4 plus weeks
4	Williams Rod	3" (3-3/64 max)	150	0.60 Fu	581	- Proprietary alloy and chemistry (strength meets ASTM A722; however, 3" rods are not covered under ASTM A722)	- Sole-source - Requires machining of bearing bottom housing for higher spherical washer and nut assembly (32 out of 96 locations) - Requires re-evaluation of the bearing bottom housing by FEM analysis to confirm if it is fit-for-purpose - Requires reaming of holes of the bearing bottom housing and the shear key bottom housing by 4mm to for larger rod diameter (192 locations) - Requires removal of grout in pipe sleeve for larger diameter rod. Requires modifications to jacking equipment	- 3 to 4 weeks
5	Prestressing Strand	16 strands	270 before losses	0.44 Fu after losses	585	- ASTM A 416	- At bearings (48 out of 96 locations), anchor frame assemblies interfere with the upper housing - Requires fabrication of anchor frame assembly - Requires reaming of holes of the bearing bottom housing and the shear key bottom housing by 10mm to for strands - Requires re-evaluation of the bearing bottom housing by FEM analysis to confirm if it is fit-for-purpose - Does not allow for bushing replaceability for both bearings and shear keys - Requires removal of grout in pipe sleeve for strands. Requires modifications to jacking equipment	- strands and anchors readily available; anchor frame assembly time estimated at 6-8 weeks

E2 Shear Keys (S3 & S4) and Bearings Connection To E2 Capbeam

Potential Fit-for-purpose Substitution
192 Rod Replacement Alternatives (2010)

(To be considered in the event that test results indicate that change of existing rods is advisable)

ID Tag	ID Text Label	Nominal Diameter [inch]	Minimum Strength (Fu) [ksi]	Prestress [ratio of Fu]	Pre-Tension Load per Bolt [kips]	Major Pros	Major Cons	Lead Time
6	Existing ASTM A354 BD Rods w/ Reduced Pre-Tension	3	140	< 0.7 Fu	< 585	- Size of components (rods, spherical washer, spherical nut) works with existing condition	- Requires fit-for-purpose evaluation	No lead time
7	ASTM A354 BC Rods	3	115	0.7 Fu	481	- Avoids use of high strength material	- Requires fit-for-purpose evaluation - May require removal of grout in pipe sleeve for rod replacement	- Estimated at 3-4 months
8	ASTM F1554 Gr. 105	3	125	0.7 Fu	522	- Size of components (rods, spherical washer, spherical nut) works with existing condition	- Requires fit-for-purpose evaluation - May require removal of grout in pipe sleeve for rod replacement	- Unknown



ASTM A354 Grade BD Rods Across SFOBB-SAS

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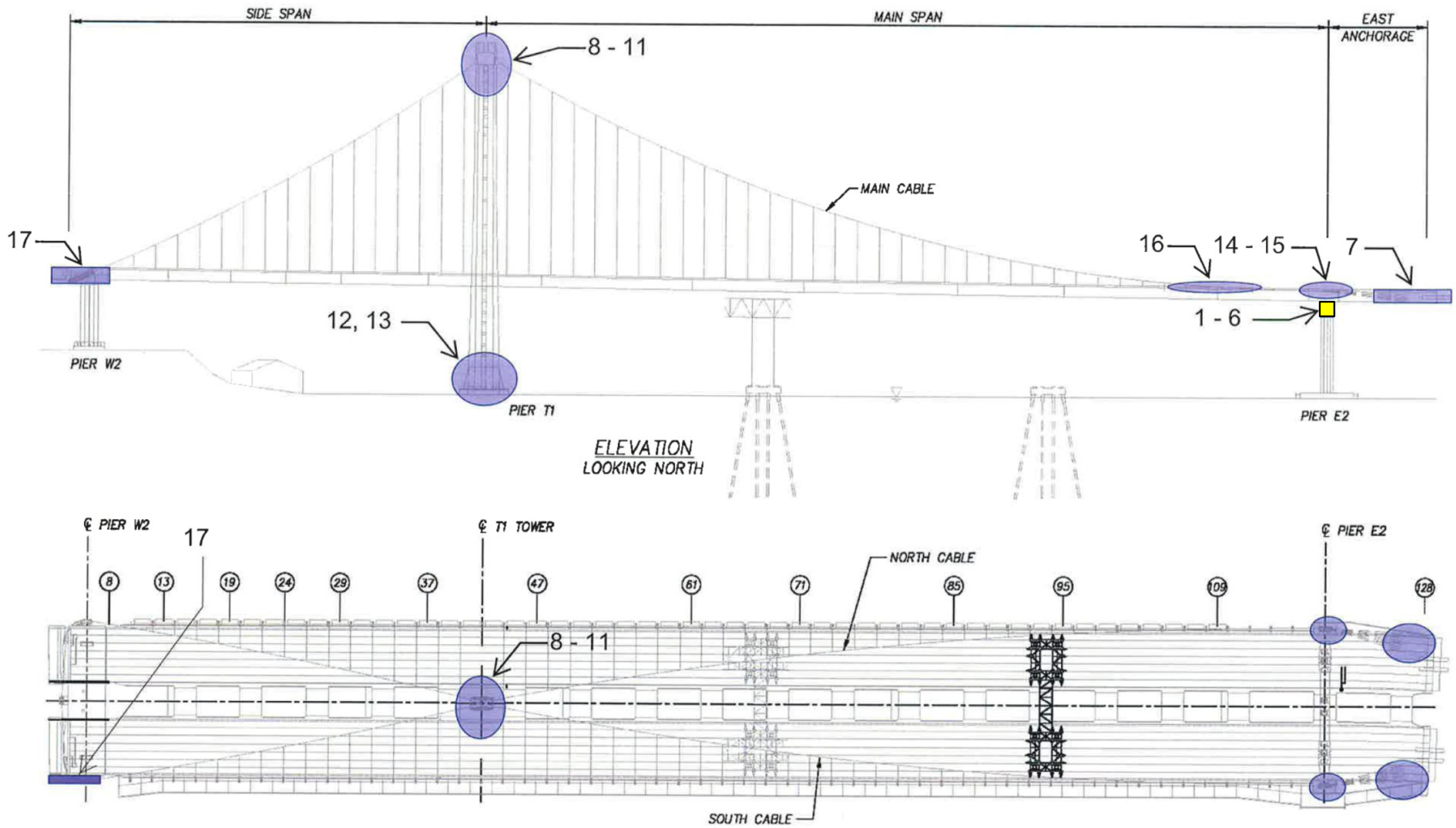


	COMPONENT	REQUIRED QUANTITY
1	E2 BEARINGS ANCHOR RODS (2008 - BOTTOM)	96
2	E2 BEARING & SHEAR KEY ANCHOR RODS (2010 - BOTTOM)	192
3	E2 SHEAR KEY RODS (TOP)	320
4	E2 BEARING RODS (TOP)	224

	COMPONENT	REQUIRED QUANTITY
5	E2 BEARING ASSEMBLY	96
6	E2 BEARING RETAINER RING PLATE ASSEMBLY	336
7	PWS ANCHOR RODS	274
8	TOWER SADDLE TIE RODS	25

	COMPONENT	REQUIRED QUANTITY
9	TOWER SADDLE TURNED RODS	108
10	TOWER SADDLE GRILLAGE	90
11	TOWER BOOM	4
12	TOWER ANCHOR RODS (TYPE 1)	388

	COMPONENT	REQUIRED QUANTITY
13	TOWER ANCHOR RODS (TYPE 2)	36
14	EAST SADDLE ANCHOR RODS	32
15	EAST SADDLE TIE RODS	18
16	CABLE BAND ANCHOR BOLTS	24
17	BIKEPATH ANCHOR RODS	43

ASTM A354 Grade BD Structural Components and Bolt Tension in Service

THE SAN FRANCISCO-OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECTS
CALTRANS BAY AREA TOLL AUTHORITY CALIFORNIA TRANSPORTATION COMMISSION

ID	Structural Component	Nominal Bolt Number of Bolts	Diameter [in]	Bolt Tension @ Service % Fu (UTS)
1	Shear Key Anchor Bolts - Bottom (S1/S2)	96	3	0.70
2	Shear Key Anchor Bolts - Bottom (S3/S4)	96	3	0.70
	Pier E2 Bearing Bolts - Bottom Housing (B1, B2, B3, B4)	96	3	0.70
3	Shear Key Anchor Bolts -Top (S1/S2)	160	3	0.70
	Shear Key Anchor Bolts -Top (S3/S4)	160	3	0.70
4	Pier E2 Bearing Bolts - Top Housing	224	2	0.70
5	Spherical Bearing Bushing Assembly Bolts	96	1	0.61
6	Bearing Retainer Ring Plate Assembly Bolts	336	1	0.40
7	PWS Strand Anchor Rods (Main Cable)	274	3-1/2	0.32
8	Tower Saddle Tie Rods	25	4	0.68
9	Tower Saddle Turned Rods (@ Splices)	100	3	0.45
		8	3	0.10
10	Tower Saddle Grillage Bolts	90	3	0.10
11	Tower Outrigger	4	3	0.10
12	Tower Anchorage Anchor Bolts (75 Dia. Anchor Bolts)	388	3	0.48
13	Tower Anchorage Anchor Bolts (100 Dia. Anchor Bolts)	36	4	0.37
14	East Saddle Anchor Rods	32	2	0.10
15	East Saddle Tie Rods	18	3	0.10
16	Cable Bracket Anchor Rods	24	3	0.16
17	Bikepath Anchor Bolts at Pier W2	43	1-1/4	0.10

Fu (Tensile Strength) per ASTM A354-11

Shear Key S1 & S2: 2008 Rod Testing Program

I. **Visual Examination/Observations**

II. **Scanning Electron Microscopy**

III. **Microstructural Examination**

IV. **Hardness Testing**

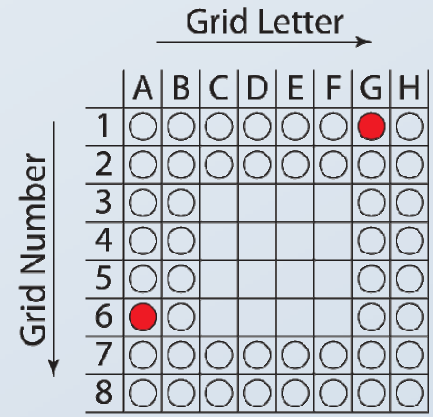
   a. Knoop Microhardness

   b. Rockwell C Hardness

V. **Tensile Test**

VI. **Charpy V-Notch Impact Test**

VII. **Chemical Analysis (Spectrochemical)**



Shear Key Rod LD Grid
Plan View (Looking Down)

Test Specimens:

- S1–G1
- S2–A6

Bearing and Shear Key Anchor Rod LD. Key:

B1 – E8

Bearing/Shear Key Piece Mark

Rod Grid Number

Rod Grid Letter

Shear Key S3, S4, and Bearing B1, B2, B3, B4: 2010 Rod Testing Program

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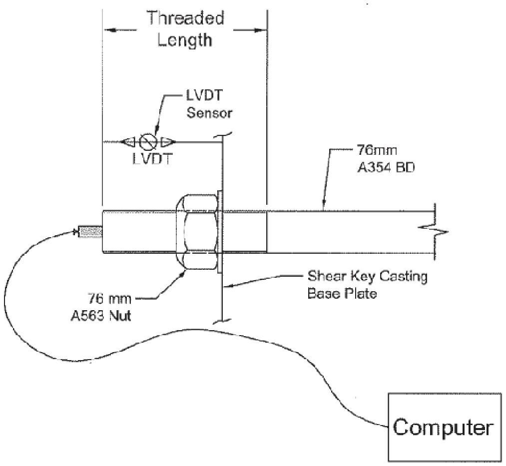
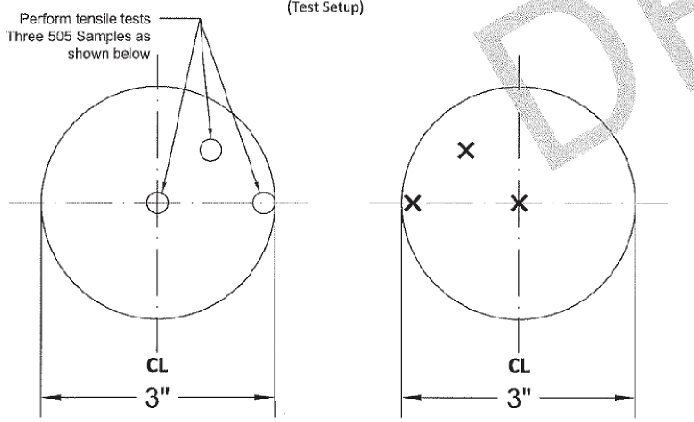


Anchor Rod Testing
(Test Setup)



Section A
NTS - Sample as close to the fractured surface as practical.

Section B
NTS - Sample as close to the fractured surface as practical.

Bay Bridge Anchor Rod Testing (192 Rods)

Sample Selection:

1. In-Situ testing shall be performed on all 192 anchor rods as described below.
2. Select 10 different rods for extended testing. 10 rod sample size (~ 5%) is larger than ASTM F1470 requirements of 7 bars for lot size of 151 to 280 rods.

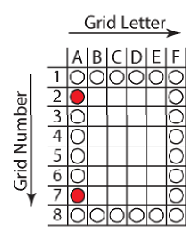
In-Situ Testing Protocol:

1. Mark the rods selected for extended testing to identify the jacking end.
2. Install acoustic measuring devices on each of the 10 sample rods selected for extended testing.
3. Load all 192 rods up to 0.75Fu (with seating loss expected to bring the final tension in the rods down to the Design load of 0.7Fu).
4. Maintain the applied load for 30 days, during which all rods will be visually inspected daily, checking for failures.
5. MFTS will monitor the acoustic measuring output on the 10 rods selected for the extended testing.
6. If any rod (of the total lot of 192 rods) fails prior to the 30 day testing period, extract and perform post fracture analysis as detailed below under "Extended Testing Protocol".
7. If no rods fail within the 30 day period, extract the 10 sample rods, transport to a testing facility/load bed.

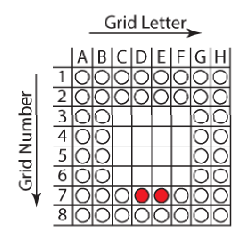
Extended Testing Protocol:
(Tests listed below to be performed at an independent testing laboratory accredited per ISO 17025 or approved by Caltrans).

1. Load the 10 samples to failure. The rods shall be jacked at the same ends as they were jacked during the in-situ testing.
2. Perform Charpy V-Notch testing of broken rods at room temperature and at 40 degrees F.
3. Perform reduced section tensile tests (.505 diameter) of the broken rods as close to the fracture surface as possible. Tensile tests to be performed as detailed in Section A.
4. Perform hardness Testing (Rockwell C and Knoop Micro-hardness) of broken rods.
5. Perform chemical analysis of broken rods at the threaded area and at the shank. Chemical tests to be performed as detailed in Section B.
6. Perform scanning electron microscopy - examination of fracture features on broken rods.
7. Perform Micro-structural examination of broken rods at the threaded area.

Note: It is expected that loading of the 192 bolts for 30 days will allow any existing hydrogen atoms to propagate in between the grain boundaries of the steel. Therefore, even if the bolts do not fail within the 30 day period, the scanning electron microscopy will provide sufficient information necessary to determine presence of Hydrogen.



Bearing Rod LD Grid
Plan View (Looking Down)

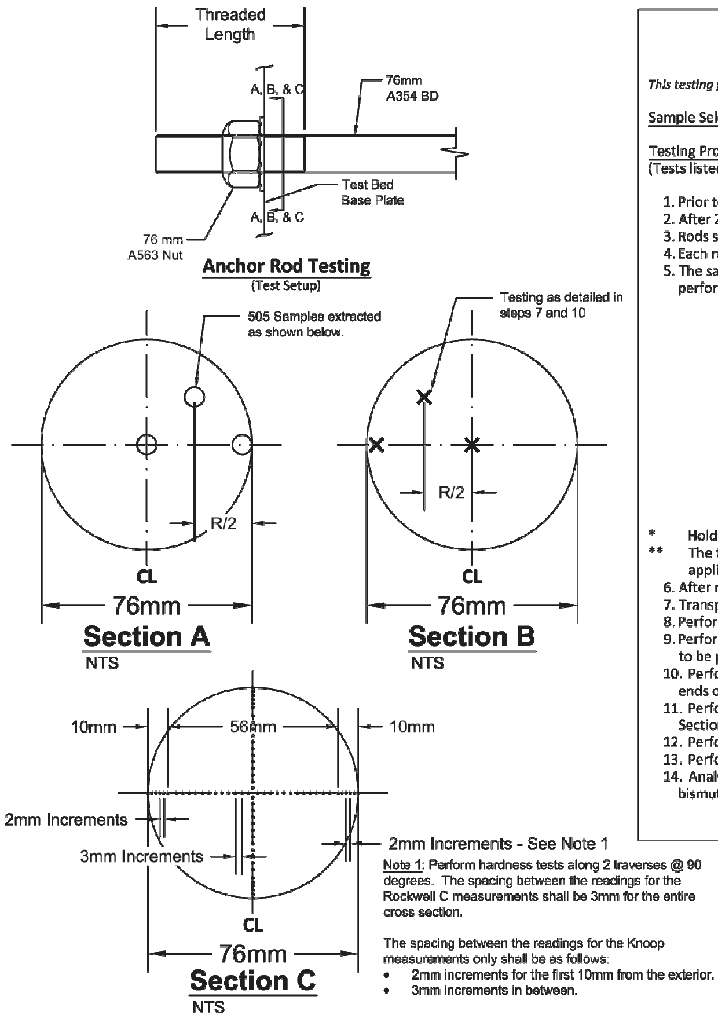


Shear Key Rod LD Grid
Plan View (Looking Down)

Test Specimens:

- S3–E7
- S4–D7
- BC–A2
- B4–A7

Shear Key S3, S4, and Bearing B1, B2, B3, B4: 2010 Rod Wet Testing Program



Anchor Rod Wet Test (192 Rods)

This testing protocol was developed with the assistance of Dr. Herb Townsend, PhD,PE, Dr. Karl Frank, PhD,PE and Mr. Doug Williams, PE.

Sample Selection: Rod selection shall be as determined by the Design Joint Venture; 4 rods total.

Testing Protocol:
(Tests listed below to be performed by an independent testing laboratory accredited per ISO 17025 or approved by Caltrans).

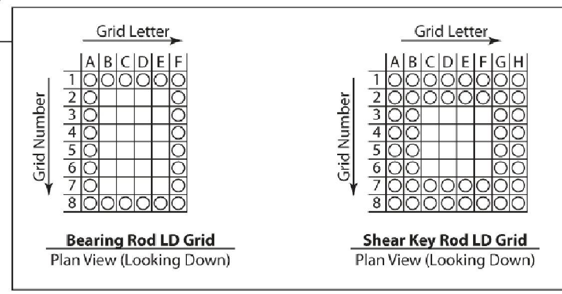
1. Prior to extraction, ABFJV shall reload the selected rods up to 0.75Fu and maintain the load for 24 hours.
2. After 24 hours, the rods shall be extracted and nondestructively tested.
3. Rods shall be cleaned to remove all contaminants and lubricants from the threads.
4. Each rod shall be Ultrasonically Tested and Magnetic Particle Tested to identify existing cracks.
5. The samples shall be transported to the selected testing facility where the slow loading tests in a 3.5% NaCl solution will be performed as follows:

%Fu	Load per Rod (Kips)	Time* (hr)
0.30	251	48
0.40	334	48
0.50	418	48
0.55	460	48
0.60	501	48
0.65	543	48
0.70	585	48
0.75	627	48
0.80	669	48
0.85	710	120

* Hold time at each load step

** The testing facility shall record the strain using a strain gauge, in addition to keeping a tabulated record showing the applied load vs measured strain vs time.

6. After maintaining the load at 0.85 Fu for 5 days (120 hours) as shown above, load the samples to failure.
7. Transport the fractured sections to the fracture analysis lab for further assessment.
8. Perform Charpy V-Notch testing of broken rods at room temperature and at 70 degrees, per Section B.
9. Perform reduced section tensile tests (.505 diameter) of the broken rods as close to the fracture surface as possible. Tensile tests to be performed as detailed in Section A.
10. Perform Rockwell C hardness and Knoop (Micro-hardness) testing per Section C, and no closer than 1 rod diameter from the ends of each rod.
11. Perform chemical analysis of broken rods at the threaded area and at the shank. Chemical tests to be performed as detailed in Section B.
12. Perform scanning electron microscopy - examination of fracture features on broken rods.
13. Perform Micro-structural examination of broken rods at the threaded area.
14. Analyze the chemistry of the coating and provide % of components. Include information on any % or trace amount of tin and bismuth.



Test Specimens:

- __________
- __________
- __________
- __________

Pier E2 Anchor Rod "Wet" Test
Test Rig Design

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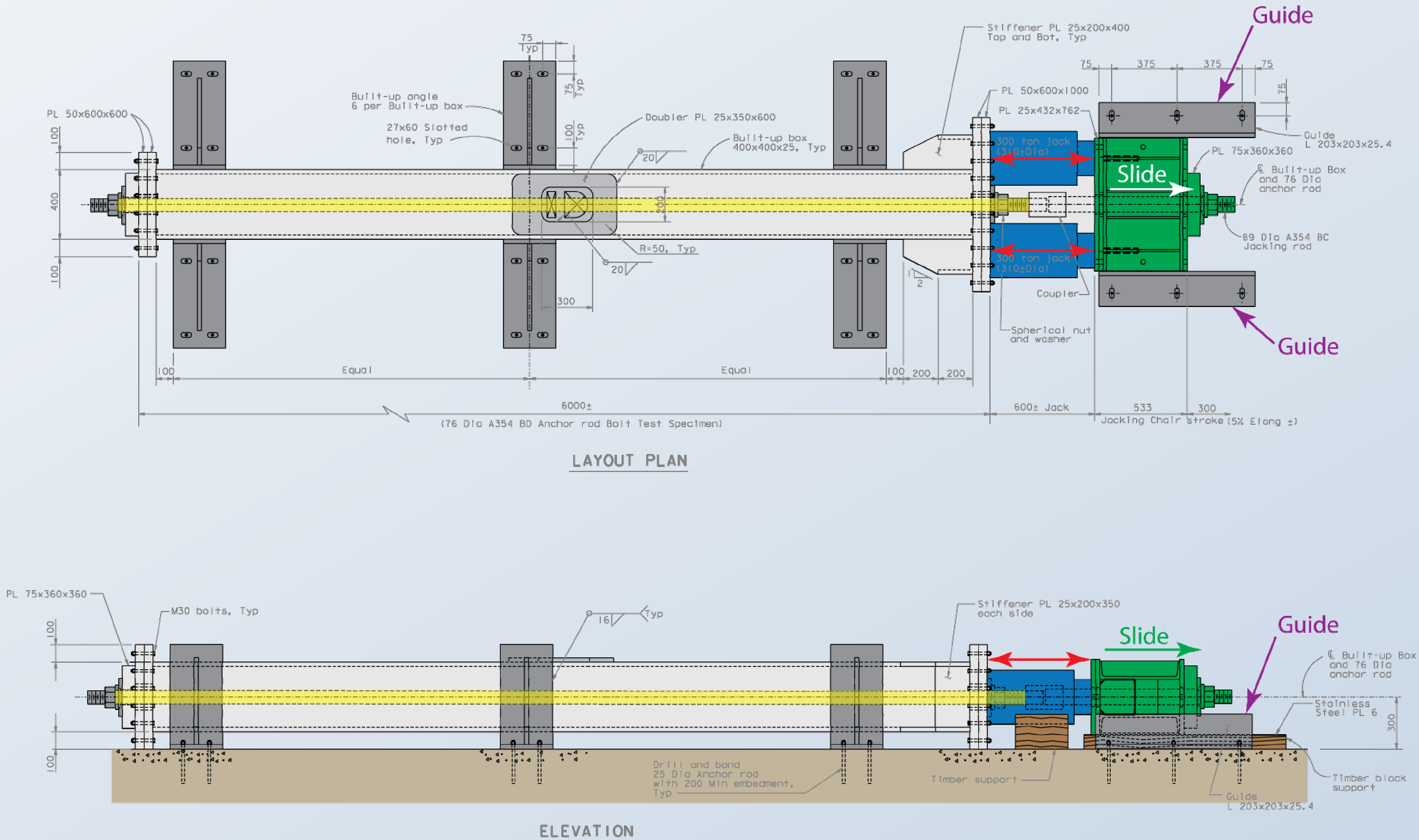
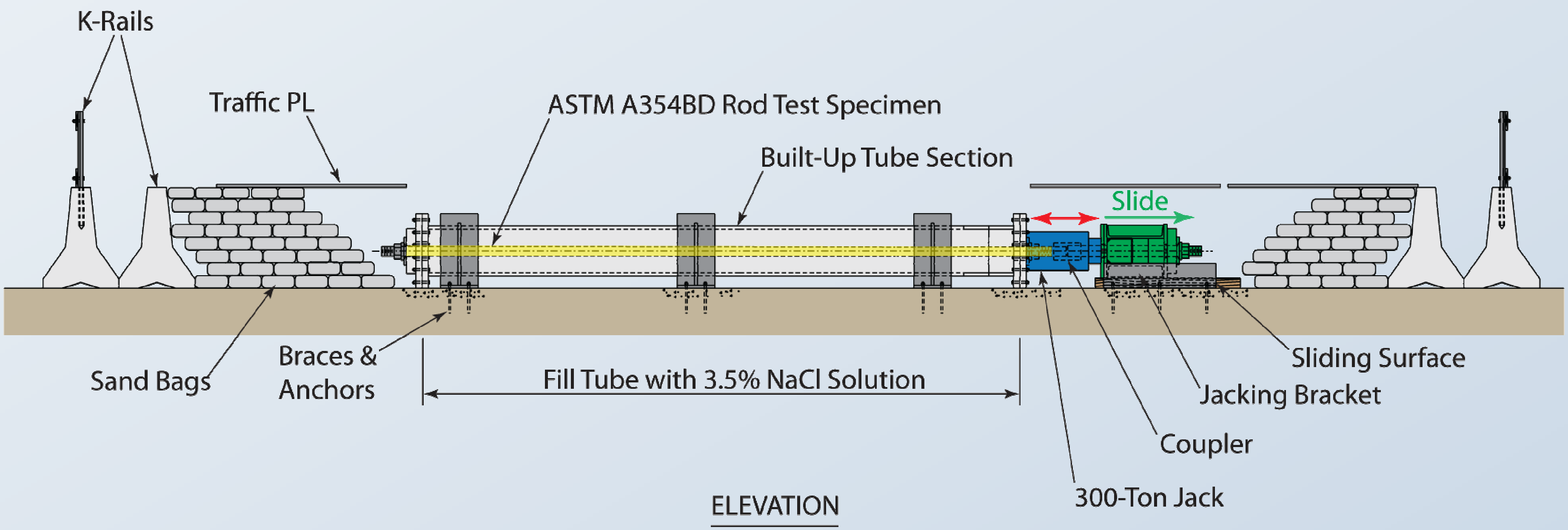


Pier E2 Anchor Rod "Wet" Test General Arrangement

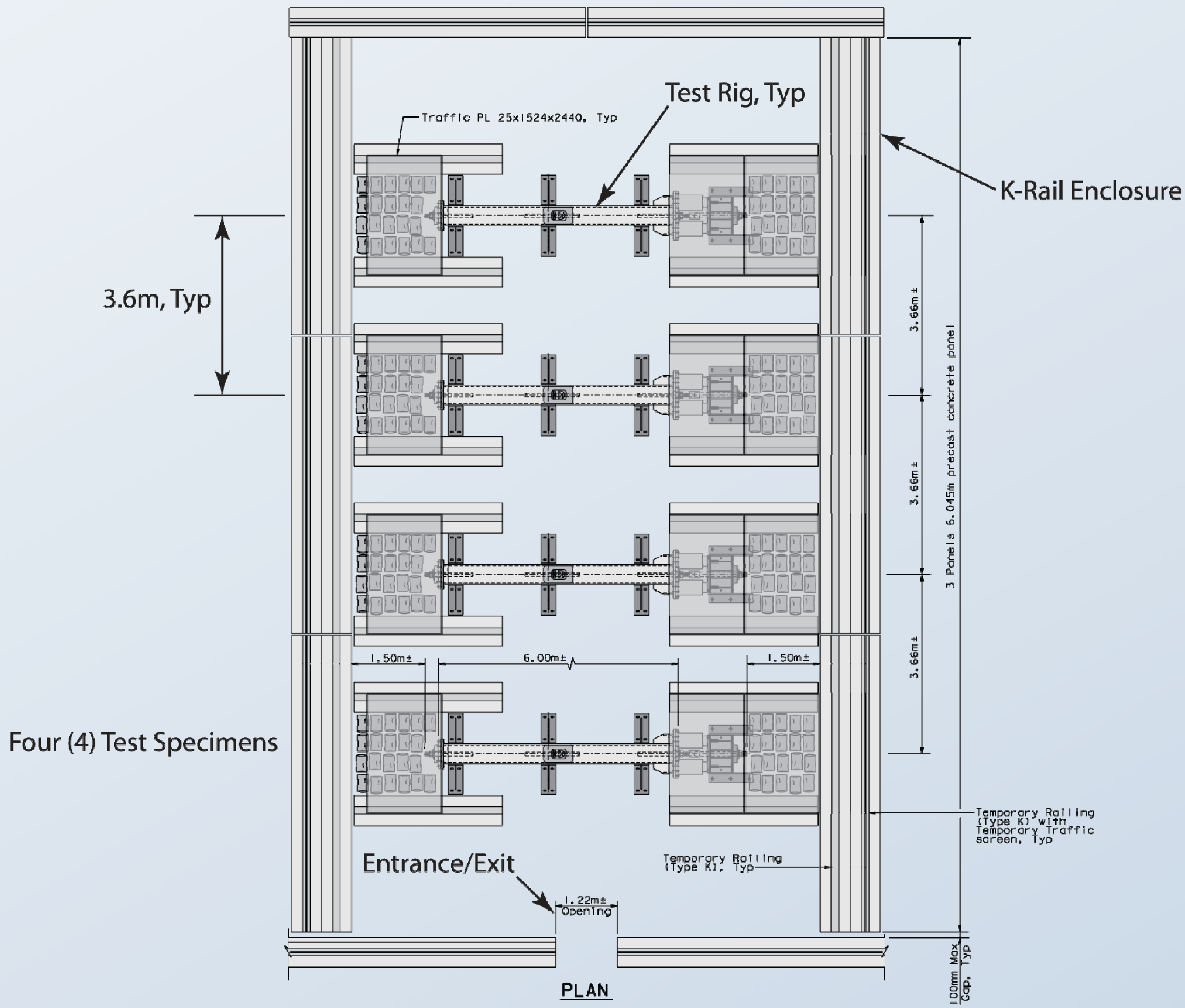
A354BD Rod Tensile Strength = 4.5 MN (w/ 1.2 overstrength factor)

Jack Capacity (2 jacks) = 6.3 MN

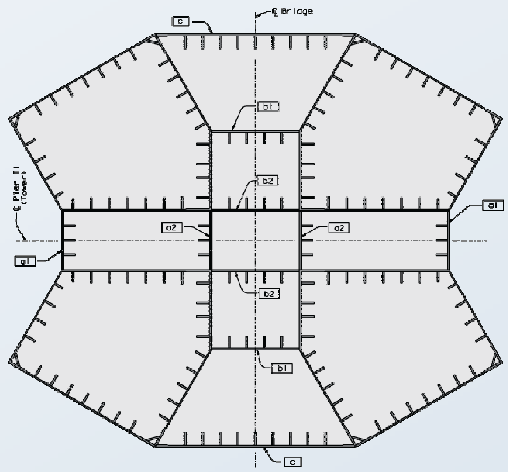
Nominal Capacity of Test Rig = 12.4 MN



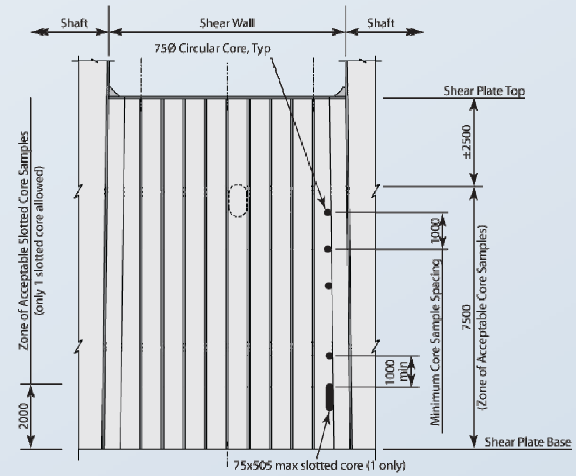
Pier E2 Anchor Rod "Wet" Test General Arrangement



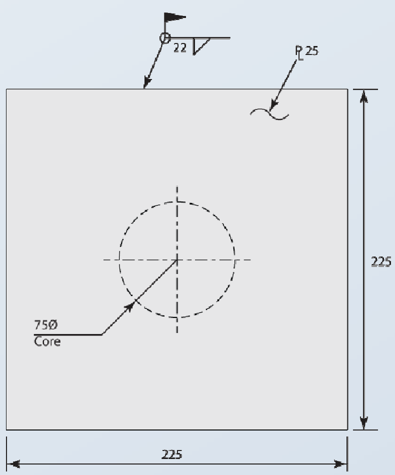
Tower ESW



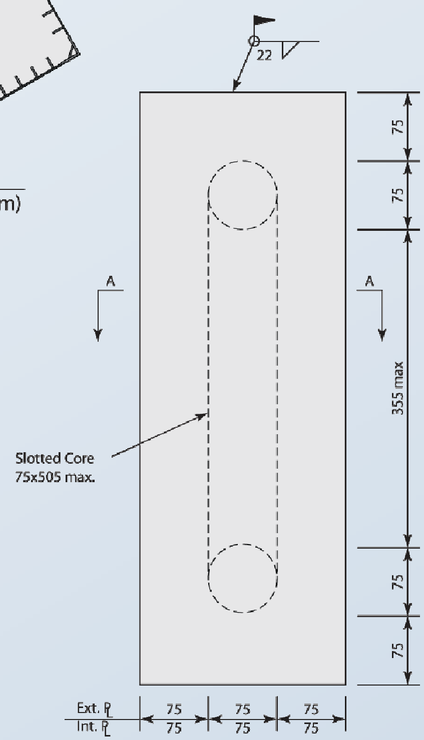
Typical Tower Base Cross Section
(Between Elev 3.125 m and Elev 13.000 m)



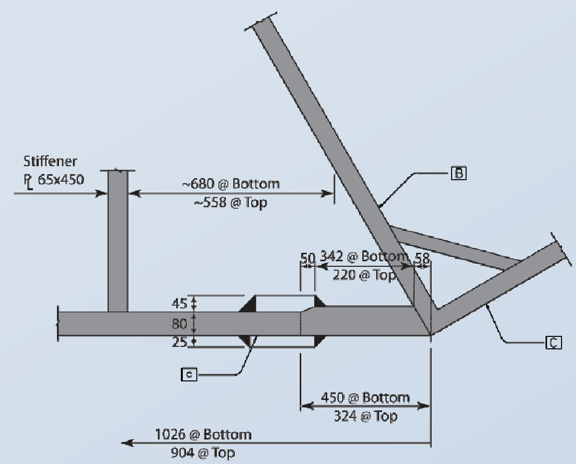
Elevation View Face C



Doubler Plate Detail (Circular Core)
(Exterior Surface of Shear Wall Only)



Double Plate Detail (Slotted Core)



Section A-A

Tower ESW

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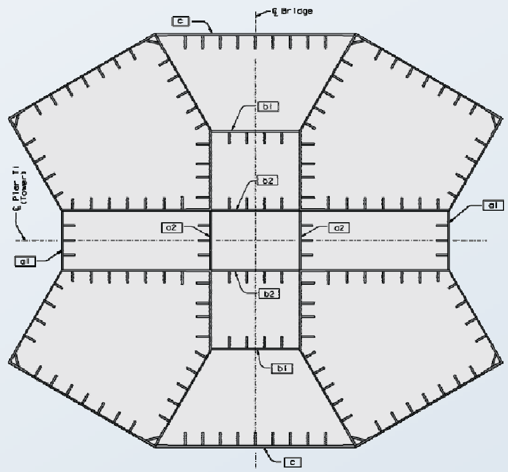
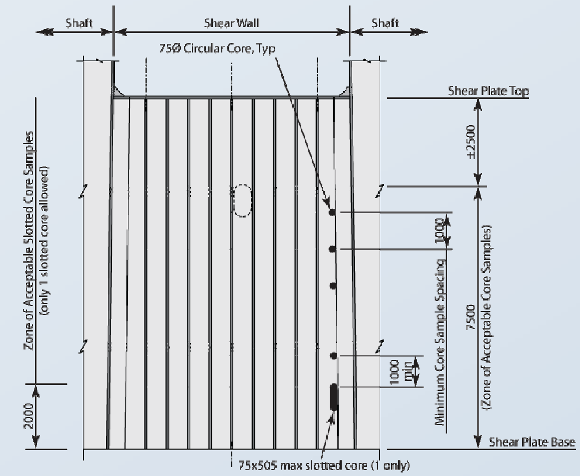
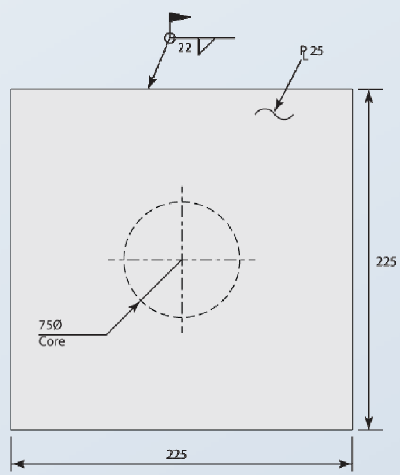


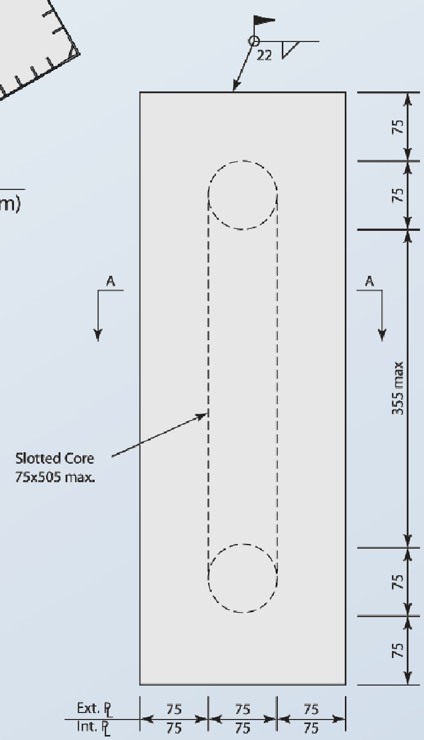
Typical Tower Base Cross Section
(Between Elev 3.125 m and Elev 13.000 m)



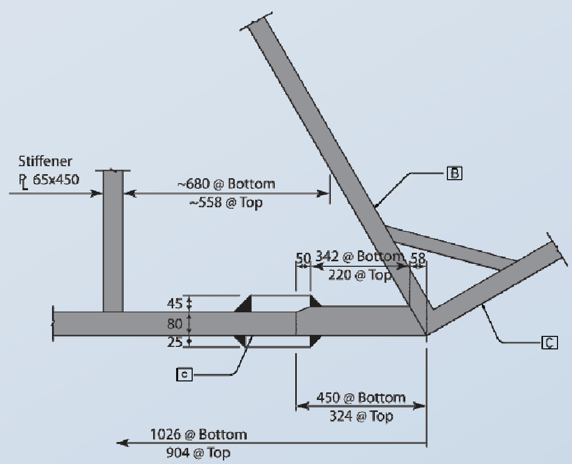
Elevation View Face C



Doubler Plate Detail (Circular Core)
(Exterior Surface of Shear Wall Only)



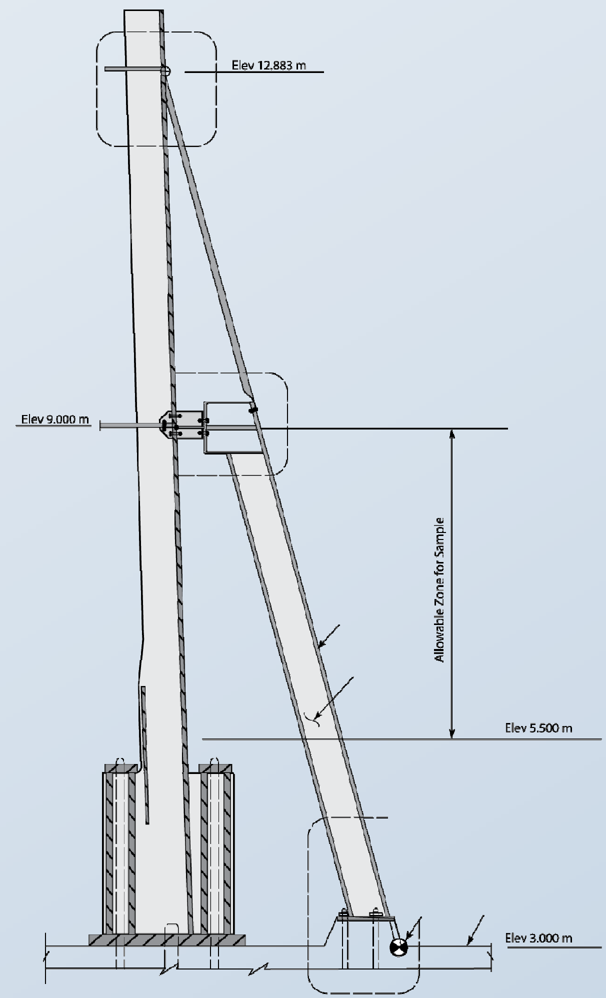
Double Plate Detail (Slotted Core)



Section A-A

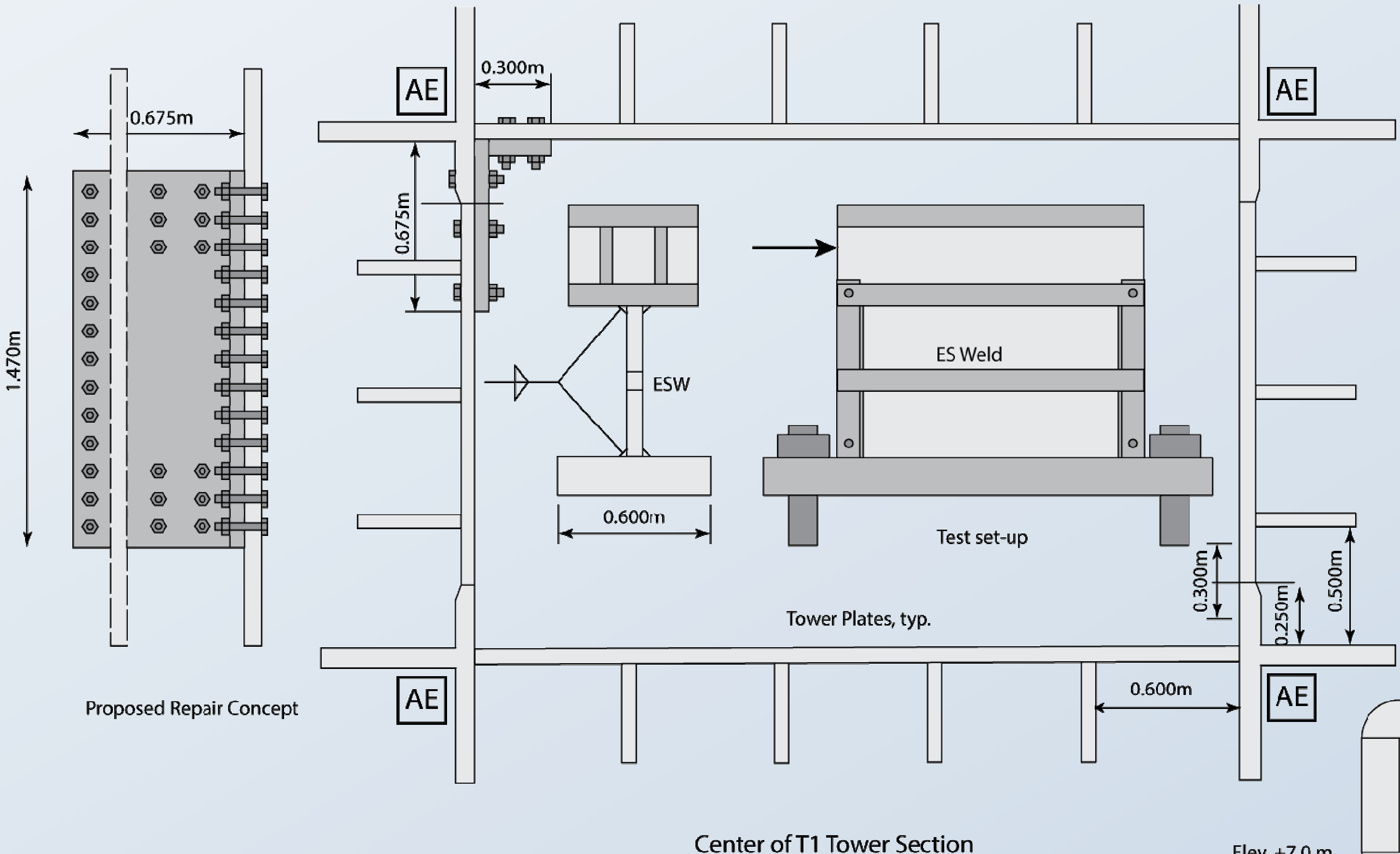
Tower ESW

Symmetric about ℄ Bridge
a1
Location of Sample
a2
b2
E
AE
A
D
Symmetric about ℄ Pier T1 (Tower)
b1
B
c
C
Shear Wall
Tower Shaft

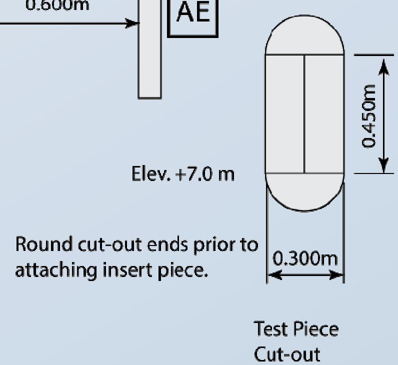


Elev 12.883 m
Elev 9.000 m
Allowable Zone for Sample
Elev 5.500 m
Elev 3.000 m

Tower ESW



0.675m
1.470m
Proposed Repair Concept
AE
0.300m
AE
0.675m
ESW
0.600m
ES Weld
Test set-up
Tower Plates, typ.
0.300m
0.250m
0.500m
AE
AE
0.600m
Center of T1 Tower Section



Elev. +7.0 m
0.450m
Round cut-out ends prior to attaching insert piece.
0.300m
Test Piece Cut-out