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An Academic Investigation of the I-35W Bridge Collapse

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University of Minnesota

PHM Conference

September 26, 2012

National Security; Roman Acqueduct in Pont du Gard, France

The Romans understood the roles of roads, water distribution, etc., in maintaining their empire.

Our infrastructure was a statement of our vision, wealth, capabilities and pride.

Infrastructure includes cultural projects!


and Education: Morrill Grant Land College Act of 1862


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Investment in Infrastructure

- 1950s and 1960s ~4% of GDP
- 1982 to 2007
  - U.S. population – 226 to 300 million
  - U.S. GDP - $3 to $13 trillion
  - current infrastructure investment < 2% of GDP

China today ~ 9% of GDP

Rockefeller Road Bridge, Cleveland, Ohio

msnbc

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Sinkhole swallows up SUV in New York street

Shocked driver escapes serious injury; vehicle rested on gas main

WNBC-TV

The SUV rests in the Brooklyn street sinkhole.

Water main break;
SUV sitting on gas main.

AP Associated Press

Updated: 11:32 a.m. CT March 27, 2006

NEW YORK – A city street collapsed under a sport utility vehicle early Monday, leaving the vehicle nose down into a deep sinkhole that officials said was caused by a water main break.

The driver of the SUV escaped without serious injures but was taken to a hospital for treatment of shock, said Fire Department spokesman Brian Conlon.

Stand and be counted

What keeps you up at night? Gut Check America is your chance to tell us what really matters in our country and to help determine what topics MSNBC.com covers. **Click here to learn more and get involved.**

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Aging N.Y. pipes raise concerns of more blasts

Steam pipes rarely inspected; air tests ease health worries in Manhattan

Timothy A. Clary / AFP - Getty Images

A destroyed tow truck sits in a hole Thursday at the site of an underground steam pipe explosion in New York. The Wednesday explosion tore a crater in Lexington Avenue near Grand Central Terminal, sending residents running for cover amid a towering geyser of steam.

83 years old steam pipe, and part of a system put into service in 1882!!!

NBC video

Launch

N.Y. worries

July 19: The explosion of a weathered steam pipe has more than just New Yorkers pondering the repercussions of an aging infrastructure. NBC's Ron Allen reports.

Nightly News

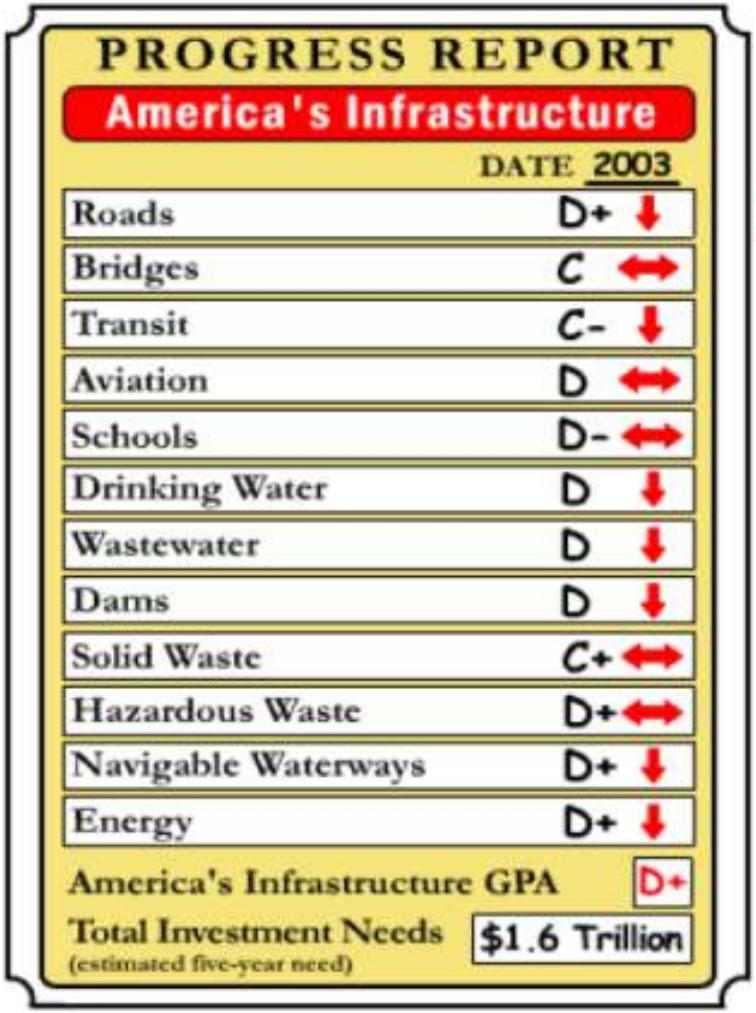
AP

Updat

o: NYC steam explosion

Courtesy of Dennis Martenson

ASCE Report Card



"**Civil engineers** are the doctors of infrastructure,-- and we have a patient that's sick and getting sicker."
ASCE Executive Director James E. Davis

↑ = Improving
↔ = No Progress
↓ = Declining

A = Exceptional
B = Good
C = Mediocre
D = Poor
F = Inadequate Trends

Solutions

It comes down to priorities and long-term planning

And now to the bridge

The scope: education of students

(Academic investigation funded by the National Science Foundation and the University's Center for Transportation Studies)

The cast:

Profs. T. Okazaki, A. Schultz, T. Galambos and R. Ballarini

Undergrads Tor Oksnevad and Charles De Vore

Grads Minmao Liao and Alicia Forbes

Our calculations and conclusions are in agreement with those that appear in the WJE report

The truss members were capable (with acceptable safety factors) of carrying the loads experienced by the bridge. There is no reason to suspect they are responsible for the collapse.

With respect to the design service loads, the safety factor of the gusset plates at nodes U10 was approximately equal to 1.0, instead of the roughly 2.0 required by the requirements of the design code in 1967. For unexplained reasons, these plates were ½" instead of 1" thick.

The bridge collapsed as a result of the failure of the gusset plate(s) at a U10 node, in the vicinity of the L9-U10 compression diagonal. The calculated capacity of the gusset plates (that failed) was very close to the demands that were placed on it at the time of the bridge collapse. Had the plates been 1" thick, the capacity would have exceeded the demands.

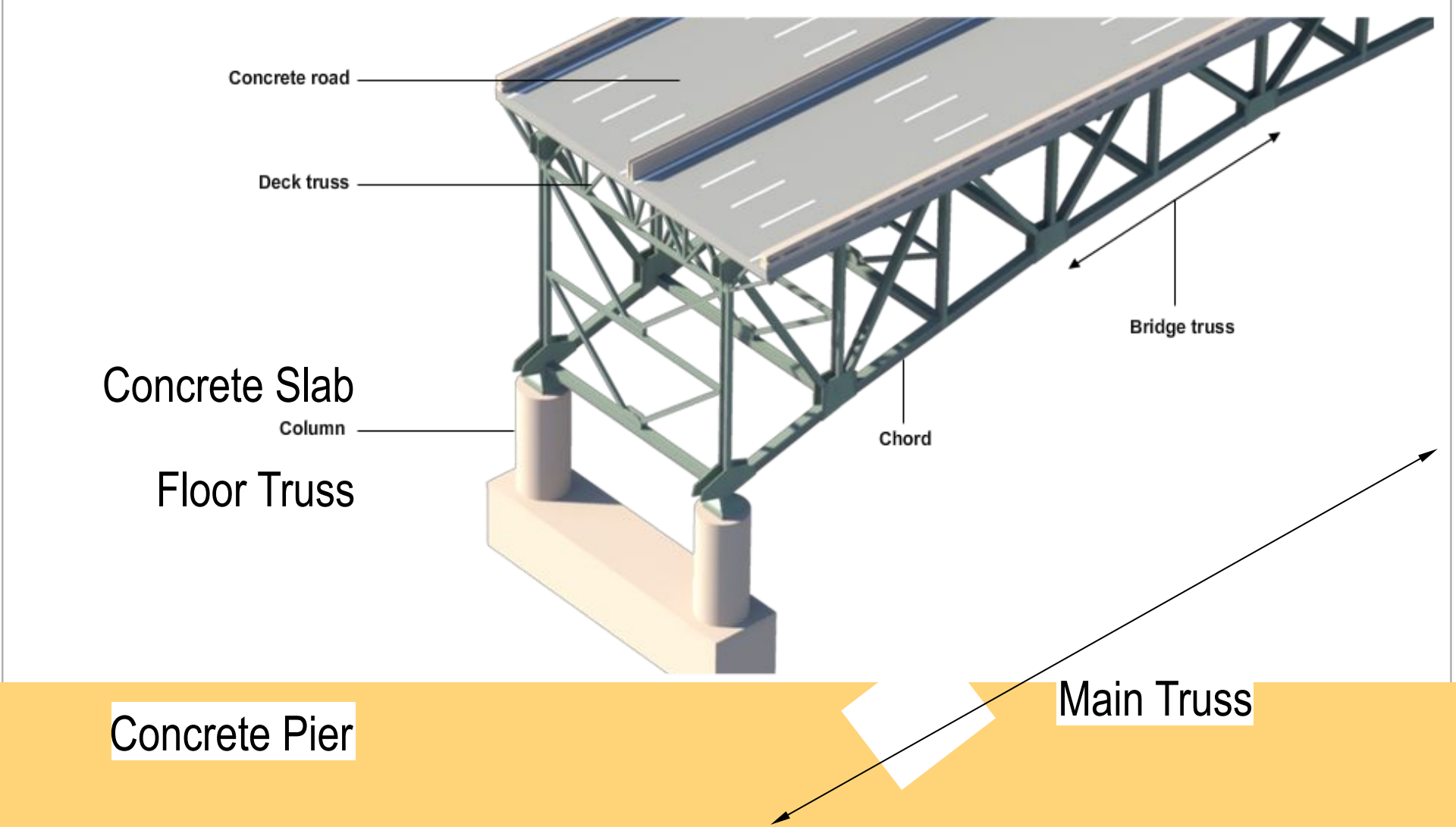
The "final straw" was most likely the weight of the construction material placed on the bridge hours before the collapse. The calculations show this weight significantly increased the stresses on the gusset plates.

We note that temperature cycles could have significantly influenced the forces in the truss members framing into the U10 nodes, and in the stresses experienced by the gusset plates, as could have a number of heavy vehicles passing over the bridge near the time of collapse.

- Opened to traffic in 1967
- 140,000 vehicles per day
- 5,700 heavy vehicles per day
- Multiple retrofits over past decade

http://en.wikipedia.org/wiki/I-35W_Mississippi_River_bridge


Concrete Slab
Floor Truss
Main Truss
Roller
Concrete Pier
http://www.visi.com/~jweeks/bridges/pages/ms16.html



It is instructive to keep in mind the relative weights:

The weight of the concrete deck is roughly three times the weight of (all of) the steel!

CONSTRUCTION ZONE IN THE HOURS BEFORE THE COLLAPSE

This photo, taken less than three hours before the bridge collapse, shows cars and trucks creeping through the construction zone which reduced traffic from eight lanes to two lanes in each direction.

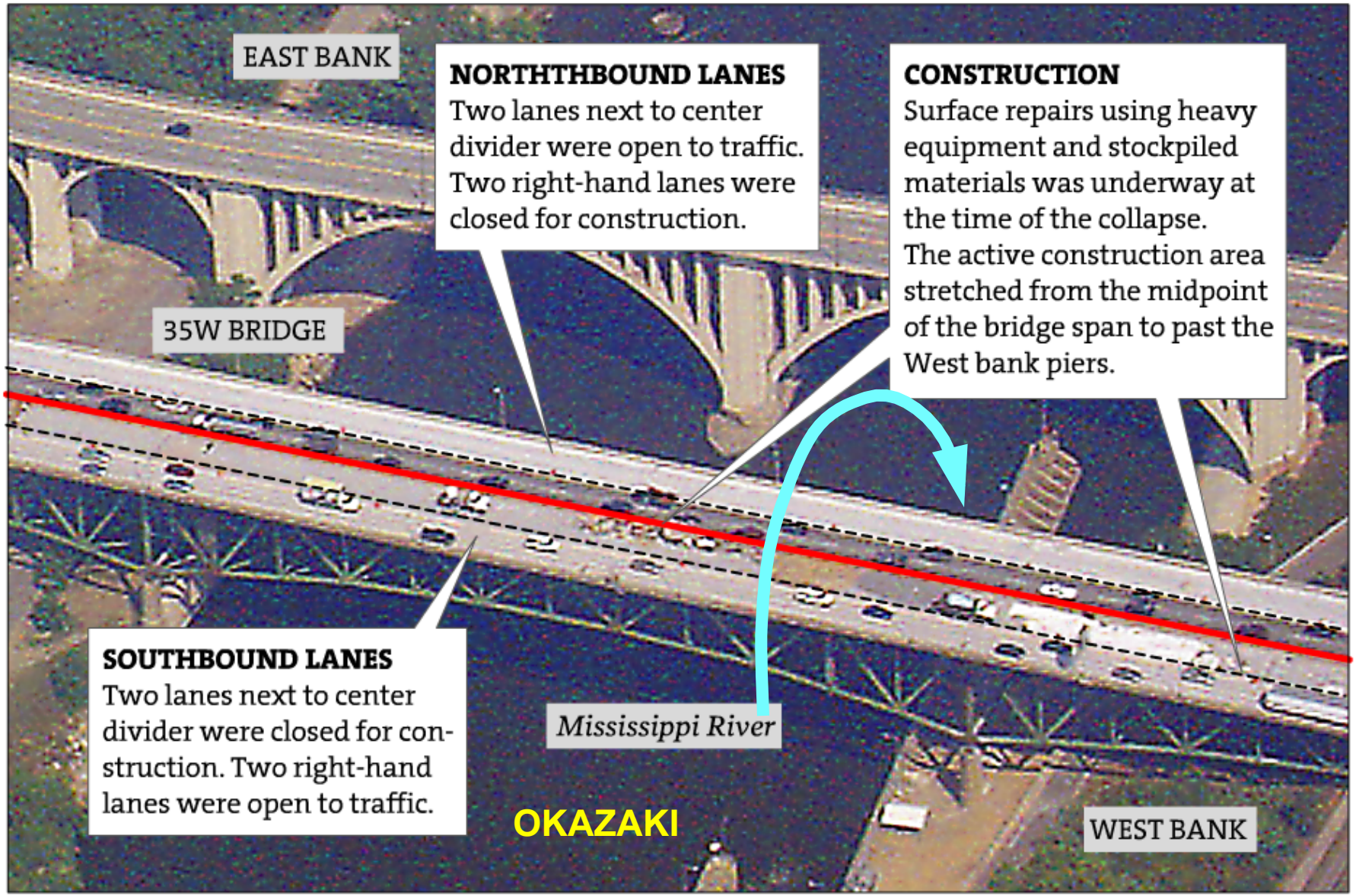
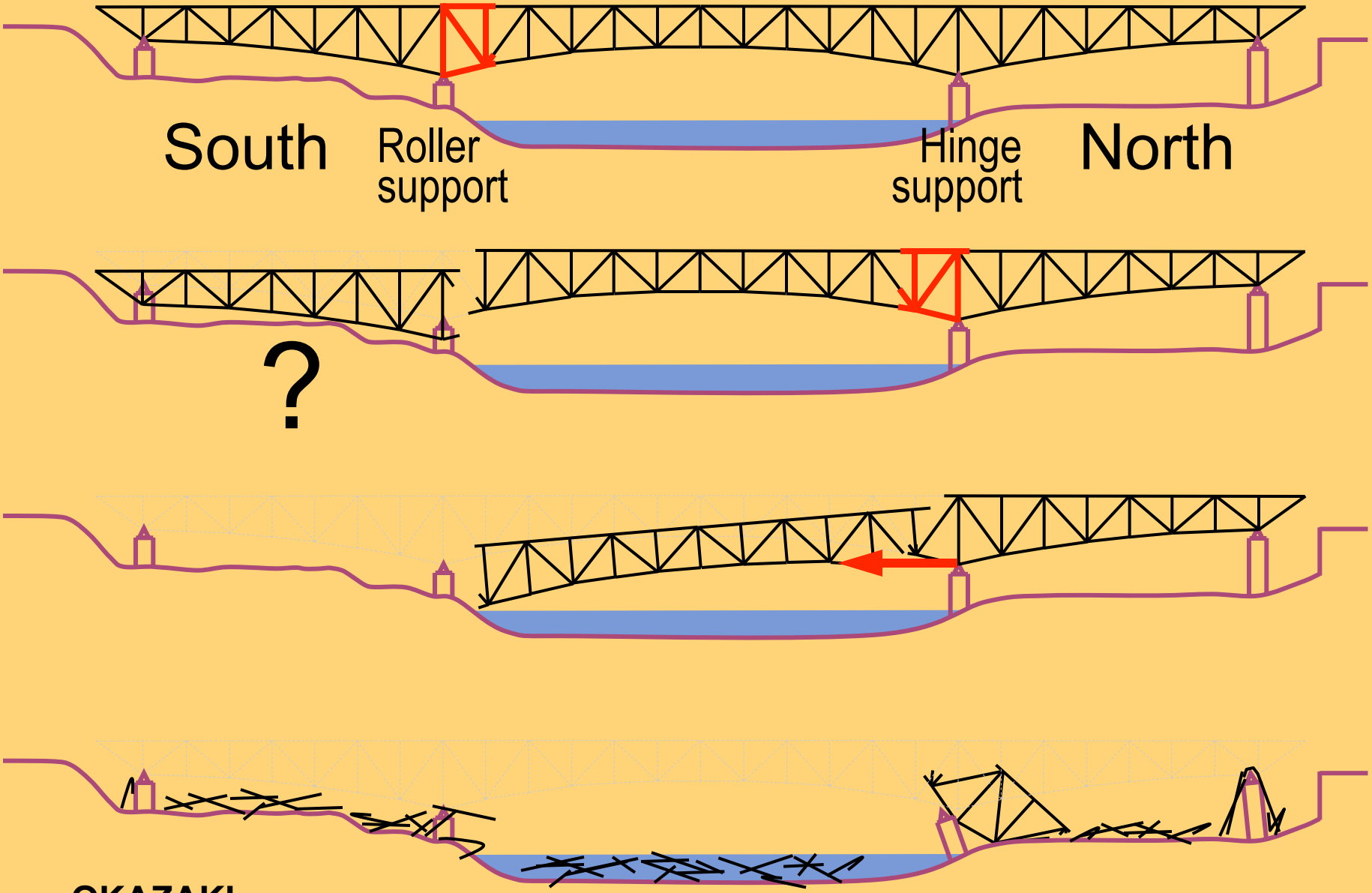


Photo by Michael Coddington • Special to the Star Tribune


South
Roller support
Hinge support
North
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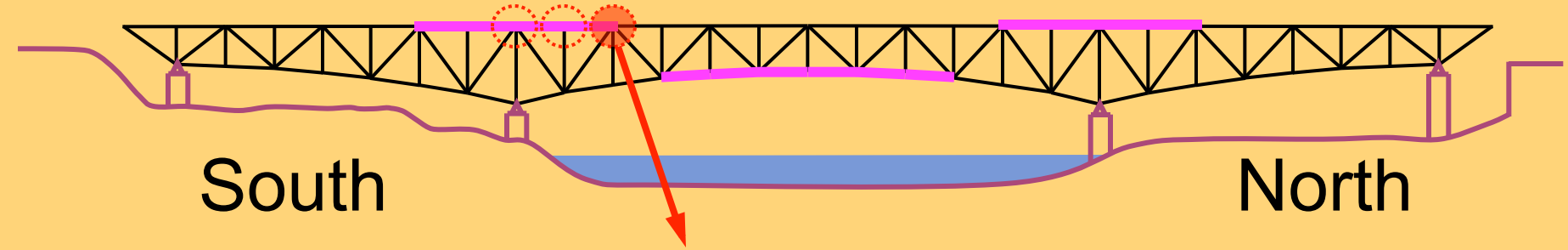
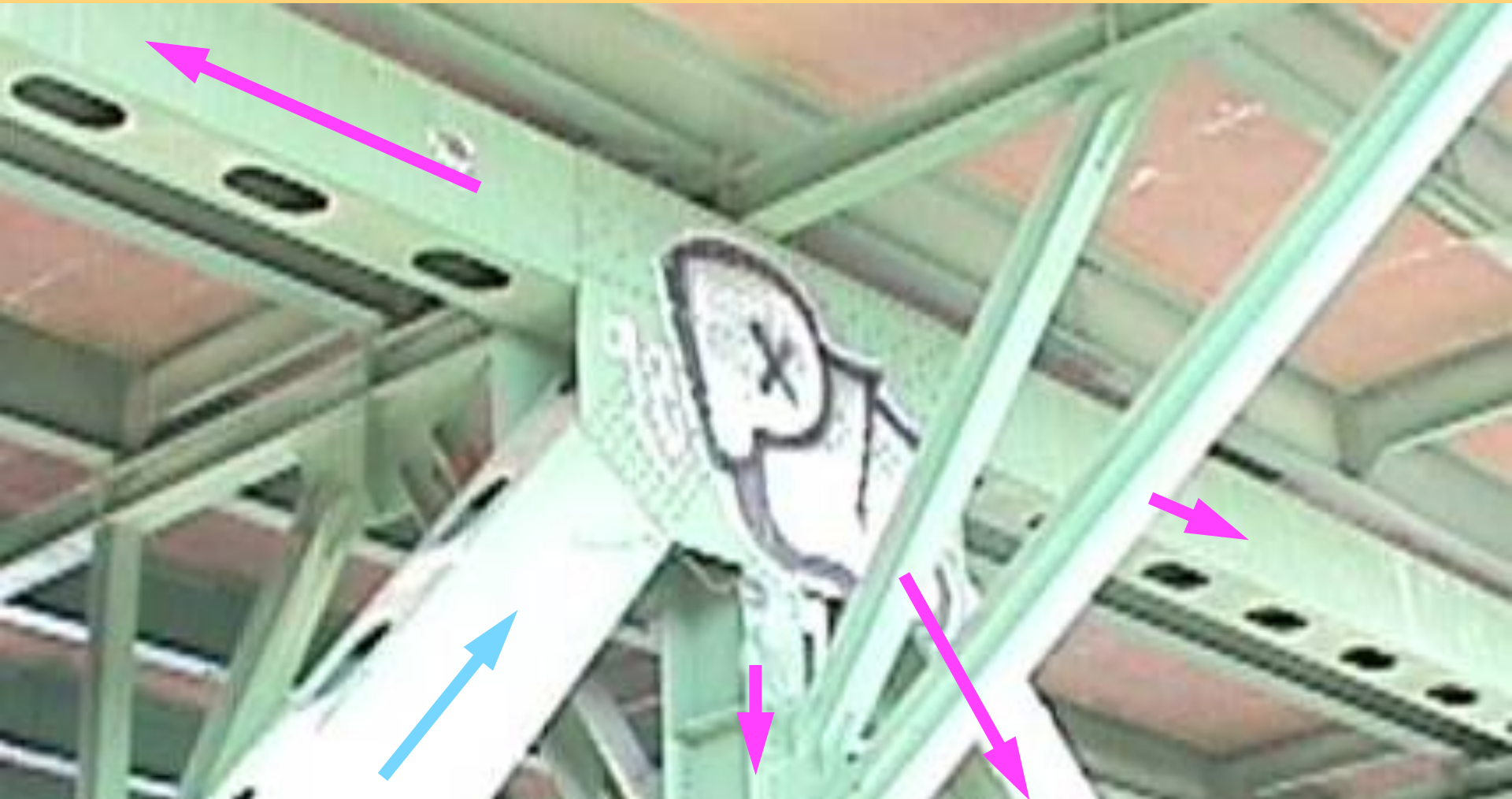
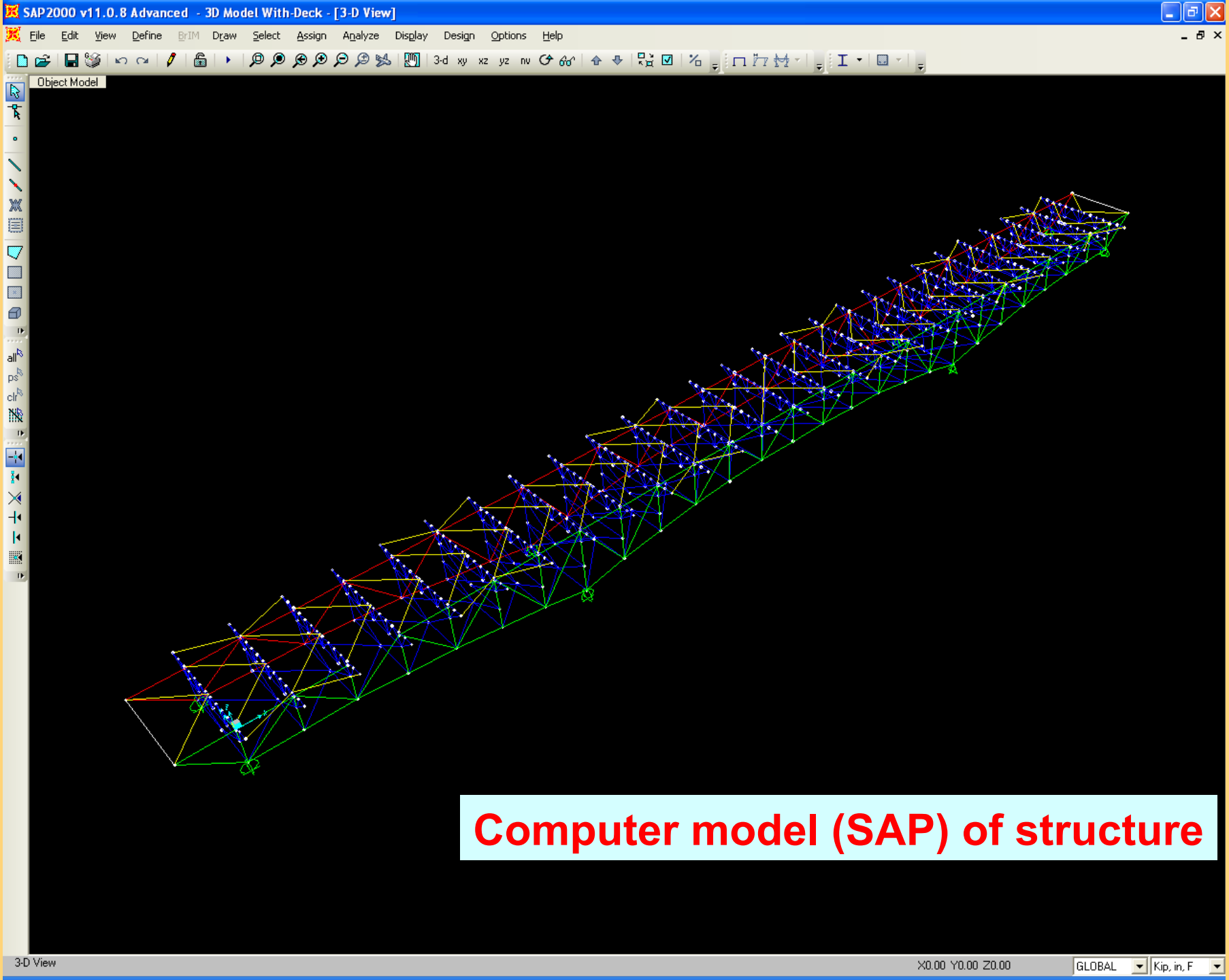
OKAZAKI


South
North




Minmao Liao
A bit grouchy;
Who really did the work?


SAP2000 v11.0.8 Advanced - 3D Model With-Deck - [3-D View]
File Edit View Define BrIM Draw Select Assign Analyze Display Design Options Help
Object Model
Computer model (SAP) of structure
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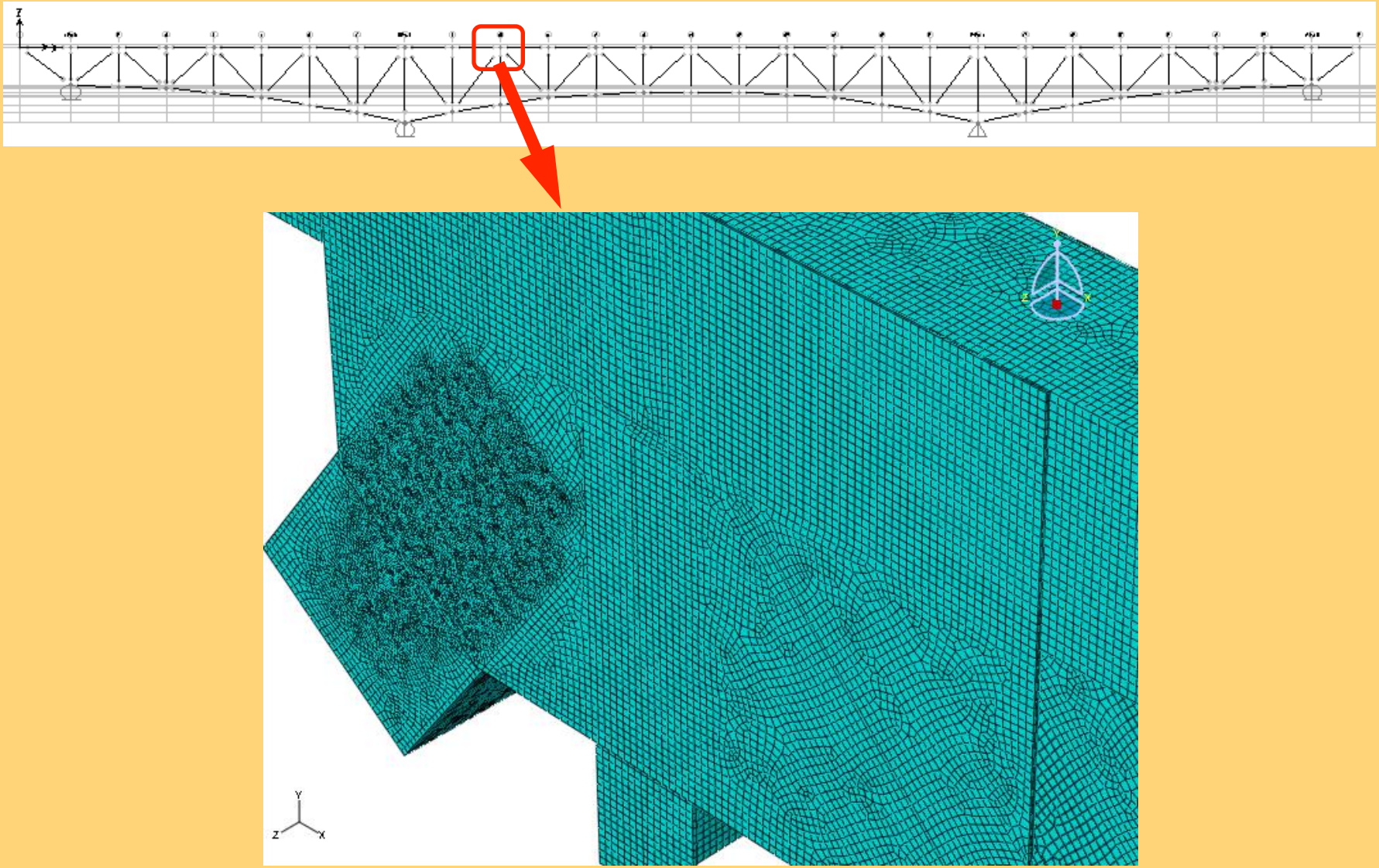
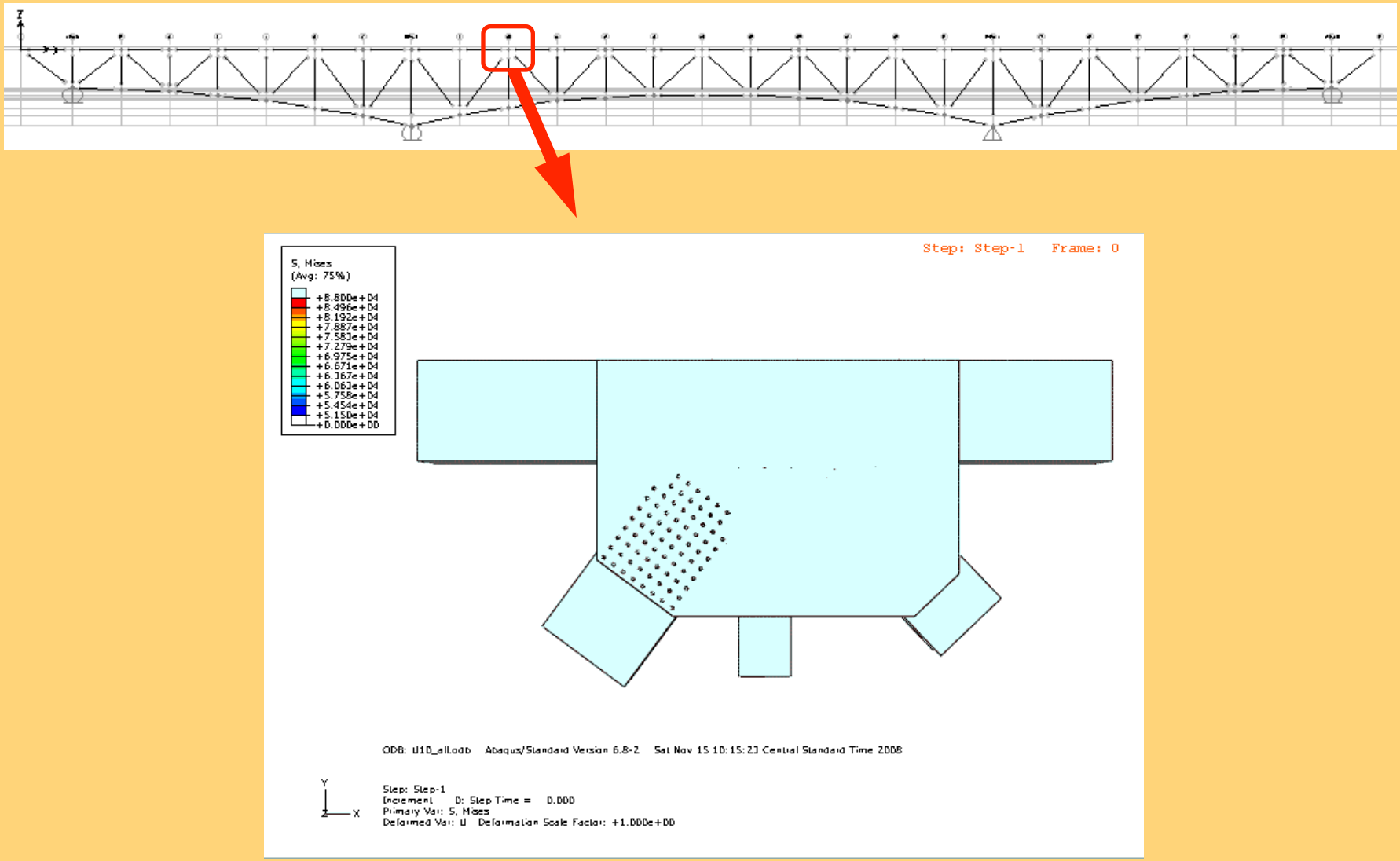
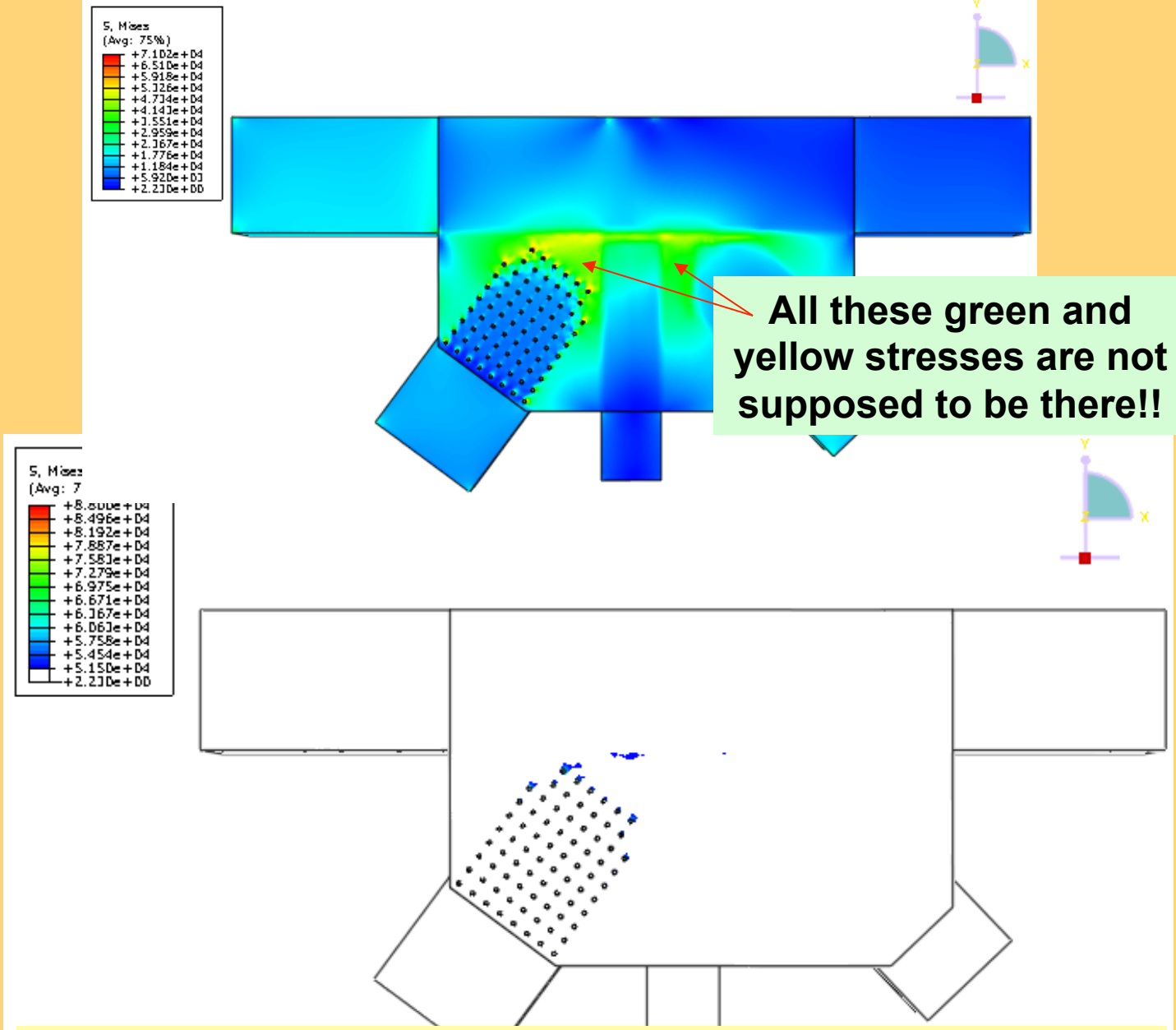


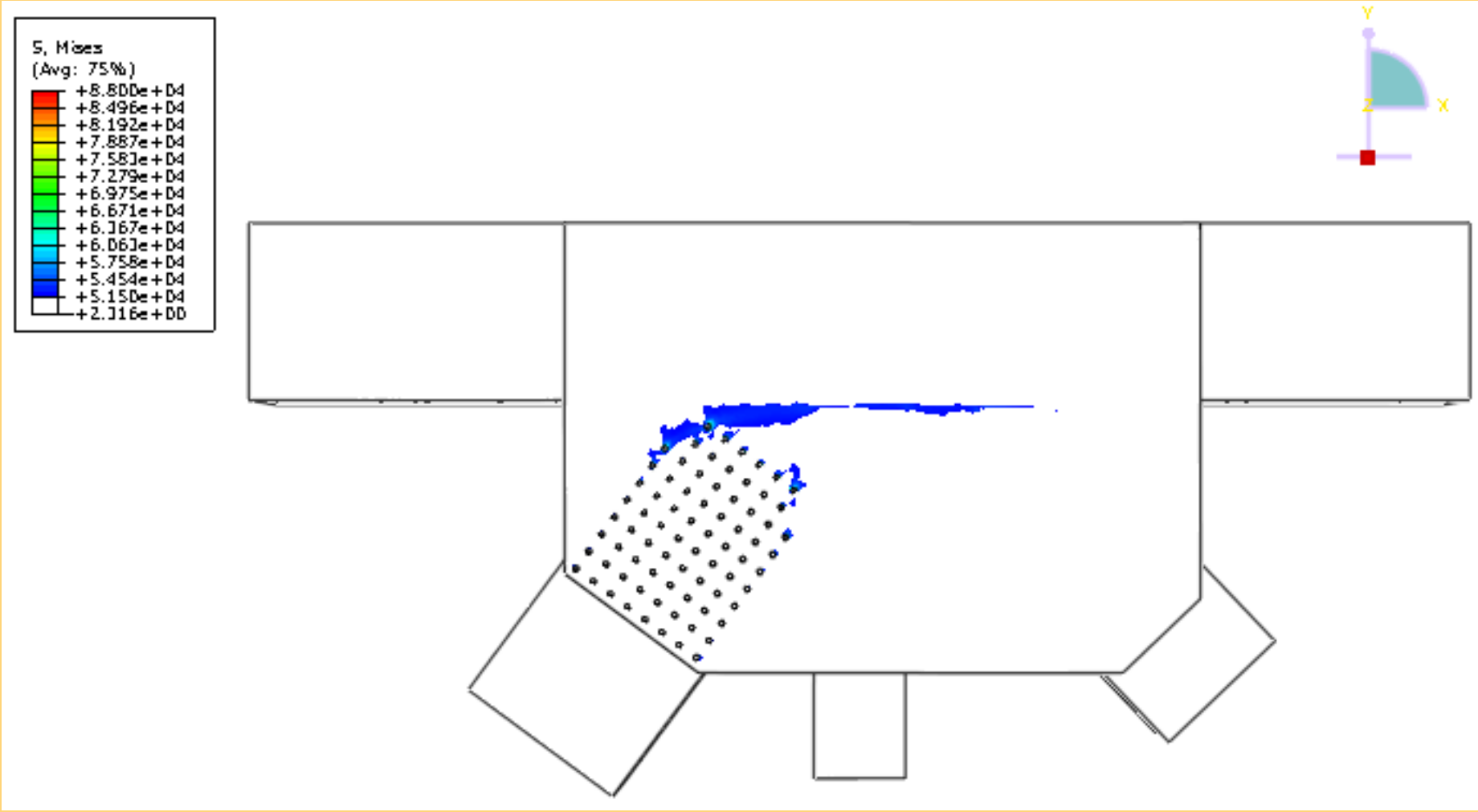
Finite Element Method Model; thanks to
The (University of) Minnesota Supercomputing Institute



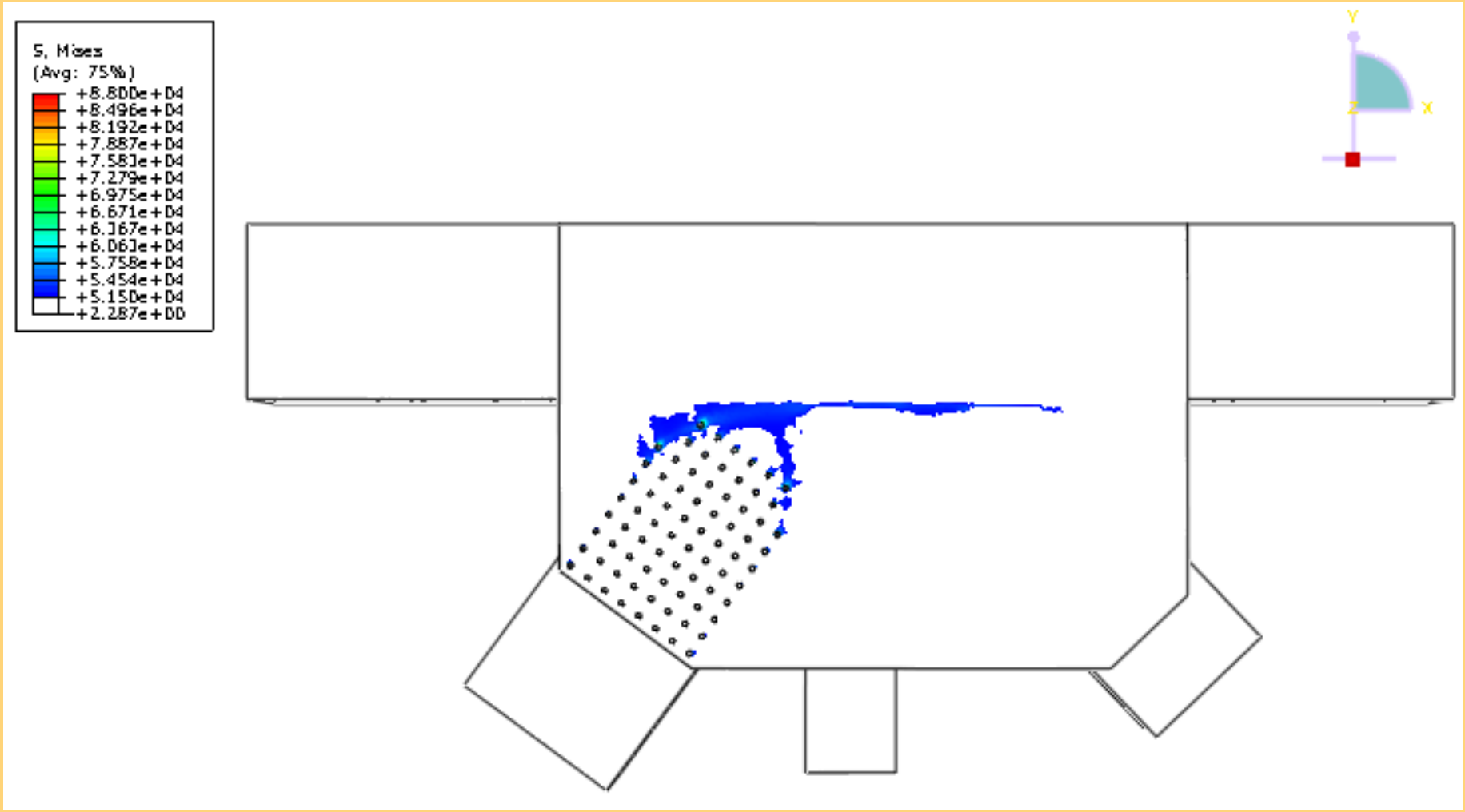
Finite Element Method Model



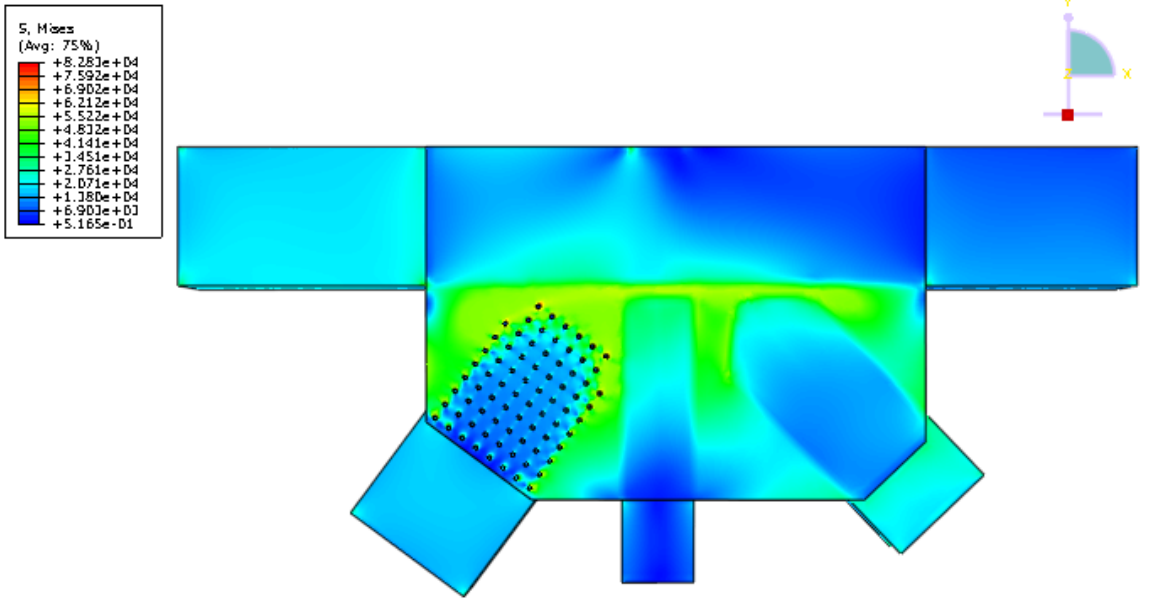
Plastic deformation of as-constructed bridge

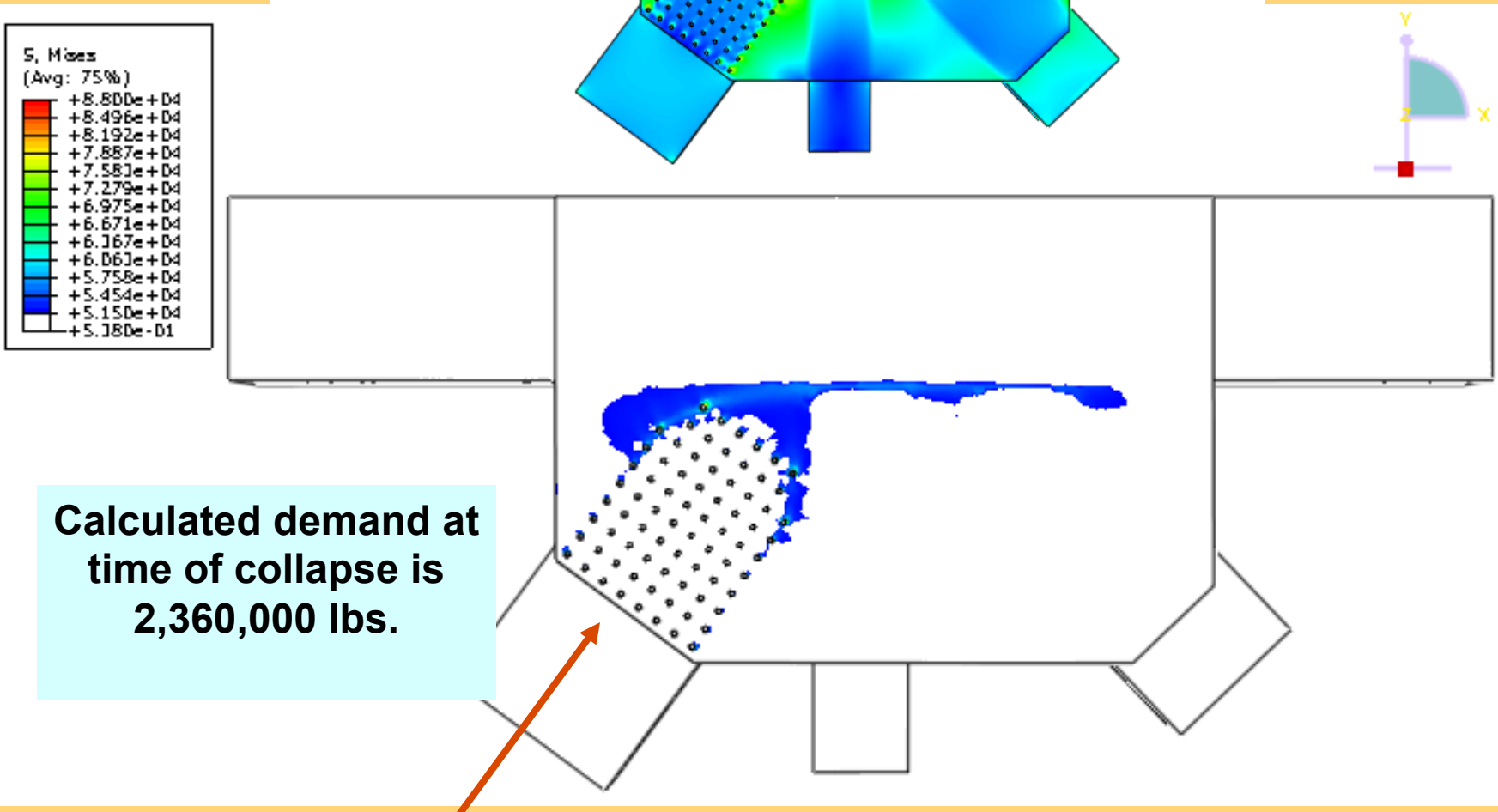


Plastic deformation resulting from increase of slab thickness from 6.5” to 8.5”

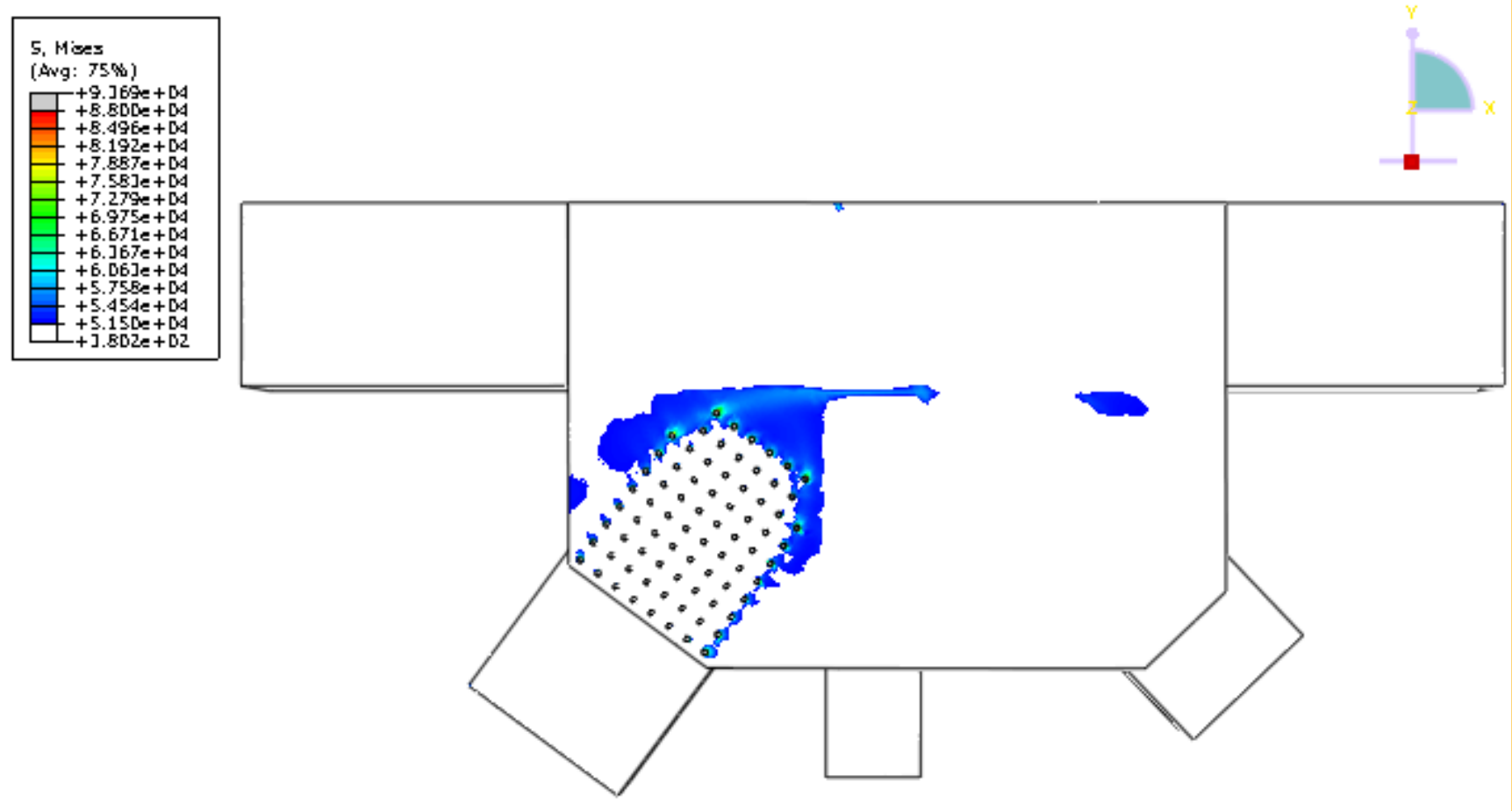


Plastic deformation resulting from averaged traffic load added to 8.5” deck

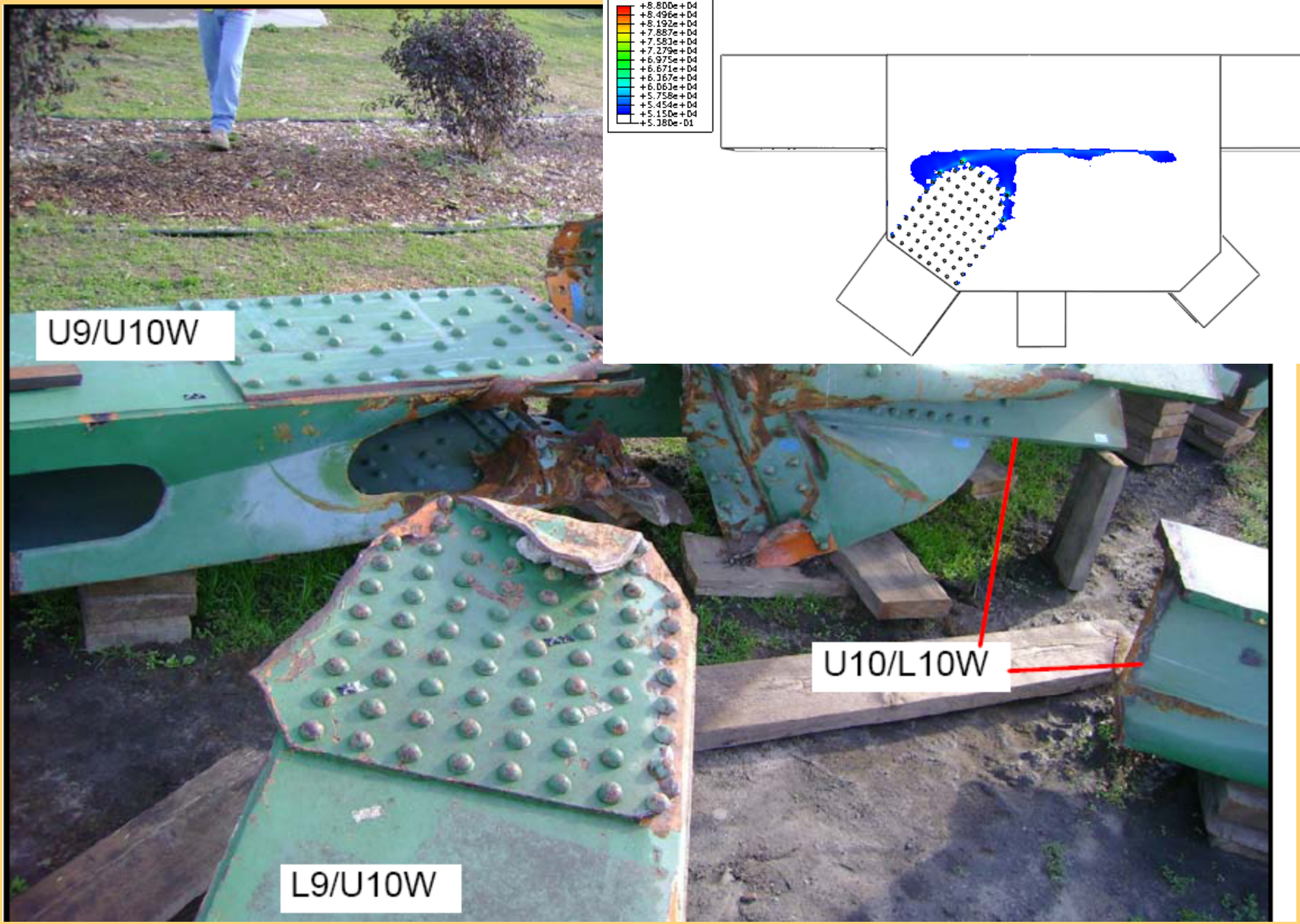




Calculated demand at time of collapse is 2,360,000 lbs.



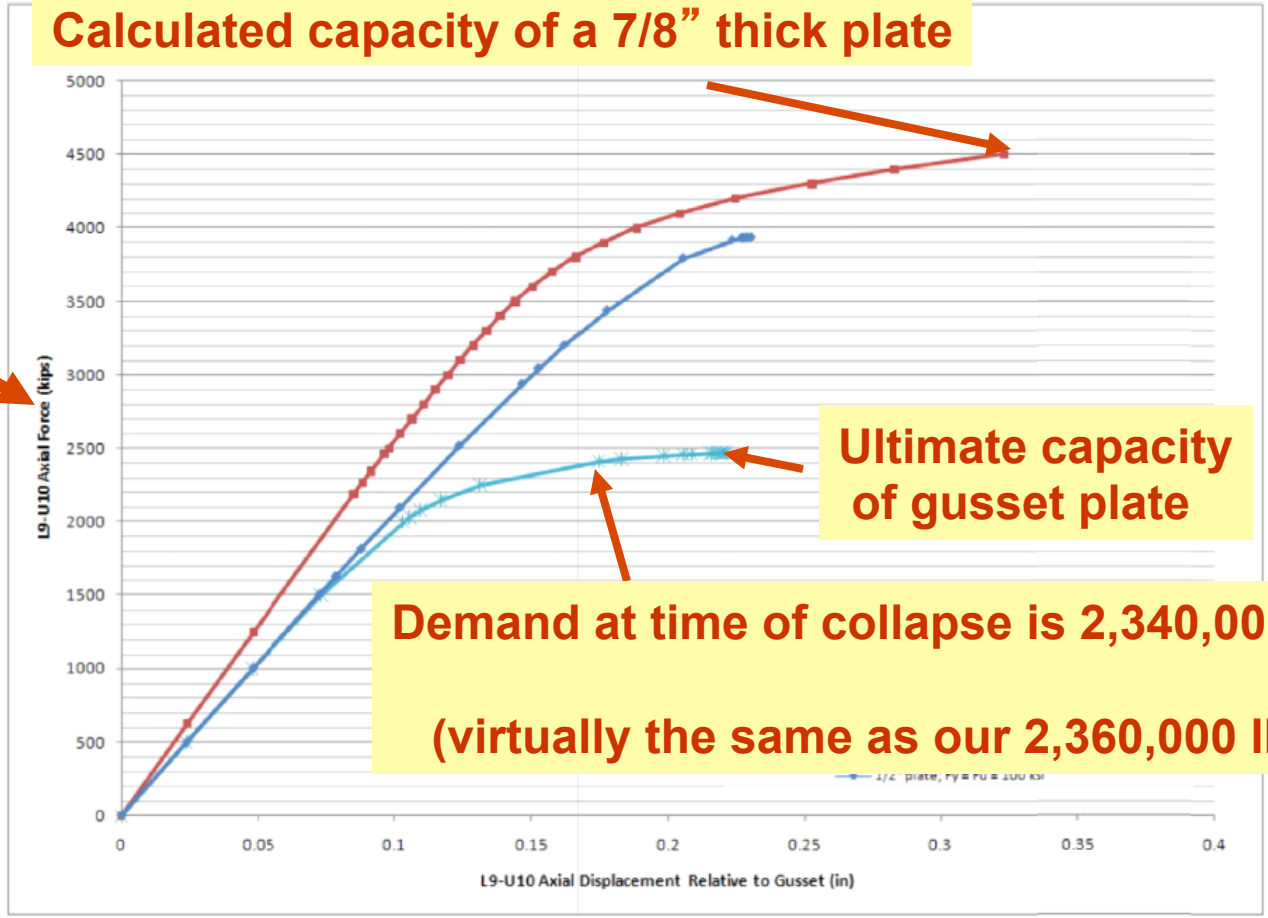
Plastic deformation resulting from addition of 30°F temperature differential from one side of joint to the other


S, Mises
(Avg: 75%)
+8.800e+04
+8.496e+04
+8.192e+04
+7.887e+04
+7.583e+04
+7.279e+04
+6.975e+04
+6.671e+04
+6.367e+04
+6.063e+04
+5.758e+04
+5.454e+04
+5.150e+04
+5.380e-01
U9/U10W
U10/L10W
L9/U10W

A comparison of our results with those In the WJE report

Force in the L9-U10 diagonal framing into the U10 node

Calculated capacity of a 7/8" thick plate



Ultimate capacity of gusset plate

Demand at time of collapse is 2,340,000 lbs

(virtually the same as our 2,360,000 lbs)

Figure 6.9 Load-displacement relationship for various configurations of U10 gusset plate.