



A Structural Reevaluation of the Collapse of World Trade Center 7

September 2017 Progress Report

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Purpose of this study

1. World Trade Center Building 7 (WTC 7) was not struck by a plane and yet it collapsed. Why?
2. The National Institute for Standards and Technology (NIST) issued a report in 2008 concluding that the structure collapsed because fires caused the floor beams and girders to expand, triggering a series of structural failures that culminated in the total collapse of the building.
3. Others argue that fire was not likely the cause of the failure.
4. This project was undertaken to answer the question: Did fire cause this building to collapse?

Project Overview:

- Methodology:
 - Assembled available documents (erection drawings etc.);
 - AUTOCAD - Used to create a virtual geometry for the 47 story building;
 - Prepared ABAQUS nonlinear models for the connections;
 - SAP2000 & ABAQUS - Framing @ 12 & 13 was modeled for fire damage
 - SAP2000 & ABAQUS - Used to study progressive collapse;
 - Virtual structure was used to simulate conditions on September 11, 2001.
- Summary & findings (This is to be peer-reviewed.)

Presentation:

- Findings to date (9-6-2017):
 - Part 1: WTC 7 was not found to collapse by fire.
 - Findings are based on results from ABAQUS & SAP2000.
 - Part 2: Progressive collapse analyses are nearly complete.
 - SAP2000 & ABAQUS are being used for this purpose.
- Acknowledgements:
 - Thanks to Architects & Engineers for 9/11 Truth; University of Alaska Fairbanks (Institute of Northern Engineering & College of Engineering & Mines).

WTC 7 (1983 to 2001)

- Height: 47-stories; an Emery Roth & Sons design with a red granite facade.
- Geometry: trapezoidal footprint, 610 feet tall, 330 ft long & 140 ft wide.
- Construction: Began in 1983 and it was opened in May 1987.
- Foundation: The building was constructed on caissons. It was built above and through a 1967 Con Edison Substation that was designed to carry a future 25 story building. New caissons were added to support the proposed building.
- Structure: A system of gravity column transfer trusses and girders were located between floors 5 and 7. The 5th floor functioned as a structural diaphragm, providing lateral stability and distribution of loads between the new and old caissons. Above the 7th floor, the building's structure was a typical tube-frame design, with columns in the core and on the perimeter, and lateral loads were to be resisted by perimeter moment frames.

WTC 1, 2 & 7

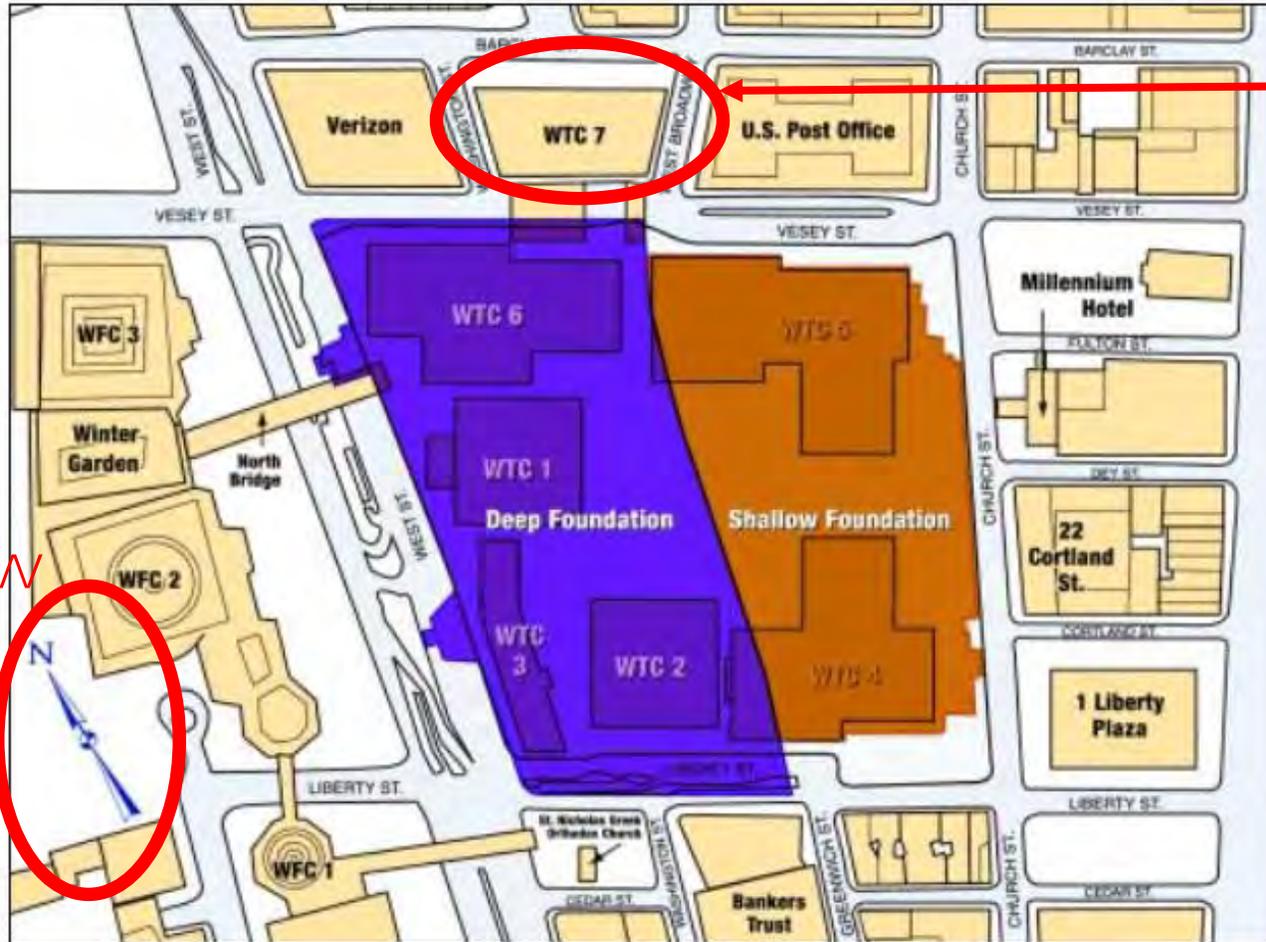


WTC7

**Located about 350 ft
North of WTC1**

WORLD TRADE CENTER
COMPLEX – (Elev.)
Prior to Sept 11, 2001

WTC 7: Sept 11, 2001



This study

WORLD TRADE CENTER COMPLEX – (Plan) Prior to Sept. 11, 2001.

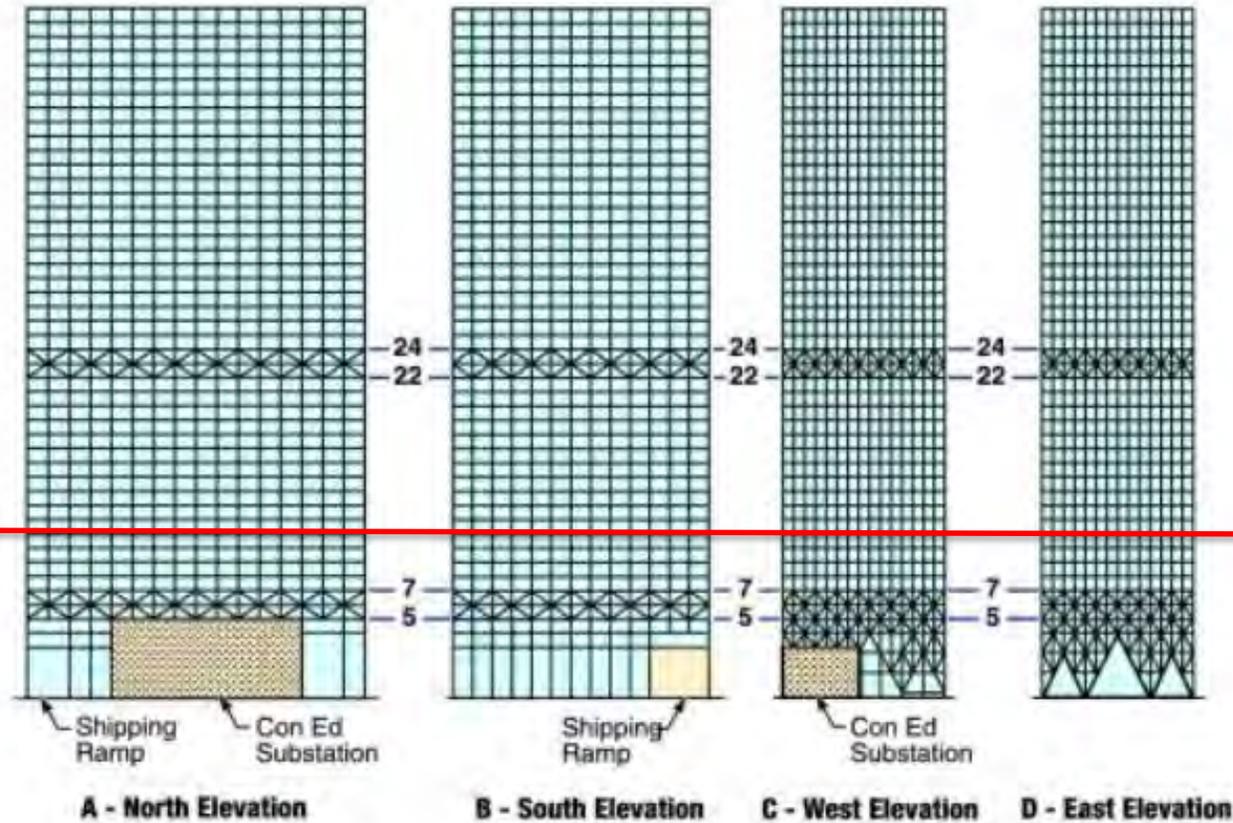
This building was not struck by a plane; yet it collapsed.

North Arrow

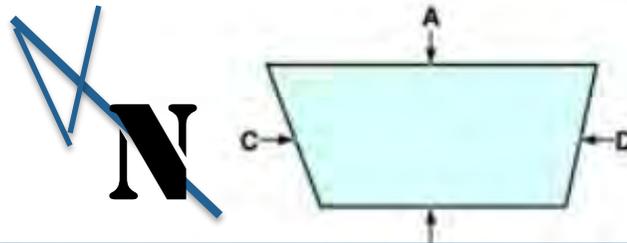
WTC 7 (Different Elev. Views)

(floor) 13

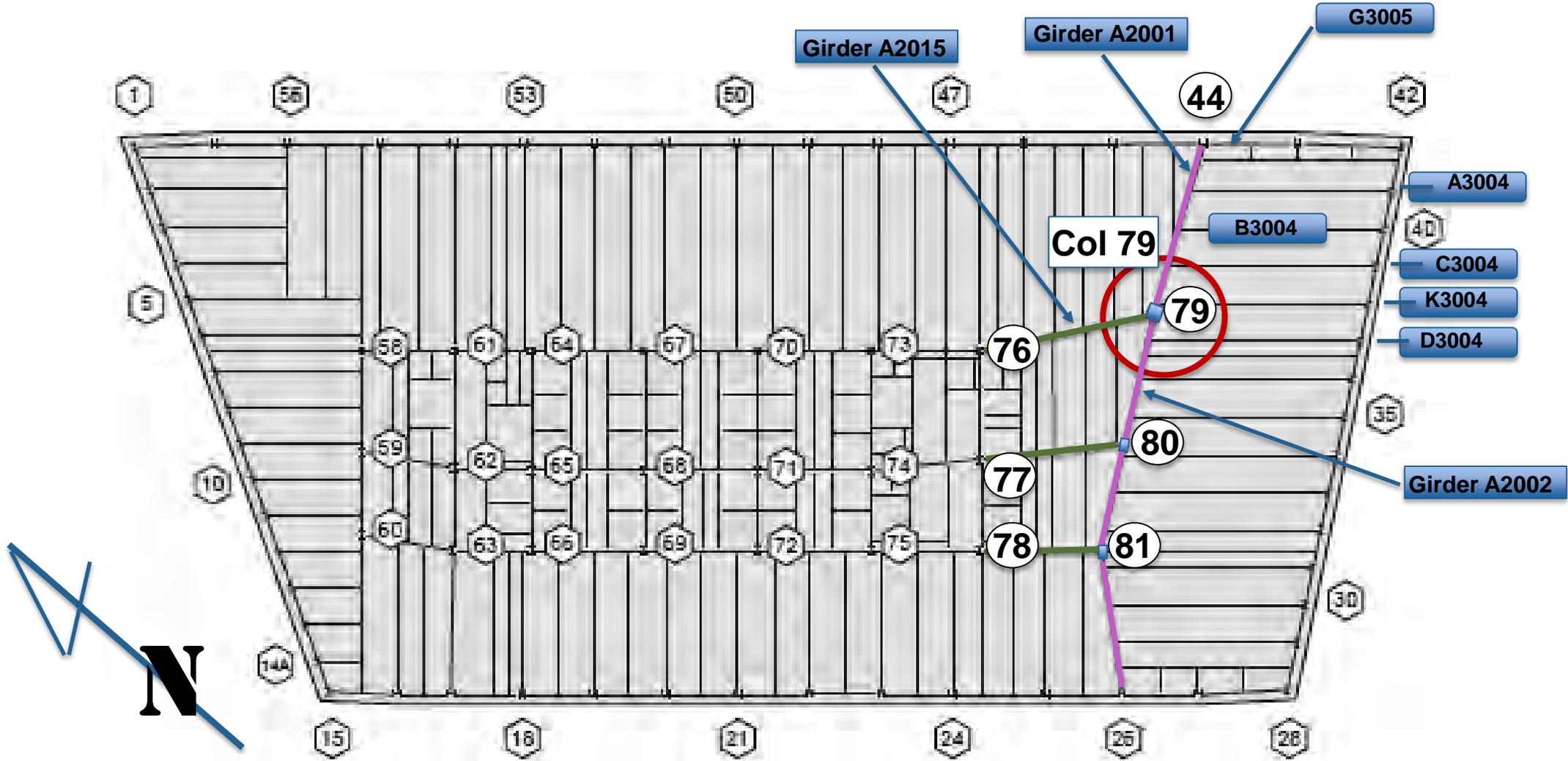
13 (floor)



NOTE: Belt trusses located at floors 5-7 and 22-24.



WTC 7 (Framing for floor 13)





Where were the fires?

- It is reported fires were on floors 7-9, 11-14, 19, 22, 29, & 30 (after NIST).

One hour before collapse

(No evidence of fires below floor 7)

NIST FOIA: WTC 7 on Fire - Version #3 (Vince DeMentri, WCBS-TV)

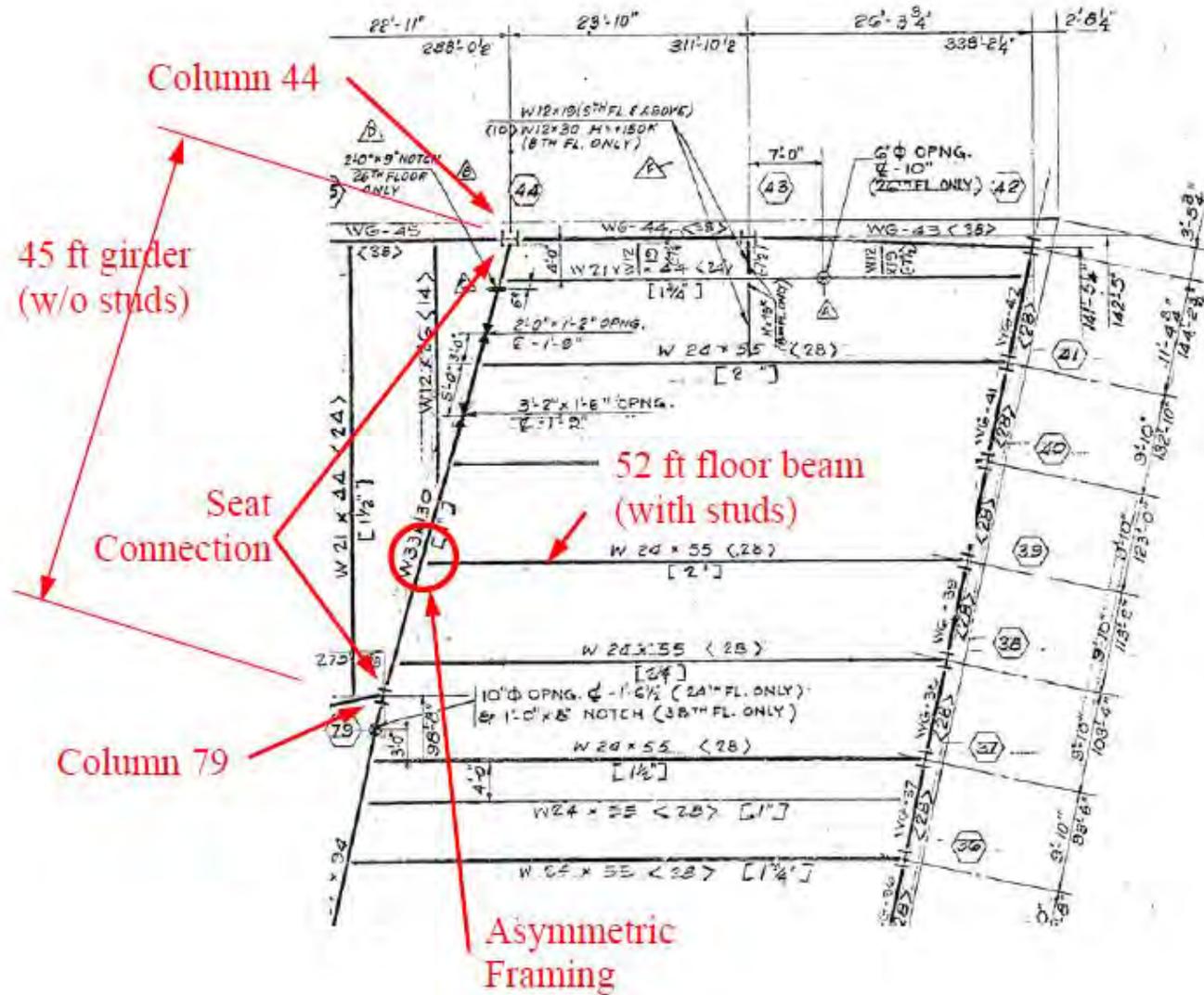
The video player displays a low-angle shot of the World Trade Center 7 building. The building's facade is covered in windows, many of which are dark, while others show signs of fire and smoke. Three red numbers are overlaid on the left side of the building, marking floors 3, 5, and 7. Two red arrows point from the text 'NO FIRE!' to the windows on floors 5 and 7. The video player interface includes a play button, a progress bar at 6:55 / 10:00, and settings and full-screen icons.

Did WTC 7 Collapse from Fires?

- Our study shows fire was not the cause.
- This contradicts findings presented by NIST.
 - Our presentation will address this issue.
 - We will discuss the NIST approach; and
 - Our approach and findings.
- **What's next?**
 - Progressive collapse analyses are ongoing.

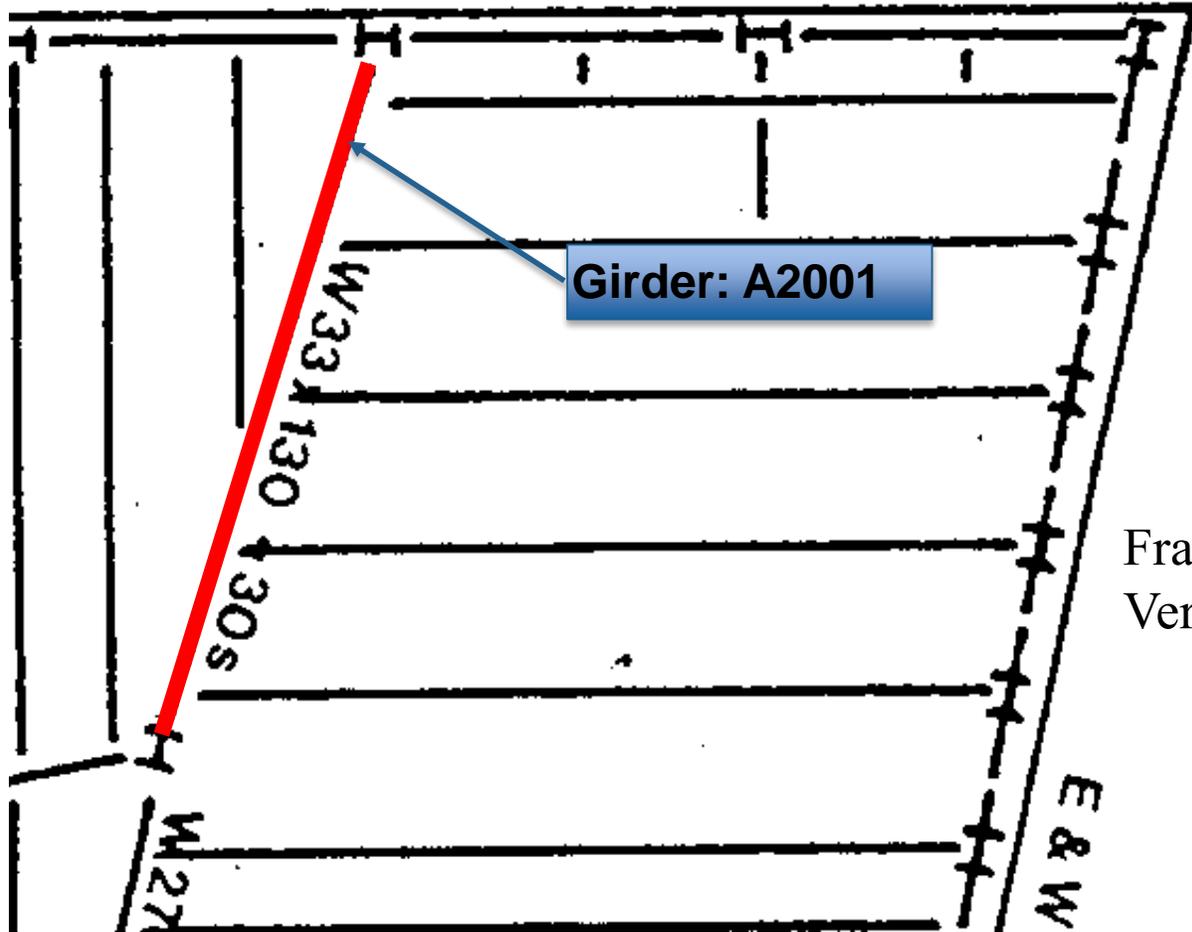
NIST Assumptions & Claims Used in UAF Analysis

- The building collapsed due to fire. The fires caused thermal expansion of beams and girders that made up the steel frame supporting structure.
 - Beam temperatures reached 600 °C. Girder temperatures (A2001 and A2015) reached 500 °C and column temperatures reached 300 °C.
 - No east exterior wall deformation occurred due to expansion of beams K3004, C3004, B3004, A3004, and G3005.
 - No shear studs were installed on the building girders.
 - Shear studs on beams K3004, C3004, B3004, A3004, & G3005 were broken.
 - Bolts fastening girder A2001 to its seats at columns 44 and 79 were broken.
 - Floor loading was 88 lbs./ft².
 - NIST computer model results were based on exterior columns being fixed in every direction.



Contrary argument to girder missing shear studs

Plans show: 30 shear studs equally spaced along girder A2001



Frankel Steel Project Mgr. Salvarinas, 1986
 Verified by ARUP's Bailey in 2010



NIST Conclusions

1. Fire-induced weakening of critical columns did not cause the WTC 7 to collapse (ref. NIST NCSTAR1-9, pg. 614)
2. Temperature in Column 79 was below 200°C (same ref).
3. Movement along the axis of beams K3004 to G3005 was caused by thermal expansion.
4. Lateral displacement of the girder framing into Column 79 was result of thermal expansion of the beams framing into the girder.

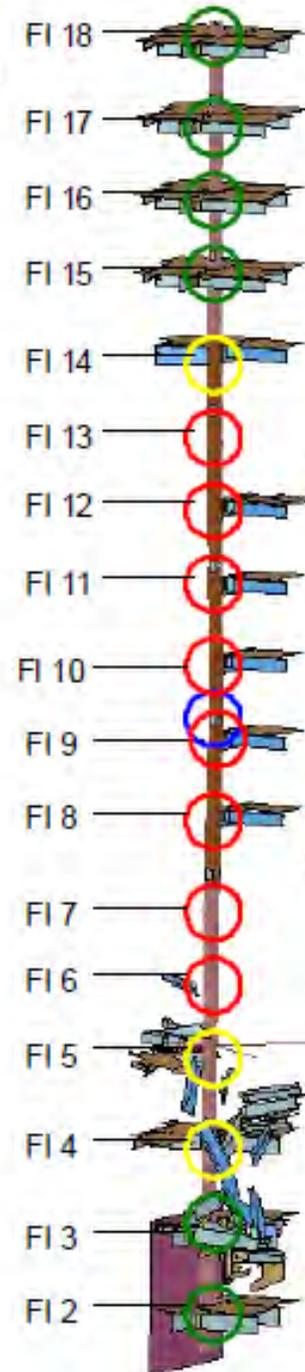
NIST

(Ref: NCSTAR 1-9)

Column 79:

Loss of lateral support for 9 stories (Floors 6 to 13) caused buckling to initiate.

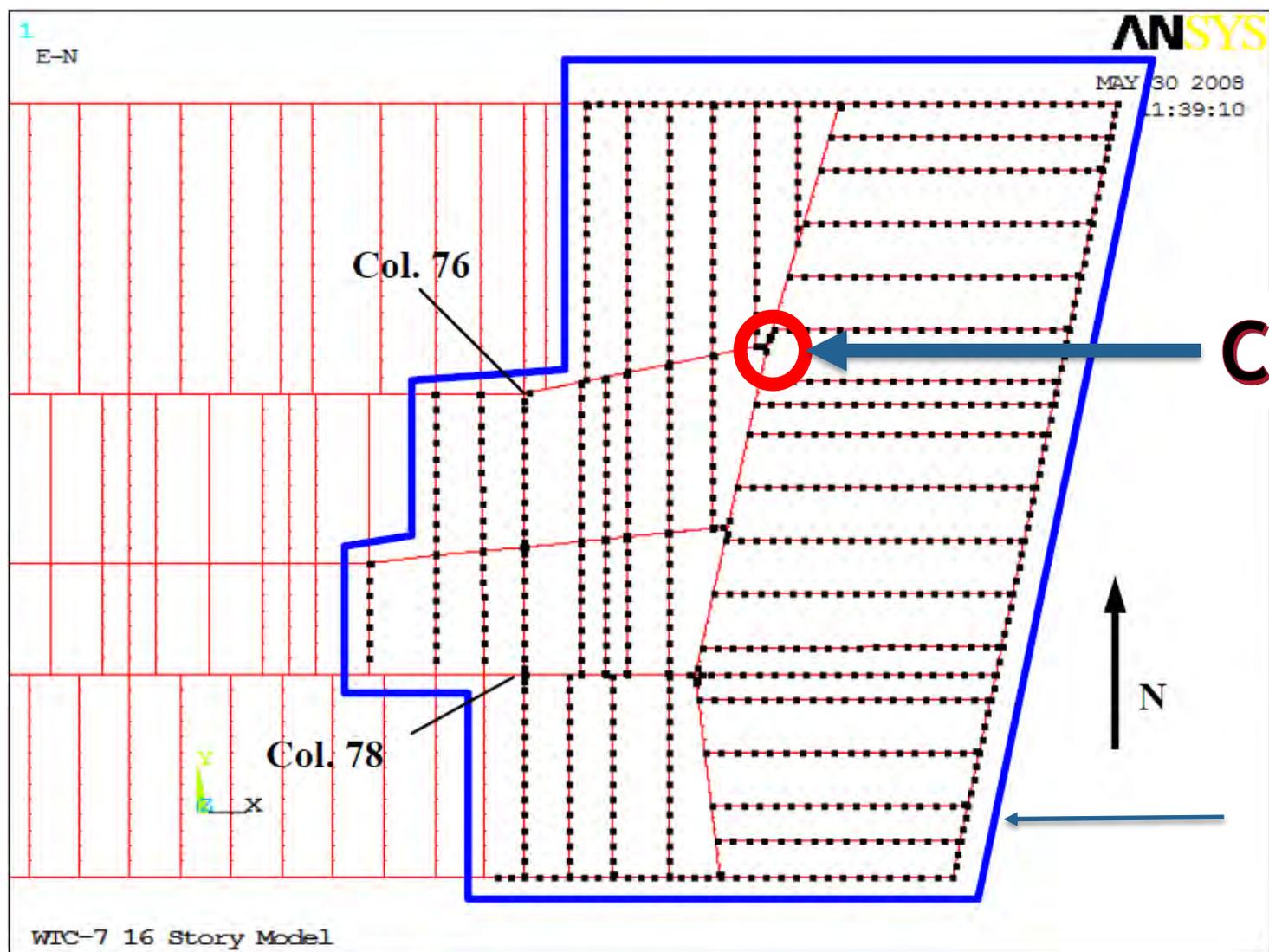
Column 79
at
-1.3 (14.7) s



- Buckling initiation points
- No support
- Partial support
- Full Support

View from southeast

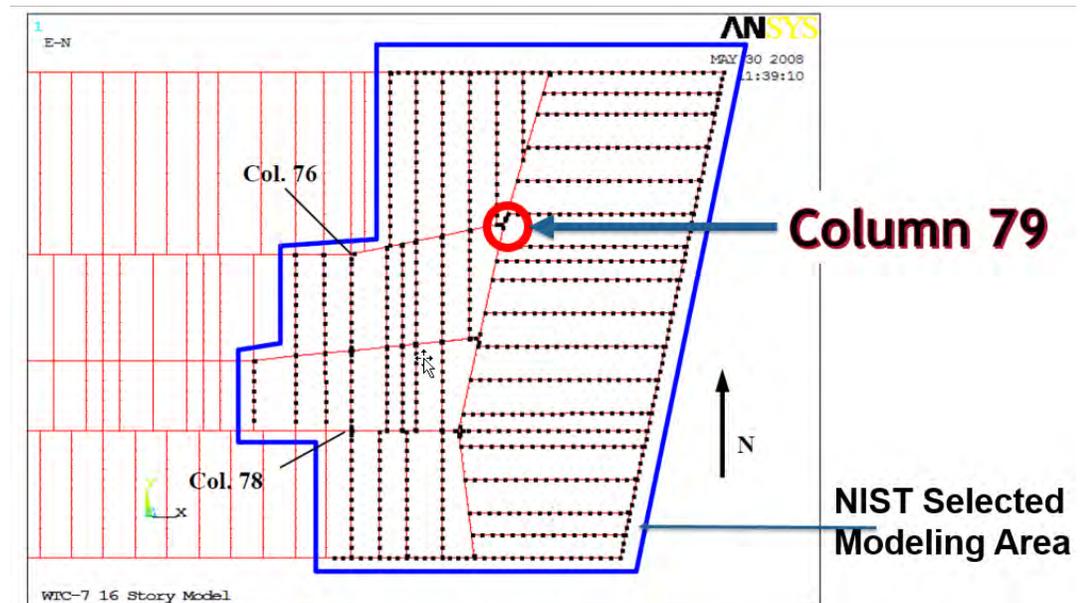
View from southeast



Area of floor where connections were modeled (Floors 8 to 14)
(NIST After, 2004)

NIST MODEL; Ref (NIST, 2004)

1. Outside the selected area, connection failures were not modeled (NIST used fixed or pinned connections).
2. Connections were not modeled for the exterior moment frame.



“A girder was considered to have lost vertical support when its web was no longer supported by the bearing seat. The bearing seat at Column 79 was 11 in. wide. Thus, when the girder end at Column 79 had been pushed laterally at least **5.5 in.**, it was no longer supported by the bearing seat.”

NIST changed the 5.5 to 6.25 inches when it was shown that the seat was actually 12 inches wide.



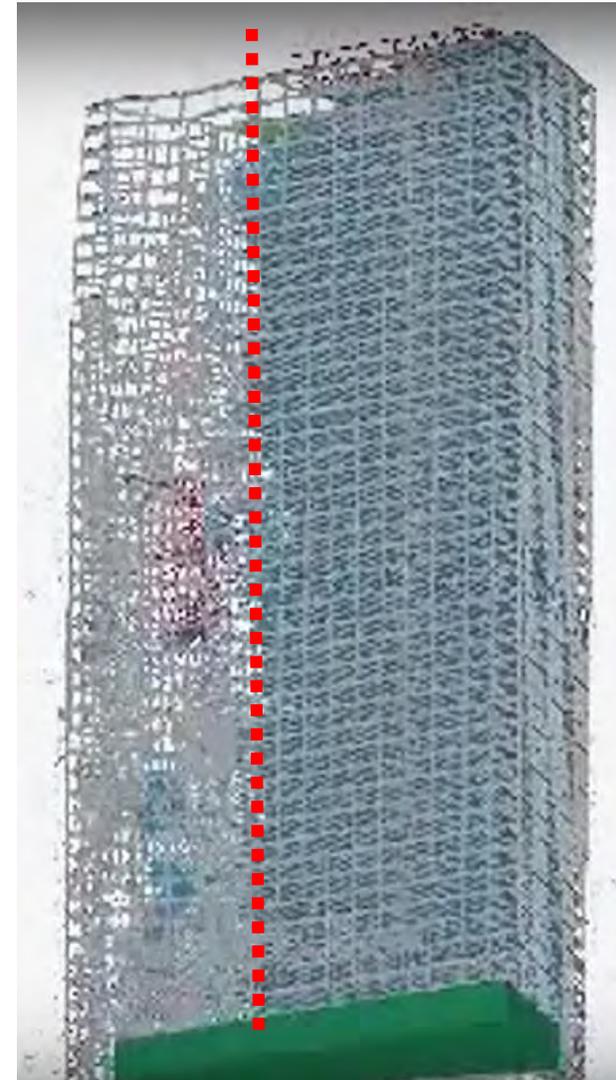
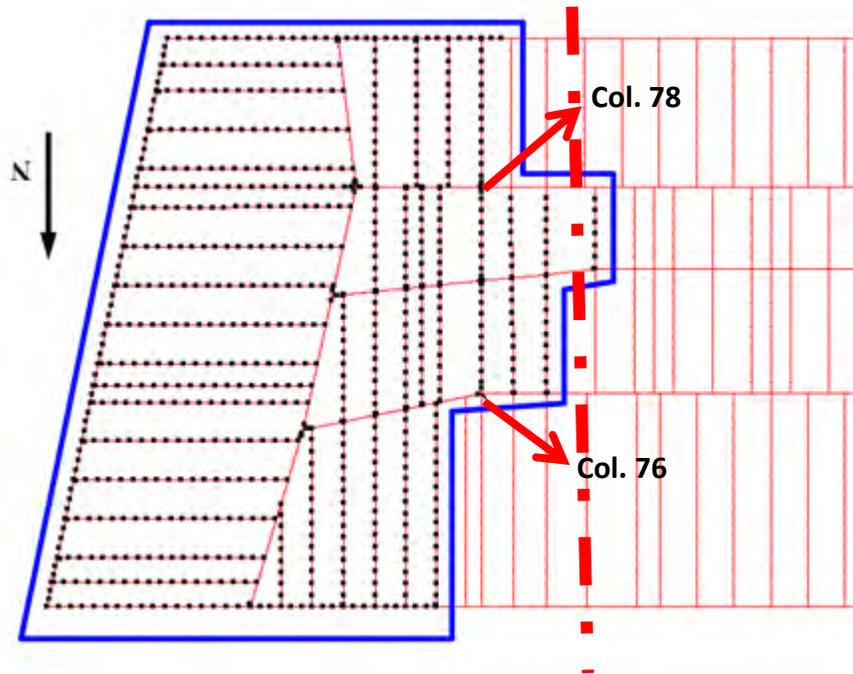
NIST Results:



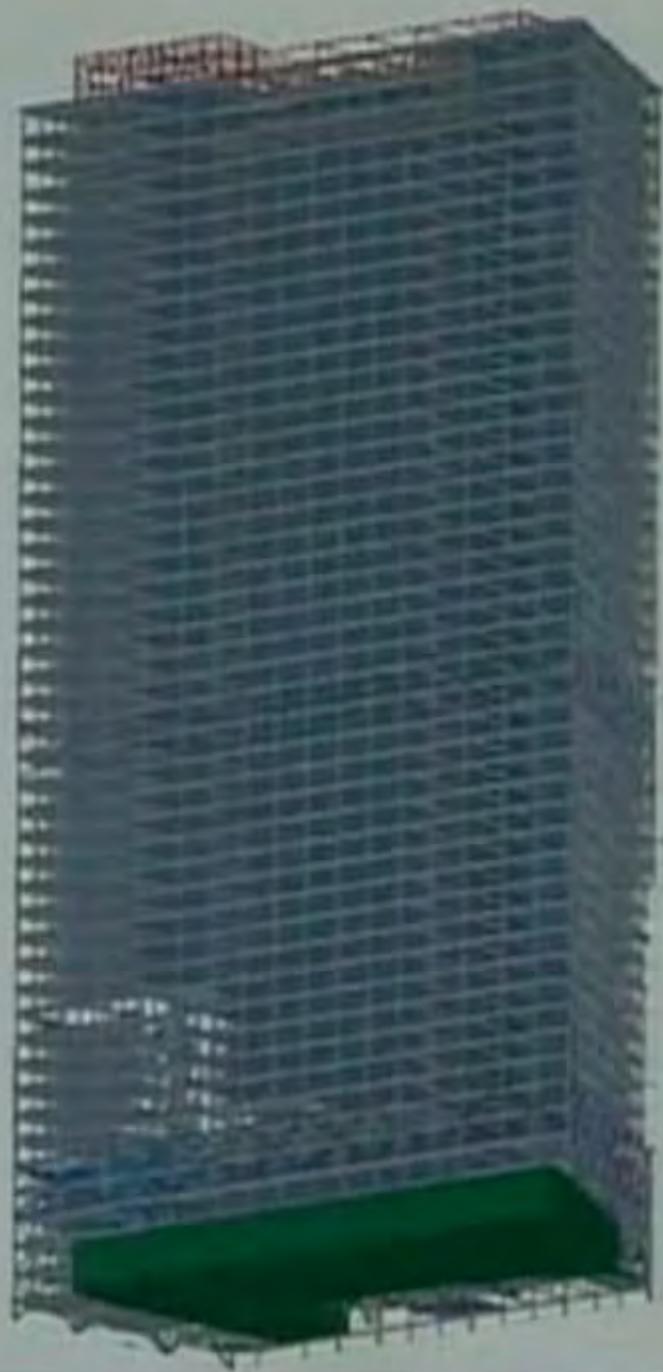
Video vs. NIST WTC7 collapse animation comparison

No exterior column deformation is evident in the actual collapse. Deformation is seen in the NIST model.

Connections were not modeled; outside selected blue space.



LSDYNA Model of WTC-7
Time = 14.9

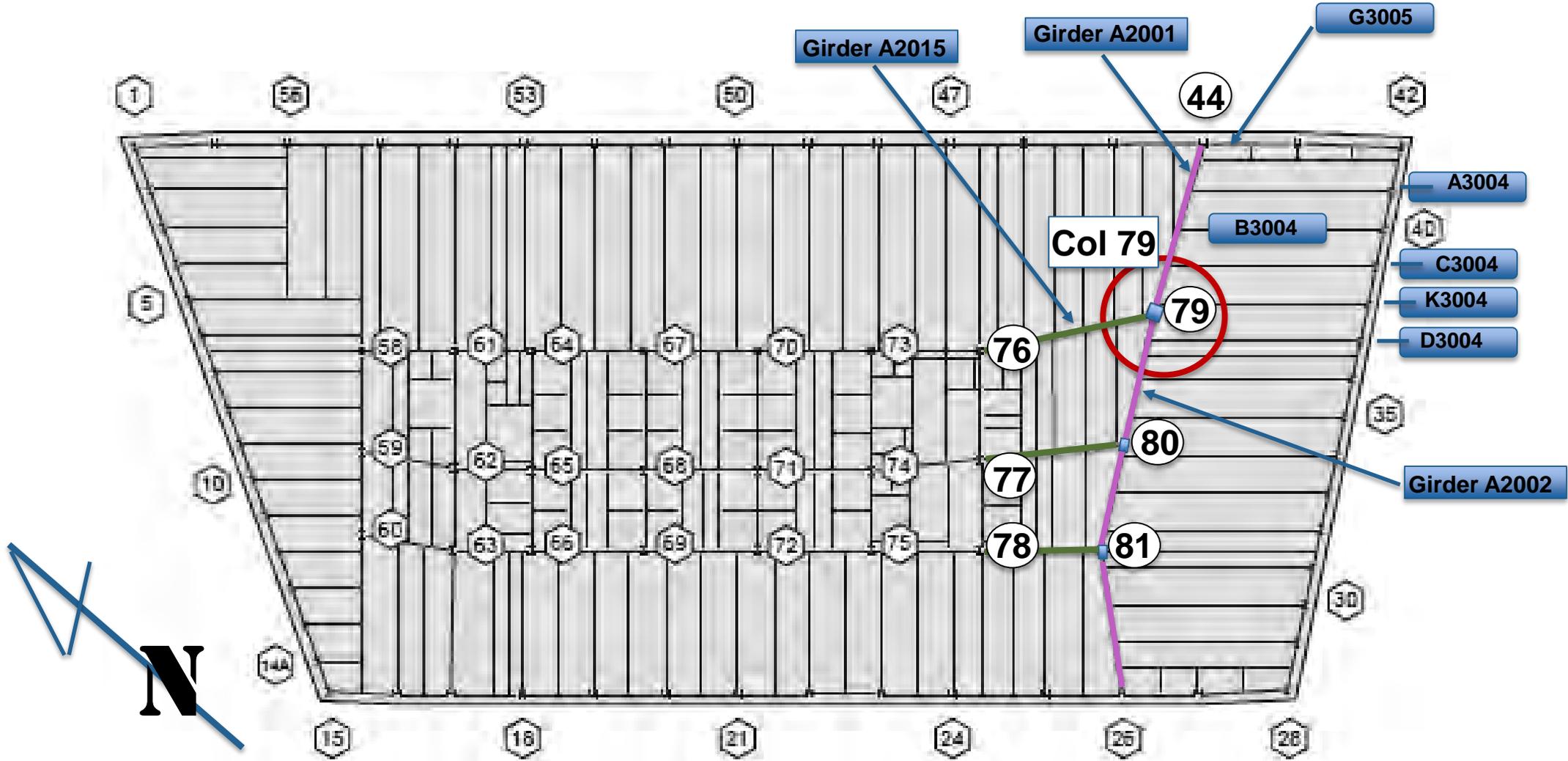


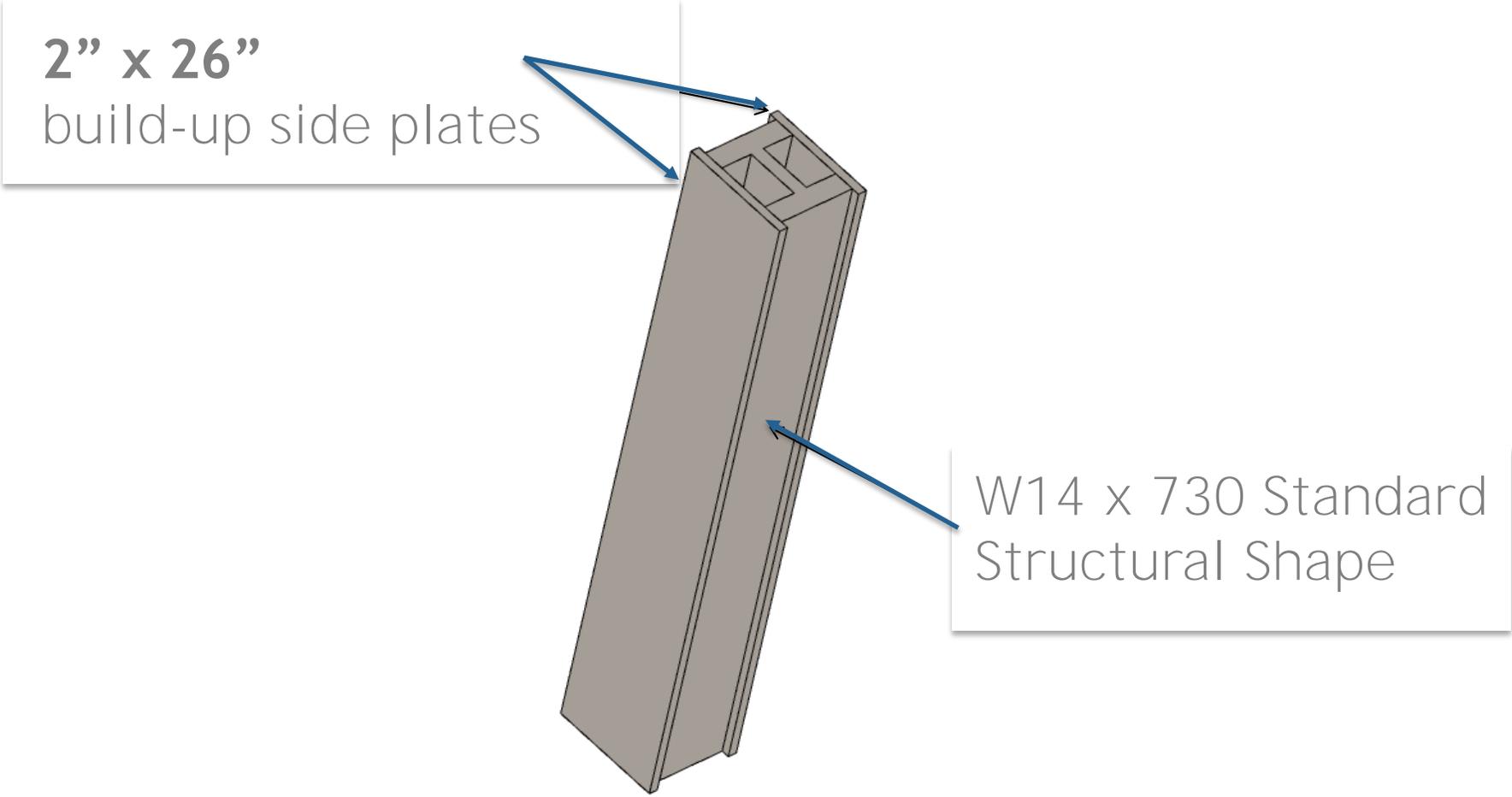
UAF: Analysis of the NIST Collapse Initiation Hypothesis and Propagation Claims

UAF Analysis of the NIST Collapse Initiation Hypothesis and Propagation

- A solid model of the structural members in the northeast corner of the 13th floor of WTC 7 was generated. A finite element analysis was then performed to replicate the result claimed in the NIST WTC 7 report that girder A2001 was pushed or rocked off its seats at columns 44 and 79 to initiate the collapse of the building.

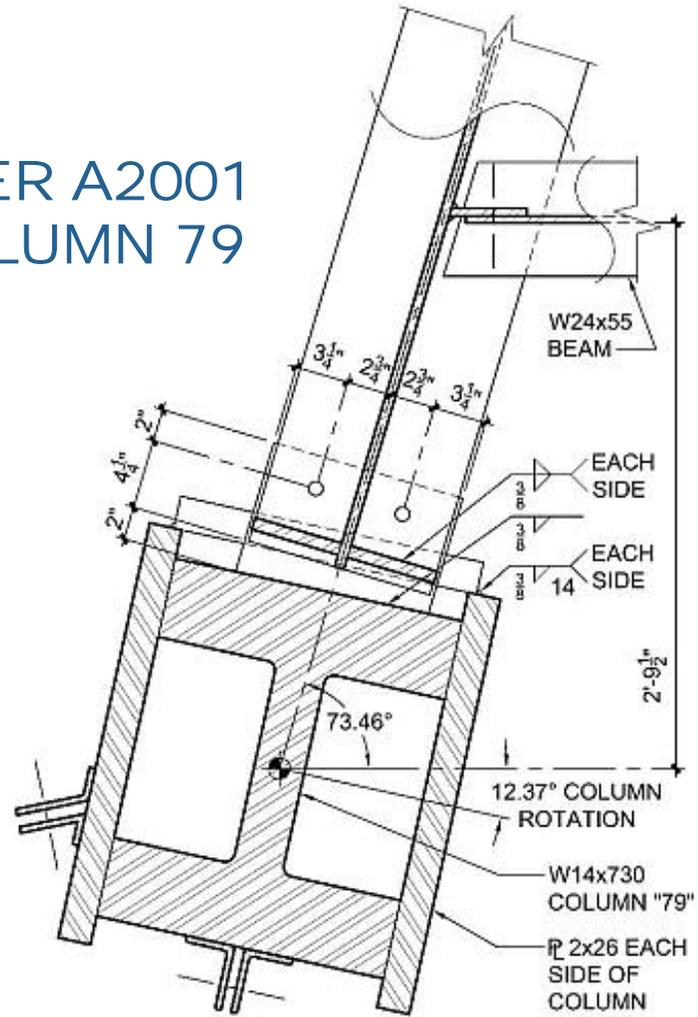
WTC 7 (Framing for floor 13)





Section of Column 79 (showing side plates)

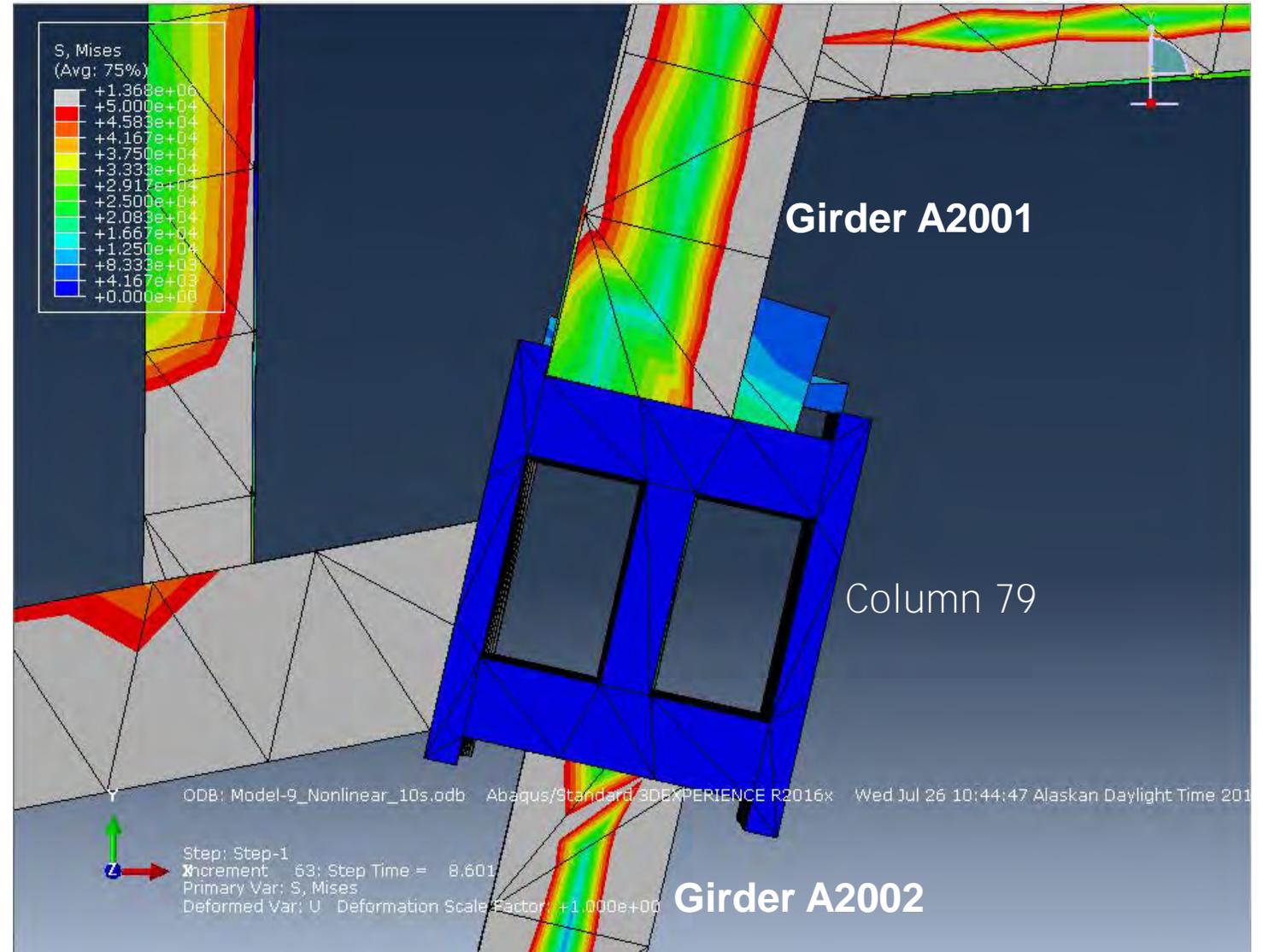
PLAN VIEW OF GIRDER A2001 CONNECTION TO COLUMN 79



Plan View of girder A2001 moving across its bearing seat at column 79 due to thermal expansion of the beams framing into the girder from the east.

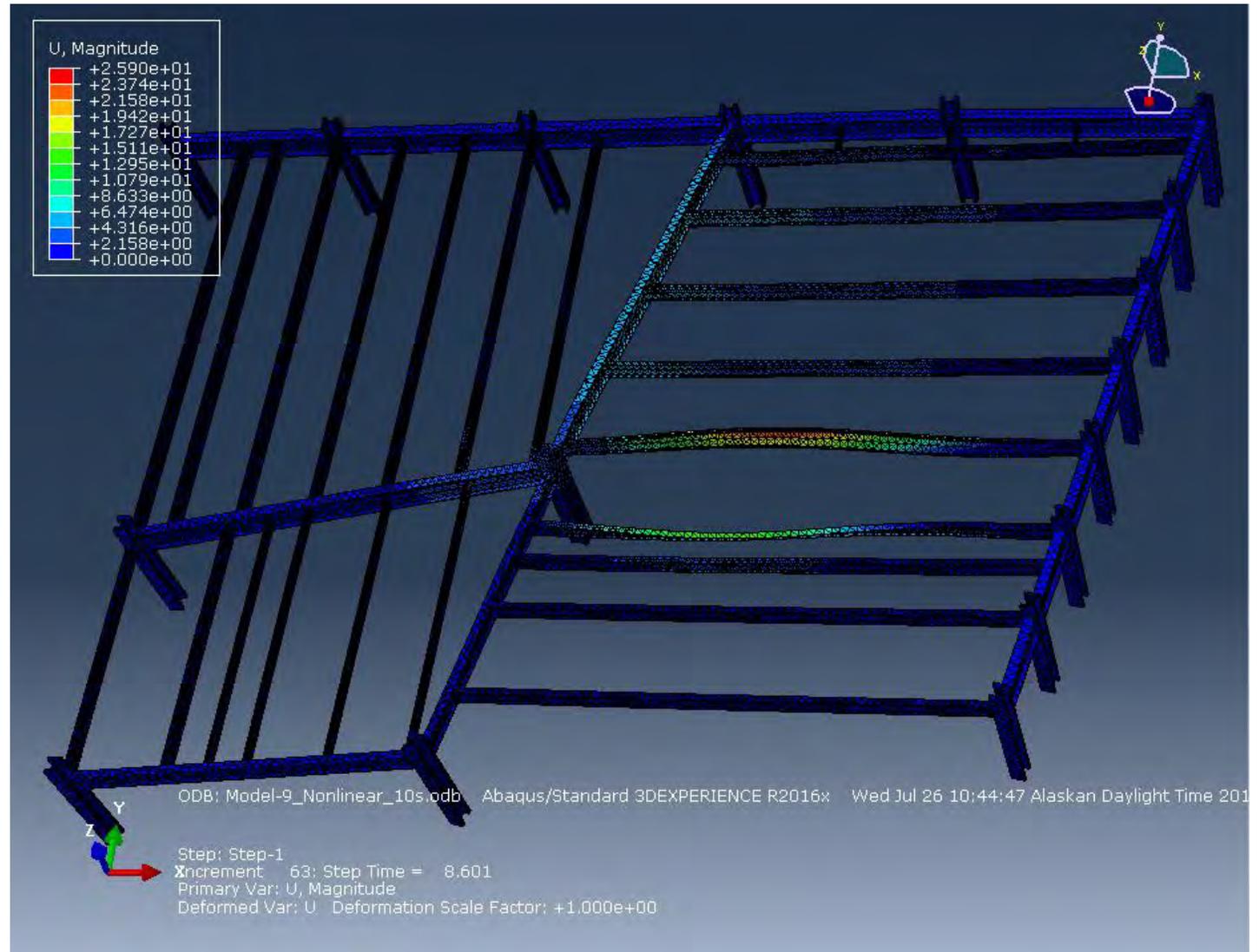
Note: This picture illustrates that A2001 is trapped by the column side plate and it is not possible for it to move the girder web beyond the seat as claimed by NIST.

It appears that NIST did not examine the side plate influence on the restriction of movement by the girder.

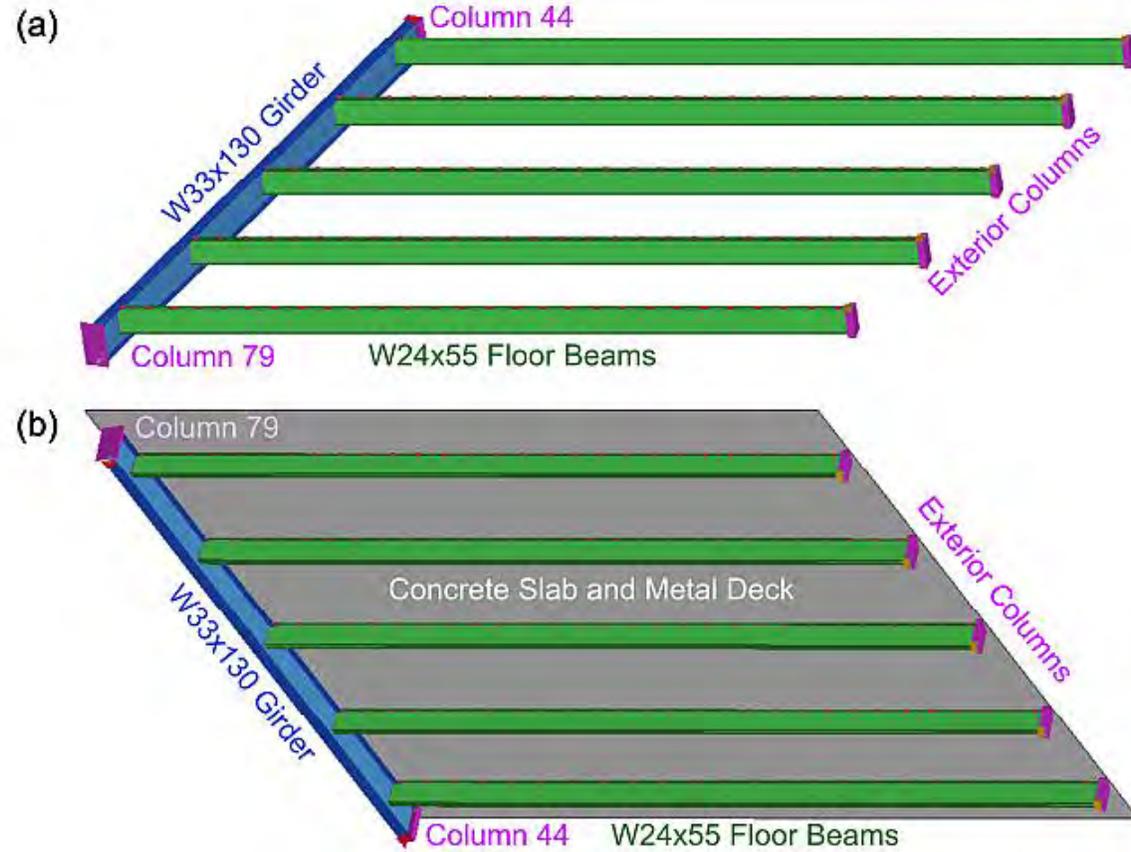


This model shows the influence of the thermal expansion at the north east corner of floor 13.

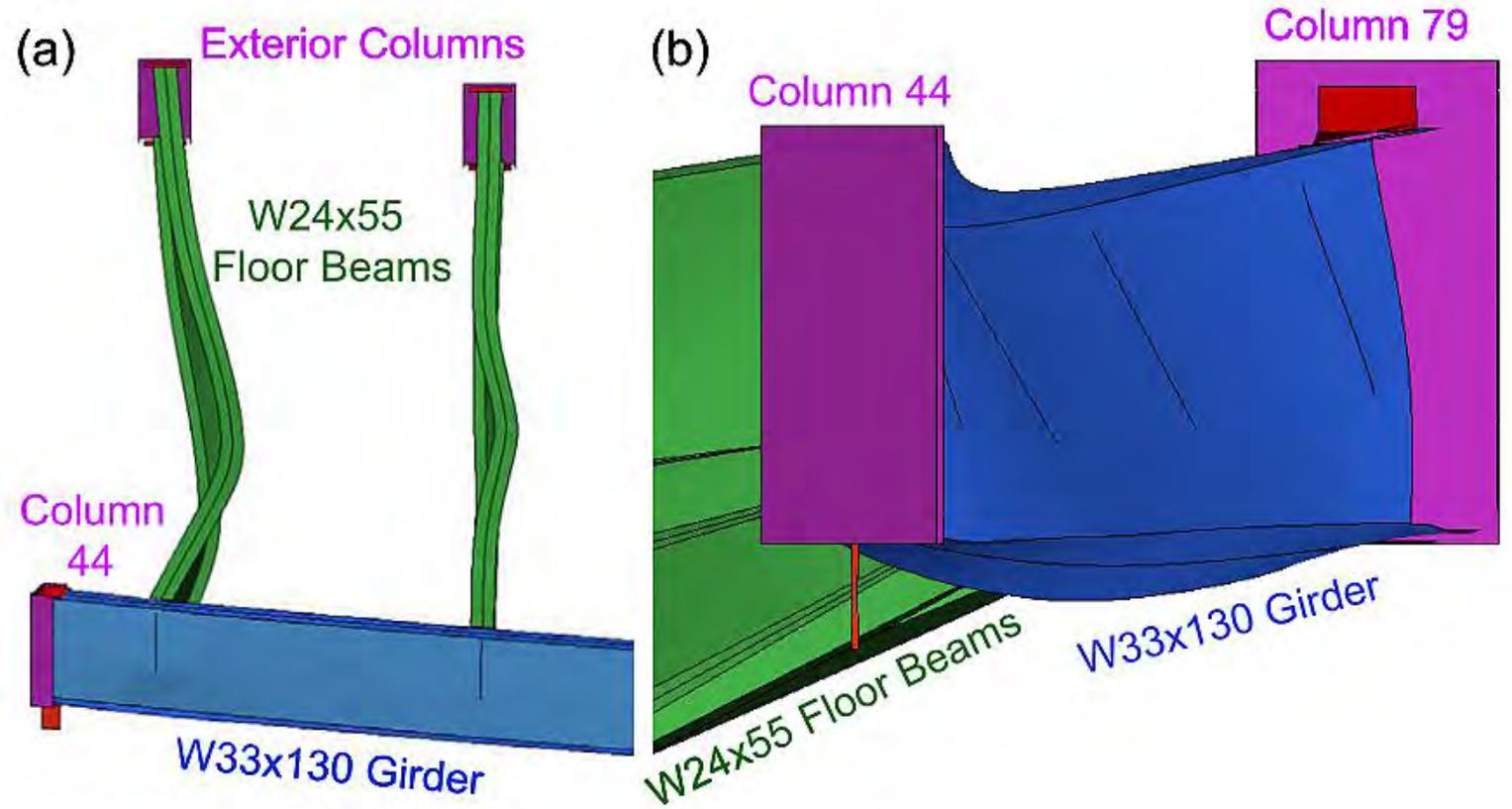
When girder A2001 is trapped behind the side plate on column 79, beams K3004 and D3004 begin to buckle.

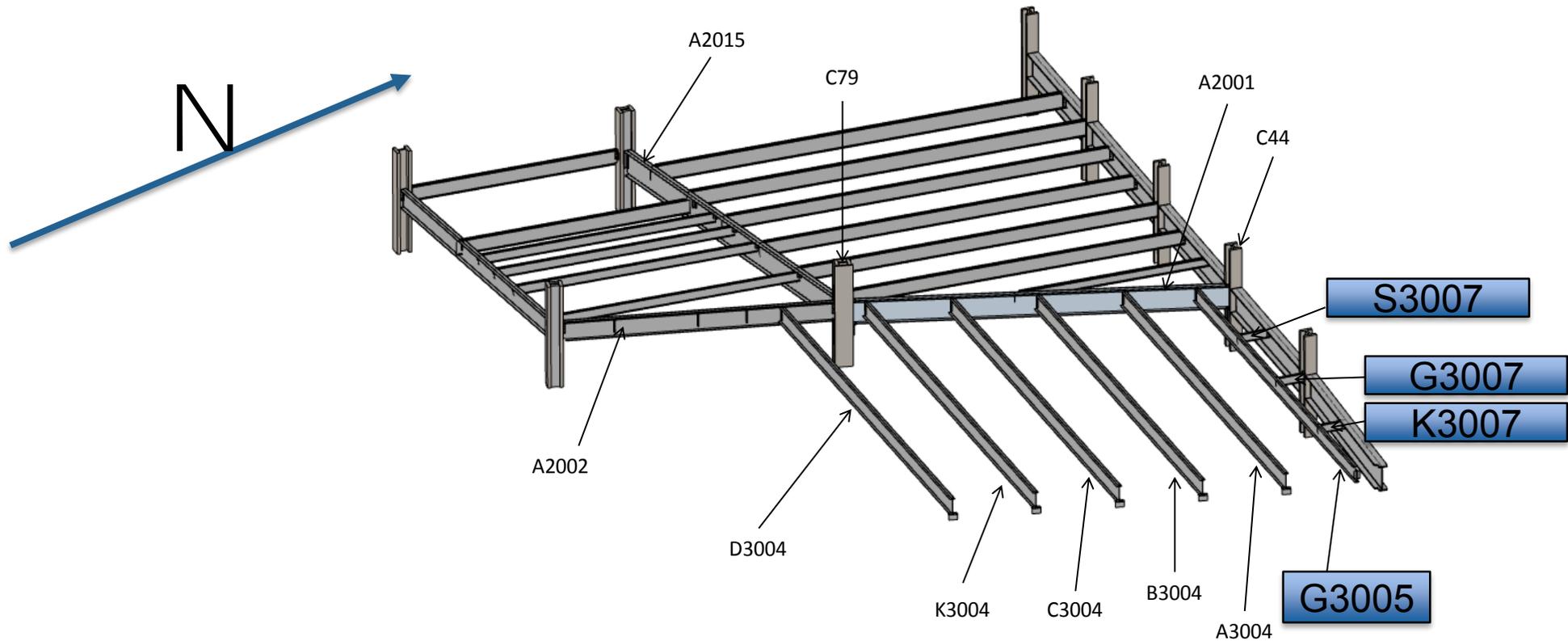


NIST WTC 7 Report Figure 8-22



NIST WTC 7 Report
Figure 8-27

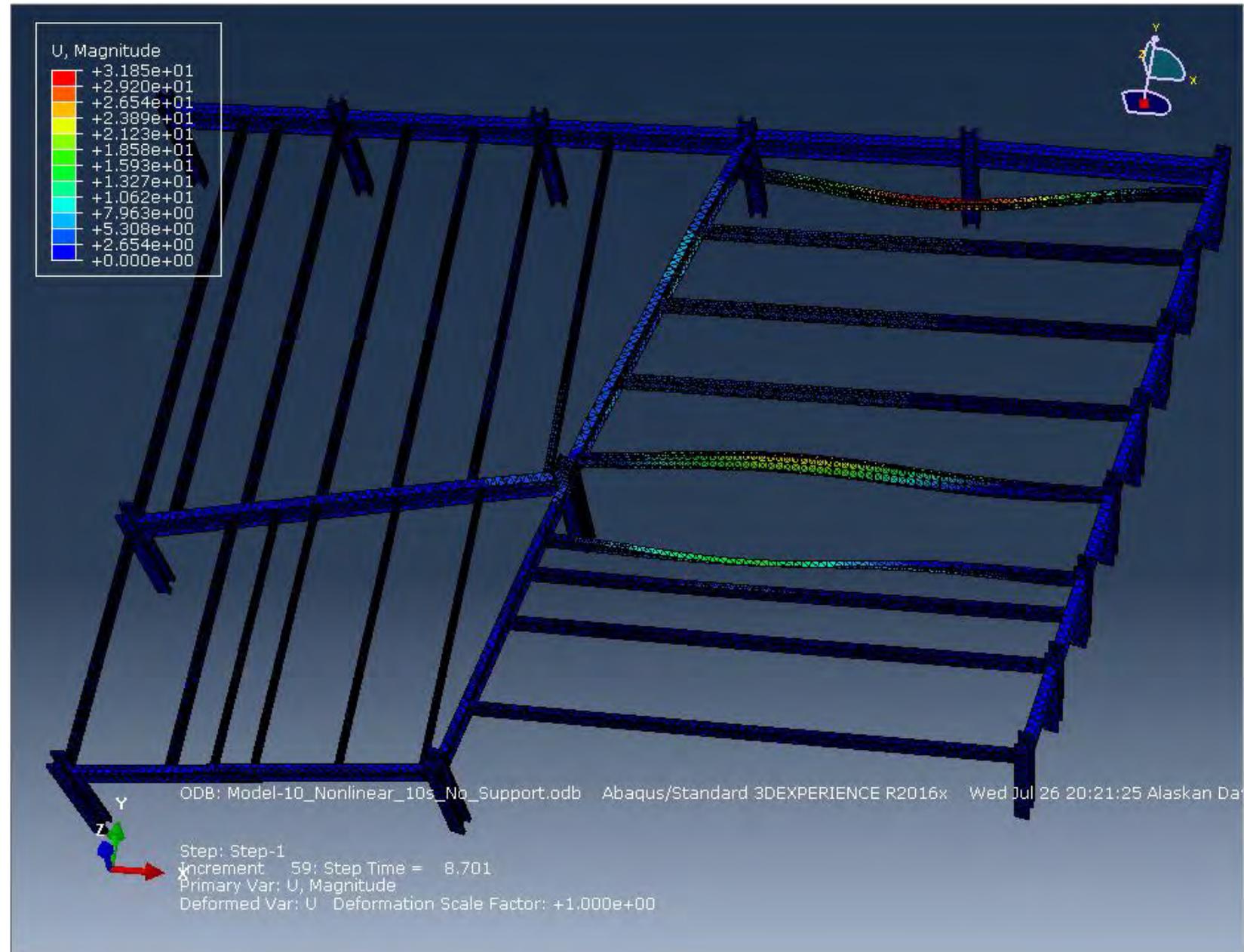




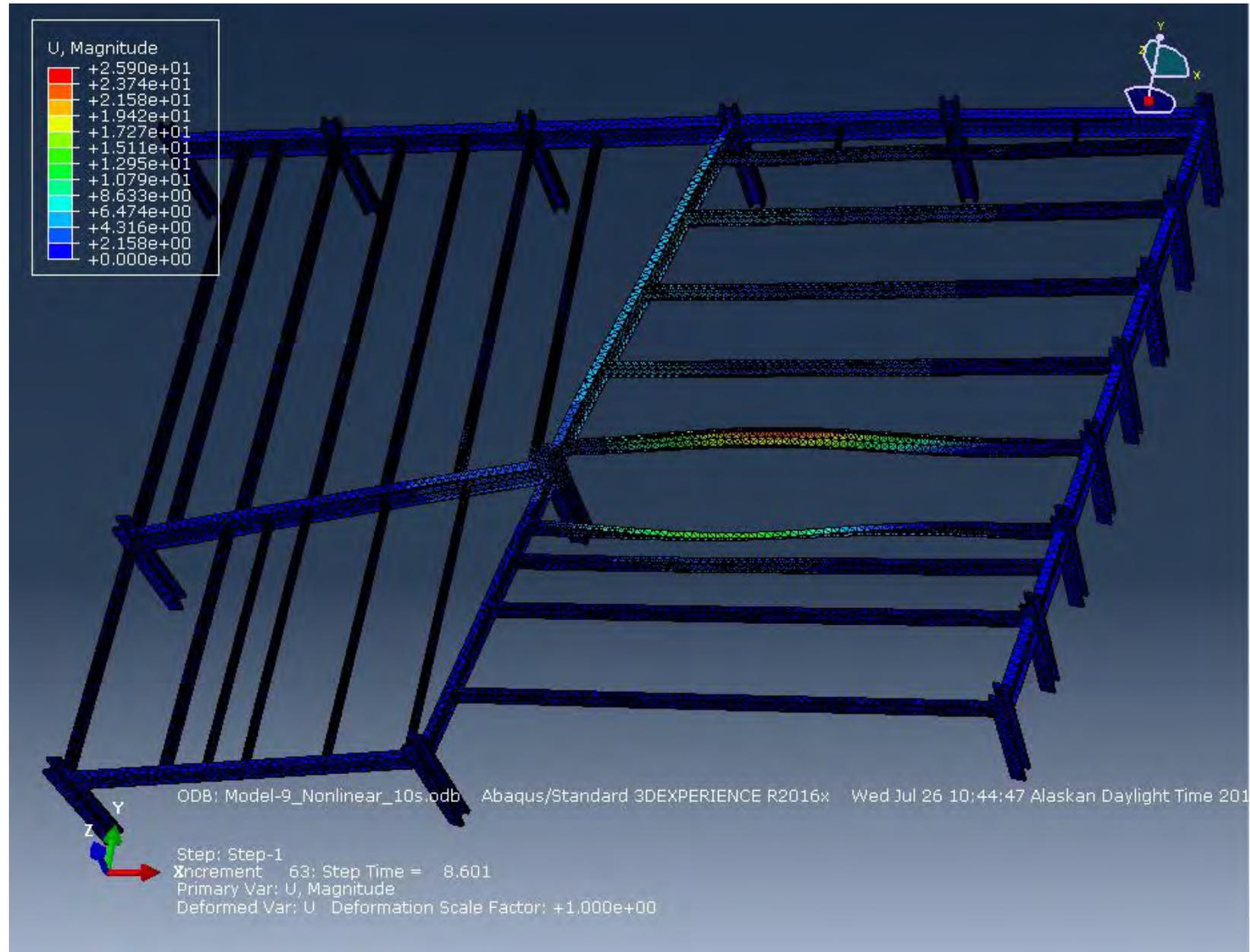
Lateral support beams S3007, G3007 & K3007 were left off G3005 in the NIST analysis.



UAF analysis showing beam G3005 does buckle when lateral support beams G3007, K3007, and S3007, spanning to it from the north exterior wall, are not installed.



UAF analysis showing beam G3005 does not buckle when lateral support beams S3007, G3007, and K3007, spanning to it from the north exterior wall, are installed.



Section view of actual configuration of girder A2001 at its column 79 end from Frankel 1985 drawing 9114, showing its partial height web stiffeners.

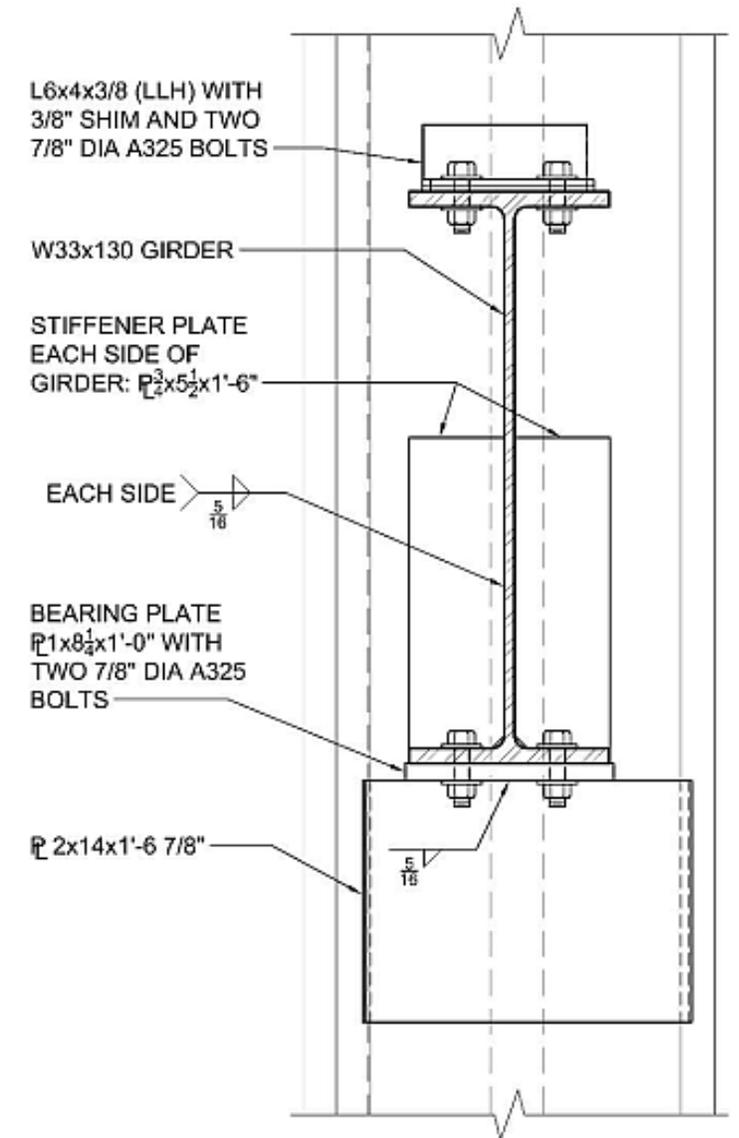
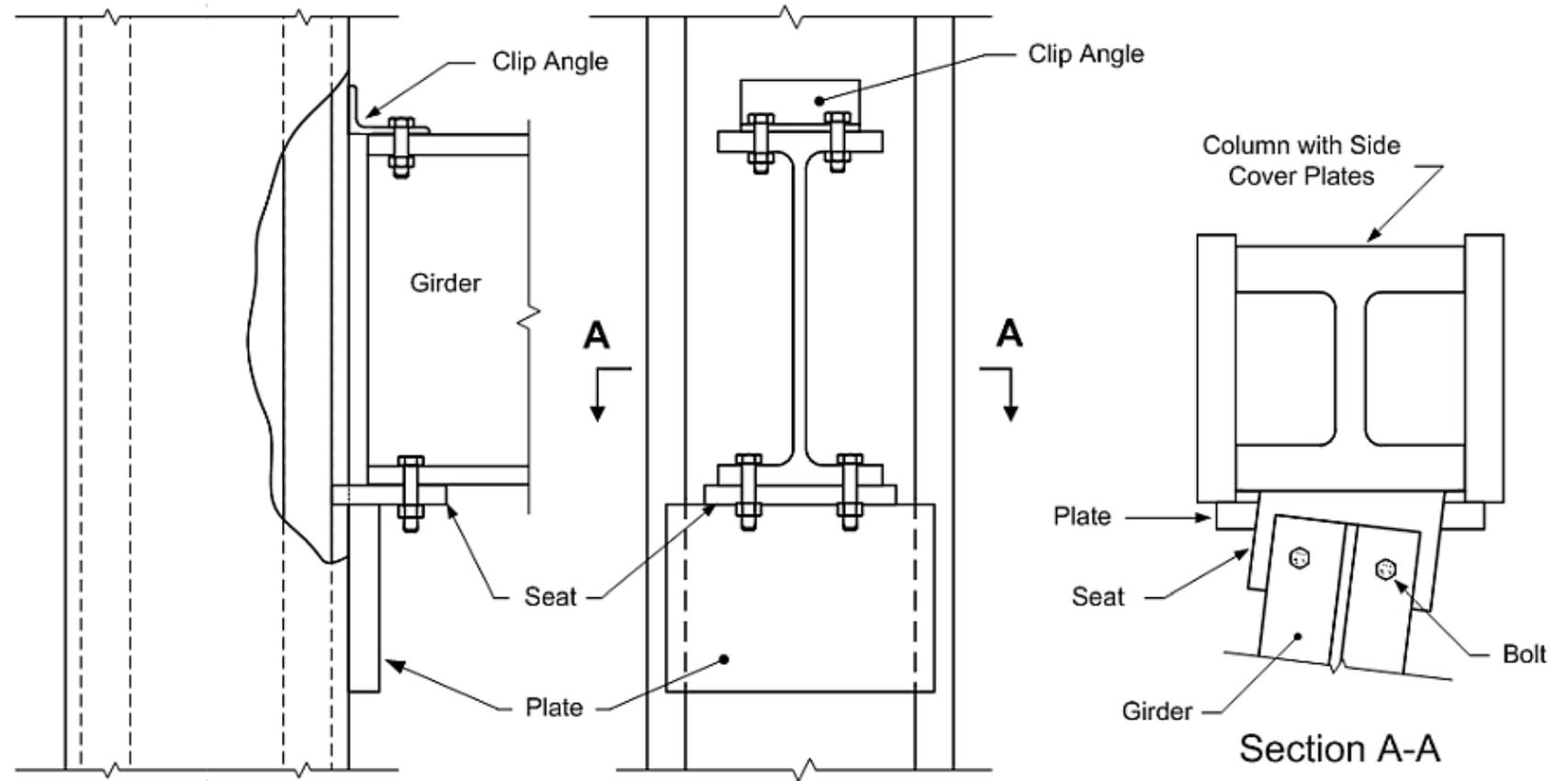


Figure 8-21 from NIST WTC 7 Report

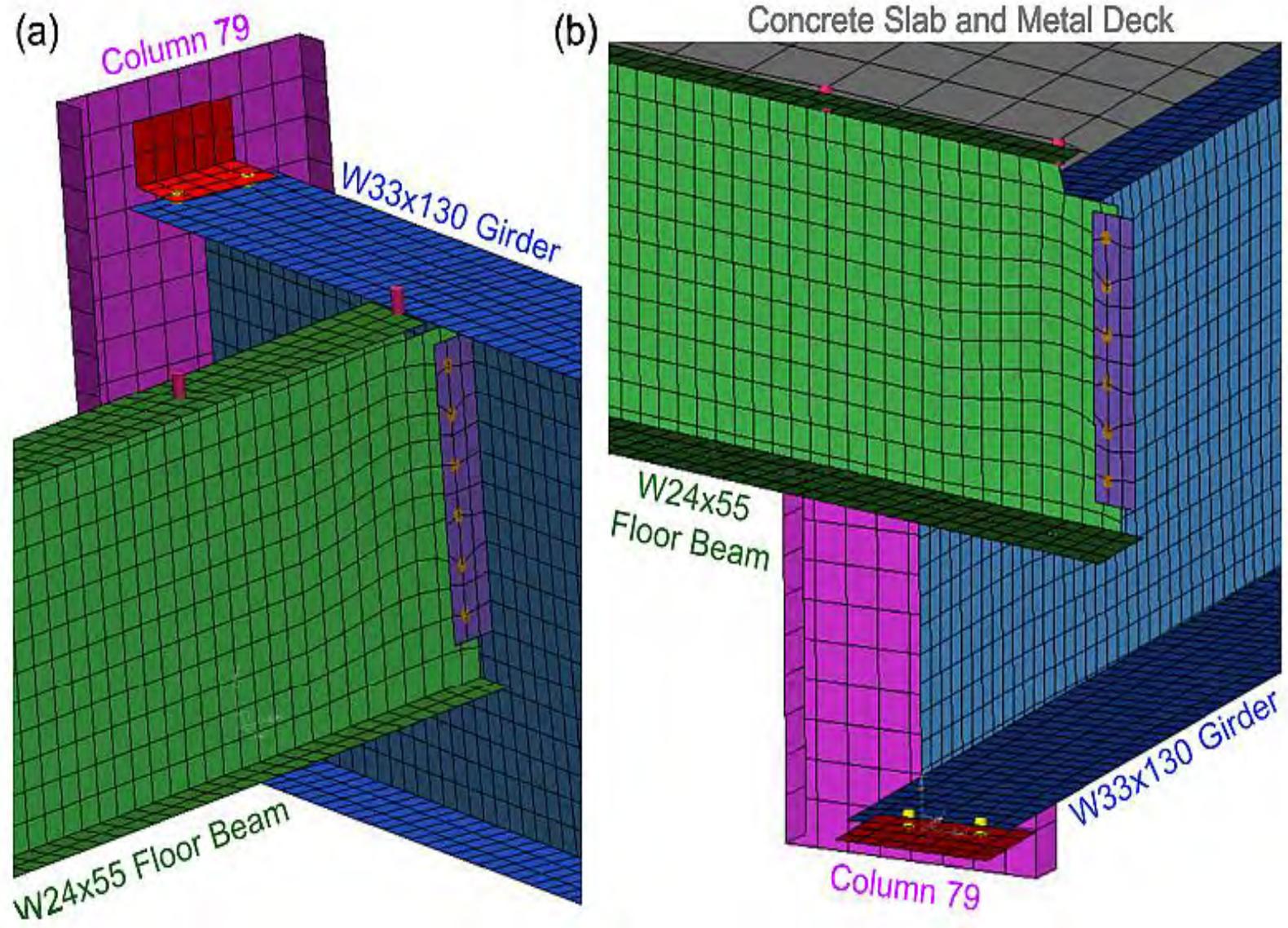
Note: partial height web stiffeners are missing; this is not per Frankel 1985.



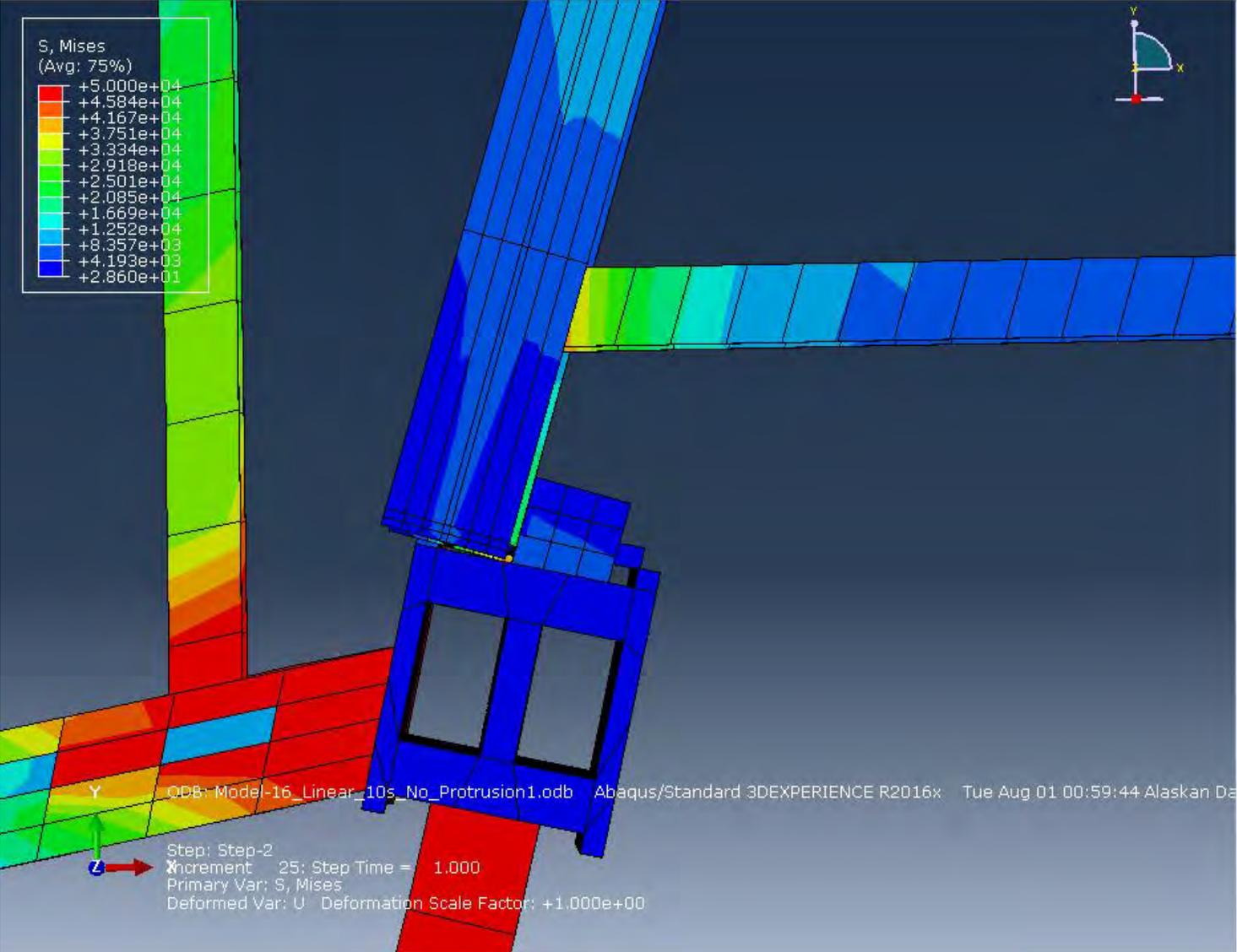
Based on fabrication shop drawings (Frankel 1985)

Figure 8-23 finite element analysis model from NIST WTC7 Report

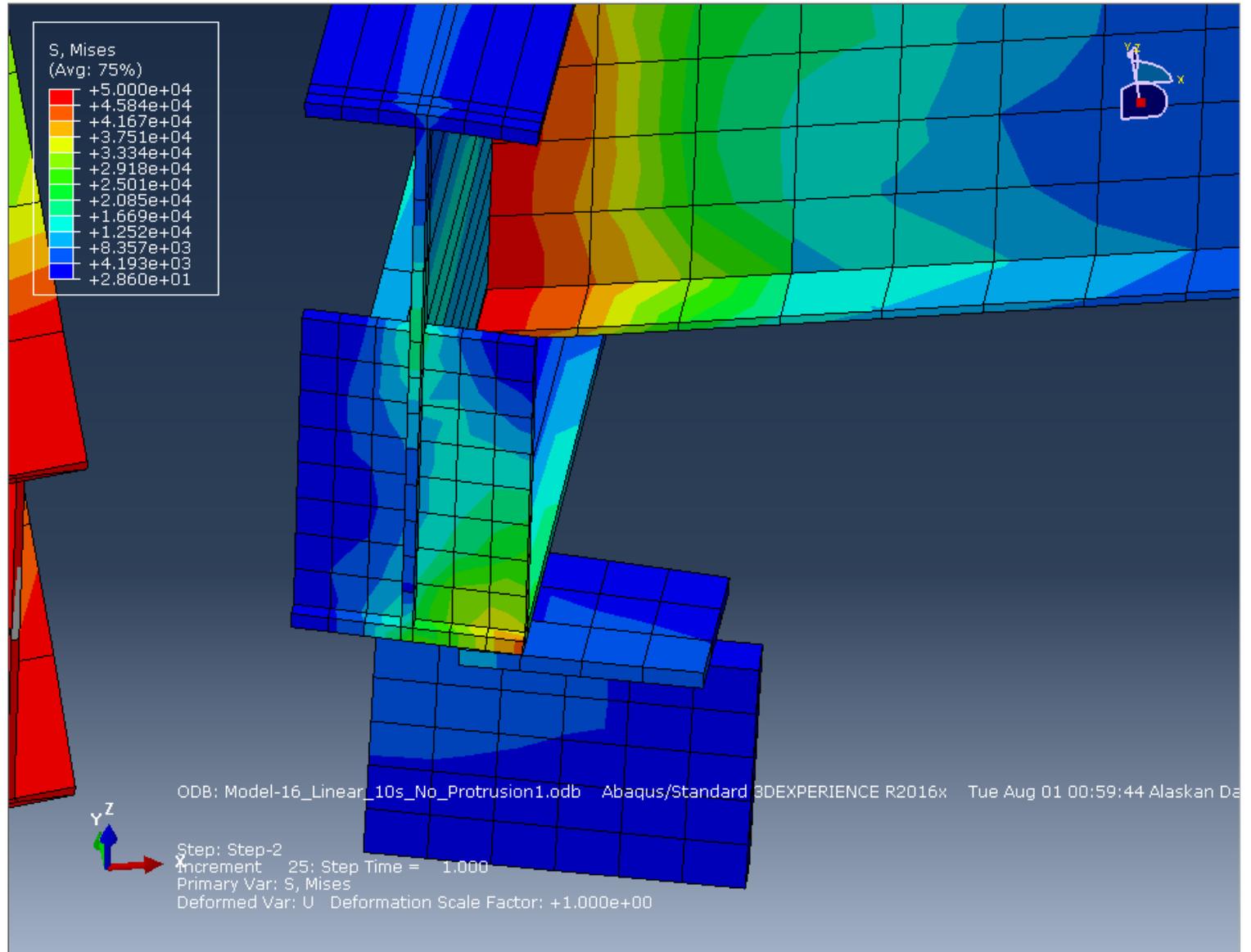
Note: partial height web stiffeners are missing.



Analysis was performed forcing girder A2001 web beyond its bearing seat by removing the column side plate and increasing the coefficient of thermal expansion of the beams framing into the girder by 40%. Without the increase in the coefficient of thermal expansion the web would not have moved sufficiently to get off the bearing seat.



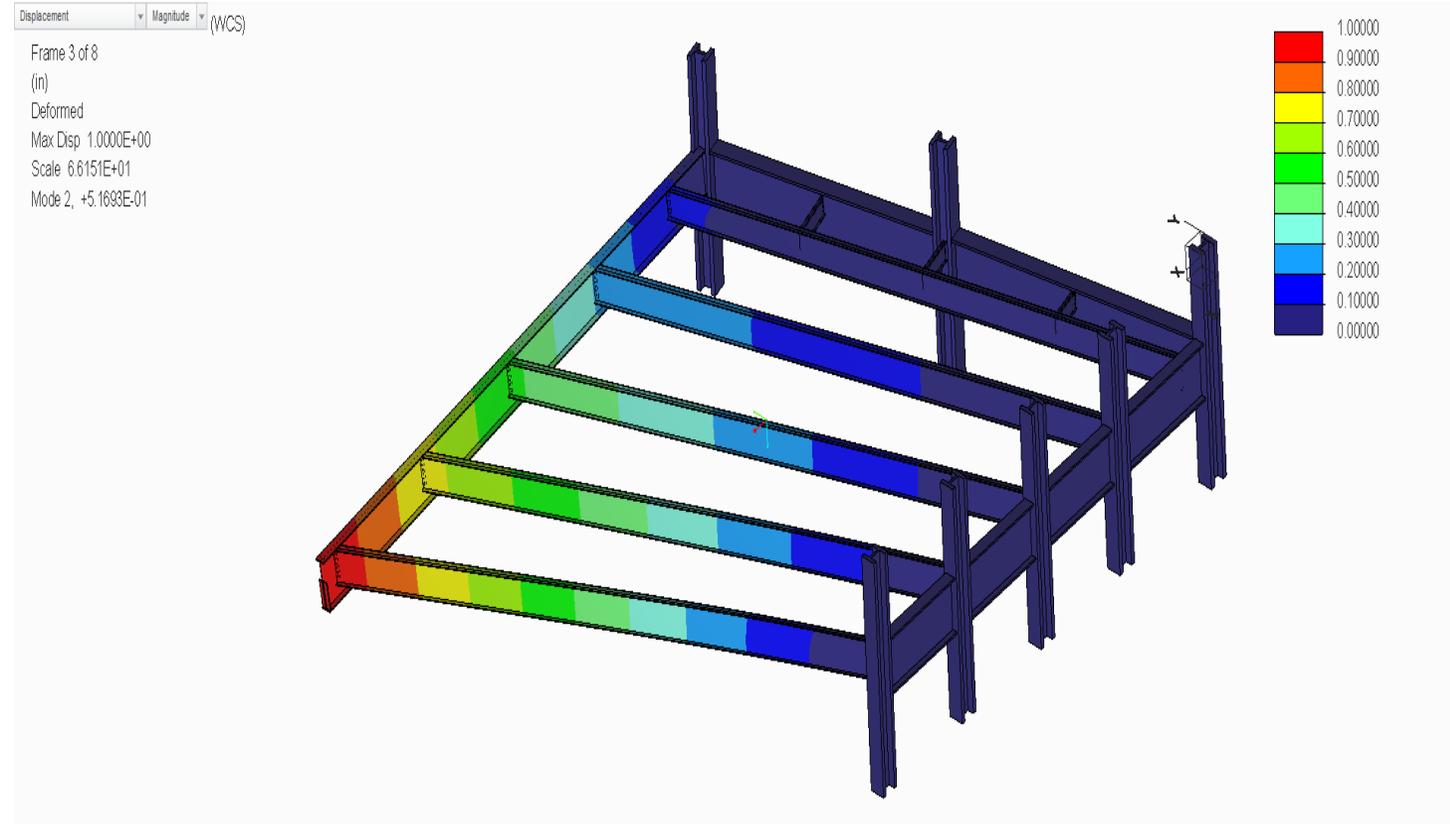
The UAF analysis shows that the girder will not fail with the partial height web stiffeners installed. The small area of high stress is not in the load path and is due to the tip of the girder being compressed against the flange of column 79. This is not a structural concern.



Modal analysis showing 52 Hz frequency mode of the falling beam and girder assembly which was needed to calculate the combined stiffness of the contacting structural members and the subsequent impact load on the girder below on the 12th floor.

Note: NIST & ARUP claimed that the falling beam & girder assembly from floor 13 impacted and broke through floor 12 resulting in an 8 floor cascade.

Based on the natural frequency the stiffness of the beams can be calculated and the amount of deflection and load can be determined. This establishes whether these phenomena could physically occur.



Frequency Analysis Calculations:

- The details for the calculations are presented in the following three slides.
- These calculations are relevant to the report prepared by Arup for the plaintiffs in the lawsuit brought by Con Edison and Aegis Insurance Co. against WTC 7 Properties and Cantor Engineering.
- The ARUP report claimed, similarly to NIST, that the girder at floor 13 came off its seat and initiated a cascade of floor failures, leaving Column 79 laterally unsupported for 9 stories.

Frequency analysis (calculations)- The weight of the beams and girder assembly is approximately 20,000 lbs., so mass (m) = 20,000/32.174 = 622 slugs. The concrete was not considered by Nordenson to act with the steel during the impact to amplify the load. This would be appropriate as the shear studs were broken and the welded wire fabric in the slab and the floor pans would keep it suspended to some degree. Knowing the natural frequency of the beam and girder assembly (F_n), along with its mass (m), stiffness could then be found using the equation

$$F_n = 1/2\pi * \text{SQRT} (K/m)$$

and rearranging to

$$K = (F_n * 2\pi)^2 * m$$

stiffness (K) of the falling beam and girder assembly can then be found

$$K = (0.52 * 6.28)^2 * 622 = 6,633 \text{ lbs./inch}$$

The stiffness to be used in the impact calculations is the combined stiffness of both the falling beam and girder assembly (K_1) and that of the girder on floor 12 below at 10 inches from its support at column 79 (K_2). It is

$$1/K_t = 1/K_1 + 1/K_2 = 1/6,633 + 1/7,627,000 = 0.00015$$

thus

$$K_t = 6,667 \text{ lbs./inch}$$

Using Nordenson's potential energy (P.E.) of 3,473,000 in-lbs. and the calculated stiffness, in the same standard equation Nordenson uses to find deflection (D)

$$\text{P.E.} = 1/2 K_t * D^2$$

$$D = \text{SQRT}(2 * \text{P.E.} / K_t) = 32.28 \text{ inches}$$

and finally using the standard equation Nordenson uses to find force (F)

$$F = K_t * D$$

$$F = 6,667 \text{ lbs./inch} * 32.28 \text{ inches} = 215,211 \text{ lbs.}$$

This 215,211 lb. impact force is only 34% of the 632,000 lb. force required and thus insufficient to shear the girder bearing seat support welds. The northeast corner of floor 12 would not have collapsed if a girder at floor 13 came off its seat at column 79 and fell onto it. Thus the ARUP analysis does not show a basis for propagation, even if the girder were to fall off its seat at column 79. These findings illustrate **that ARUP's explanation is invalid.**

The NIST WTC7 report also states that the falling girder would break through the next floor down. Therefore the NIST explanation is also invalid on this ground.

Weidlinger Associates Report

- The 2010 Weidlinger Associates report was prepared for the defendant in the lawsuit brought by Con Edison and Aegis Insurance Co. against WTC 7 Properties and Cantor Engineering.
- The Weidlinger **report examined the ARUP report and showed ARUP's claim of** the falling beam and girder assembly at the 13th floor breaking through the next floor down was not possible.
- The Weidlinger report claims that the failure occurred at the 9th and 10th floors on the east side of the building between columns 79 and 80, which were simultaneously heated to extraordinary temperatures (approximately 750 °C).
- Structural steel member temperatures of 750 °C due to office fires can be considered unusually high and be substantiated. At this point there is no evidence to illustrate the validity of those temperatures.

i. Brief discussion and Discussion of the WTC 7 report by Weidlinger Associates

The 2010 Weidlinger Associates report was prepared for the defendant in the lawsuit brought by Con Edison and Aegis Insurance Co. against WTC 7 Properties and Cantor Engineering. It was not entered into the court record, although the judgement was ultimately for the defendant with the U.S. Circuit Court of Appeals ruling **against the plaintiff's negligent design claim.**

The Weidlinger **report examined the ARUP report and showed ARUP's claim of the falling beam and girder** assembly at the 13th floor breaking through the next floor down was not possible. This confirms the error in the ARUP analysis that was also determined in the work done for this report.

The Weidlinger report claims that the failure occurred at the 9th and 10th floors on the east side of the building between columns 79 and 80. Here Weidlinger posits the structural steel members of both floors were simultaneously heated to extraordinary temperatures (approximately 750 °C). Weidlinger argues that due to these extremely high temperatures the 10th floor fell onto the 9th floor which failed because it was already thermally weakened. The steel temperatures claimed are said to be from a 2010 thermal analysis by a Dr. Craig Beyler of Hughes Associates. However, the details of that report are not shown in the Weidlinger report and this thermal analysis has not been made public. Structural steel member temperatures of 750 °C due to office fires can be considered unusually high and be substantiated. At this point there is no evidence to illustrate the validity of those temperatures.

NIST APPROACH

(5.5” movement @ girder bearing support; Col 79)

Issues that led to the 5.5” of movement.

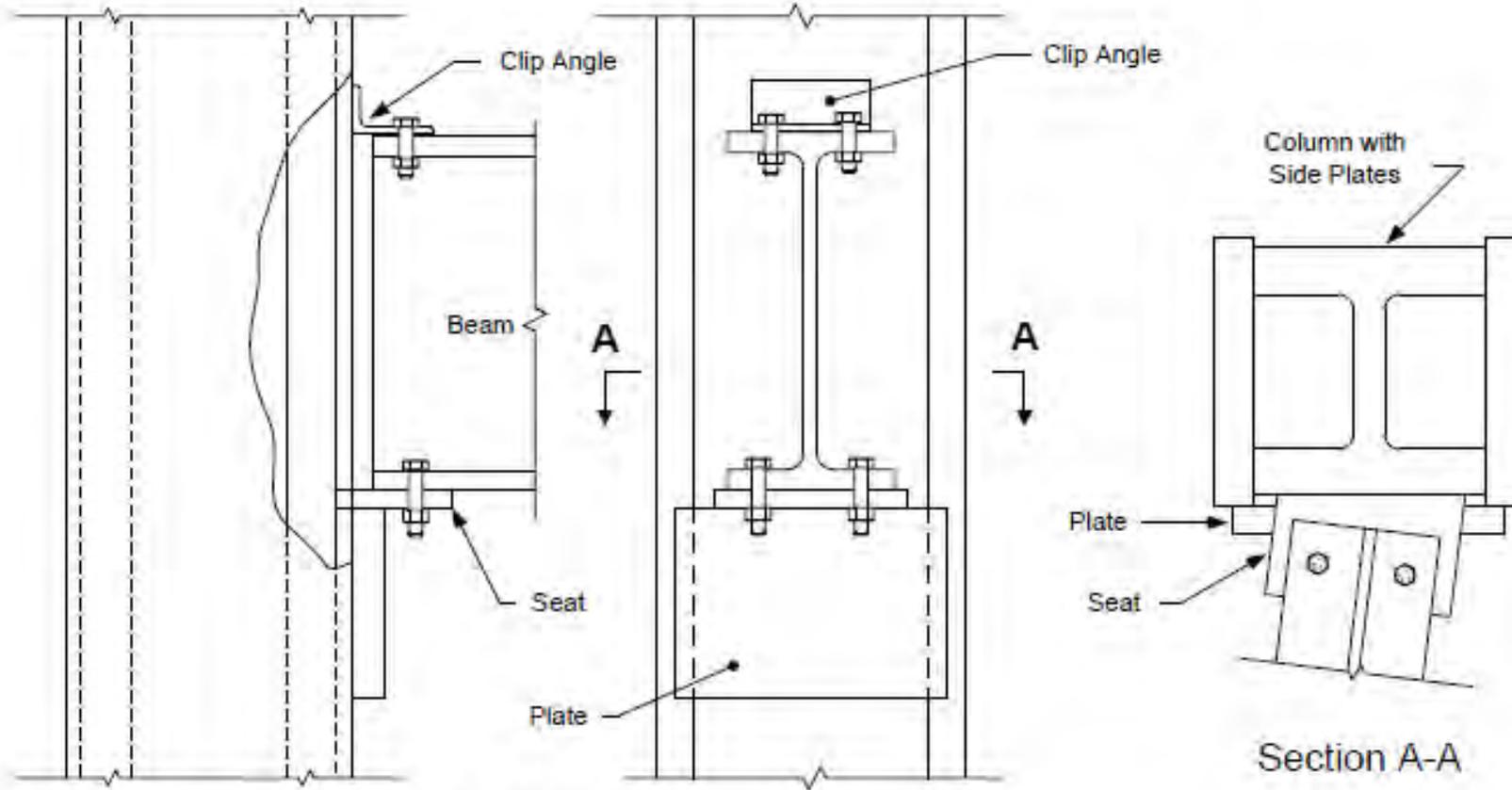
- Non-composite at Main Girders
- ***Neglected Thermal Expansion of the concrete slab
- ***Separated connection Modeling
- ***Missed Web-Flange Stiffeners

UAF RESEARCH APPROACH

- Structural Modeling (2 programs):
 - Quality Control (2 researchers & 2 programs) -
 - ABAQUS
 - Developed Nonlinear springs for the structural connections
 - Composite, partially composite & non-composite response
 - Floors 12 & 13; springs, thermal expansion
 - SAP2000 (floors 12 & 13; floors 3 to 47)
- Fire (NIST fire models)
- Heat Transfer (SOLIDWORKS)

UAF Research Approach continued-

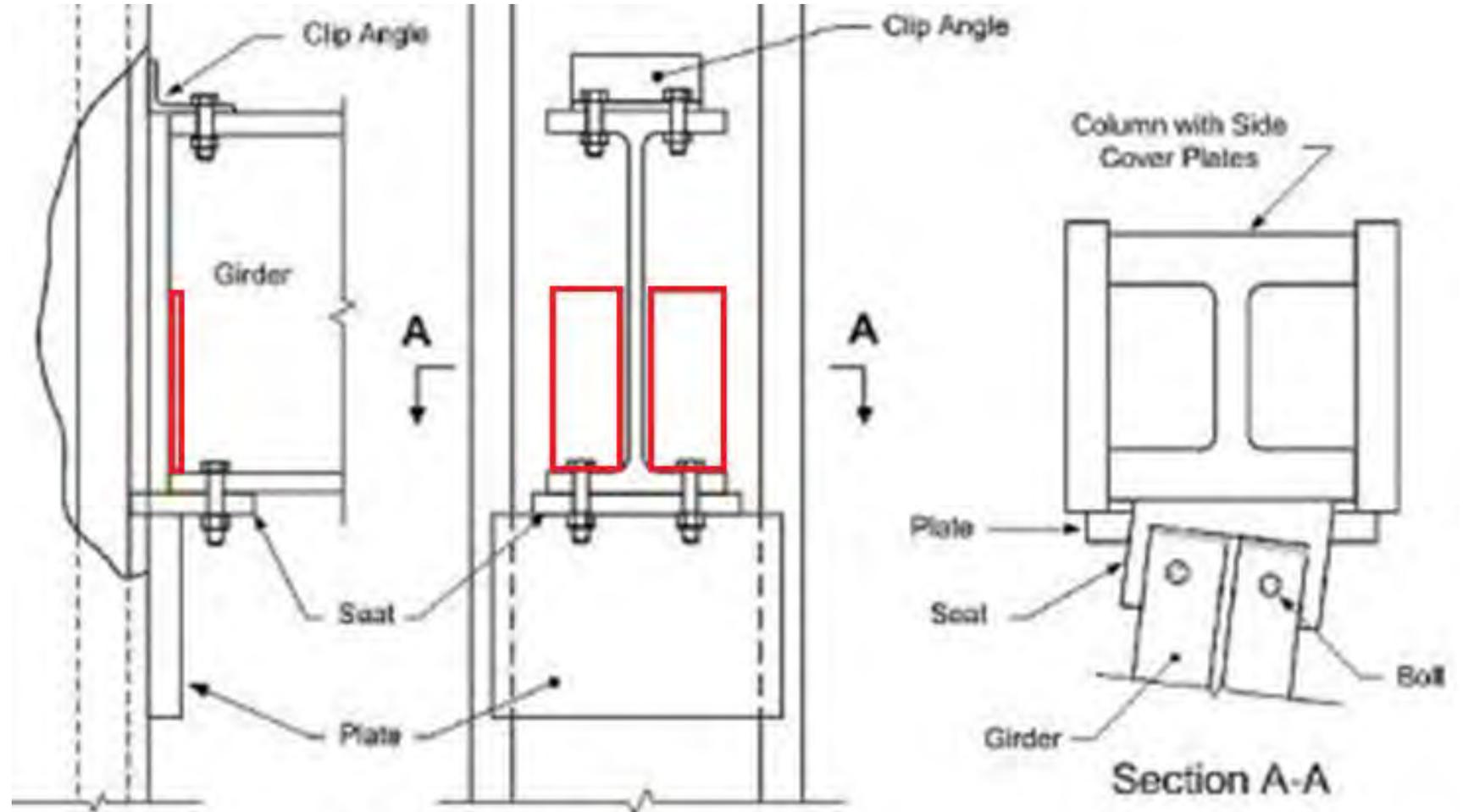
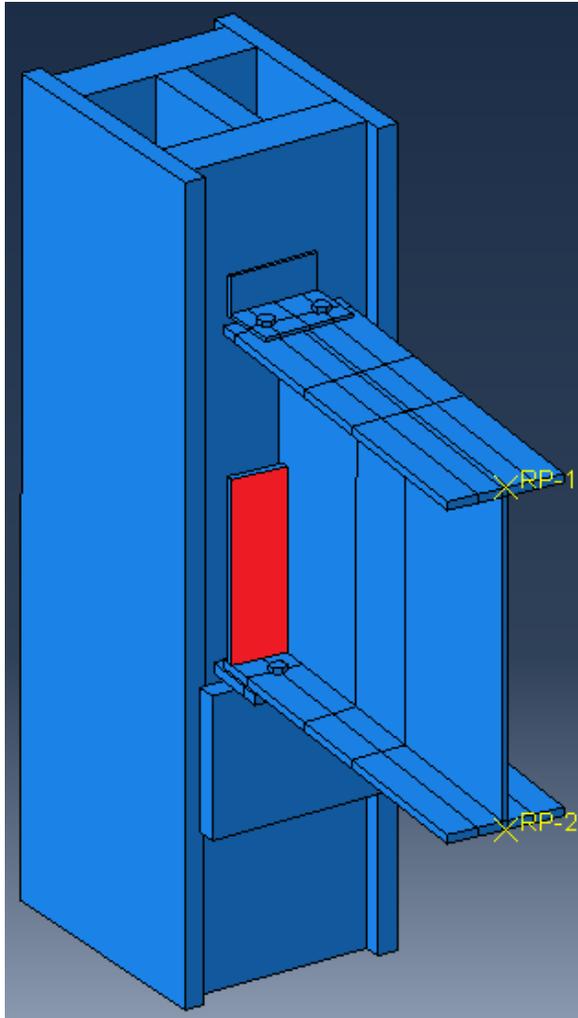
1. Steel Framing
 - Connections (columns, beams & girders)
 - Nonlinear springs @ all stories
2. Sub-structuring frames and concrete floor were used to minimize computer time.
3. Heat transfer was studied for:
 - Floor tile over concrete floor with WWF, stay-in-place forms (flutes), air space between floor framing and drop ceiling, fire protection vs no fire protection.
 - Equivalent concrete conductivity & expansion accounting for Dolomite aggregate, WWF, and geometry for the section.



Based on fabrication shop drawings (Frankel Steel 1985)

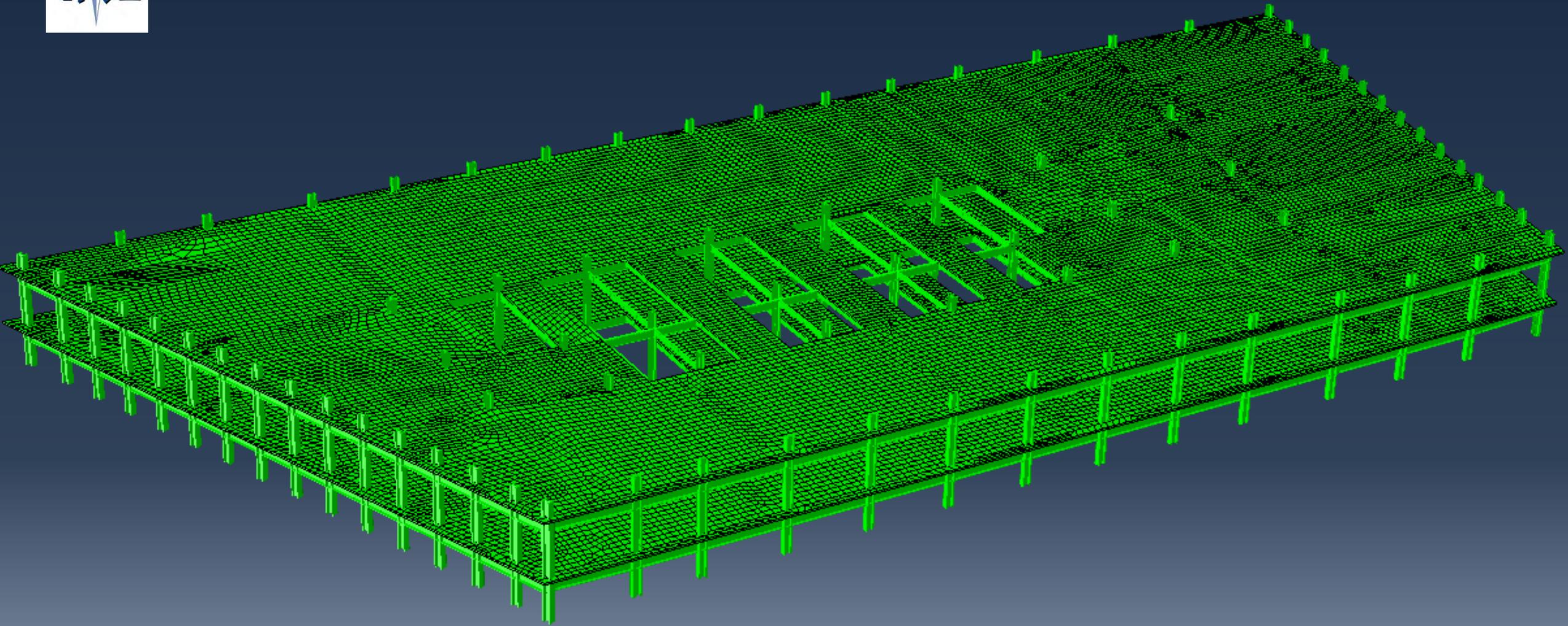
Figure 8-21. Seat connection at Column 79.

UAF: Beam Seat Connection for Col 79



Based on fabrication shop drawings (Frankel 1985)

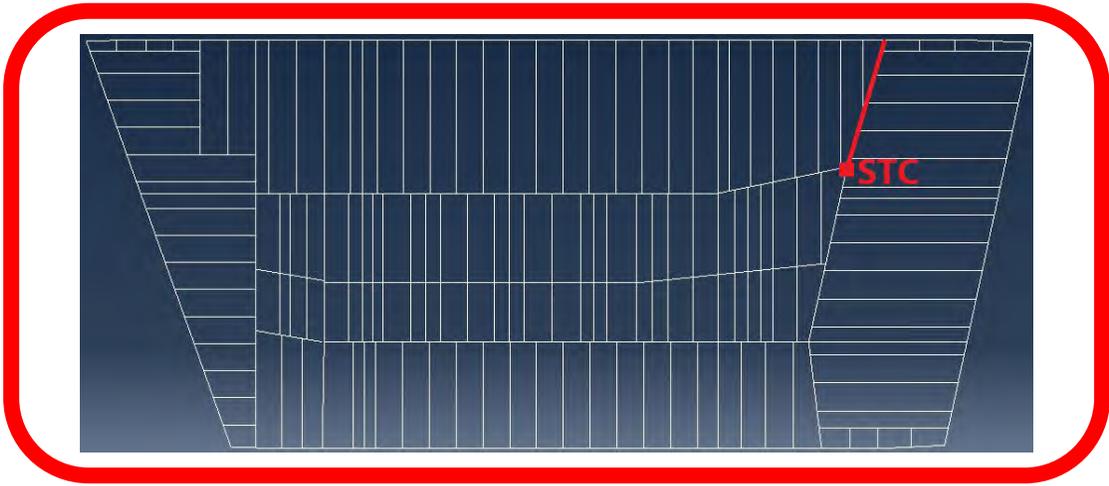
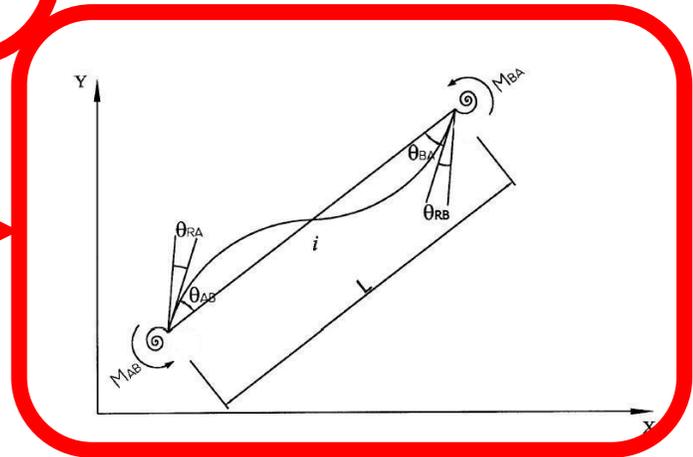
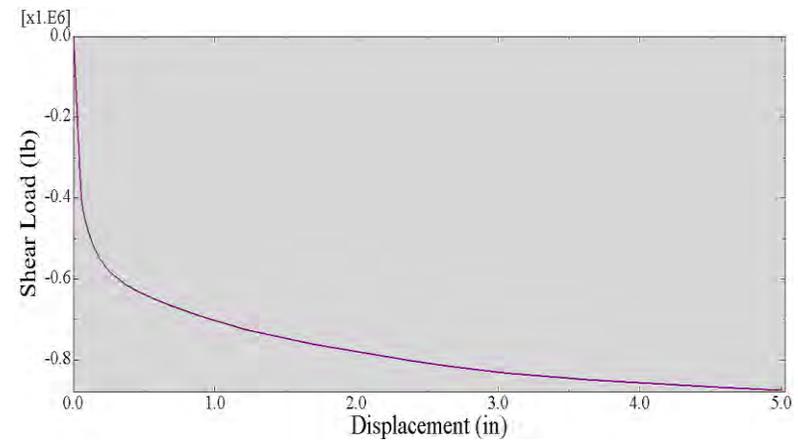
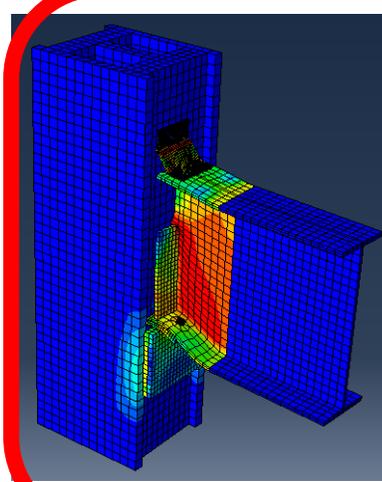
UAF: WTC 7 ABAQUS Modeling





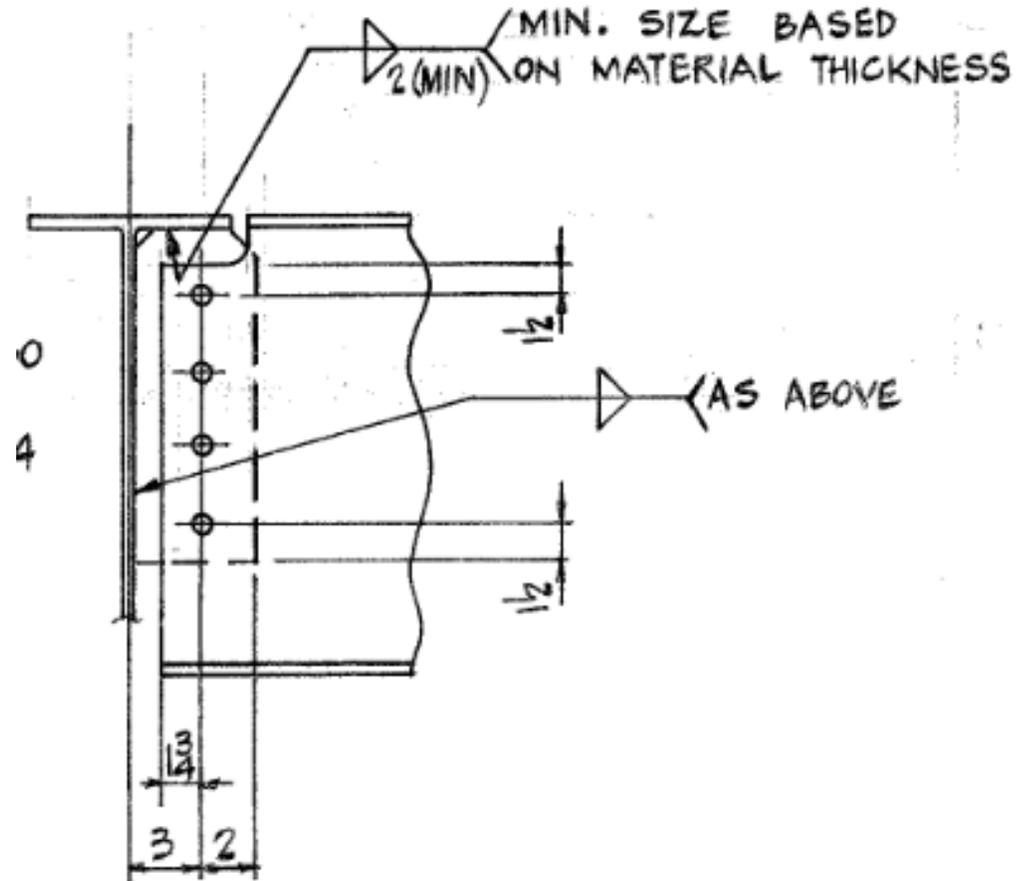
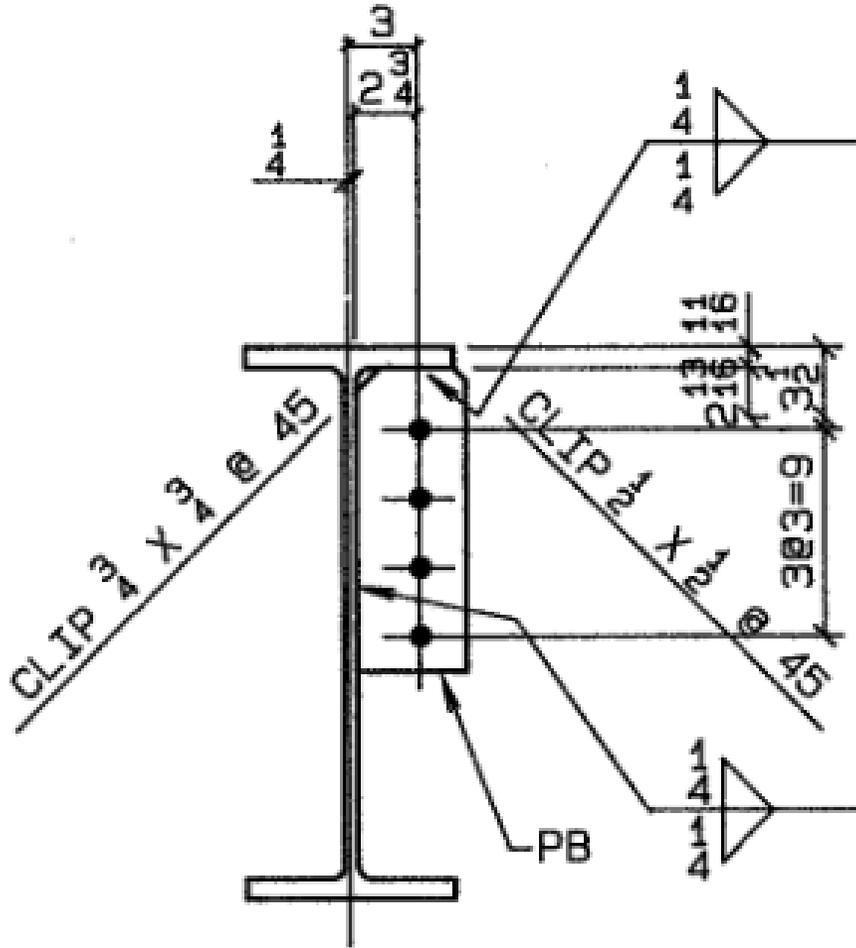
UAF:

SAMPLE CONNECTION RESPONSE

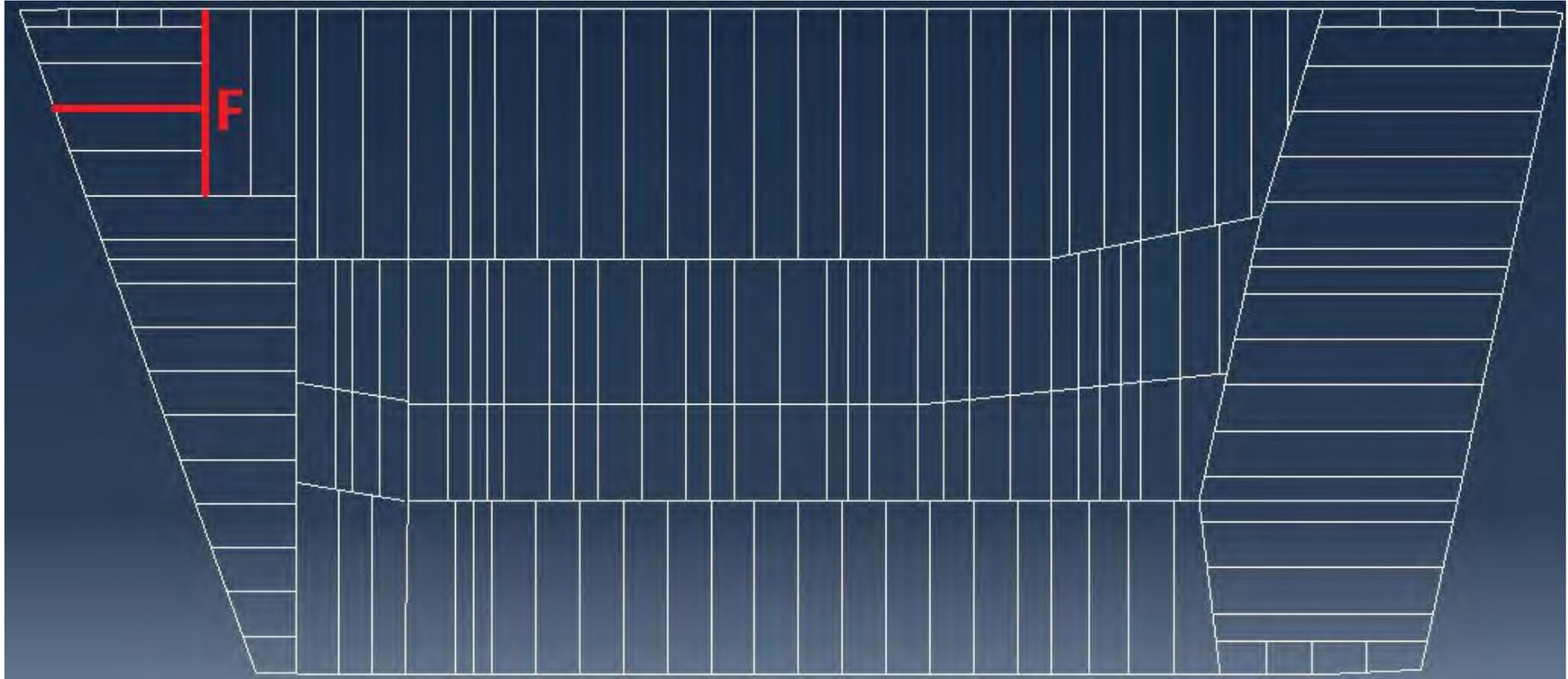


Fin (F) Connection Sample

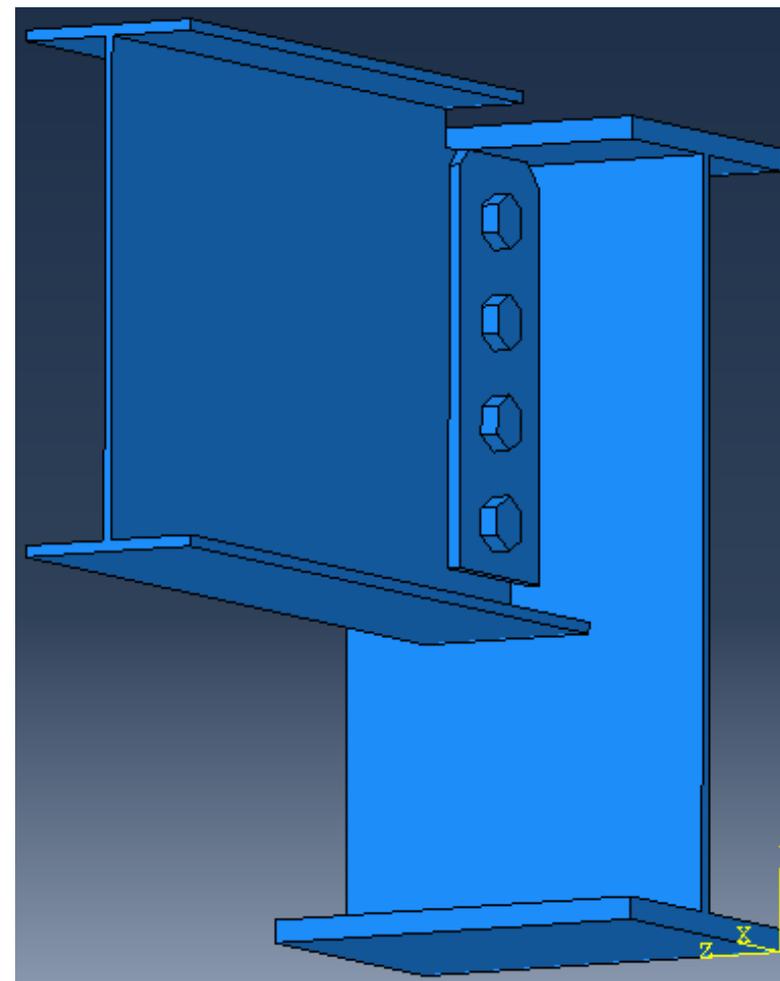
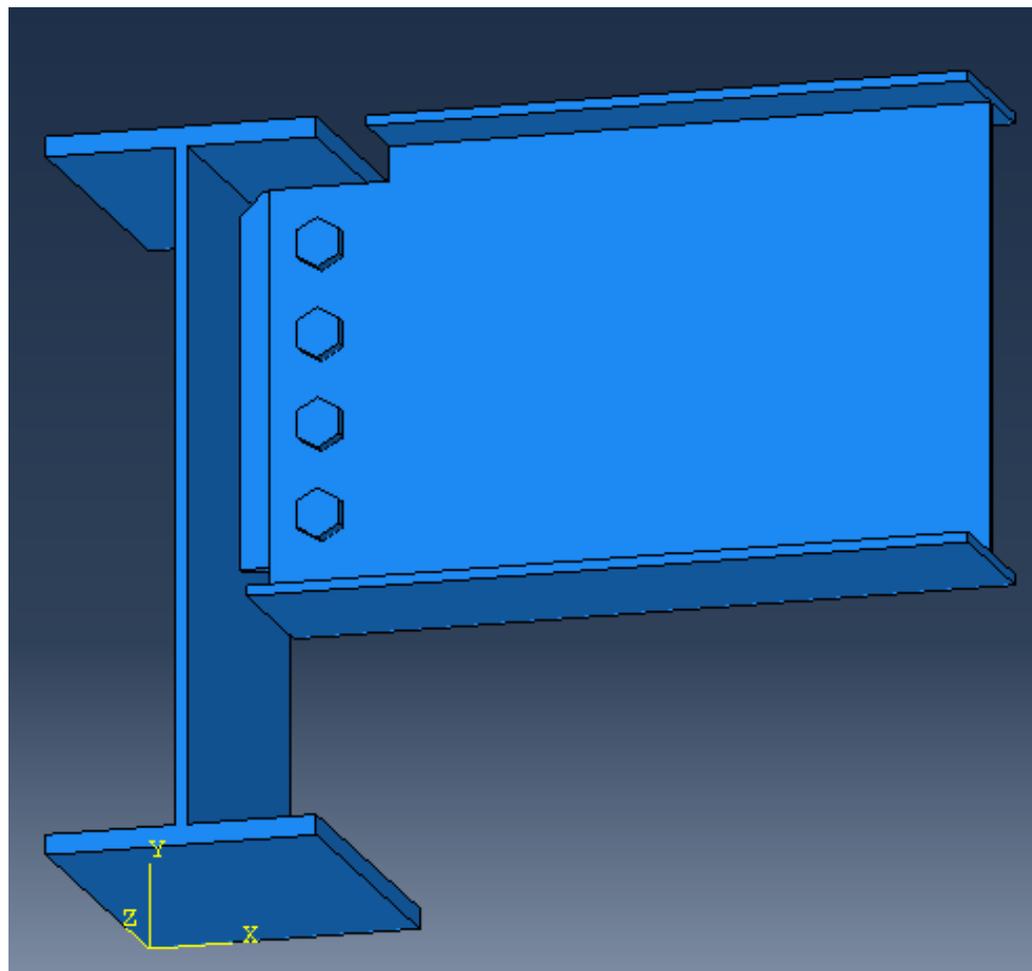
Interior Girder C4333 (W24x76) - Beam C4328 (W16x26)



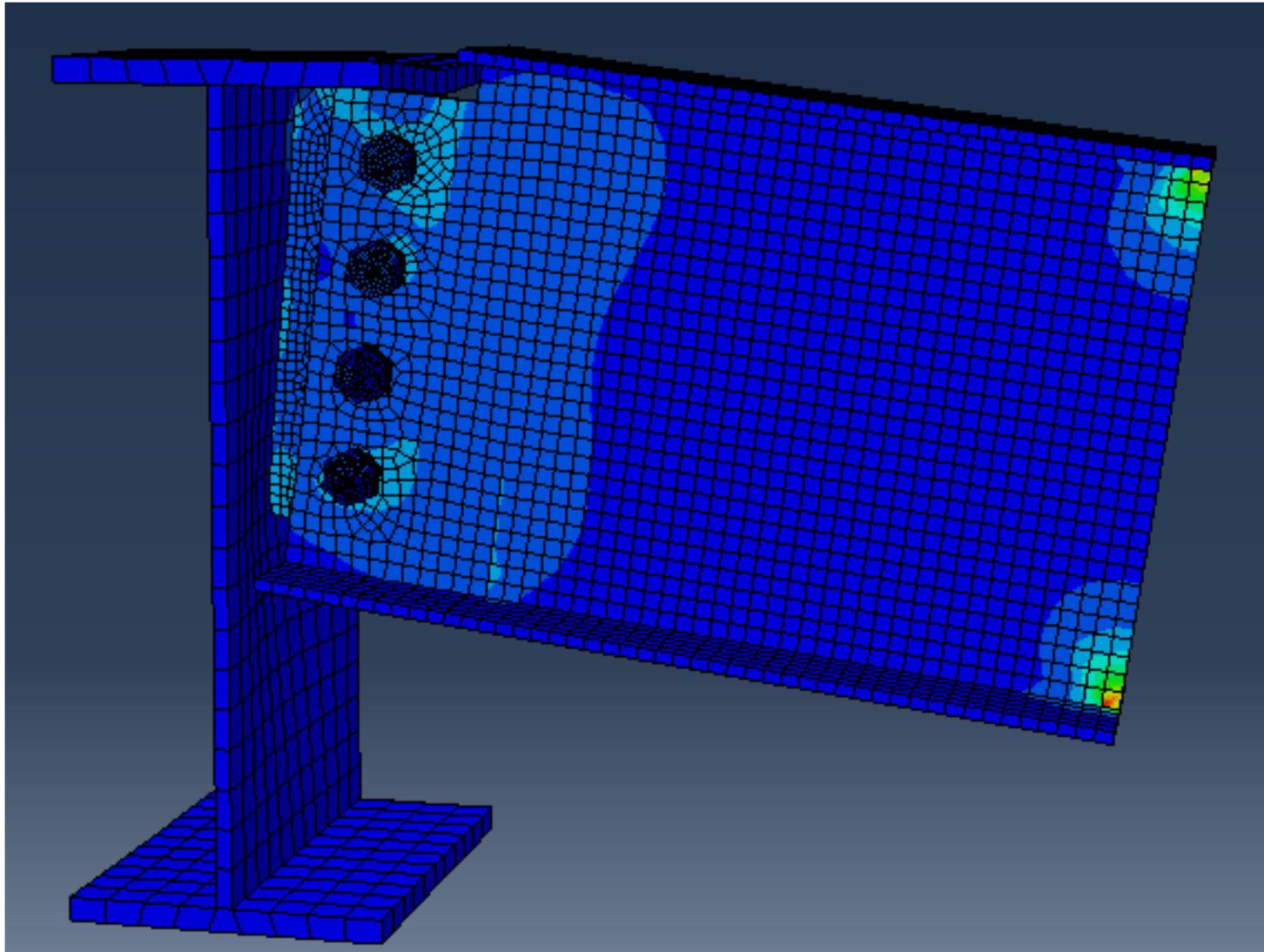
UAF - ABAQUS Building Model



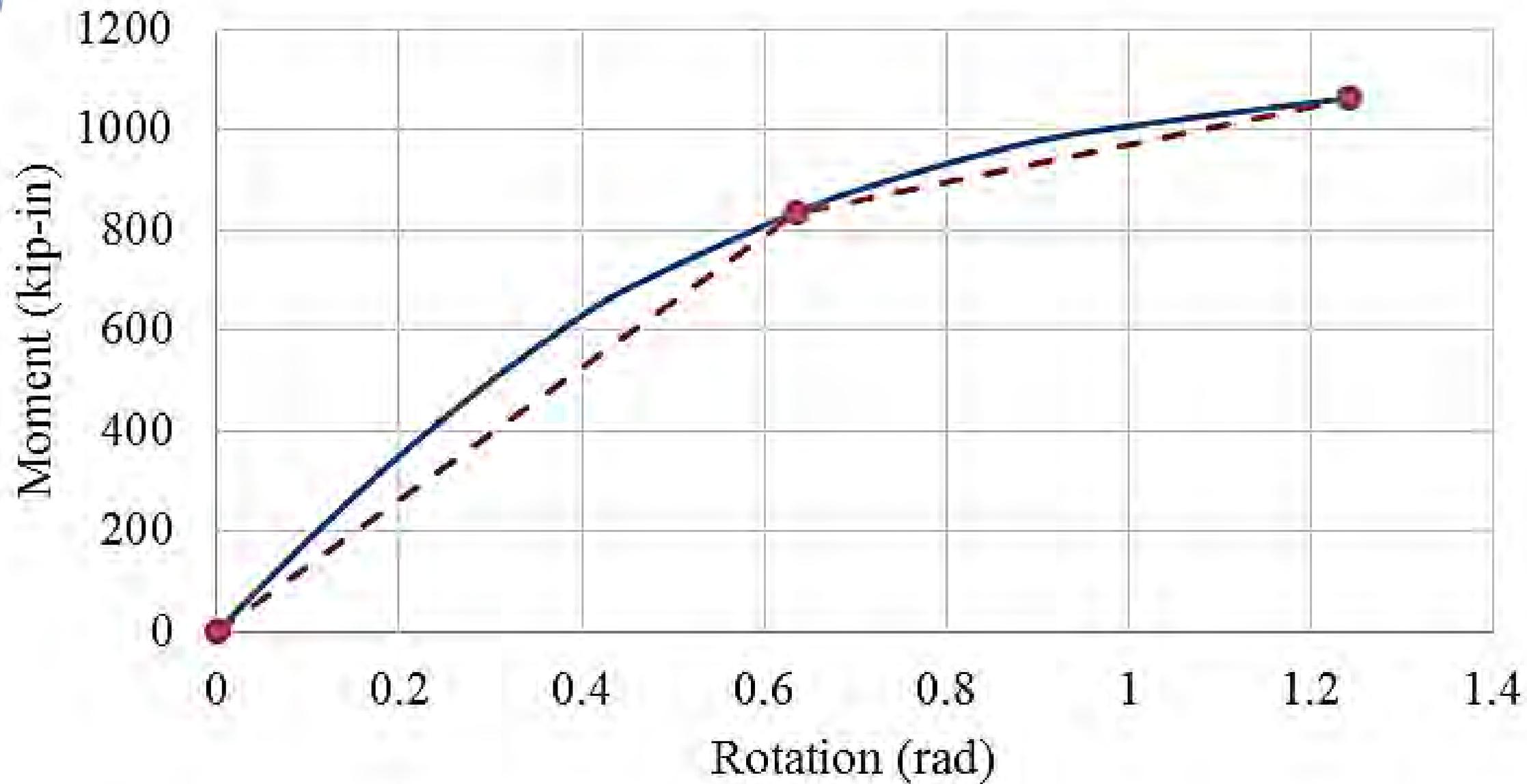
ABAQUS Connection Model

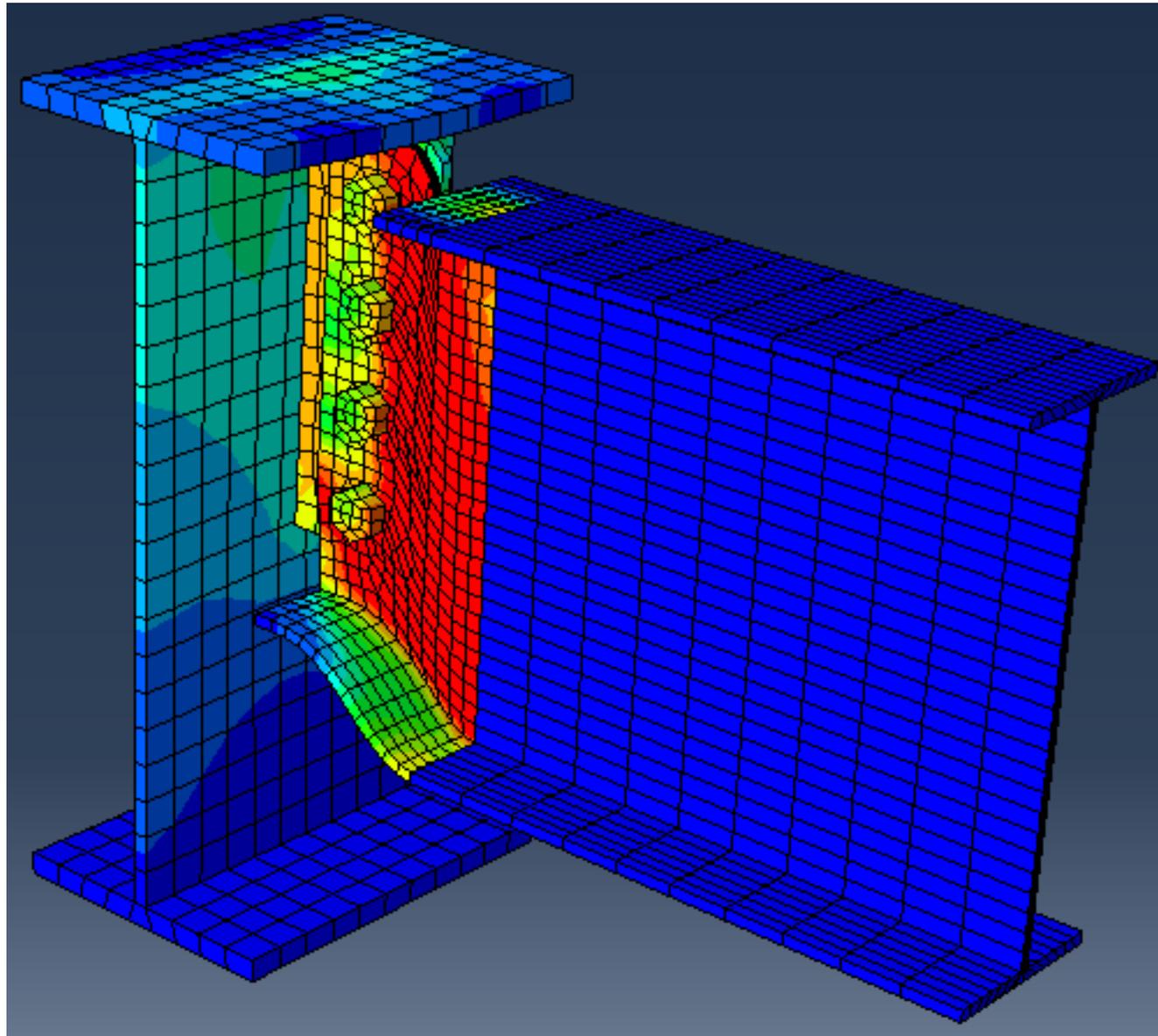


Fin Connection Sample

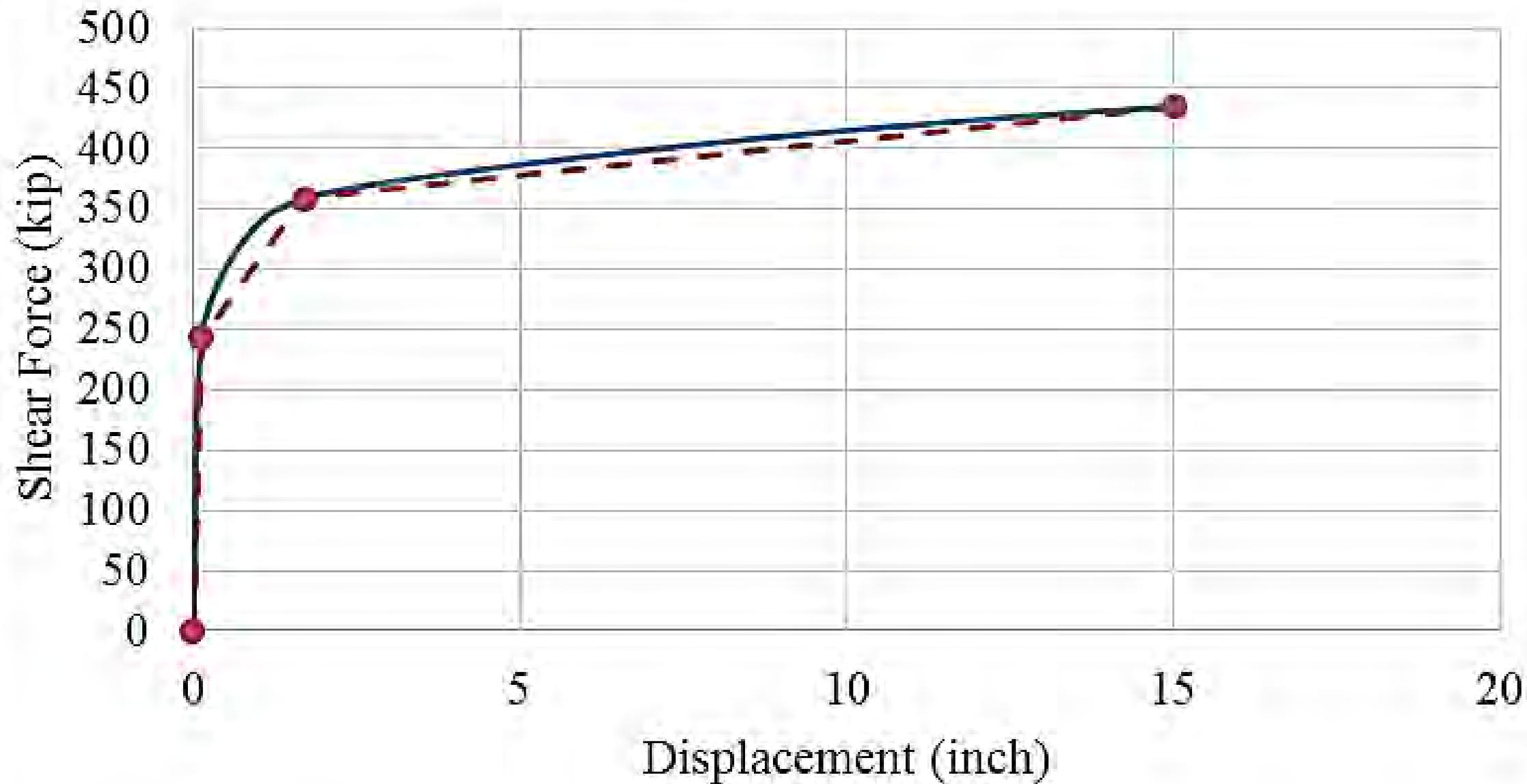


Moment - Rotation (F)

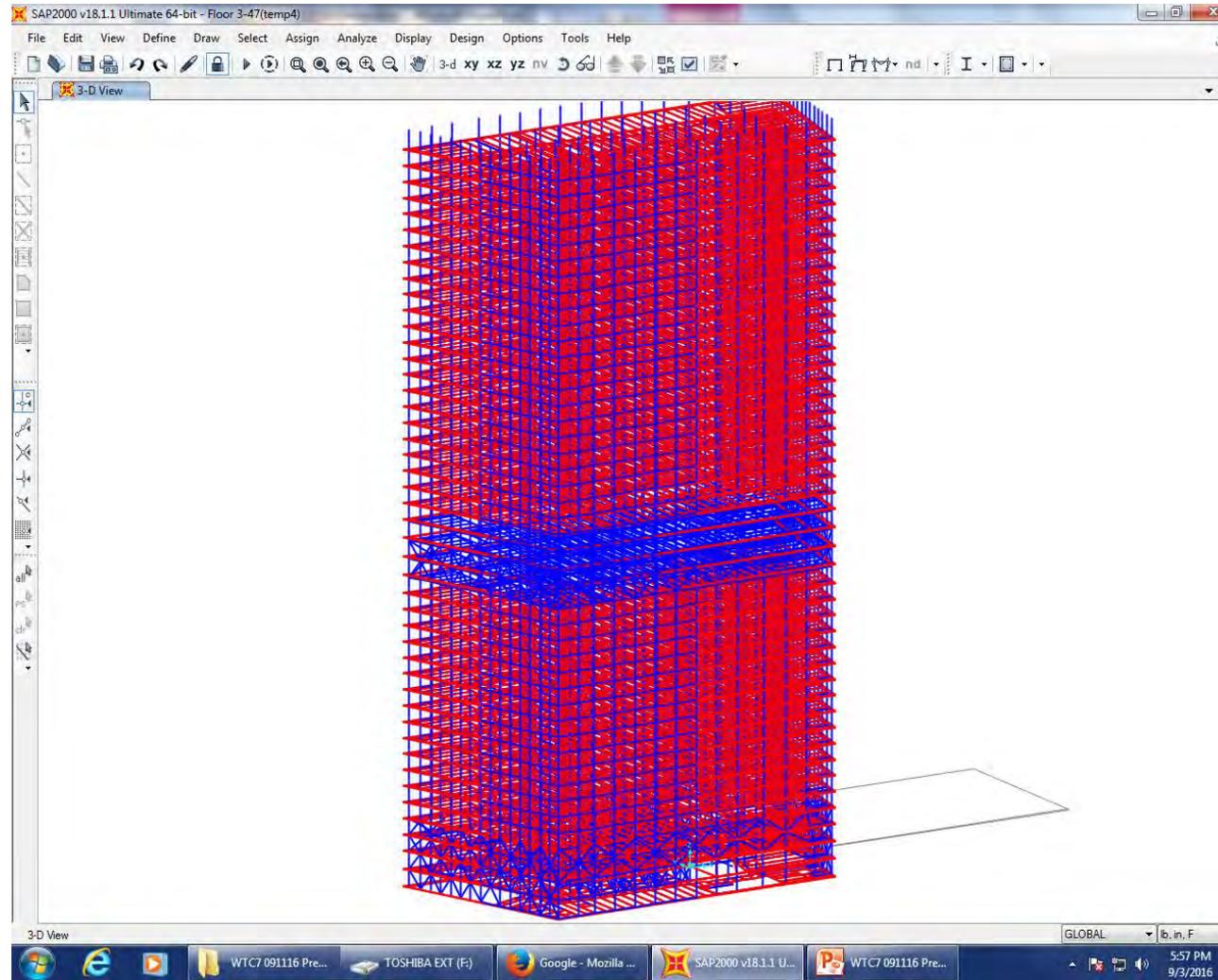




Shear - Displacement (H)



UAF SAP Model: Floors 3-47 (Bracing & Framing)



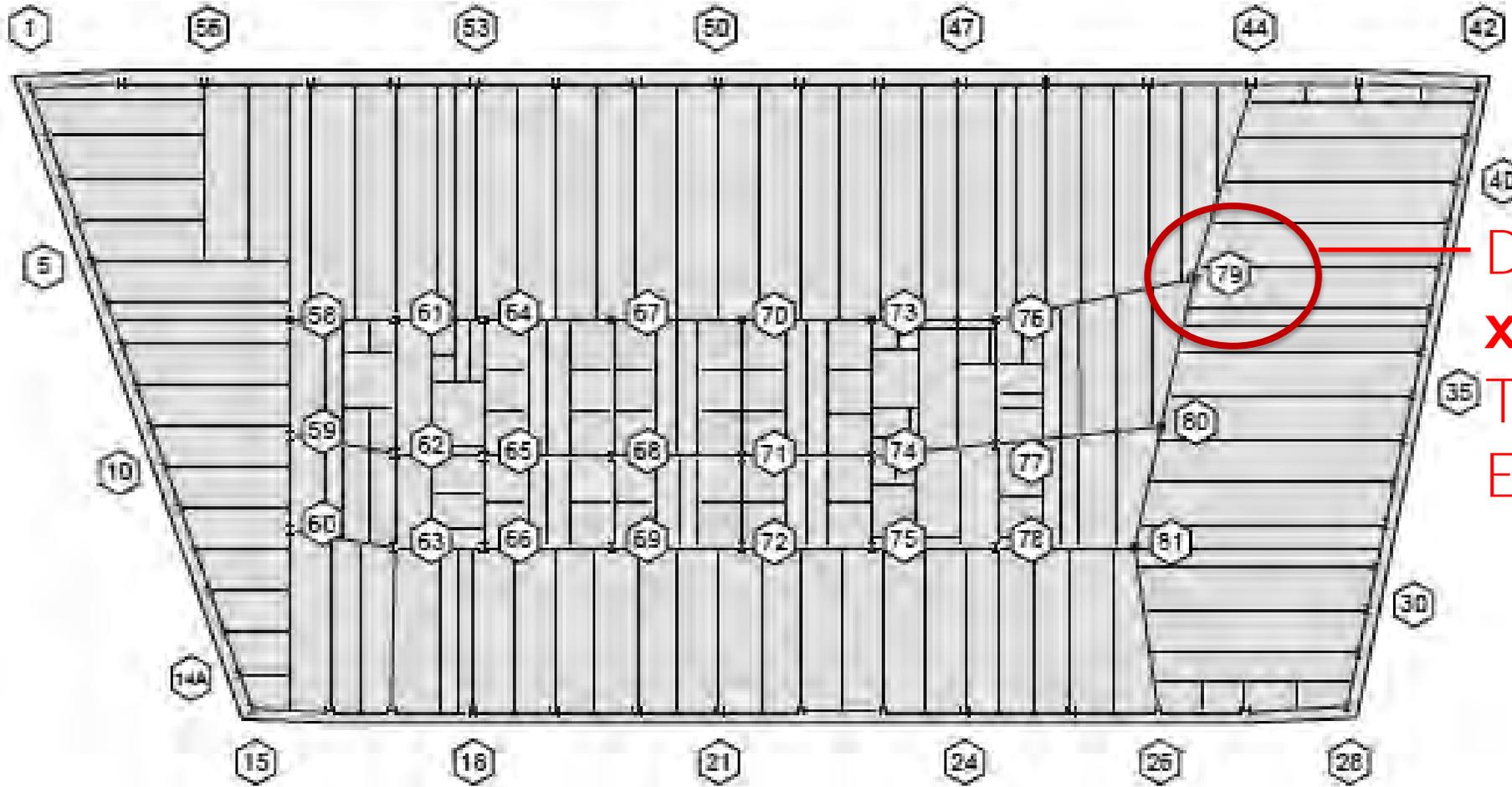
UAF:

MATERIAL PROPERTIES

1. Steel: ASTM A572 (yield = 50 ksi)
 - Thermal Conductivity: 35 BTU/(hr-ft-F)
 - Thermal Strain: $7.78e-06$ in/in/°F (value used by NIST)
 - Density: 490 pcf

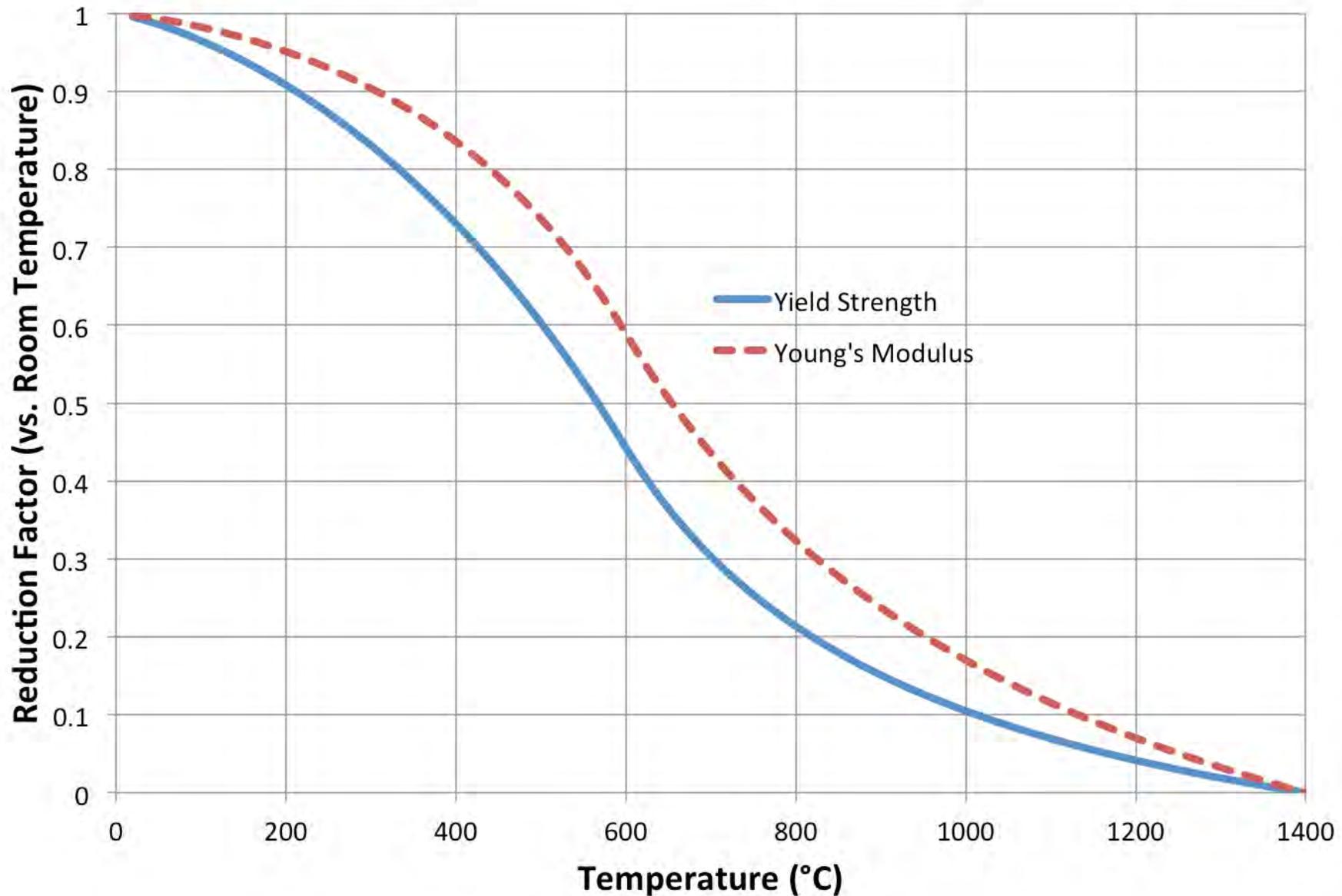
2. Concrete: 28 day compressive strength; 3,500 psi
 - Density: 145 pcf
 - Dolomite aggregate
 - Concrete thermal conductivity - 1 BTU/(hr-ft-F)
 - Equivalent conductivity (conc, WWF, forms) - 1.28 btu/(hr-ft-F)
 - Thermal expansion - $5.9e-06$ in/in/°F.

UAF SAP Model: PLAN VIEW – FLOOR 13



DL: 5,142k
x = 1.92"; y = 0.73"
 The floor moved East @ column 79.

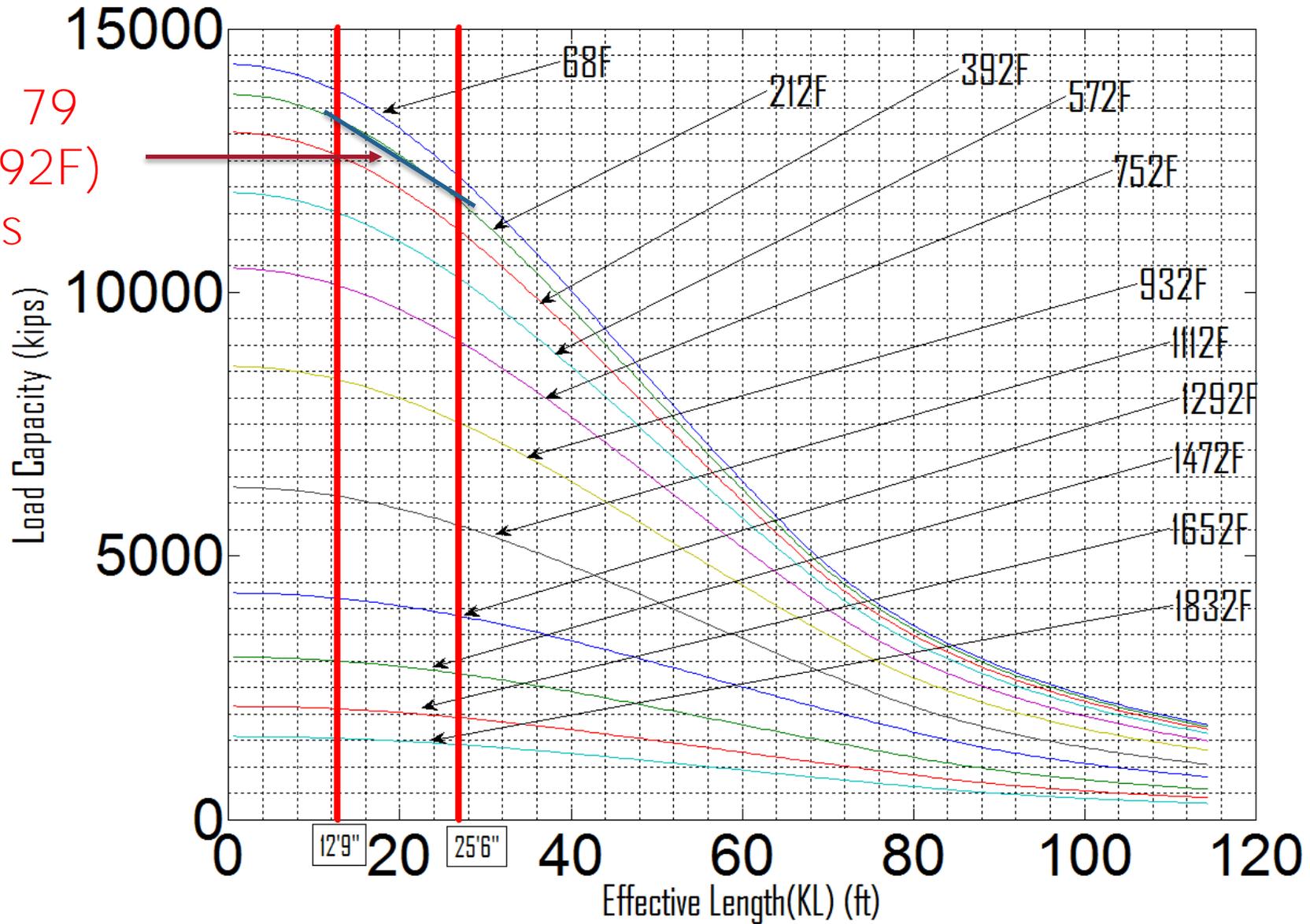
UAF: MATERIAL RESPONSE VS TEMP(°C)



UAF: Column 79; Column capacity (kips)

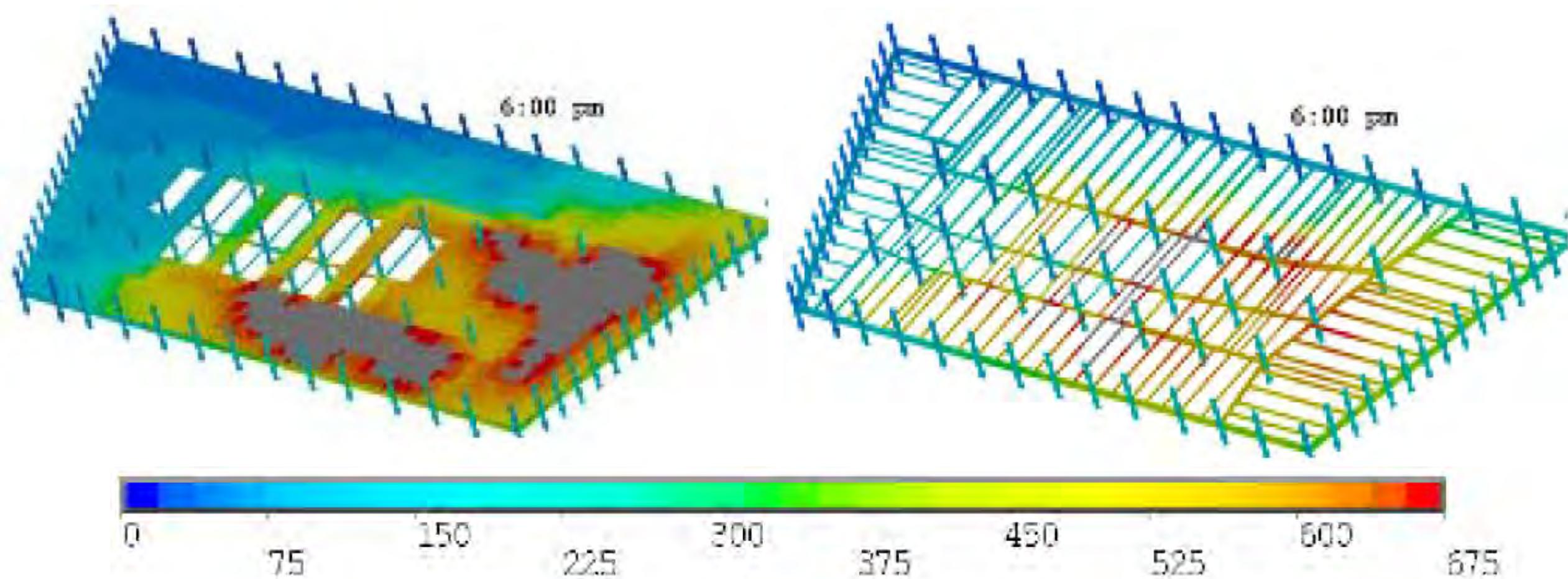
Column 79 Load Capacity (kips) VS Effective Length @ Various Temperatures (LRFD)

NIST Col 79
temp (392F)
All floors

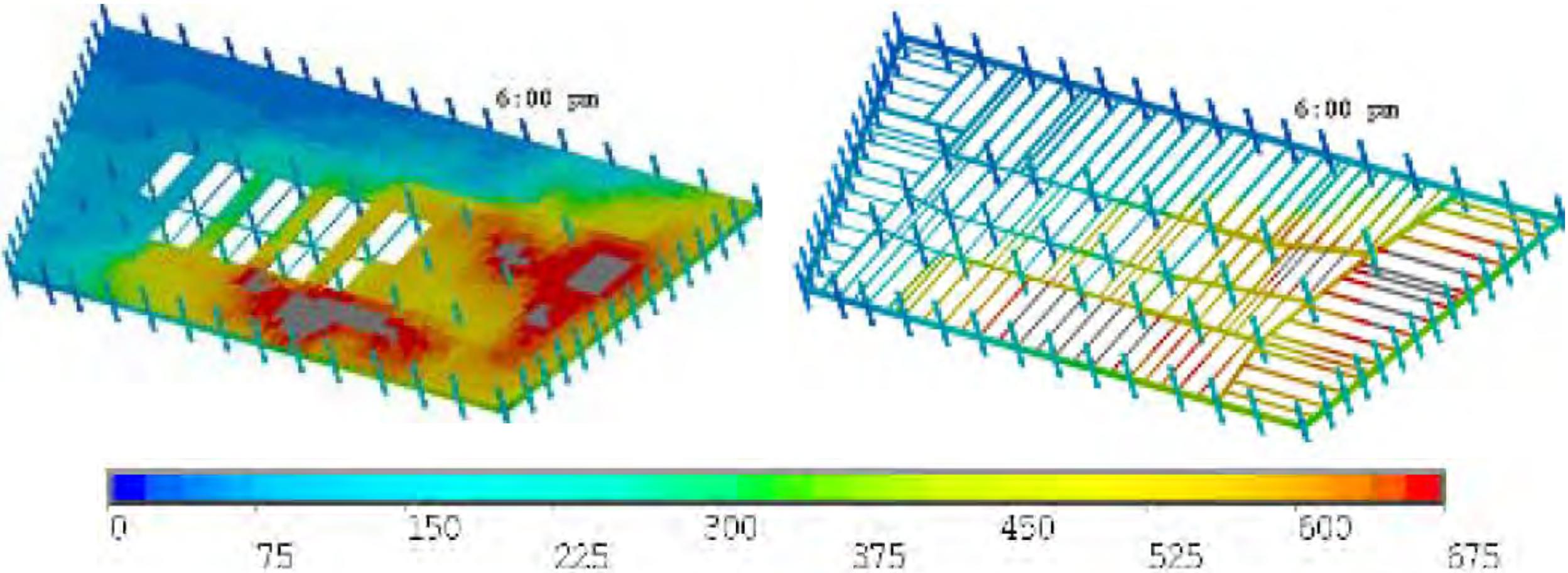


NIST FIRES (UAF STUDIES)

Temperature distribution (°C) on floor 13 (After, NIST)

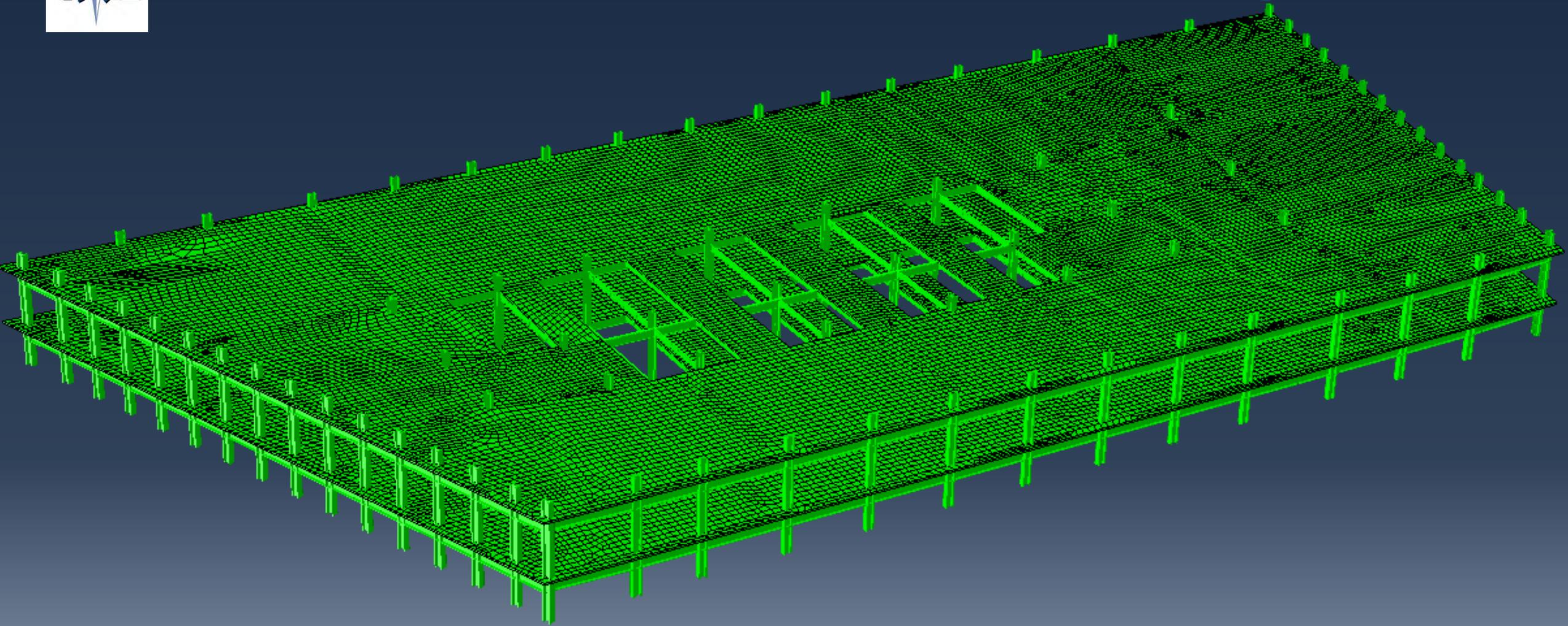


Temperature distribution (°C) on floor 12 (After, NIST)



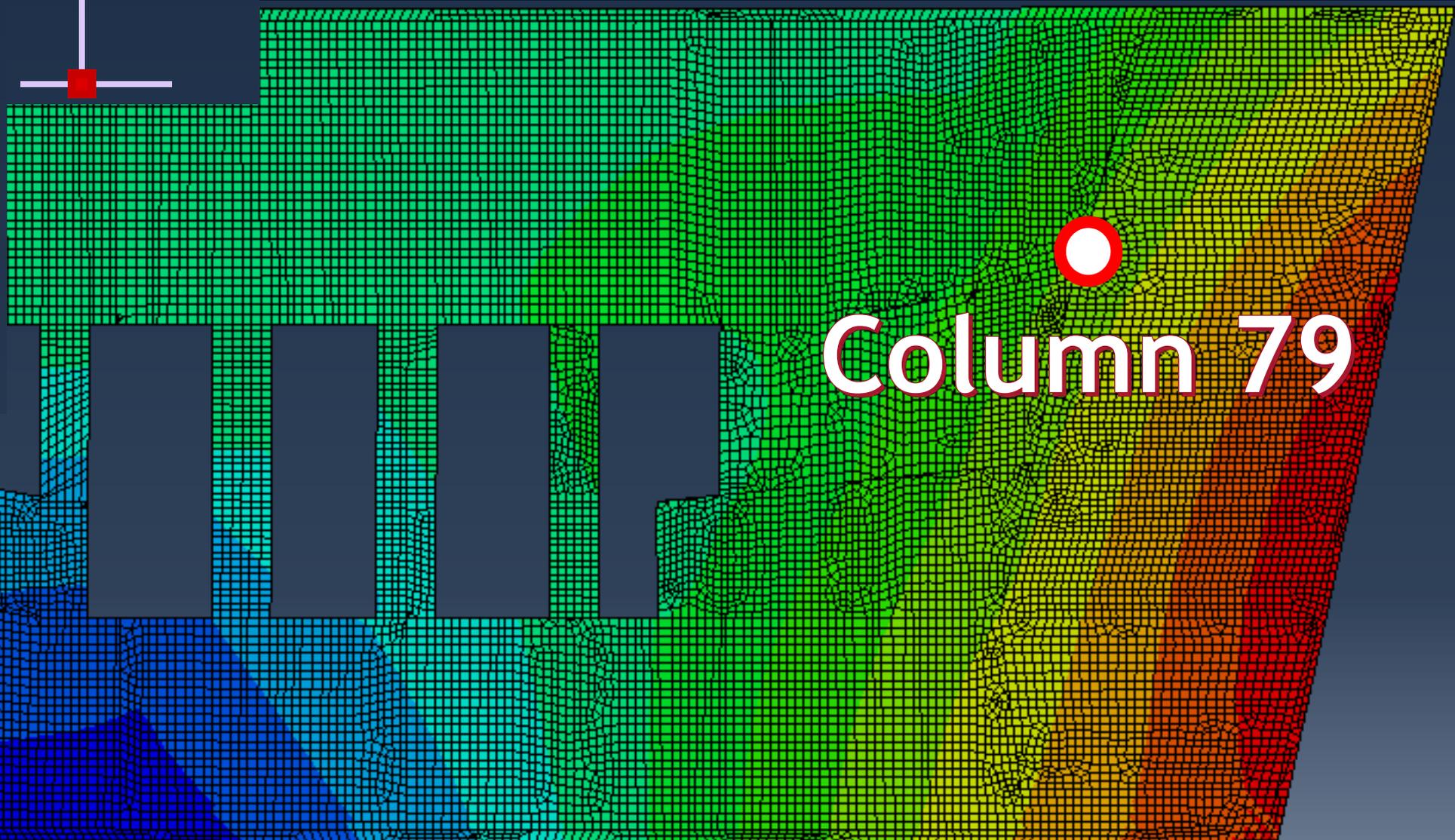
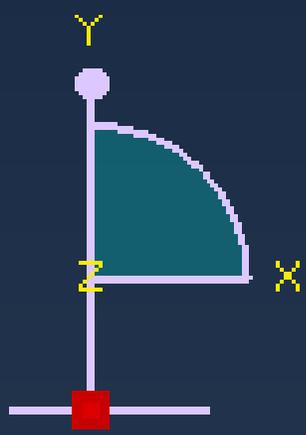
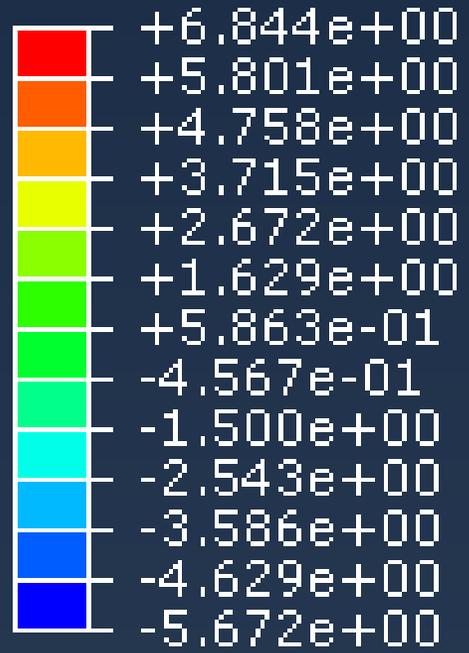
UAF (ABAQUS): STRUCTURAL EXPANSIVE MOVEMENTS

1. UAF ABAQUS Modeling



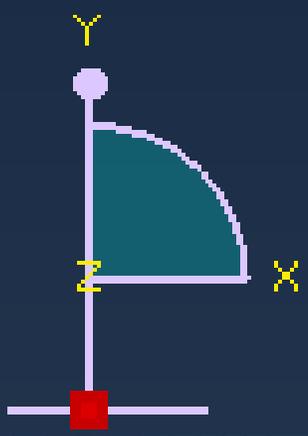
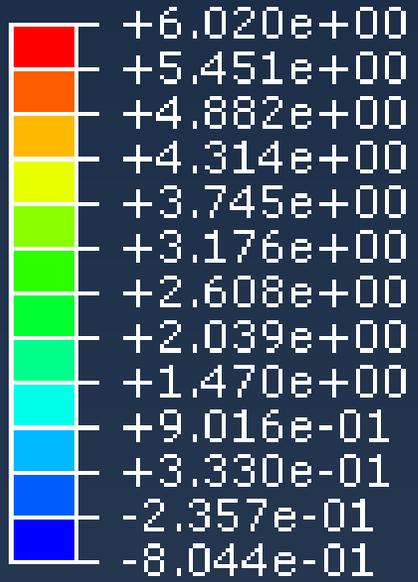
Floor 13

U, U1



Column 79

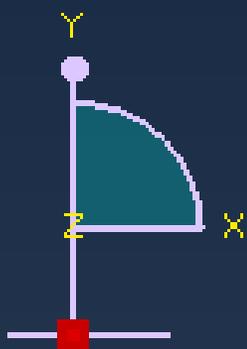
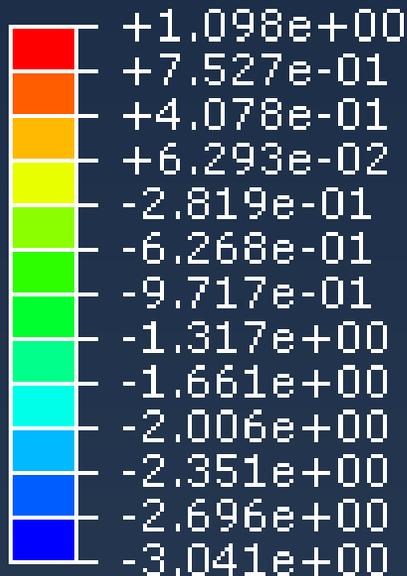
U, U1



Column 79 at Floor 13
(1.85 in, 0.94 in)

Vertical Movement

U, U3



W 33 x 130

W 21 x 44

W 24 x 55

W 24 x 55

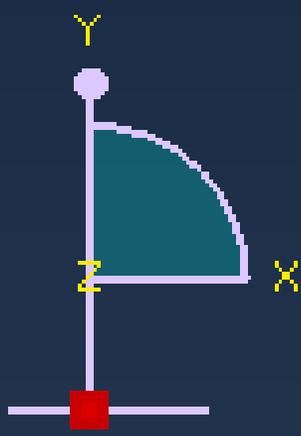
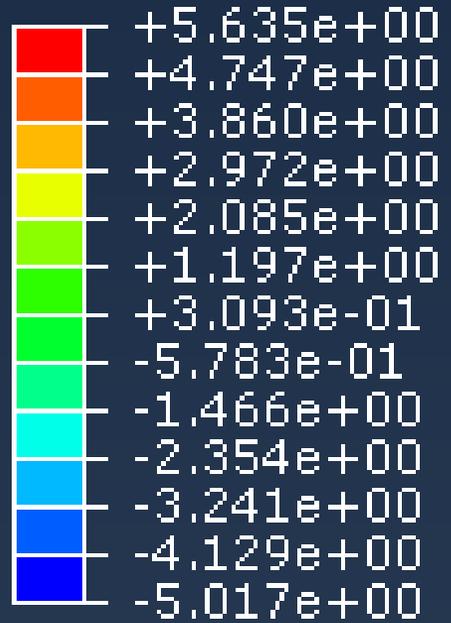
W 24 x 55

Column 79



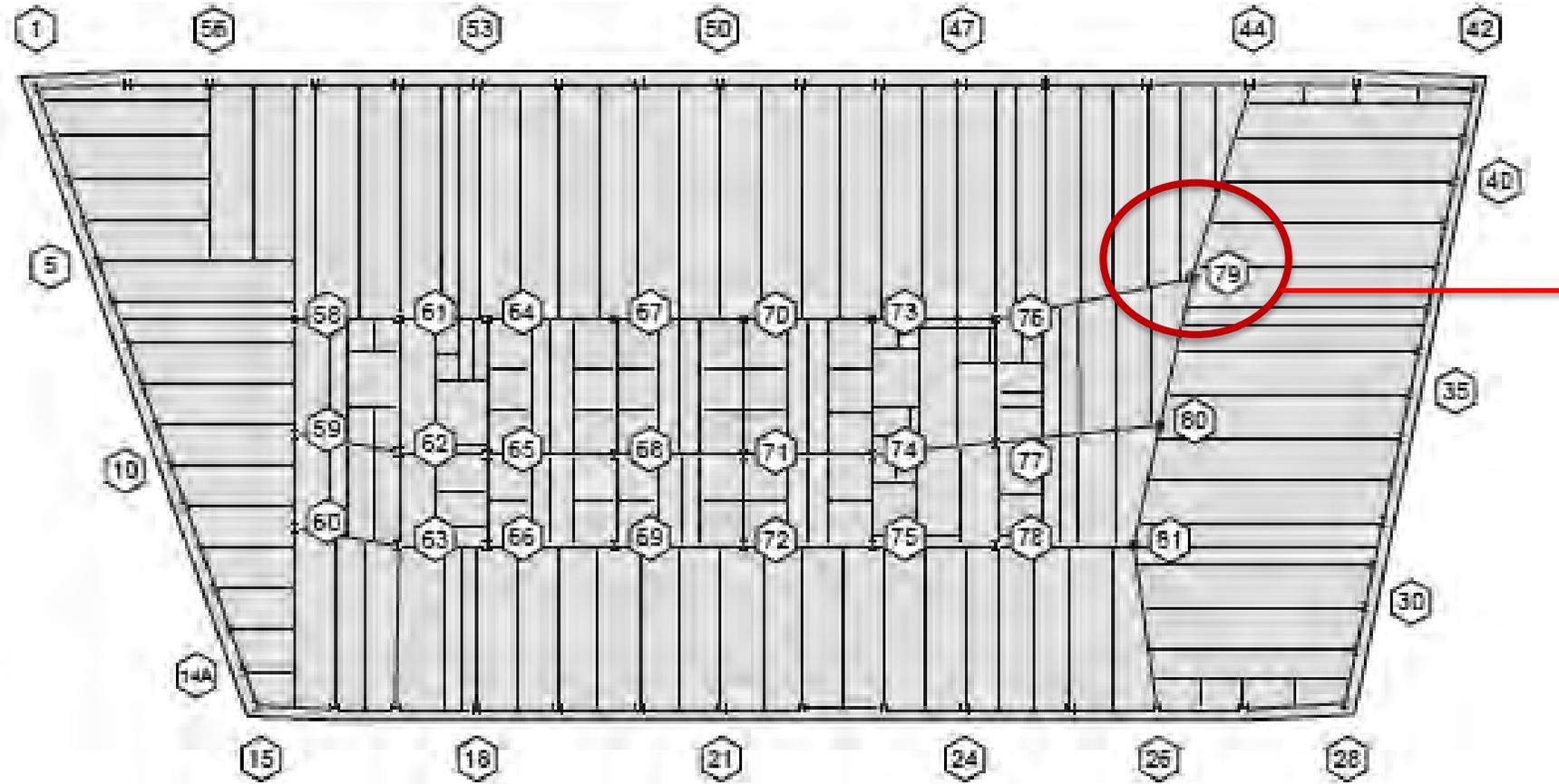
Floor 12

U, U1



Column 79

UAF SAP, ABAQUS Models: PLAN VIEW – Column 79; FLOOR 13



SAP:
DL: 5,142k
x = 1.92"; y = 0.73"
→

ABAQUS:
1.85", y = 0.94"
→

NIST:
5.5", Revised: 6.2"
← ←

COMPARATIVE STUDIES

Items	Yes	No	Partial
Floor Framing - Steel Connections (springs)	UAF		NIST
Exterior steel framing connections included (springs)	UAF	NIST	
Girder to column Stiffener Plates @ Col 79	UAF	NIST	
Floors (composite with beams, not girders)	UAF, NIST		
Floors (composite with beams & girders)	UAF	NIST	
Thermal expansion of the concrete deck	UAF	NIST	
Thermal conductivity & expansion for matl. properties	UAF	NIST	
Thermal horizontal movement @ col 79 (NIST: 5.5"; UAF: < 2")			
UAF: Based on NIST Column Temperatures; col 79 did not buckle under gravity loading.			

Did Building 7 Collapse from Fires?

- No (this is based on our calculations)
- This contradicts findings by the National Institute of Standards and Technology (NIST)
 - The NIST Approach
 - UAF Research Team approach and findings

UAF Conclusions:

- The concrete floor diaphragm stiffness is significant and even with no shear connectors, frictional resistance to thermal expansion is not trivial.
- The thermal expansion of the concrete deck cannot be ignored and it is likely less than steel (the value is highly dependent upon the type of aggregate).
- The research team evaluated fire by considering the air space below the beams in the space between the drop ceiling and the structural steel framing. The result is that a fire underneath will likely burn through the drop ceiling quickly and its resistance to heat transfer is likely not available to help.
- The NIST vertical collapse was not consistent with that of the actual collapse. The difference was primarily influenced by not modeling a significant portion of the structural framing connection details.

What's Next

- We welcome input;
- We will be making the study available for public comment and peer review;
- We are completing examination of progressive collapse caused by various conditions;
 - Failure at the substation level;
 - Examining building response for various columns removed;
 - Examining issues related to the perimeter trusses.