

RBS Moment Connection Analysis Using a Solid Model

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Abstract

The unpredictability of the steel beam welding connection has led to many solutions, including the are of focus for this research; Reduced Beam Section (RBS) Moment Connections. The RBS in steel moment connection facilitates the calculation and predictability of failure in design. The RBS section is created by cutting out part of the flanges in a beam. This creates a plastic hinge where the beam will fail first [1]. This creates a model of predictability on the durability and strength of the beams. Creating a RBS connection increases the overall ductility of the steel frame. The RBS section reduces the flange width which causes stress concentration on the reduced section and this then lowers the stress on the welds. The lower stress then prevents unexpected brittle fracture in the welding a predicted plastic deformation of the RBS section during a seismic event [2,3]. The research is focused on optimizing the RBS connection. Finite models will be created using ANSYS to investigate how different RBS connections react in different situations and what is the most efficient design in terms of safety and cost.

Introduction

After the 1994 Northridge Earthquake, the inadequacy of the welding in steel beam connections was highlighted leading to a dire need for improved steel beam to column connections. Steel beam to column connections had brittle fracture at the welded areas due to the seismic load concentration, far less than estimated by the engineers [1]. Since the properties of steel beams have a specific ductility, the designed beam did not provide relief to the welds but instead concentrated the stress on the welded points [1,2,3]. The changes steel undergoes while welding differs due to many factors, including human error and environmental factors, thus it cannot be accurately quantitatively estimated [4]. Seismic events required a certain amount of ductility from the steel frame that the structure lacked since the welds did not provide a factor of ductility. [3,5] The cost of 1994 Northridge Earthquake was an estimated \$20 billion in property damage, including approximately 200 bridges that were damaged [6].

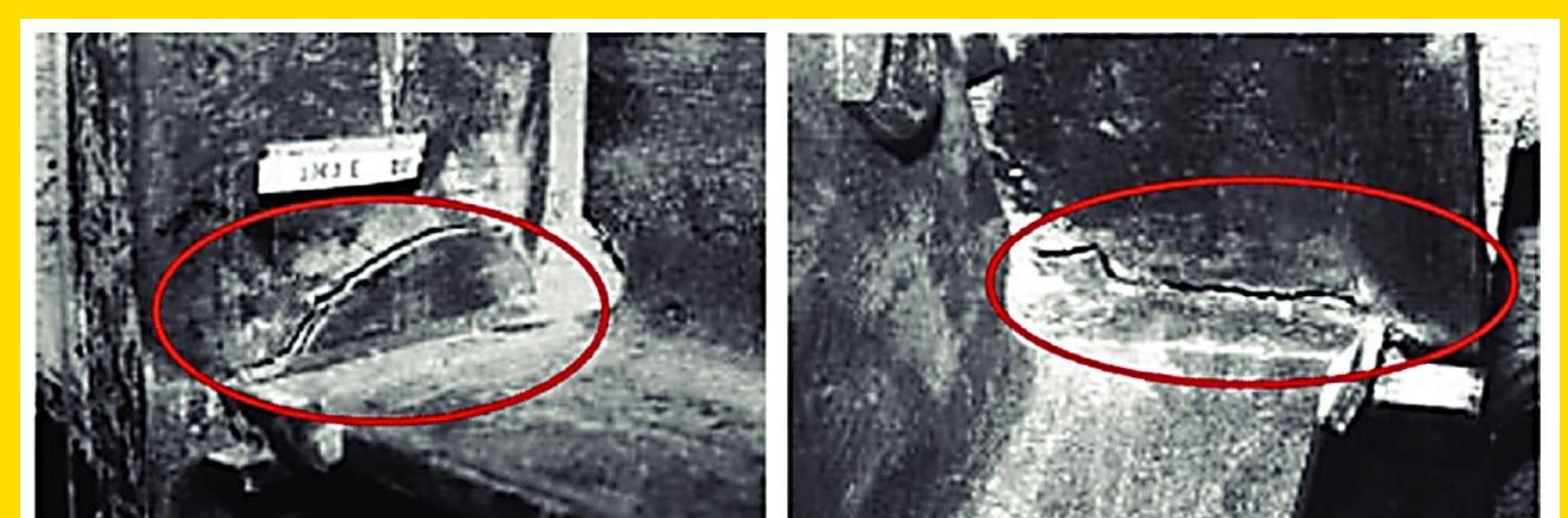


Figure 1: Brittle failures due to welding on beam to column connections pre-Northridge [8]

The brittle fractures of the welds occur due to the material properties of the welding [7]. Welds are known to be susceptible to fracture under high stress events [7,8]. Two examples of what brittle fracture looked like during the Northridge Earthquake in 1994 are shown in Figure 1. These brittle fracture are significant because they have lead to multiple engineering failures, including bridge frames, and building that collapsed. In addition to financial loss, there were approximately 125,000 residents left homeless, in addition to multiple civilian injuries and fatalities' [6].

The main prevention now is the RBS section because it does not require additional support or systems. It requires less material due to flange material being cut out. The purpose of cutting the flanges is to increase the stress in that section which reduces stress on the welds. The main purpose of the research is to make RBS section more efficient and reduce costs when different situations occur due to architectural designs. In short, to optimize RBS moment connections.

Creation of Solid Model

The solid model as shown in Figure 2 has refined mesh, which allows for more accuracy in calculations, around the more sensitive areas. The reason for this is because these areas are the most critical in terms of analysis. If the whole structure was using a mesh that fine it would take much longer for the computer to solve and it would take up a vast amount of computer storage.

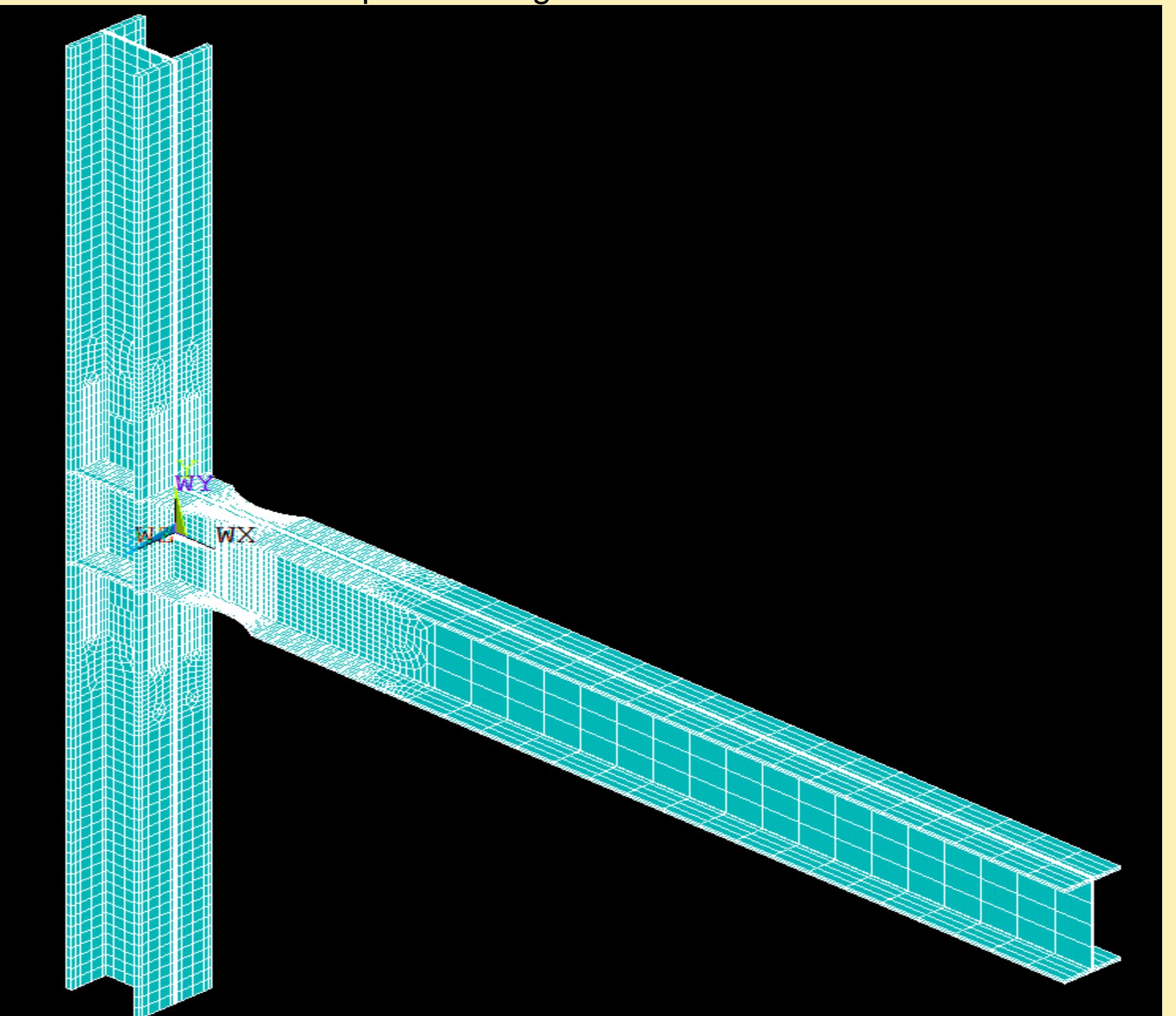


Figure 2: Meshing of the Solid Model.

Verifying Results

The graph shown in Figure 3 is comparing the research results to a published paper by Taber and Deylami in 2005 [7] to the model we helped created. This comparison shows a strong correlation between the two graphs, which brings us to a conclusion that our finite element model is accurate and verified. It is crucial to verify the model before moving on to any further research because if the model has a problem in it there is no way to check other than by verification.

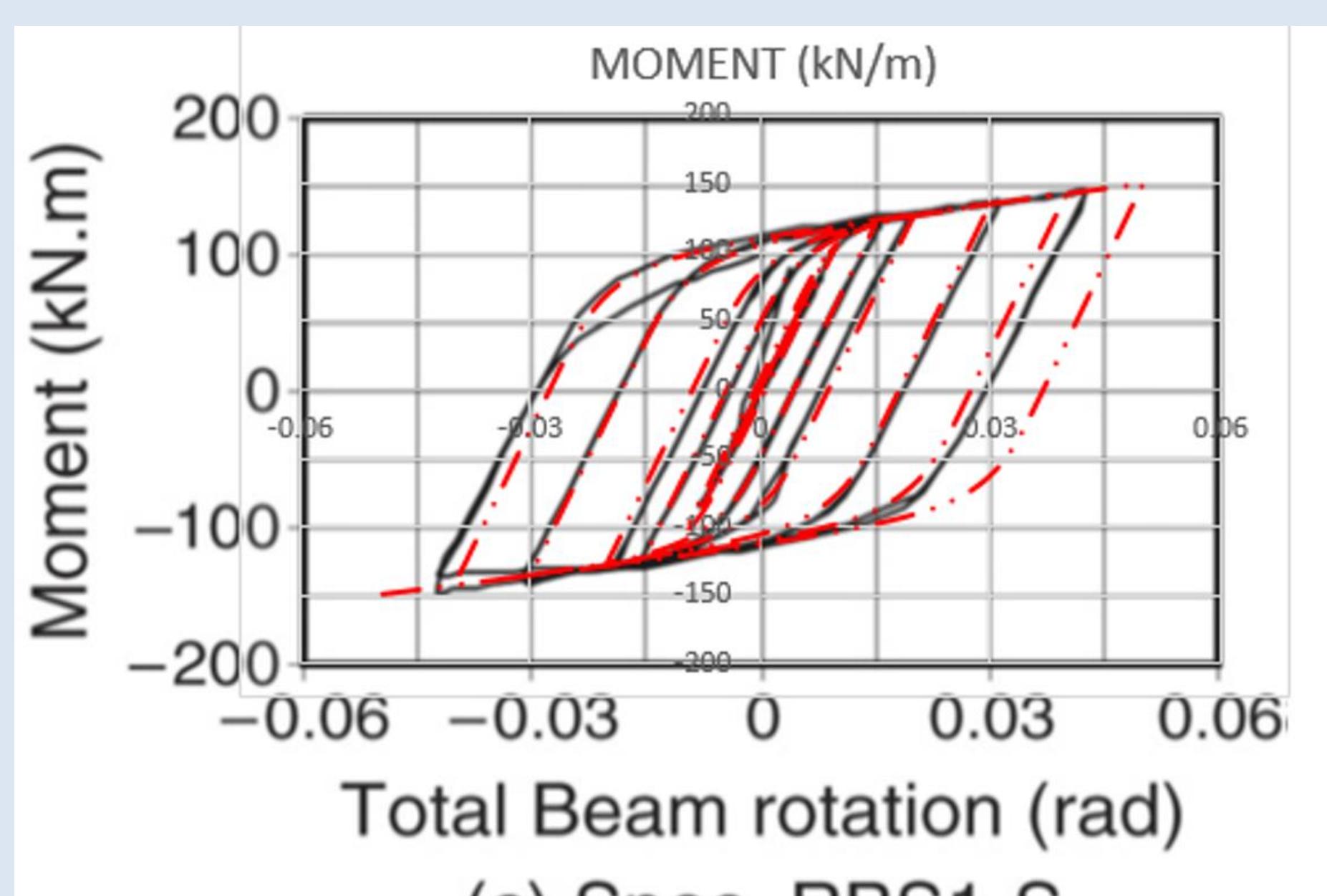


Figure 3: The red dashed lines are the results of our mode. The black graph is from the published article [7].

Method and Deflection Results

The results obtained from the Finite Element Analysis is shown in Figures 4 and Figure 5. In Figure 4 a better visualization of the beam deflection due to loads applied is shown below. It can clearly be noted that the beam is deflecting more at the RBS section due to the plastic hinge.

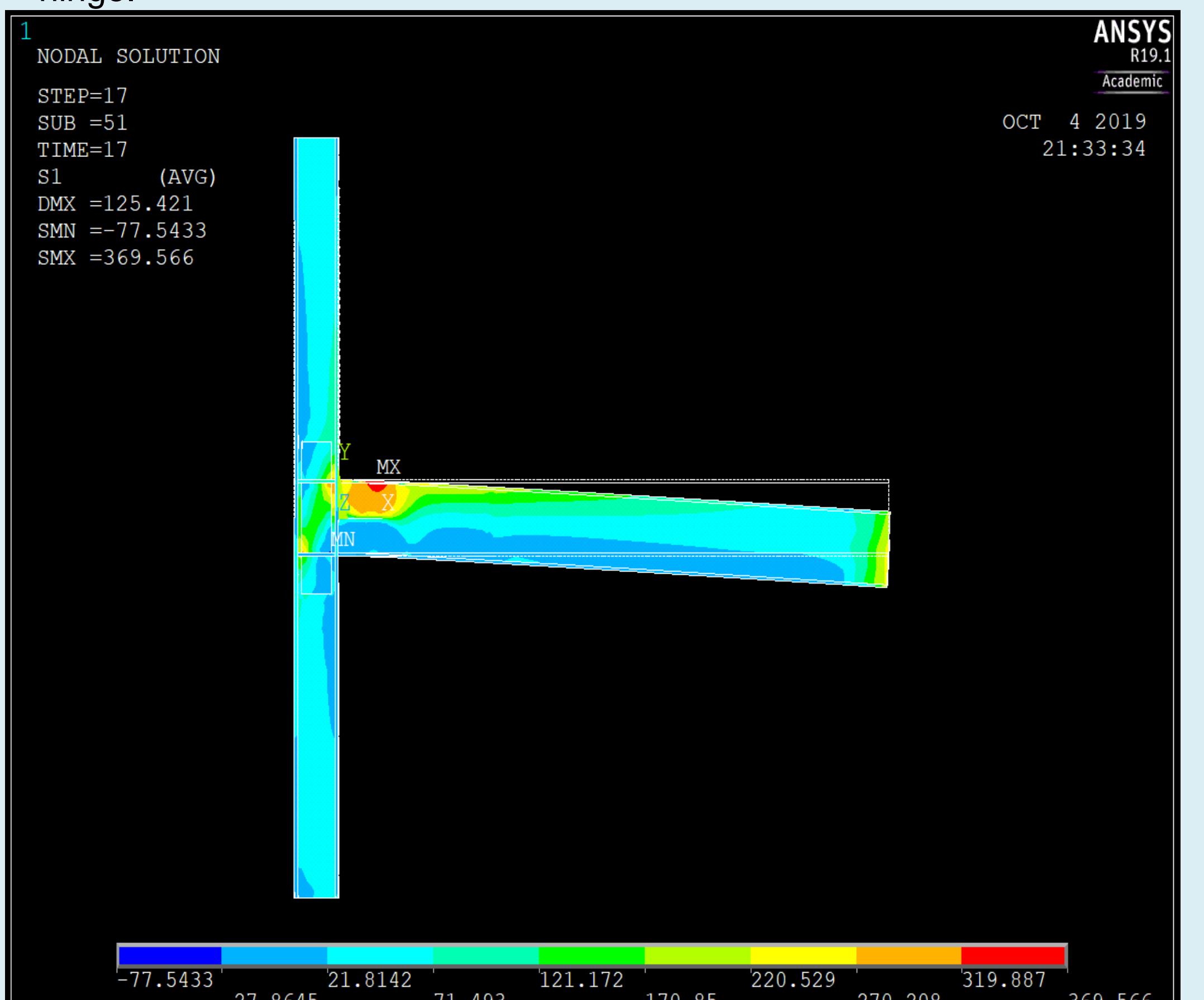


Figure 4: Deflection of the beam.

Method and Stress Distribution Results

The Figure 5 shows the stress distribution throughout the section. The reason this may look different from the shell model is because the solid model has 3D elements to it. This allows a more accurate computation of the stresses in the assembly, but it cannot efficiently calculate for buckling. Thus a solid model was created to ensure accuracy and efficiency in all calculations. Additionally, in Figure 5, a better visualization of the beam deflection is shown. Note how the RBS sections are clearly denoted as experiencing the most amount of stress in the structure.

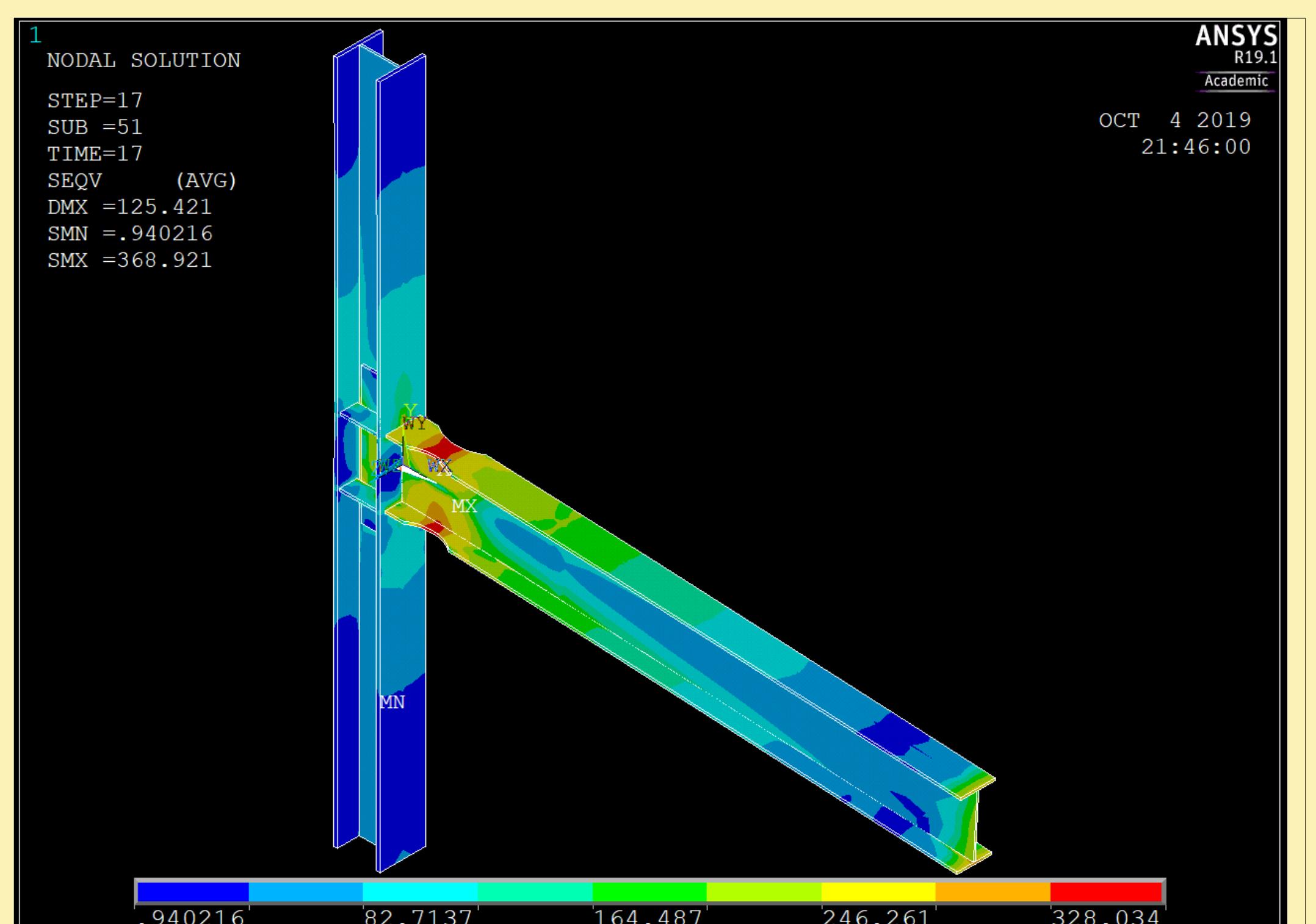


Figure 5: Isometric view of stress distribution in the Solid Model.

Conclusions

- The solid model captured a more accurate representation of the stresses through the structure. The more accurate the results the more confident the research is. The verification of the solid model shown in Figure 3 was almost identical to the reference graph.
- As expected the RBS section experienced the highest stress in the beam. The stress in the RBS shows that the design is doing its job and took some of the stress off of the Welds. More accurate criteria need to be identified to test the shape and size that will provide optimum ductility and strength to the beam.
- The RBS experienced high amounts of rotation of the beam. The high amount of rotation is the plastic hinge phenomena. These results were critical in identifying areas of optimization of the RBS design. Future work will be focused on providing optimization to the design.
- The results identified from the model confirm that the RBS section is efficient in controlling stresses in the weld. Brittle fracture can be prevented using this method. Optimization of the RBS section will create a safer and more cost efficient solution to seismic events in the future.

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Acknowledgements

This research has been made possible by Dr. Saber Moradi, professor of Civil Engineering at Ryerson University. Thank you Dr. Saber Moradi for having placed your faith in me, and for spending your time on guiding me through the research. I have grown as an individual, a student, and a professional throughout this project.