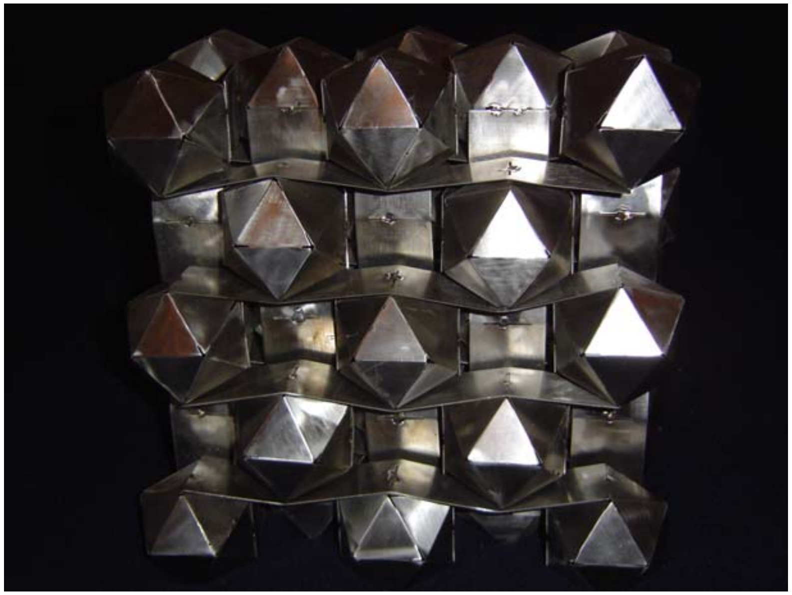

October 2005

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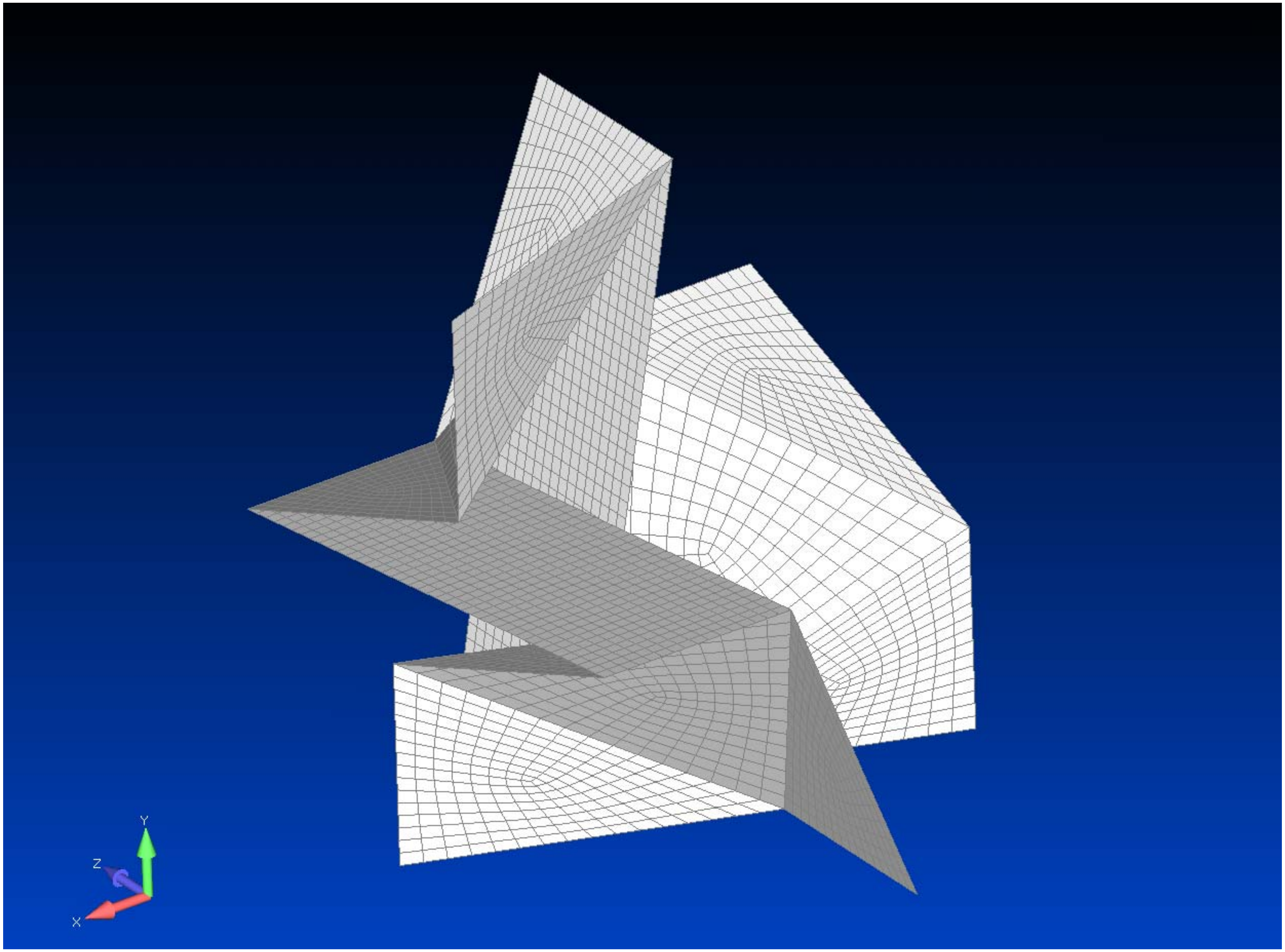
The modeling project used a densely-packed array of icosahedrons connected via rectangular straps as a guide to the FEA model construction. With a bit of inspection, several planes of symmetry within the structure can be visualized if one assumes uniform loading on any set of opposing faces.



For this modeling exercise, it is assumed that a uniform compressive load is applied in the ZX plane and it compresses the structure in the Y-direction. No free surfaces are assumed and the structure repeats itself off into infinity. Given these assumptions, the above symmetric representation can be created. The unit size of each icosahedron was 1.00" per edge.

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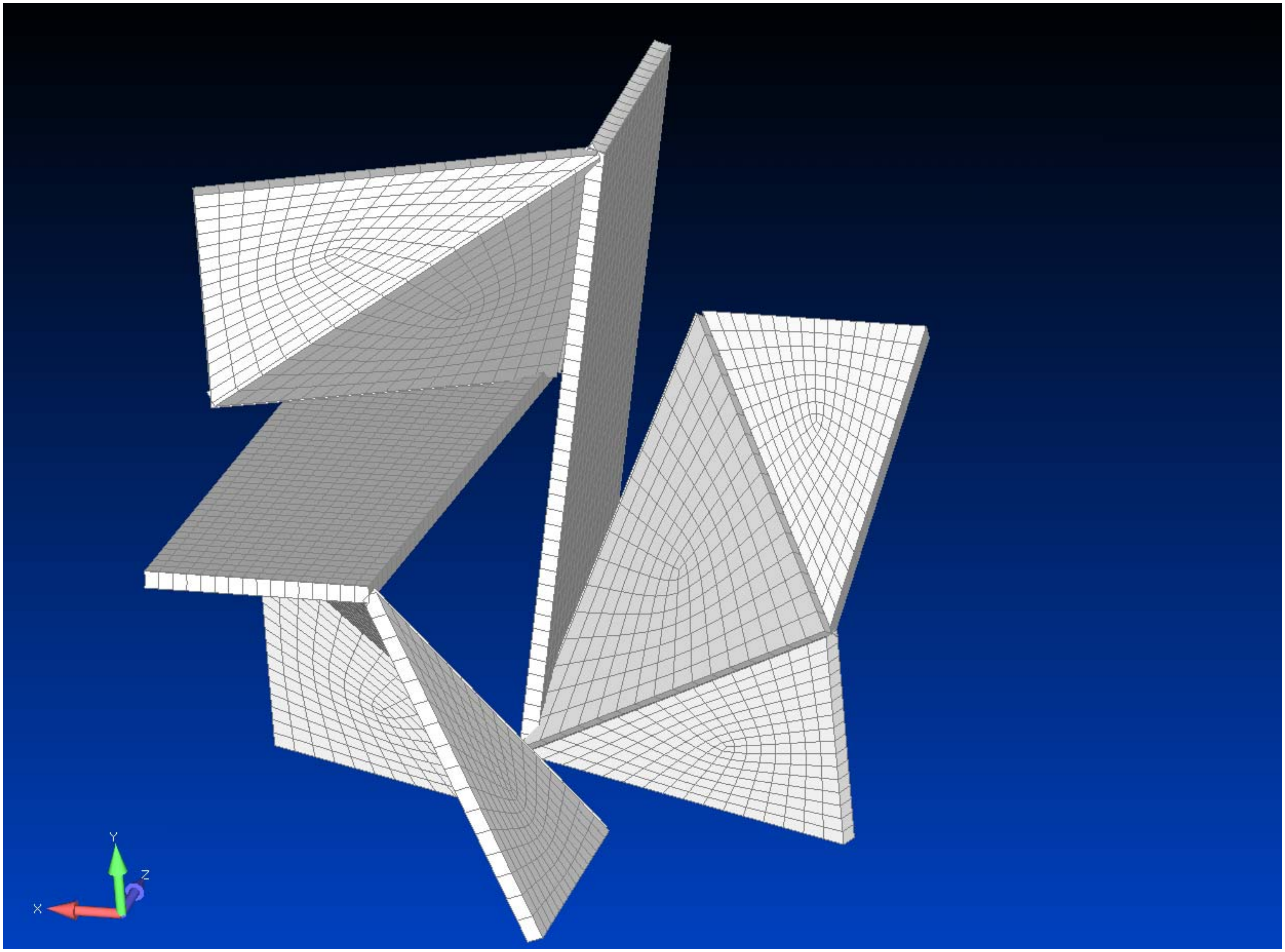

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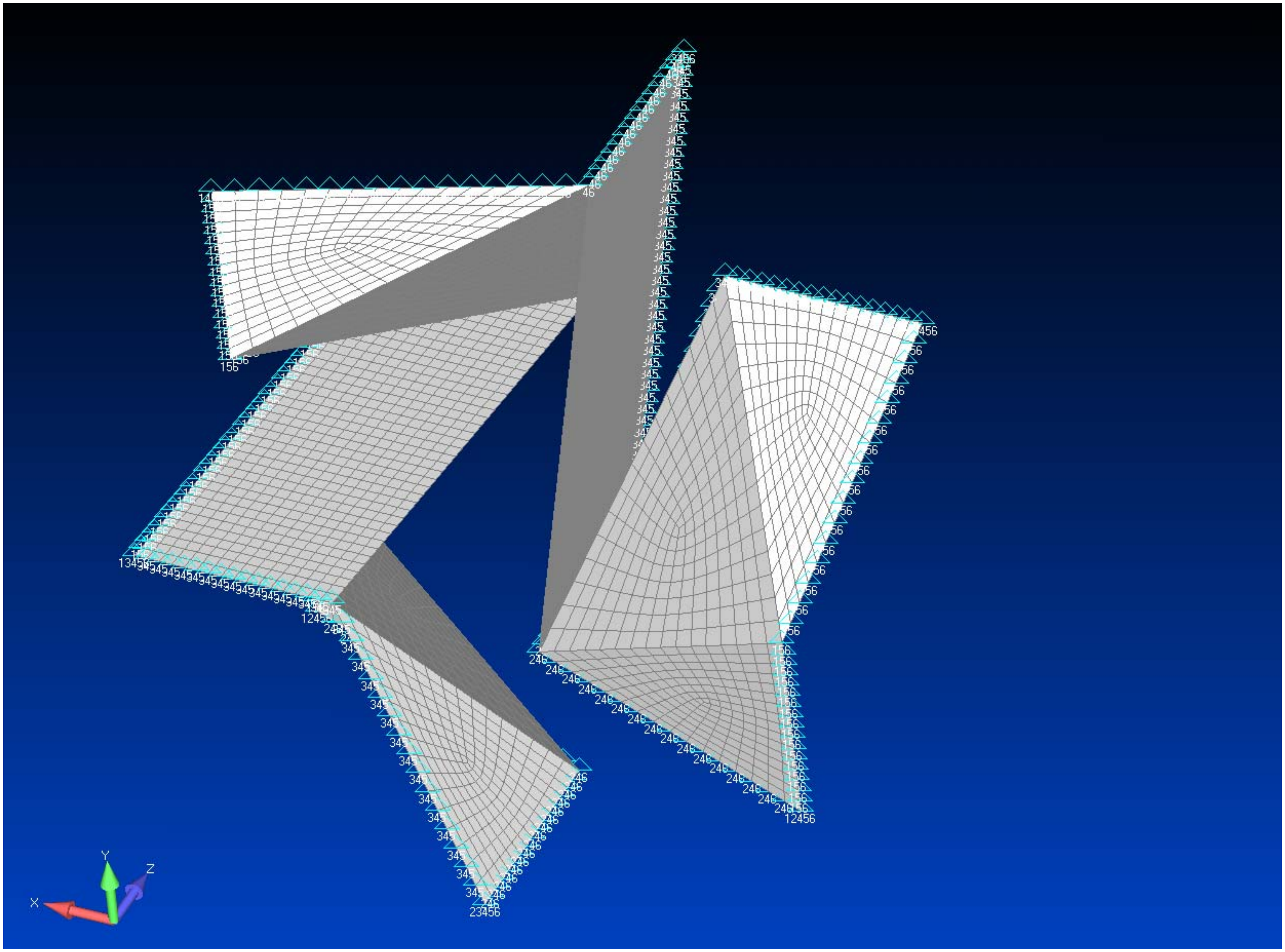
The structure was modeled using plate elements. Plate elements are meshed over surfaces and their thicknesses are assigned via a data entry item. One of the advantages of using plate elements is that the thickness of the strap or the icosahedron can be easily changed.



The symbols shown above enforce symmetry planes on the structure. In this model we are enforcing three planes of symmetry. In all, we have quarter-symmetry. However, a symmetry plane is also enforced within the ZX direction. A better understanding of how symmetry functions in this model can be visualized in the stress animations included along with this report.

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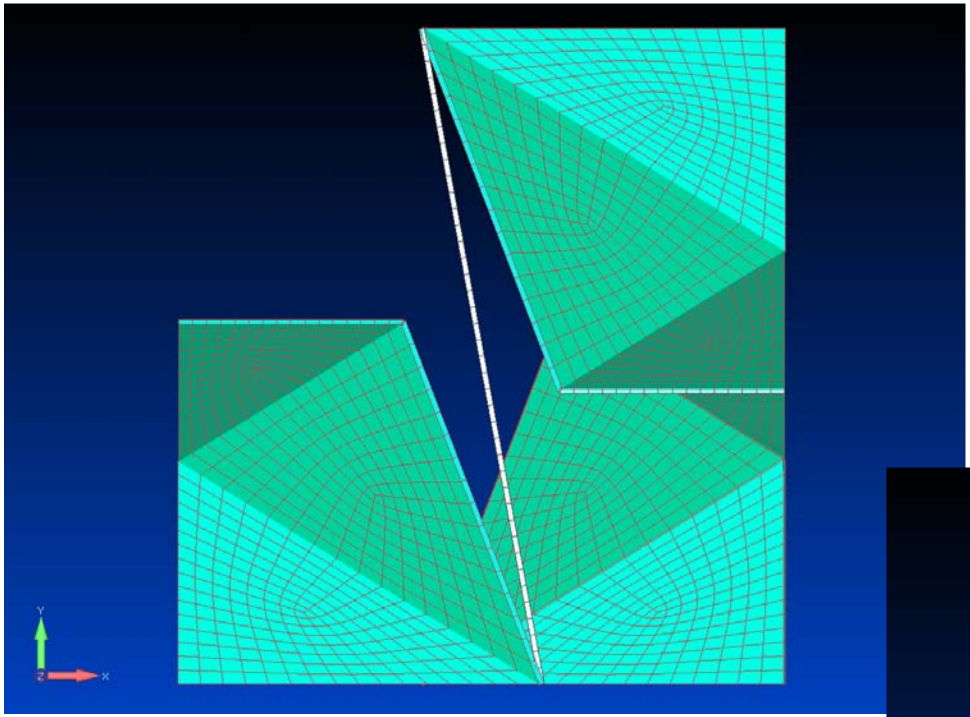

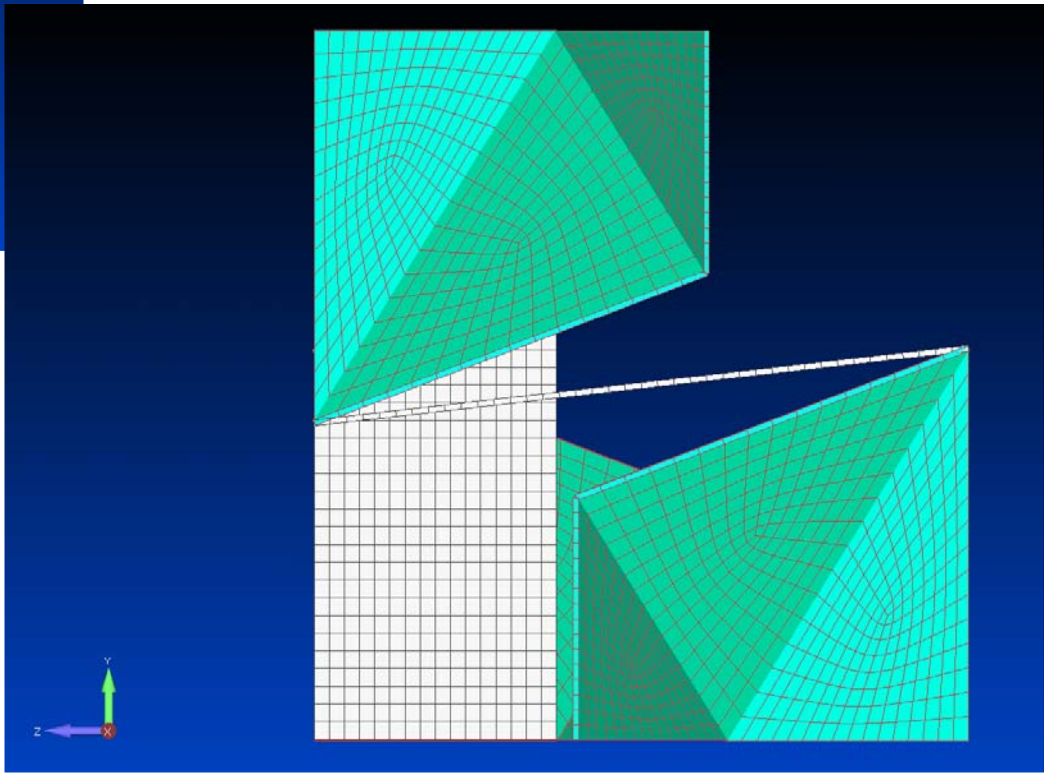

The packing density of the icosahedrons was estimated using the stainless-steel prototype model provided by Flextegrity. The above thicknesses for the plate elements is 0.012” or 30 gauge.

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Stress Results for 30 Gauge (0.012”) Structure

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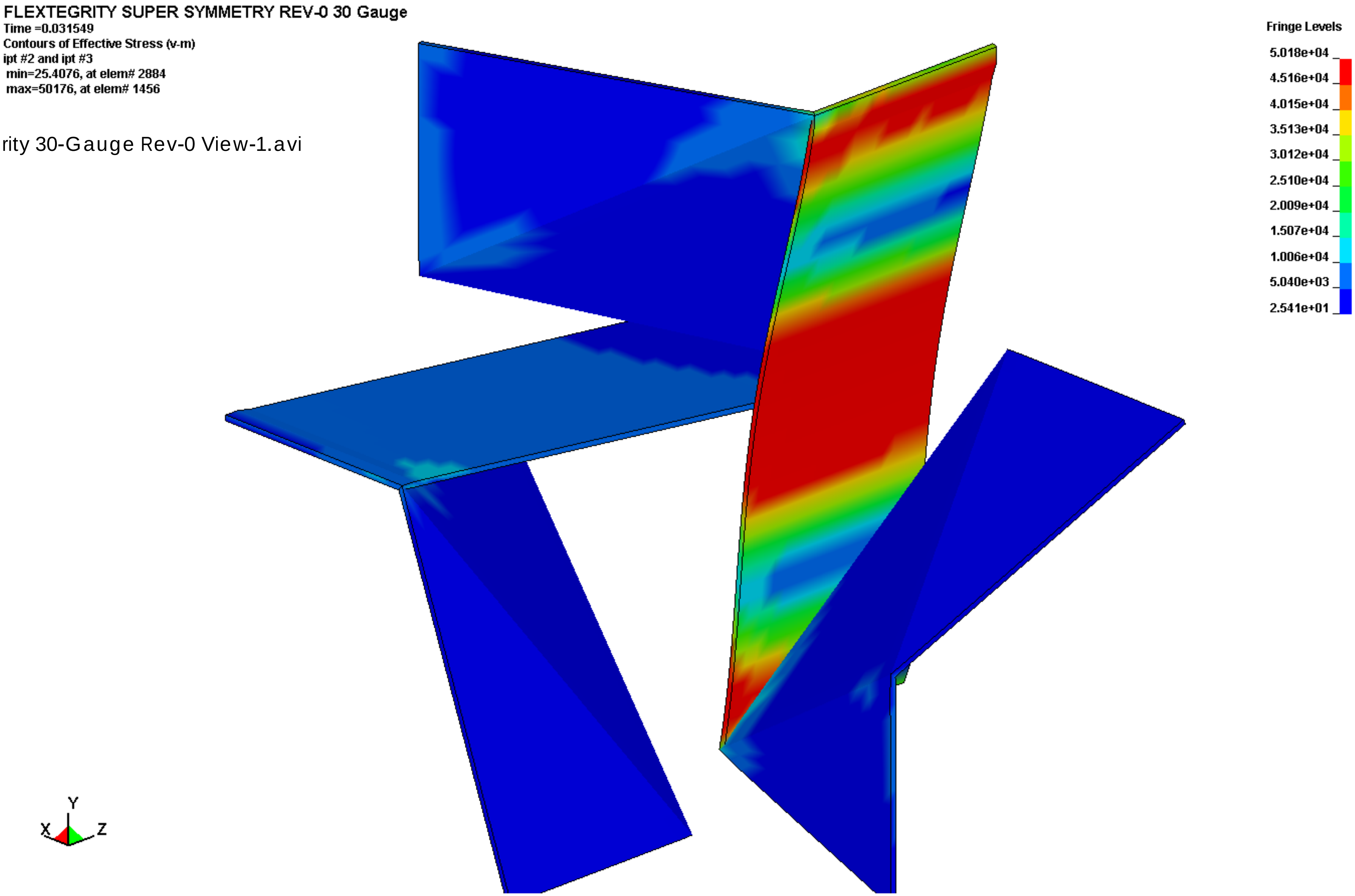
Flextegrity 30-Gauge Rev-0 View-1.avi



As a rigid plate in the ZX plane (not shown) is moved downward across the top of the structure, the load is almost exclusively carried by the vertical strap which quickly starts to overload and buckle. The yield stress of the material was set to 50,000 psi. That is, once stresses in excess of 50,000 psi are reached, the structure undergoes irreversible plastic deformation (damage).

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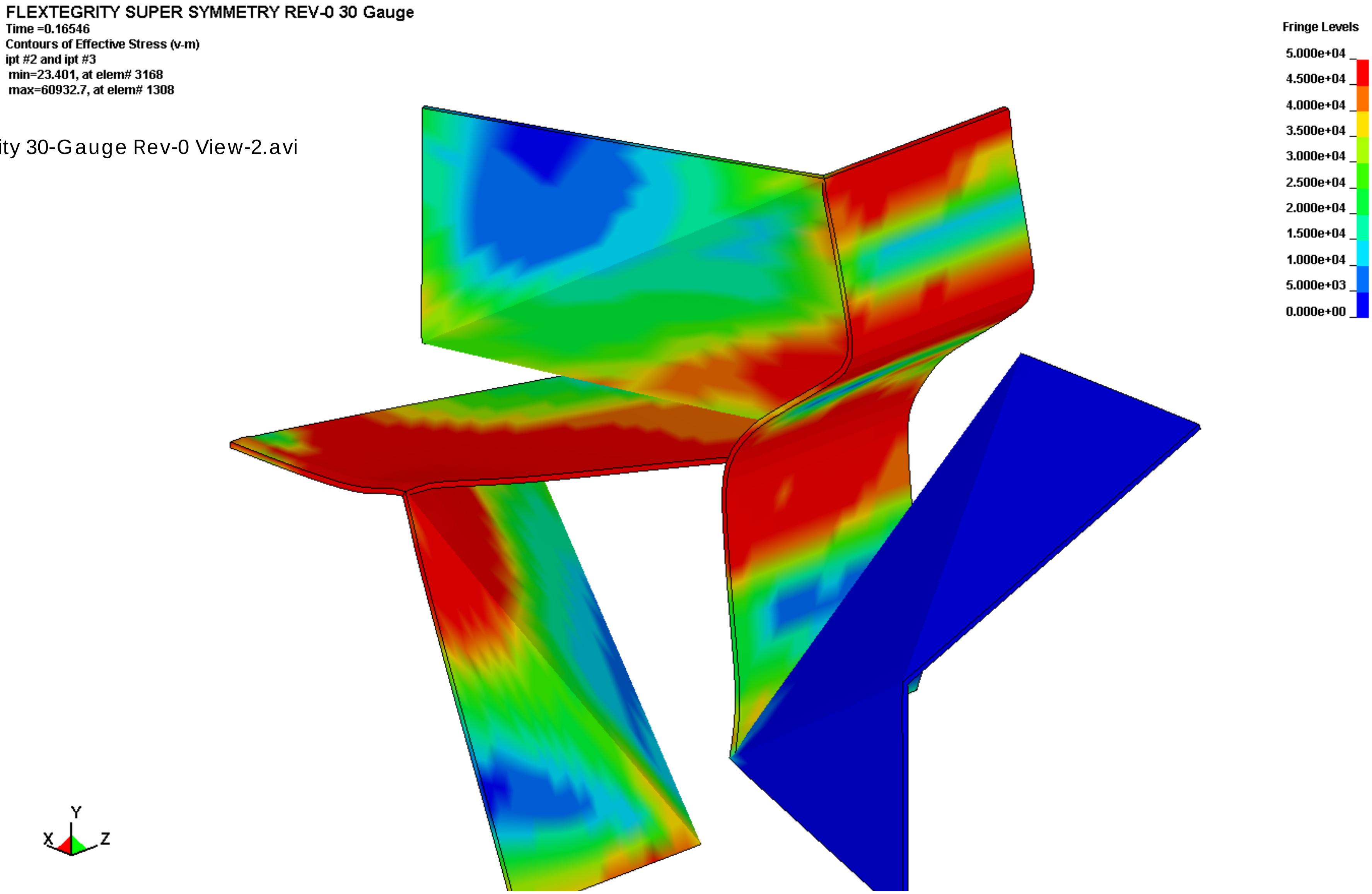
Flextegrity 30-Gauge Rev-0 View-2.avi



In this view, the stress legend is capped at 50,000 psi. As shown, the structure is severely overloaded. The rigid plate has moved about 0.16" into the structure. If the load was pure tension, then only the cross-sectional area of the strap bears load. This is a simple calculation to determine the load bearing capacity of the structure. That is, the cross-sectional area of the strap times the number of straps times the yield stress of the material will yield the load carrying capacity in lbf.

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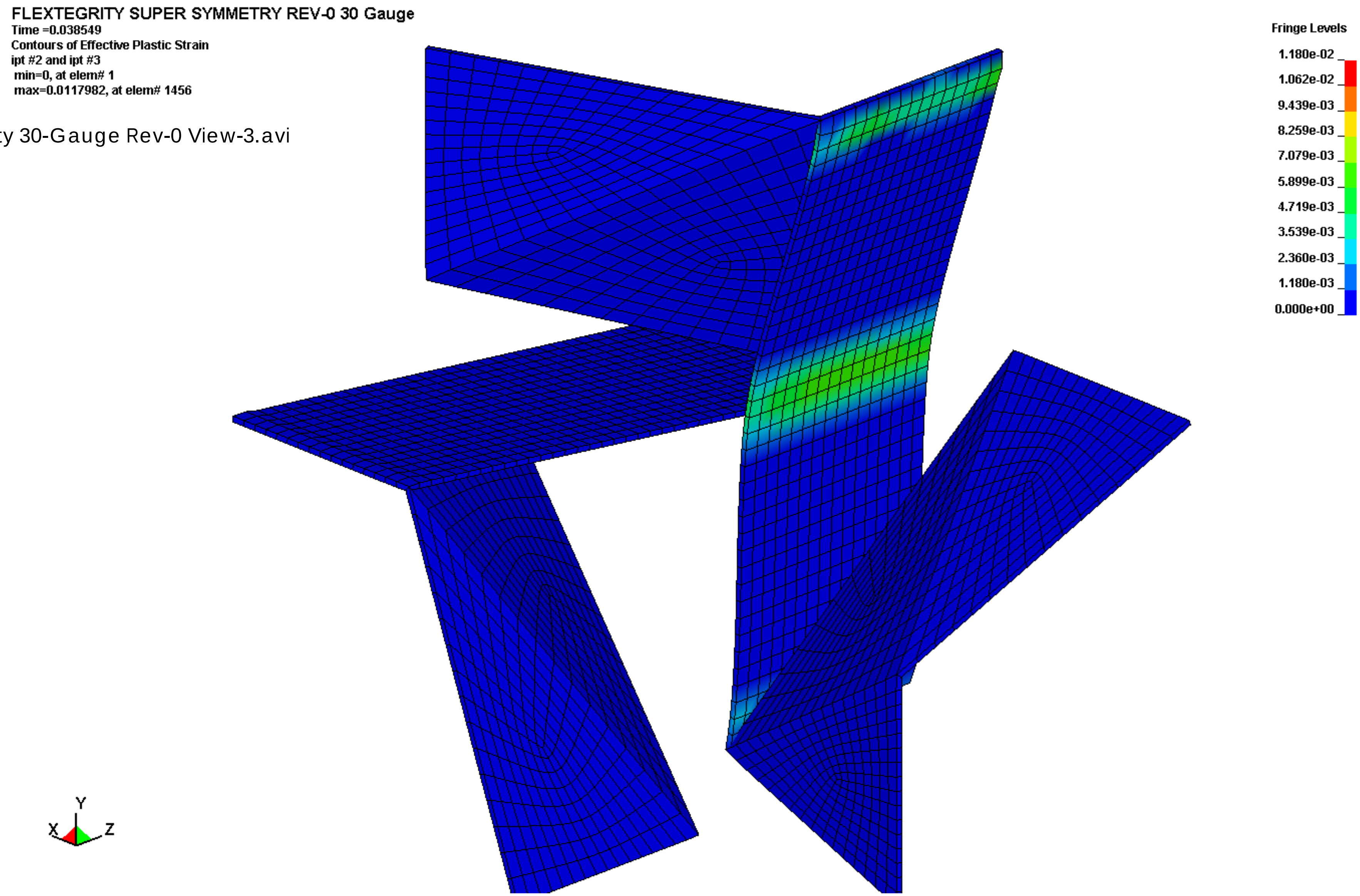

Flextegrity 30-Gauge Rev-0 View-3.avi

This contour plot shows the plastic strain in the structure during the crushing event. At a time interval of 0.038, a plastic strain of 0.0118 or 1.18% exists. If the design target is infinite life under repeated loadings, then any plastic strain is too much plastic strain. That is, the structure must operate linearly or elastically.

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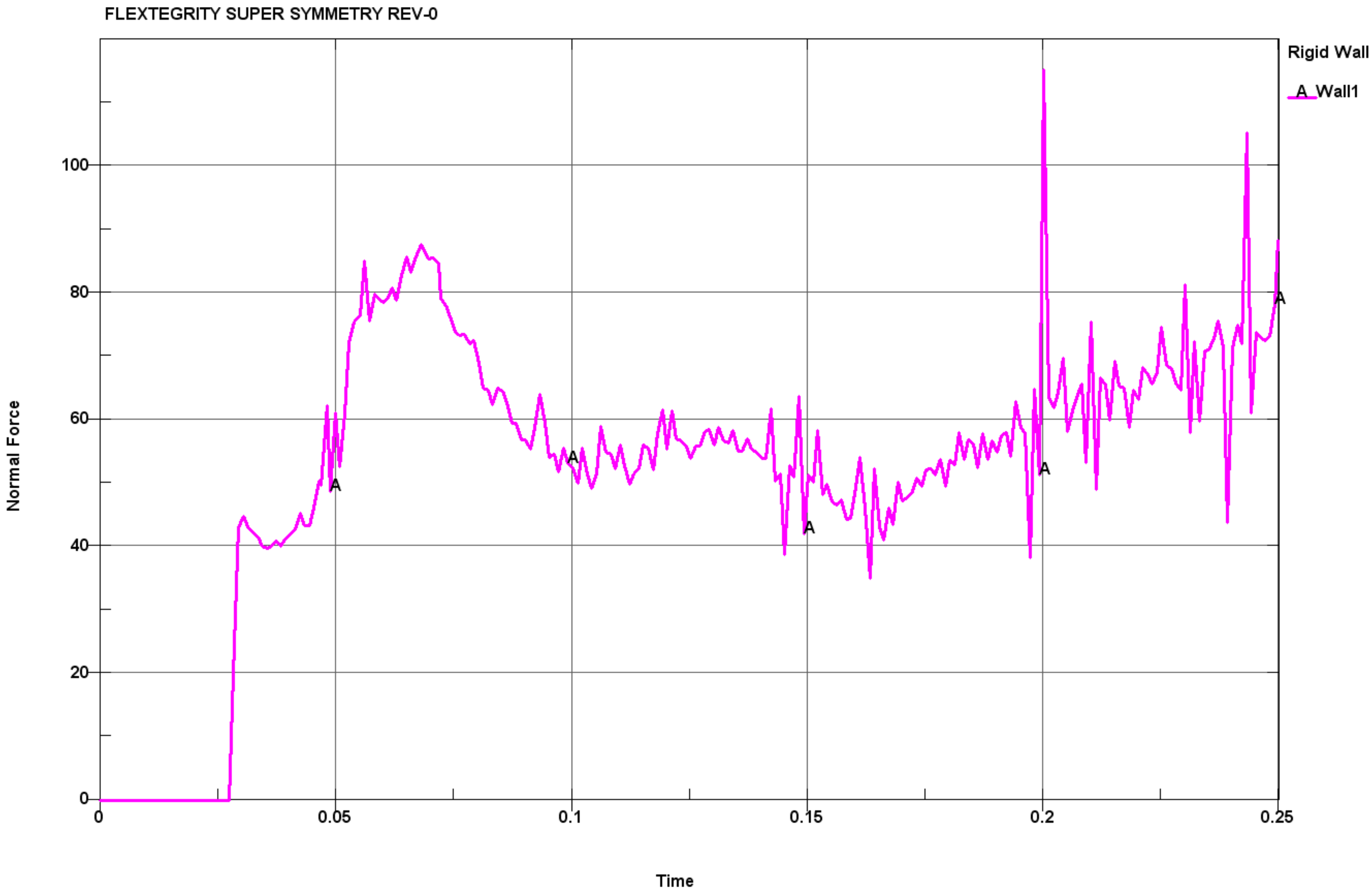
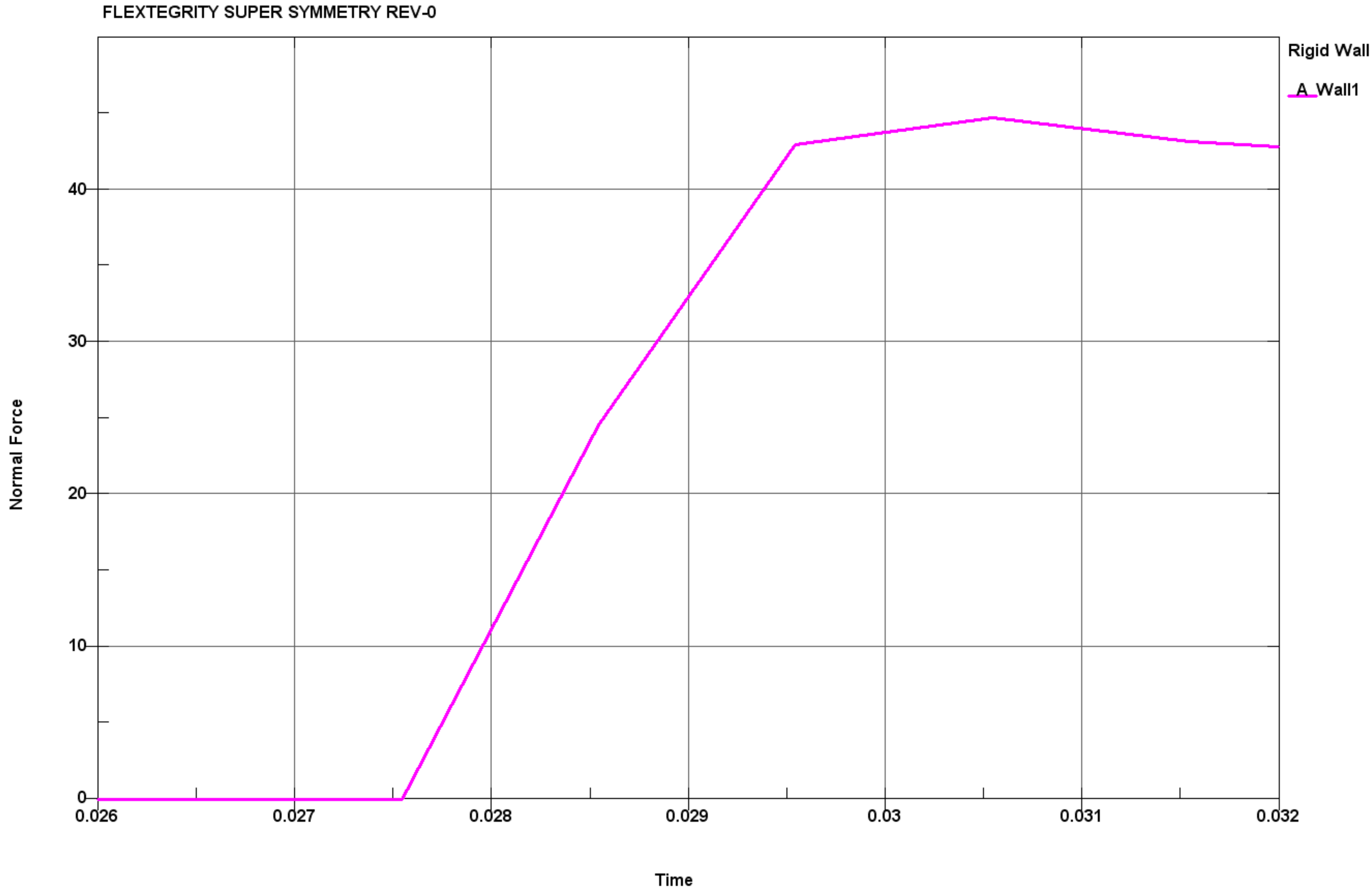


This graph shows the load versus time trace for the simulation. The rigid wall moves at 1.0"/sec. However, the wall is not exactly position over the structure and only comes into contact with the structure after traveling ~0.025". The simulation ends after a distance of 0.25" or a time interval of 0.25 sec.



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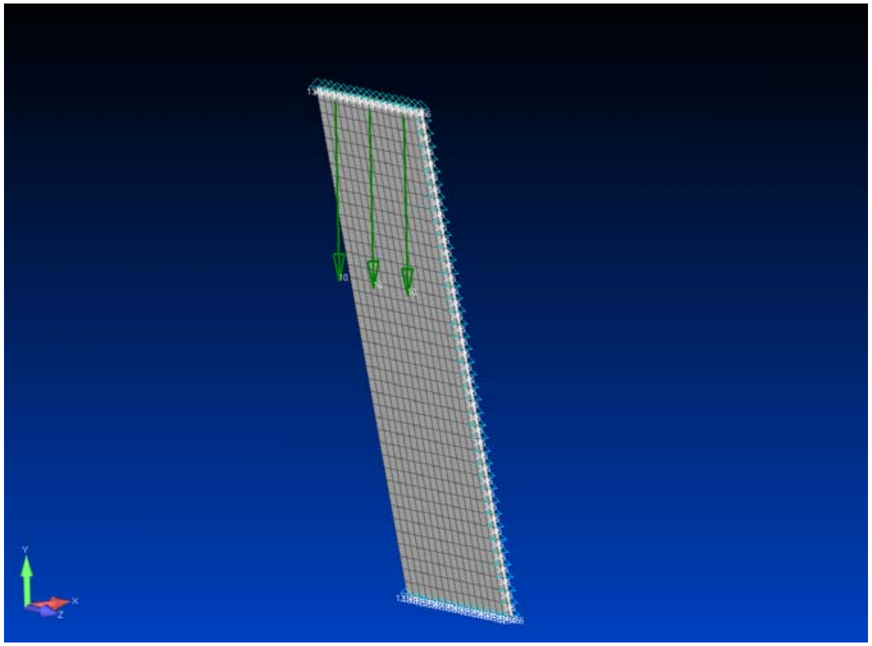
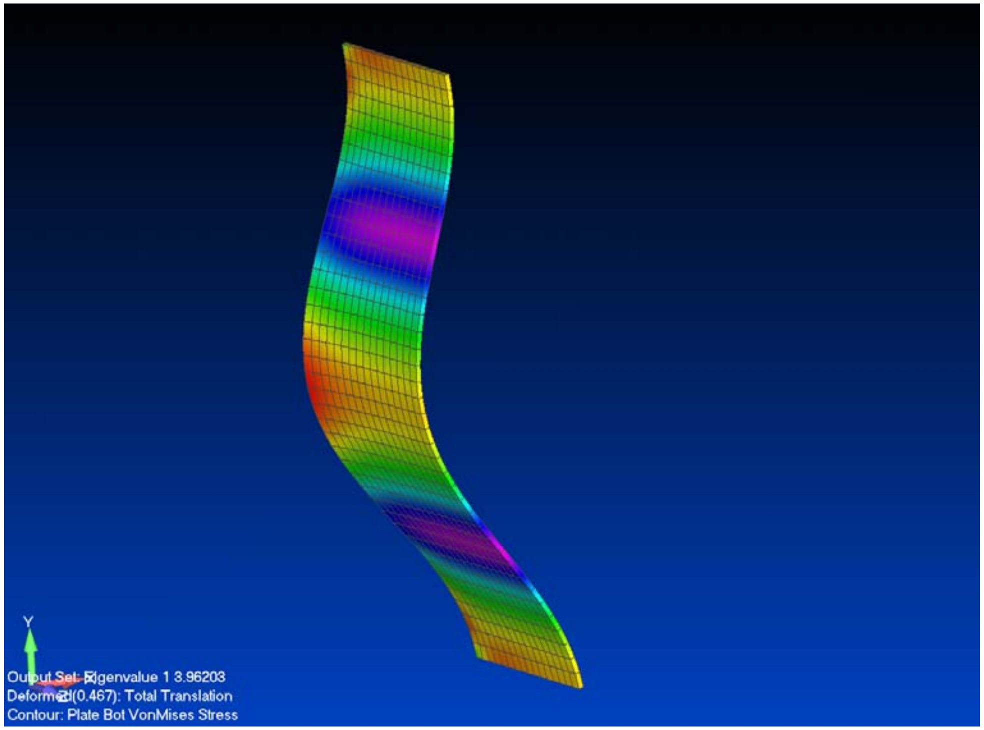
This graph provides a better estimation of the load carrying capacity of the structure. The vertical strap starts to buckle at a load of 43 lbf with a total deflection of (0.0295-0.0276) 0.0019”. For a complete icosahedron, the load carrying capacity would be 4*43 = 172 lbf. However, all the load is carried by the strap.





To confirm the dependency of the icosahedron structure upon the load carrying capacity of the vertical strap, a simplified buckling analysis was done on the 30 gauge strap. The buckling load was 3.96*10=39.6 lbf. This load is within 9% of the plastic limit for the complete model (43 lbf). Consequently, the structure's response is controlled by the vertical strap.

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Stress Results for 35 Gauge (0.0078”) Structure

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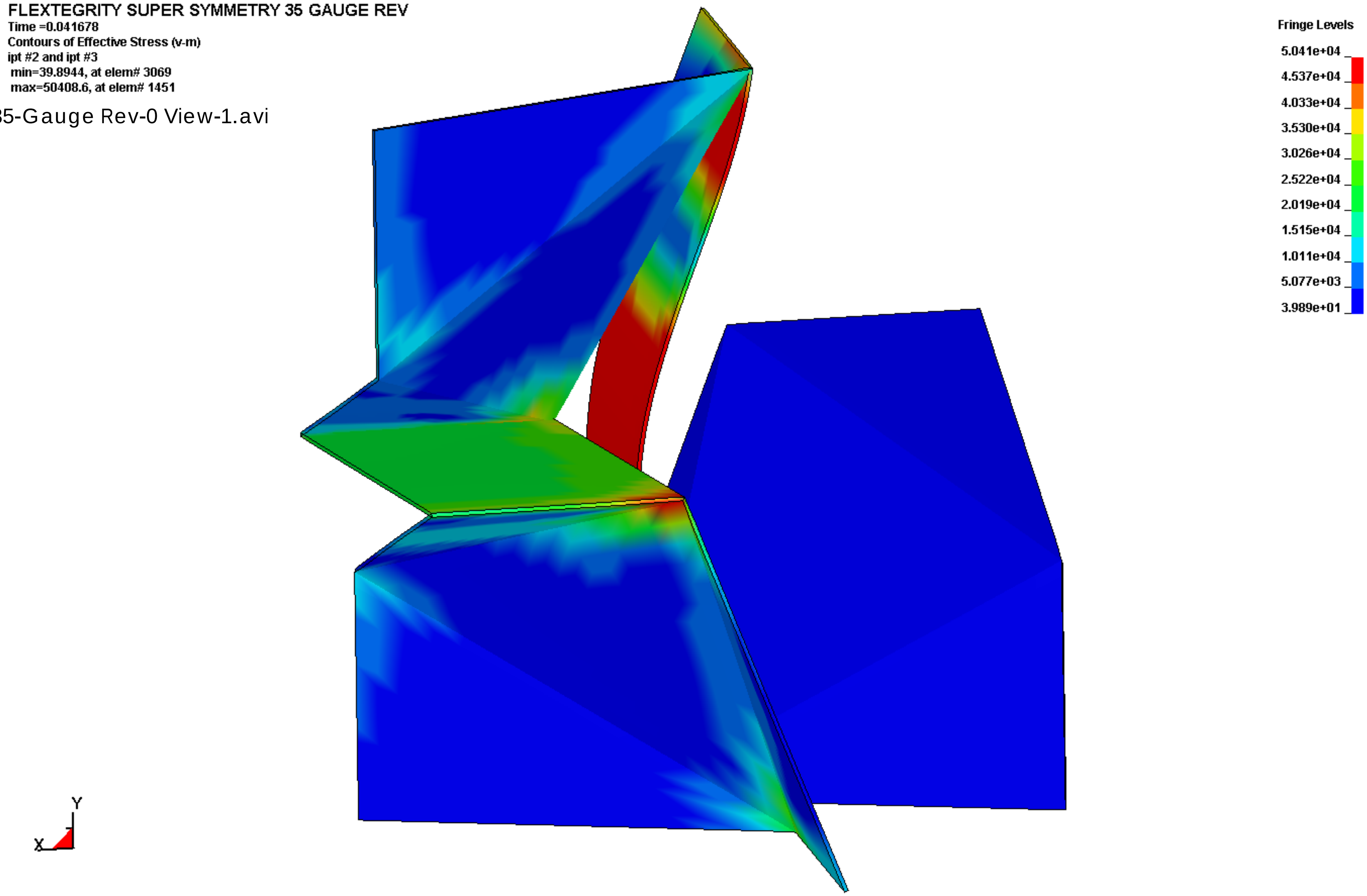

Flextegrity 35-Gauge Rev-0 View-1.avi

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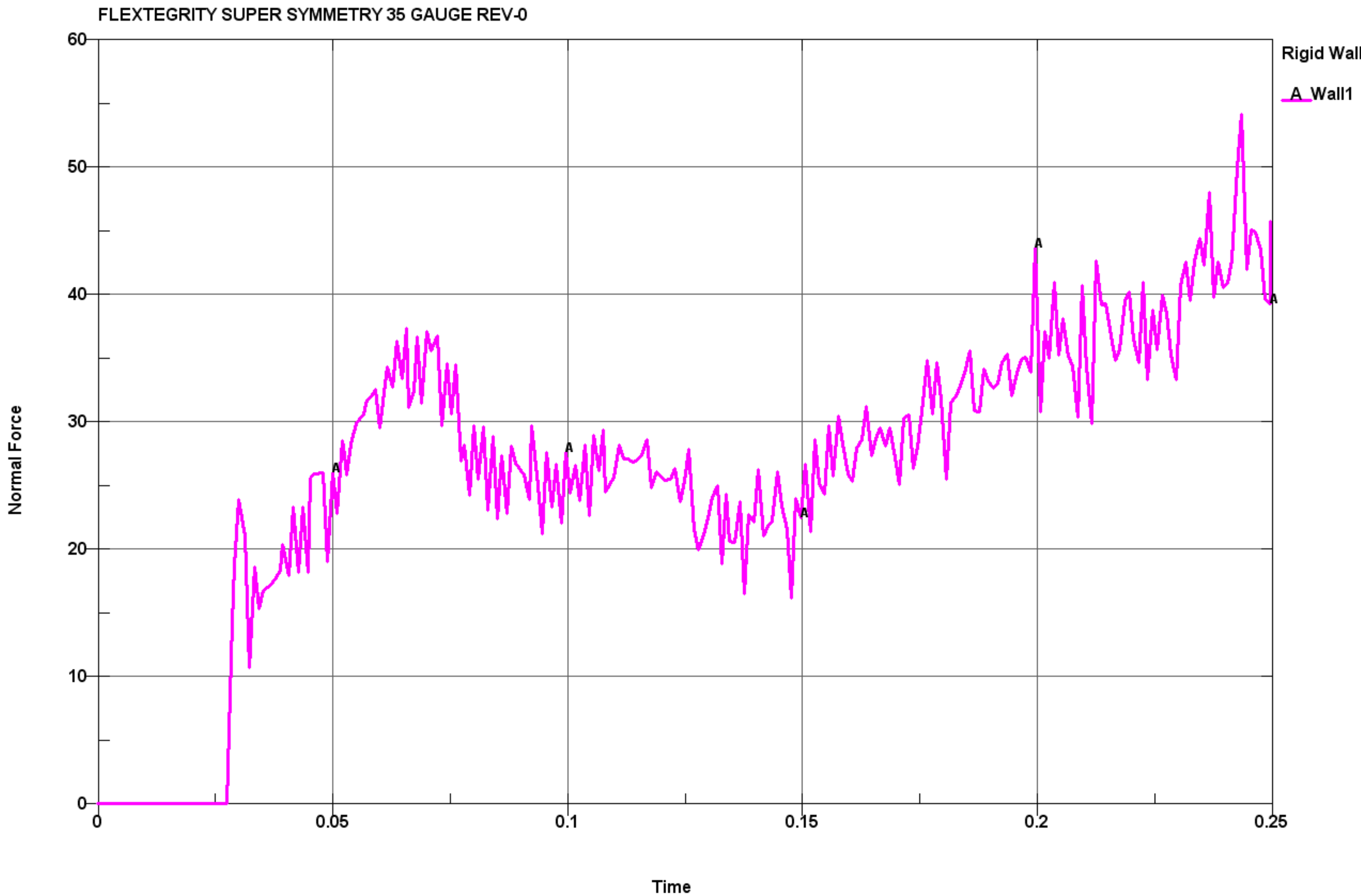

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The thinner strap (0.00785 as versus 0.012) yields the expected reduction in load carrying capacity.

Stress Results for 20/30 Gauge (0.0375/0.012") Structure

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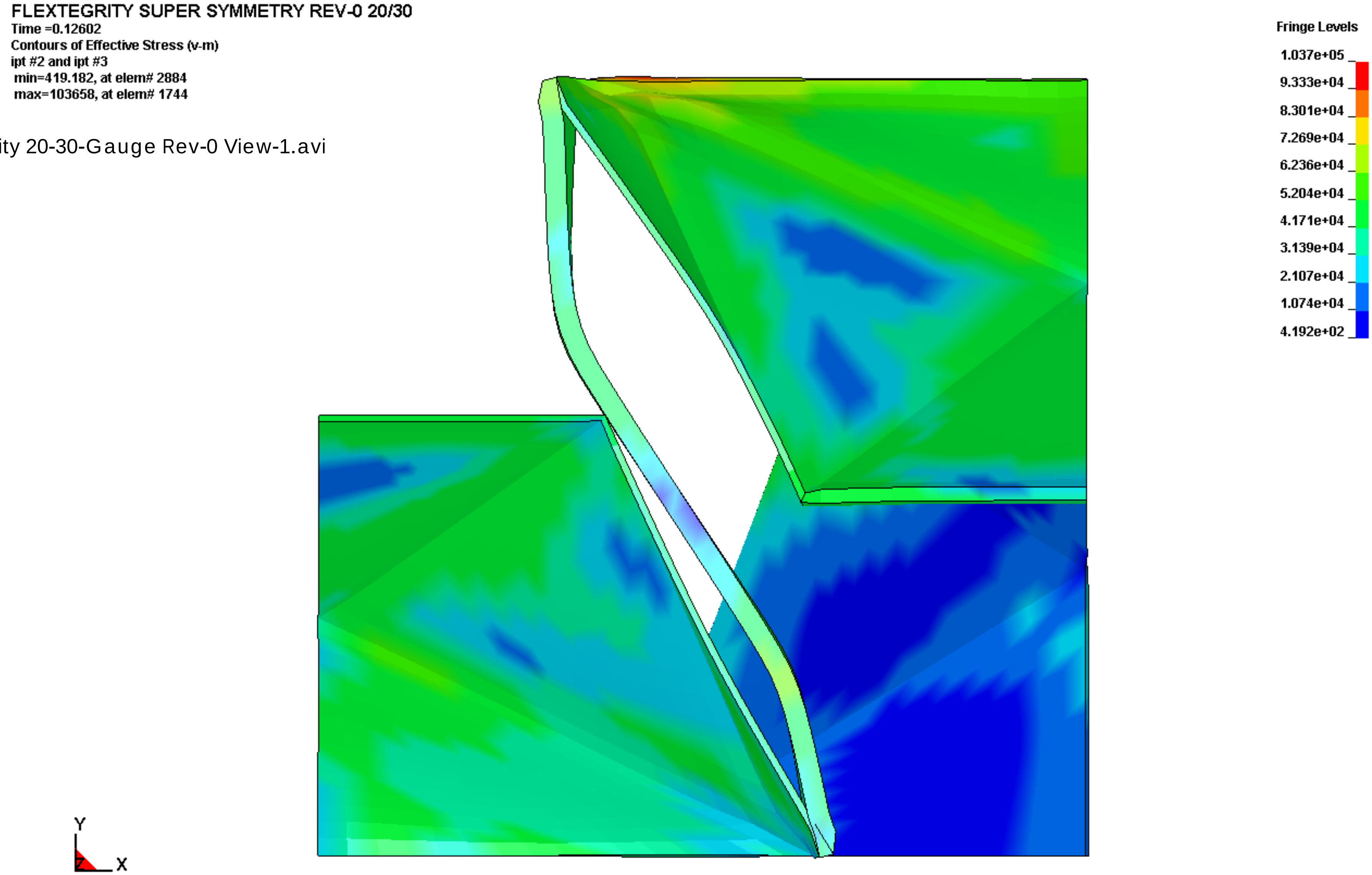
Flextegrity 20-30-Gauge Rev-0 View-1.avi



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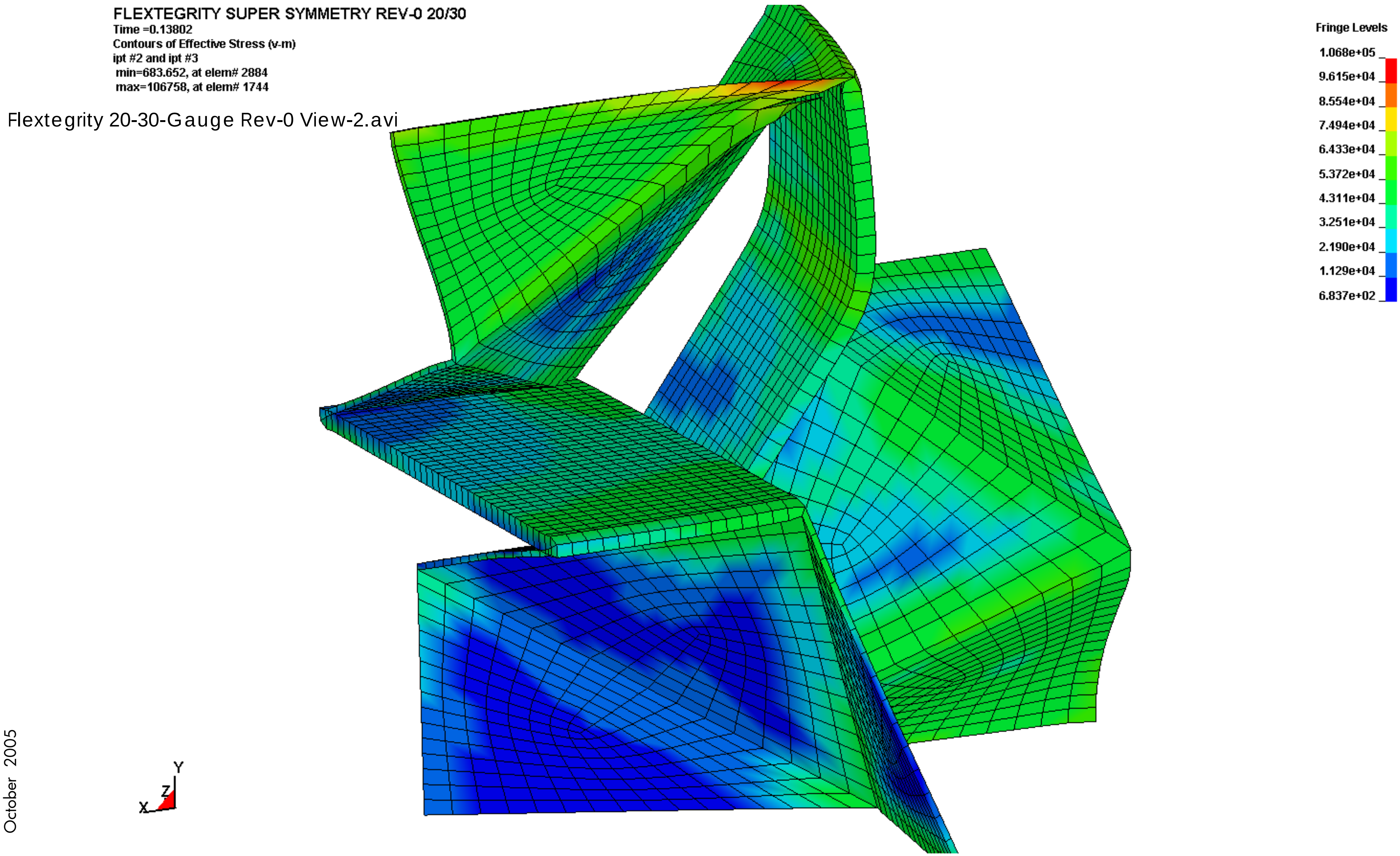

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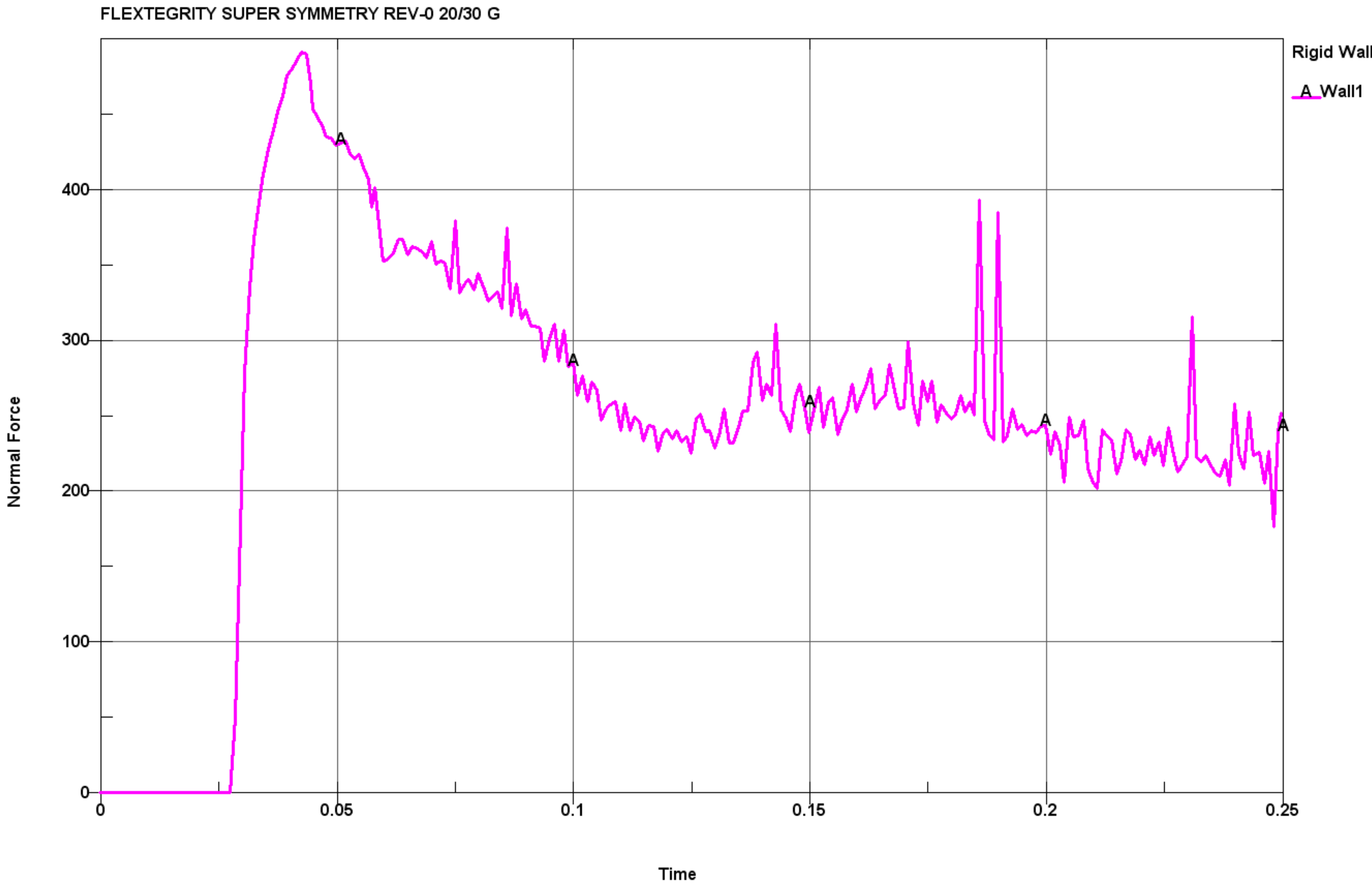

As can be seen, the thicker (20 gauge / 0.0375") strap provides a big boost in the structural bearing load with a peak force of roughly 450 lbf prior to the formation of plastic strain. This would imply a bearing load of 4*450 = 1800 lbf per icosahedron. The increase in load carrying capacity is proportional to the square of the thickness of the strap. That is, from 0.012 to 0.0375, the increase in load is ~1800/200 = 9 while the thickness varies ~0.0375/0.012 = 3.

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Appendix

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Oregon State Board of Examiners
for Engineering and Land Surveying

GEORGE LAIRD II

Registered As	Cert. #	Status	Expires
Professional Engineer	13327PE	Active	12/31/2006

All work within this report was done under best industry practices and was executed by George Laird, Ph.D., P.E.

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