# APPENDIX H. FARO DATA

The FARO was used to track the motions of 57 targets applied to the gussets and members. Figure H1 shows the approximate locations of these targets. On each member there were three targets located near the mid depth of the member. These were measured by placing the spherically mounted reflector (SMR) in a "pin nest" which has a 0.25 inch diameter shoulder. For the first three specimens, the pin nest was slipped into aluminum blocks with 0.25 inch diameter holes drilled in them, which were in turn glued to the members. However, this mounting solution proved to be unreliable because of the frequency the targets would debond, plus the locations were not constant from one specimen to the next. From the fourth specimen onward, 0.25 inch diameter holes were drilled directly into the members to accept the pin nest.

The remaining 42 targets were mounted on select bolts connecting the gusset plate and members. A special machined nut was threaded onto the bolt stickout that could solidly accept the SMR for a repeatable measurement. Since each plate had its own unique geometry and bolt pattern, the same bolts were not tracked for each specimen.

The FARO system was always positioned on the North side of the load frame for monitoring the targets during testing. Therefore, targets on the south side of the load frame could not be monitored during testing. Though, when the gusset plate shapes were encoded pre- and post-test, a "device move" was used to reposition the FARO to the south side to attain data in a consistent coordinate system.

Every specimen had a coordinate system established as shown in Figure H1. The SMR with an "edge nest" was swept along the bottom horizontal edge of the gusset plate and the West vertical edge. The best-fit line through the horizontal edge data defined the x-axis. The origin of the coordinate system was defined as the intersection of the best-fit lines from the horizontal and vertical edge data. The software automatically establishes an orthogonal coordinate system once the x-axis is defined, and a general direction of +y. The right-hand rule is used to establish the +z direction, which in this case is to the south.

Before each test was started, zero data was taken with no load applied to any of the members. Subsequently throughout the testing, the data was collected from all 57 targets at each hold in load. This allowed for the relative motion of each target to be calculated considering the pre-test location to be the zero locations.

For brevity, this appendix will only present the data from the final test to failure for each specimen. For all specimens, the same series of plots will be presented in this appendix. Sometimes data was accidently not collected and no figure could be made. A description of the plots are as follows:

1. "Pretest out-of-plane shape contour plots". Before each test, the SMR was swept across the entire gusset plate surface of the as-built connection, collecting a data point approximately every square inch. This data was used to develop out-of-plane shape contour plots. These plots were used to define initial imperfections into the finite element models to predict the failure of the specimens. Note, the program used to create these contour plots could only work with rectangular data

sets, and would interpolate data where there was none. Therefore, the data is only valid in the places the gusset plate exists. In some plots white or black lines are shown to provide reference of where the plate boundary is.

2. "Pretest planar alignments". These plots show the relative alignment of the members to each other. They were developed by fitting a best-fit line through the three targets applied to the members. Three plots are presented for each of the three orthogonal views.

3. "Amplified displacement (x50) of member targets". These three plots show the relative movement of the members (based on the three targets applied to each) from the pretest location, to the step in the failure loading sequence when the last FARO data was collected. This is presented in terms of an applied load fraction (ALF). The displacement has been multiplied by 50 times, such that the relative motion of the targets using the axis scale must be divided by 50 to get the real displacement.

4. "Amplified displacement (x50) of member targets, post-failure" Like the plots described in #3, these show the relative movement of the members from the pretest unloaded state, to the post-test unloaded state.

5. "Vector motions of gusset plate targets". The vector plots show the relative motion of the gusset plate targets from the pretest, unloaded position to the post-test, unloaded position. Generally these give an indication of the gusset plate deformation. The tail of the vector is the pretest location, the head of the vector is the post-test location. These plots were very helpful in distinguishing between shear and buckling failures.

6. "Post-test out-of-plane shape contour plots". After the gusset plate had failed, the SMR was swept over the surface of the plates and data points were collected roughly every square inch. This data was used to develop out-of-plane deformation contour plots of the deformed shape.

At the end of the experimental study, the real shape of the five members was measured with the FARO and compared to the three target points on each member. This was done to establish the accuracy of the "best-fit" lines through the three target data points assumed in many of the plots within this appendix.

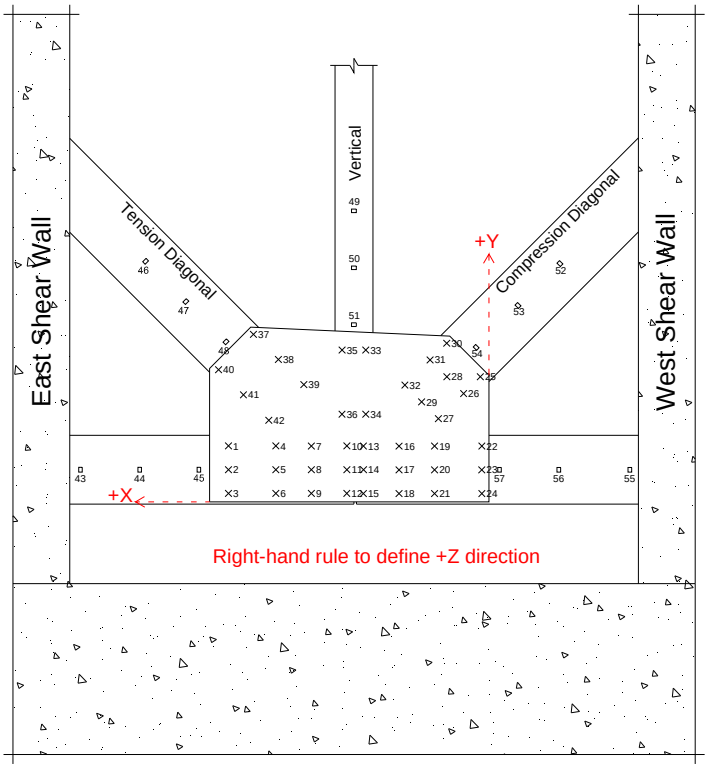
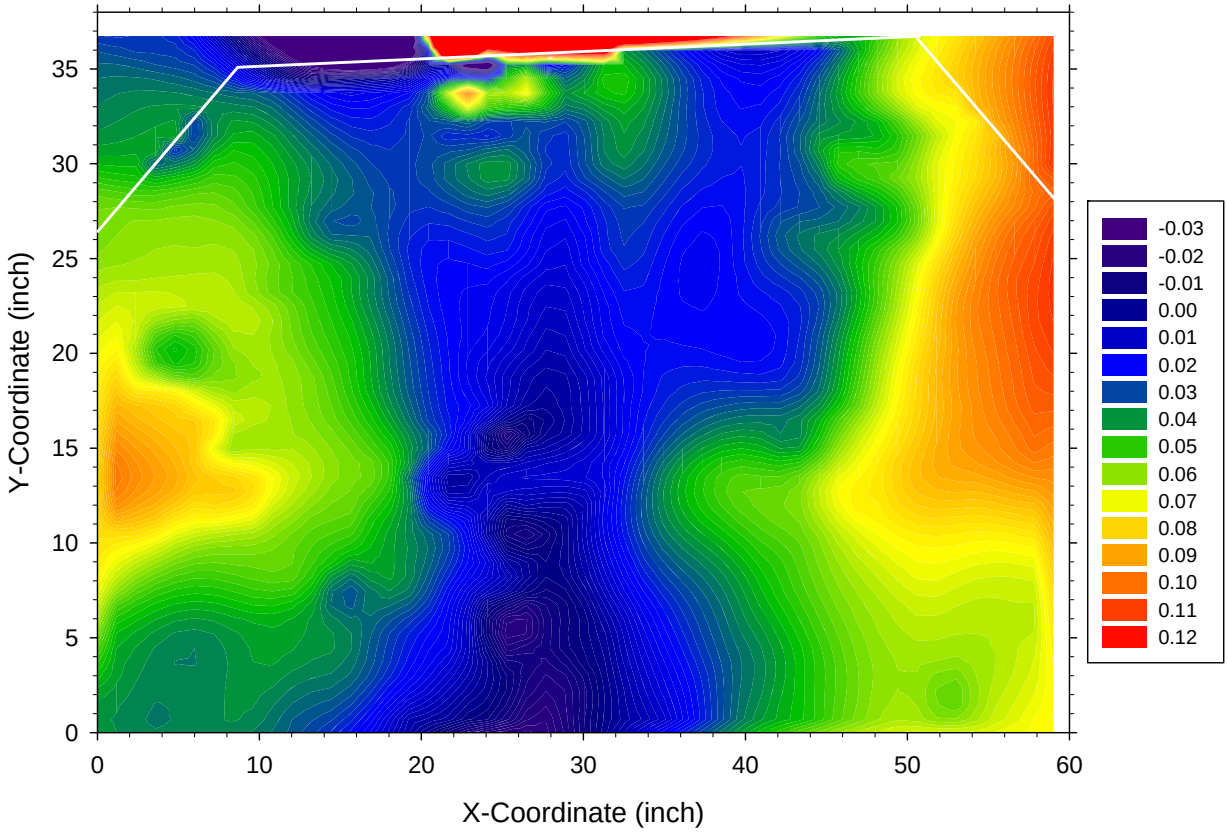



Figure H1. Locations of FARO targets.

**SPECIMEN 307SS3**




NO DATA COLLECTED FOR SOUTH PLATE

Figure H2. Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

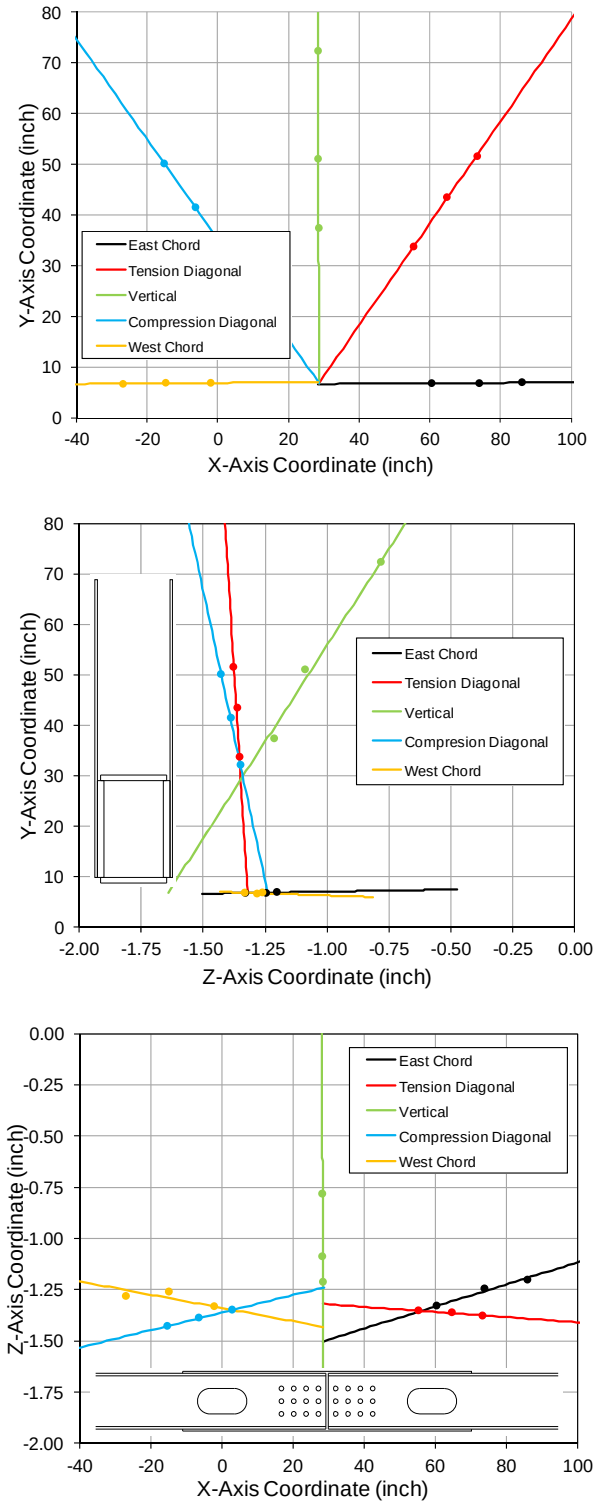



Figure H3. Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

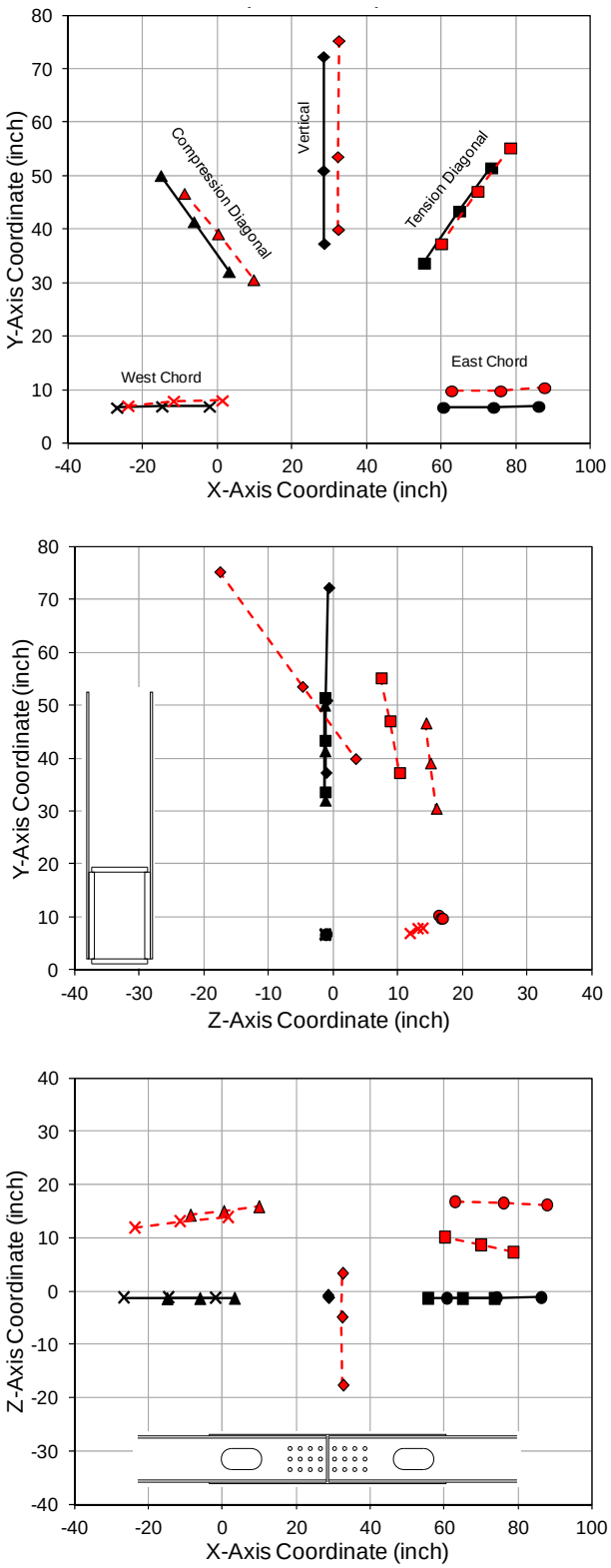



Figure H4. Amplified displacement (x50) of member targets at an ALF of 0.62. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

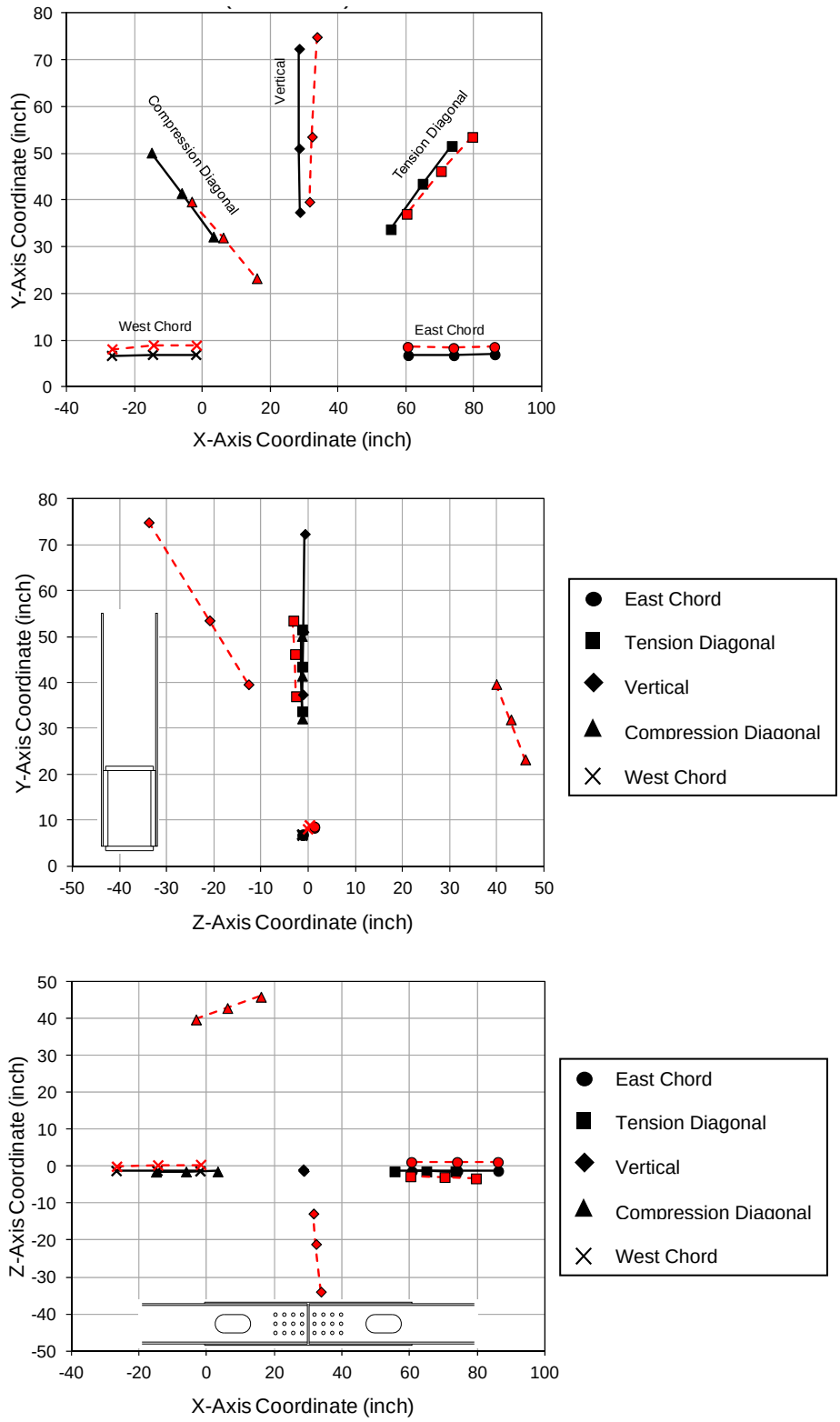



Figure H5. Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

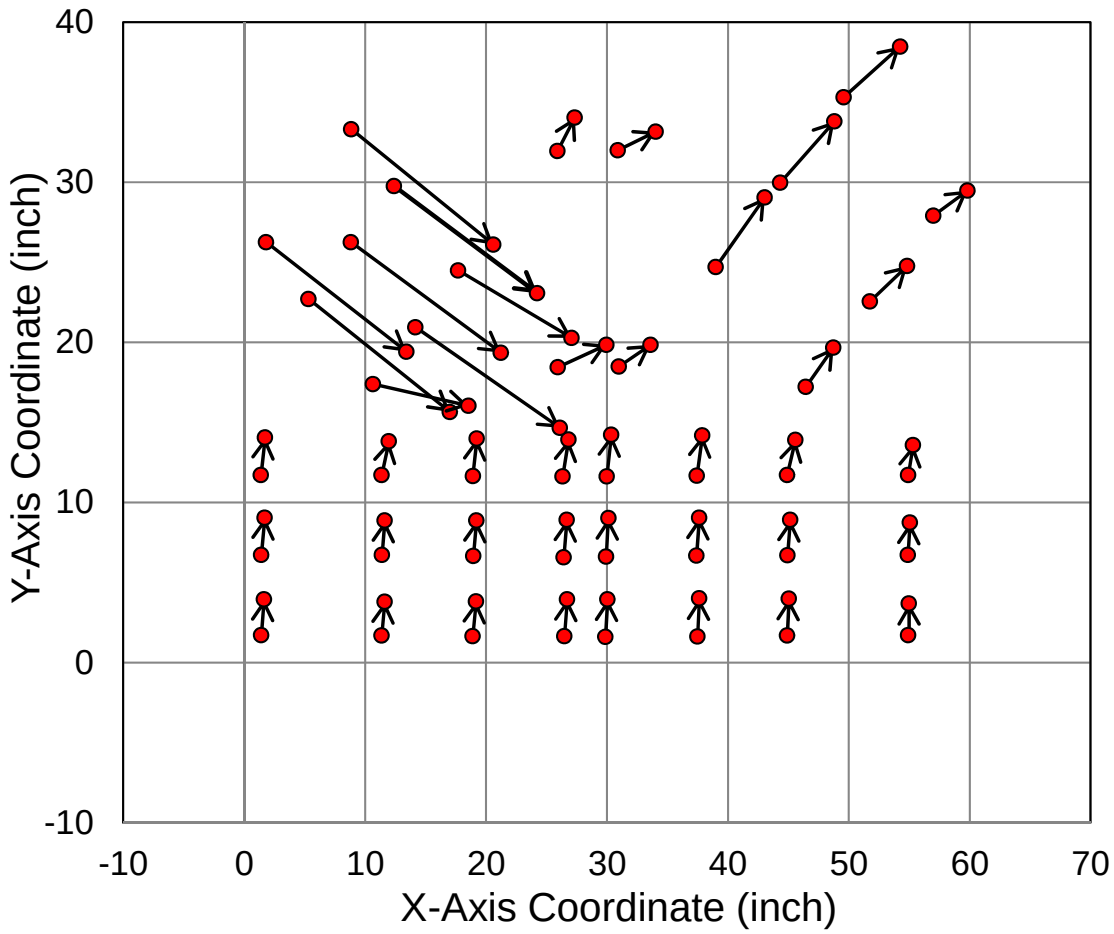
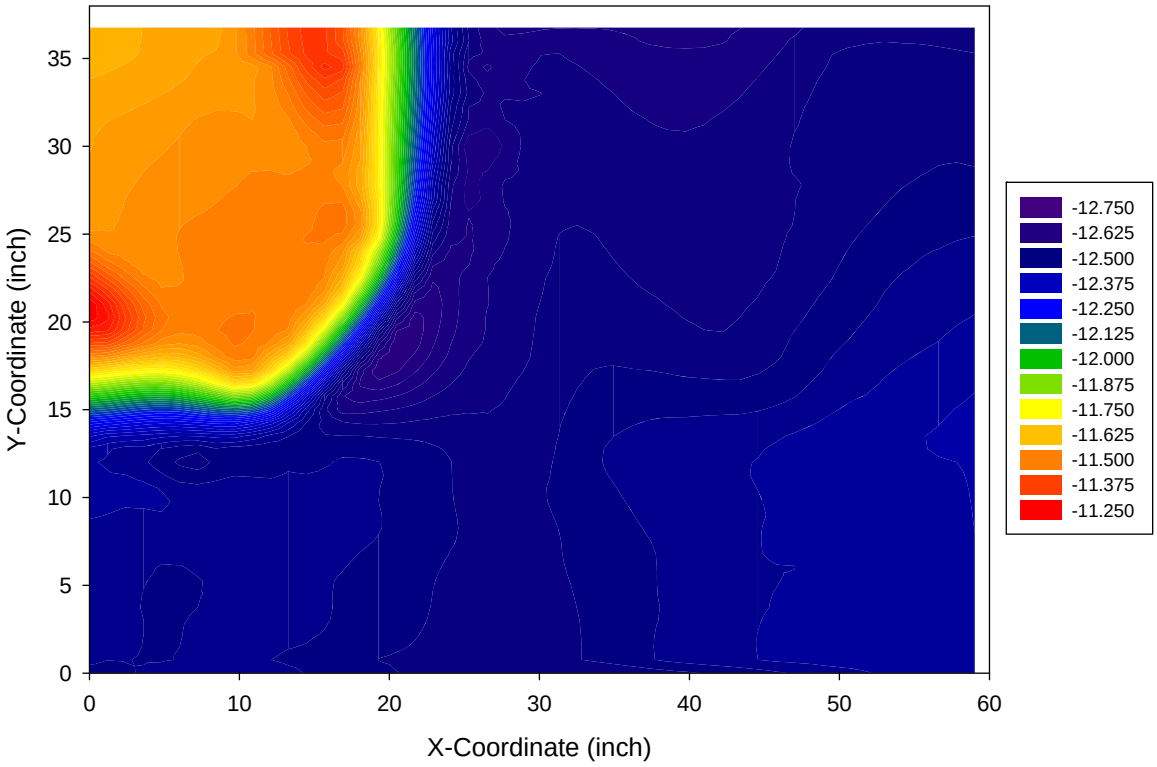



Figure H6. Vector motions of gusset plate targets amplified 50 times.



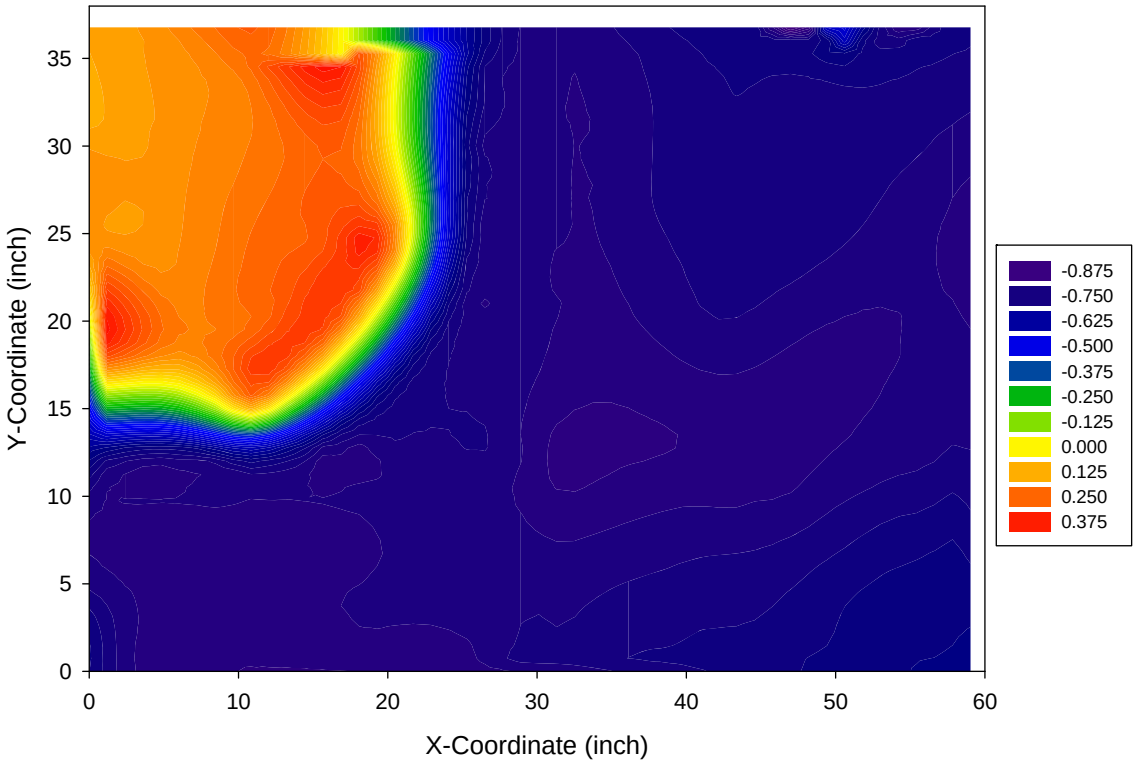




Figure H7. Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 490SS3**

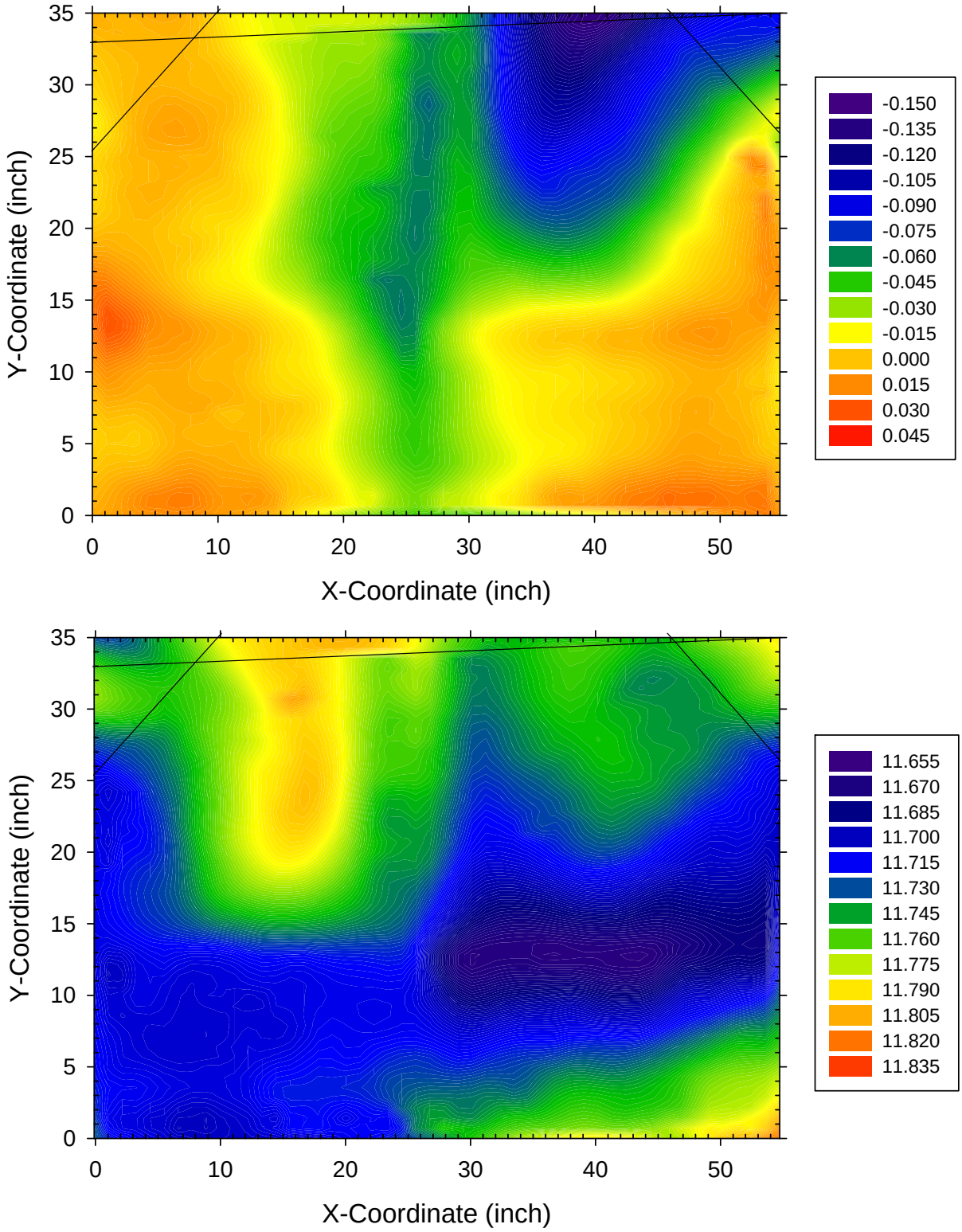



Figure H8. Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

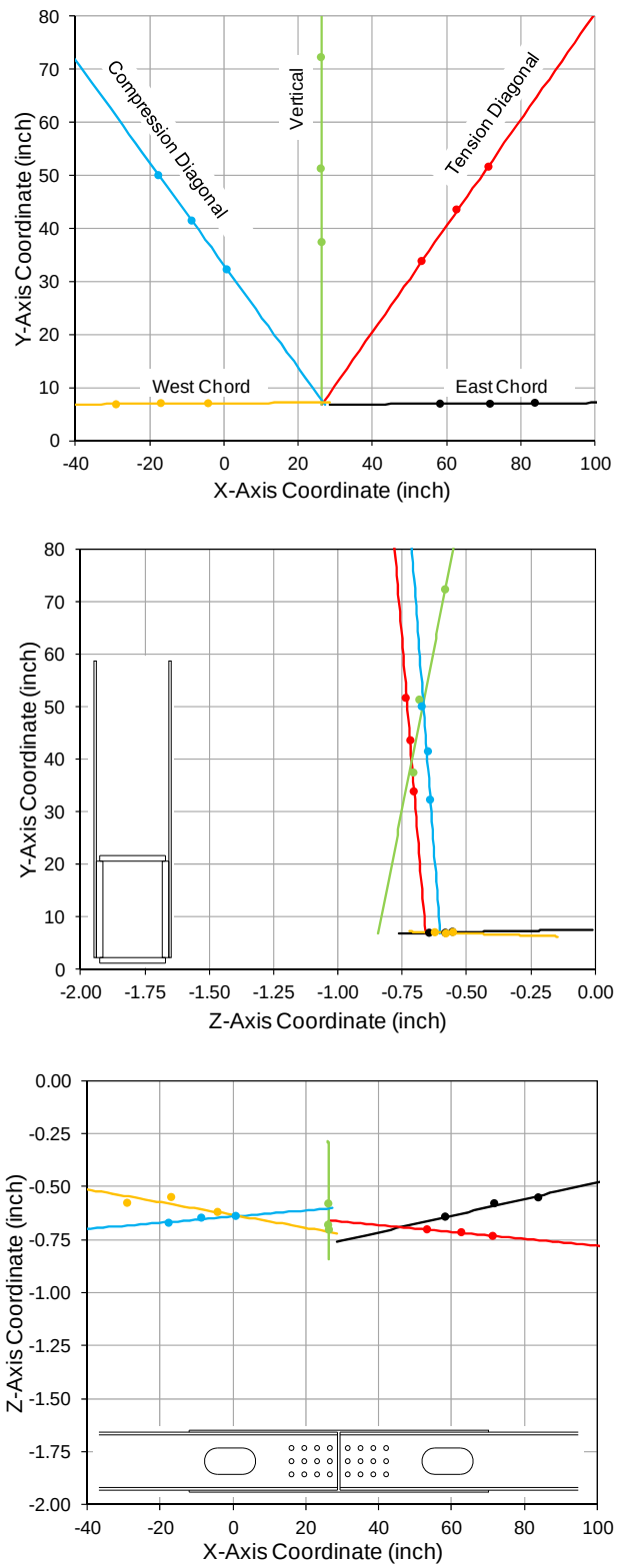



Figure H9. Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

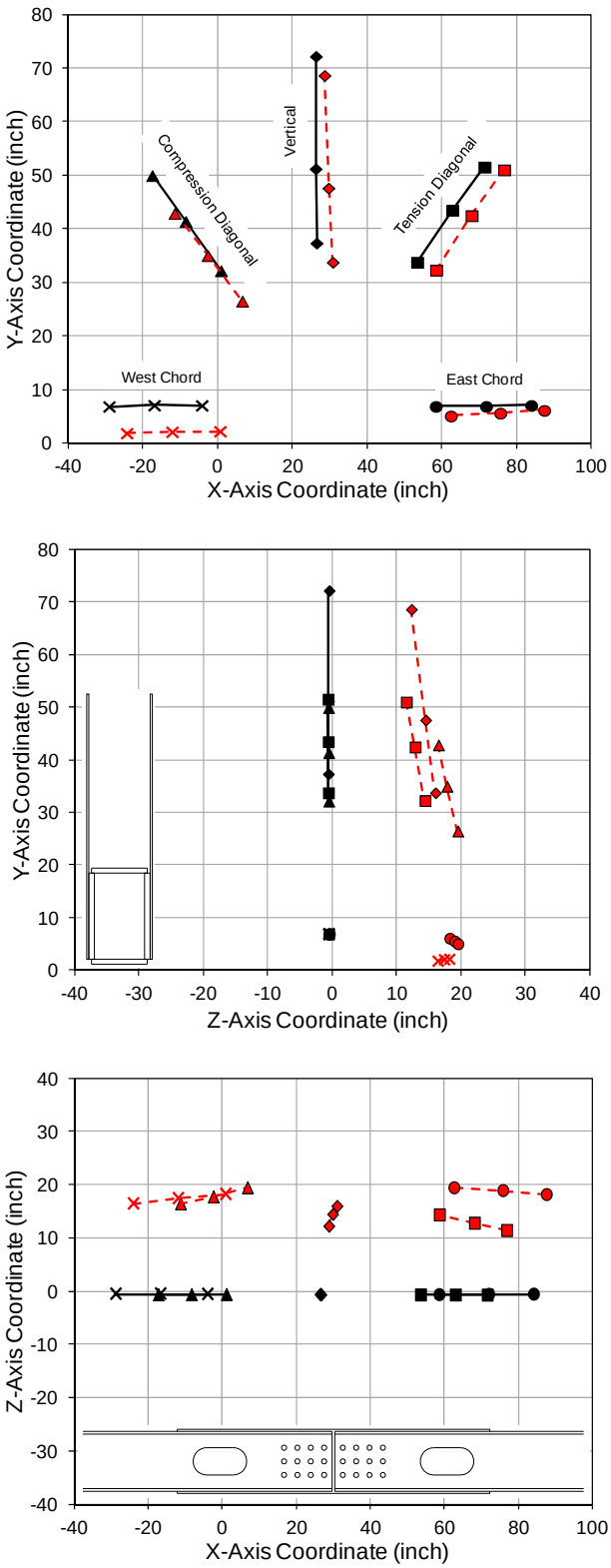



Figure H10.Amplified displacement (x50) of member targets at an ALF of 0.54. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

MEASUREMENTS NOT COLLECTED

Figure H11.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

MEASUREMENTS NOT COLLECTED

Figure H12.Vector motions of gusset plate targets amplified 50 times.

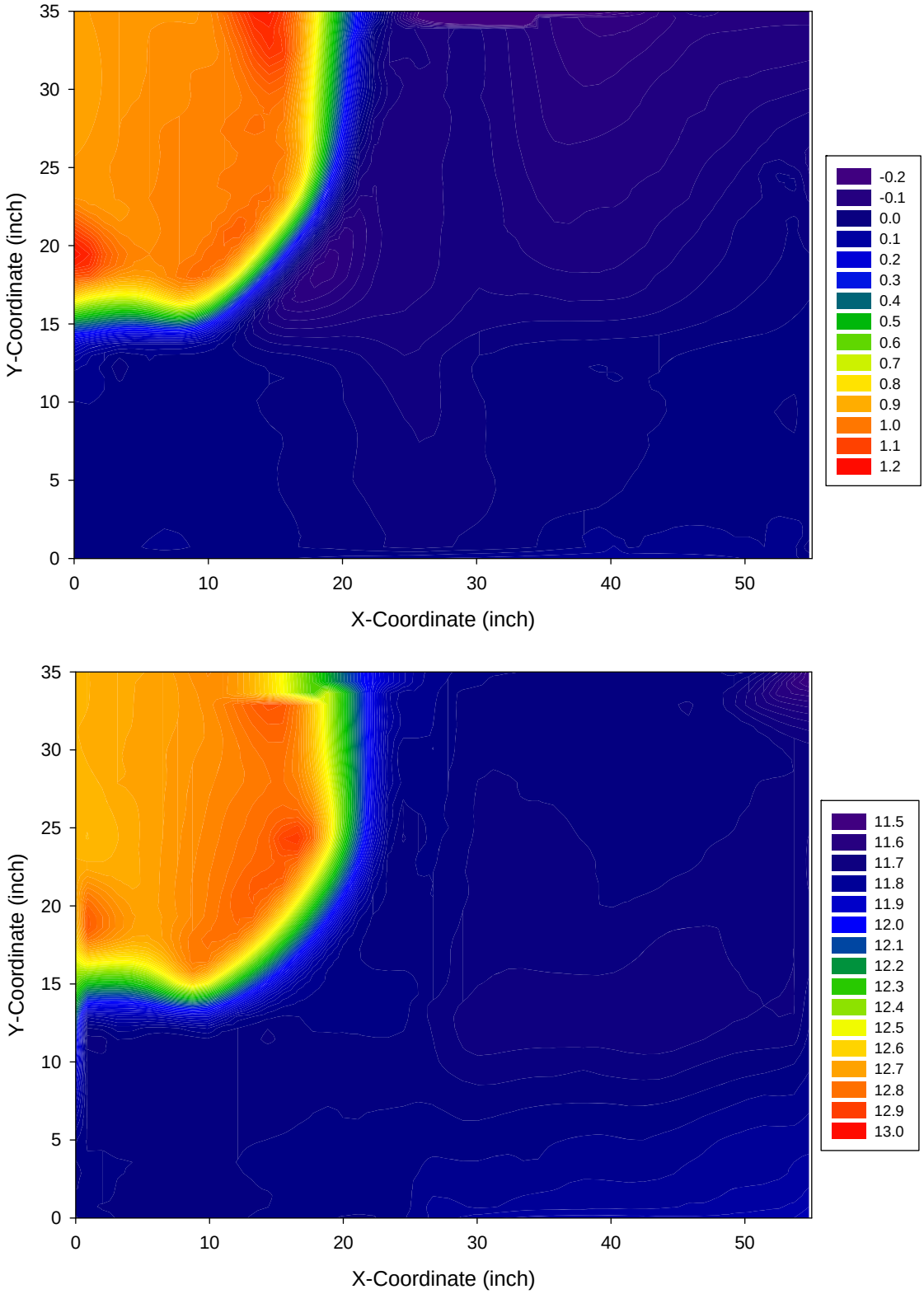
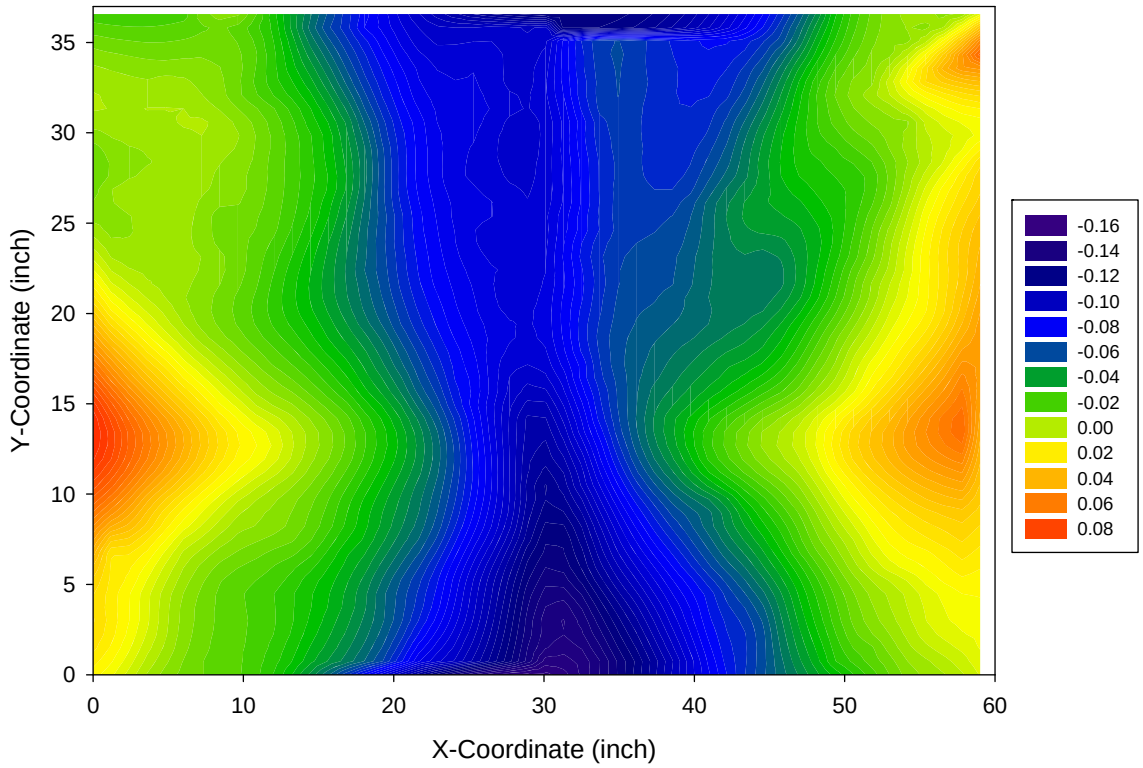



Figure H13. Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 490LS3**



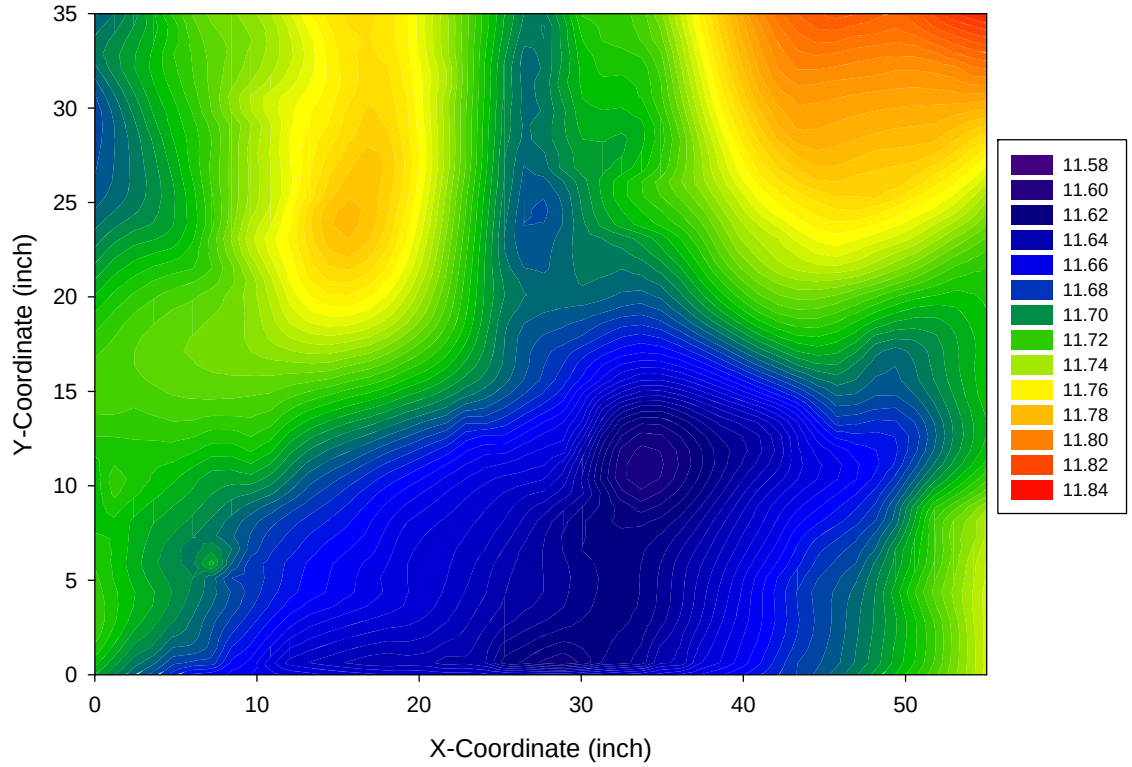




Figure H14.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

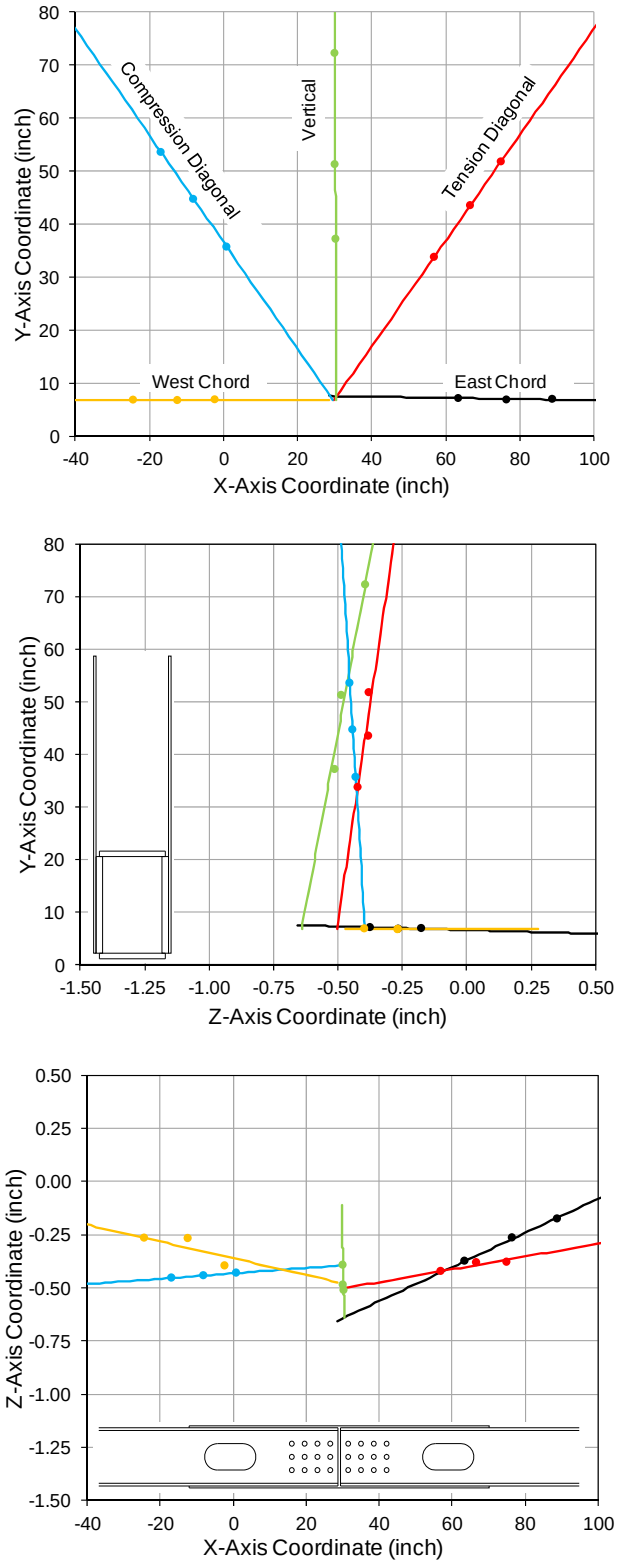



Figure H15.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

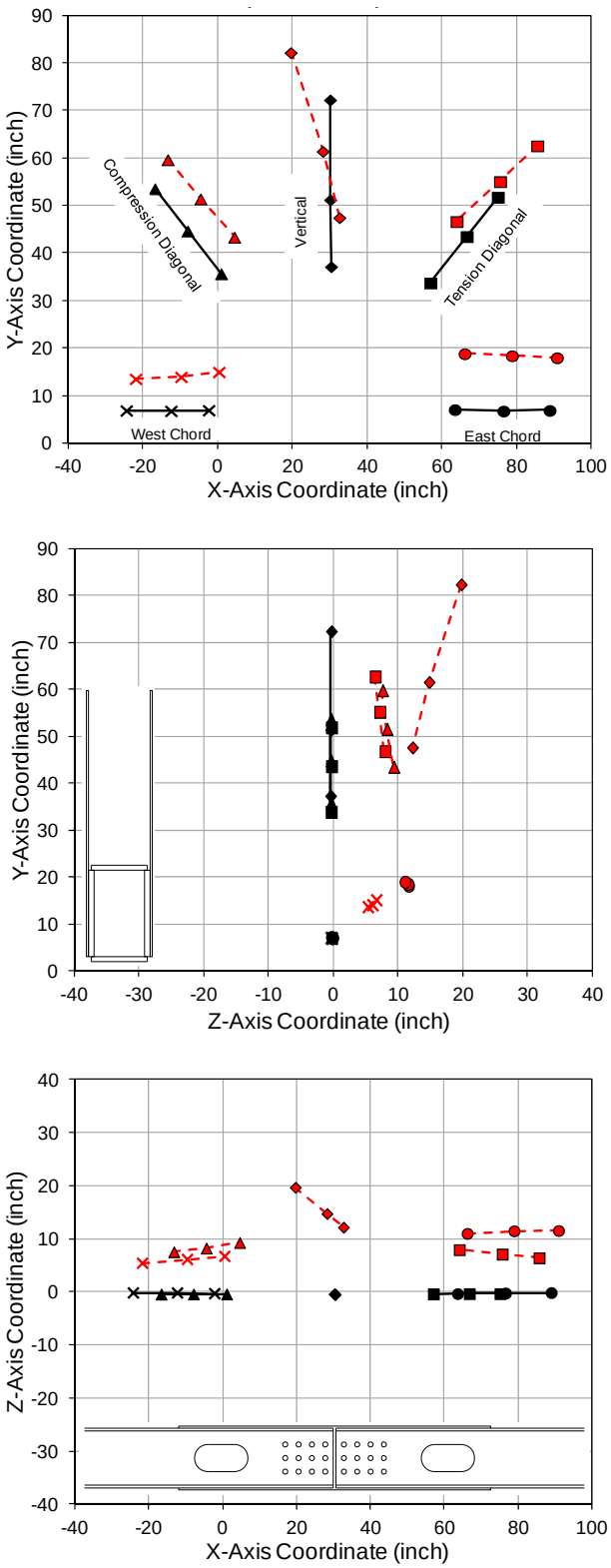



Figure H16.Amplified displacement (x50) of member targets at an ALF of (STEP 10). XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

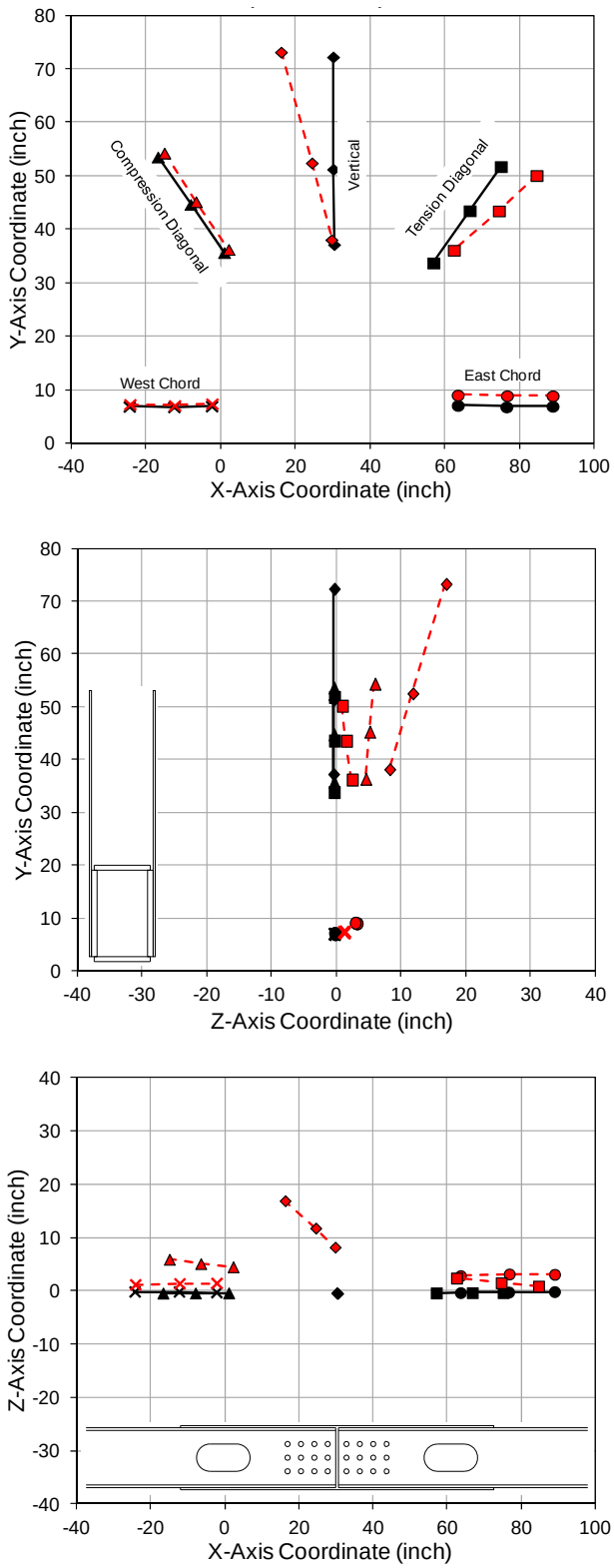



Figure H17.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

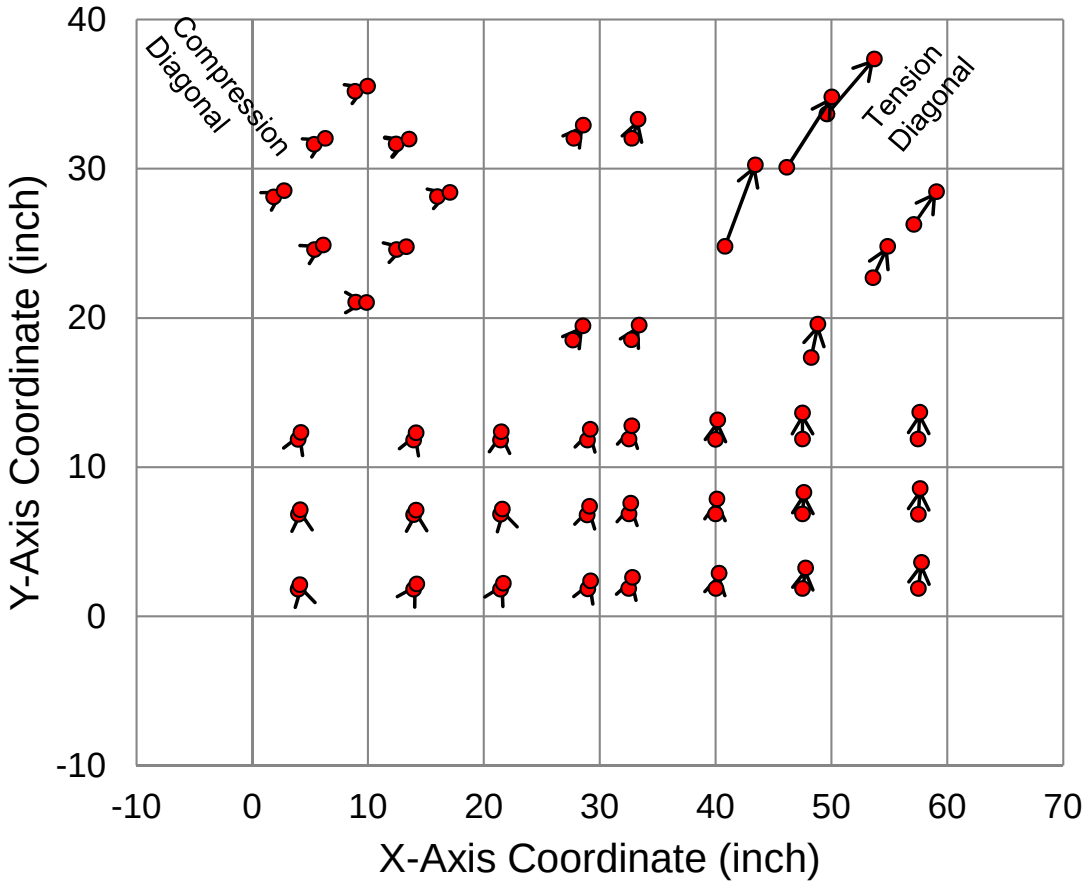
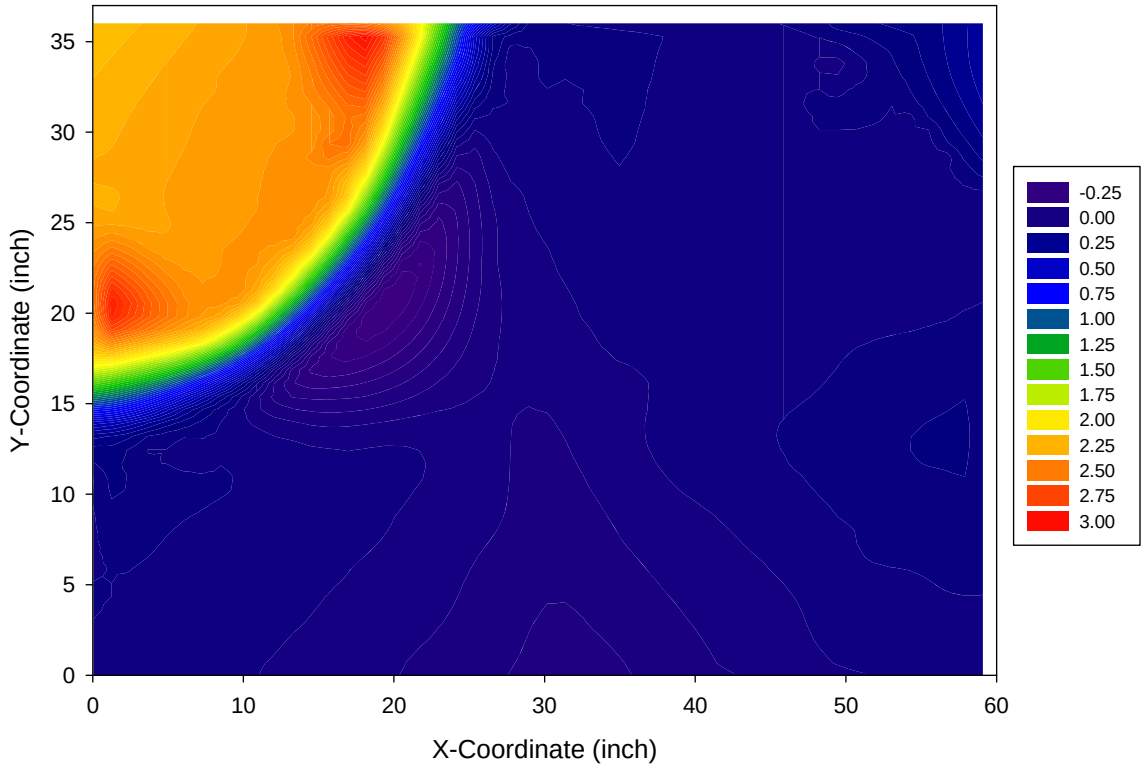



Figure H18.Vector motions of gusset plate targets amplified 50 times.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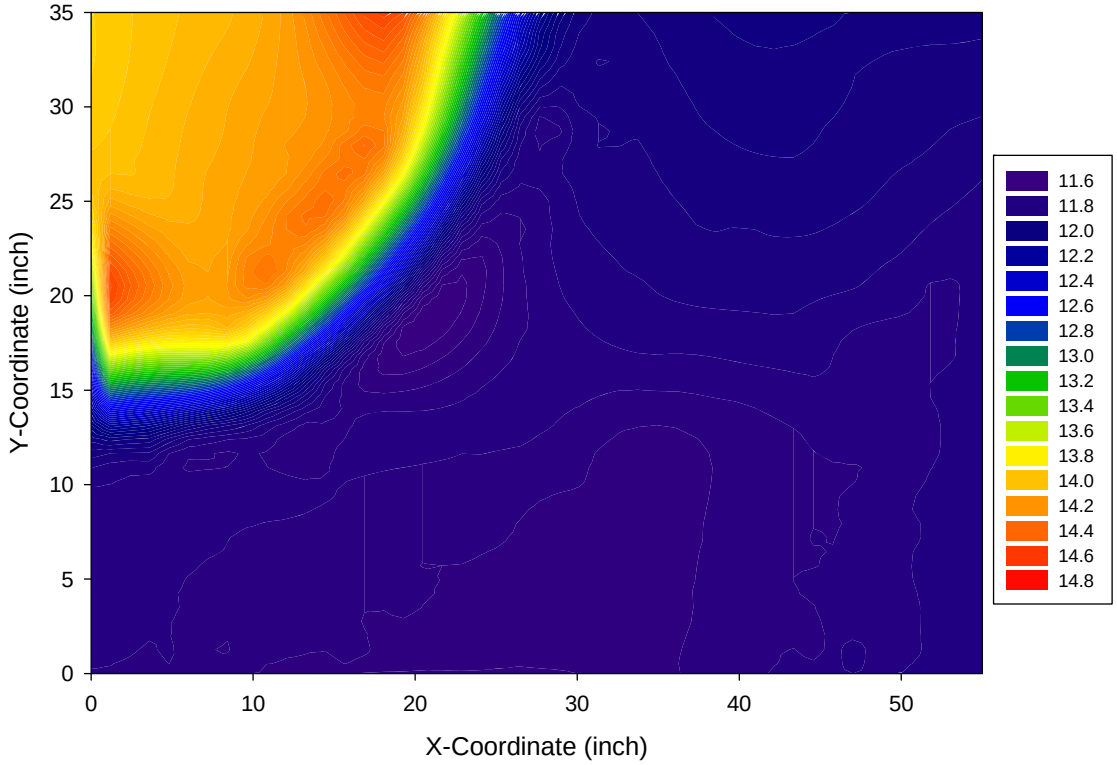
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Figure H19.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 490LS3-1**

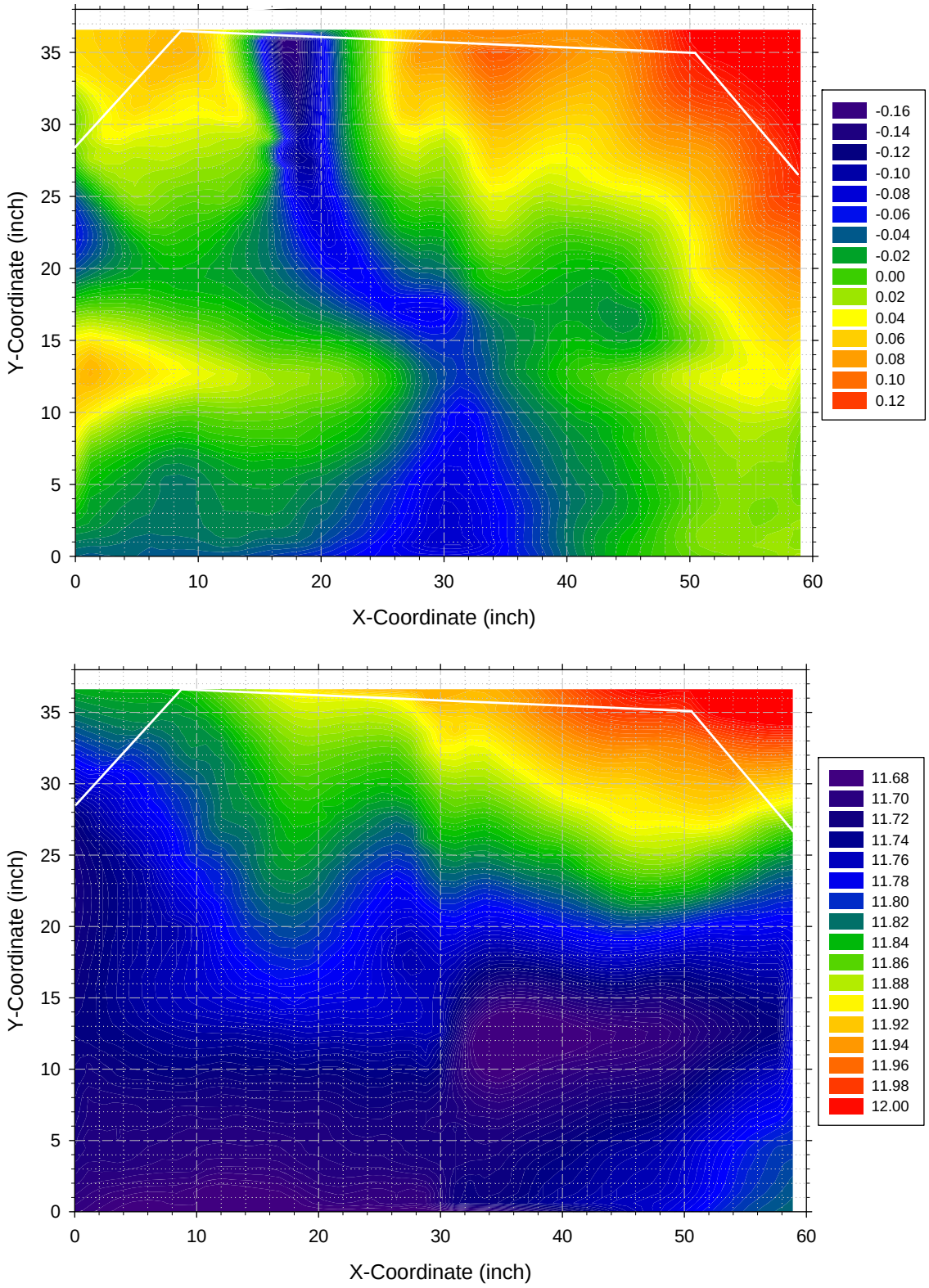



Figure H20.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

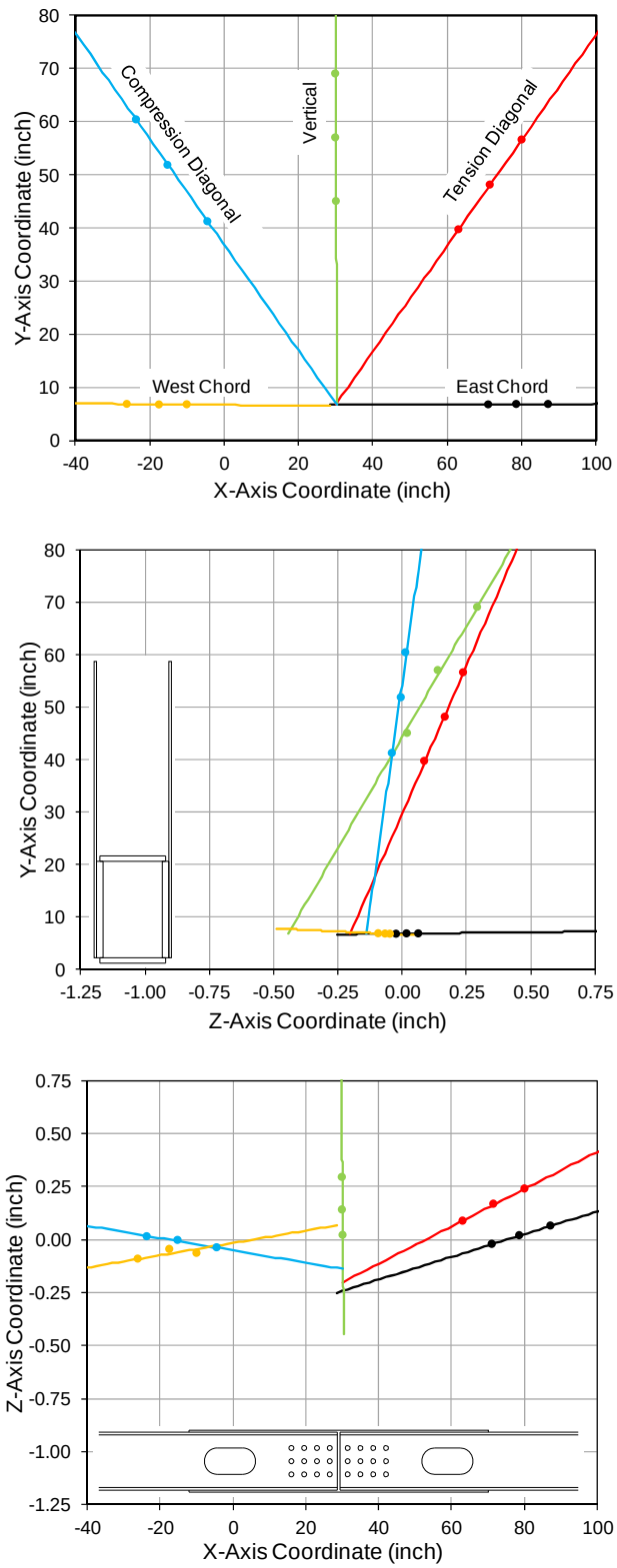



Figure H21.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

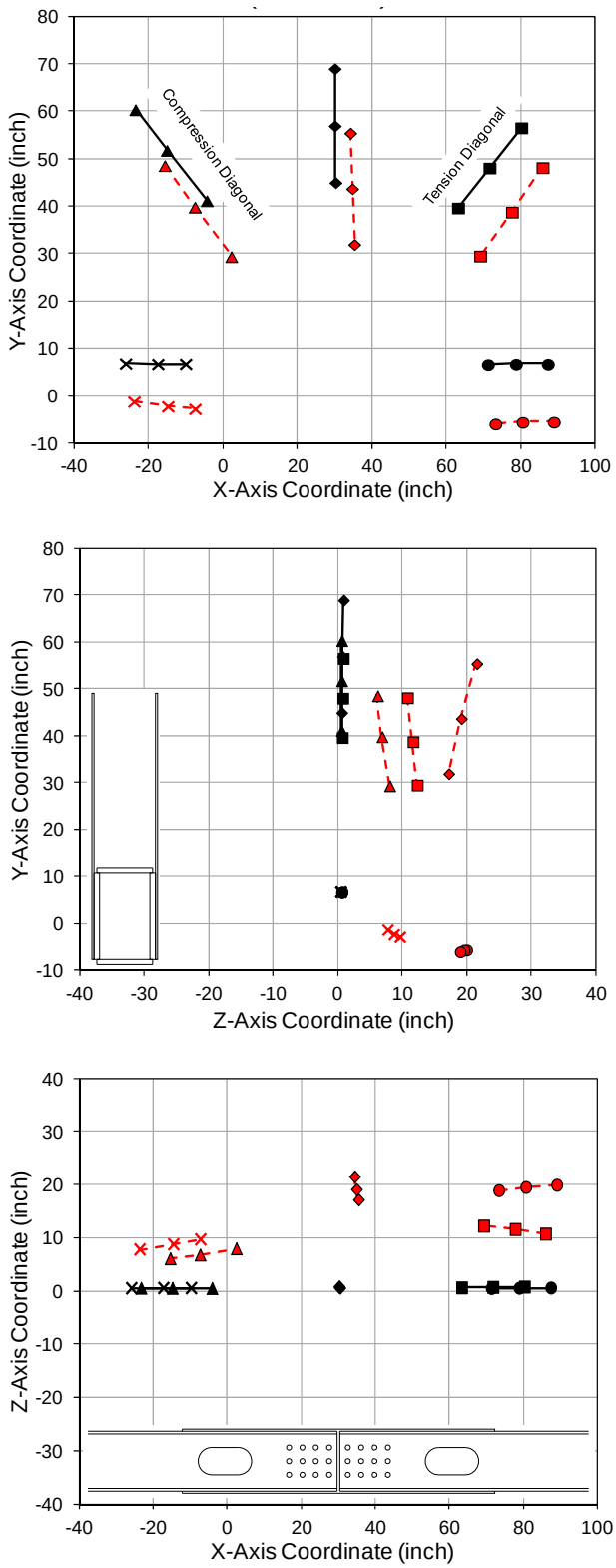



Figure H22.Amplified displacement (x50) of member targets at an ALF of 0.74. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

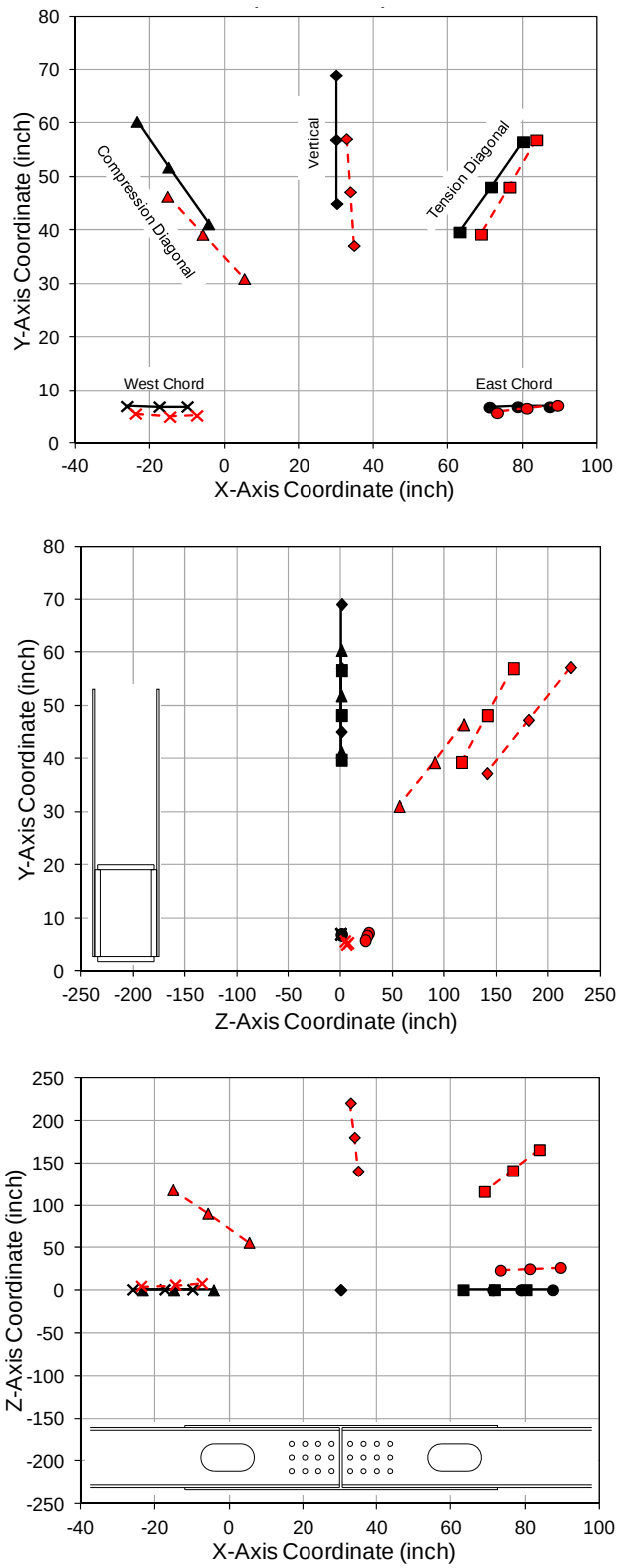



Figure H23.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

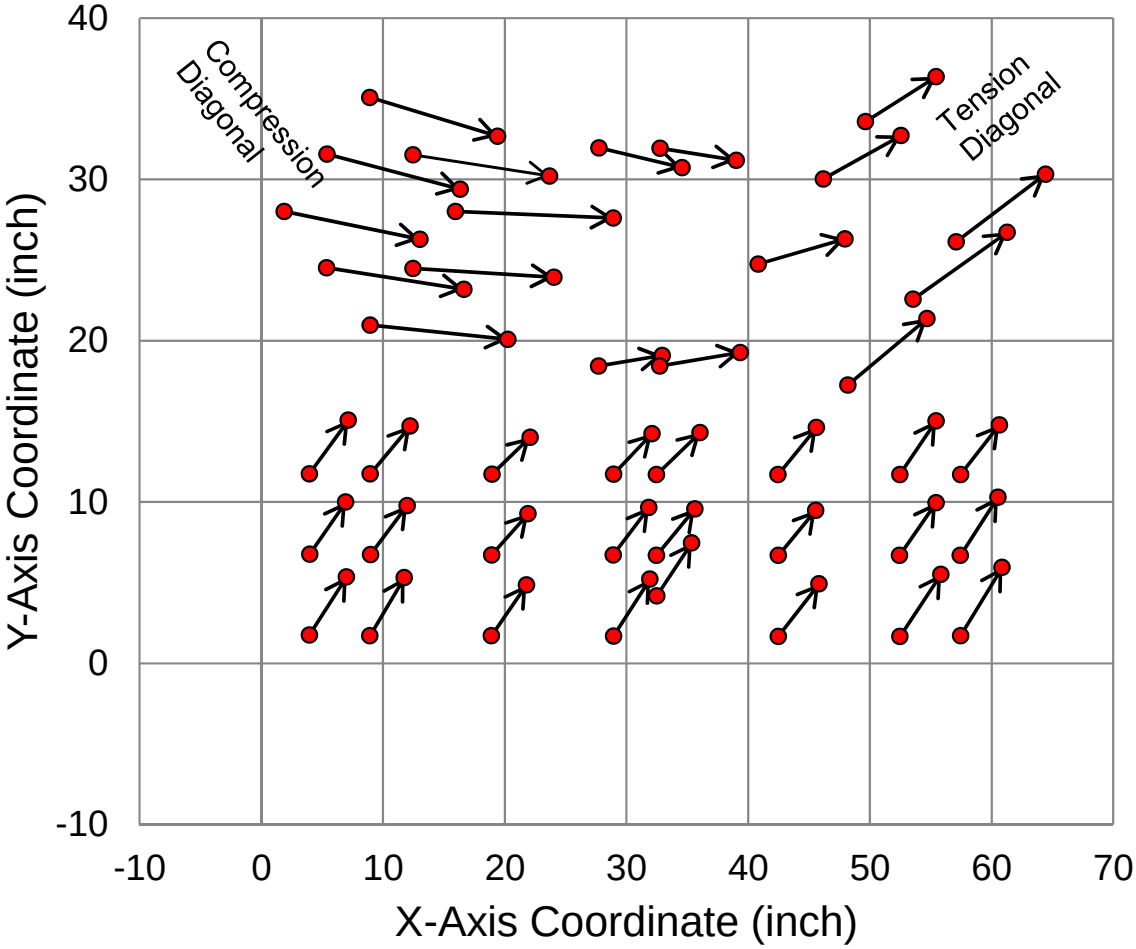
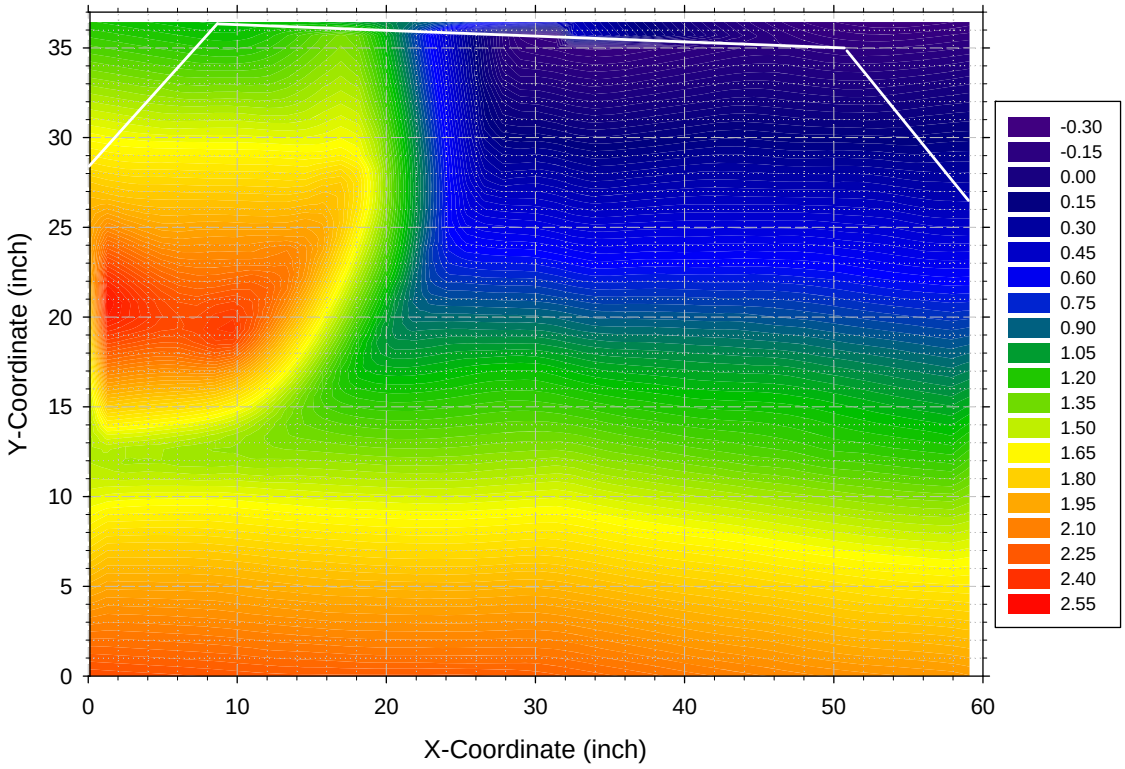



Figure H24.Vector motions of gusset plate targets amplified 50 times.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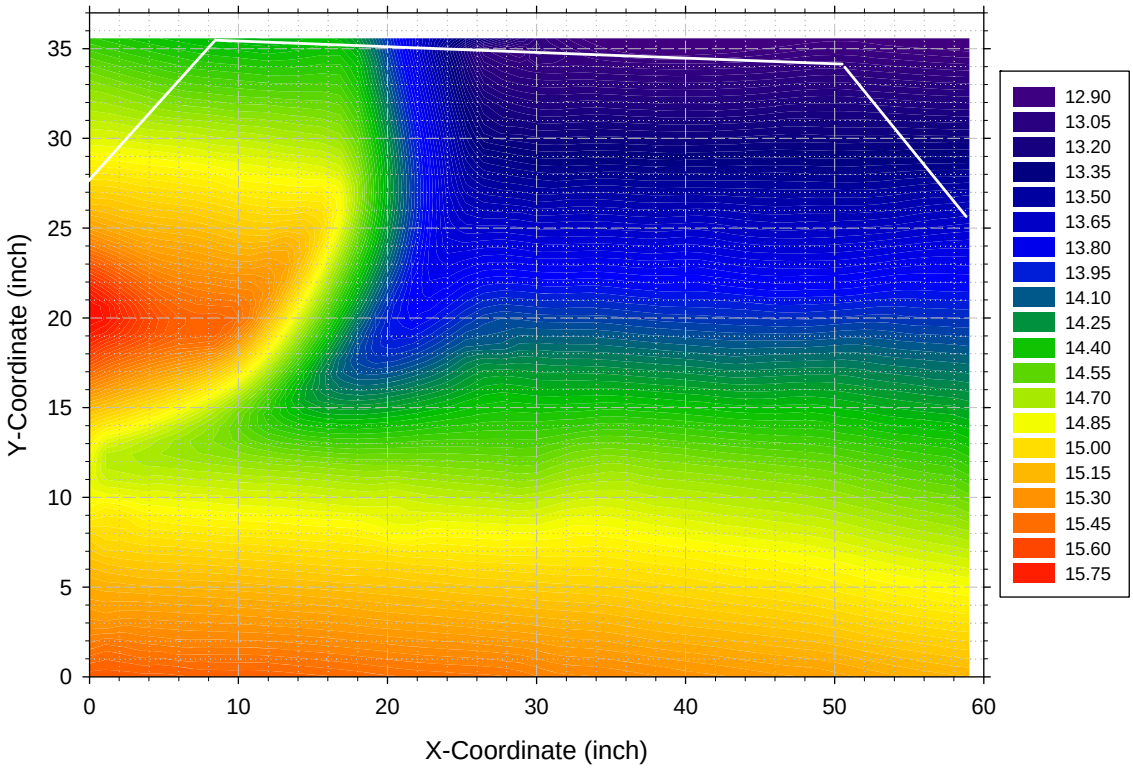



Figure H25.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307LS3**

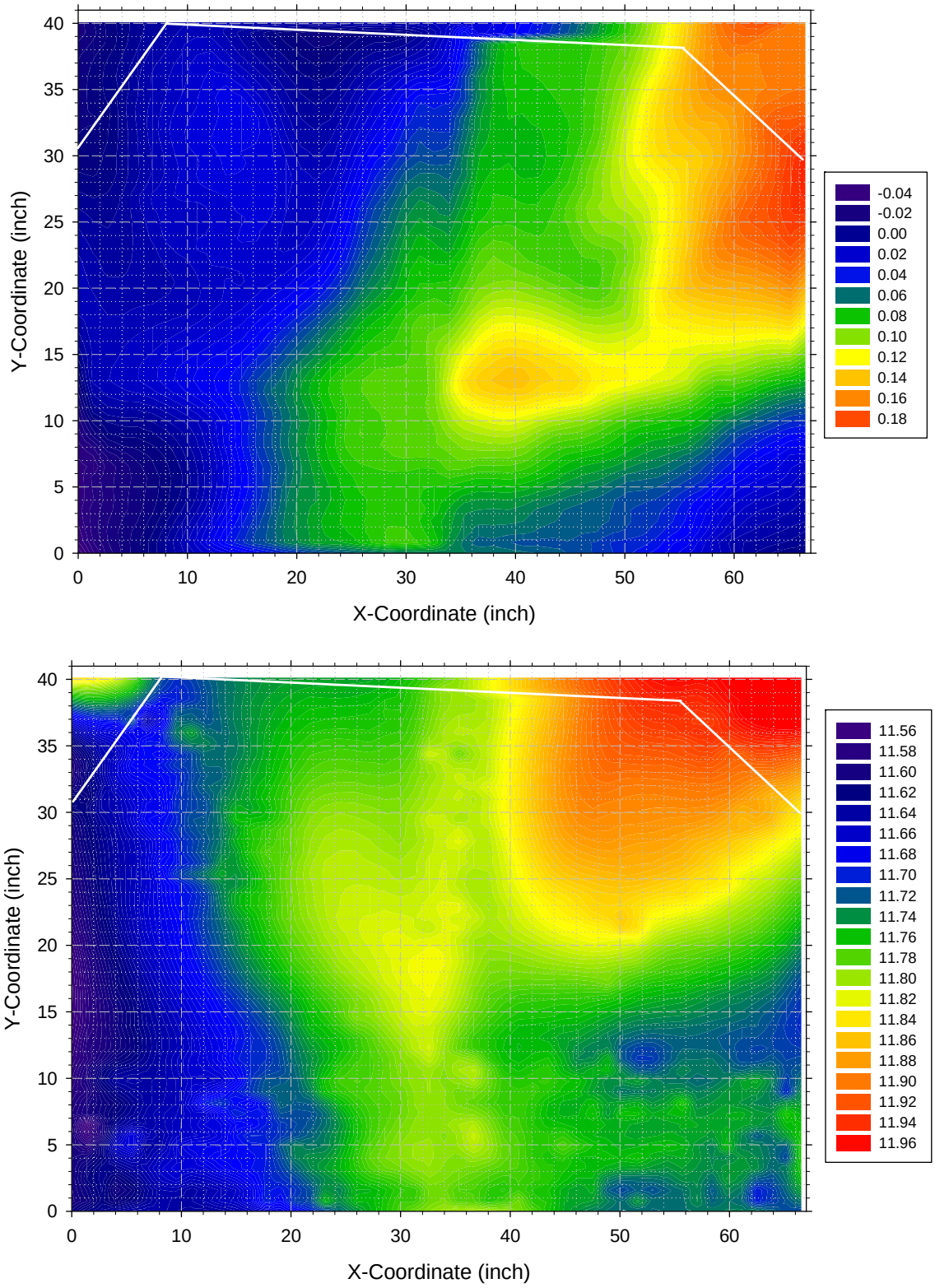



Figure H26.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

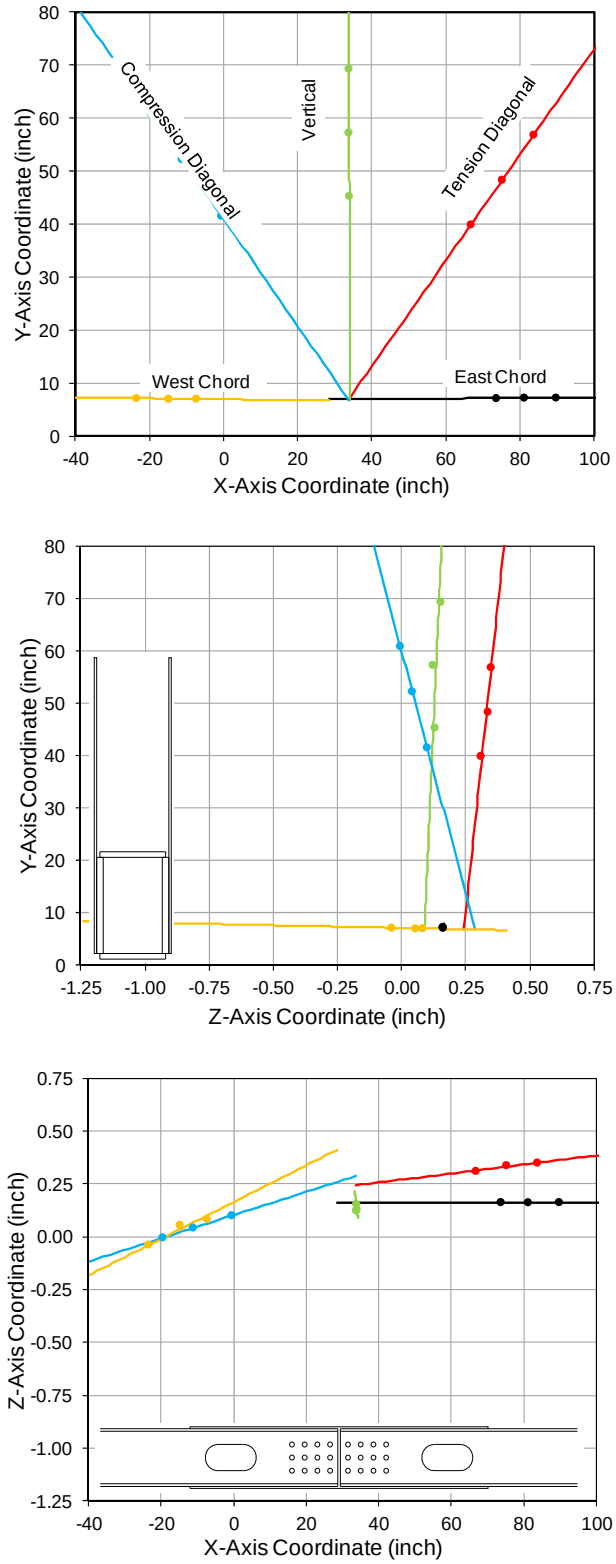



Figure H27.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

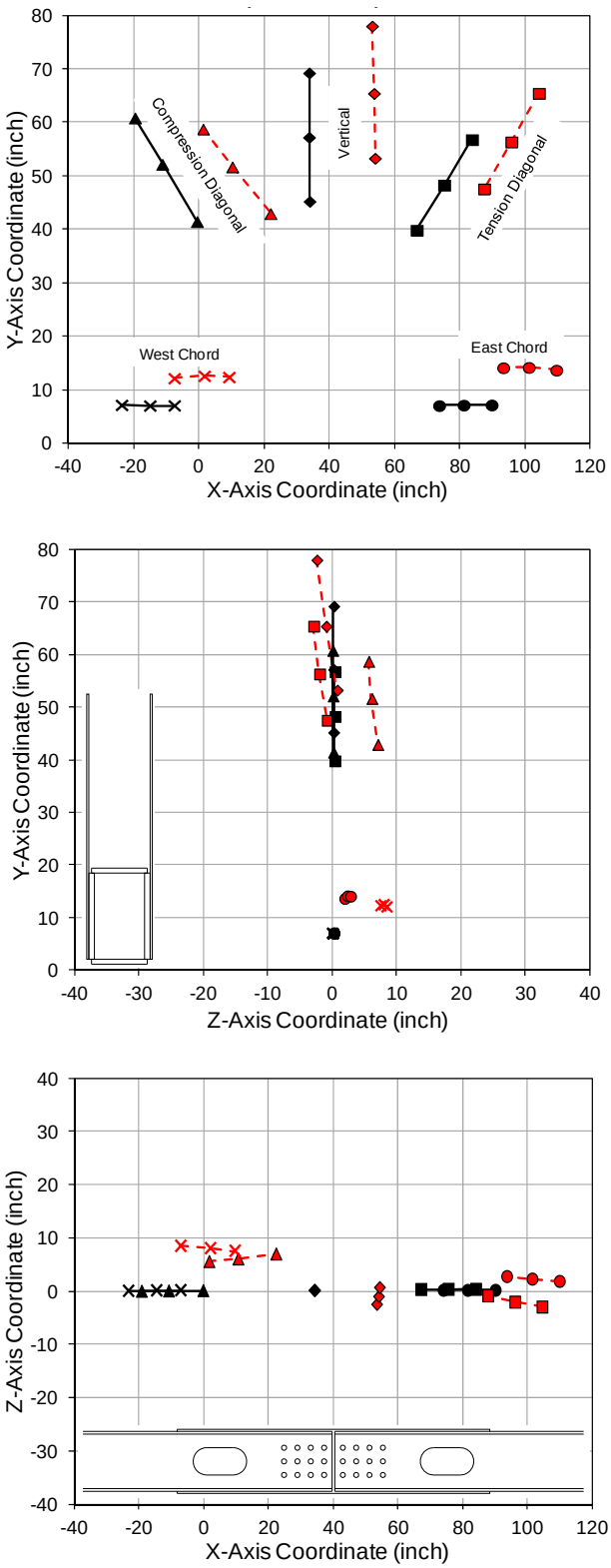



Figure H28.Amplified displacement (x50) of member targets at an ALF of 1.00. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

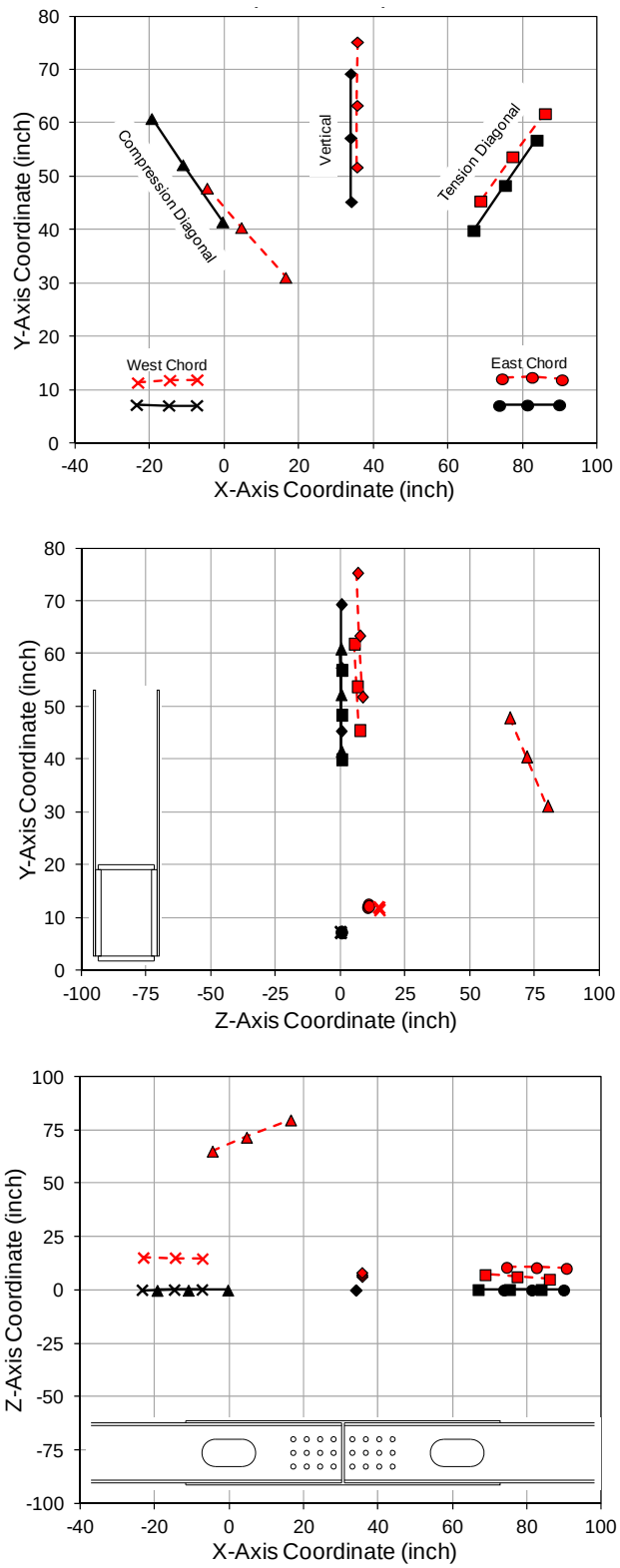



Figure H29.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

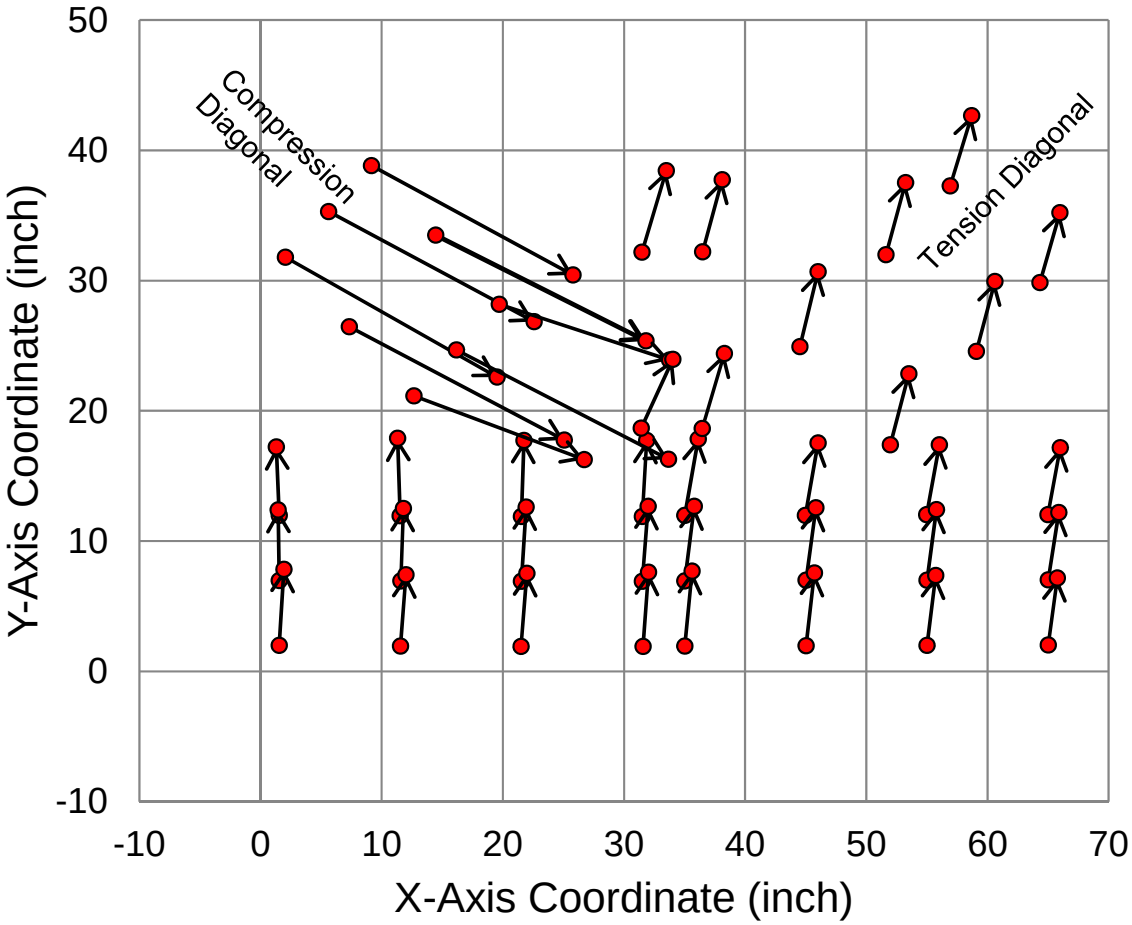
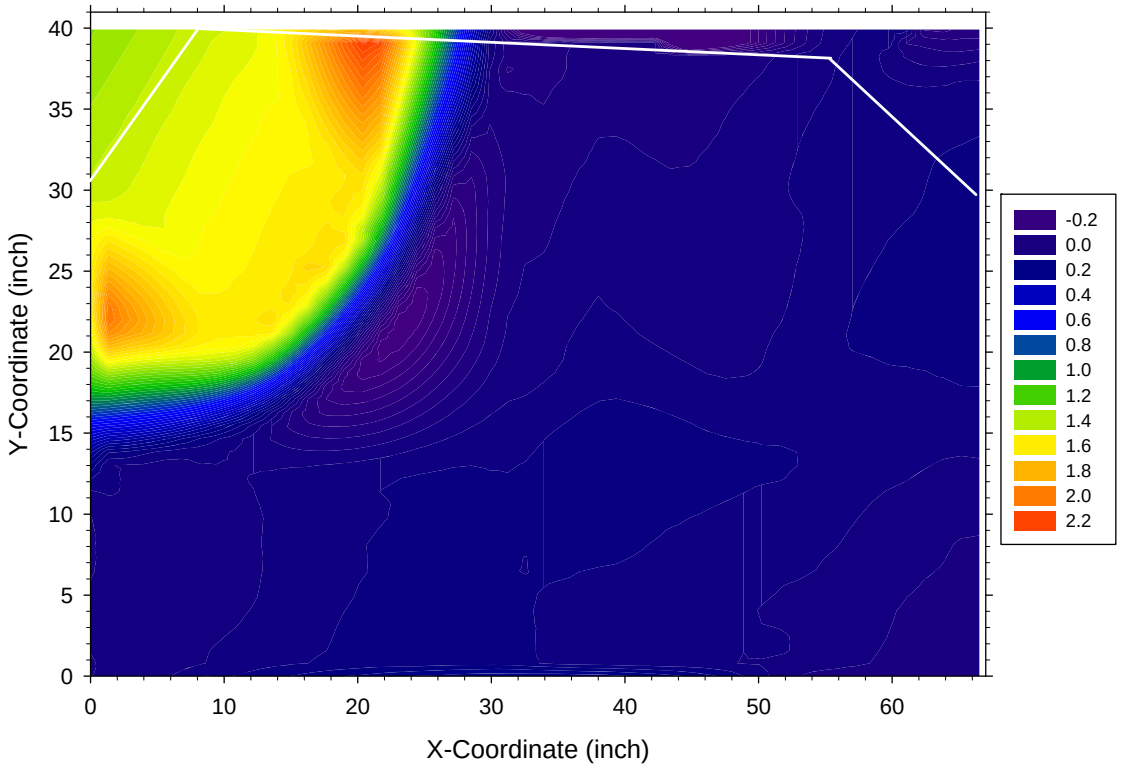



Figure H30.Vector motions of gusset plate targets amplified 50 times.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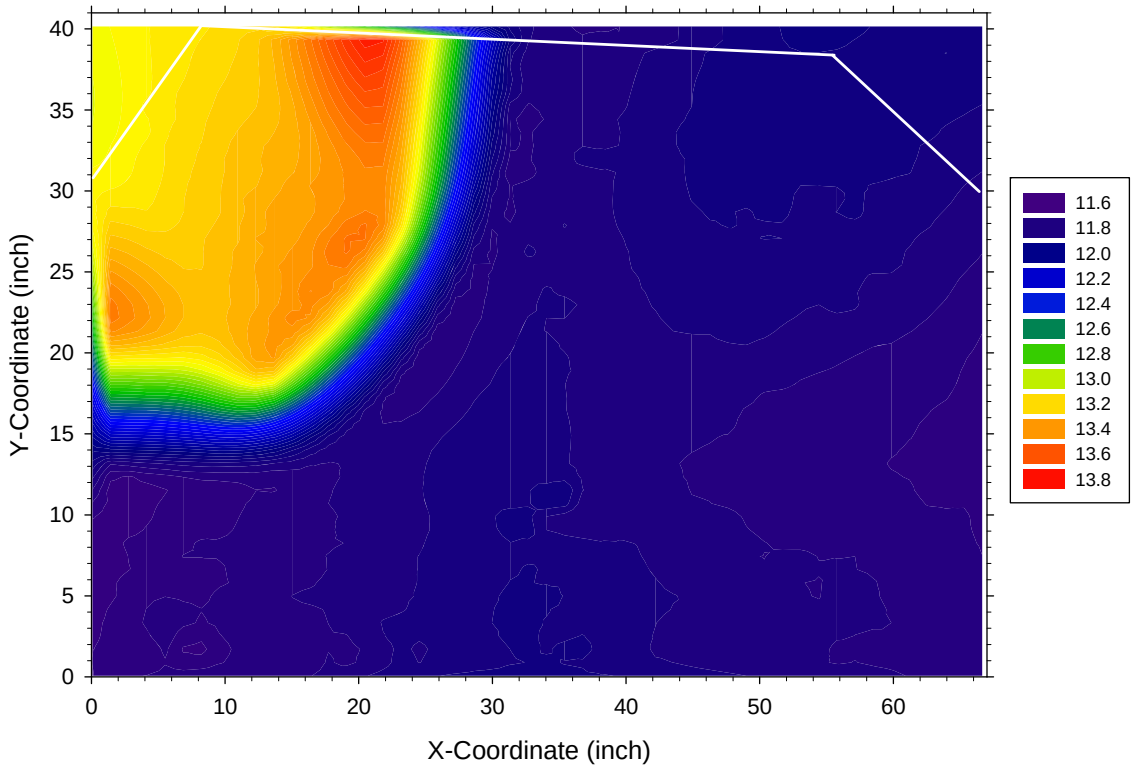
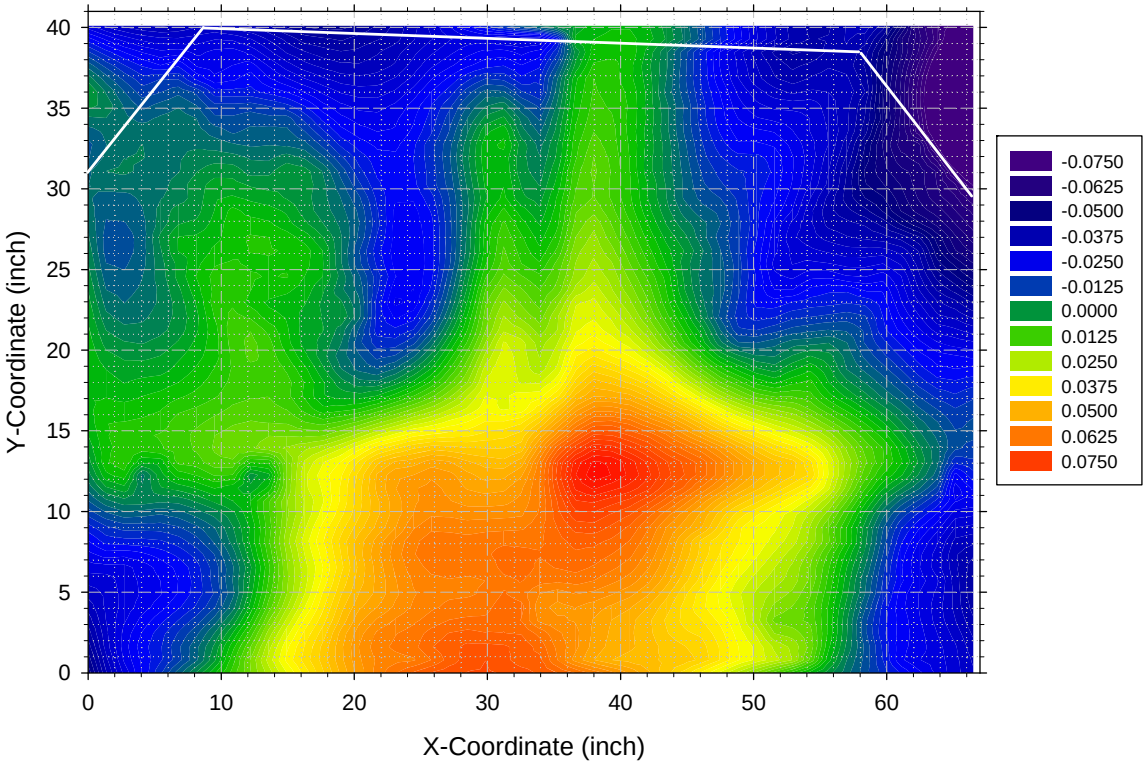



Figure H31.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SL3**



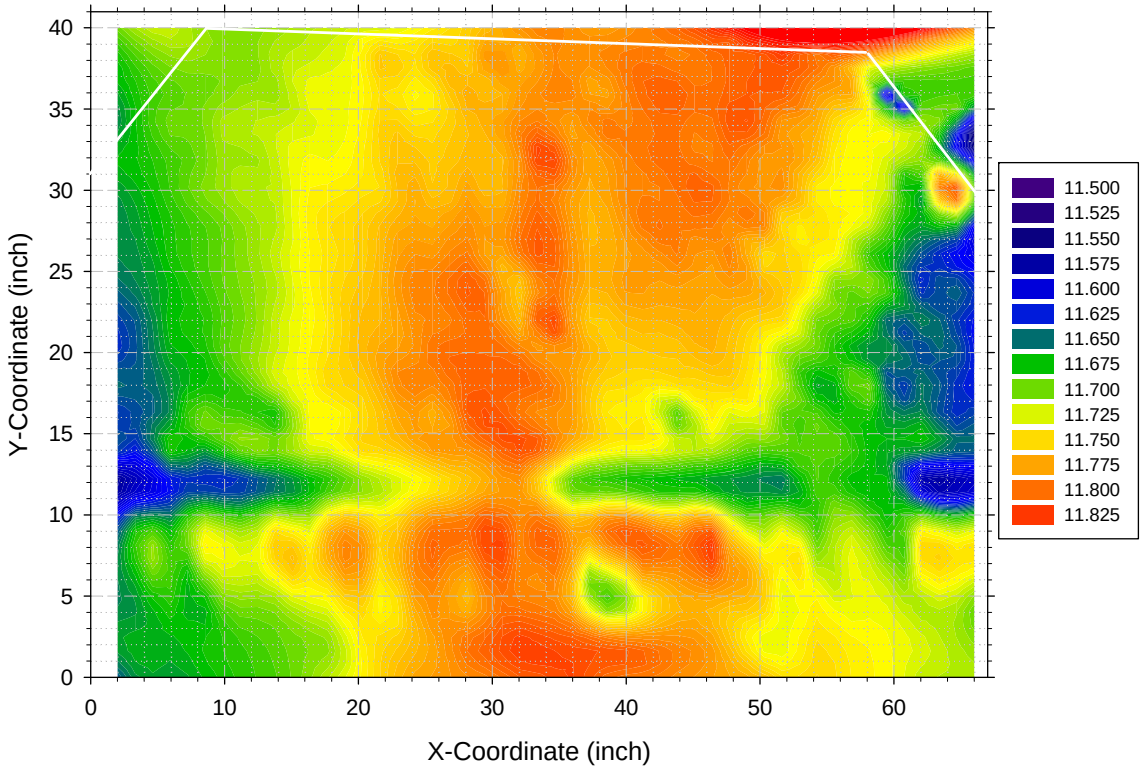




Figure H32.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

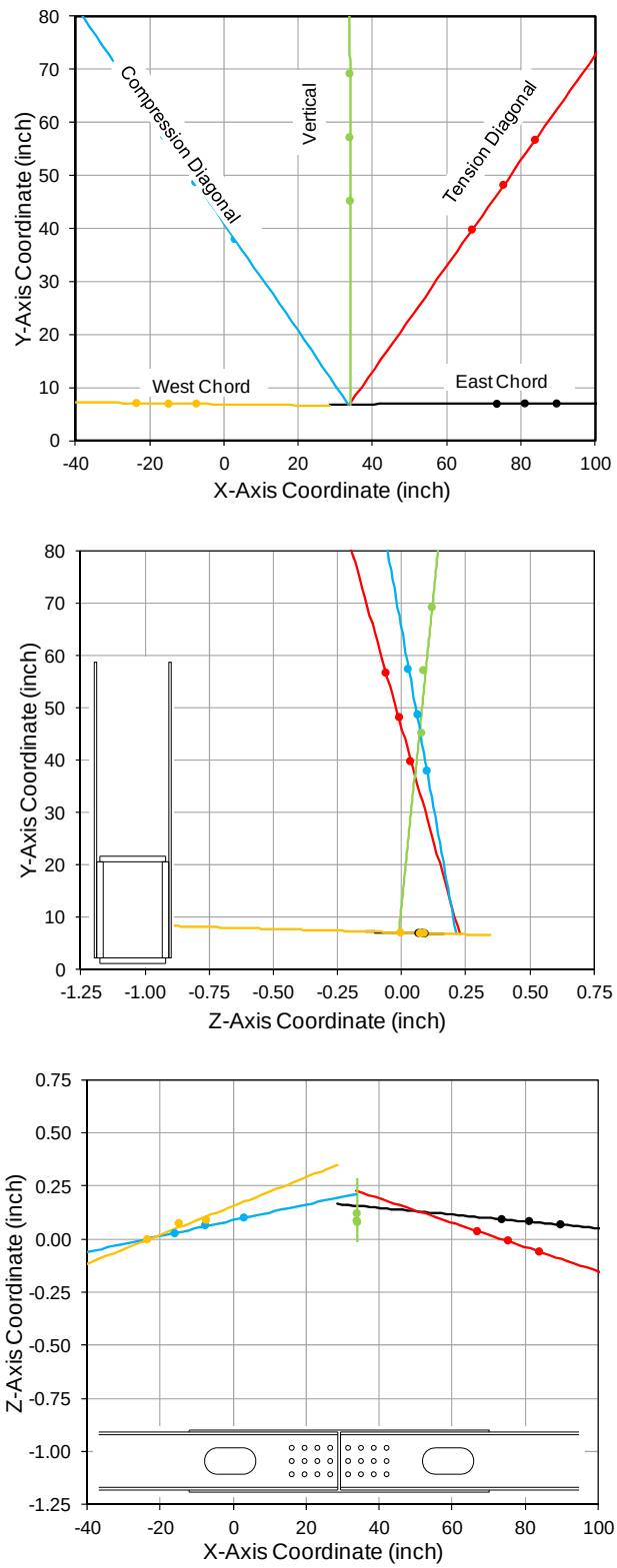



Figure H33.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

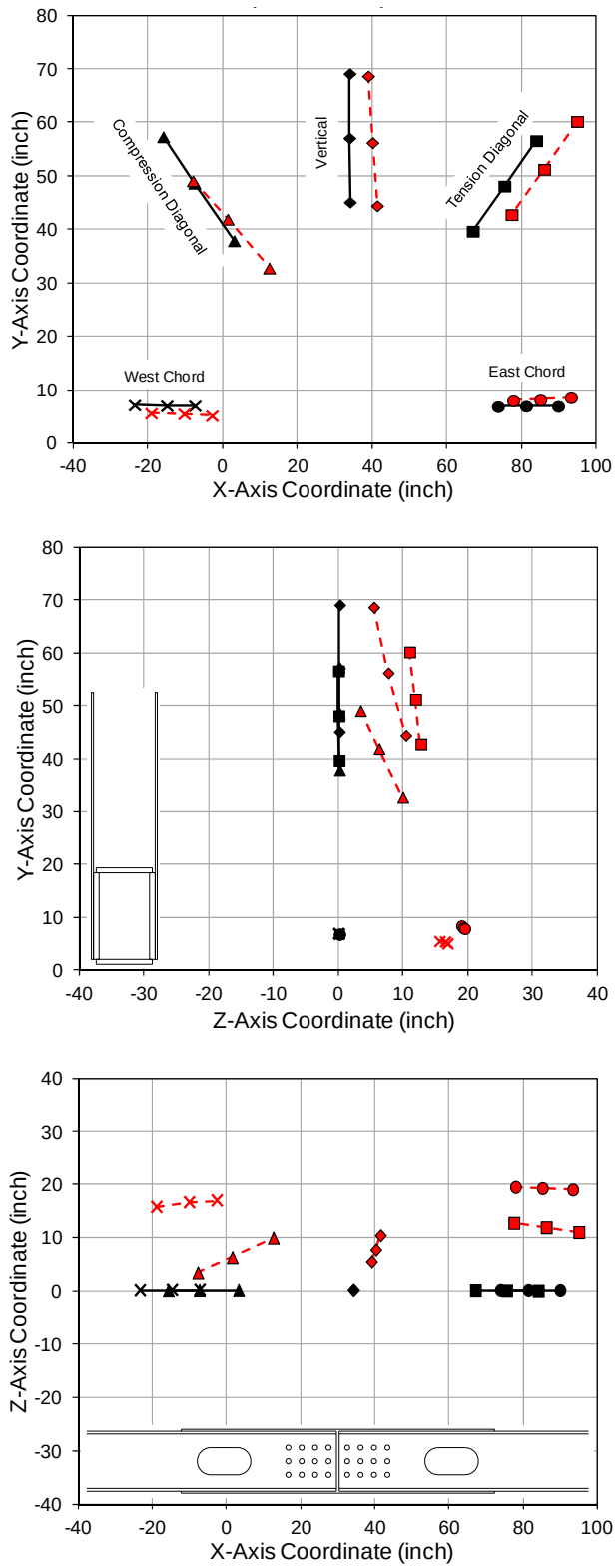



Figure H34.Amplified displacement (x50) of member targets at an ALF of 0.77. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

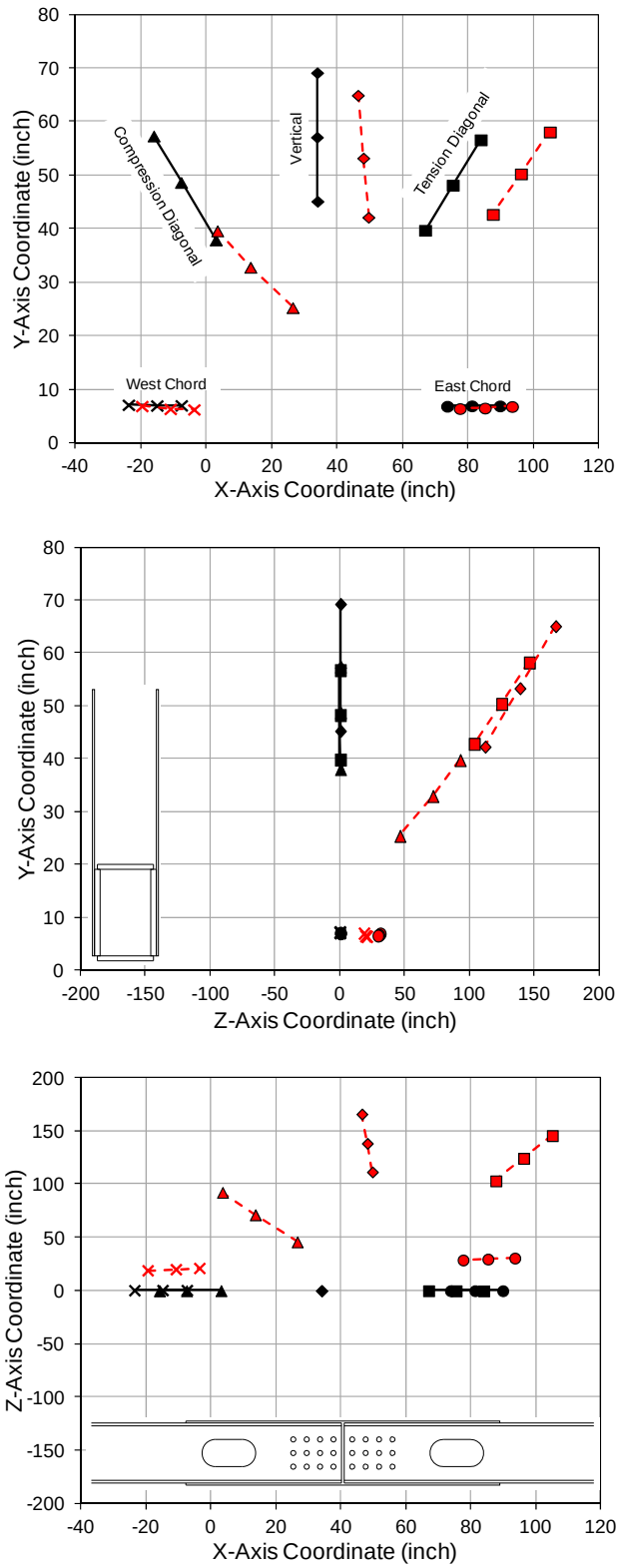



Figure H35.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

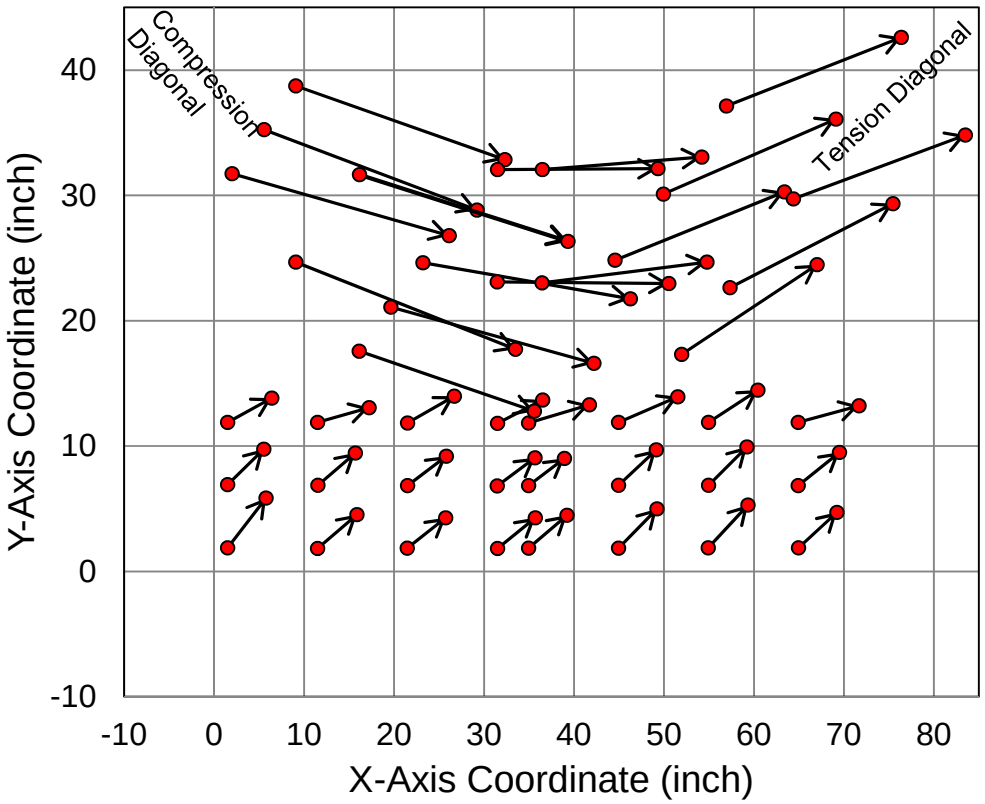



Figure H36.Vector motions of gusset plate targets amplified 50 times.

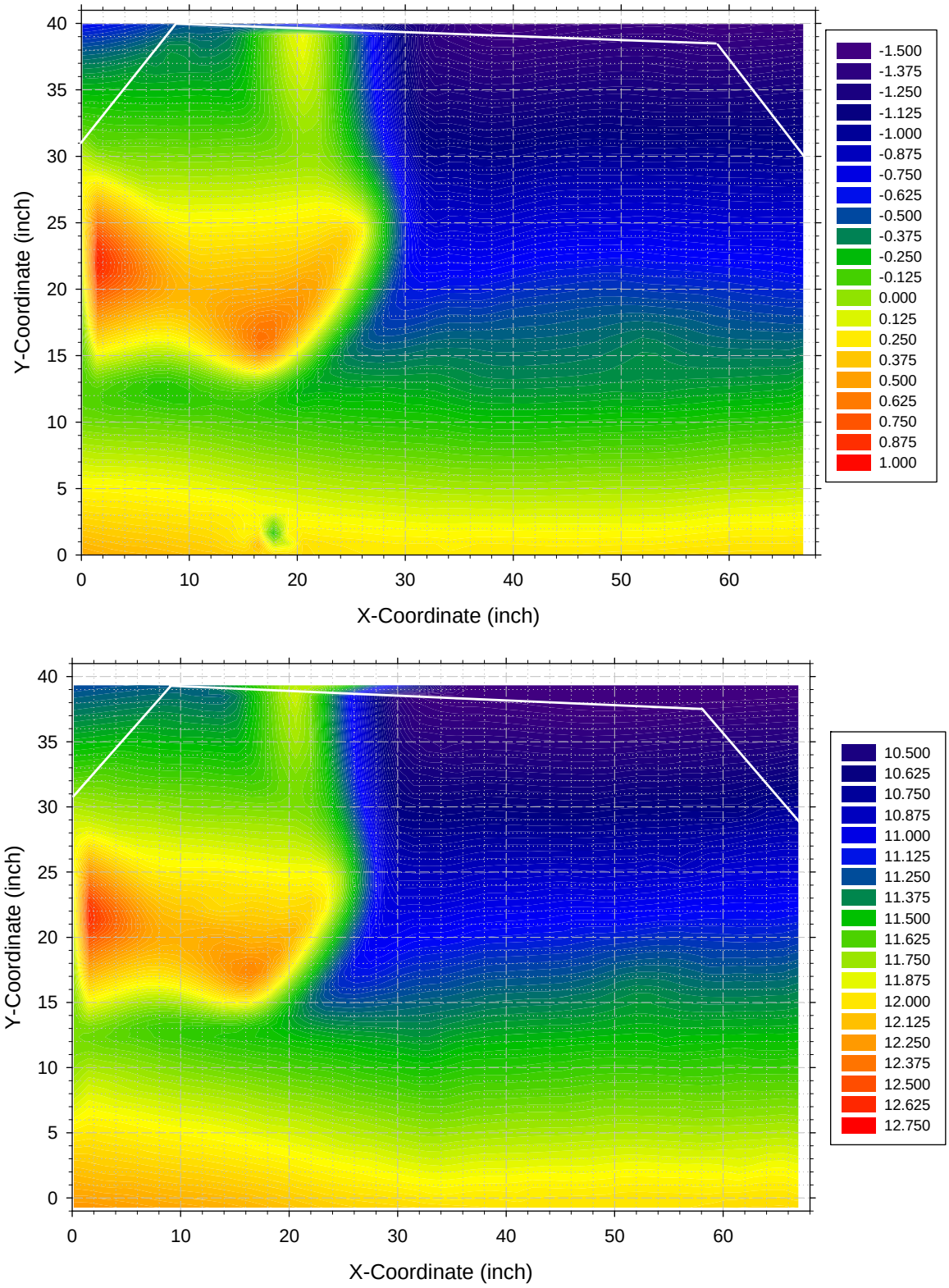



Figure H37.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SL4**

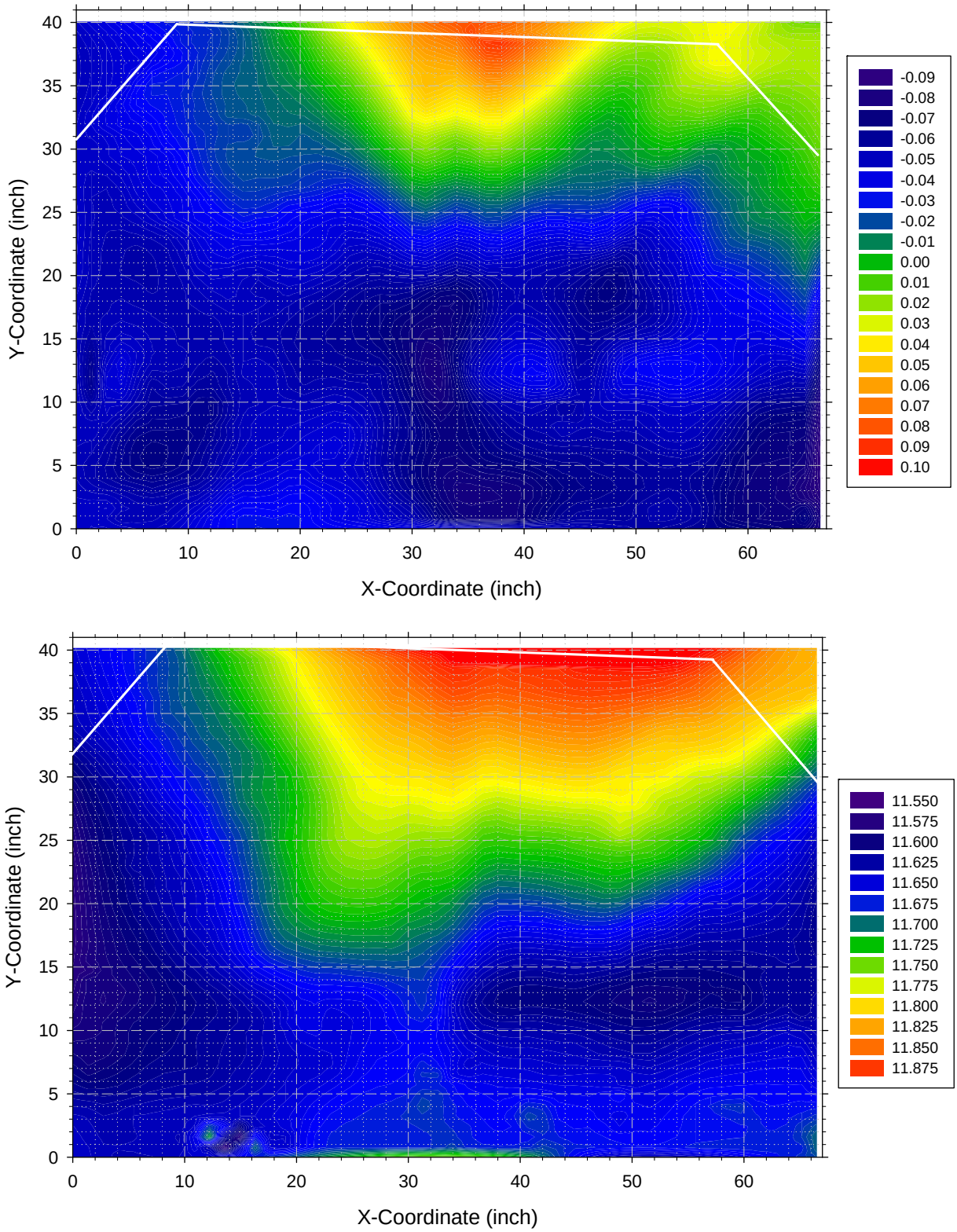



Figure H38.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

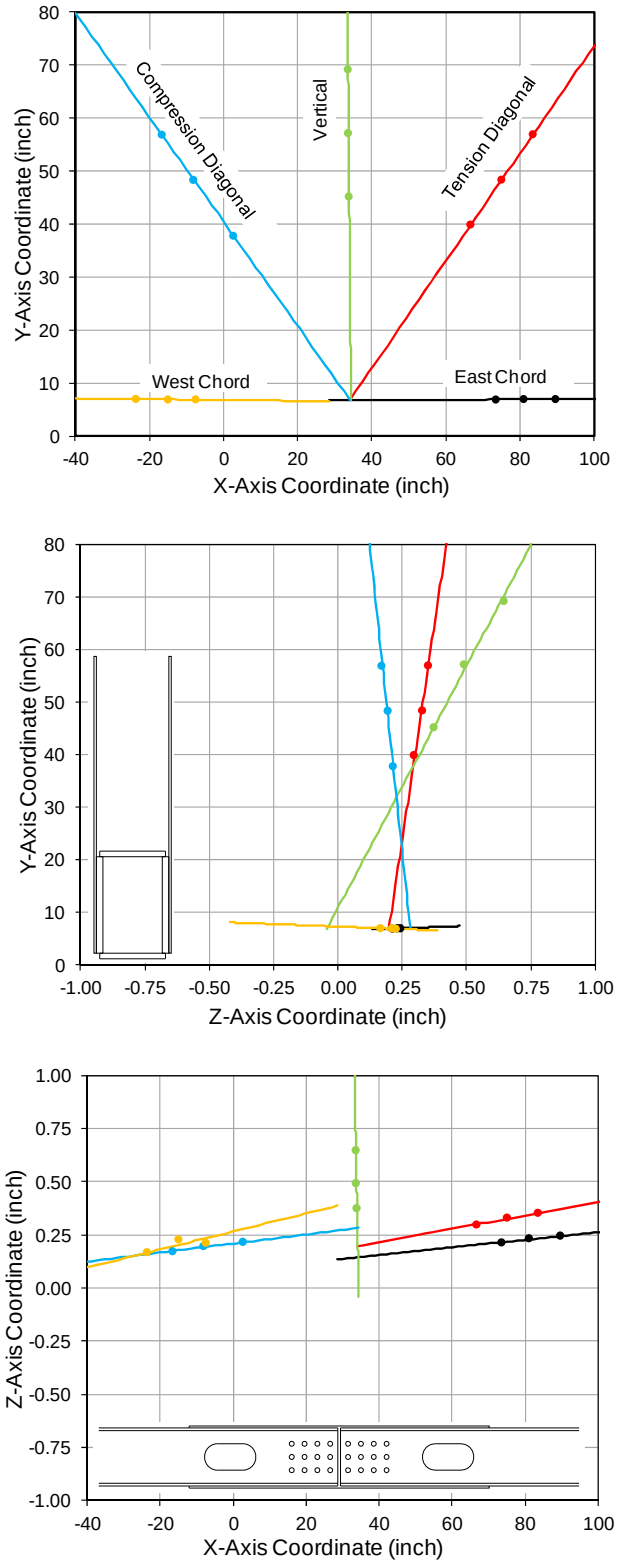



Figure H39.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

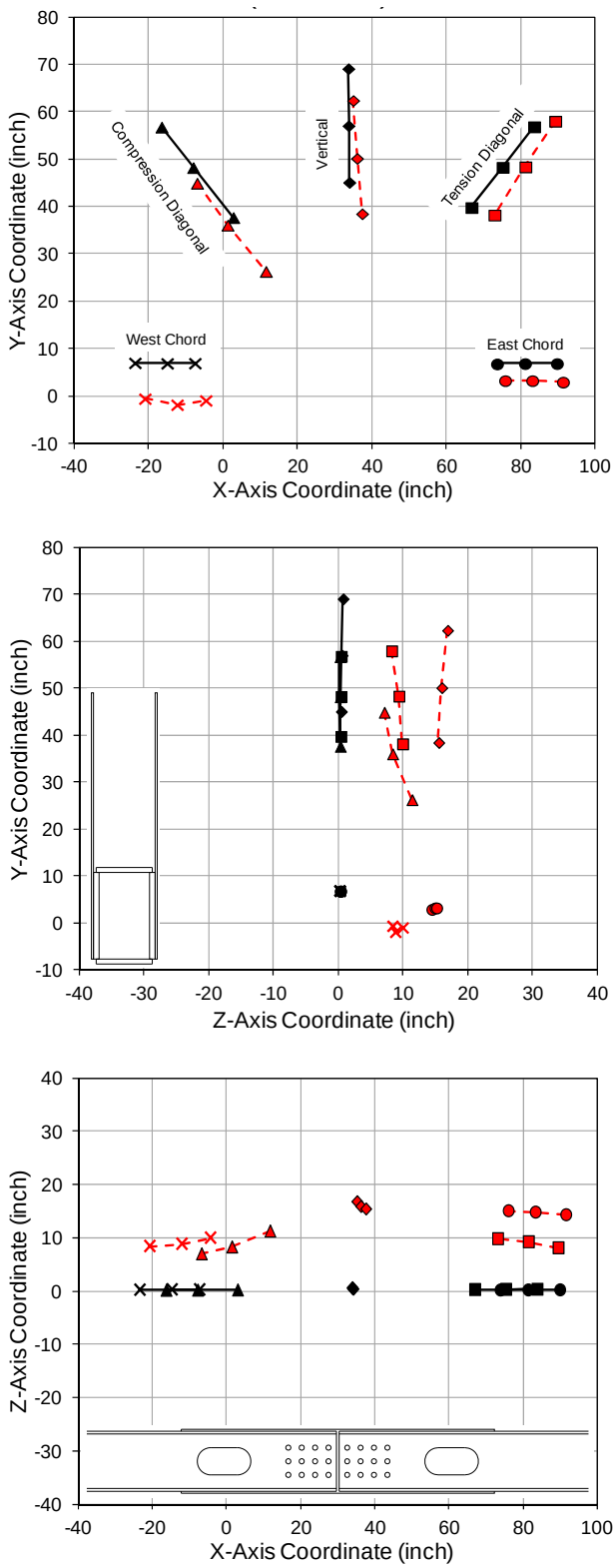



Figure H40.Amplified displacement (x50) of member targets at an ALF of 0.78. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

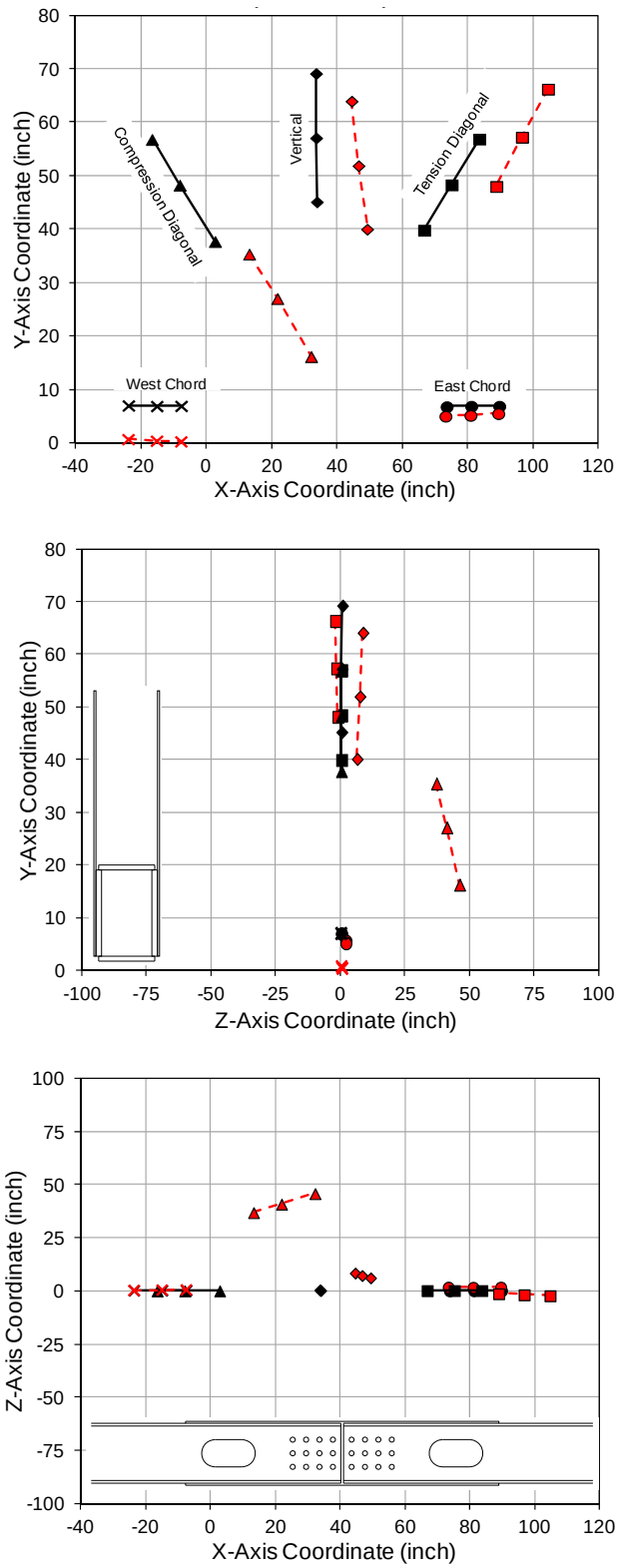



Figure H41.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

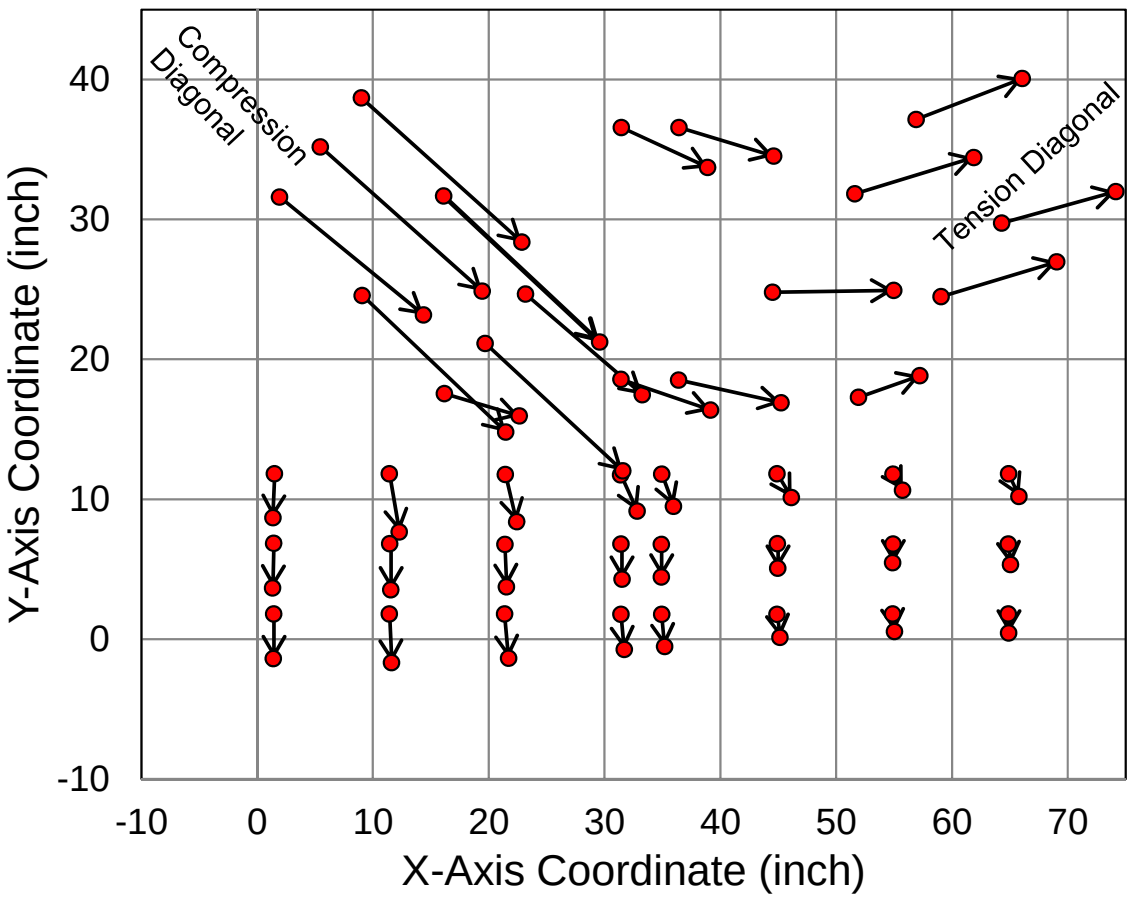
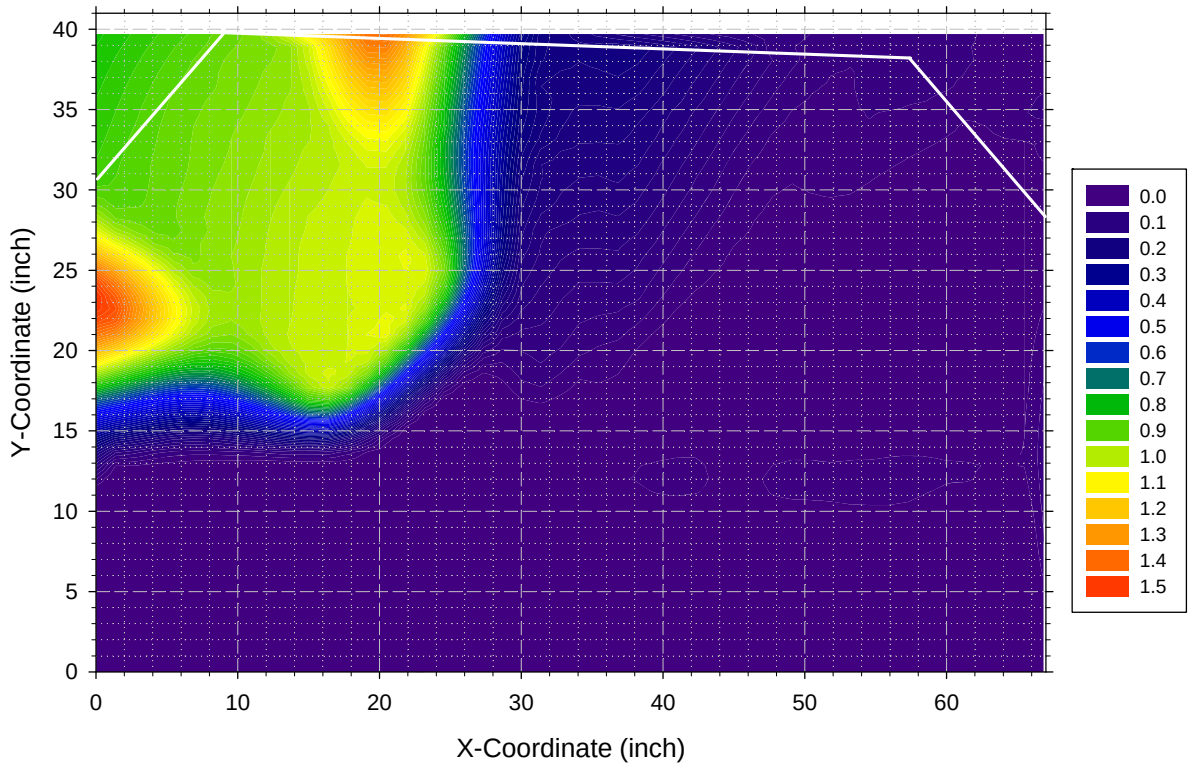



Figure H42.Vector motions of gusset plate targets amplified 25 times.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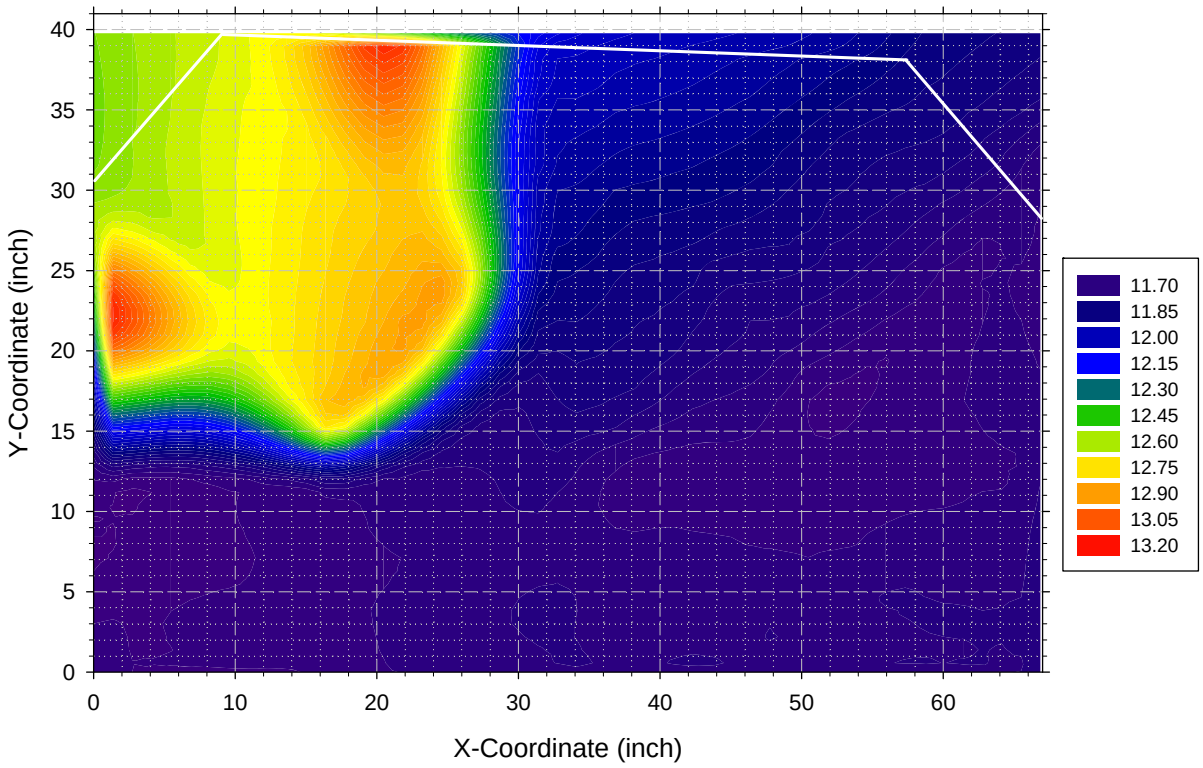
1.3
1.4
1.5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11.85
12.00
12.15
12.30
12.45
12.60
12.75
12.90
13.05
13.20

Figure H43.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 490LS3-2**

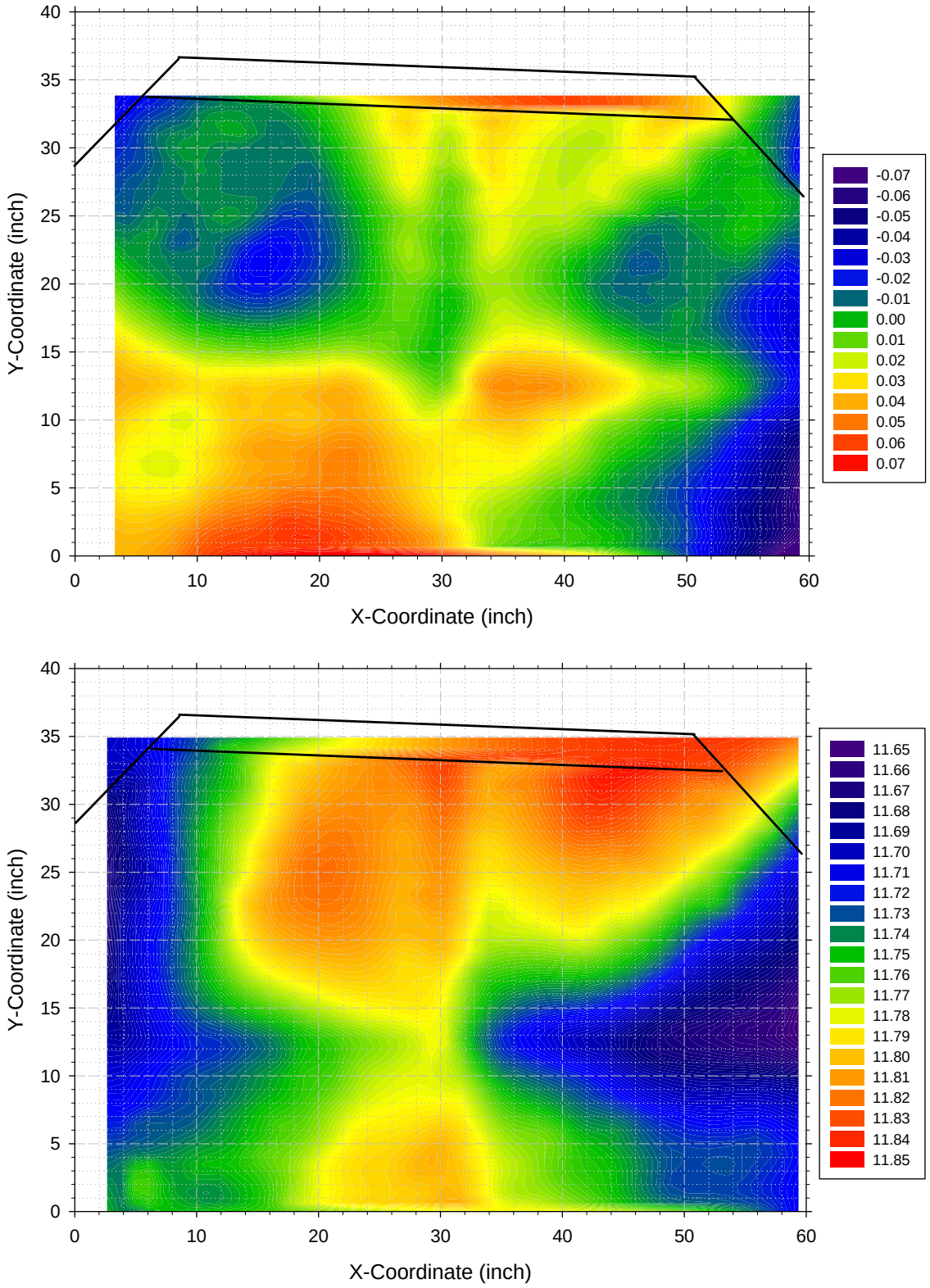



Figure H44.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

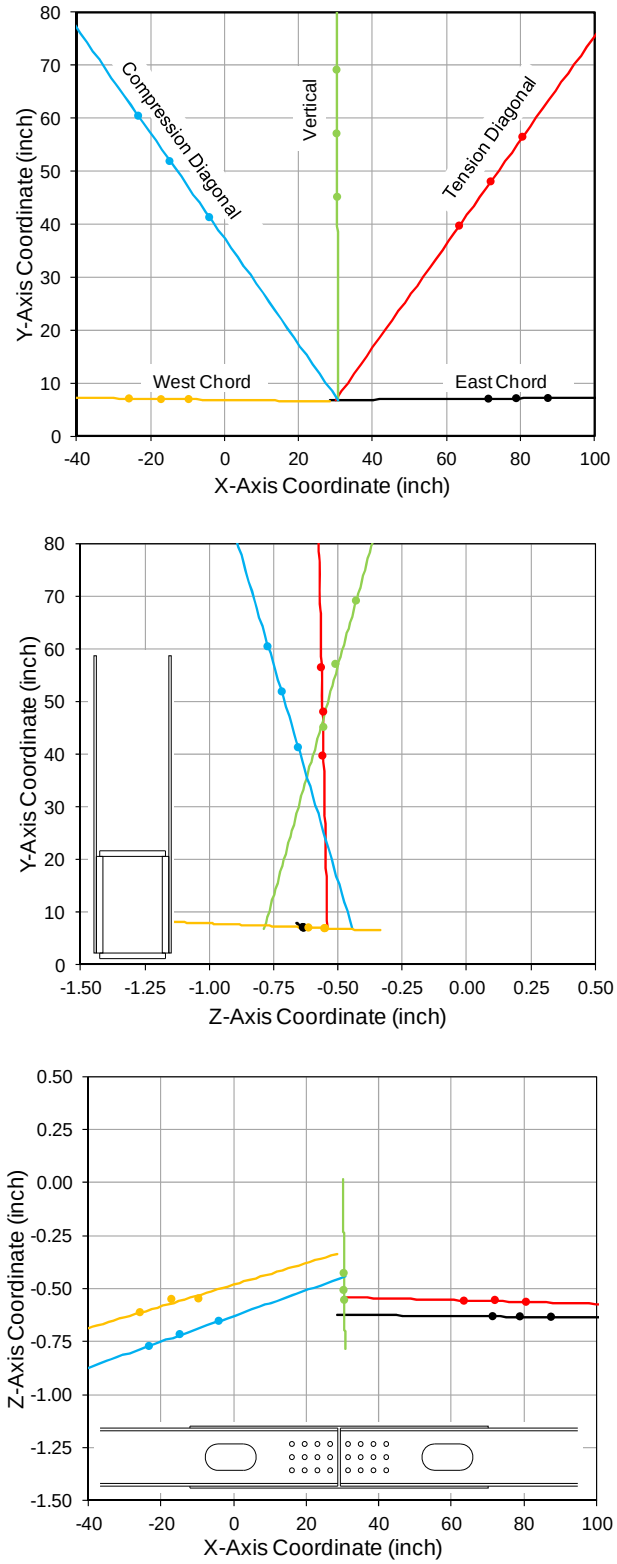



Figure H45.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

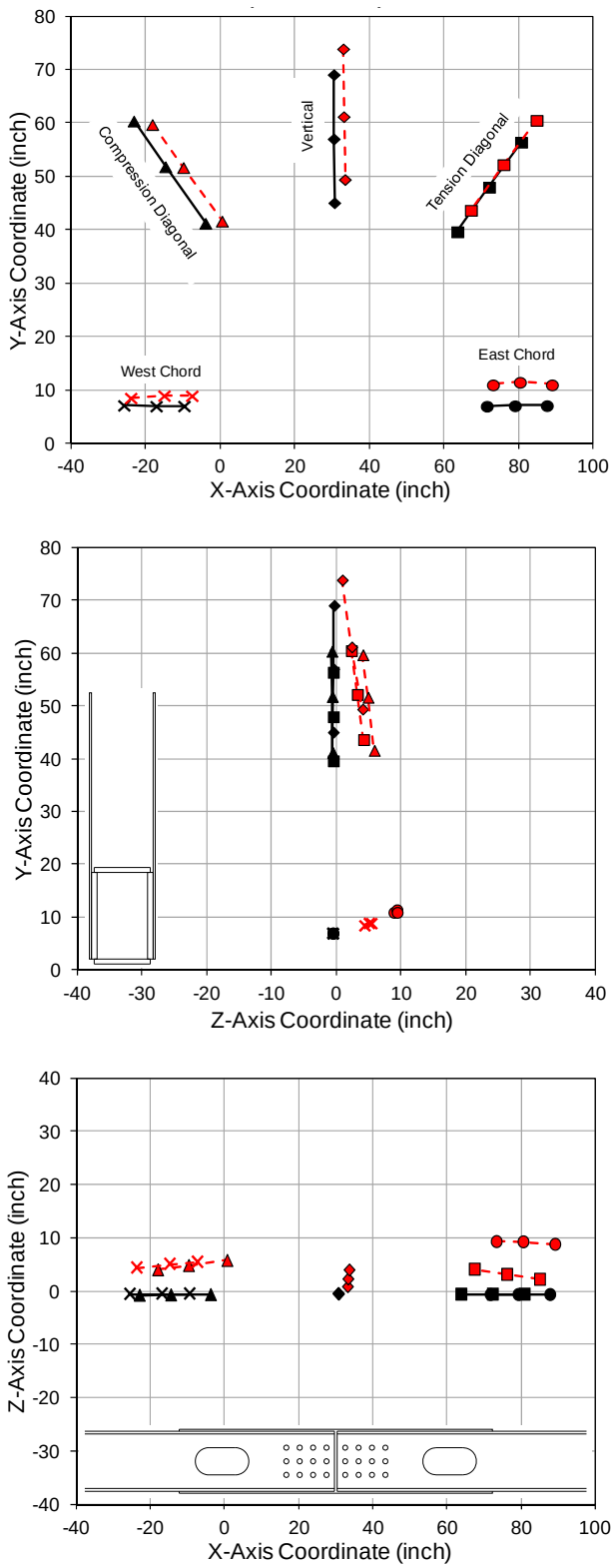



Figure H46.Amplified displacement (x50) of member targets at an ALF of 0.77. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

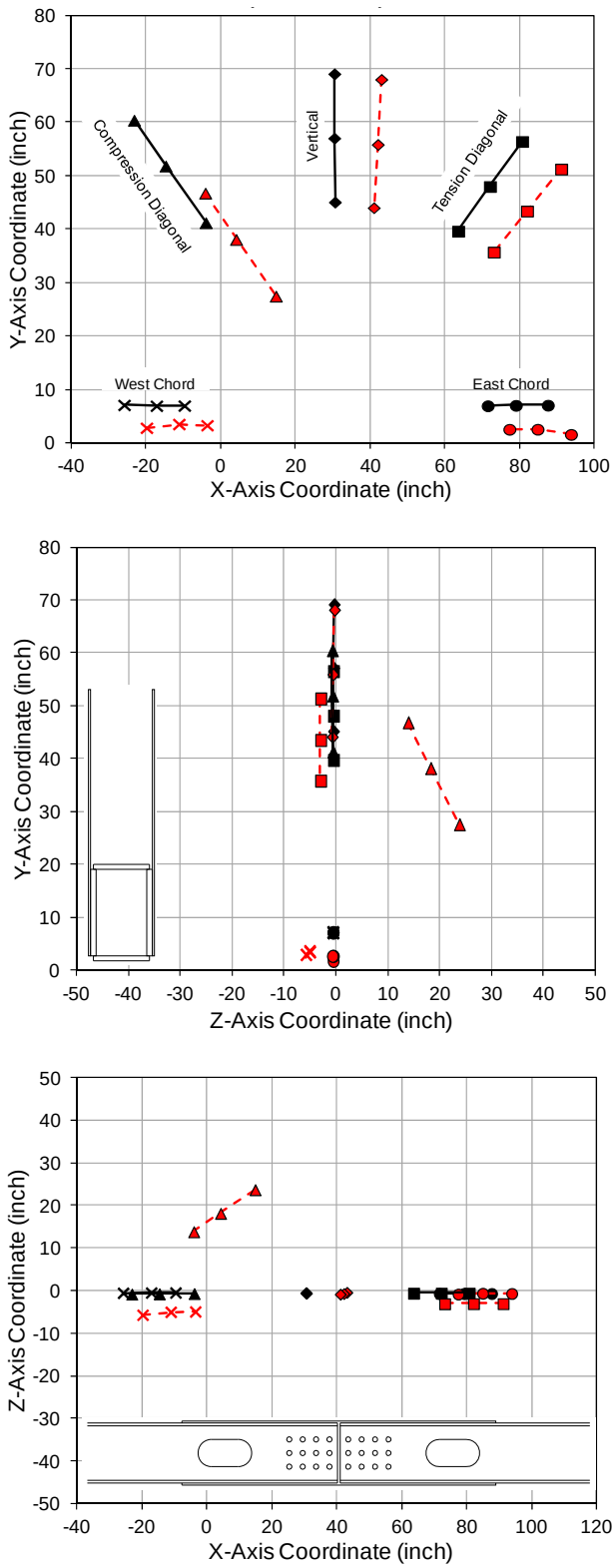



Figure H47.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

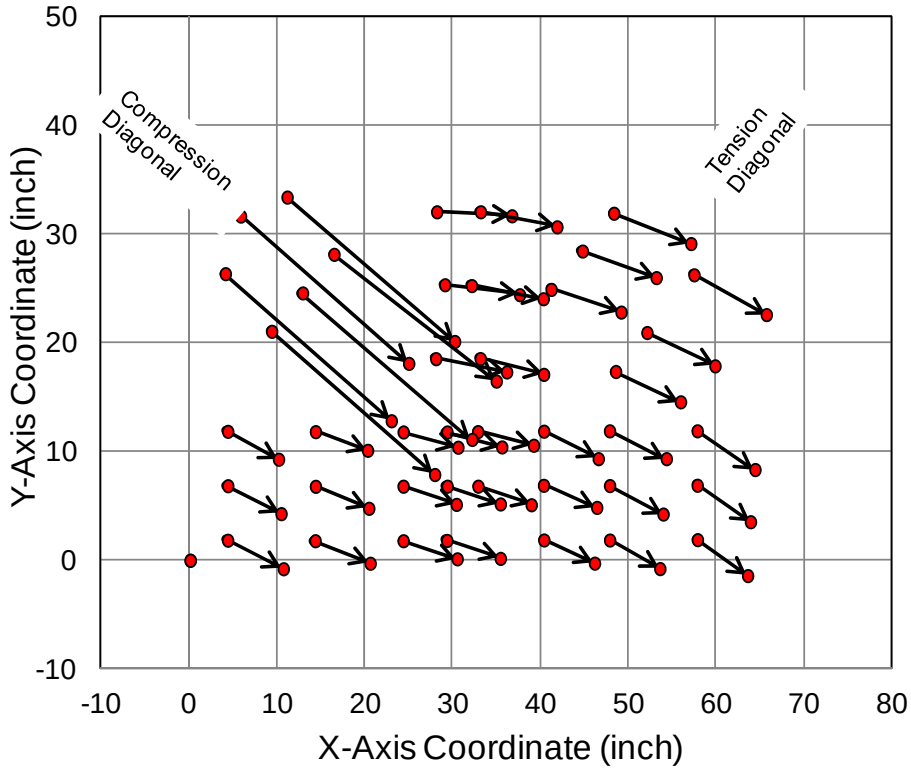



Figure H48.Vector motions of gusset plate targets amplified 50 times.

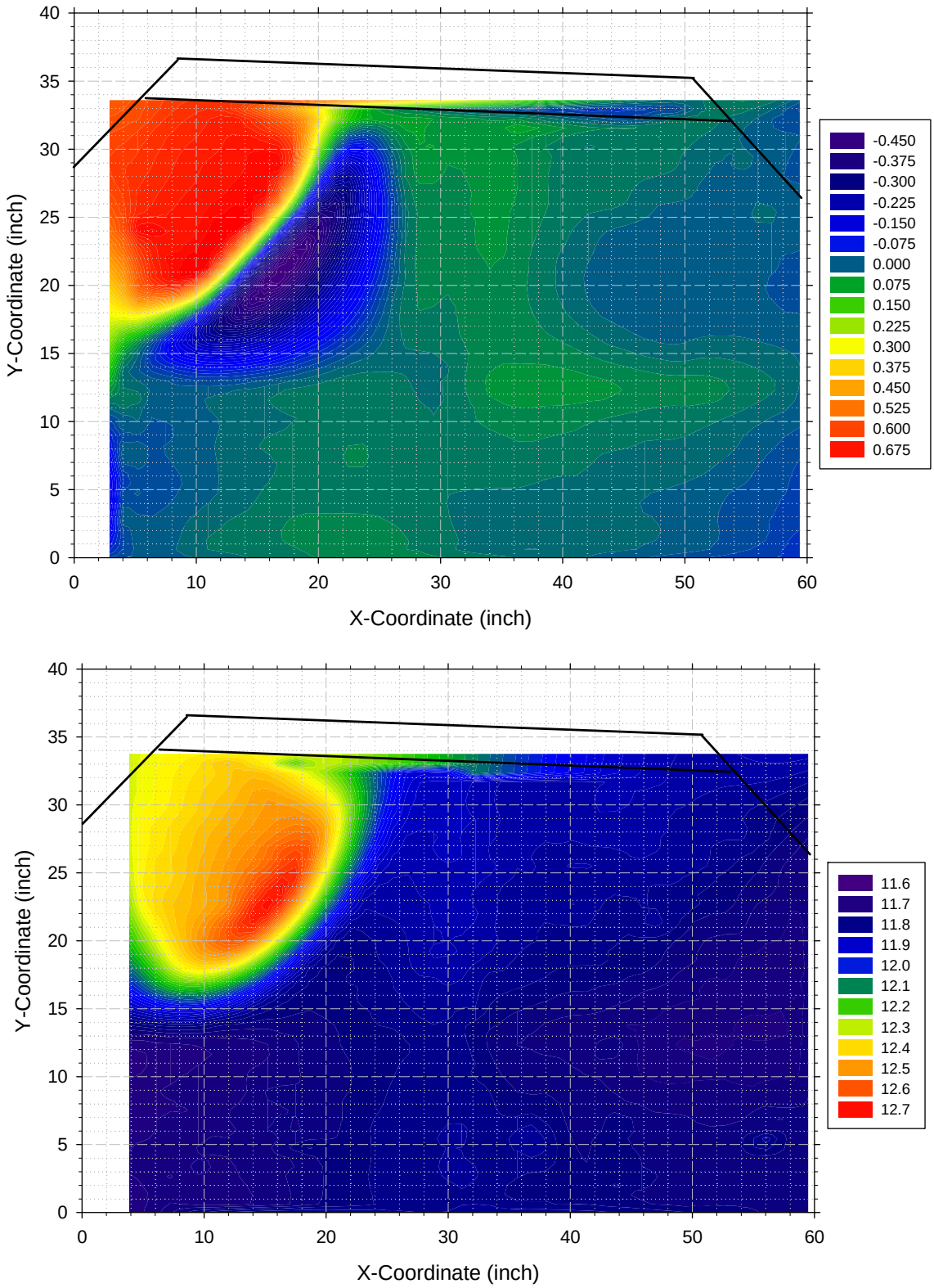



Figure H49.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 490SS3-1**

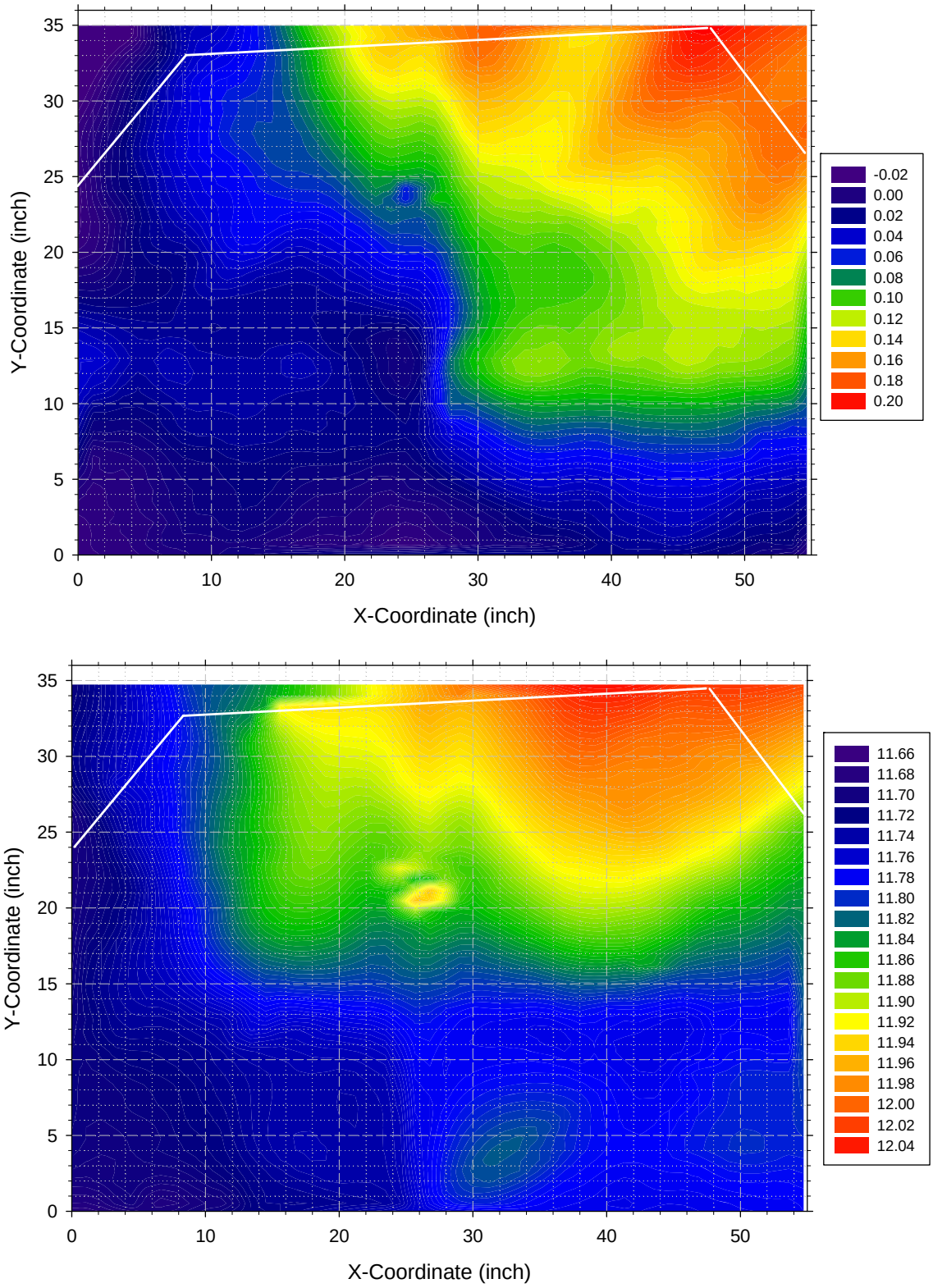



Figure H50.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

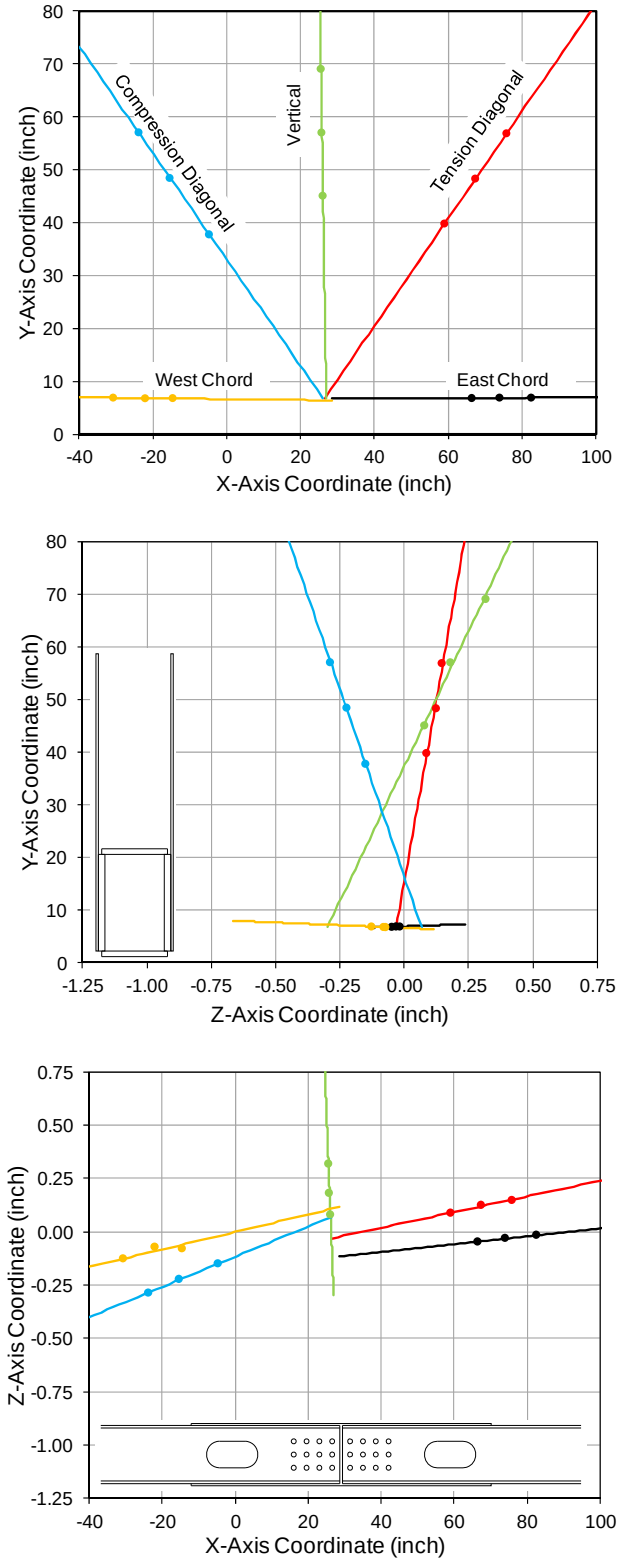



Figure H51.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

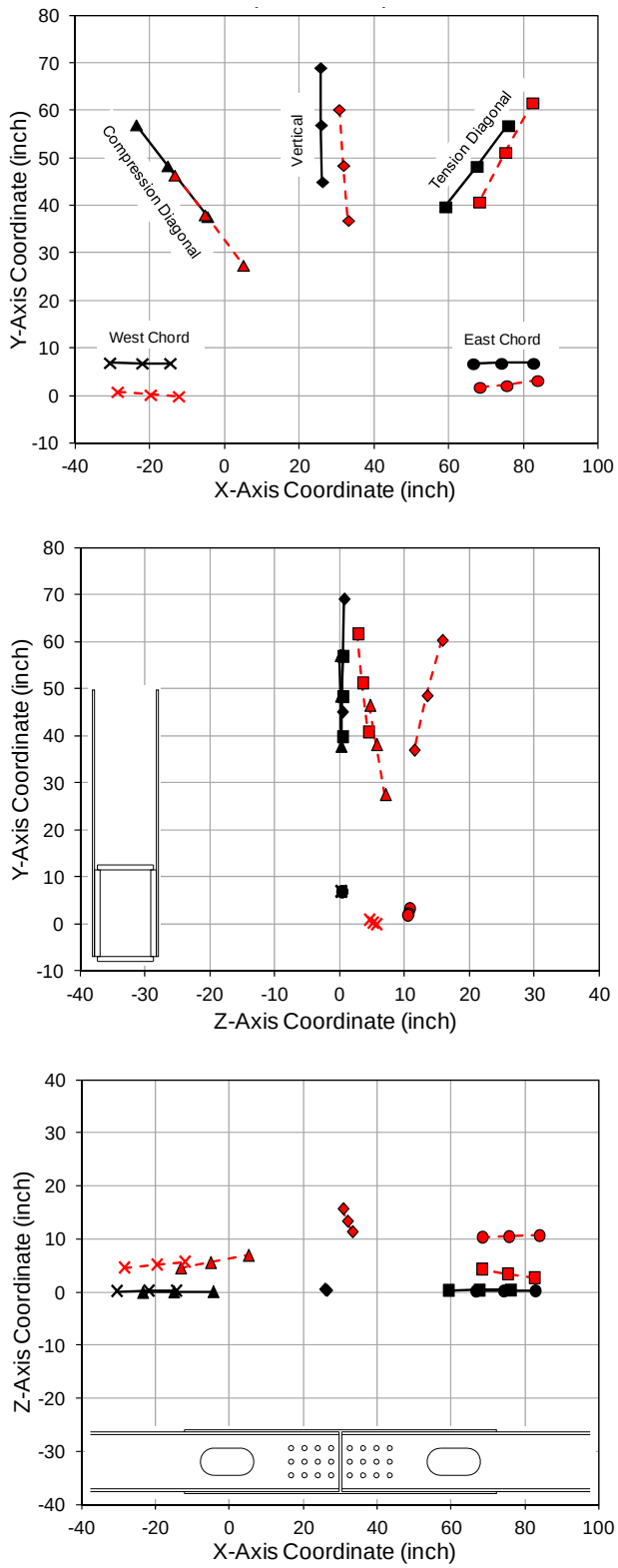



Figure H52.Amplified displacement (x50) of member targets at an ALF of 0.79. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

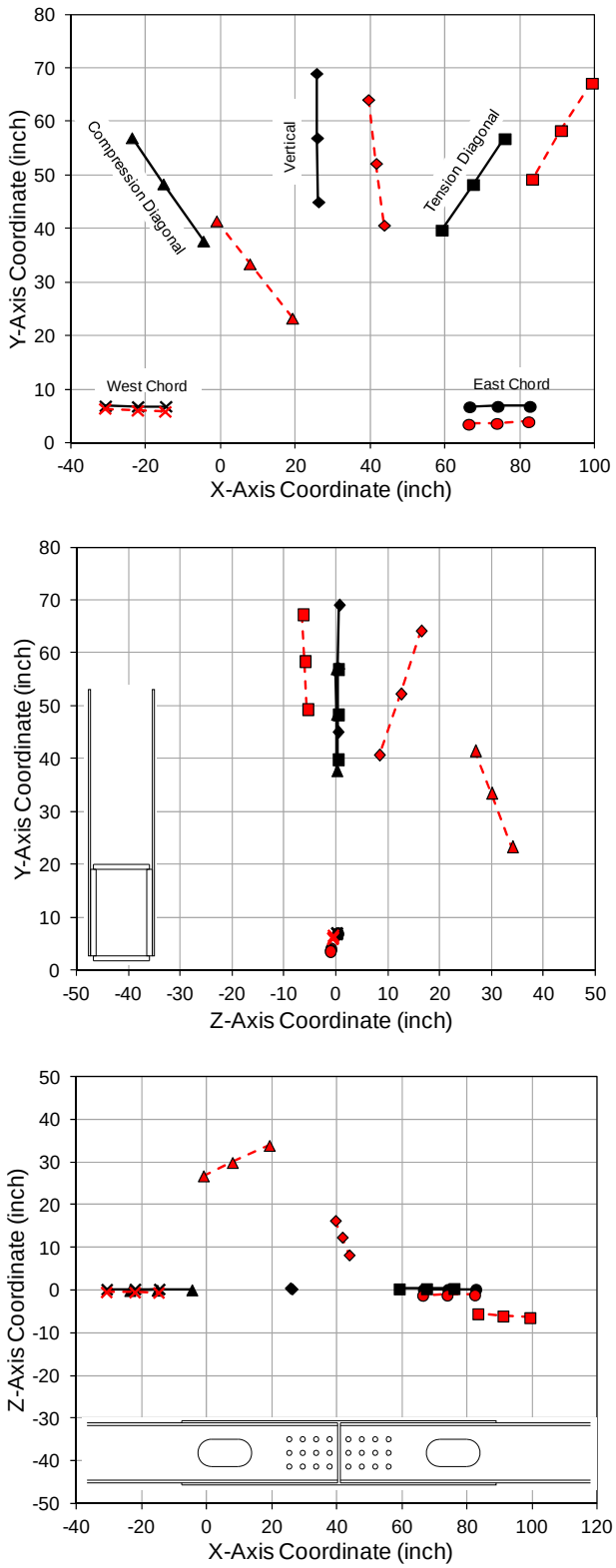



Figure H53.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

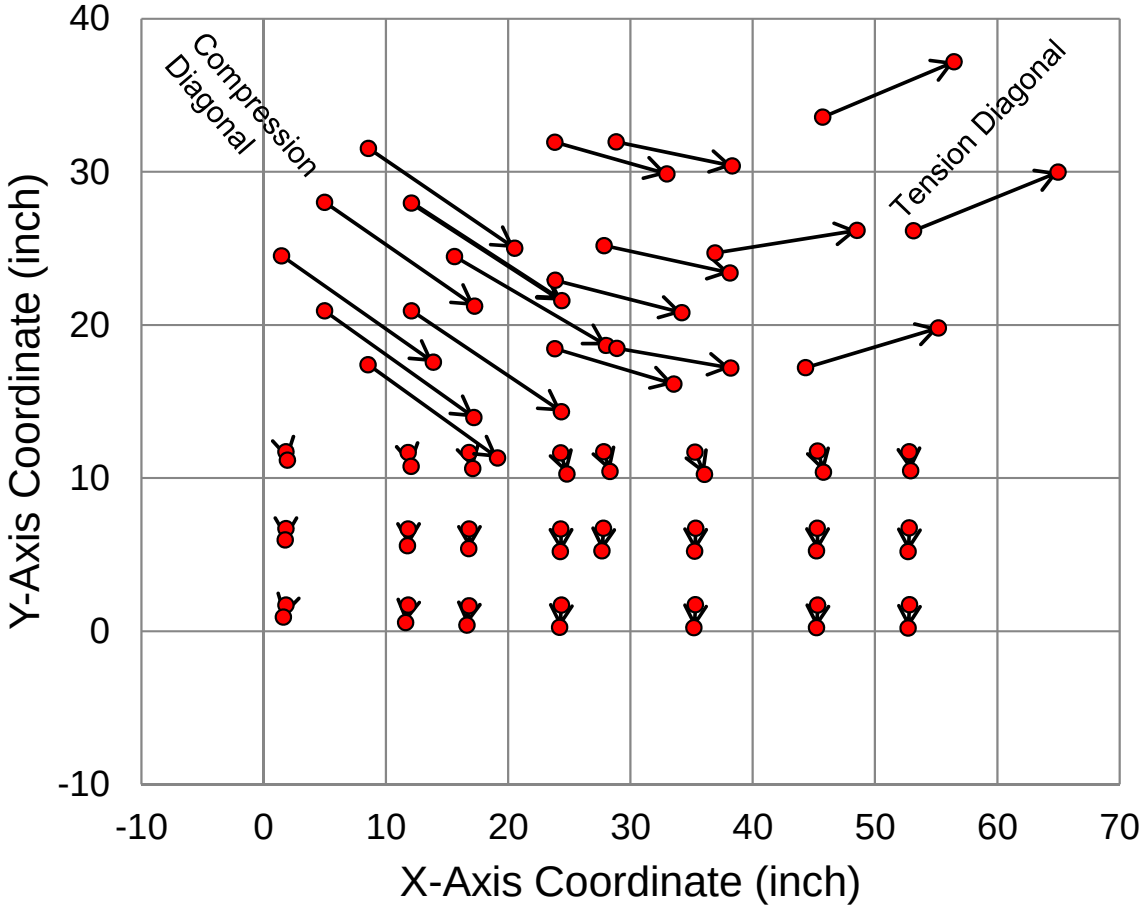
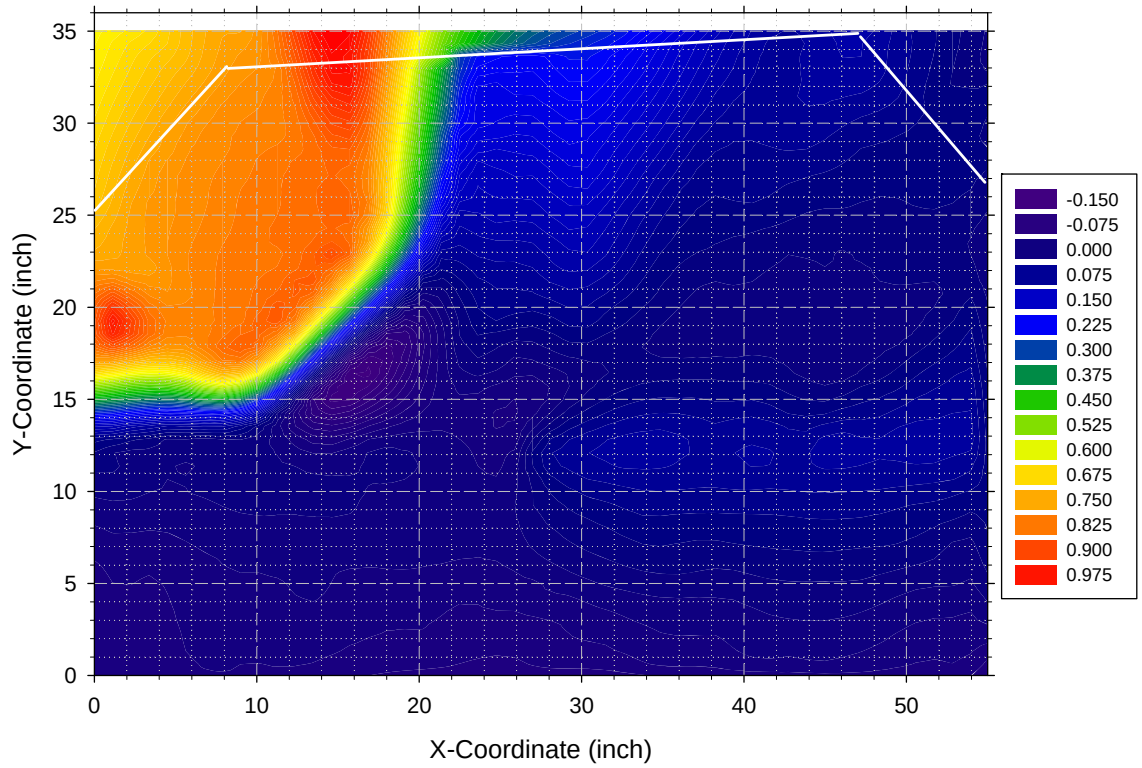



Figure H54.Vector motions of gusset plate targets amplified 25 times.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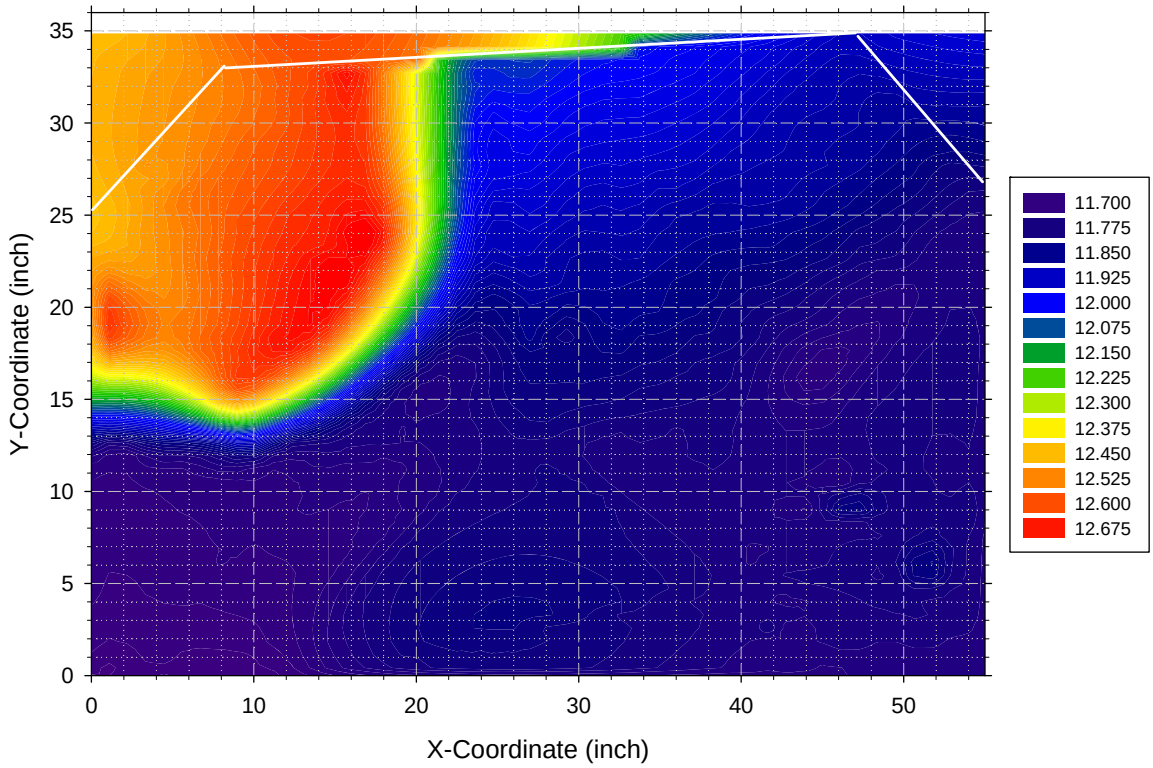
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11.775
11.850
11.925
12.000
12.075
12.150
12.225
12.300
12.375
12.450
12.525
12.600
12.675

Figure H55.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SS3-1**

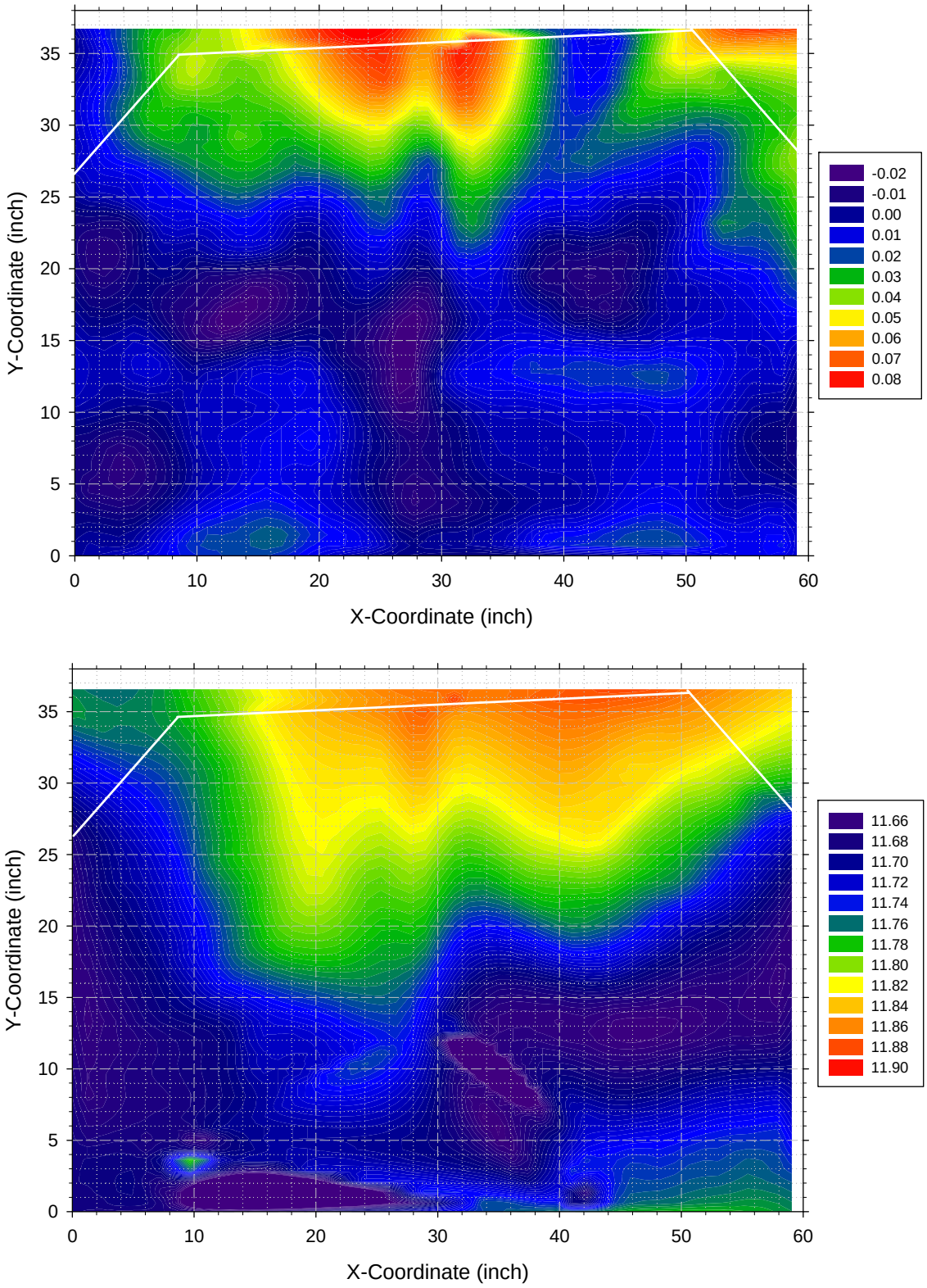


Figure H56.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

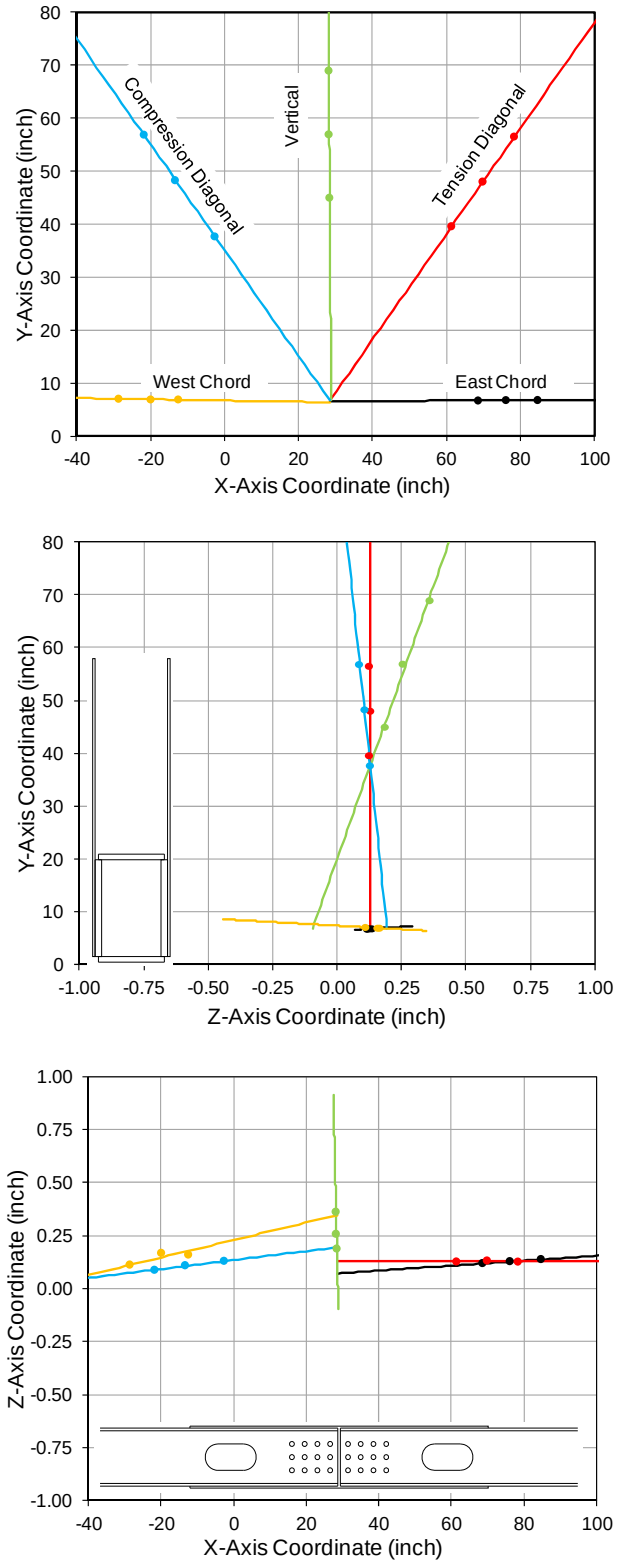


Figure H57.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

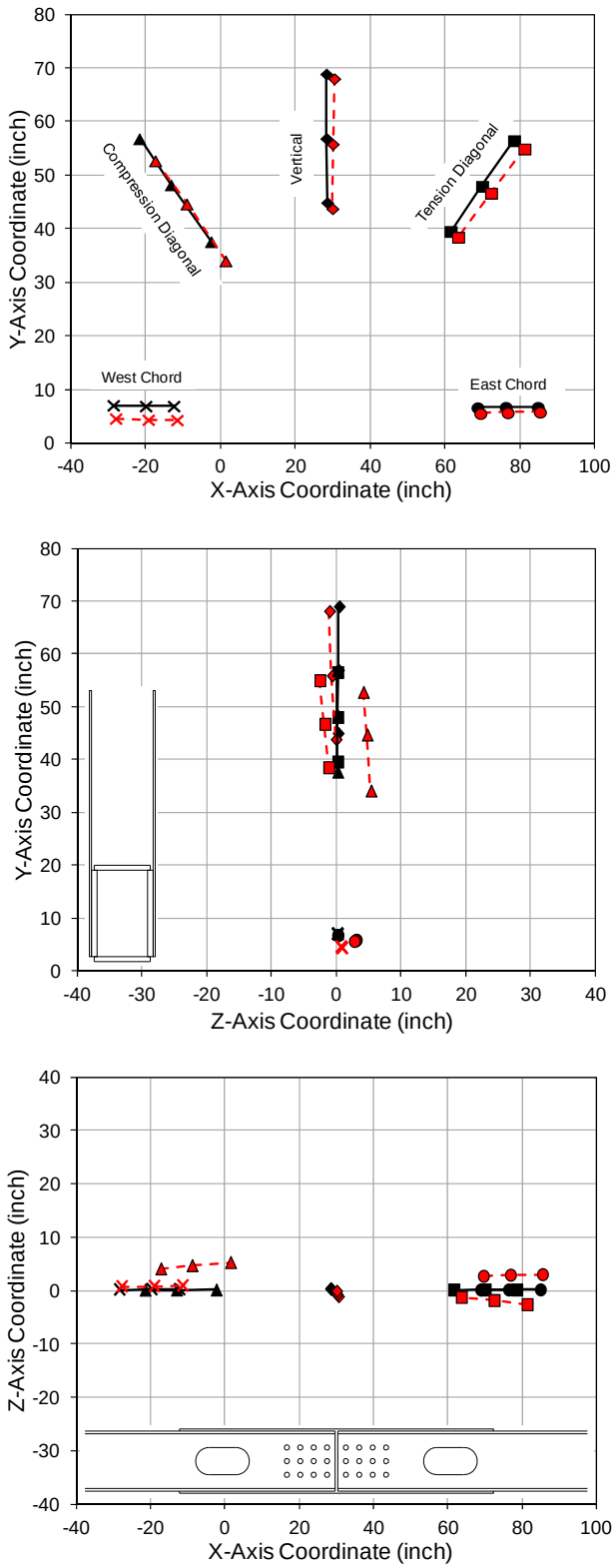


Figure H58.Amplified displacement (x50) of member targets at an ALF of 0.40. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

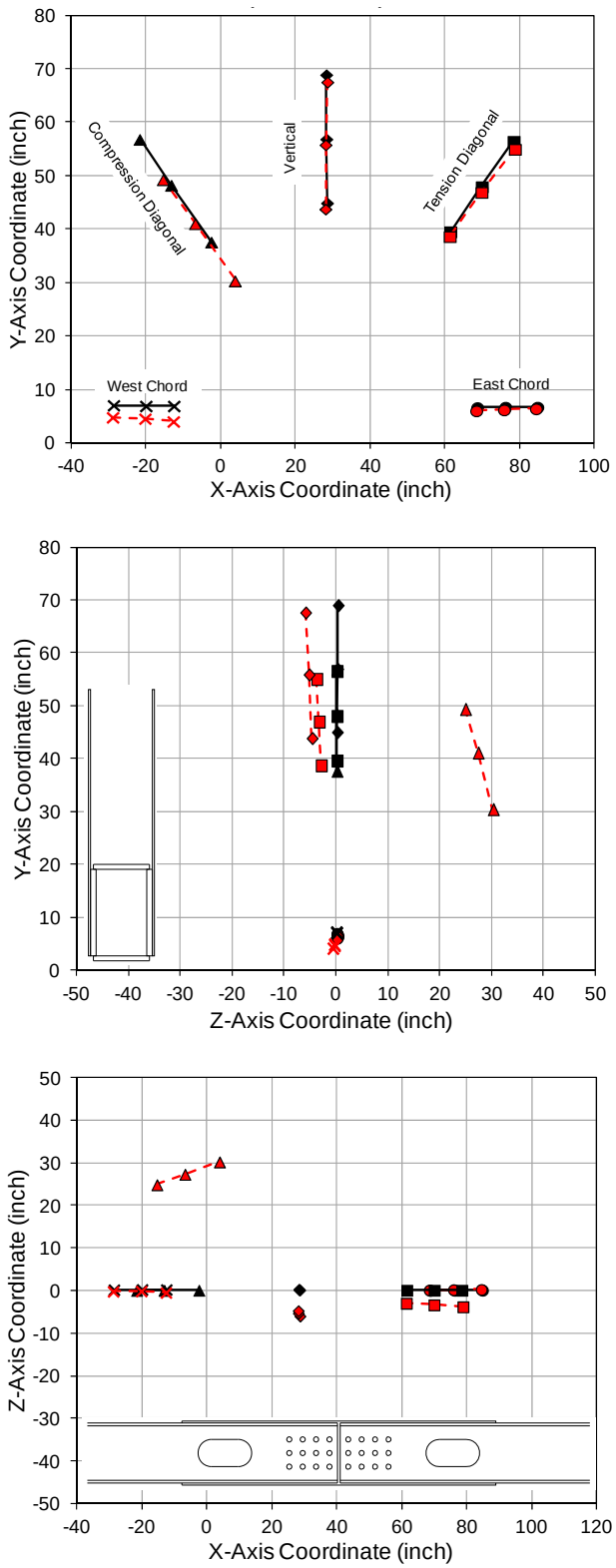


Figure H59.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

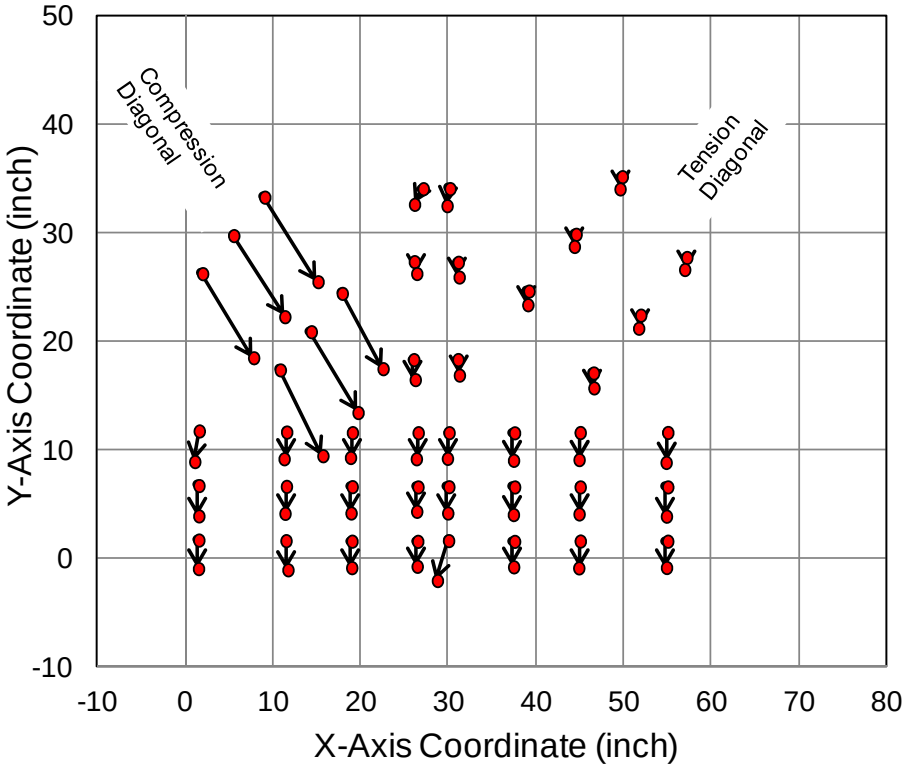


Figure H60.Vector motions of gusset plate targets amplified 50 times.

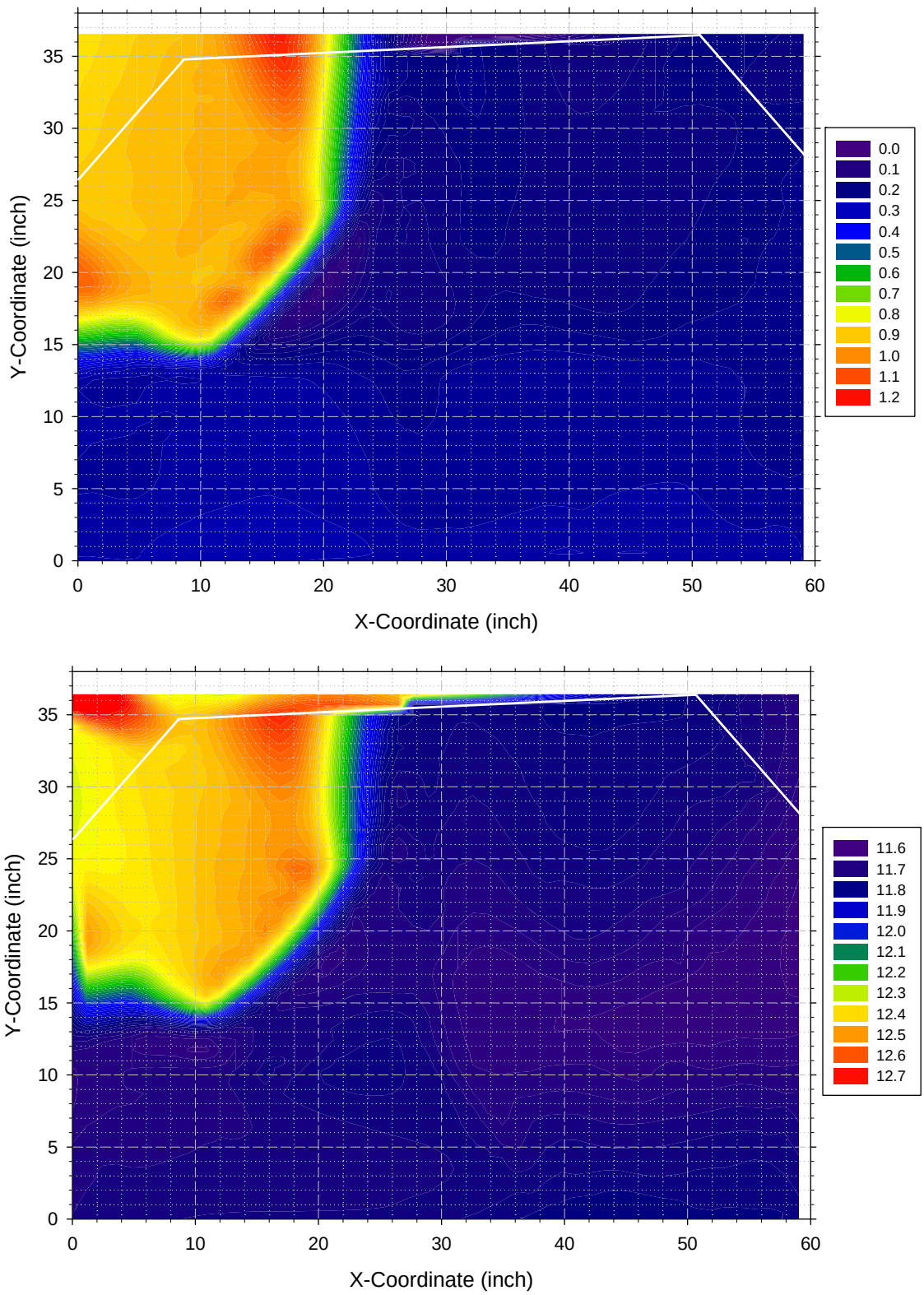


Figure H61.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SS3-2**

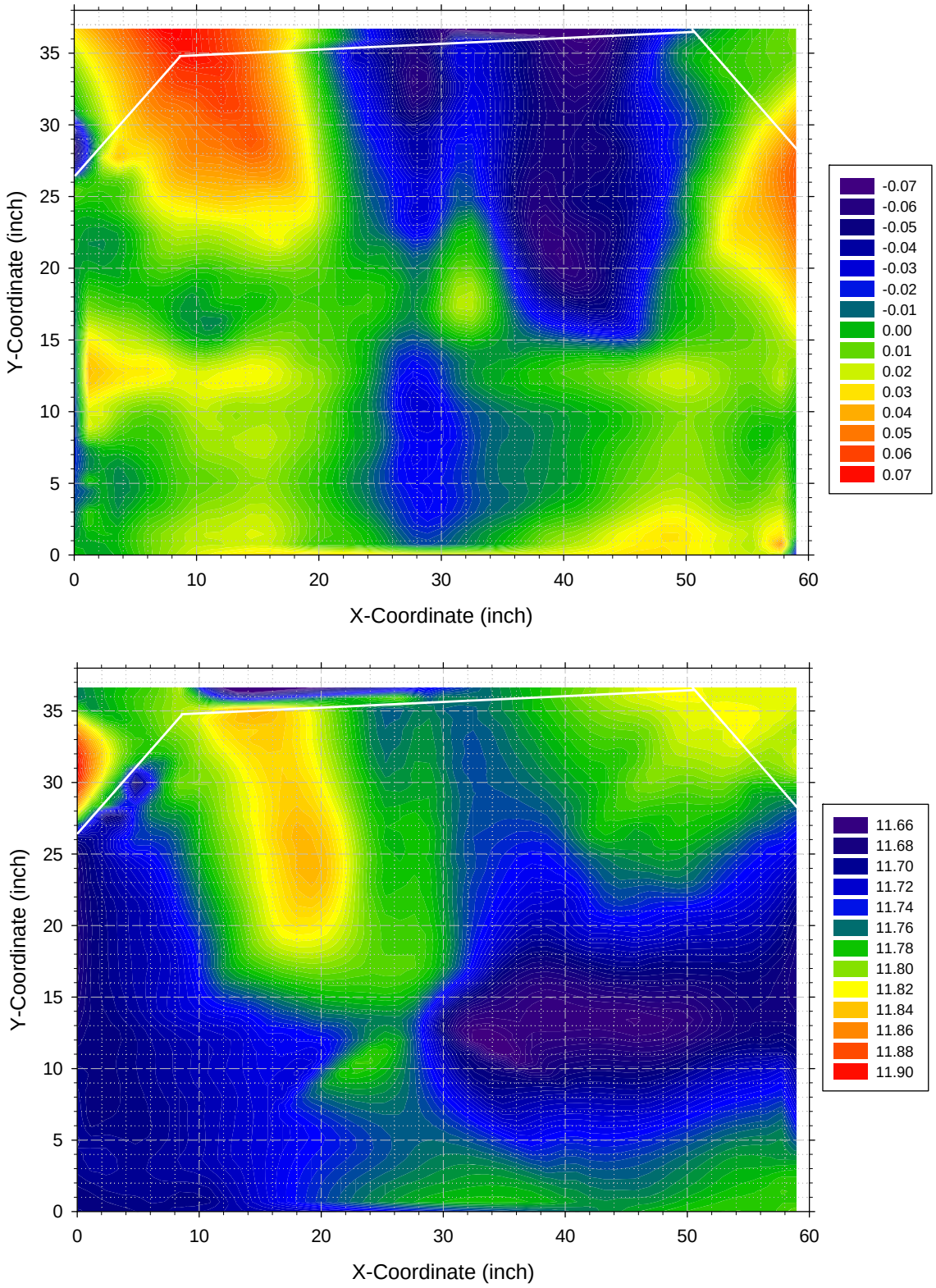


Figure H62.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

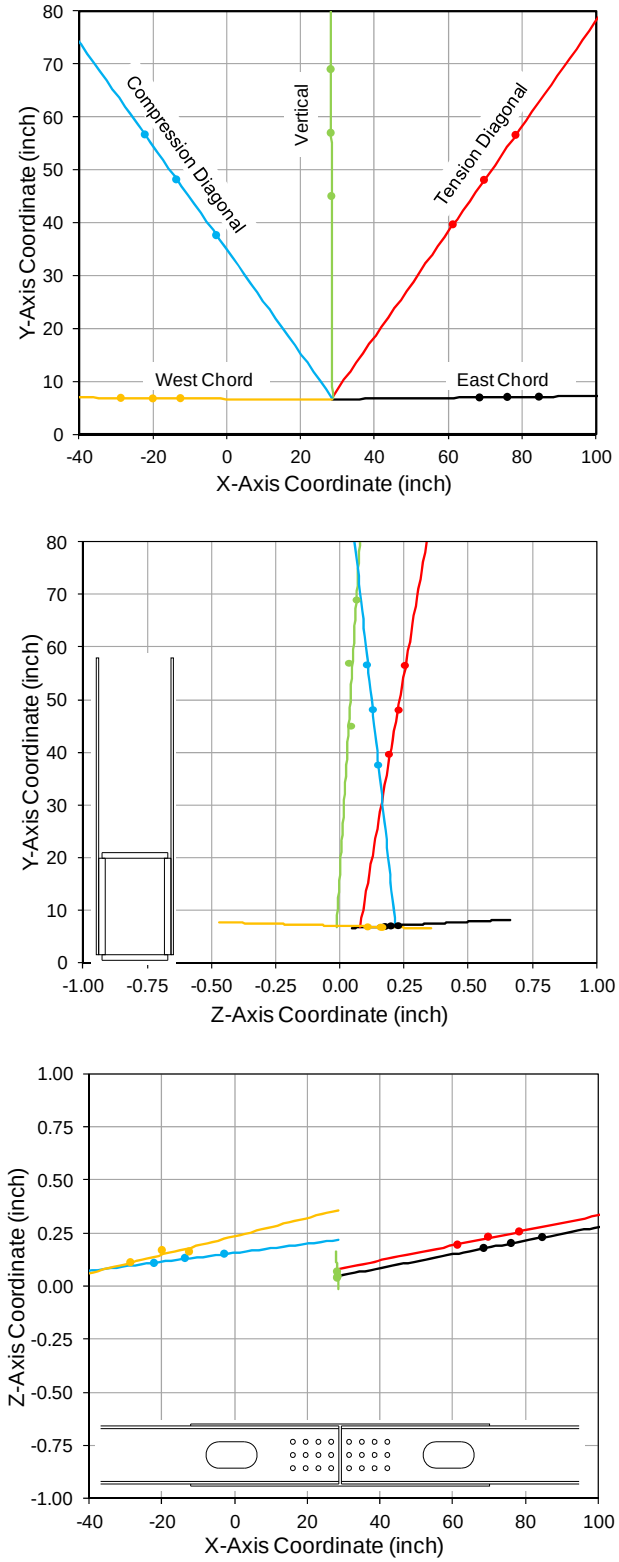


Figure H63.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

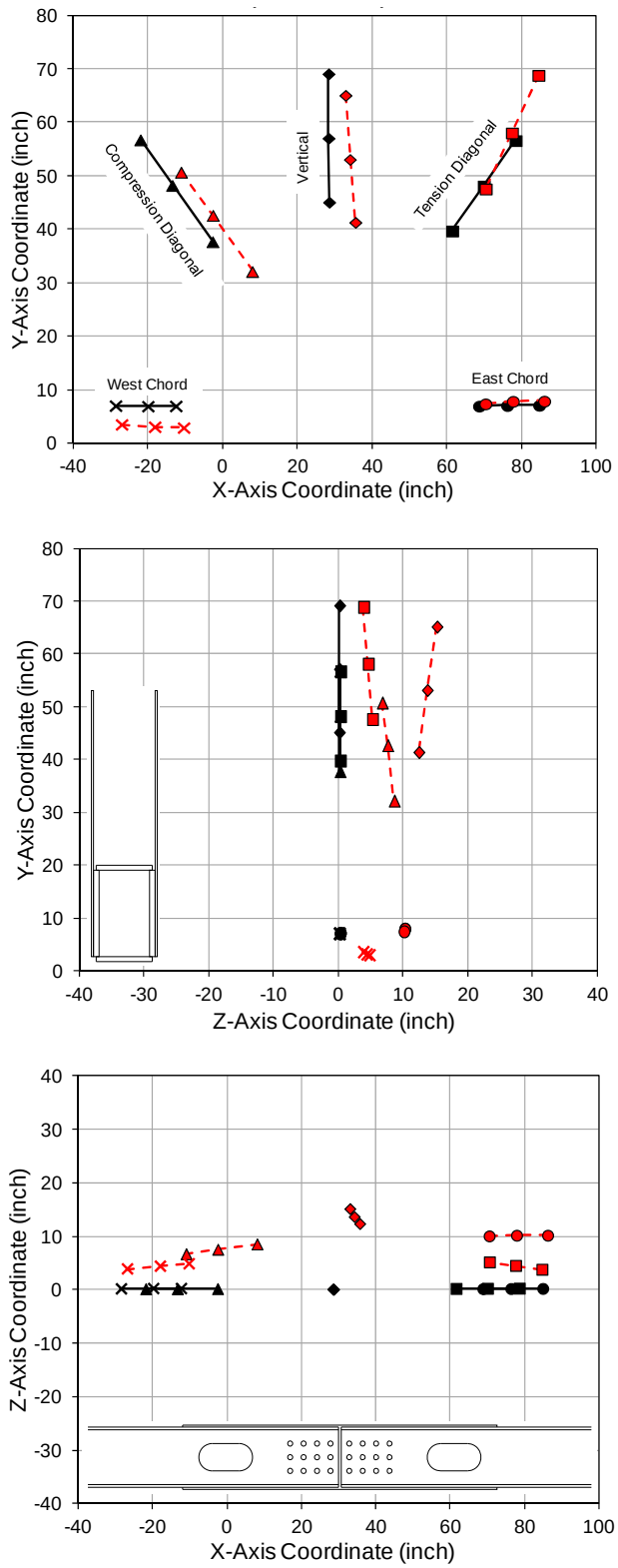


Figure H64.Amplified displacement (x50) of member targets at an ALF of 0.62. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

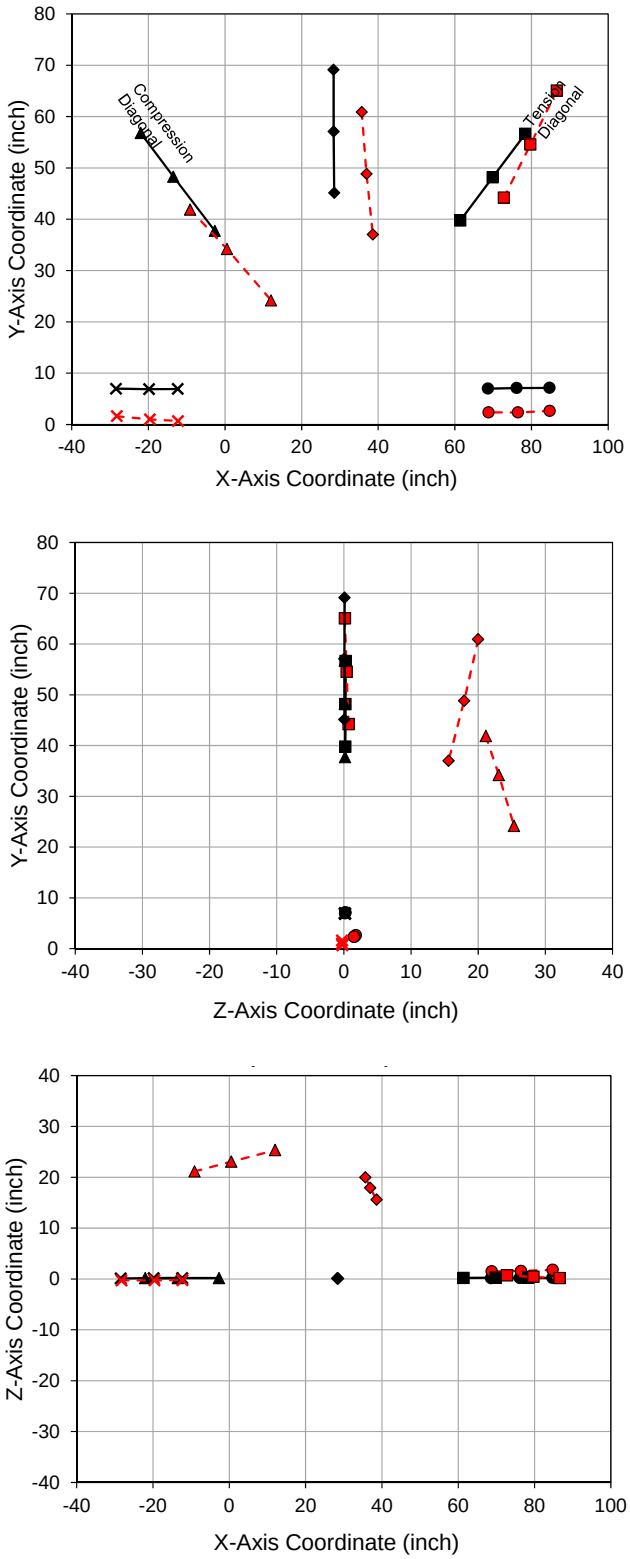


Figure H65. Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

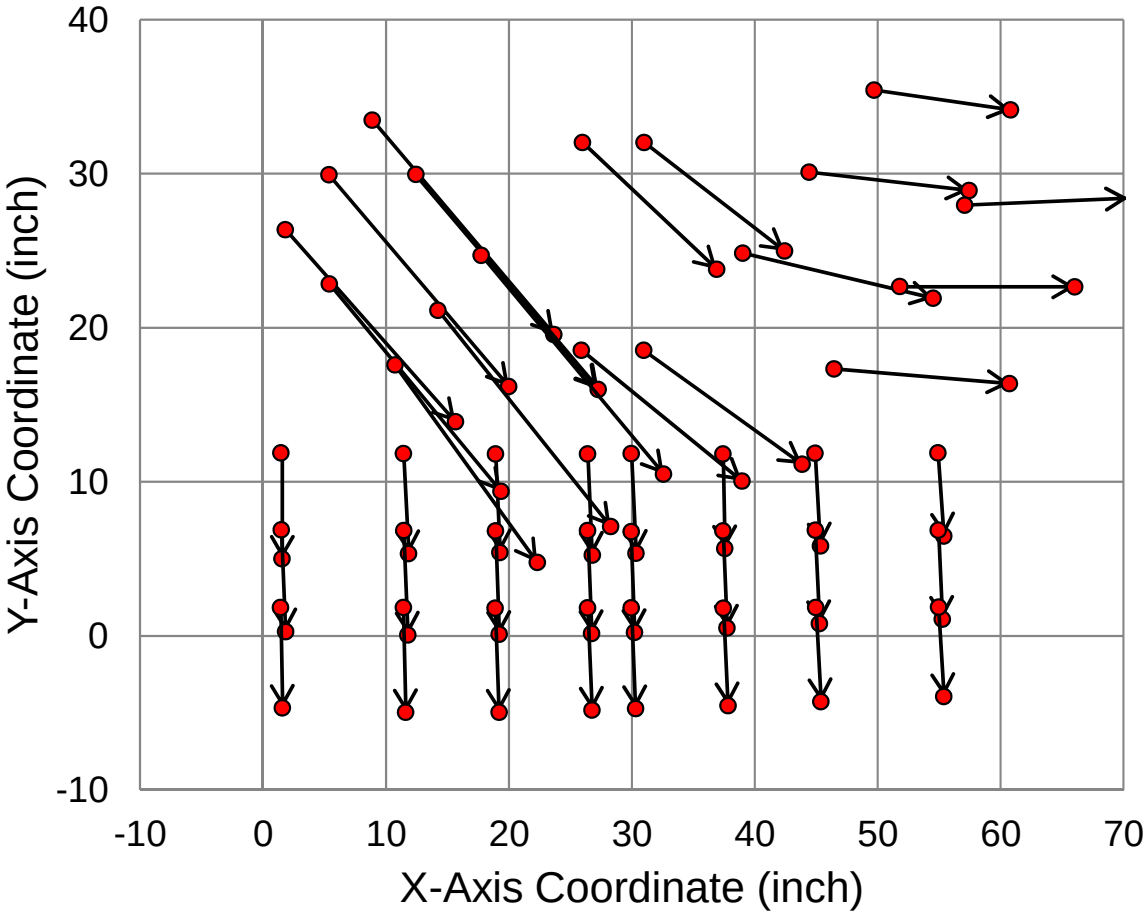


Figure H66.Vector motions of gusset plate targets amplified 50 times.

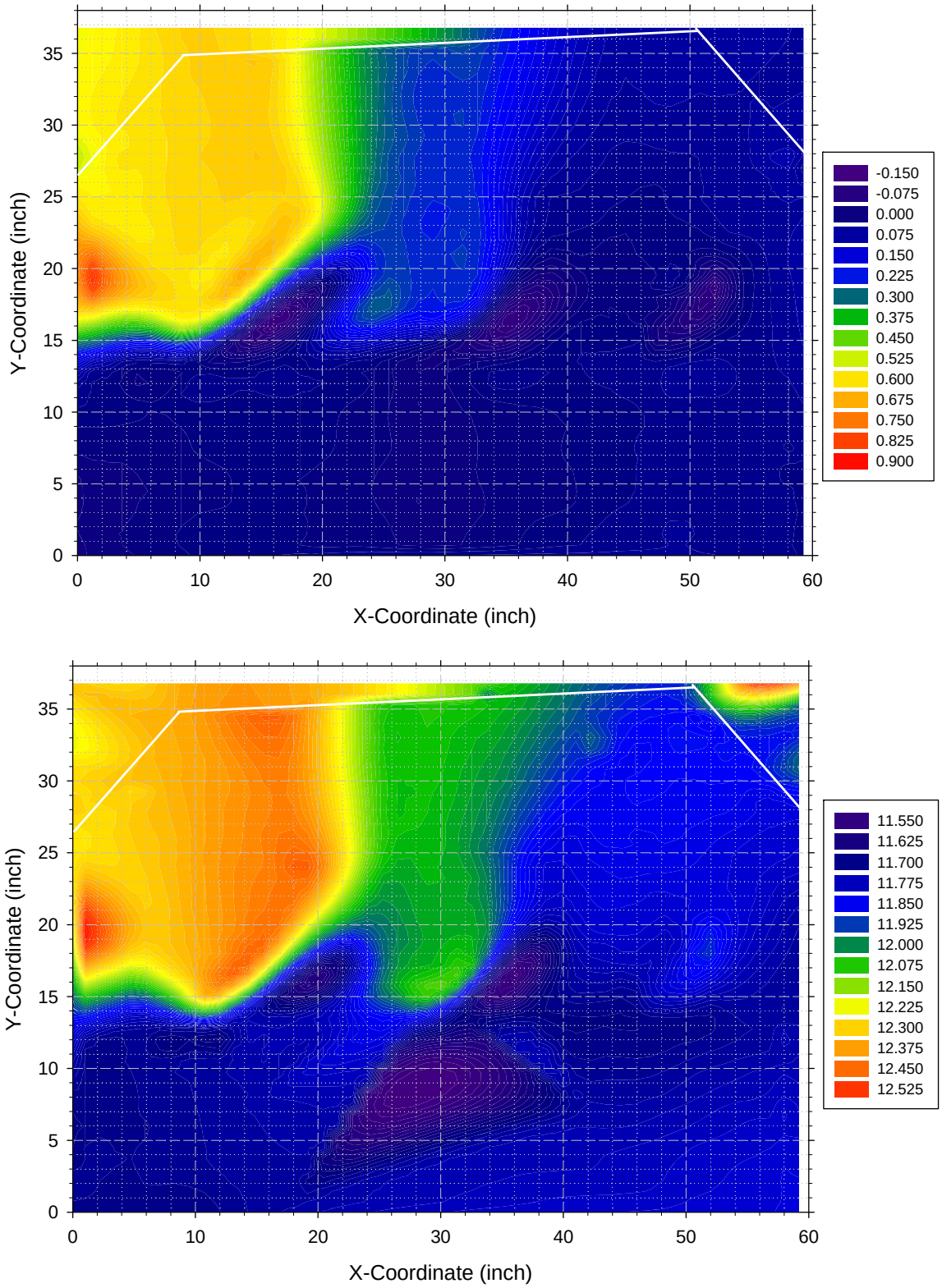


Figure H67.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SS3-3**

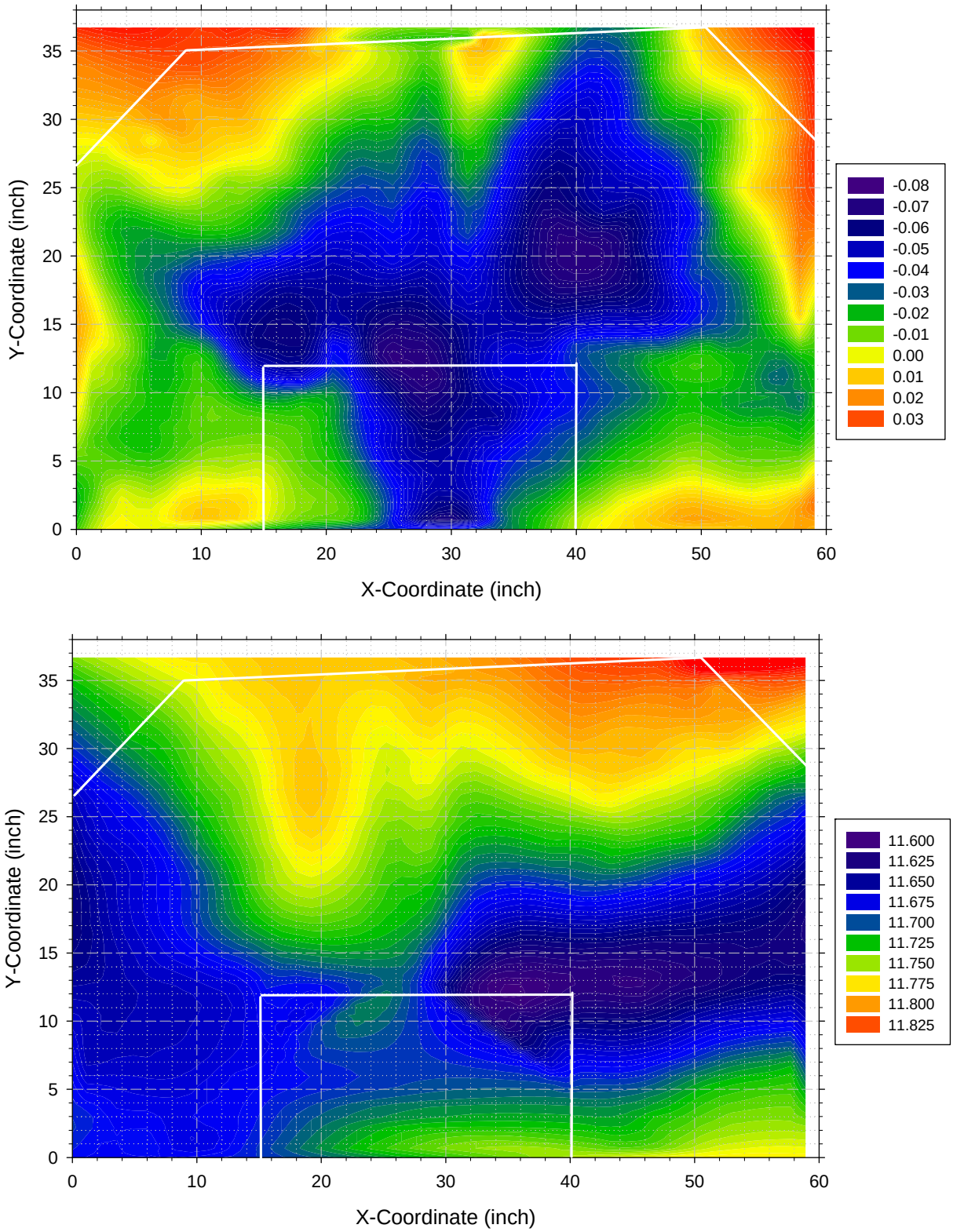


Figure H68.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

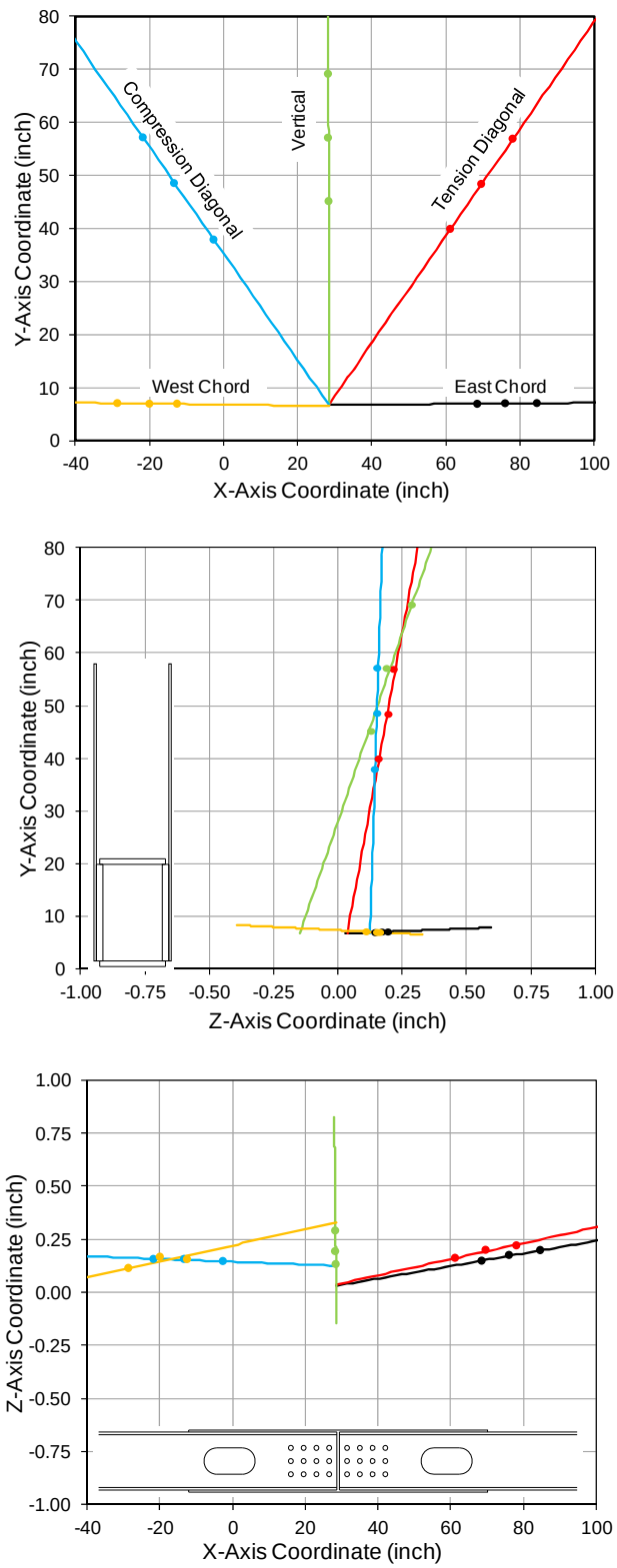


Figure H69.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

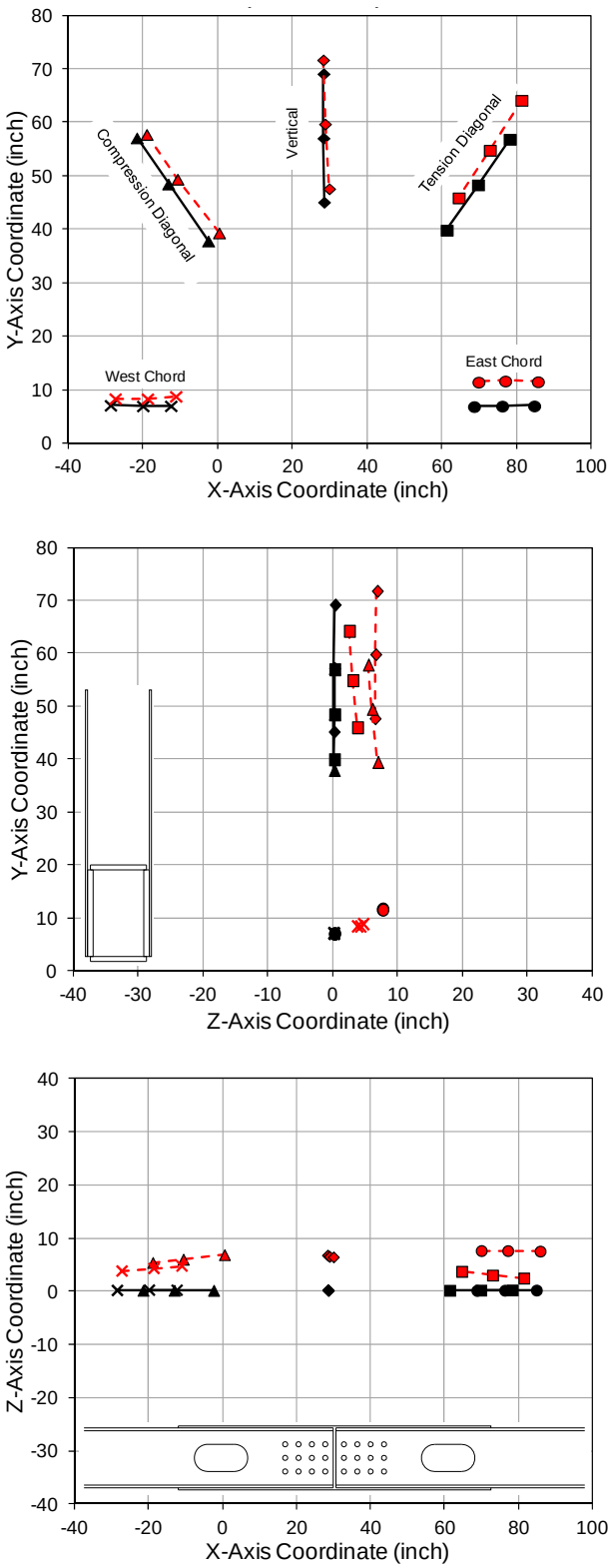


Figure H70.Amplified displacement (x50) of member targets at an ALF of 0.45. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

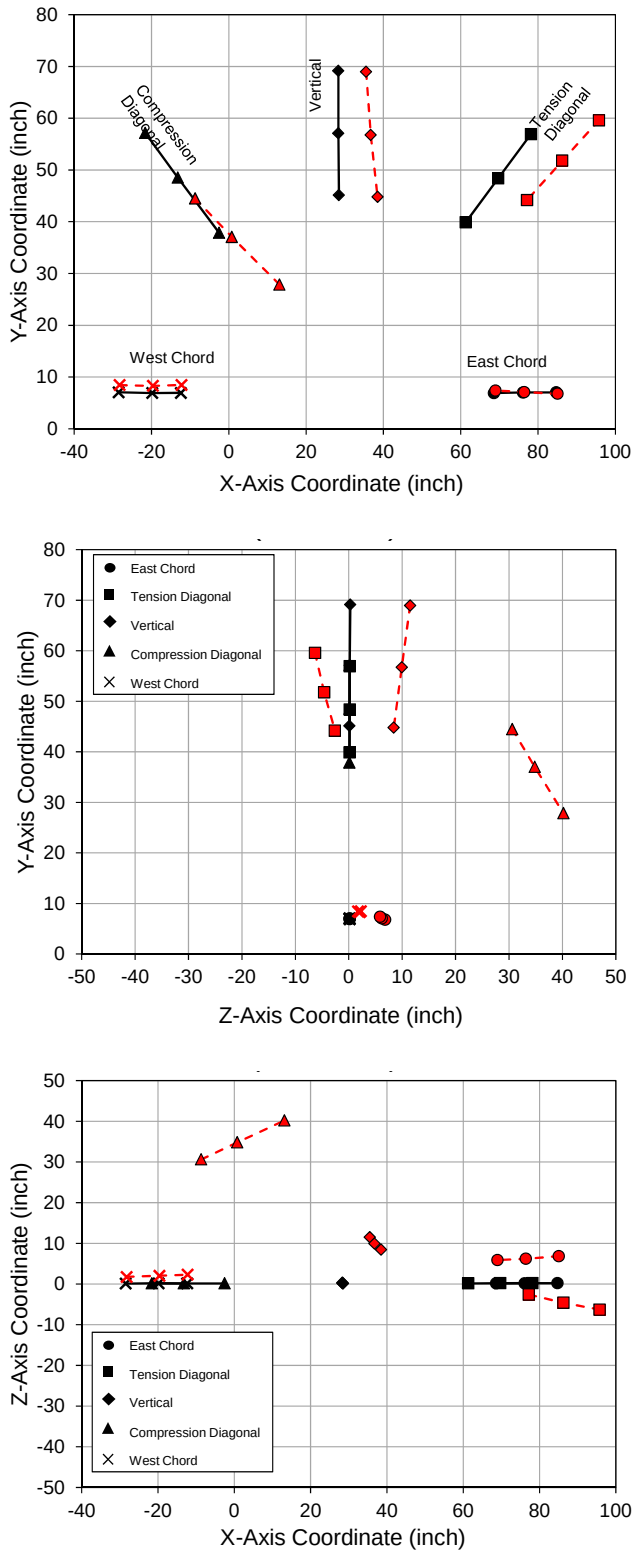


Figure H71.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

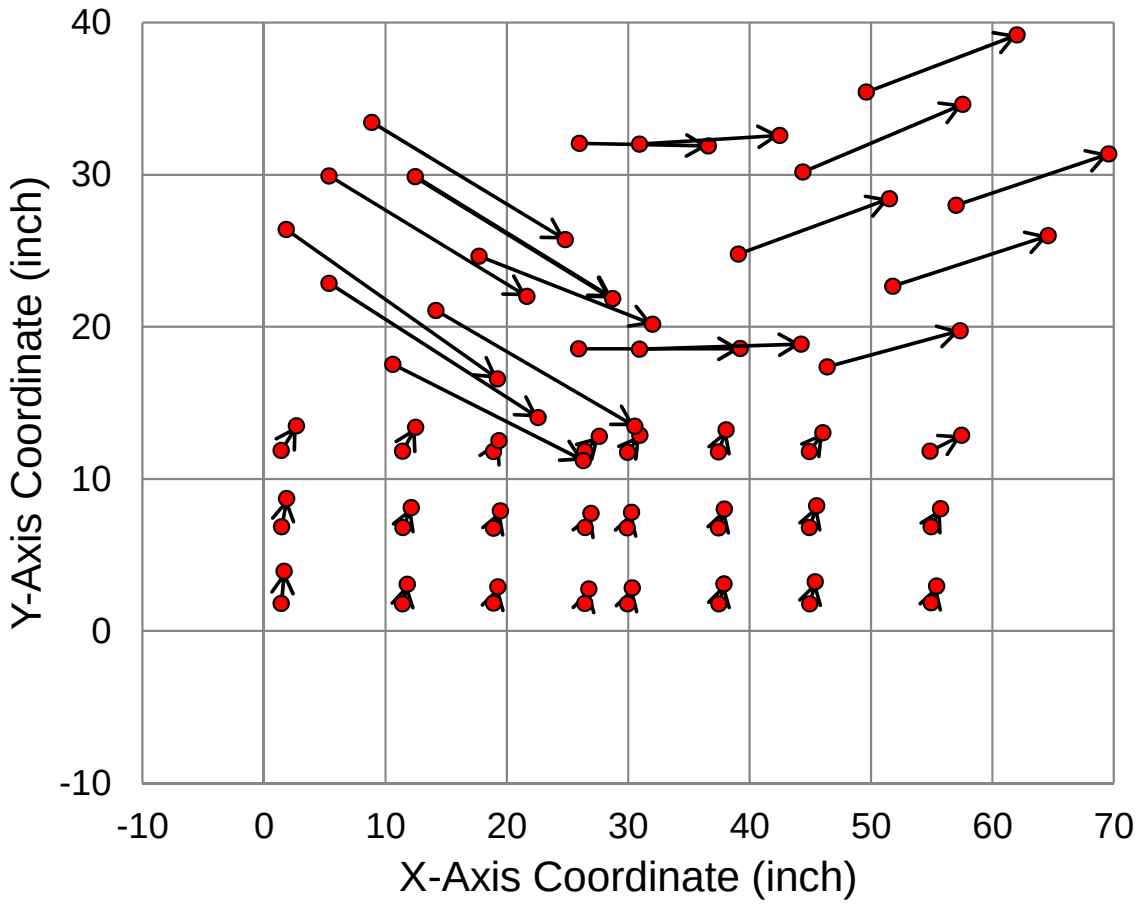


Figure H72.Vector motions of gusset plate targets amplified 50 times.

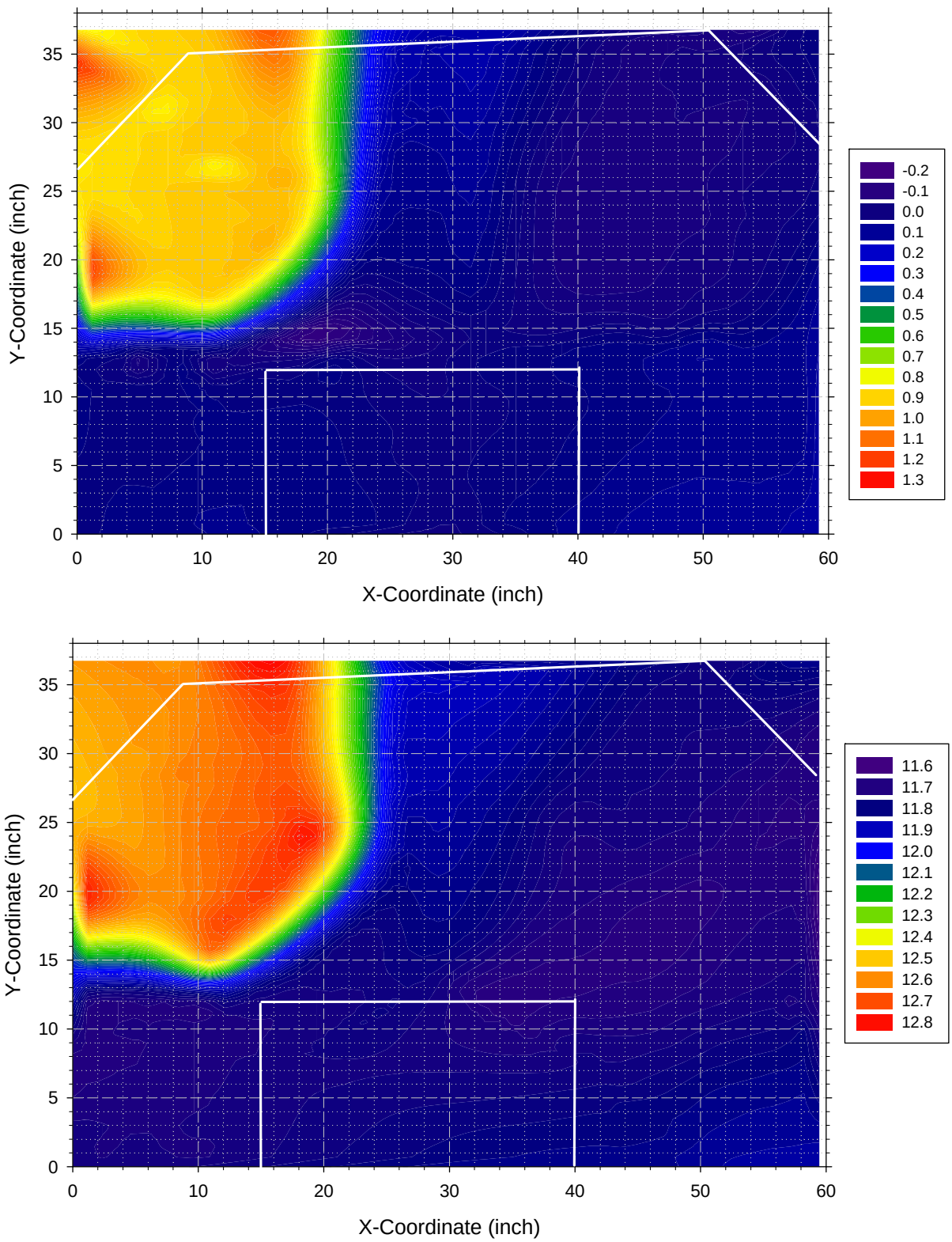


Figure H73.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**SPECIMEN 307SS3-4**

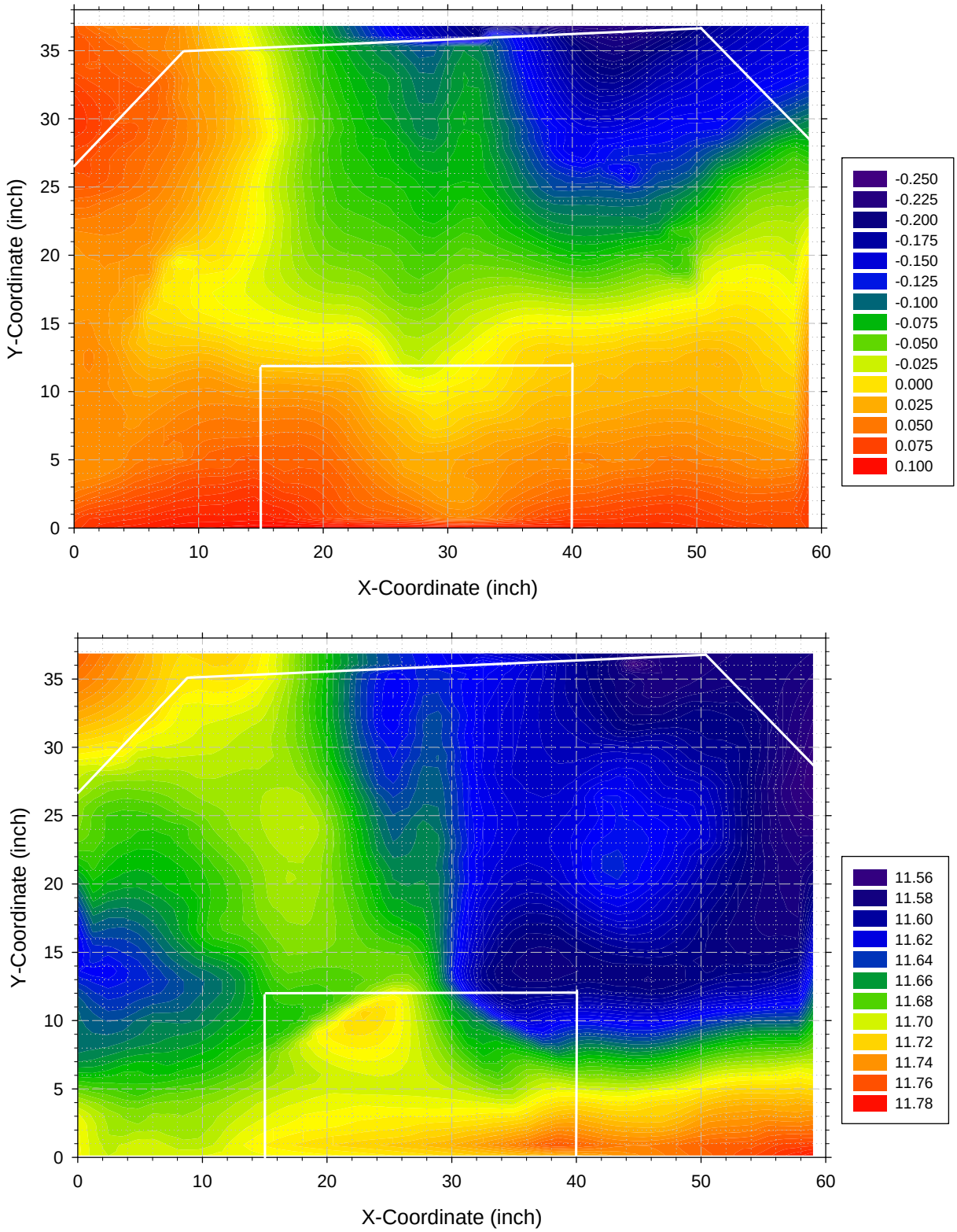


Figure H74.Pretest out-of-plane shape contour plots. North plate (top), South plate (bottom).

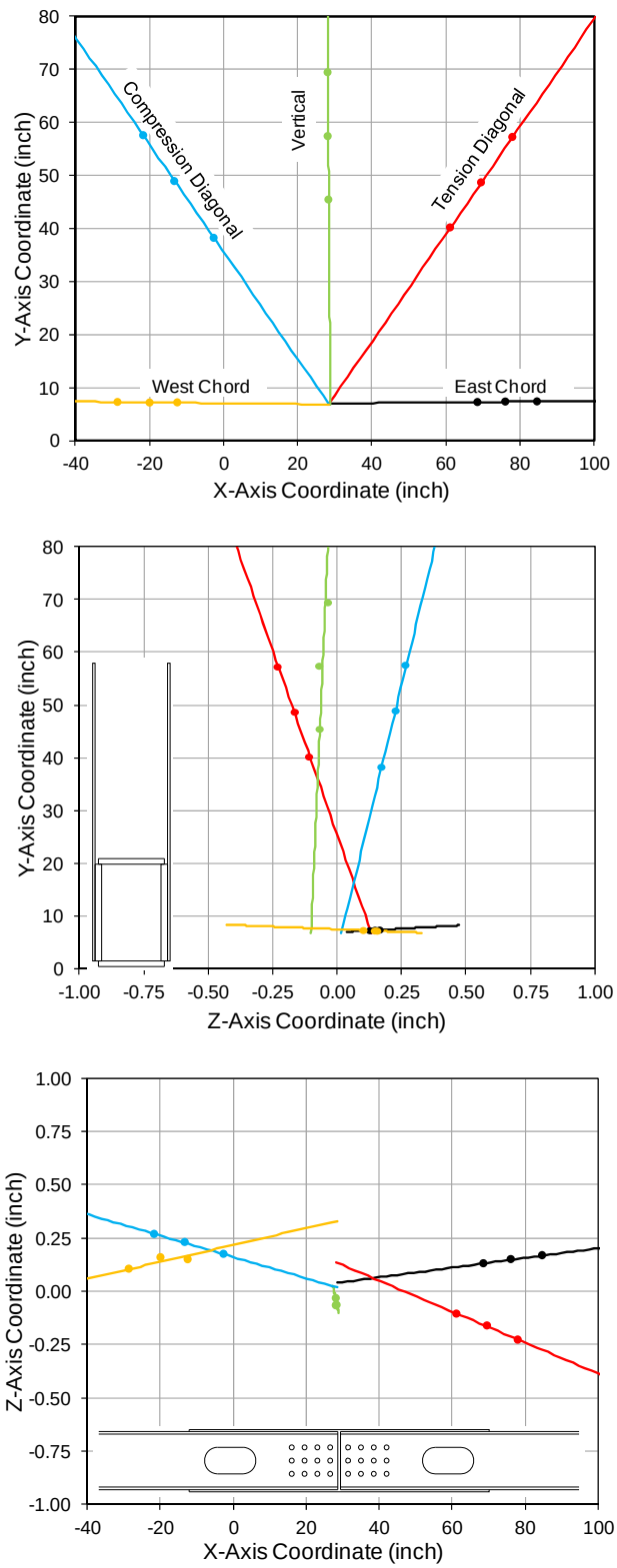


Figure H75.Pretest planar alignments. XY-plane (top), YZ-plane (middle), XZ-plane (bottom).

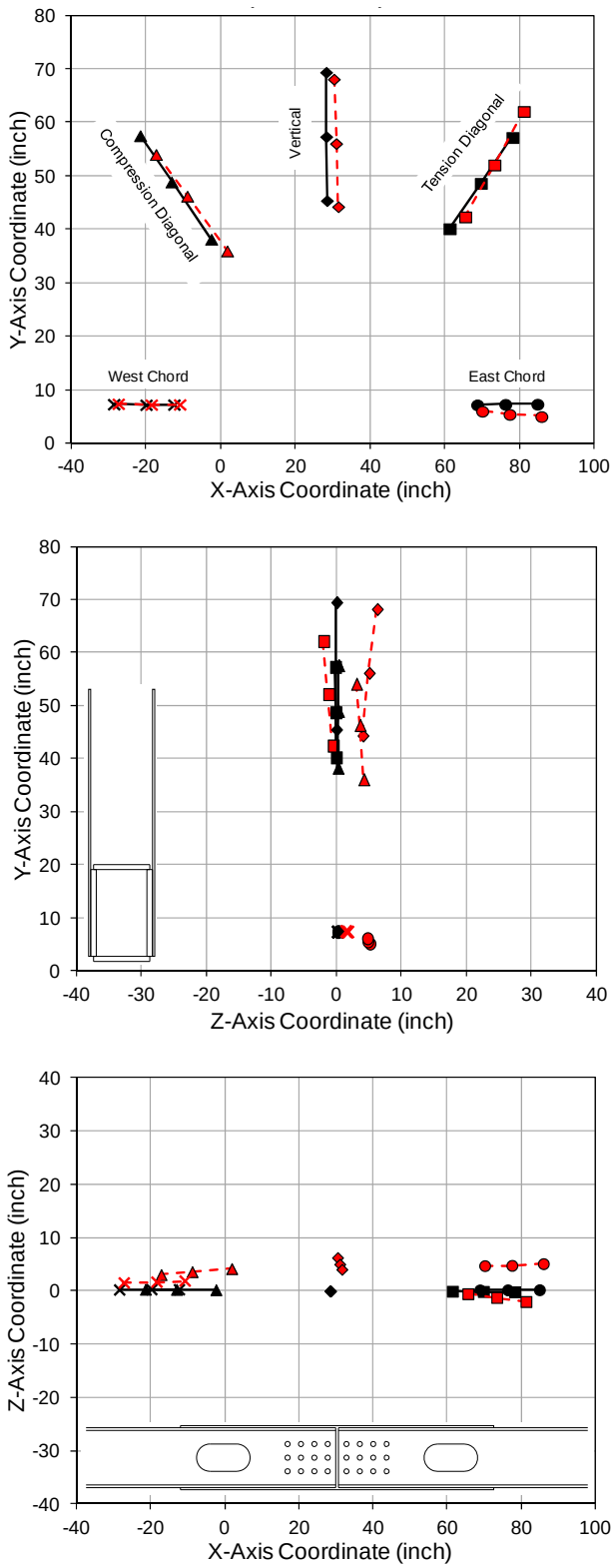


Figure H76.Amplified displacement (x50) of member targets at an ALF of 0.56. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, under load in red.

DATA NOT COLLECTED

Figure H77.Amplified displacement (x50) of member targets post-failure. XY-plane (top), YZ-plane (middle), XZ-plane (bottom). Pretest location shown in black, unloaded post-test in red.

DATA NOT COLLECTED

Figure H78.Vector motions of gusset plate targets amplified 50 times.

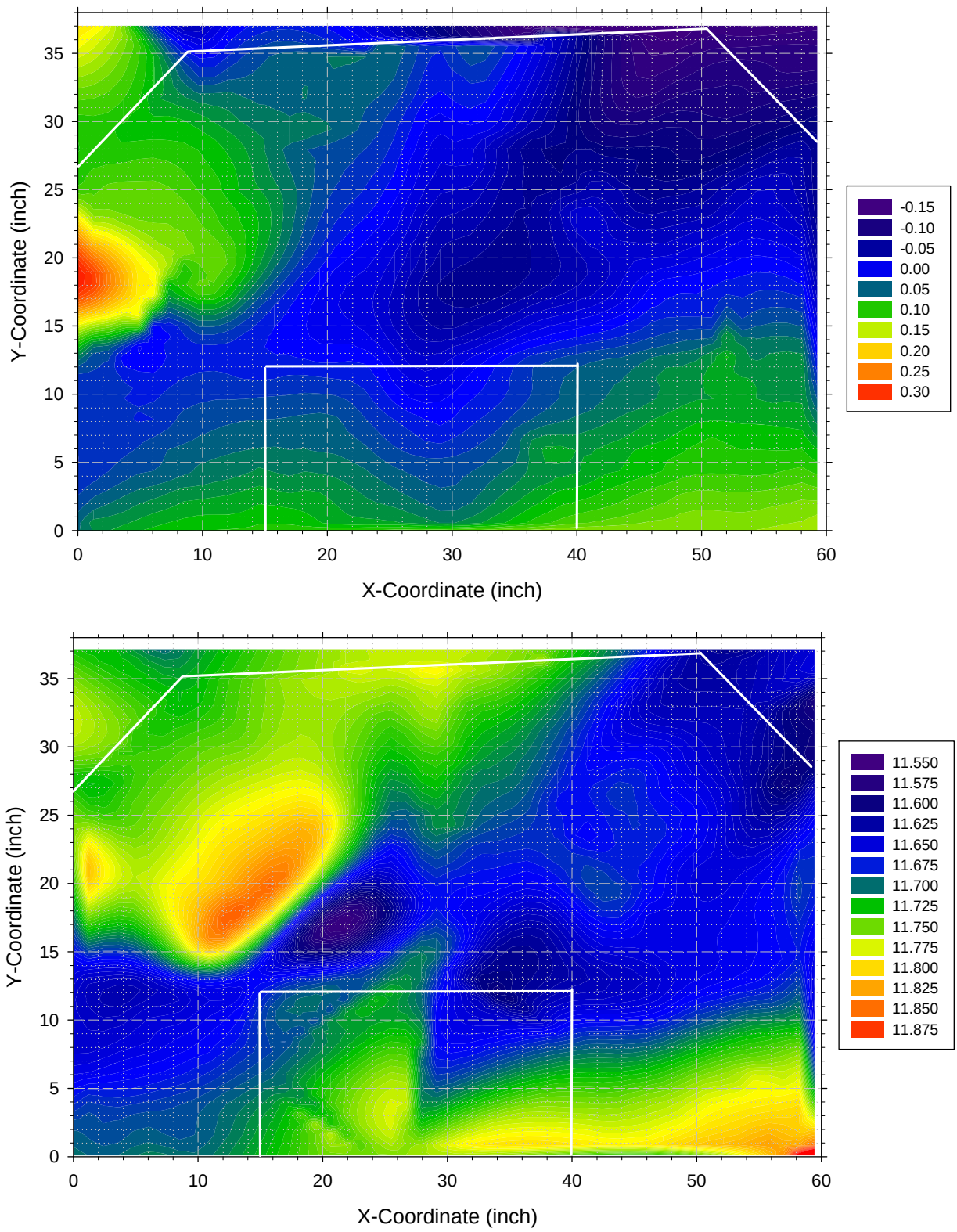


Figure H79.Post-test out-of-plane shape contour plots. North plate (top), South plate (bottom).

**MEMBER SHAPE**

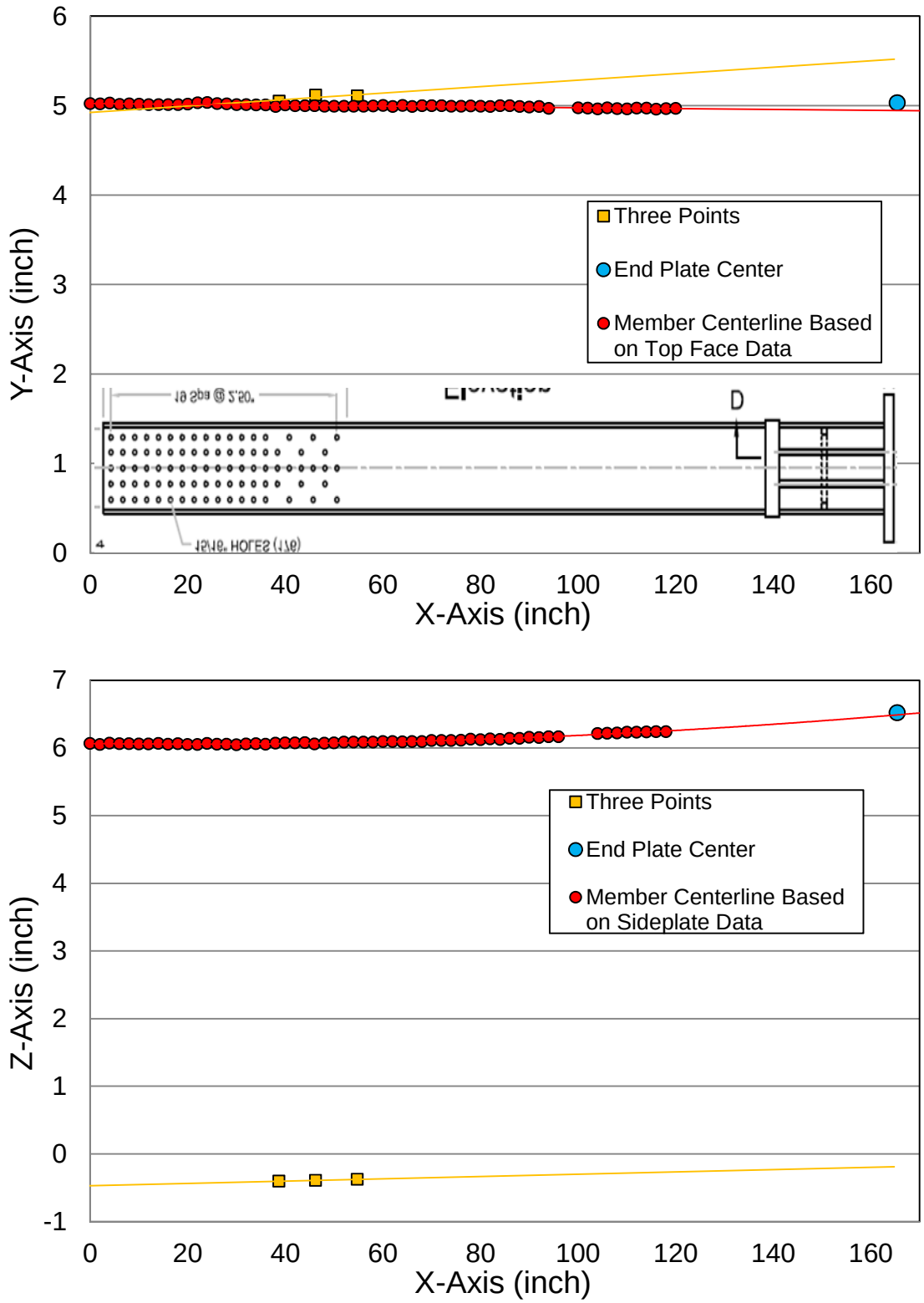


Figure H80. East chord member shape. X-Y plane (top). X-Z plane (bottom).

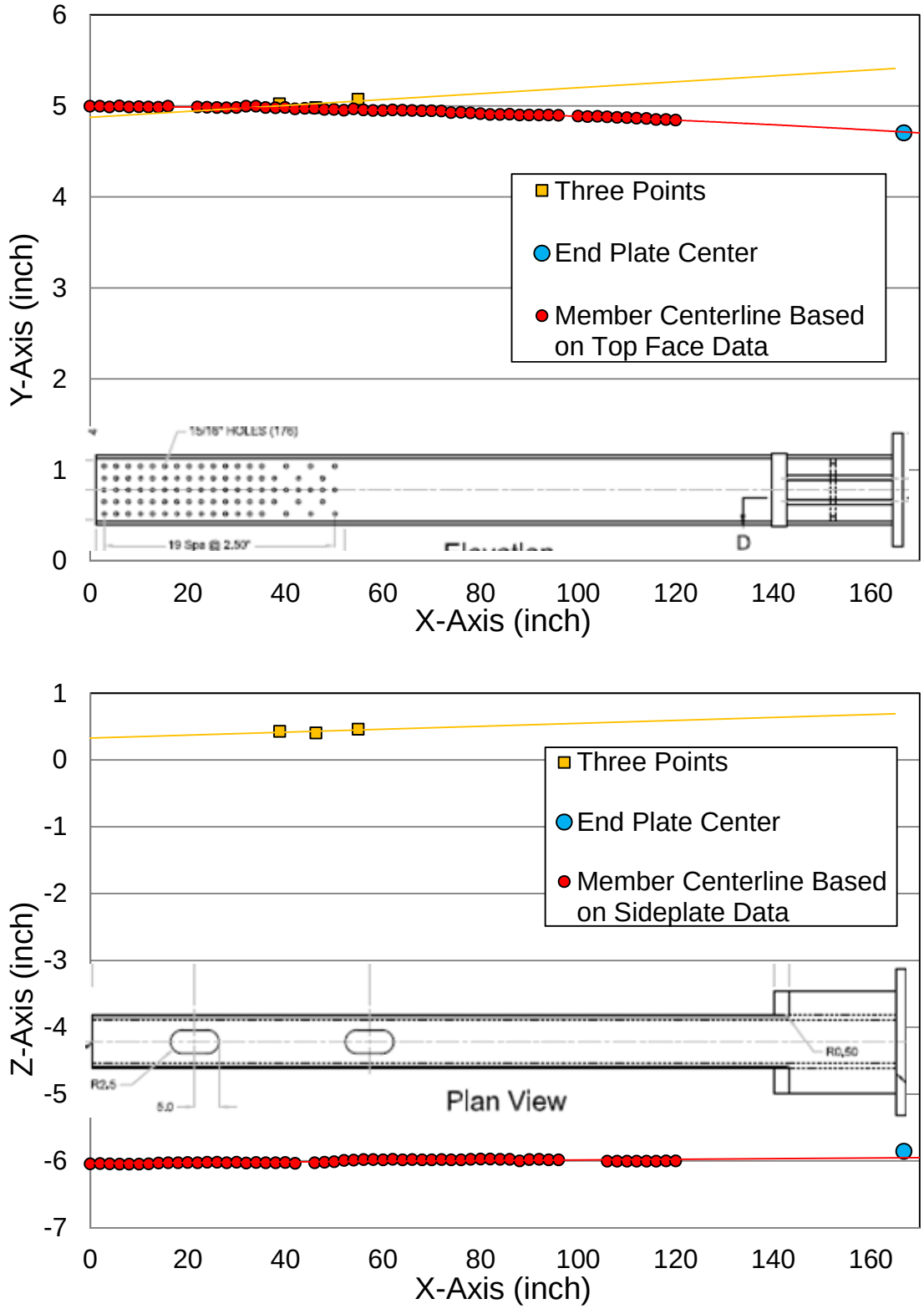


Figure H81. West chord member shape. X-Y plane (top). X-Z plane (bottom).

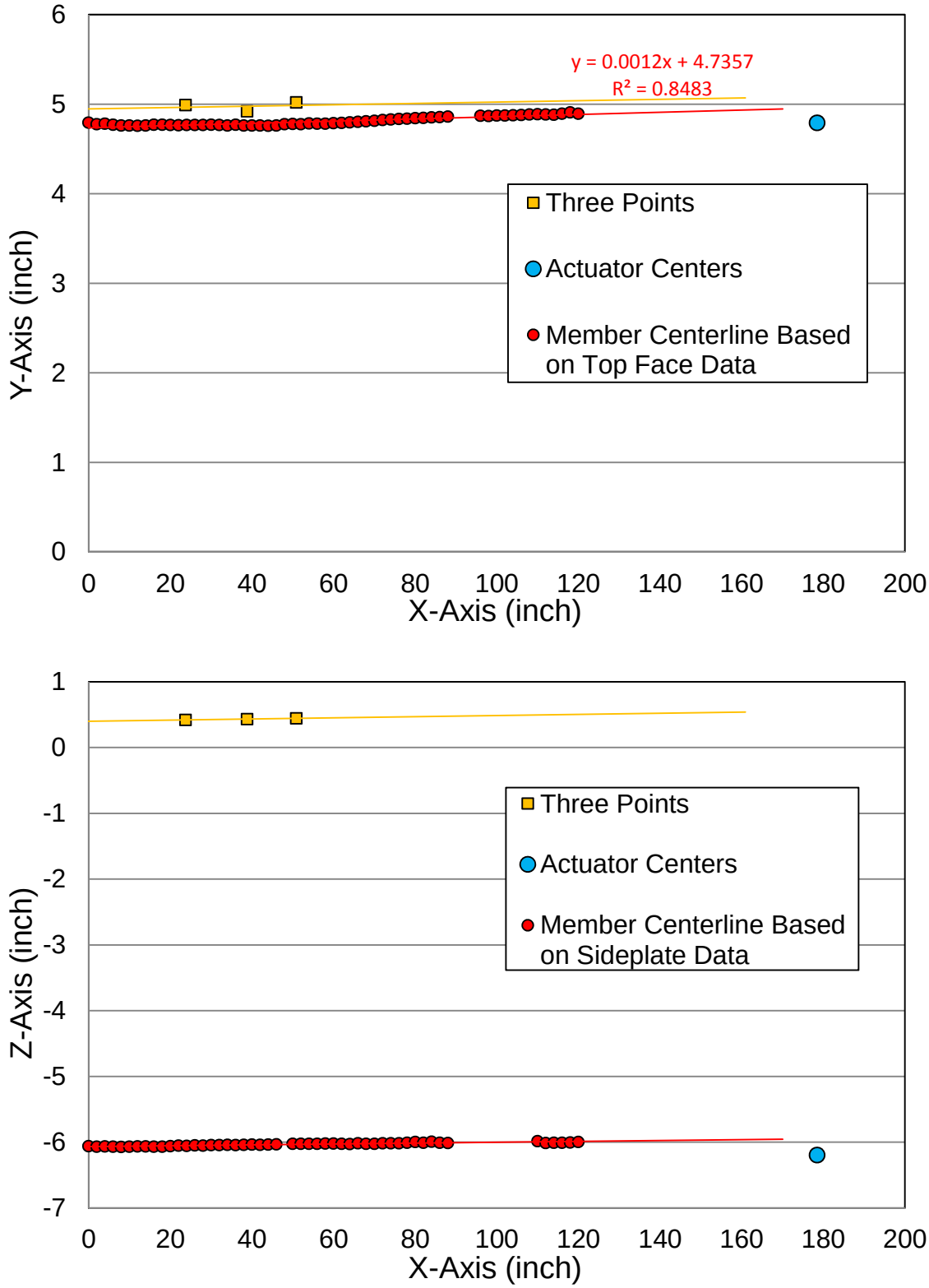


Figure H82. Compression diagonal member shape. X-Y plane (top). X-Z plane (bottom).

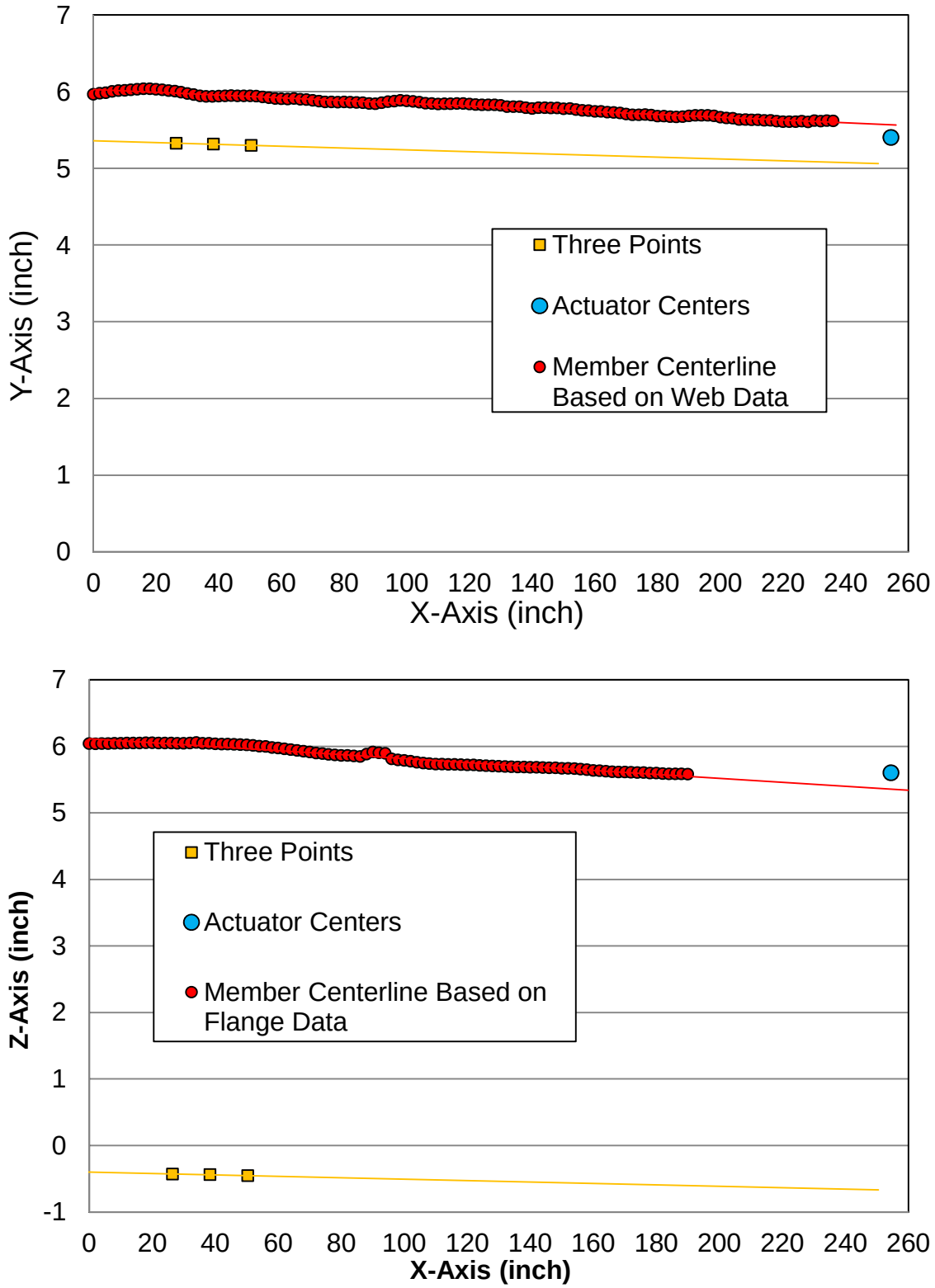


Figure H83. Tension diagonal member shape. X-Y plane (top). X-Z plane (bottom).

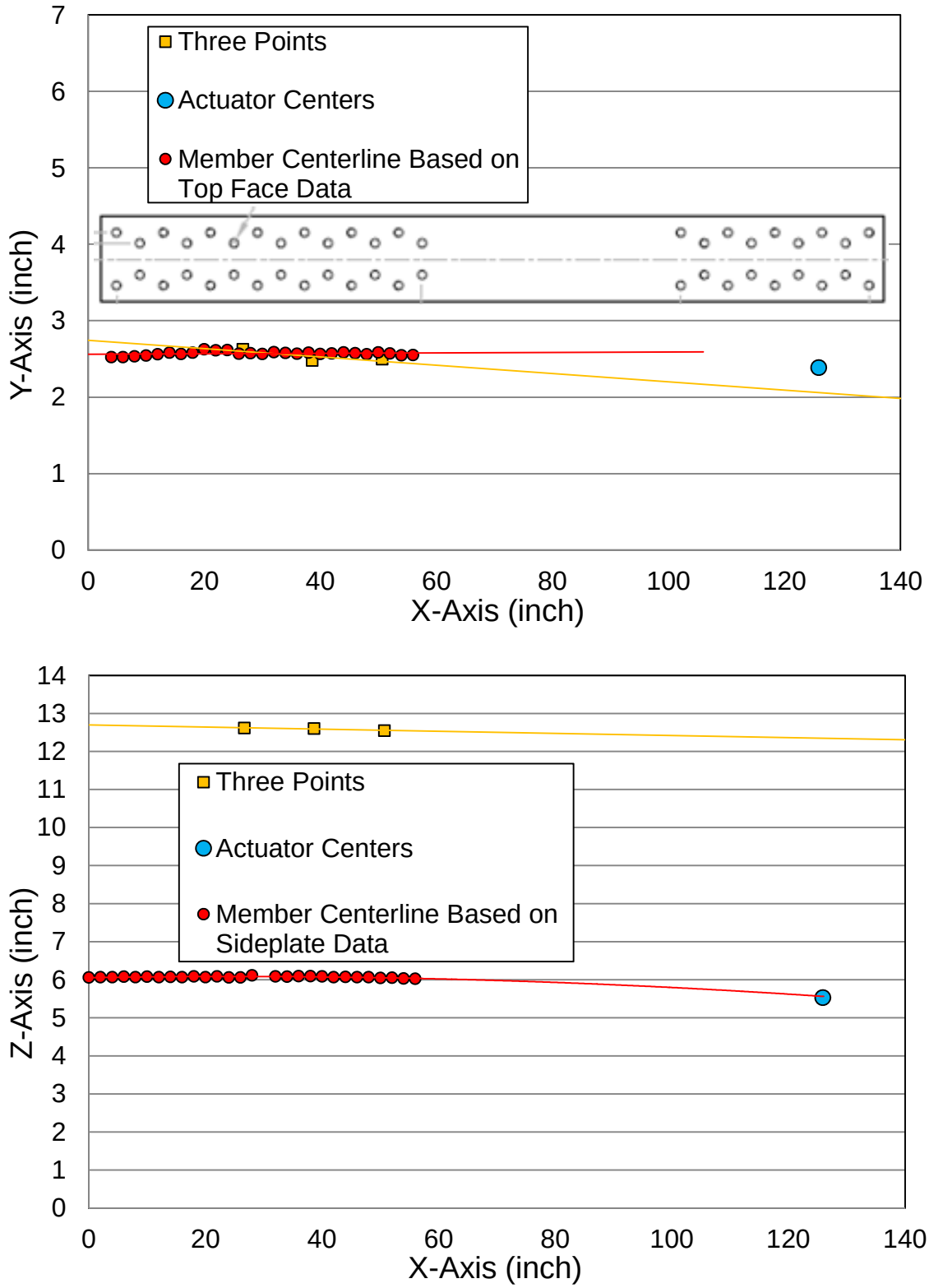


Figure H84. Vertical member shape. X-Y plane (top). X-Z plane (bottom).