COLD-FORMED STEEL PORTAL FRAMES AT ELEVATED TEMPERATURES

Benchmark Study

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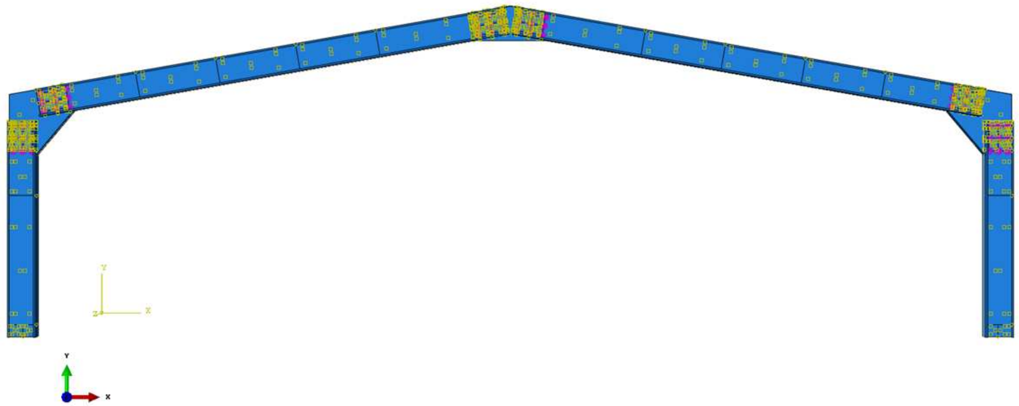
Integrated Fire Engineering and Response

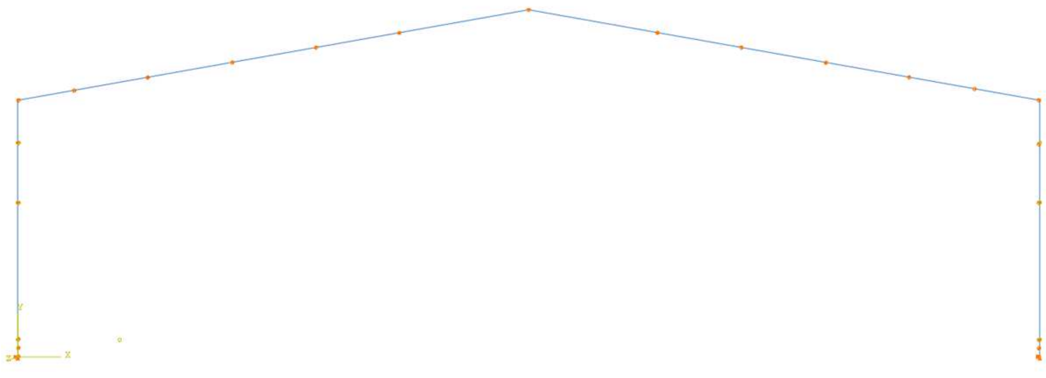
COST TU0904 Training School for Young Researchers

Lulea, March 2014

ABAQUS FE IDEALISATIONS

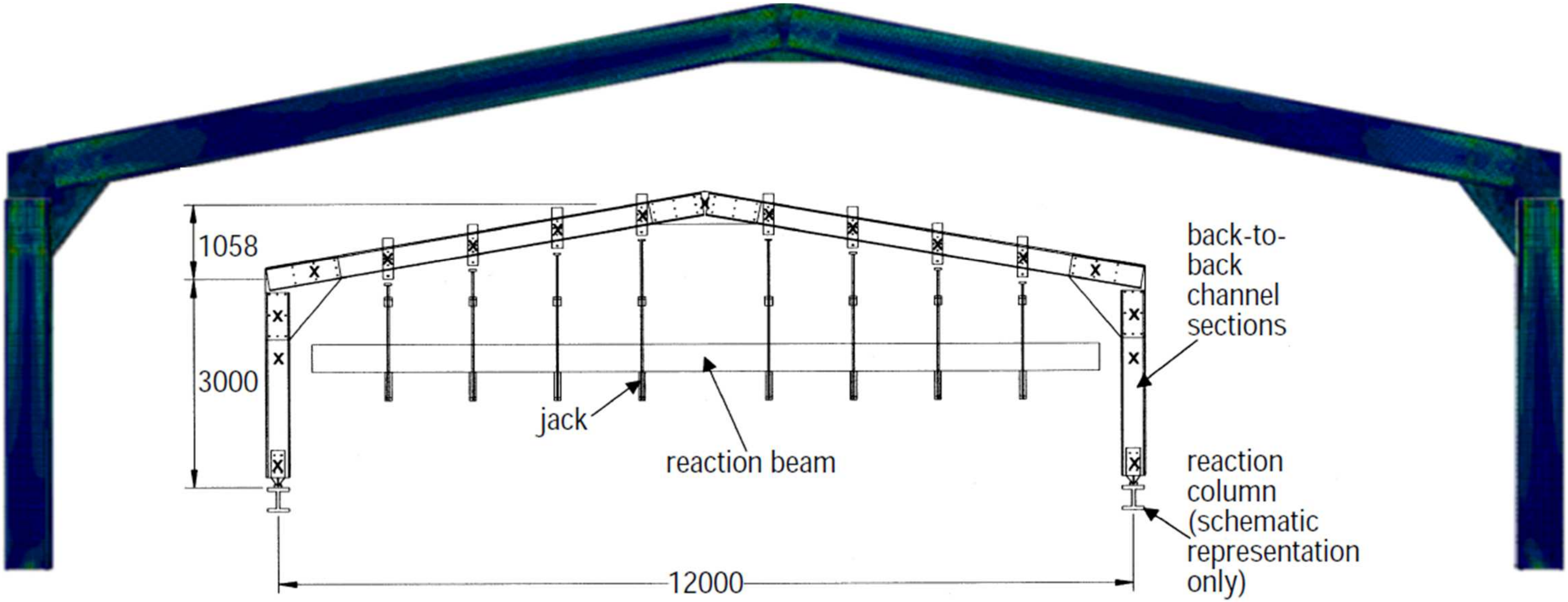


The geometry and arrangement chosen was taken from **Lim and Nethercot (2004)**. Lim described two full scale tests on a cold-formed steel portal frame at ambient temperature. Their frame A was used in this benchmark study. The frame dimensions were: roof pitch of 10°, span of 12 m and height to eaves of 3 m.

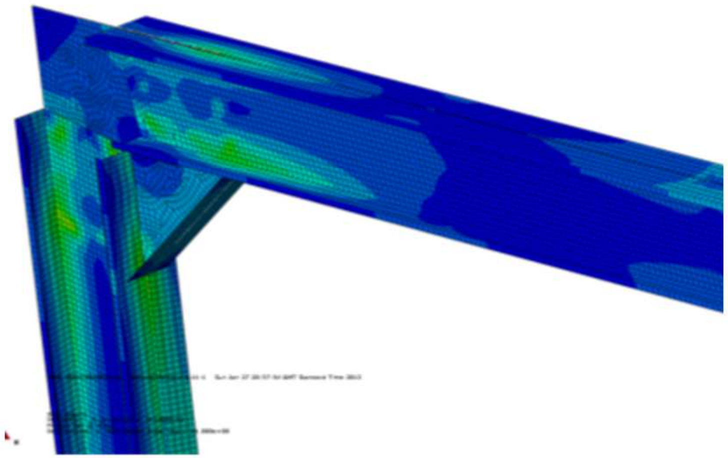


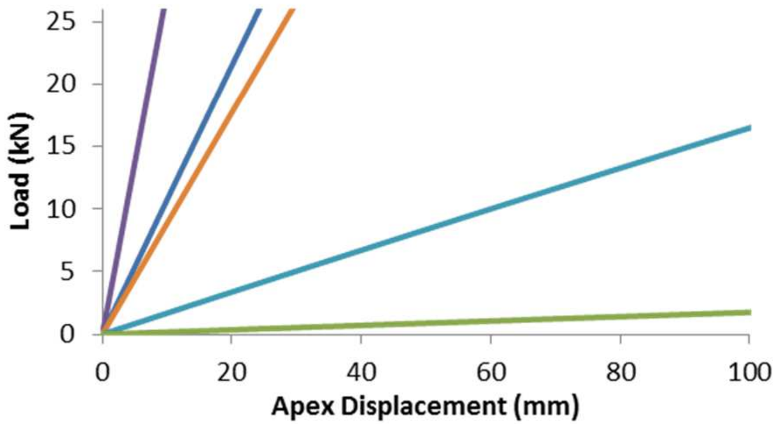
For this study, the elastic and plastic mechanical properties presented by **Chen and Young (2007)** are used. Chen carried out investigation of G550 and G450 steel grades. G550 used for purposes of this study.

VALIDATION AT AMBIENT TEMP



× location of lateral restraint





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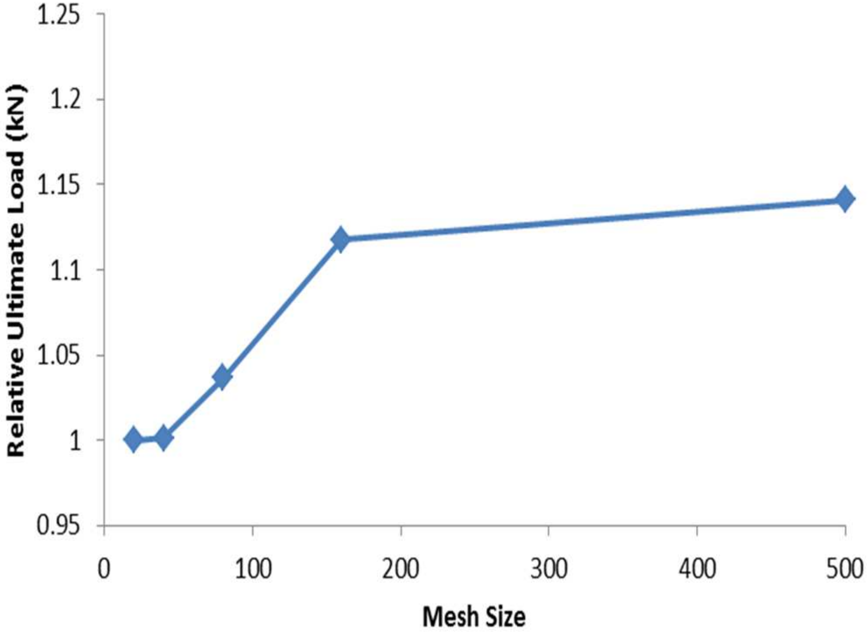
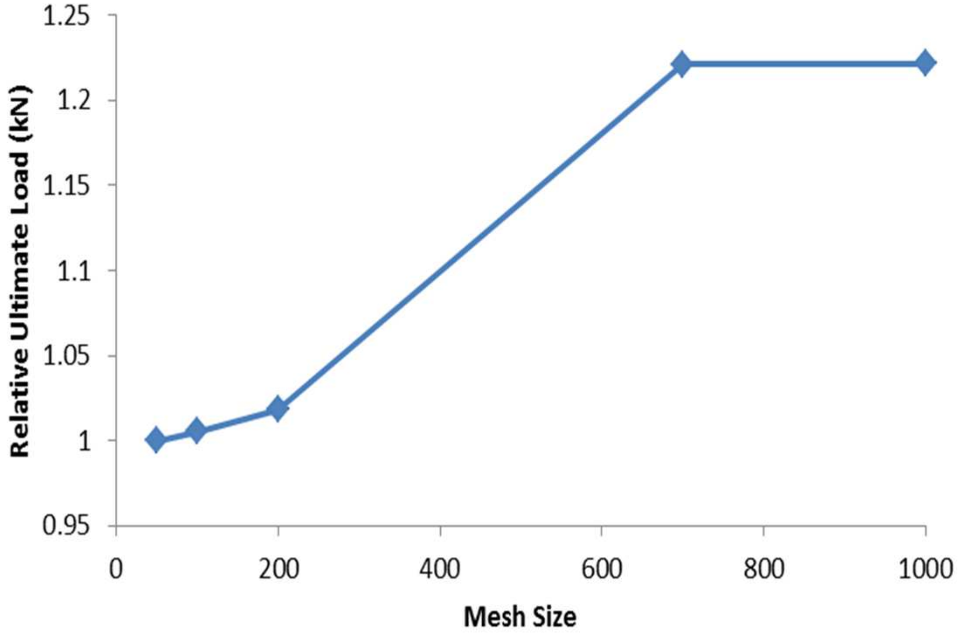
MESH





SHELL

BEAM

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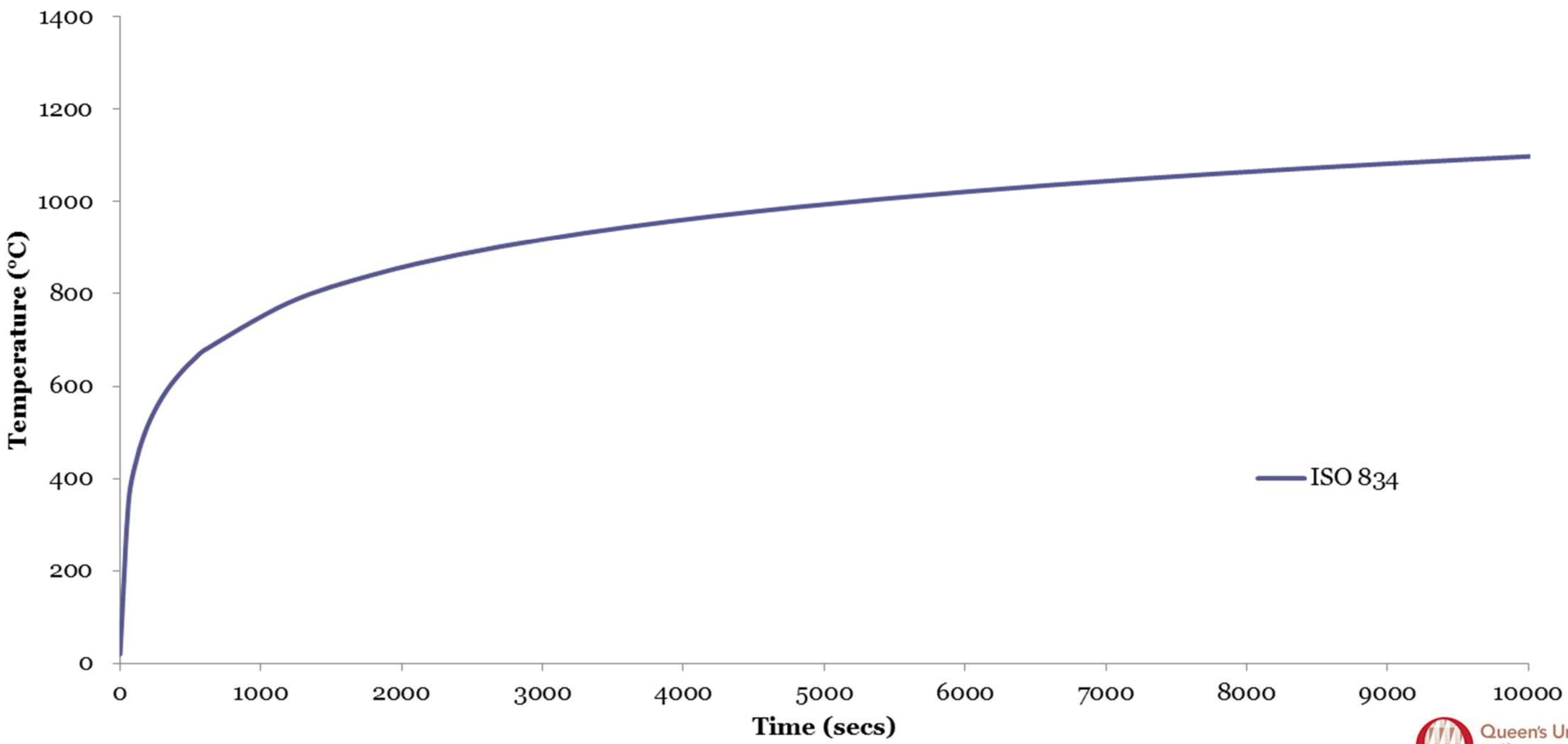
FIRE CURVE

The ISO 834 standard nominal time-temperature curve was adopted for this study. This was inserted into ABAQUS as an amplitude, linked in turn to a predefined field. For this benchmark study columns and rafters were assumed unprotected and to have uniform heating.



ANALYSIS STEPS

- INITIAL
- LOADING STEP – static. BC's & loading applied. (Propogated to temperature step)
- TEMPERATURE STEP – implicit dynamic quasi-static. Time vs Temp amplitude curves linked to geometric predefined fields. In turn linked to temperature dependent material properties.

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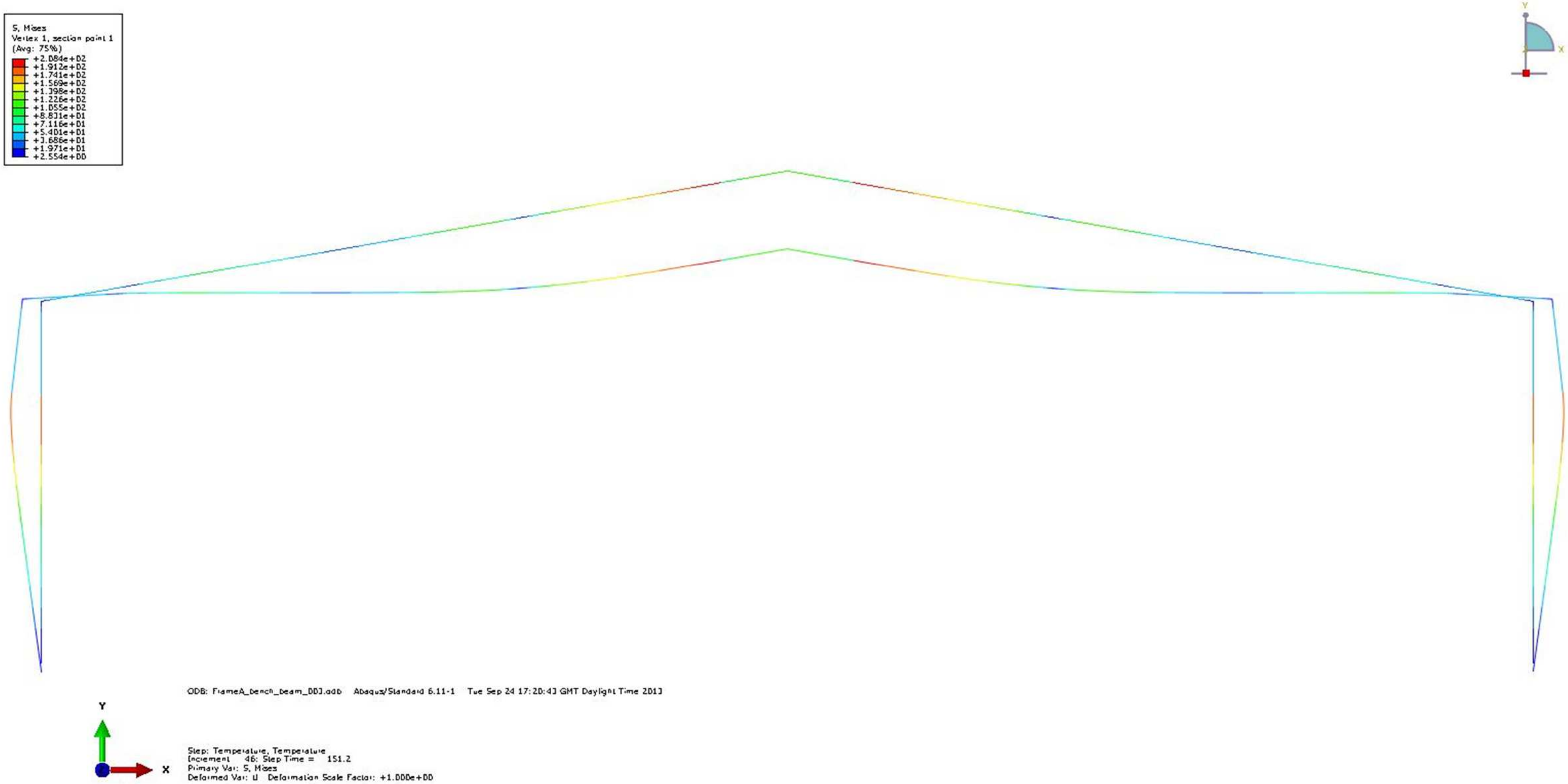
OPTIONS FOR ANALYSIS

- BEAM

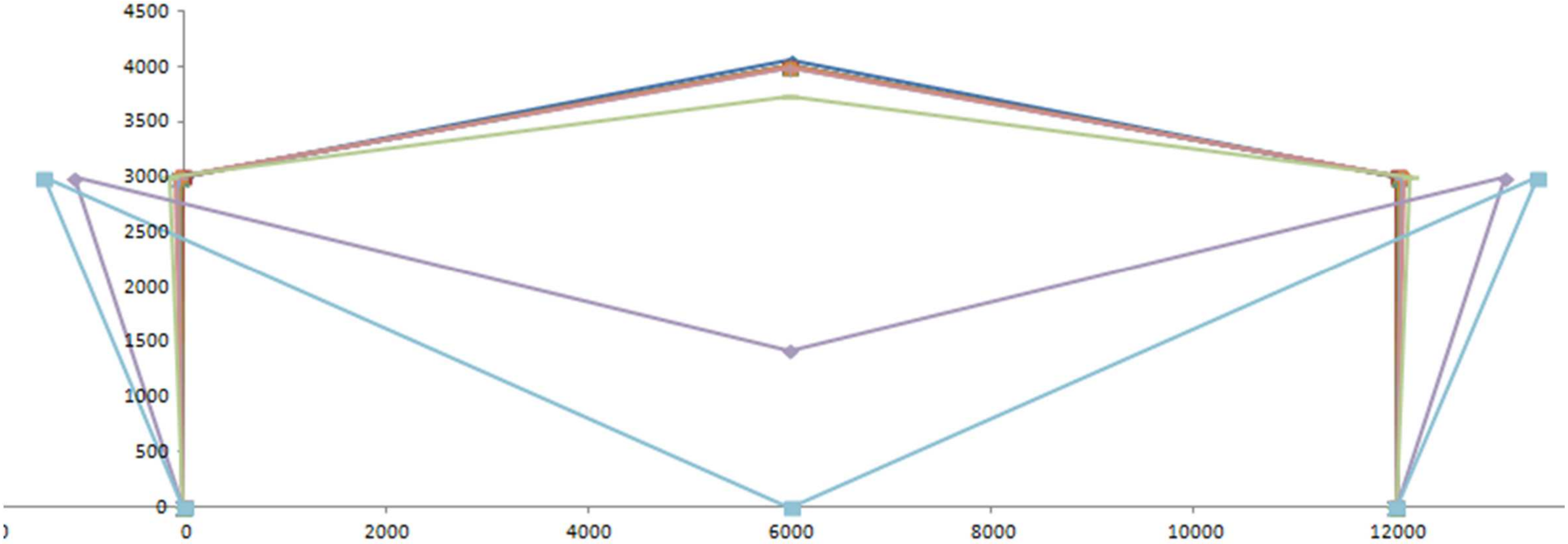
- SHELL

- SHELL (NLGEOM ON)

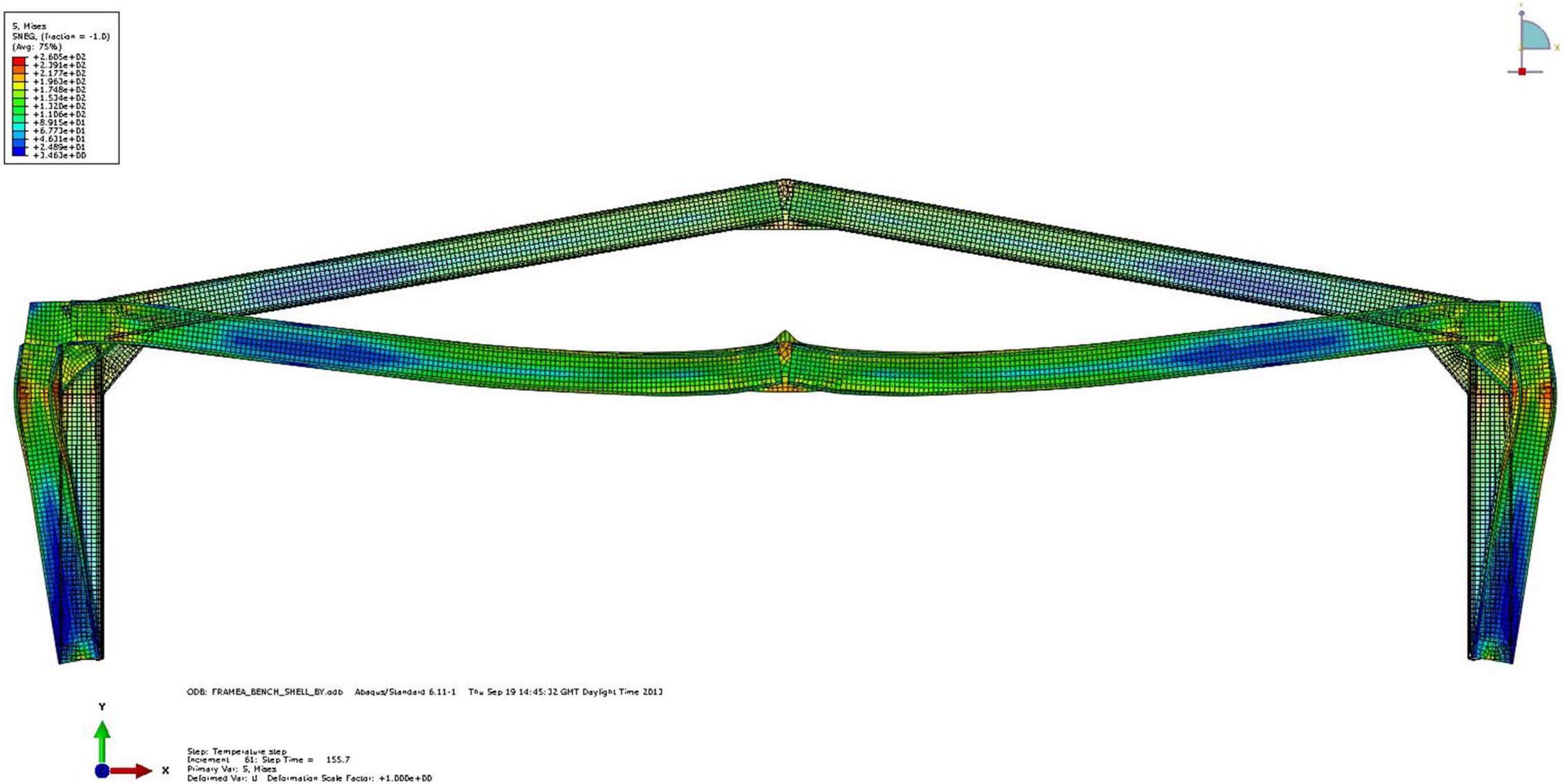
BEAM


S, Mises
Vertex 1, section point 1
(Avg: 75%)
+2.084e+02
+1.912e+02
+1.741e+02
+1.569e+02
+1.398e+02
+1.226e+02
+1.055e+02
+8.831e+01
+7.116e+01
+5.401e+01
+3.686e+01
+1.971e+01
+2.554e+00
ODB: FrameA_bench_beam_003.odb Abaqus/Standard 6.11-1 Tue Sep 24 17:20:43 GMT Daylight Time 2013
Y
X
Step: Temperature, Temperature
Increment 46: Step Time = 151.2
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +1.000e+00

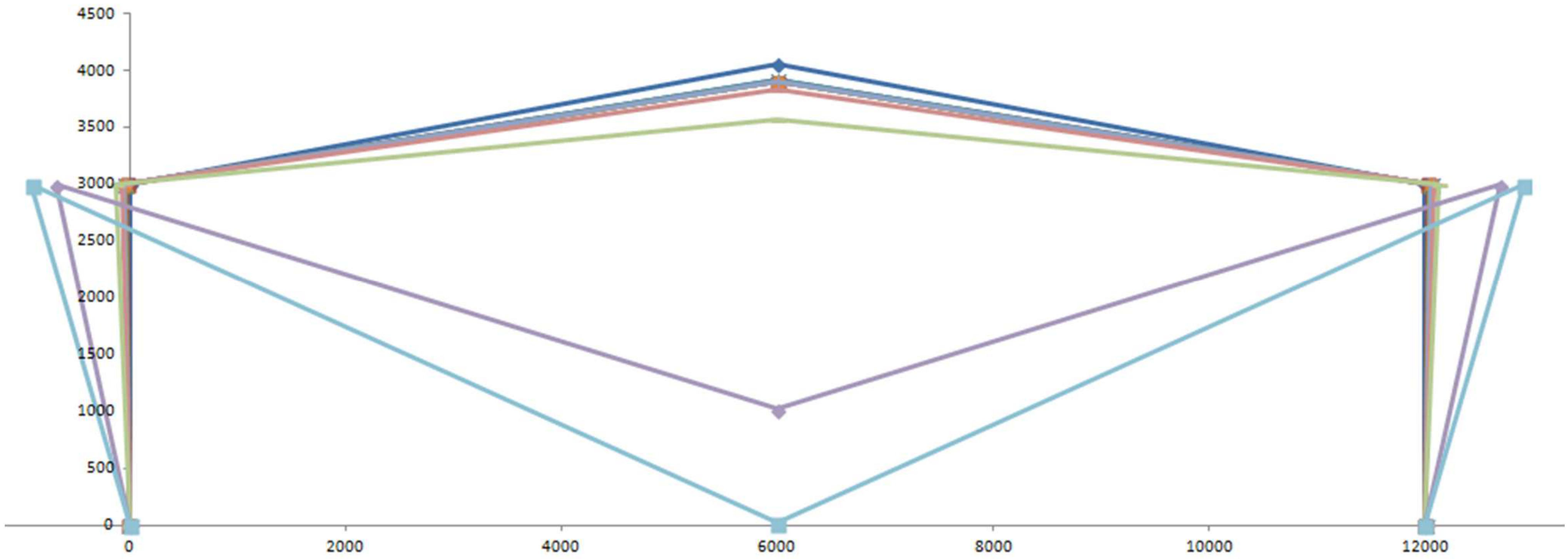
BEAM


4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000
10000
12000

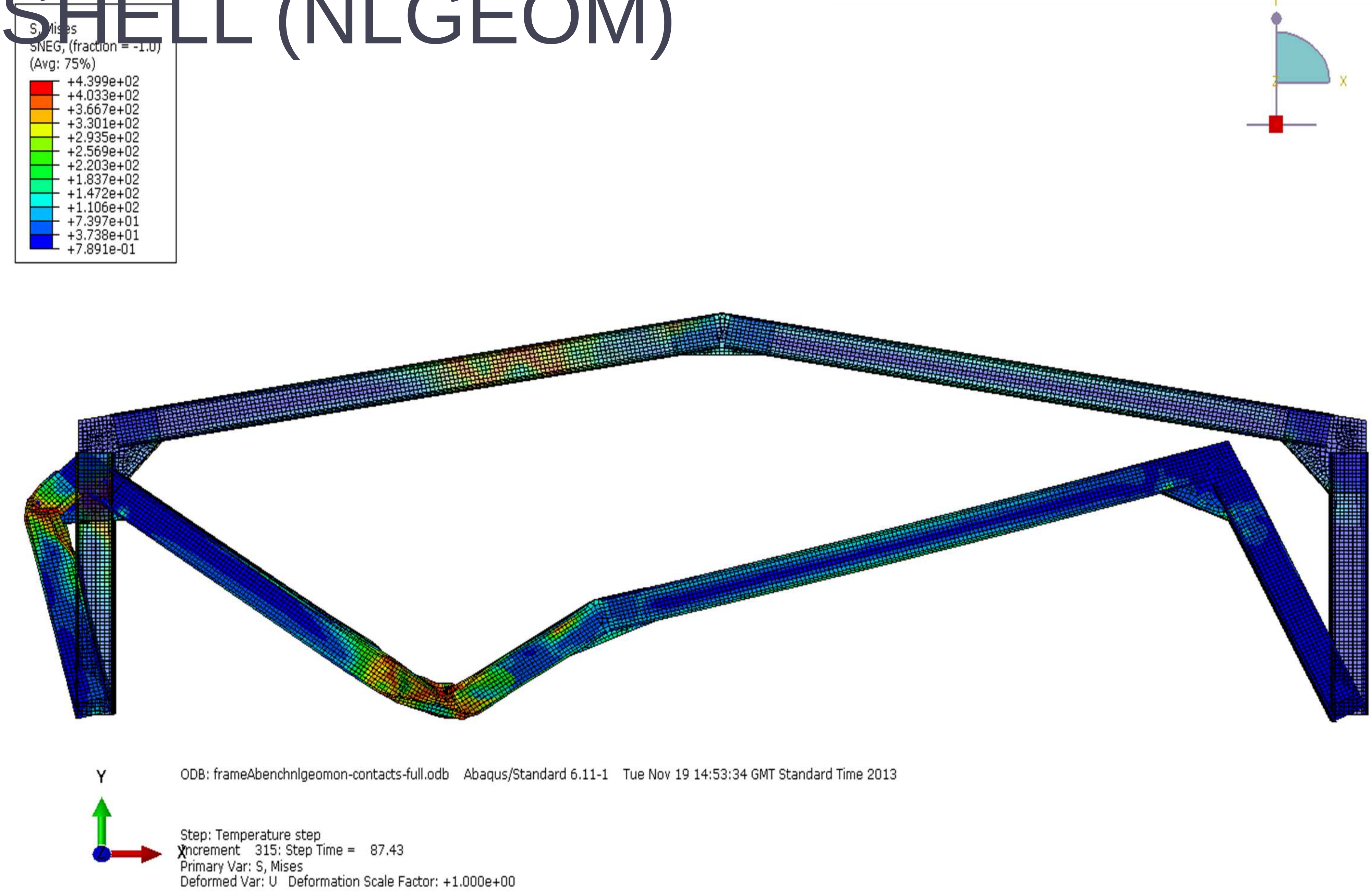
SHELL


S, Mises
SNEG, (fraction = -1.0)
(Avg: 75%)
+2.605e+02
+2.391e+02
+2.177e+02
+1.963e+02
+1.748e+02
+1.534e+02
+1.320e+02
+1.106e+02
+8.915e+01
+6.773e+01
+4.631e+01
+2.489e+01
+3.463e+00
ODB: FRAMEA_BENCH_SHELL_BY.odb Abaqus/Standard 6.11-1 Thu Sep 19 14:45:32 GMT Daylight Time 2013
Y
X
Step: Temperature step
Increment 61: Step Time = 155.7
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +1.000e+00

SHELL


4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000
10000
12000

SHELL (NLGEOM)



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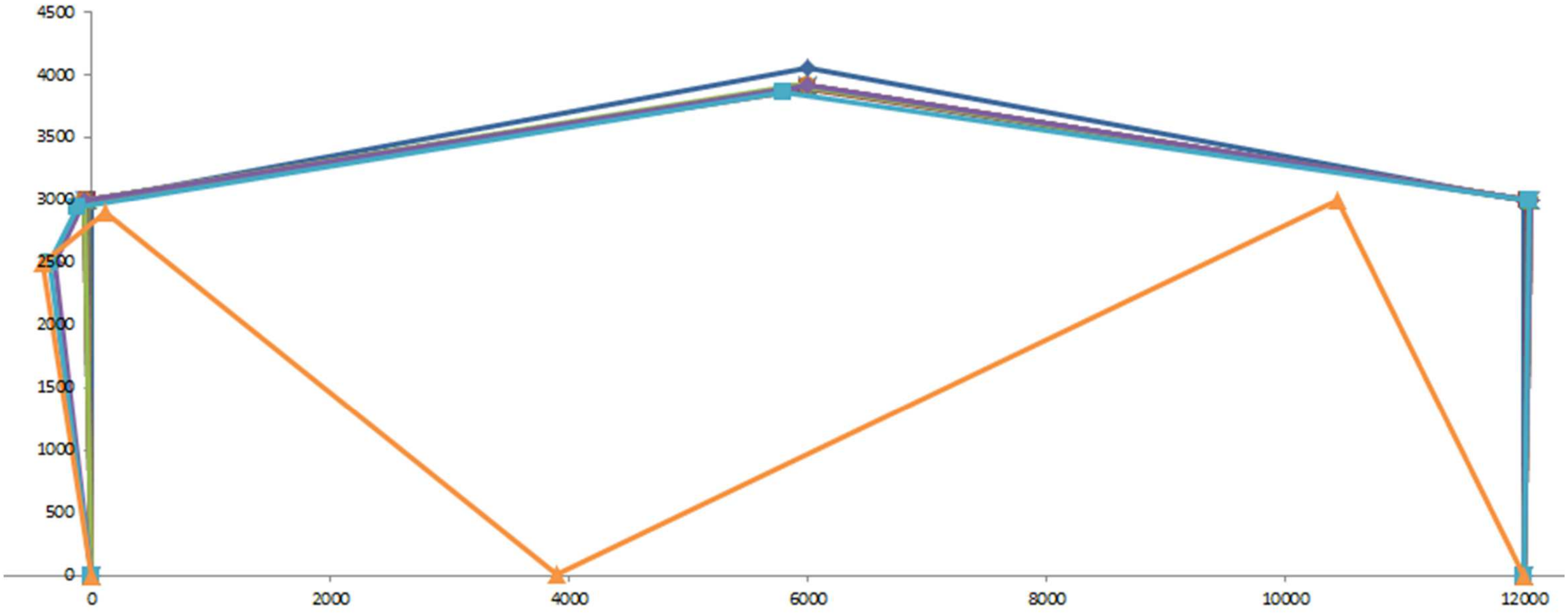
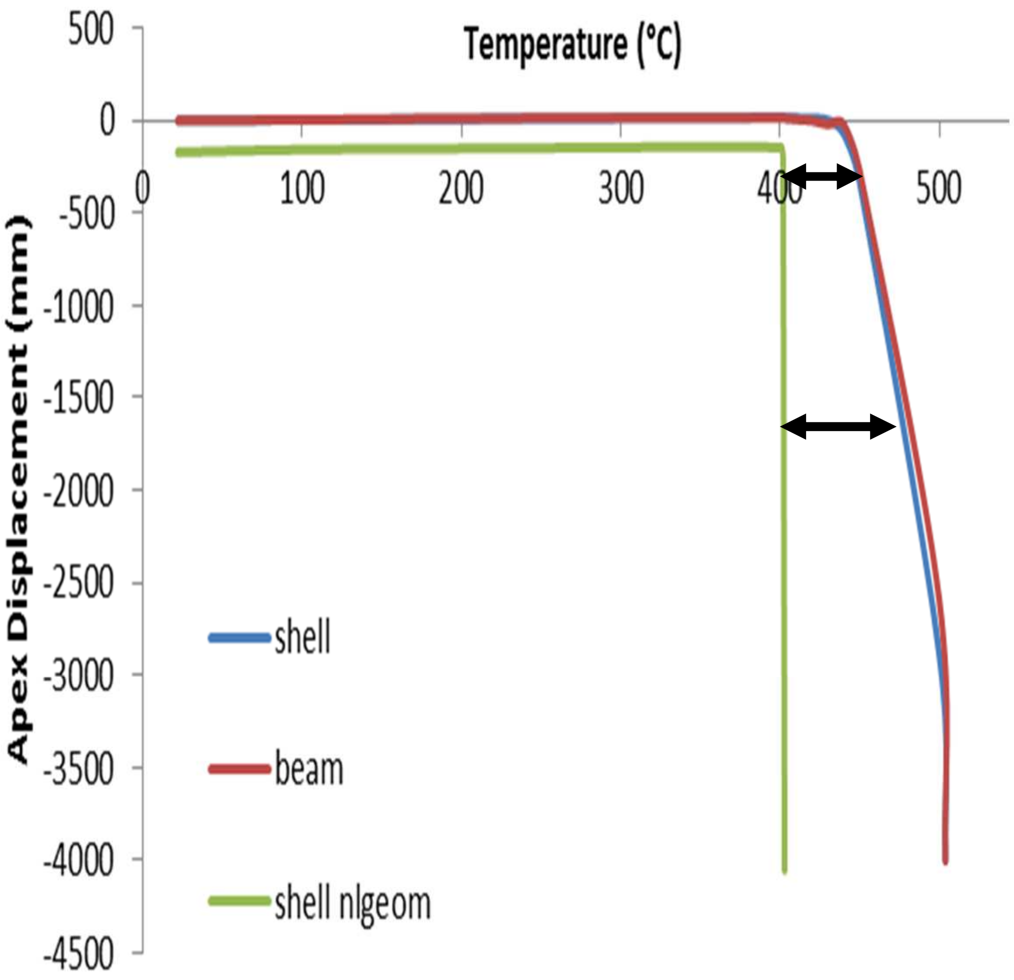
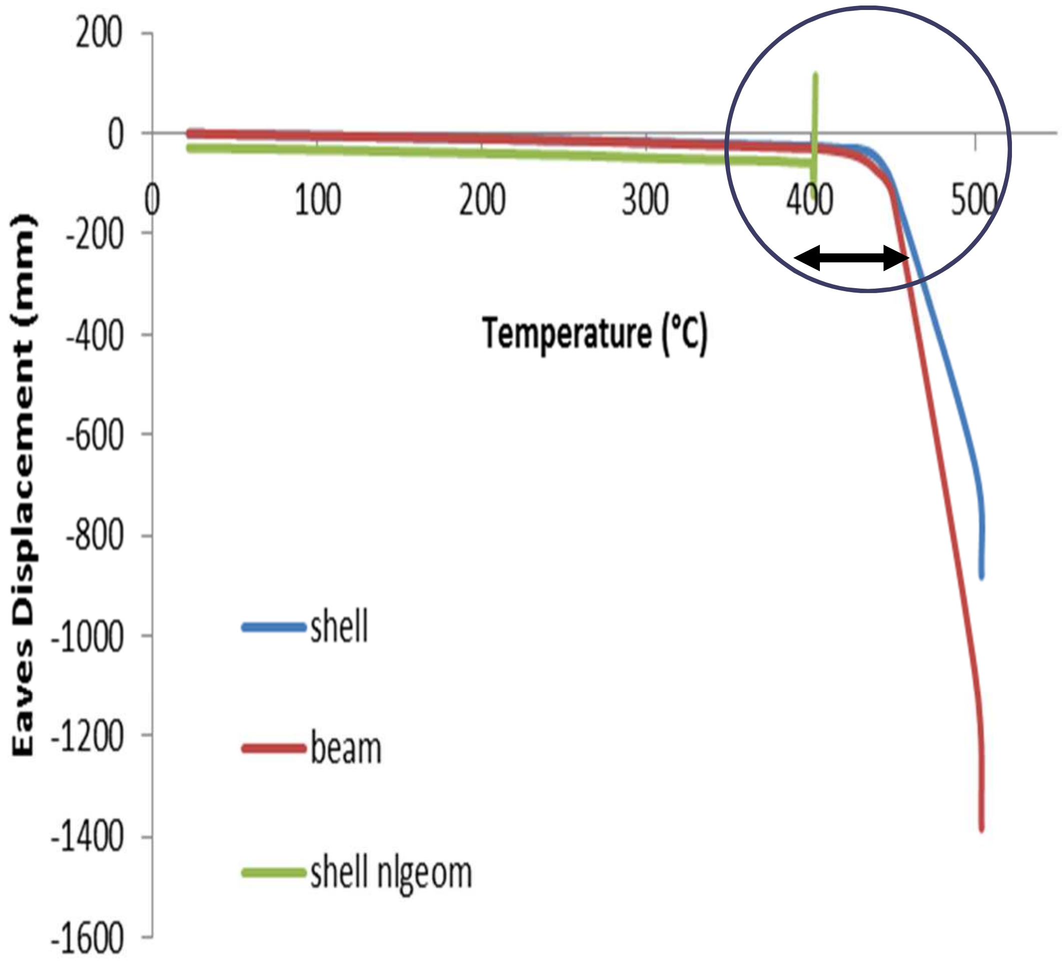
SHELL (NLGEOM)

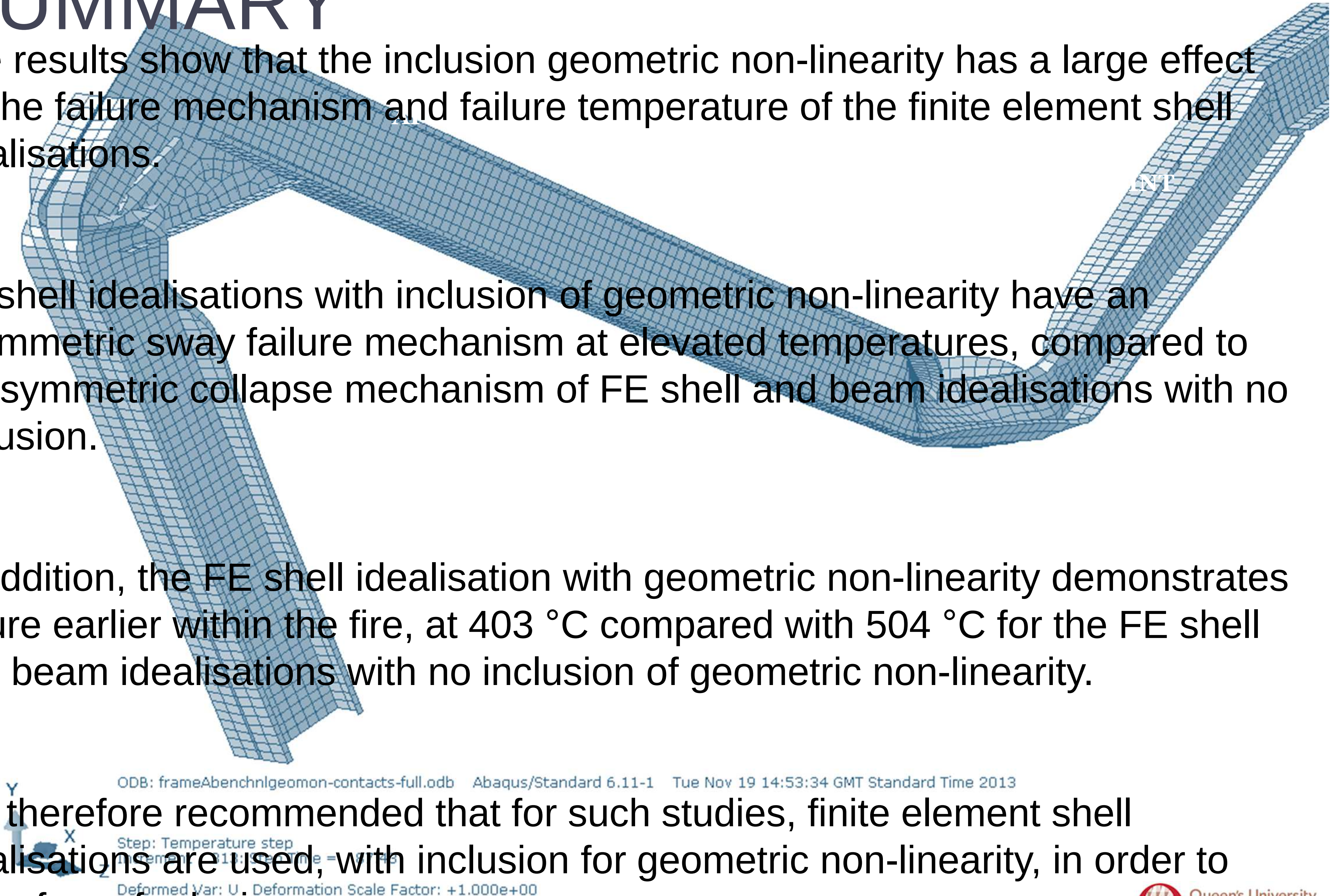


COMPARISON


Temperature (°C)
Apex Displacement (mm)
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
0
100
200
300
400
500
shell
beam
shell nlgeom


Temperature (°C)
Eaves Displacement (mm)
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
0
100
200
300
400
500
shell
beam
shell nlgeom

SUMMARY



The results show that the inclusion geometric non-linearity has a large effect on the failure mechanism and failure temperature of the finite element shell idealisations.

FE shell idealisations with inclusion of geometric non-linearity have an asymmetric sway failure mechanism at elevated temperatures, compared to the symmetric collapse mechanism of FE shell and beam idealisations with no inclusion.

In addition, the FE shell idealisation with geometric non-linearity demonstrates failure earlier within the fire, at 403 °C compared with 504 °C for the FE shell and beam idealisations with no inclusion of geometric non-linearity.

It is therefore recommended that for such studies, finite element shell idealisations are used, with inclusion for geometric non-linearity, in order to allow for safe design.

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Thank you