AE462
Exercise 4

<u>Date</u>
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<u>Instructor</u>
Prof. G.M. Kamath

<u>Group 11</u>
Aryaman Badkul
Palmate Aditya Tukaram
Shrutikirti Singh
Prabuddha Singh
Shikha Sharma
Rahangdale Prachi Sanjay

Content

Procedure Flowchart:

1. Pre-processing Part
- Modelling
- Part defining(material used)
- Assembly
- Application of Loads & Boundary Conditions
- See Results Obtained

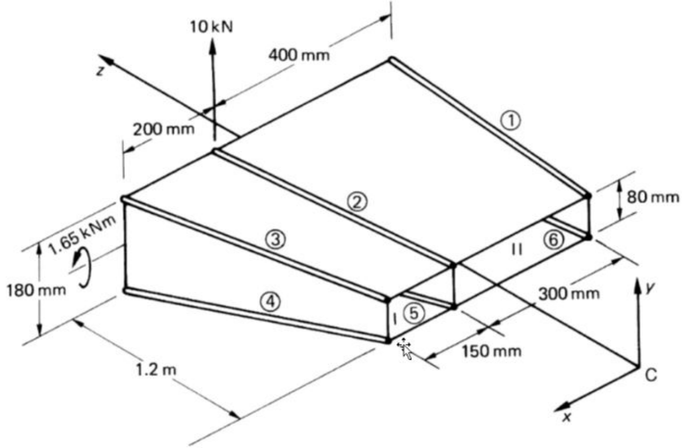
2. Post-processing Part
- Multiple Files will get generated
- Use .odp file to see the Results

Problem Statement

Example 23.4

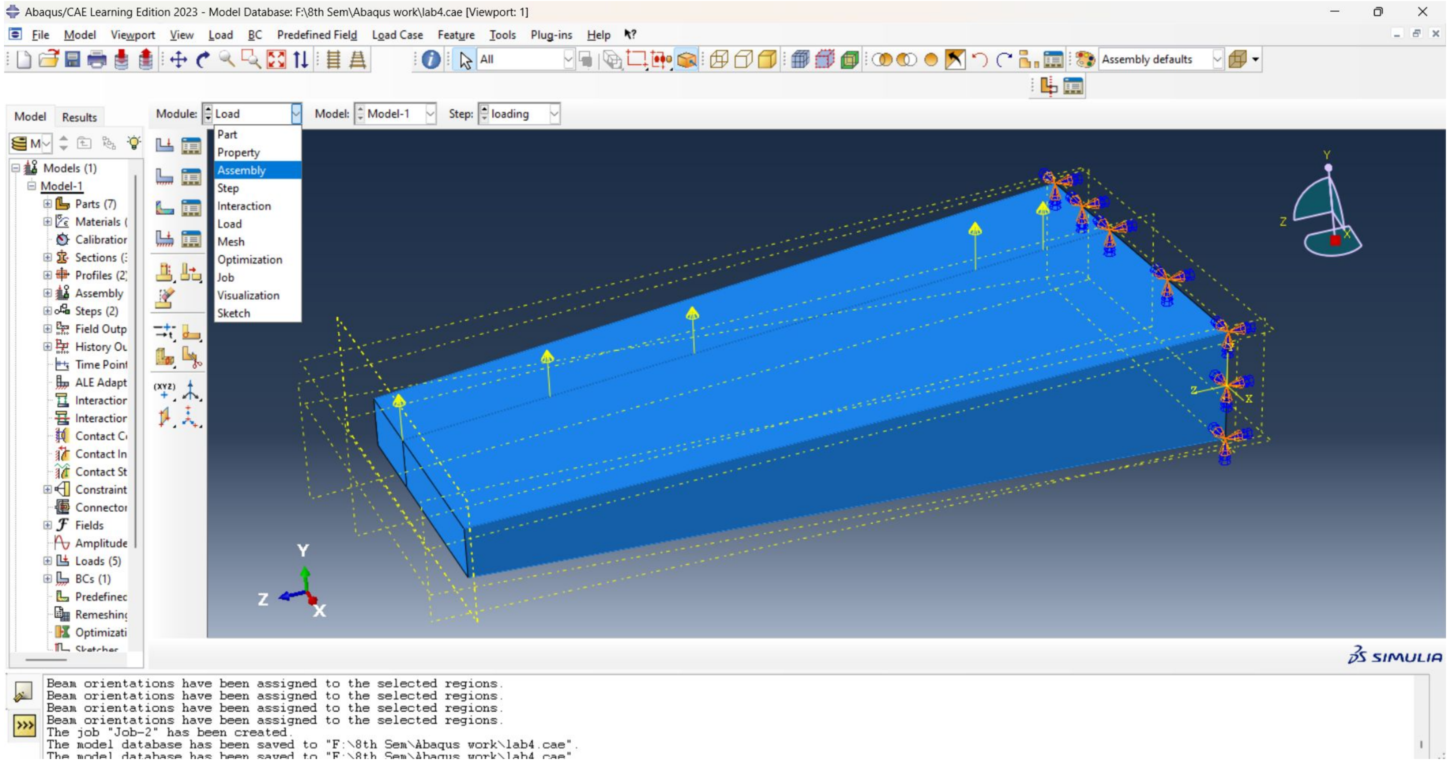
A two-cell beam has singly symmetrical cross-sections 1.2 m apart and tapers symmetrically in the y direction about a longitudinal axis (Fig. 23.12). The beam supports loads which produce a shear force $S_y = 10$ kN and a bending moment $M_x = 1.65$ kN m at the larger cross-section; the shear load is applied in the plane of the internal spar web. If booms 1 and 6 lie on a plane which is parallel to the yz plane, calculate the forces in the booms and the shear flow distribution in the walls at the larger cross-section. The booms are assumed to resist all the direct stresses while the walls are effective only in shear. The shear modulus is constant throughout, the vertical webs are all 1.0 mm thick, while the remaining walls are all 0.8 mm thick:

$$\text{Boom areas: } B_1 = B_3 = B_4 = B_6 = 600\ \text{mm}^2,\ B_2 = B_5 = 900\ \text{mm}^2$$

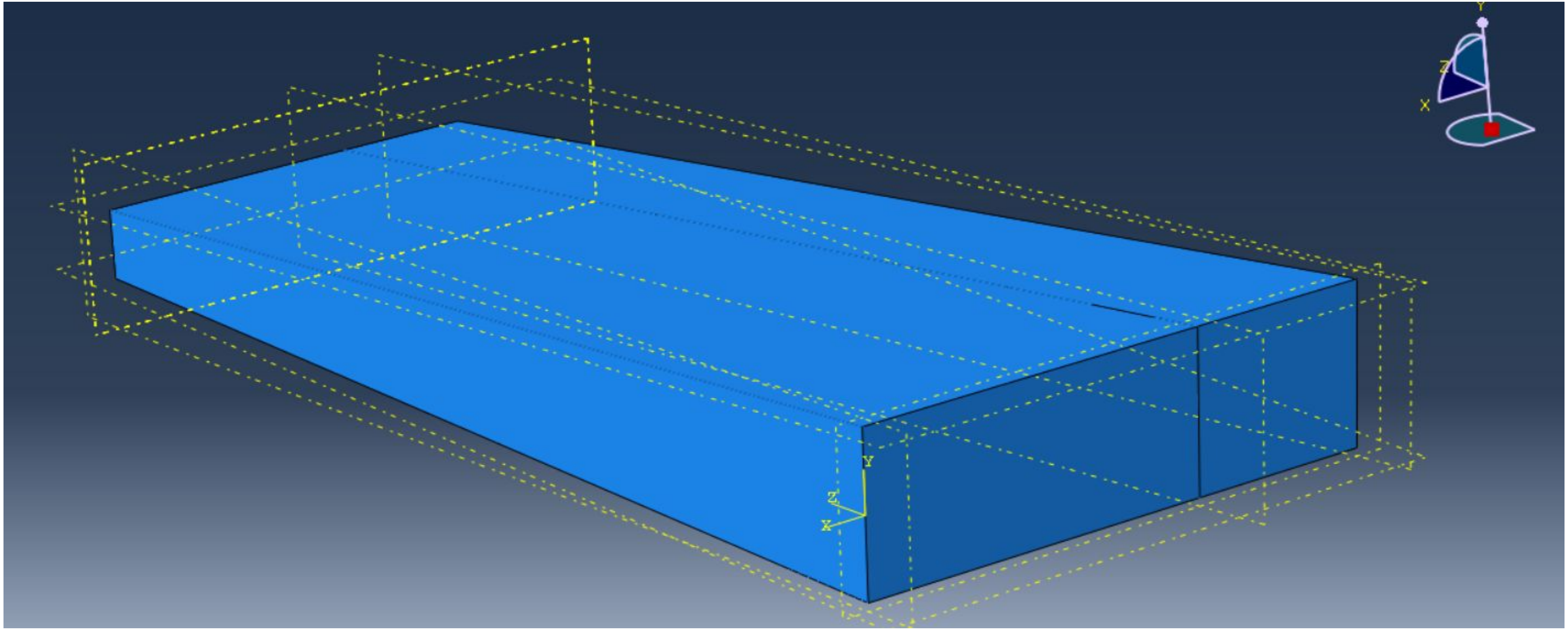


Link for CAE file- [Lab4_Group11]

Abaqus Workspace

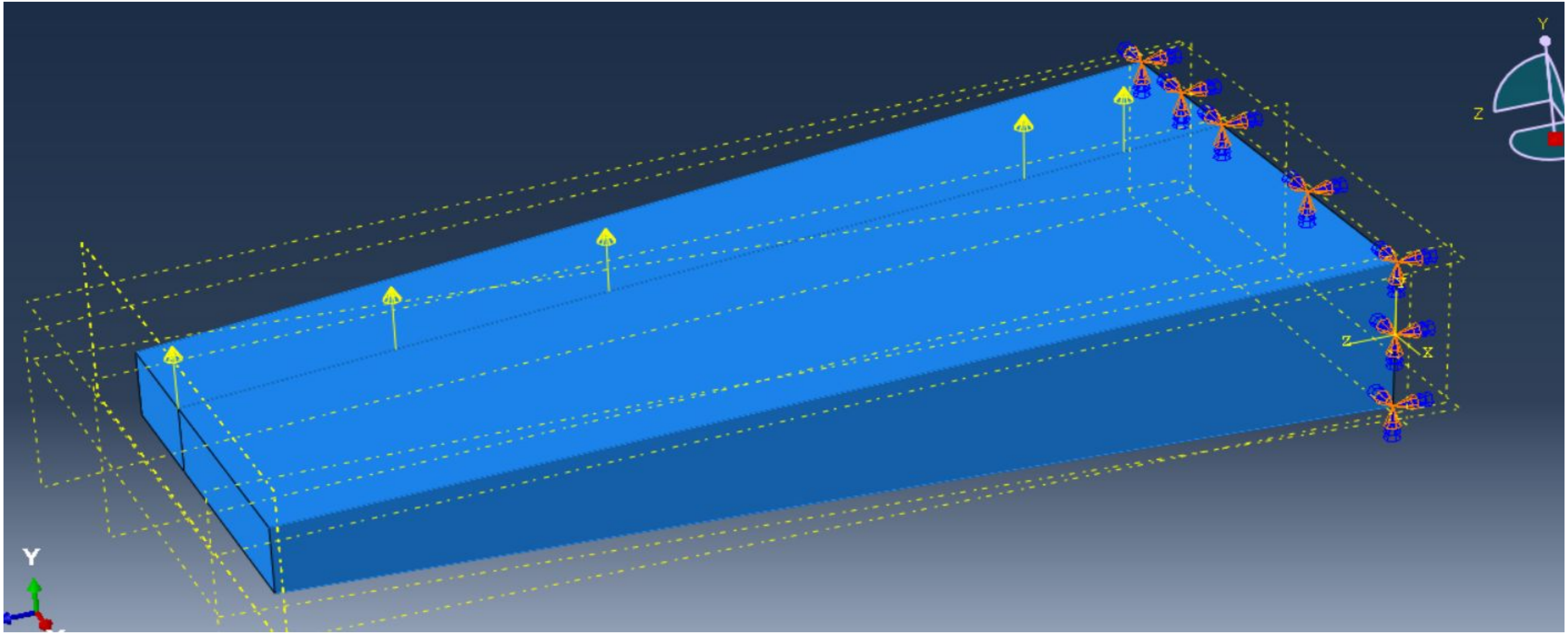


Model of a Two-Cell Beam

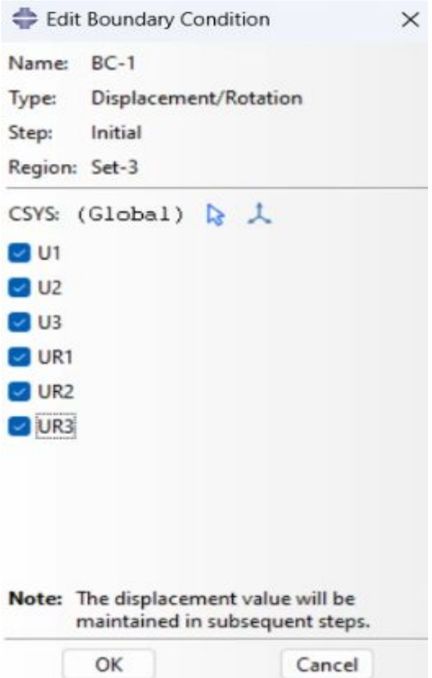


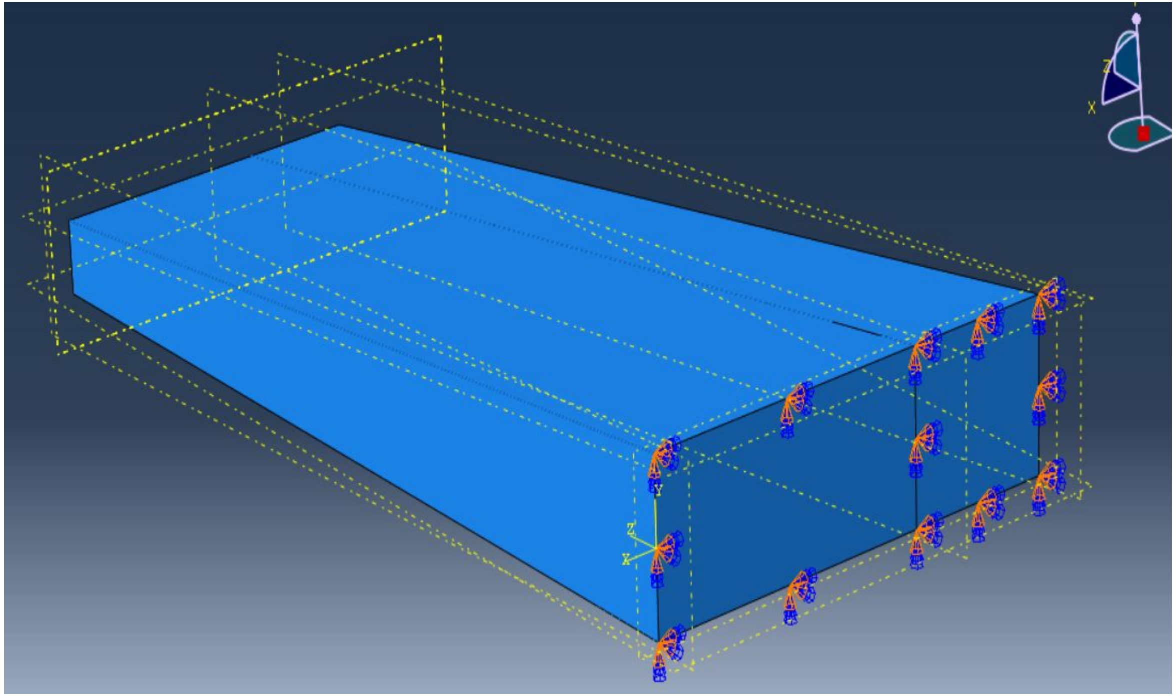
Loads Applied along with Boundary Conditions

Distance from root	Force(KN)
0.1	6
0.2	3.5
0.6	0.3
0.8	0.15
1	0.05

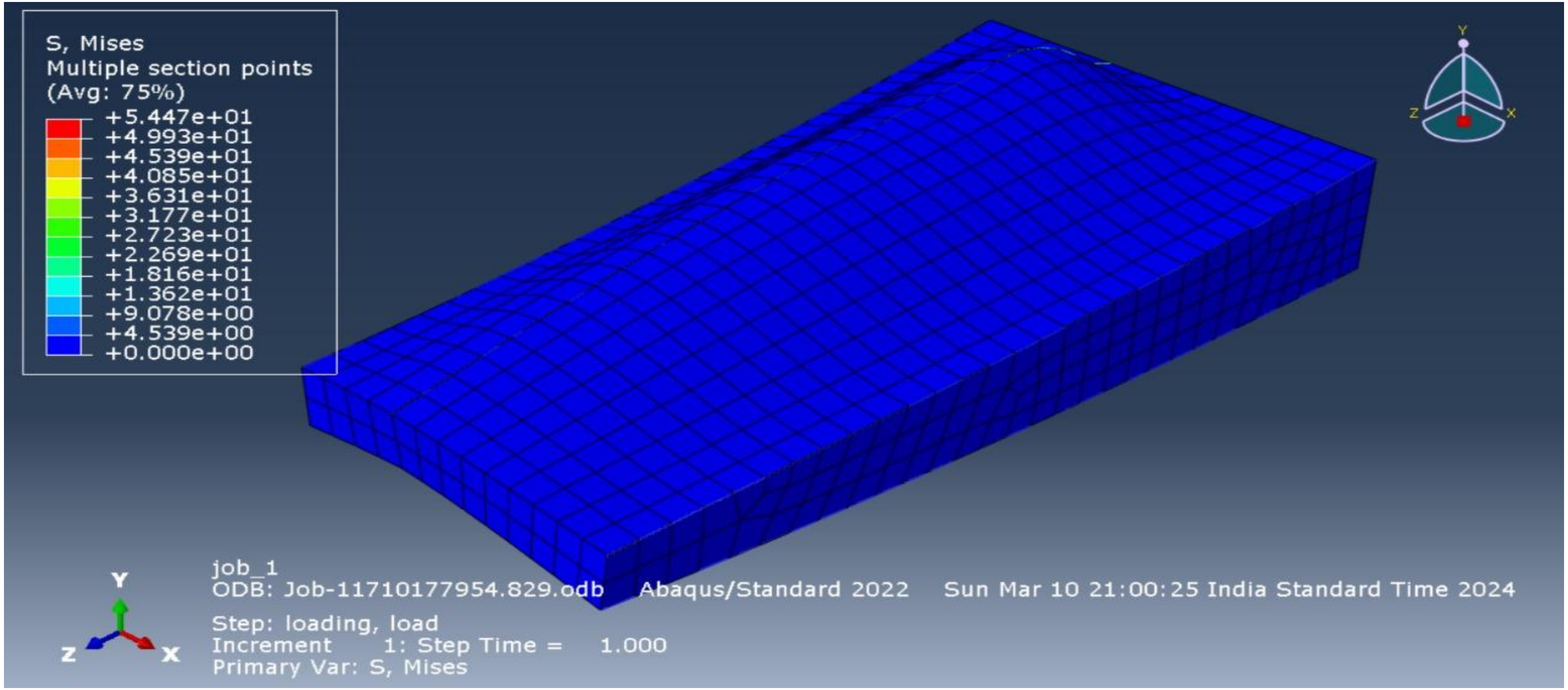


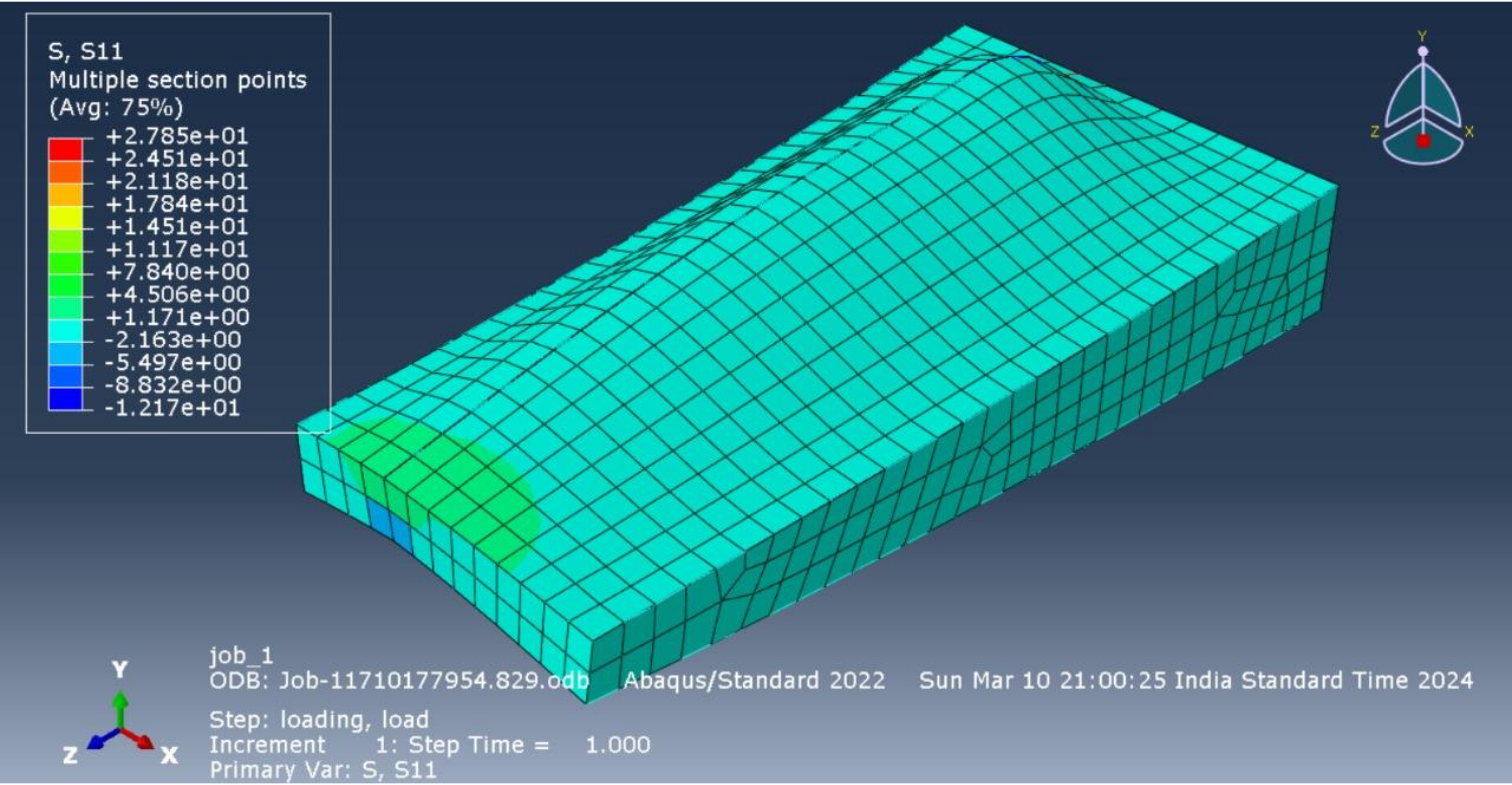
Boundary Conditions:

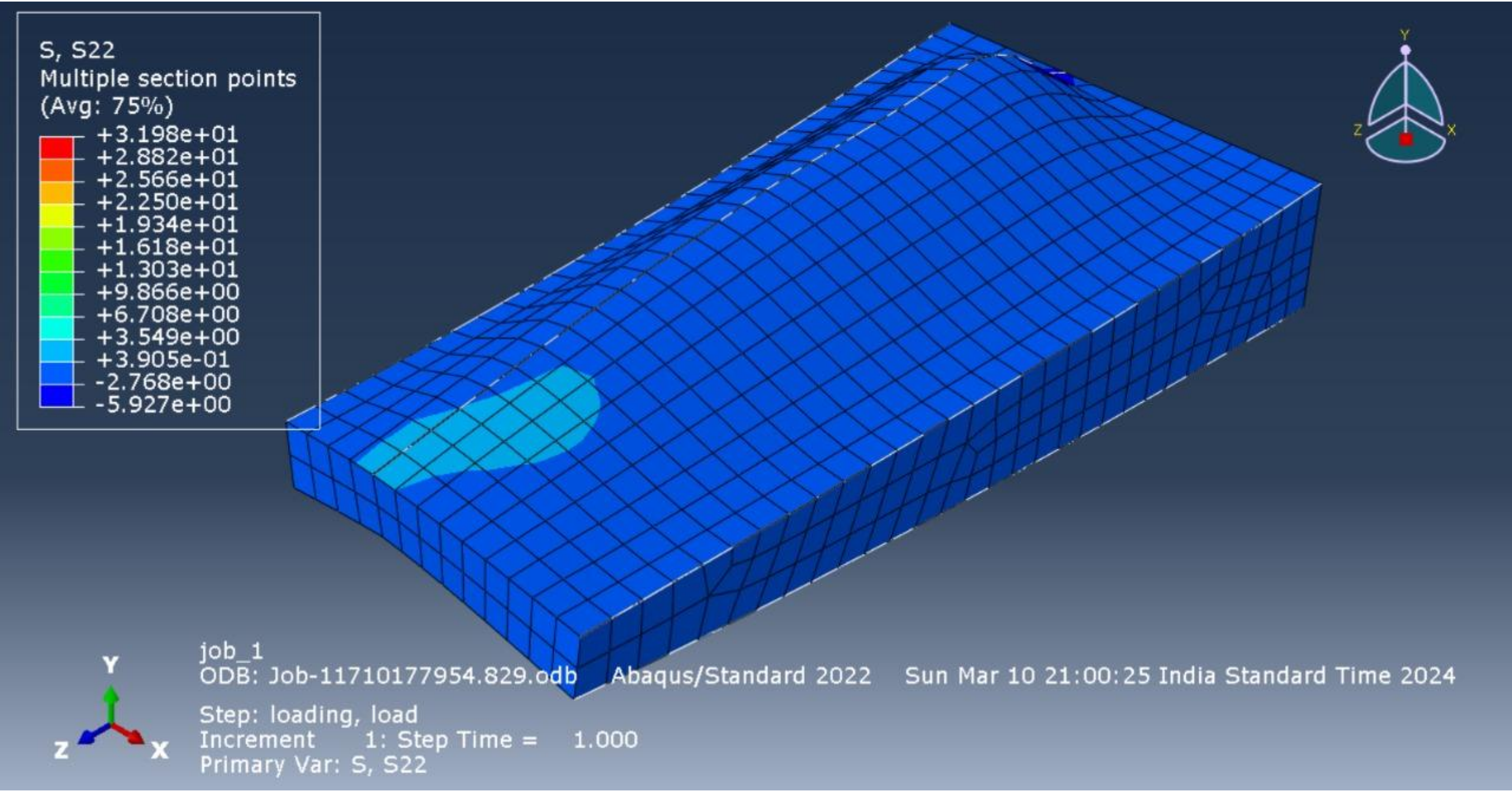


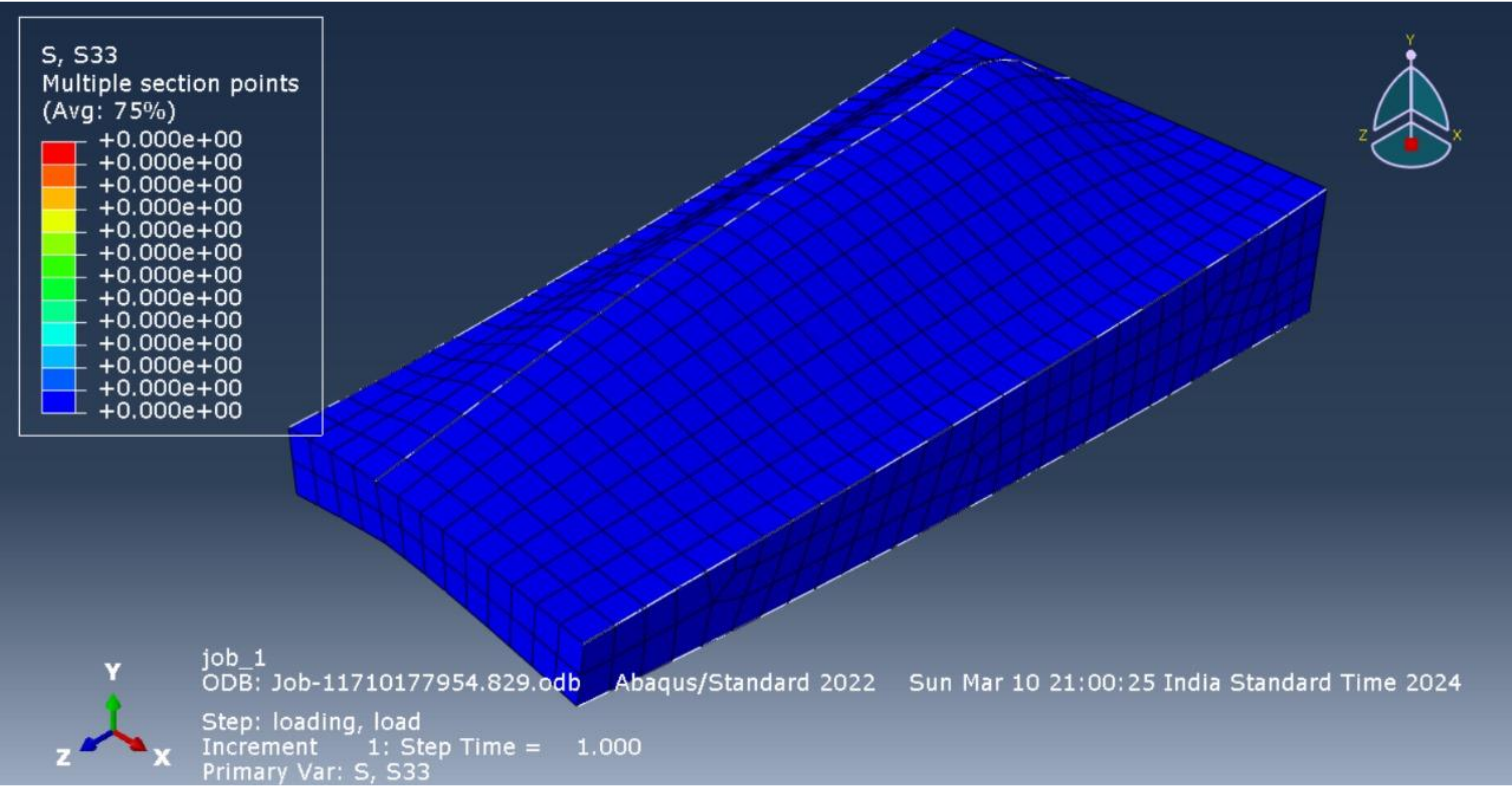


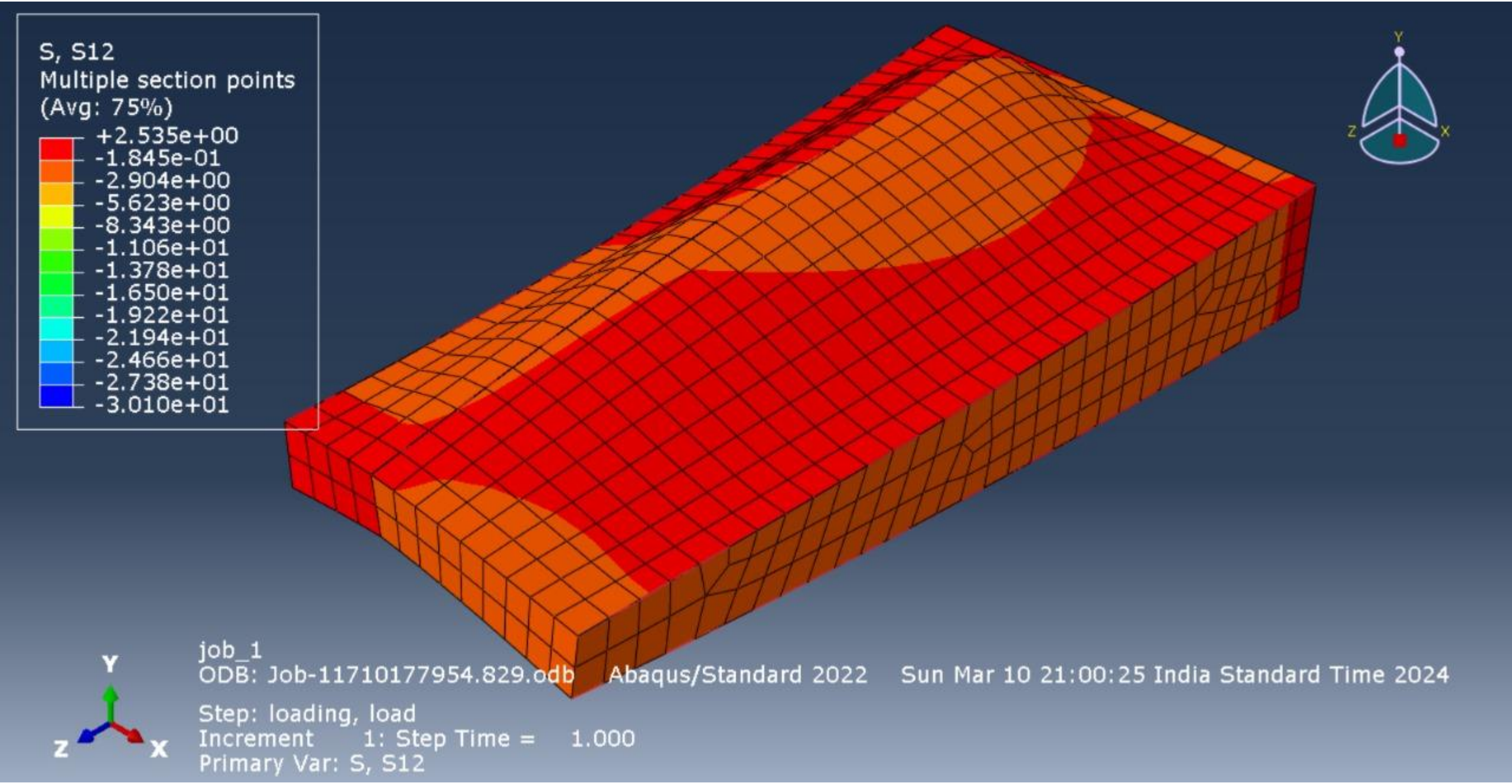
Stress Analysis:



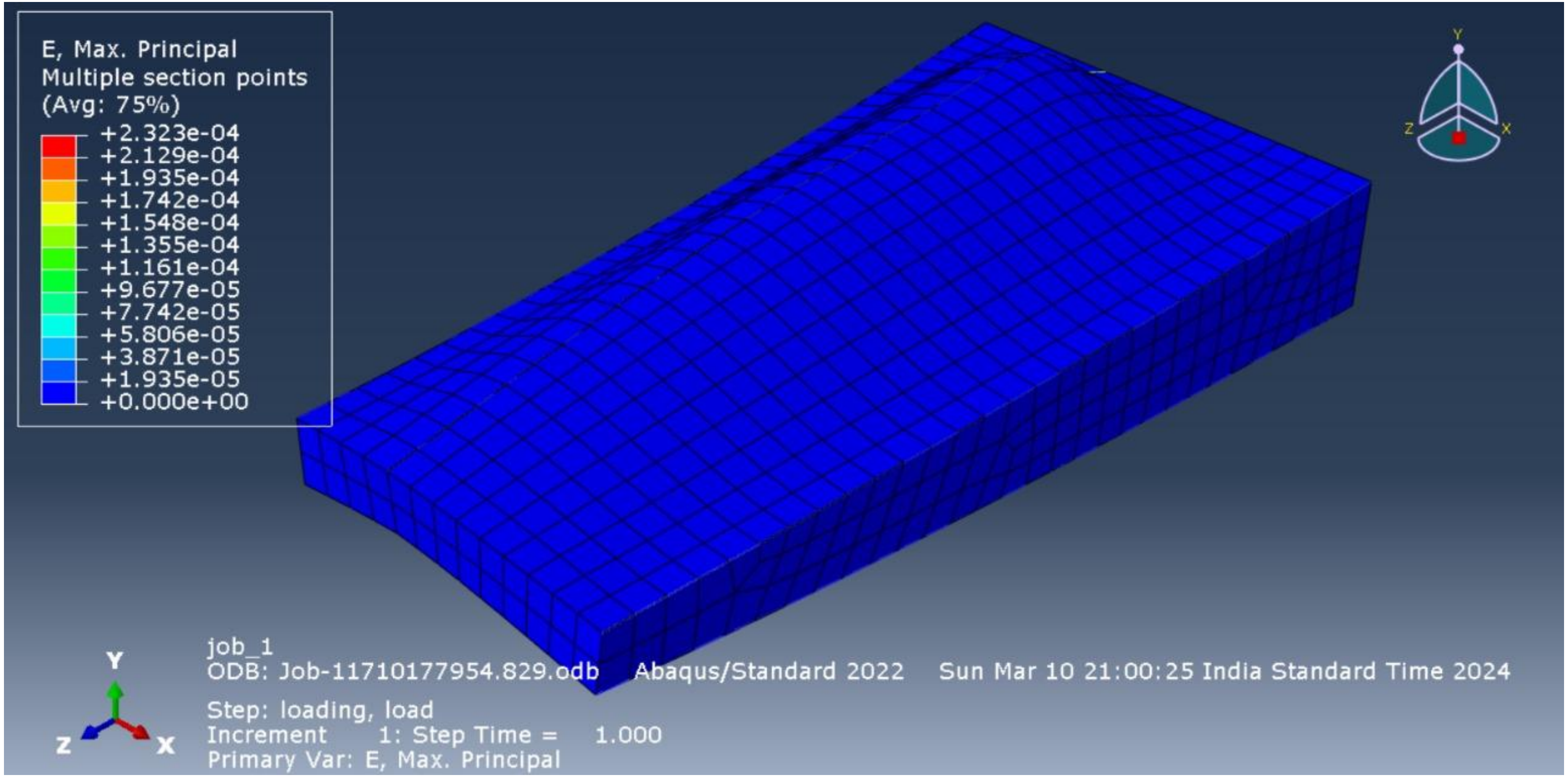

S, S11
Multiple section points
(Avg: 75%)
+2.785e+01
+2.451e+01
+2.118e+01
+1.784e+01
+1.451e+01
+1.117e+01
+7.840e+00
+4.506e+00
+1.171e+00
-2.163e+00
-5.497e+00
-8.832e+00
-1.217e+01
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: S, S11
Y
Z
X

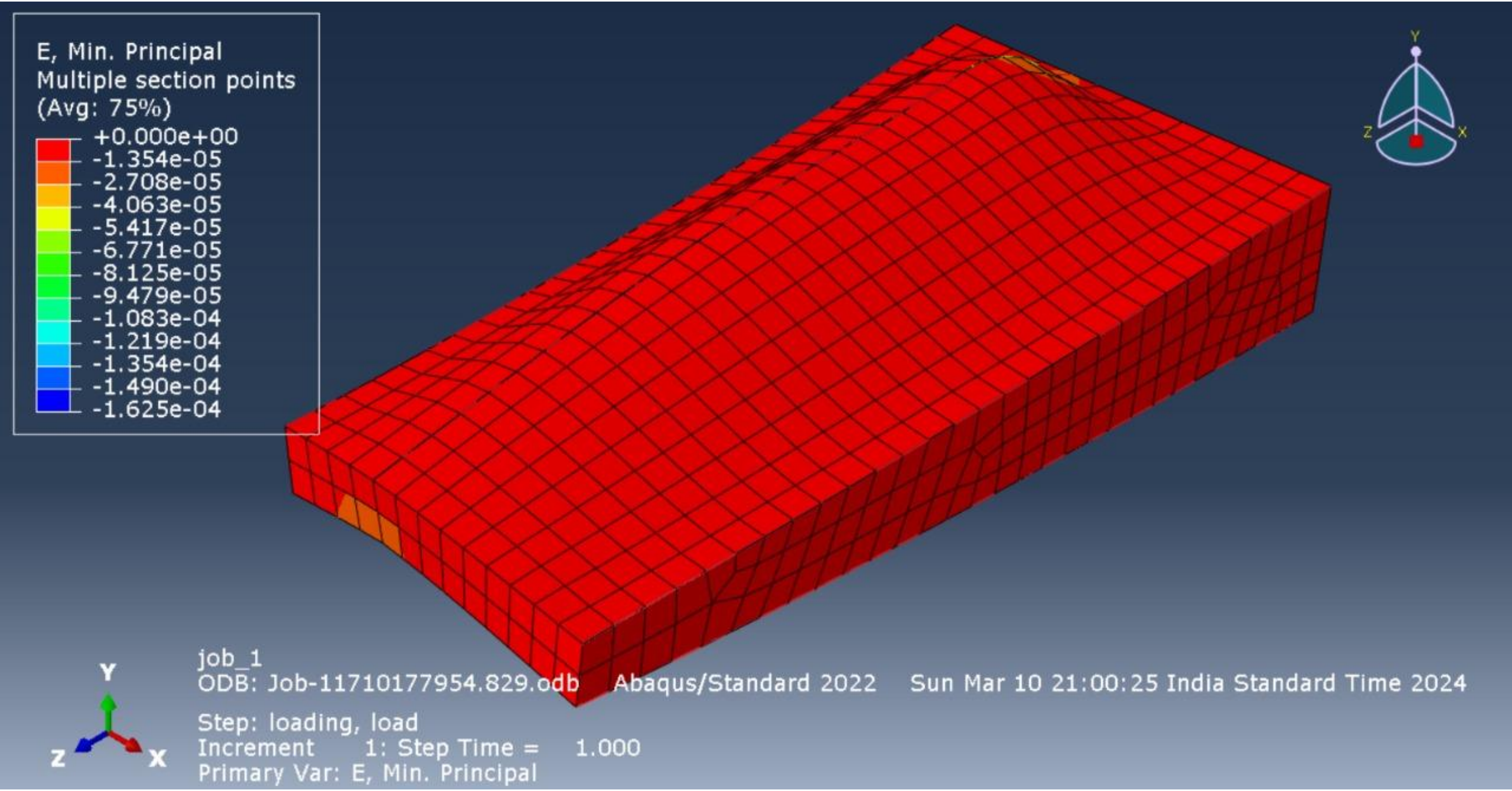

S, S22
Multiple section points
(Avg: 75%)
+3.198e+01
+2.882e+01
+2.566e+01
+2.250e+01
+1.934e+01
+1.618e+01
+1.303e+01
+9.866e+00
+6.708e+00
+3.549e+00
+3.905e-01
-2.768e+00
-5.927e+00
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: S, S22

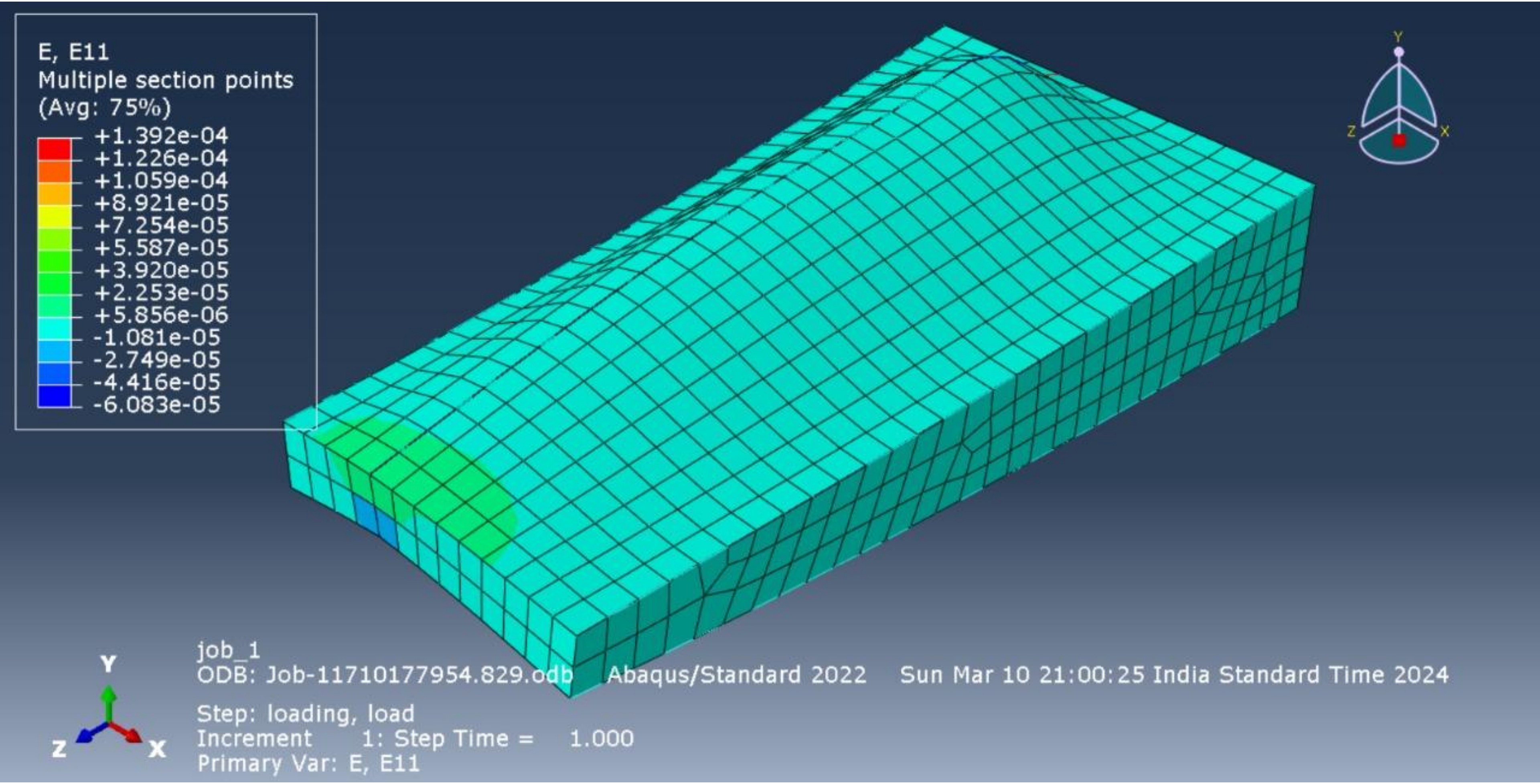

S, S33
Multiple section points
(Avg: 75%)
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: S, S33

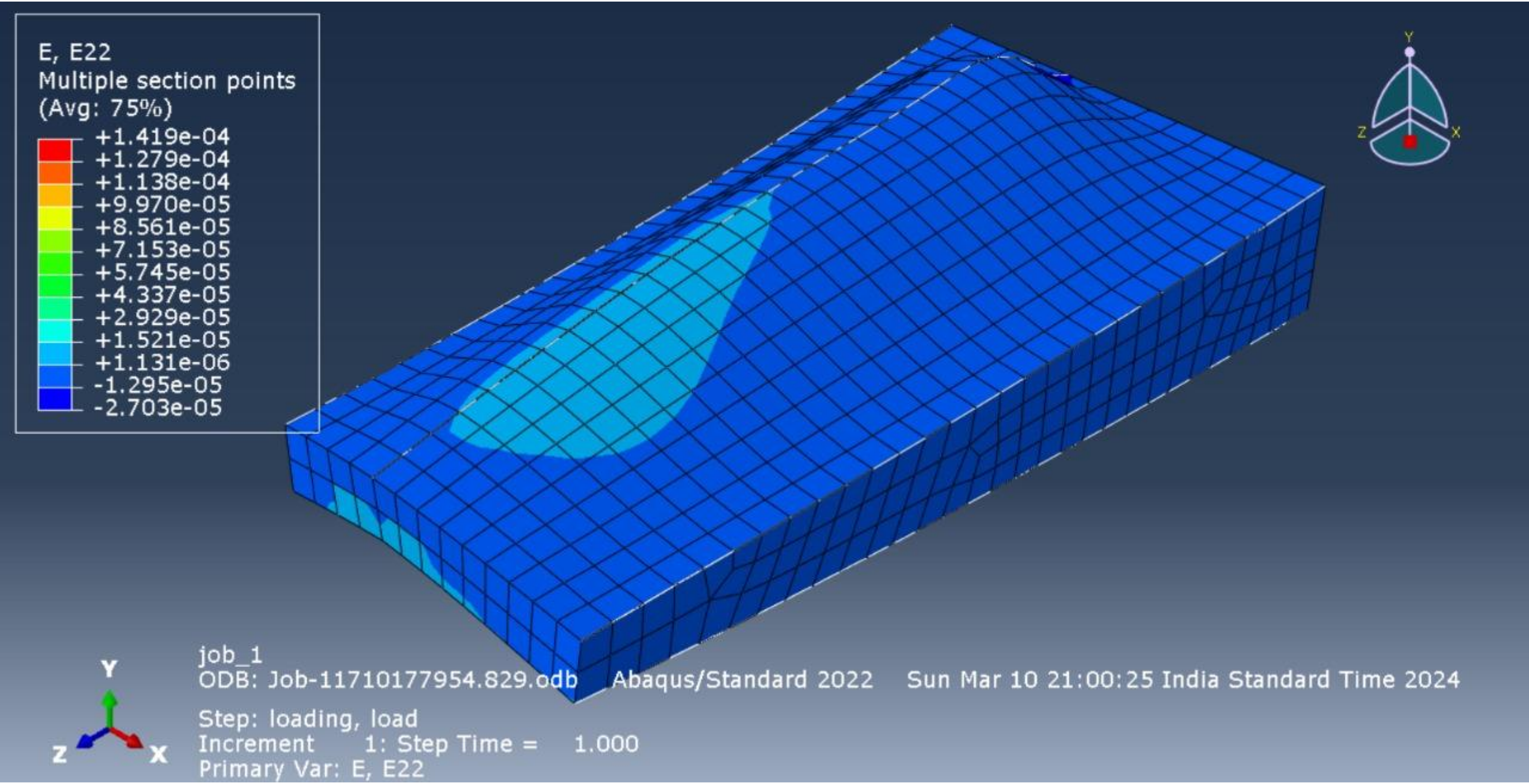

S, S12
Multiple section points
(Avg: 75%)
+2.535e+00
-1.845e-01
-2.904e+00
-5.623e+00
-8.343e+00
-1.106e+01
-1.378e+01
-1.650e+01
-1.922e+01
-2.194e+01
-2.466e+01
-2.738e+01
-3.010e+01
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: S, S12

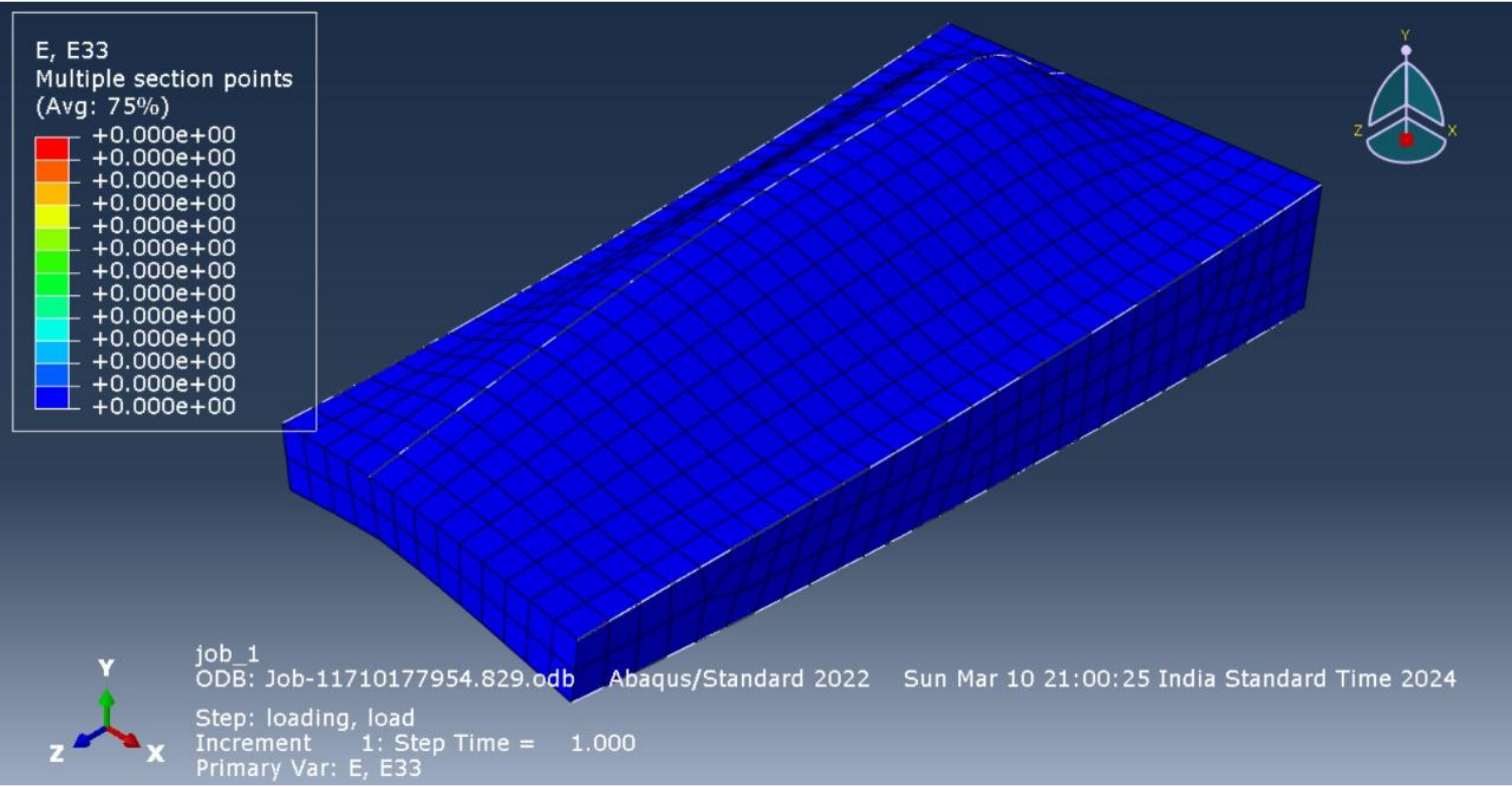
Strain Analysis:

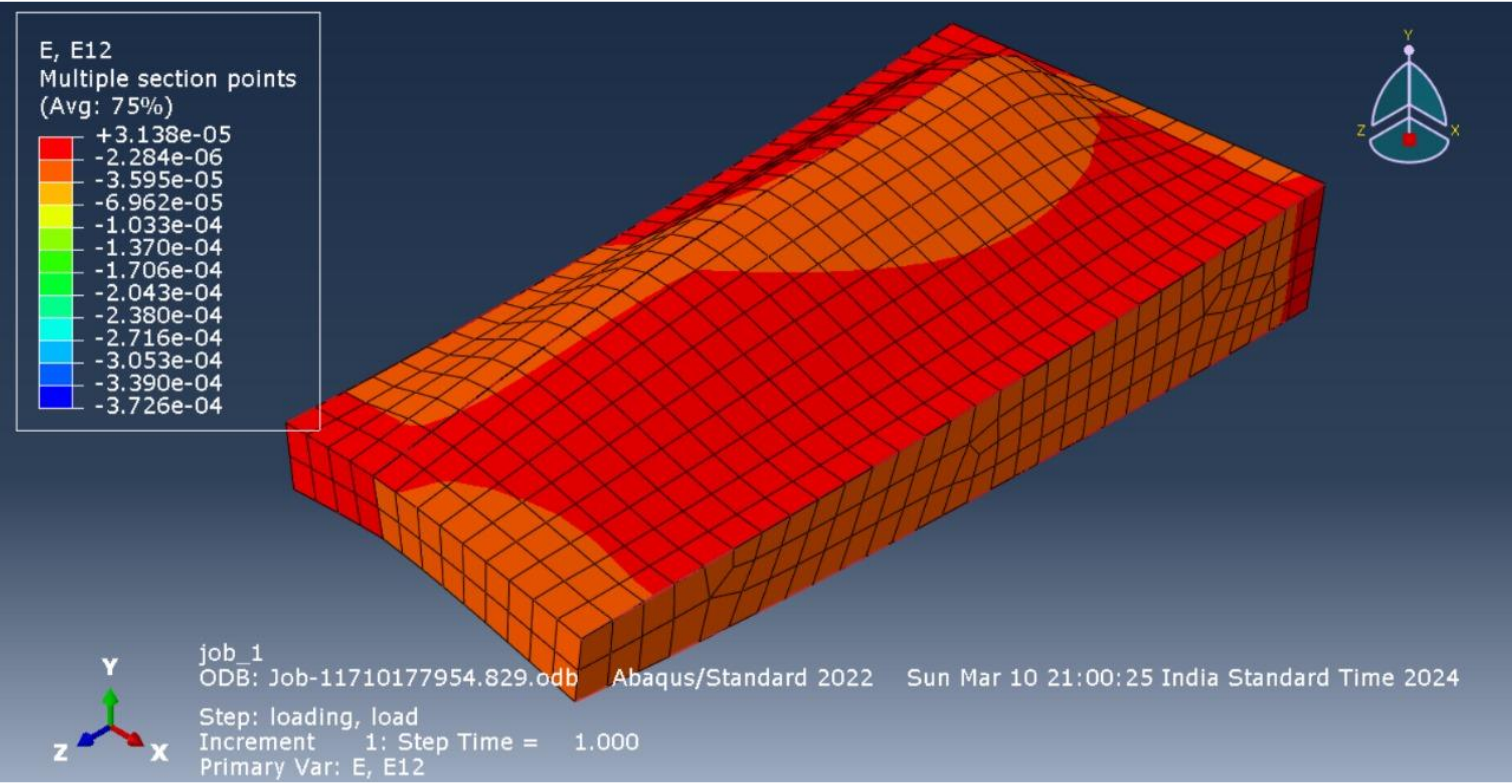



E, Min. Principal
Multiple section points
(Avg: 75%)
+0.000e+00
-1.354e-05
-2.708e-05
-4.063e-05
-5.417e-05
-6.771e-05
-8.125e-05
-9.479e-05
-1.083e-04
-1.219e-04
-1.354e-04
-1.490e-04
-1.625e-04
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: E, Min. Principal
Y
Z
X

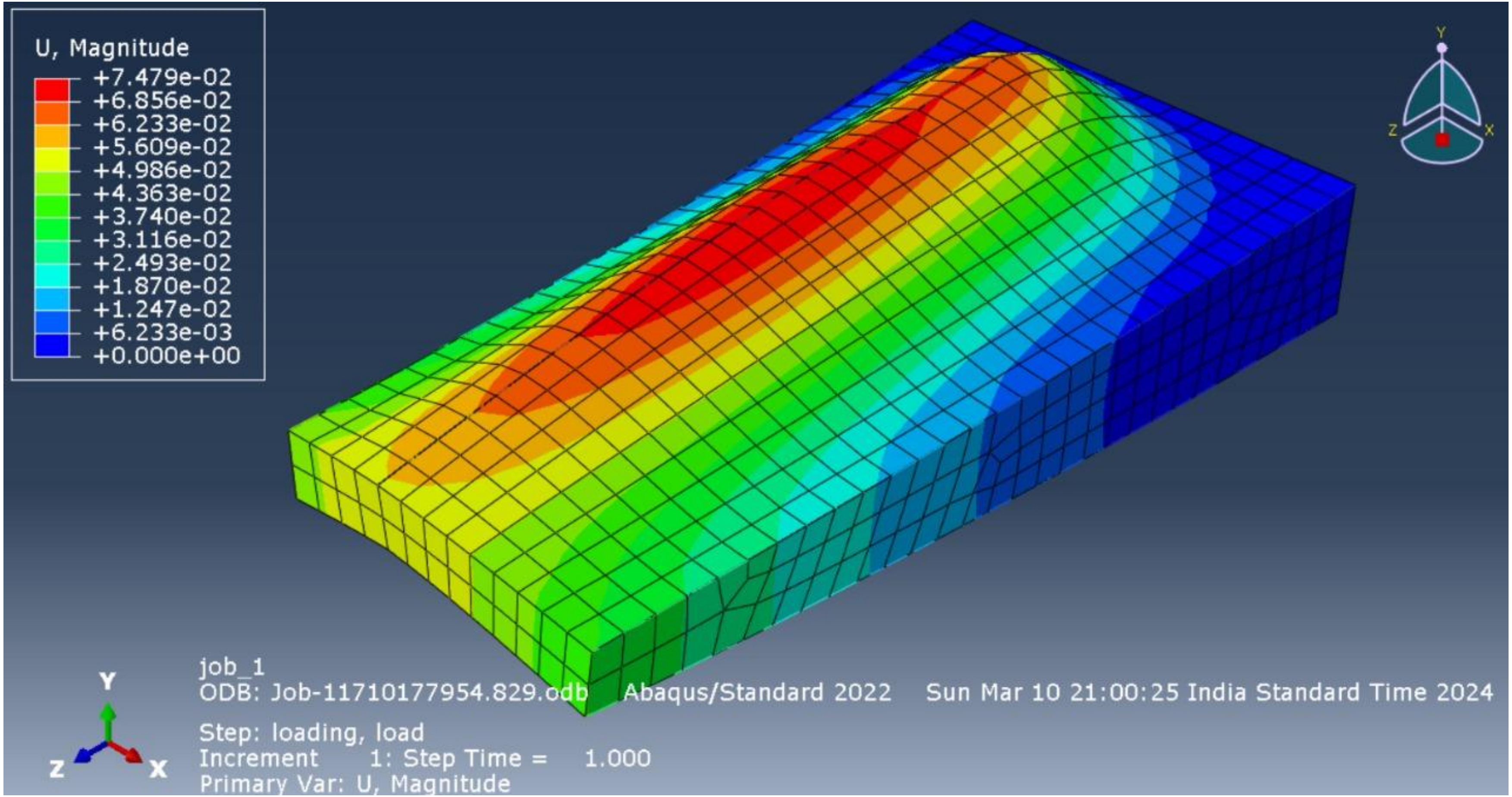

E, E11
Multiple section points
(Avg: 75%)
+1.392e-04
+1.226e-04
+1.059e-04
+8.921e-05
+7.254e-05
+5.587e-05
+3.920e-05
+2.253e-05
+5.856e-06
-1.081e-05
-2.749e-05
-4.416e-05
-6.083e-05
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: E, E11

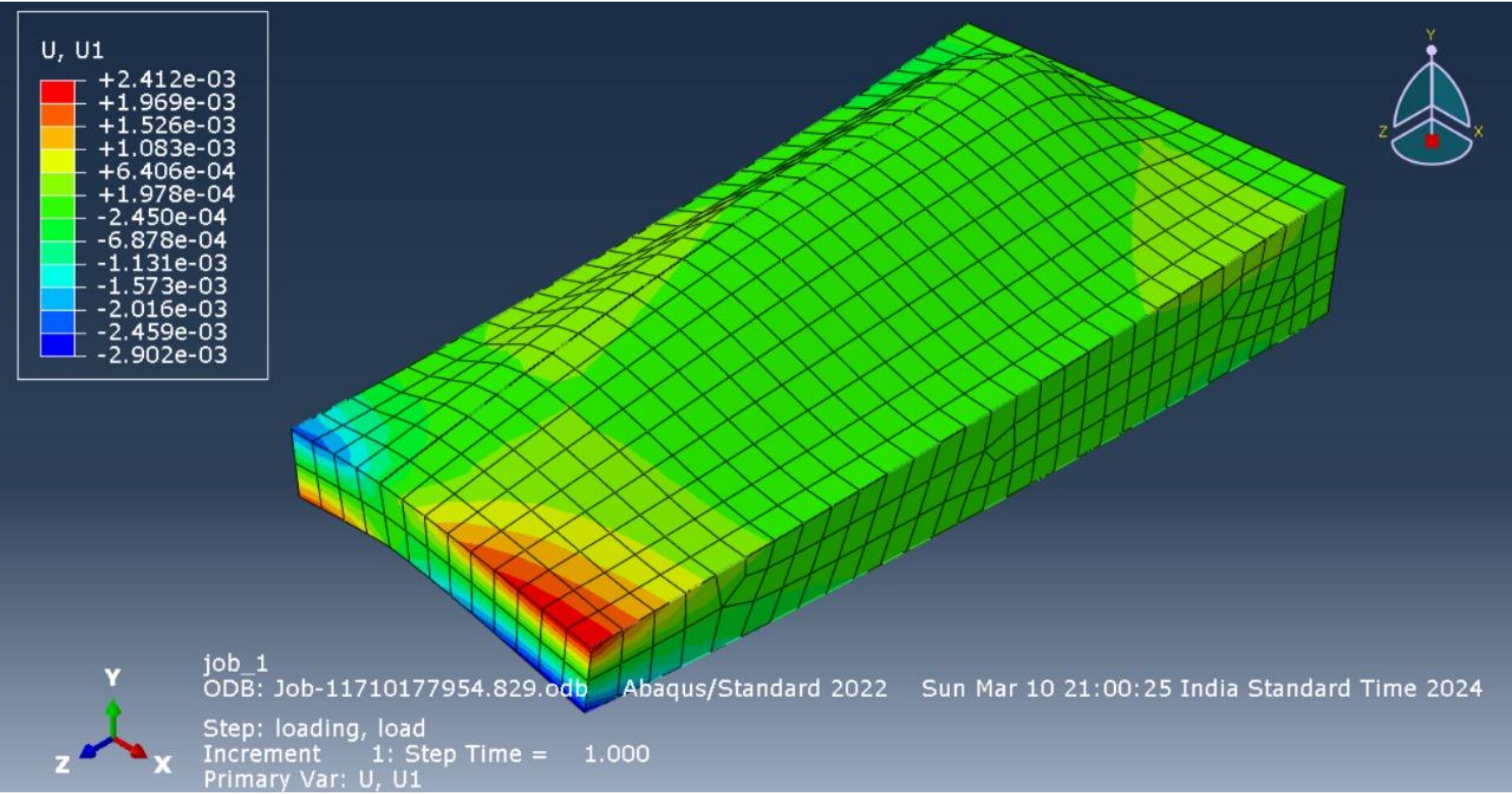

E, E22
Multiple section points
(Avg: 75%)
+1.419e-04
+1.279e-04
+1.138e-04
+9.970e-05
+8.561e-05
+7.153e-05
+5.745e-05
+4.337e-05
+2.929e-05
+1.521e-05
+1.131e-06
-1.295e-05
-2.703e-05
Y
Z
X
job_1
ODB: Job-11710177954.829.odb   Abaqus/Standard 2022   Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment   1: Step Time =   1.000
Primary Var: E, E22

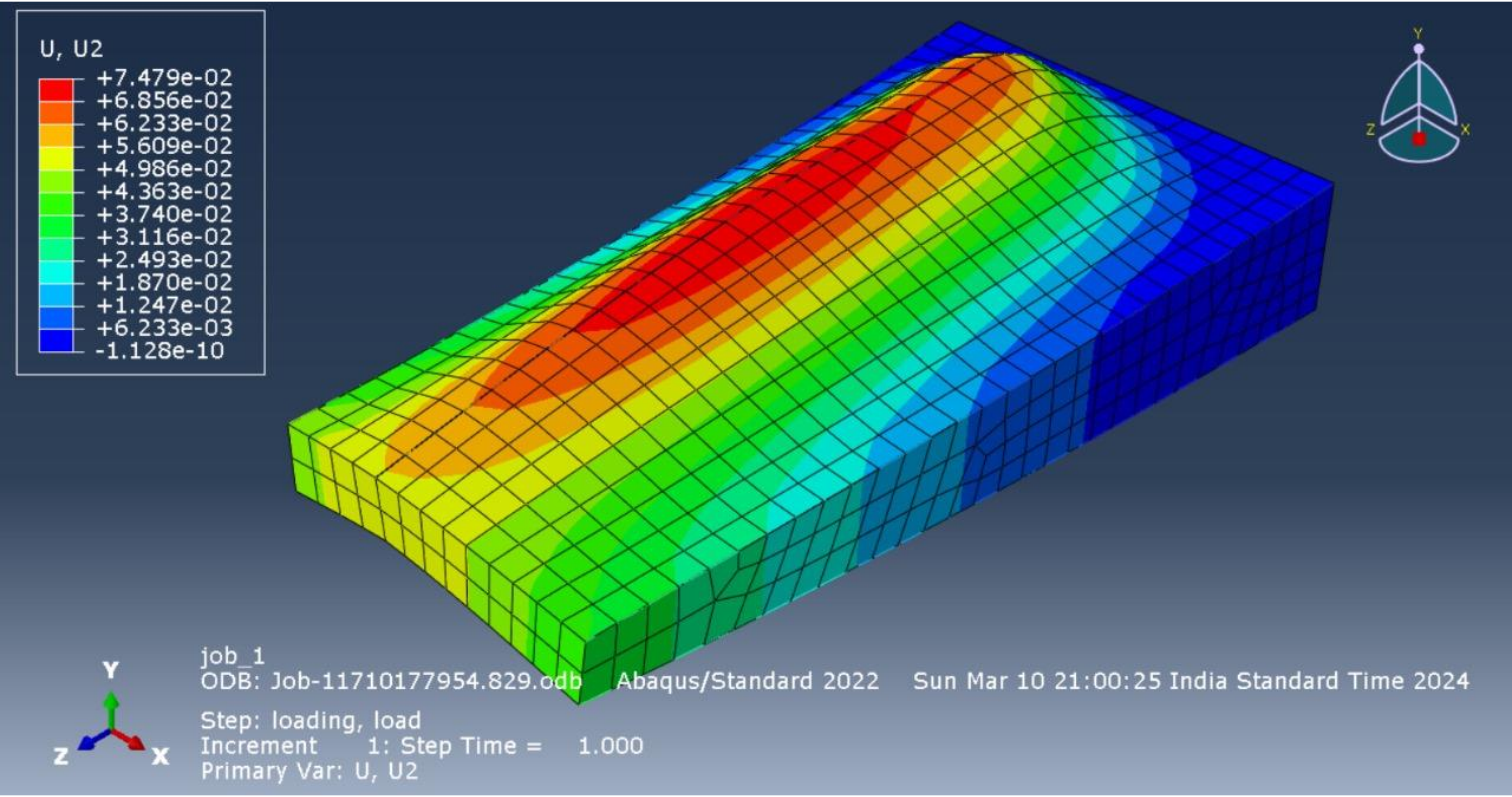

E, E33
Multiple section points
(Avg: 75%)
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
+0.000e+00
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: E, E33

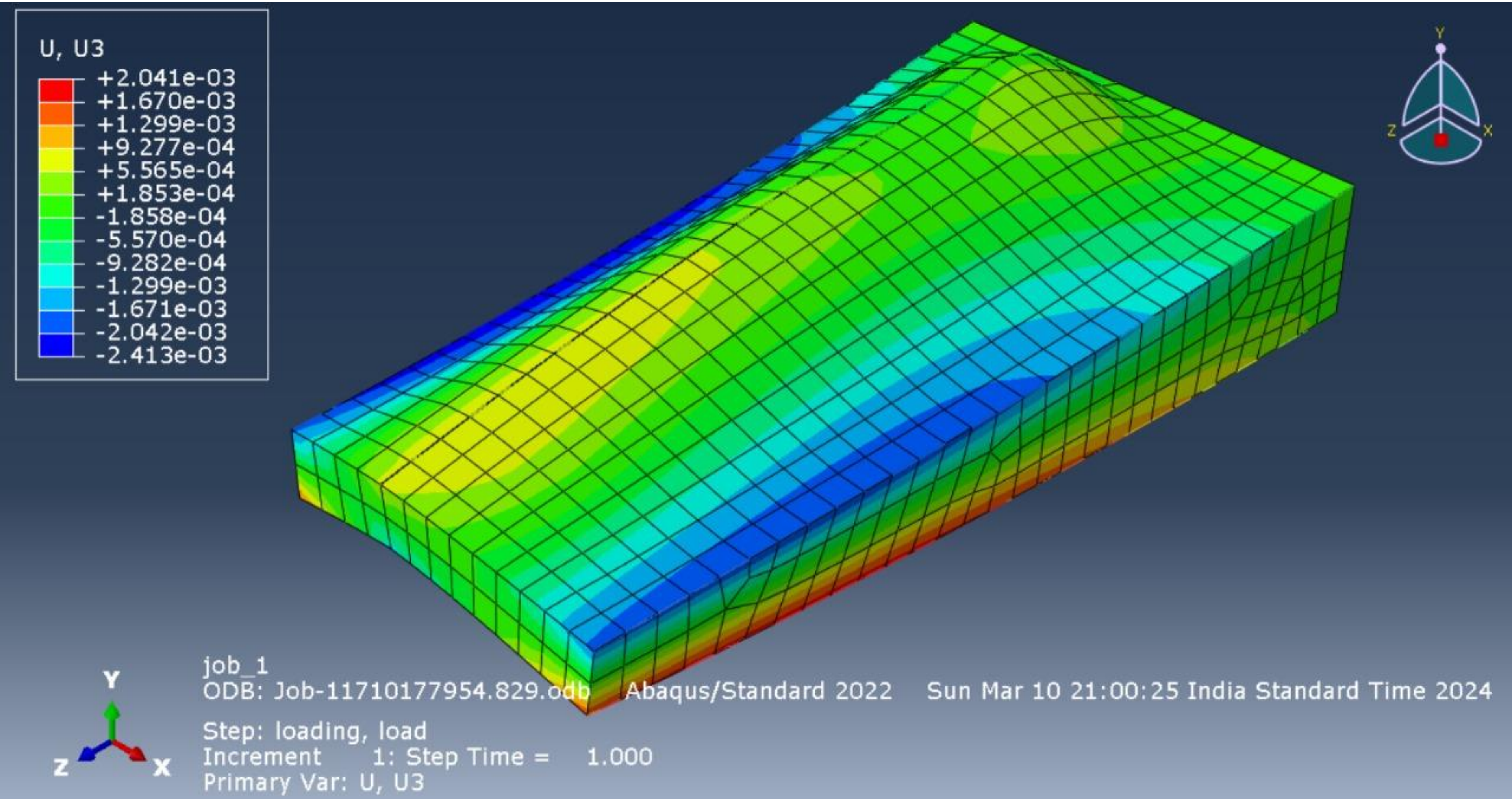

E, E12
Multiple section points
(Avg: 75%)
+3.138e-05
-2.284e-06
-3.595e-05
-6.962e-05
-1.033e-04
-1.370e-04
-1.706e-04
-2.043e-04
-2.380e-04
-2.716e-04
-3.053e-04
-3.390e-04
-3.726e-04
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: E, E12

Deflection Analysis:




U, U1
+2.412e-03
+1.969e-03
+1.526e-03
+1.083e-03
+6.406e-04
+1.978e-04
-2.450e-04
-6.878e-04
-1.131e-03
-1.573e-03
-2.016e-03
-2.459e-03
-2.902e-03
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: U, U1


U, U2
+7.479e-02
+6.856e-02
+6.233e-02
+5.609e-02
+4.986e-02
+4.363e-02
+3.740e-02
+3.116e-02
+2.493e-02
+1.870e-02
+1.247e-02
+6.233e-03
-1.128e-10
Y
Z
X
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: U, U2


U, U3
+2.041e-03
+1.670e-03
+1.299e-03
+9.277e-04
+5.565e-04
+1.853e-04
-1.858e-04
-5.570e-04
-9.282e-04
-1.299e-03
-1.671e-03
-2.042e-03
-2.413e-03
job_1
ODB: Job-11710177954.829.odb Abaqus/Standard 2022 Sun Mar 10 21:00:25 India Standard Time 2024
Step: loading, load
Increment 1: Step Time = 1.000
Primary Var: U, U3
Y
Z
X

Results Validation

At the larger cross-section

$$I_{xx} = 4 \times 600 \times 90^2 + 2 \times 900 \times 90^2 = 34.02 \times 10^6 \text{ mm}^4$$

The direct stress in a boom is given by Eq. (16.18) in which $I_{xy} = 0$ and $M_y = 0$, i.e.

$$\sigma_{z,r} = \frac{M_x y_r}{I_{xx}}$$

whence

$$P_{z,r} = \frac{M_x y_r}{I_{xx}} B_r$$

or

$$P_{z,r} = \frac{1.65 \times 10^6 y_r B_r}{34.02 \times 10^6} = 0.08 y_r B_r \qquad \text{(i)}$$

The value of $P_{z,r}$ is calculated from Eq. (i) in column ② of Table 23.2; $P_{x,r}$ and $P_{y,r}$ follow from Eqs (21.10) and (21.9), respectively in columns ⑤ and ⑥. The axial load P_r is given by $[②^2 + ⑤^2 + ⑥^2]^{1/2}$ in column ⑦ and has the same sign as $P_{z,r}$ (see Eq. (21.12)). The moments of $P_{x,r}$ and $P_{y,r}$, columns ⑩ and ⑪, are calculated for a moment centre at the mid-point of the internal web taking anticlockwise moments as positive.
From column ⑤

$$\sum_{r=1}^{6} P_{x,r} = 0$$

(as would be expected from symmetry).
From column ⑥

$$\sum_{r=1}^{6} P_{y,r} = 764.4 \text{ N}$$

From column ⑩

$$\sum_{r=1}^{6} P_{x,r}\eta_r = -117\,846 \text{ N mm}$$

From column ⑪

$$\sum_{r=1}^{6} P_{y,r}\xi_r = -43\,680 \text{ N mm}$$

From Eq. (21.15)

$$S_{x,w} = 0 \quad S_{y,w} = 10 \times 10^3 - 764.4 = 9235.6 \text{ N}$$

Also, since Cx is an axis of symmetry, $I_{xy} = 0$ and Eq. (20.6) for the 'open section' shear flow reduces to

$$q_b = -\frac{S_{y,w}}{I_{xx}} \sum_{r=1}^{n} B_r y_r$$

or

$$q_b = -\frac{9235.6}{34.02 \times 10^6} \sum_{r=1}^{n} B_r y_r = -2.715 \times 10^{-4} \sum_{r=1}^{n} B_r y_r \qquad \text{(ii)}$$

'Cutting' the top walls of each cell and using Eq. (ii), we obtain the q_b distribution shown in Fig. 23.13. Evaluating δ for each wall and substituting in Eq. (23.10) gives for cell I

$$\frac{d\theta}{dz} = \frac{1}{2 \times 36\,000G}(760 q_{s,0,\mathrm{I}} - 180 q_{s,0,\mathrm{II}} - 1314) \qquad \text{(iii)}$$

for cell II

$$\frac{d\theta}{dz} = \frac{1}{2 \times 72\,000G}(-180 q_{s,0,\mathrm{I}} + 1160 q_{s,0,\mathrm{II}} + 1314) \qquad \text{(iv)}$$

Taking moments about the mid-point of web 25 we have, using Eq. (23.13)

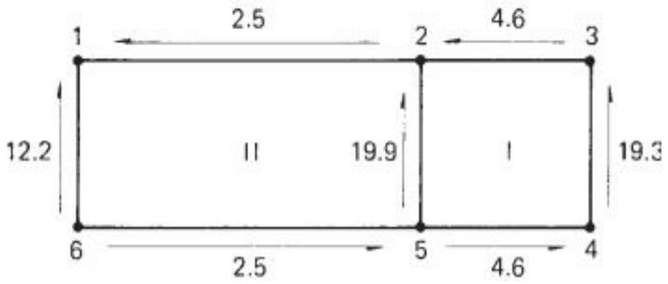
$$0 = -14.7 \times 180 \times 400 + 14.7 \times 180 \times 200 + 2 \times 36\,000 q_{s,0,\mathrm{I}} + 2 \times 72\,000 q_{s,0,\mathrm{II}} \\ -117\,846 - 43\,680$$

or

$$0 = -690\,726 + 72\,000 q_{s,0,\mathrm{I}} + 144\,000 q_{s,0,\mathrm{II}} \qquad \text{(v)}$$

Resultant Distribution of Shear Flow:

① Boom	② $P_{z,r}$ (N)	③ $\frac{\delta_{x_r}}{\delta_z}$	④ $\frac{\delta_{y_r}}{\delta_z}$	⑤ $P_{x,r}$ (N)	⑥ $P_{y,r}$ (N)	⑦ P_r (N)	⑧ ξ_r (mm)	⑨ η_r (mm)	⑩ $P_{x,r}\eta_r$ (N mm)	⑪ $P_{y,r}\xi_r$ (N mm)
1	2619.0	0	0.0417	0	109.2	2621.3	400	90	0	43 680
2	3928.6	0.0833	0.0417	327.3	163.8	3945.6	0	90	−29 457	0
3	2619.0	0.1250	0.0417	327.4	109.2	2641.6	200	90	−29 466	21 840
4	−2619.0	0.1250	−0.0417	−327.4	109.2	−2641.6	200	90	−29 466	21 840
5	−3928.6	0.0833	−0.0417	−327.3	163.8	−3945.6	0	90	−29 457	0
6	−2619.0	0	−0.0417	0	109.2	−2621.3	400	90	0	−43 680



Insights:

1. Material Behavior:

   Material properties such as modulus of elasticity, yield strength, and Poisson's ratio significantly influence stress and strain distributions.

   Higher modulus of elasticity leads to stiffer behavior and lower deflections under load.

   Variations in material properties, such as defects or imperfections, can cause localized stress concentrations.

   Understanding material behavior allows for optimization of material selection to improve overall structural performance.

Insights:

2. Structural Integrity:

   Critical points of stress concentrations often occur at areas subjected to high loads.

   Stress concentrations can lead to material failure or fatigue over time, impacting structural integrity.

   Simulation results provide insights into potential failure modes such as yielding, buckling, or fracture, aligning with theoretical expectations.

Insights:

3. Performance Enhancement:

   Design modifications such as adding ribs or reinforcements can enhance structural performance by distributing loads more effectively.

   Enhancing geometric features to promote uniform stress distribution can improve overall structural integrity and longevity.

   Performance enhancements based on FEA insights lead to more resilient and reliable structures in service.

Thank You