Euler Buckling Load analysis with Southwell's Plot

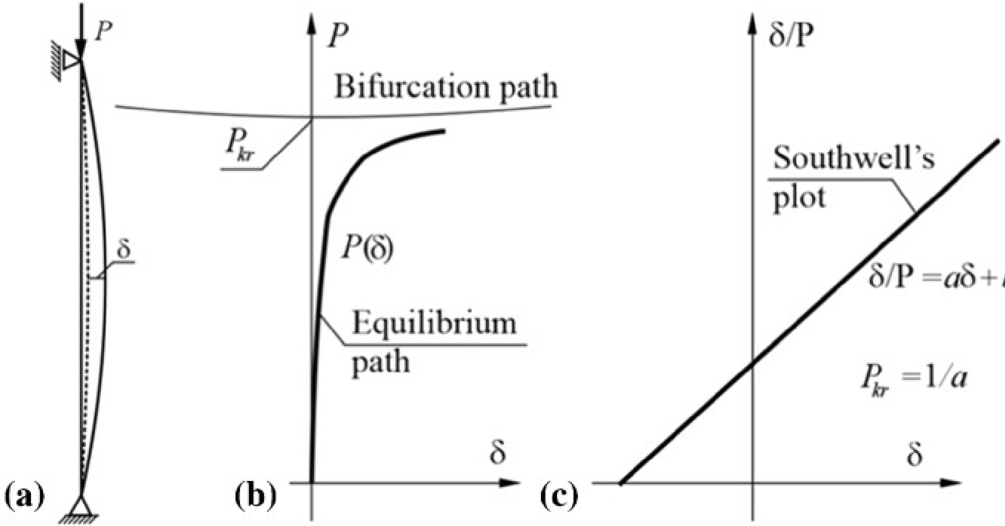
AS2070 Course Project (Group G)

Importance of Buckling

- Aerospace structures, such as aircraft fuselages, wings, and spacecraft components, are designed to be as lightweight as possible to maximize fuel efficiency, payload capacity, and overall performance.
- Understanding and accurately predicting buckling behavior allows engineers to design structures that are just strong enough to withstand the expected loads without excessive weight.

Importance of Southwell’s Plot

- **Non-Destructive Testing:** The primary importance of the Southwell plot lies in its ability to predict the critical buckling load (Pcr) from experimental data obtained at loads *below* the critical load. This avoids the risk of damaging the structure during testing.
- **Estimation of Critical Load:** It provides a practical way to estimate the theoretical buckling load, which might not be achievable in a real experiment due to material yielding or other non-linear effects.



Specimen Fabrication

- Scrap Material (Sheet Metal) of varying thickness were found in the Workshop
- The Sheet Metal was measured and cut with the help of a Bench Shear
- Holes were drilled for nut to be attached with the Buckling Apparatus
- Specimens were 70cm x 2cm x 1mm, 70cm x 2cm x 0.5mm and one with varying breadth as 7cm x (1.8cm to 2.5cm) x 2mm

Bench Shear

Experiment Apparatus

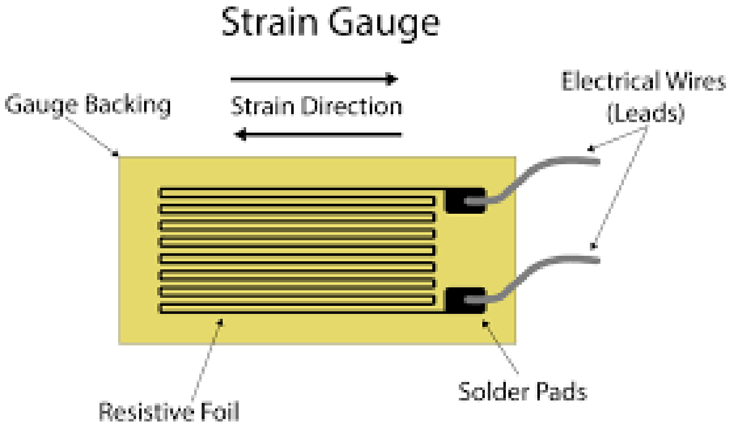
- The specimen is fixed within both supports
- Dial Gauge and Strain Gauge were used to measure the central deflection

SM1005 Euler Buckling Apparatus

Strain and Dial Gauge

- The deflection at the tip of the gauge is compressed, thereby measuring the deflection on the scale
- The magnetic base secured the gauge to the ground in order to resist the deflection

- The Strain Gauge can be used to derive the deflection in the beam by measuring the strain of the beam at the point where its placed in the direction of the angle at which it is placed



Southwell's Plots

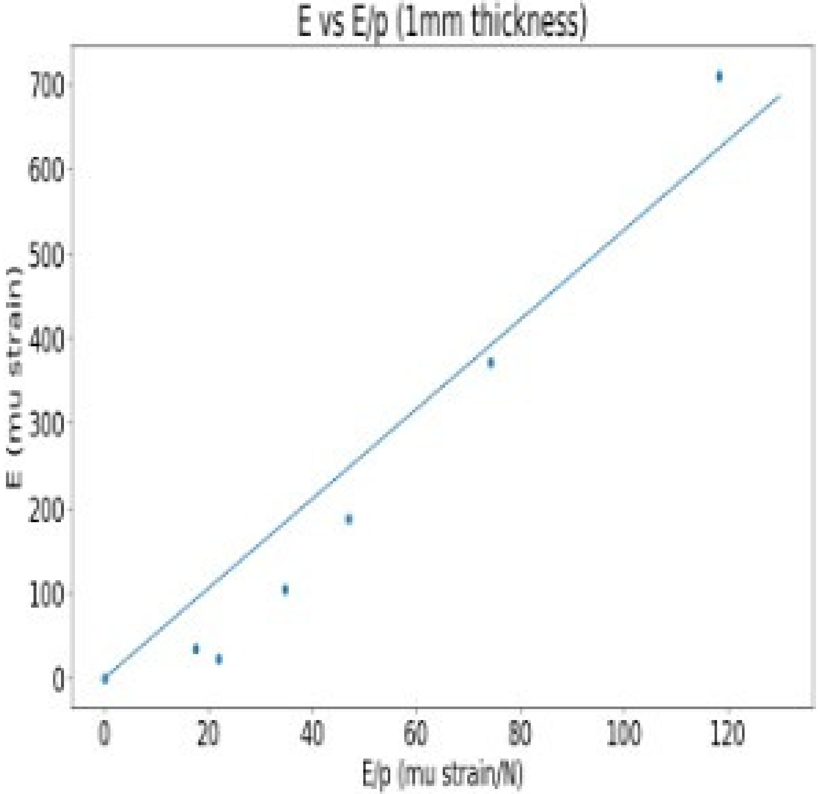
- Out of the readings taken , we obtain two plots for two beams

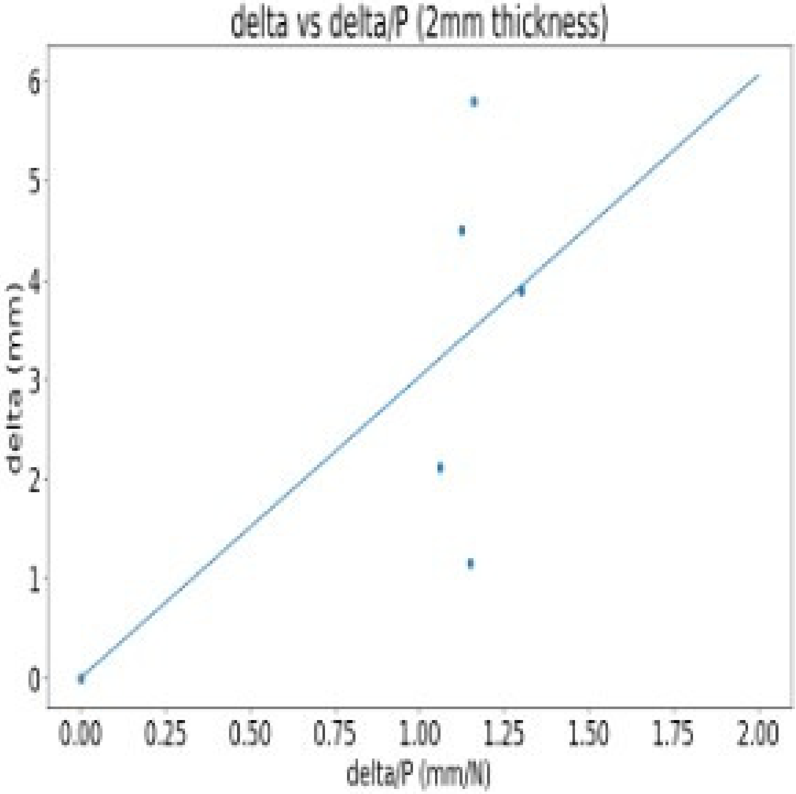
Load (N)	Strain ($\mu\epsilon$)
0	0
1	22
2	35
3	104
4	188
5	372
6	710

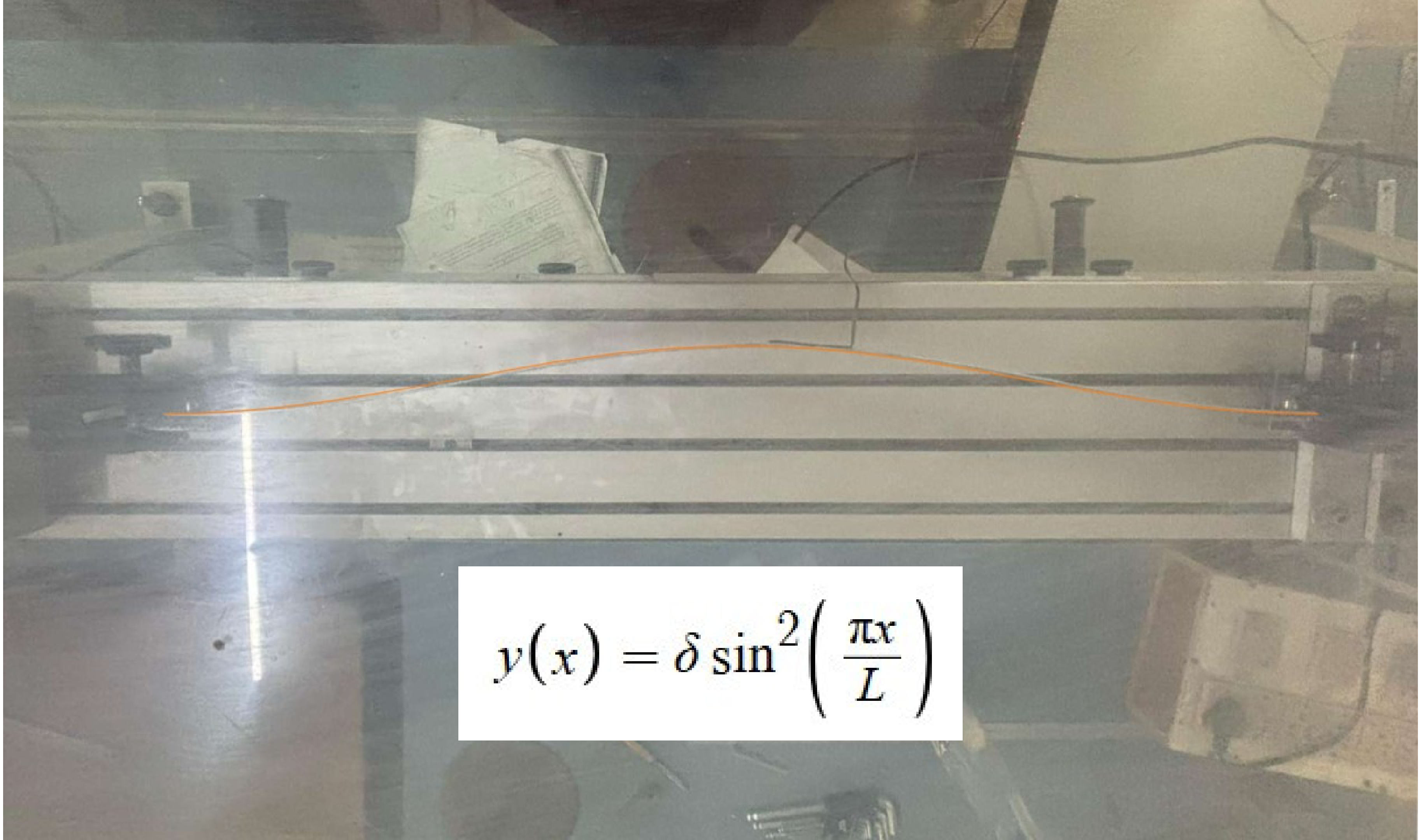
Table 1: Strain vs Load 1mm

Load (N)	Deflection (mm)
0	0
1	1.15
2	2.12
3	3.9
4	4.5
5	5.8

Table 2: Load vs Deflection 2mm


E vs E/p (1mm thickness)
E (mu strain)
E/p (mu strain/N)
0
100
200
300
400
500
600
700
0
20
40
60
80
100
120


delta vs delta/P (2mm thickness)
delta (mm)
delta/P (mm/N)
0
1
2
3
4
5
6
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

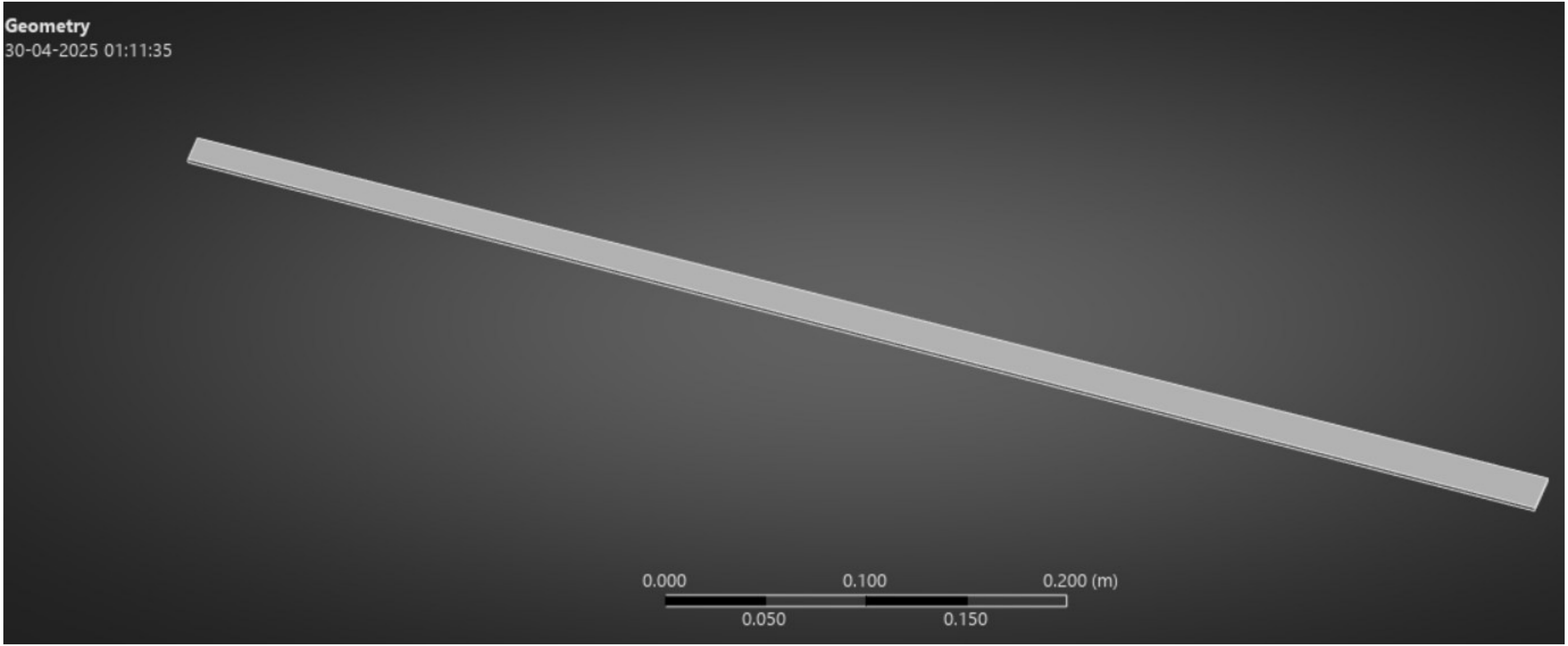

$$y(x) = \delta \sin^2\left(\frac{\pi x}{L} \right)$$

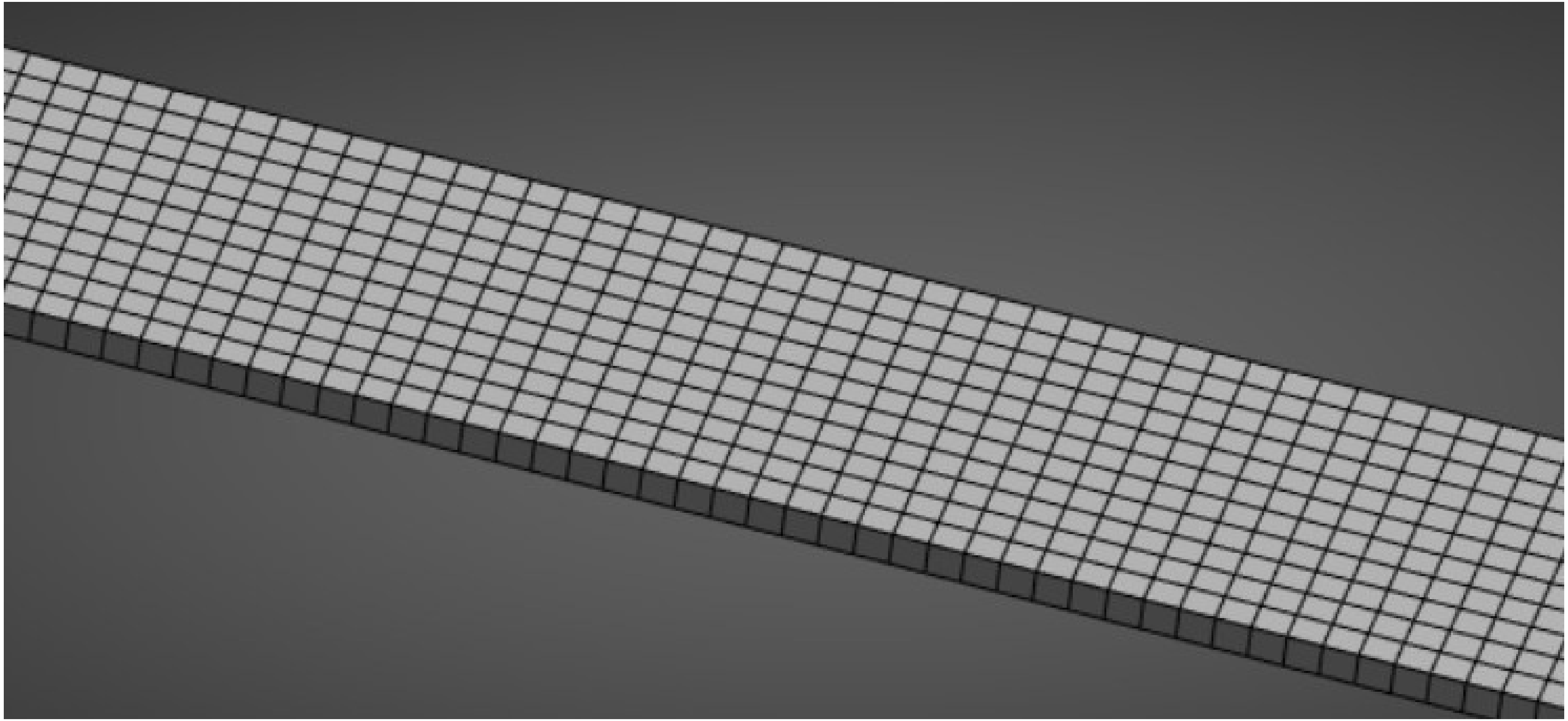
Errors and Observations

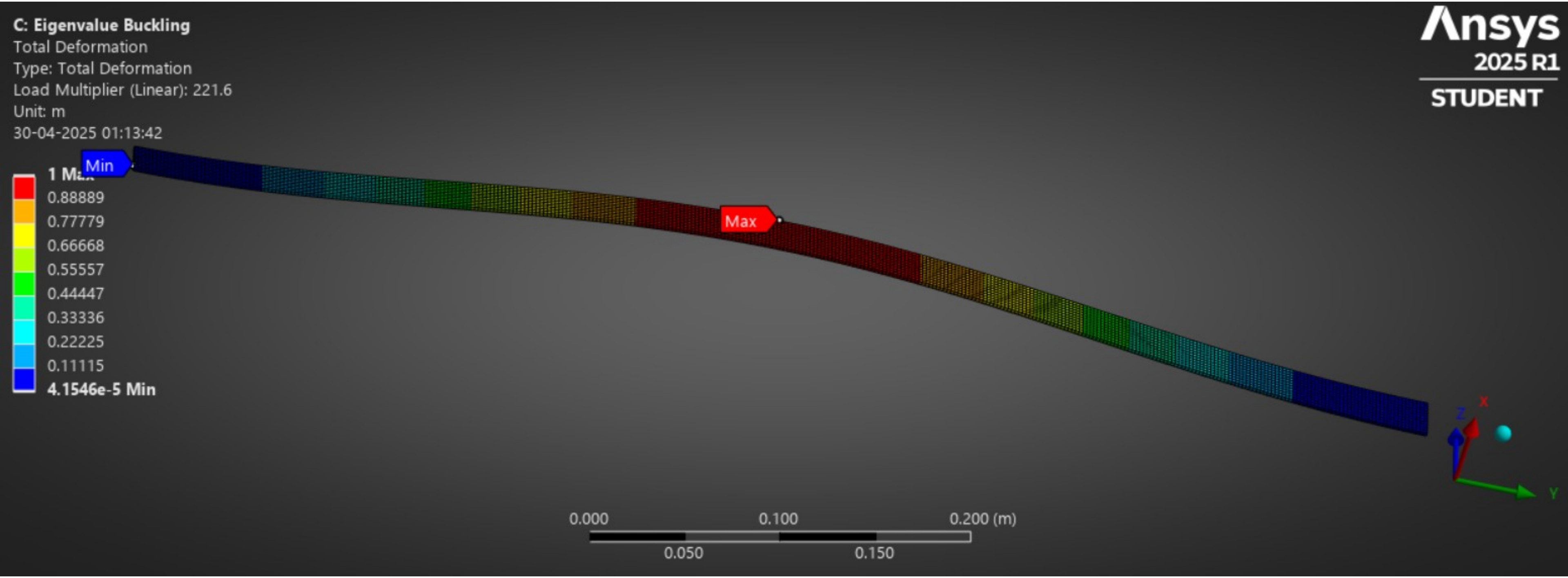
- Errors may have originated from geometric tolerances, manufacturing defects, equipment defects, and theoretical assumptions used.
- Error in beam dimensions were reasonably significant
- Dial gauge was sensitive to base vibrations
- Beams were partially pre-buckled due to material defects.

- Saw machine cannot be used to cut specimens as thin bodies cause excessive vibrations when operating the machinery
- Bench Shear was used instead
- Buckling Apparatus requires beam of minimum length ~65cm
- Any beam of thickness <1mm results in the critical load to go below the least count of both gauges.

FEA Simulations

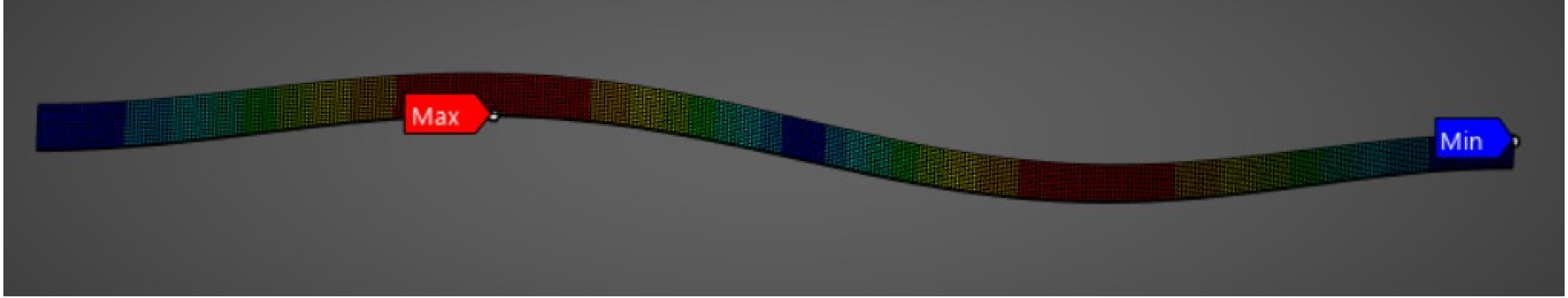


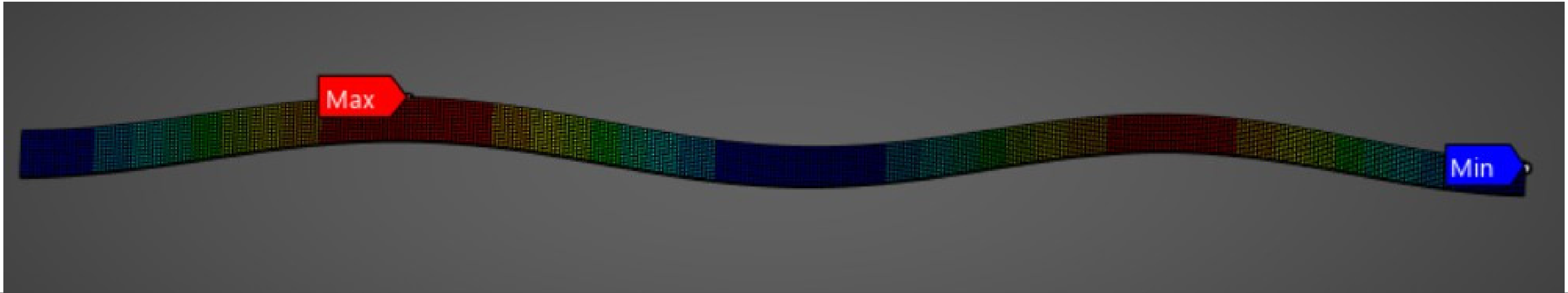



C: Eigenvalue Buckling
Total Deformation
Type: Total Deformation
Load Multiplier (Linear): 221.6
Unit: m
30-04-2025 01:13:42
1 Max
0.88889
0.77779
0.66668
0.55557
0.44447
0.33336
0.22225
0.11115
4.1546e-5 Min
Min
Max
Ansys
2025 R1
STUDENT
0.000
0.100
0.200 (m)
0.050
0.150
Z
X
Y

Model and Results

- Element size: 2mm
- Critical Load: 221.6 N
- 28.8k Nodes, 3.8k elements
- Higher stress concentration lies slightly on the thicker side of the beam


Max
Min


Max
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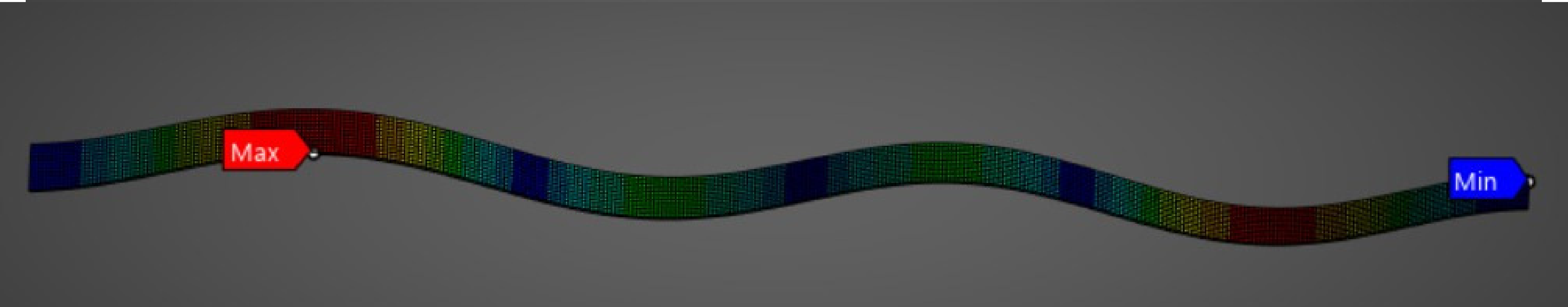
Max
Min