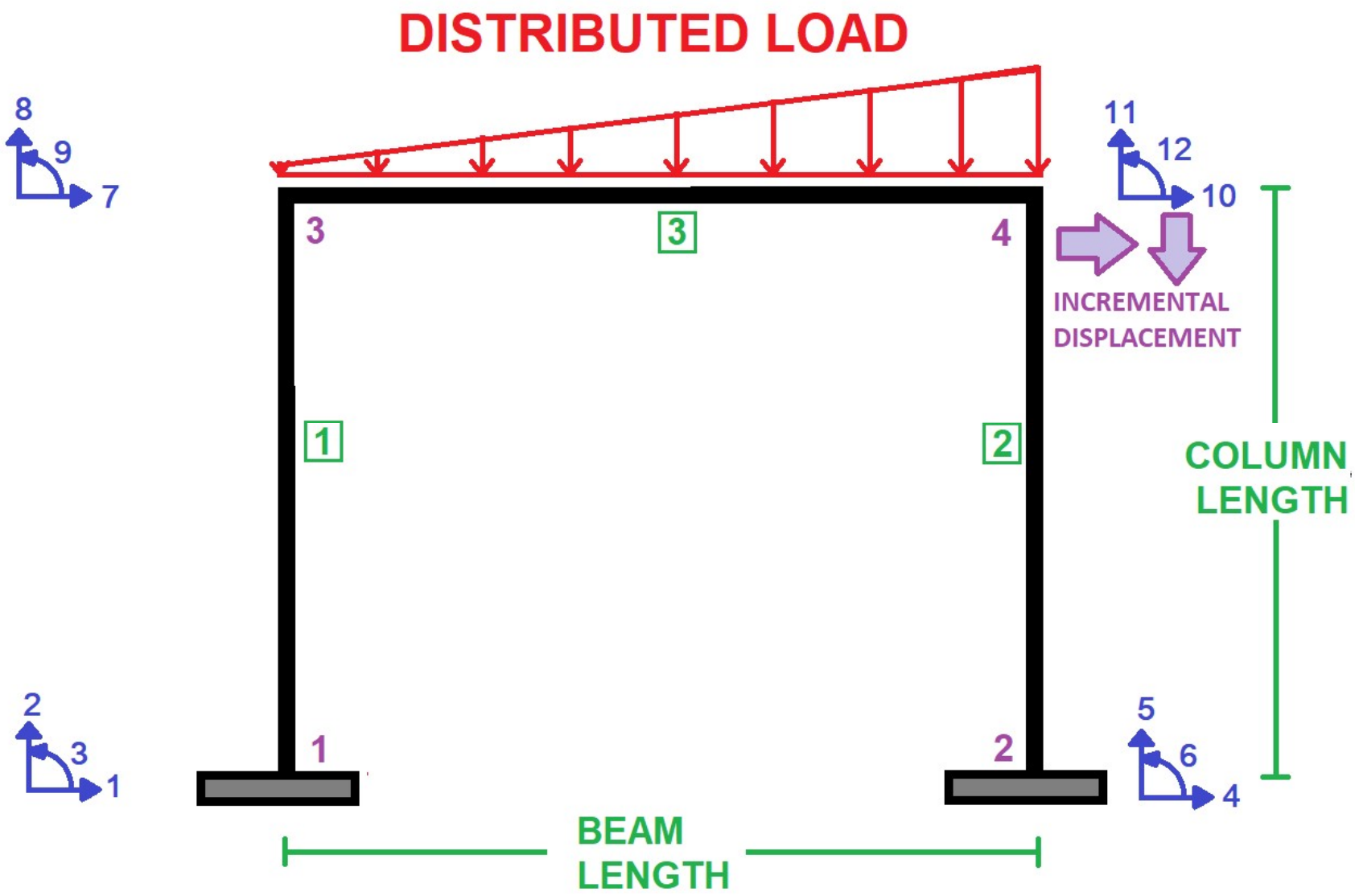
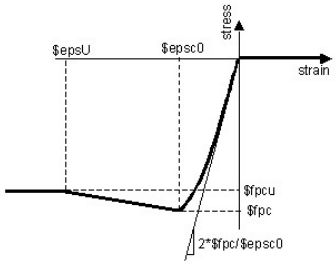
IN THE NAME OF ALLAH

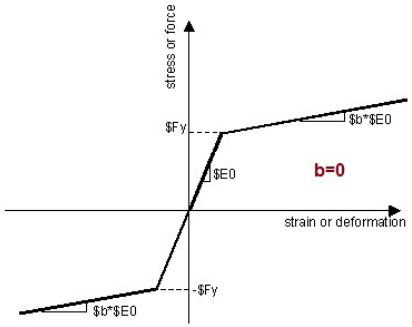
PROGRESSIVE COLLAPSE ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENSEES. DISPLACEMENT CONTROL

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

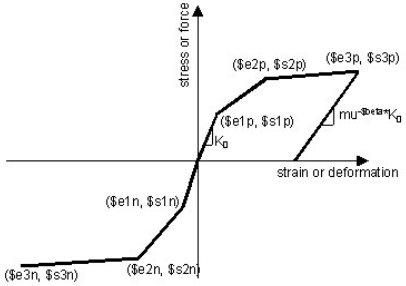

DISTRIBUTED LOAD
8
9
7
11
12
10
3
3
4
INCREMENTAL
DISPLACEMENT
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH



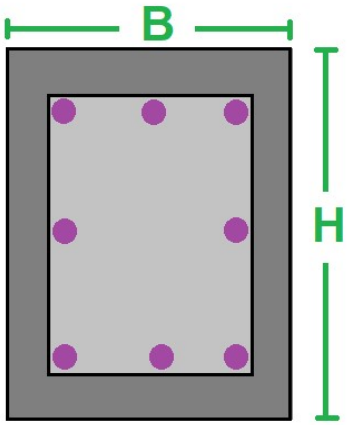
CORE AND COVER CONCRETE REALTION



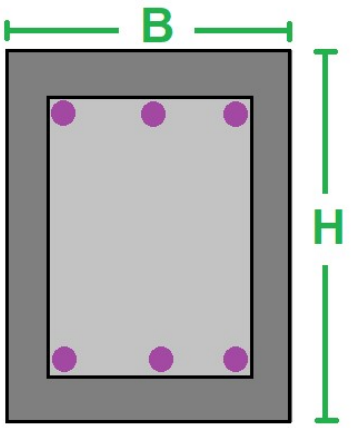
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN

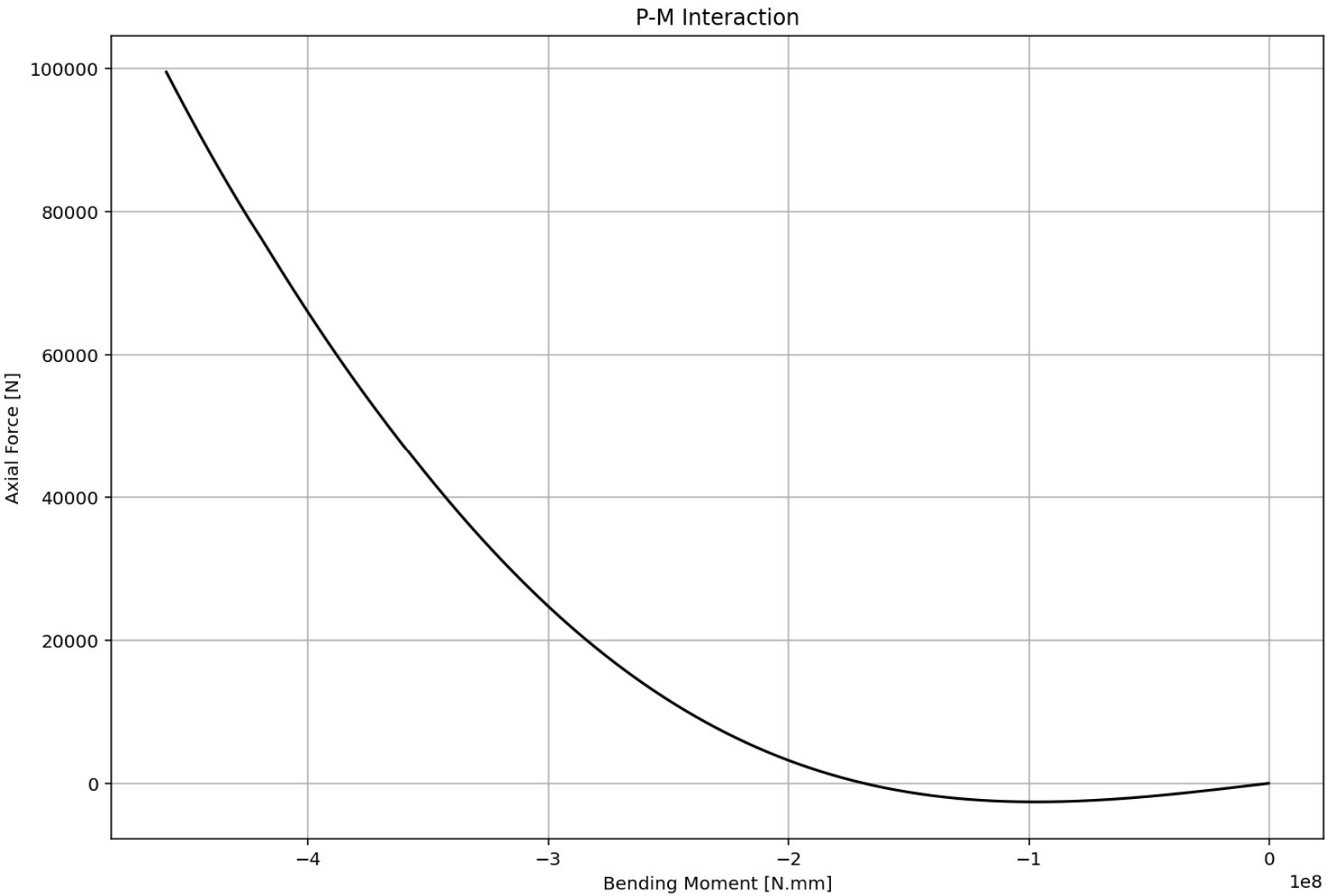


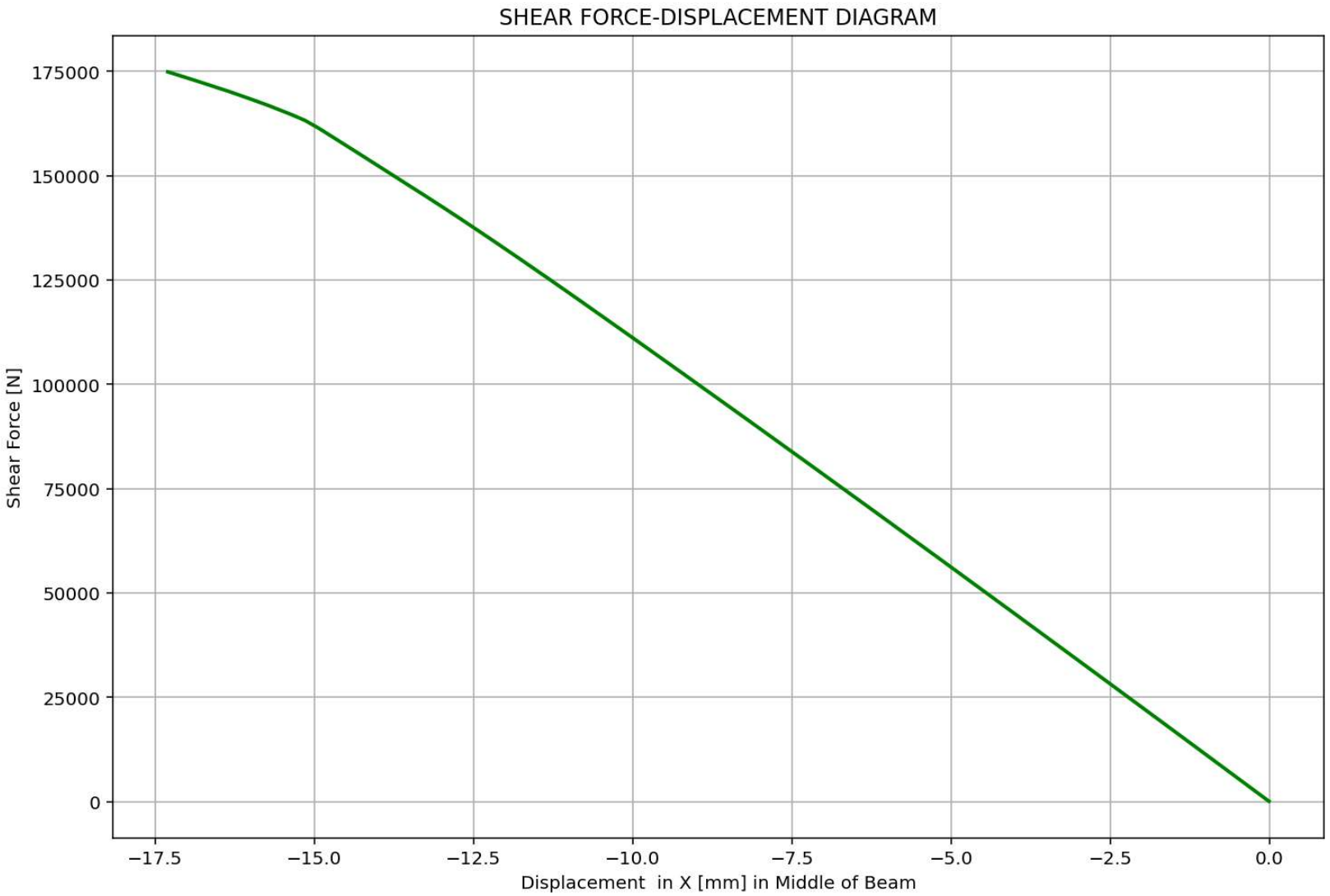
COLUMN SECTION

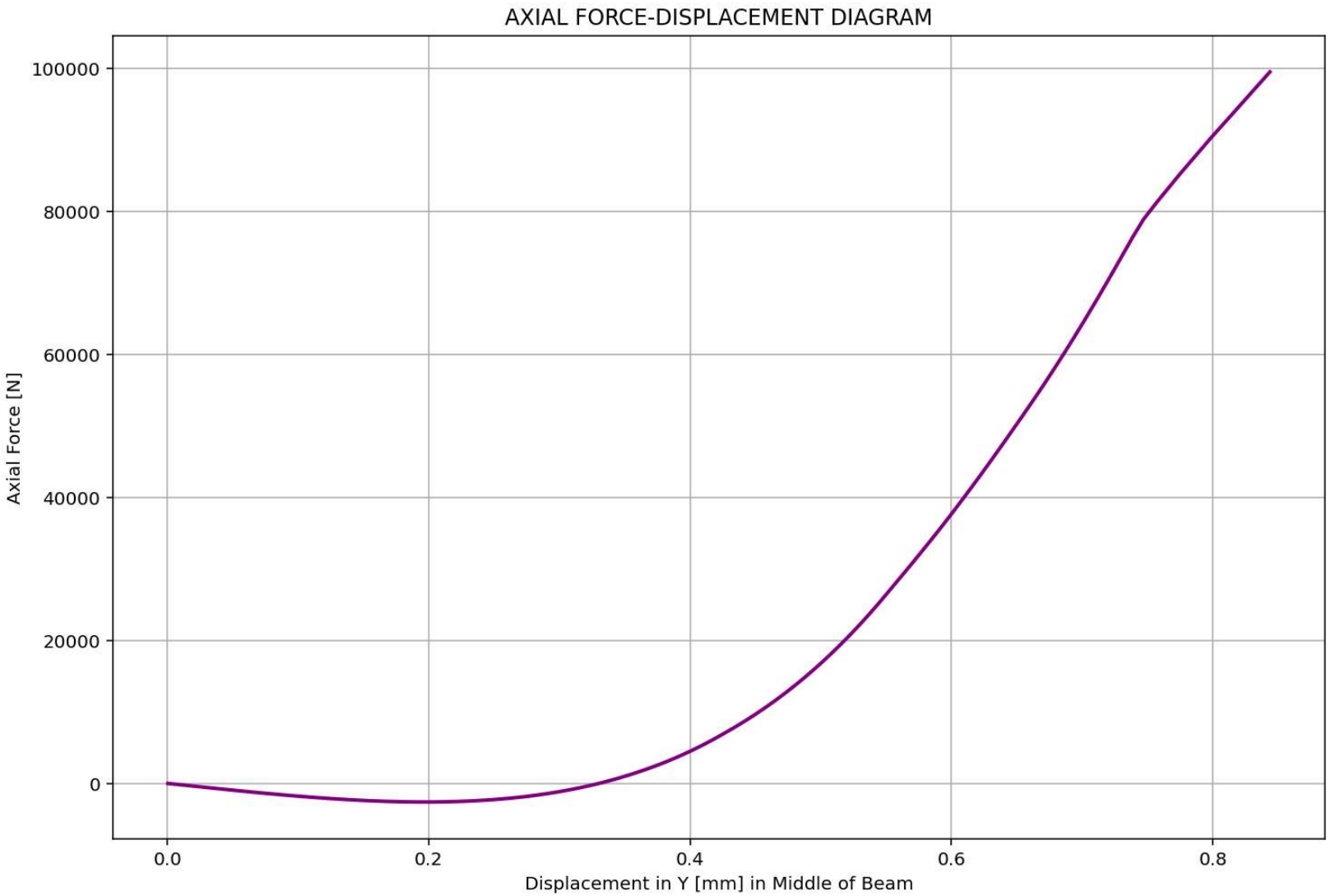


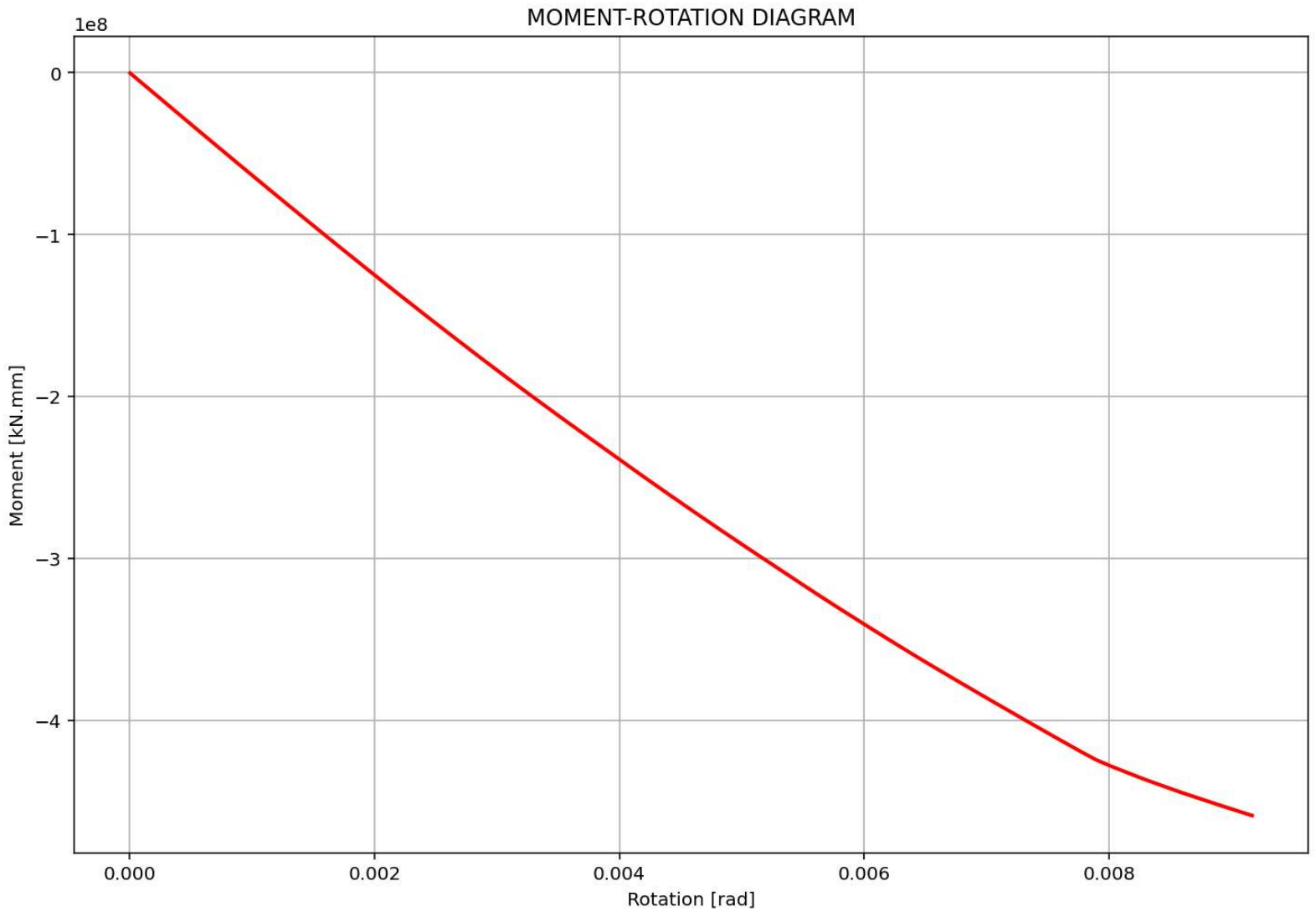
BEAM SECTION

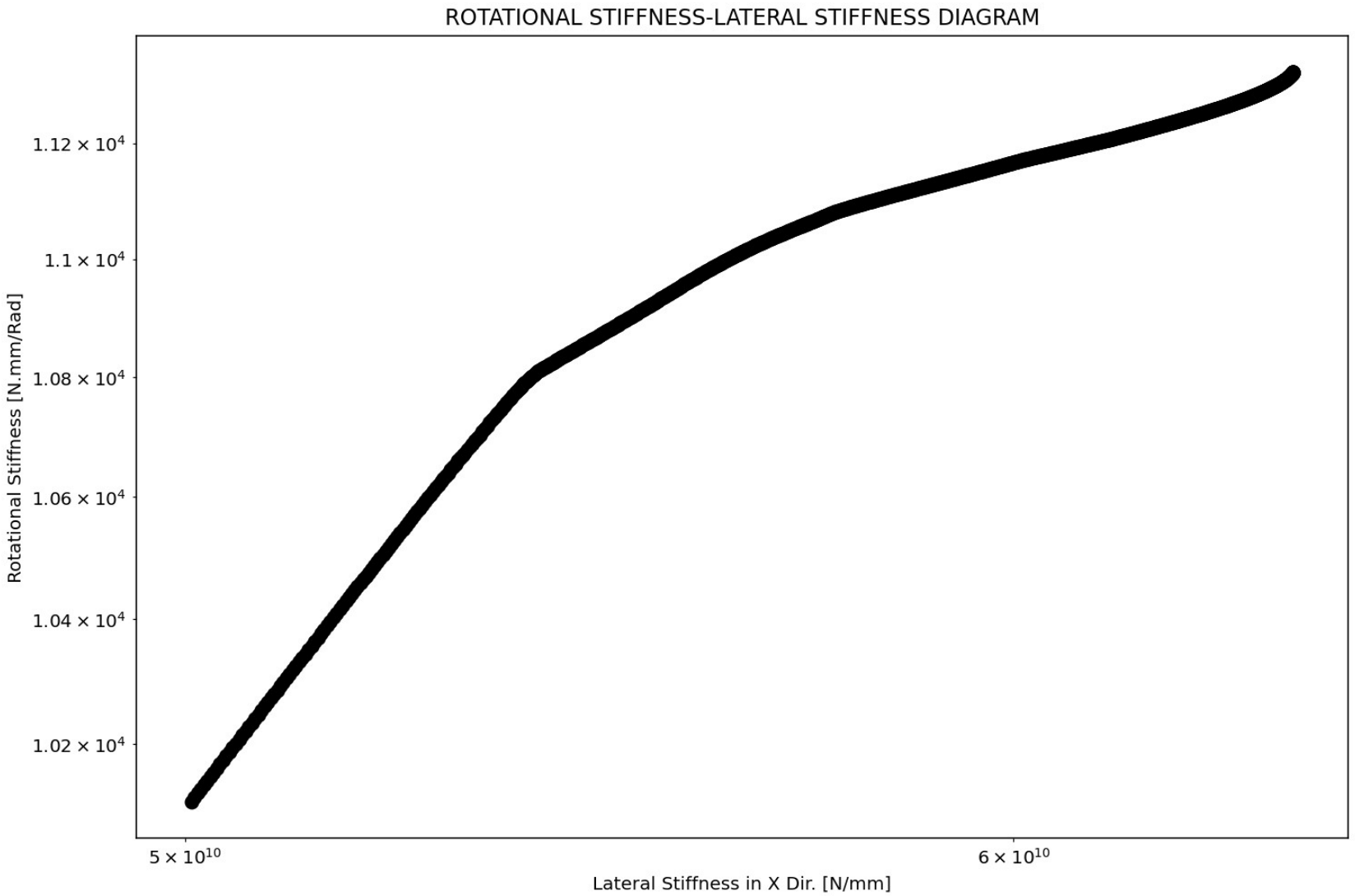
DISPLACEMENT CONTROL

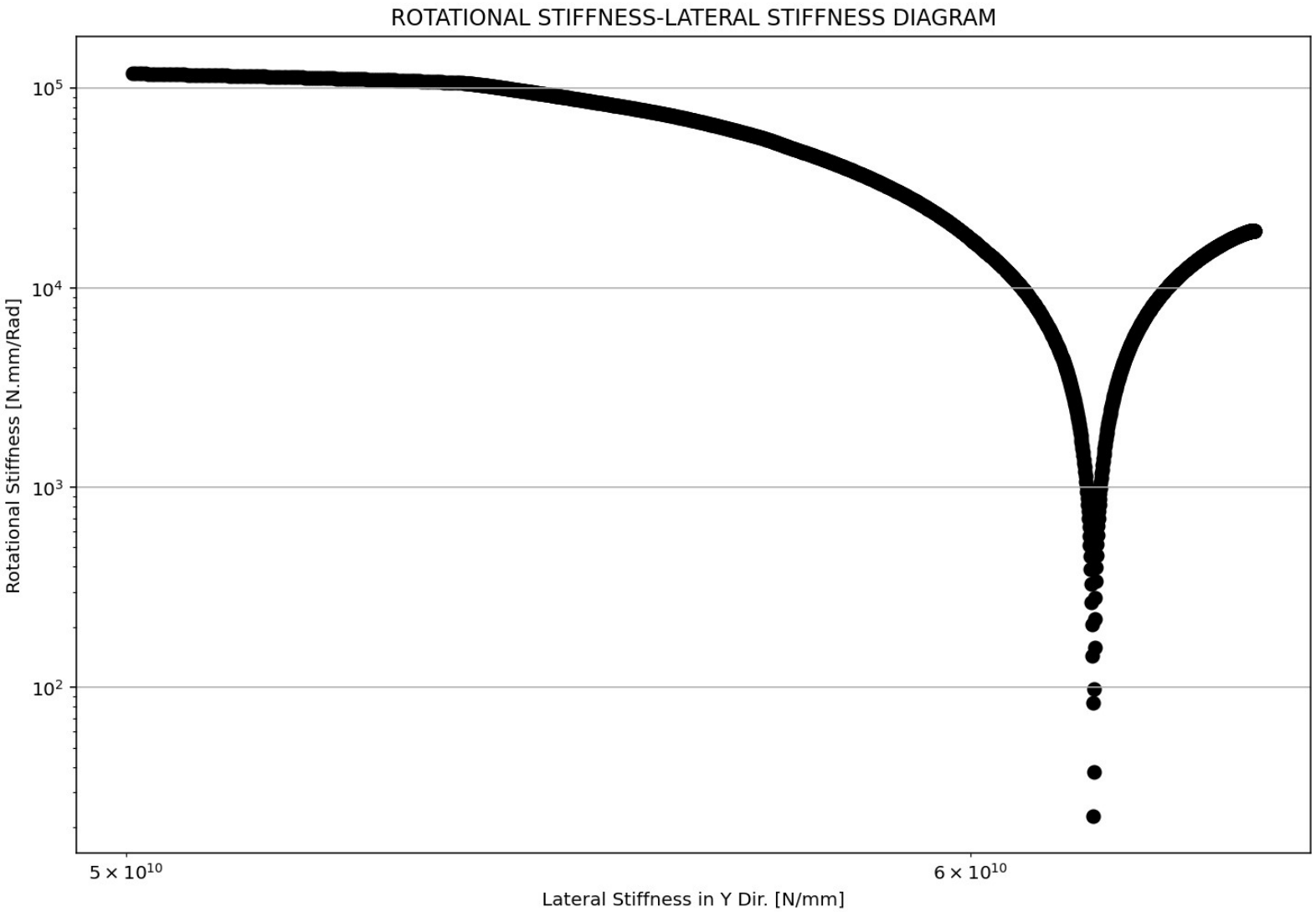

P-M Interaction
Axial Force [N]
100000
80000
60000
40000
20000
0
−4
−3
−2
−1
0
Bending Moment [N.mm]
1e8

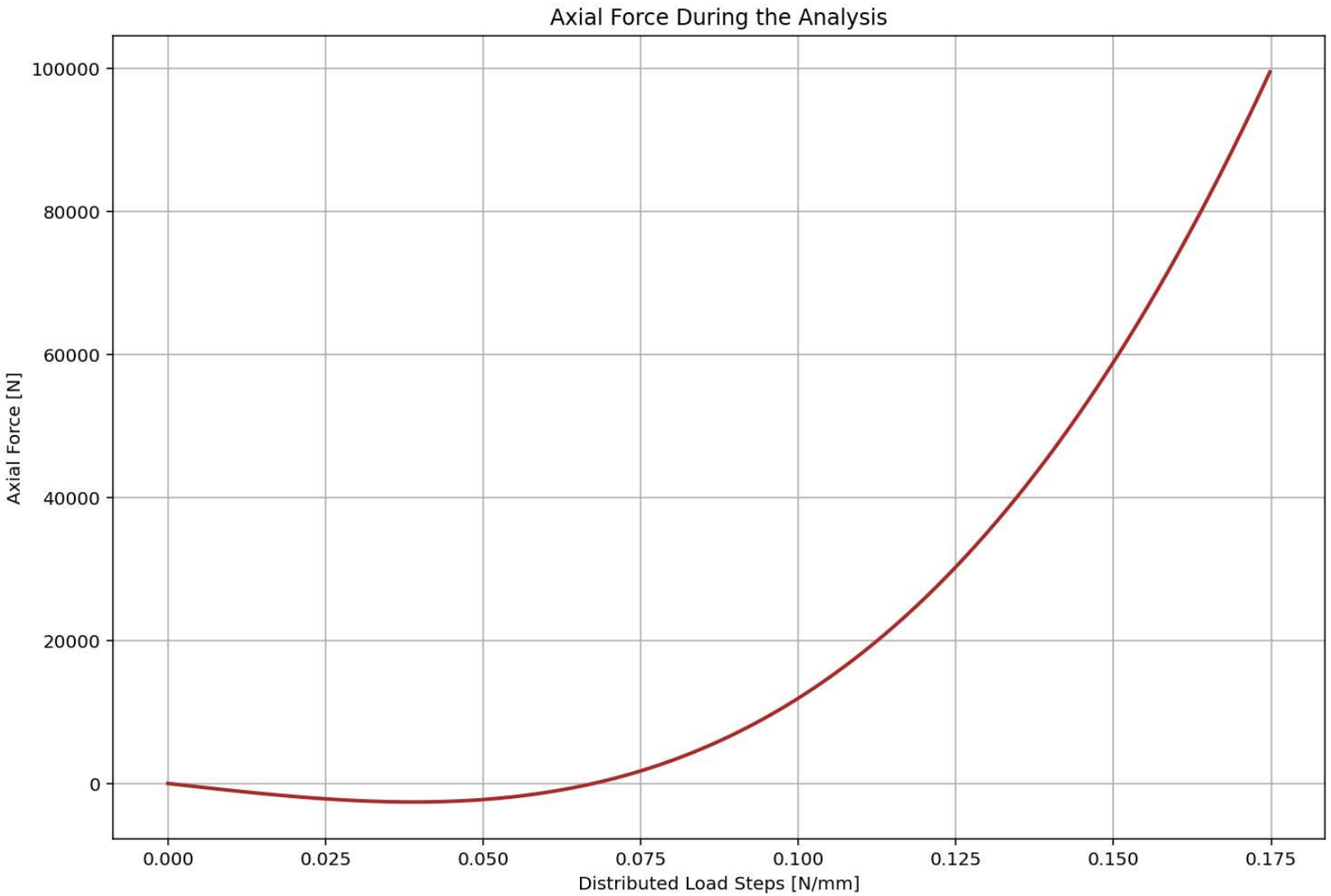

SHEAR FORCE-DISPLACEMENT DIAGRAM
Shear Force [N]
175000
150000
125000
100000
75000
50000
25000
0
−17.5
−15.0
−12.5
−10.0
−7.5
−5.0
−2.5
0.0
Displacement in X [mm] in Middle of Beam

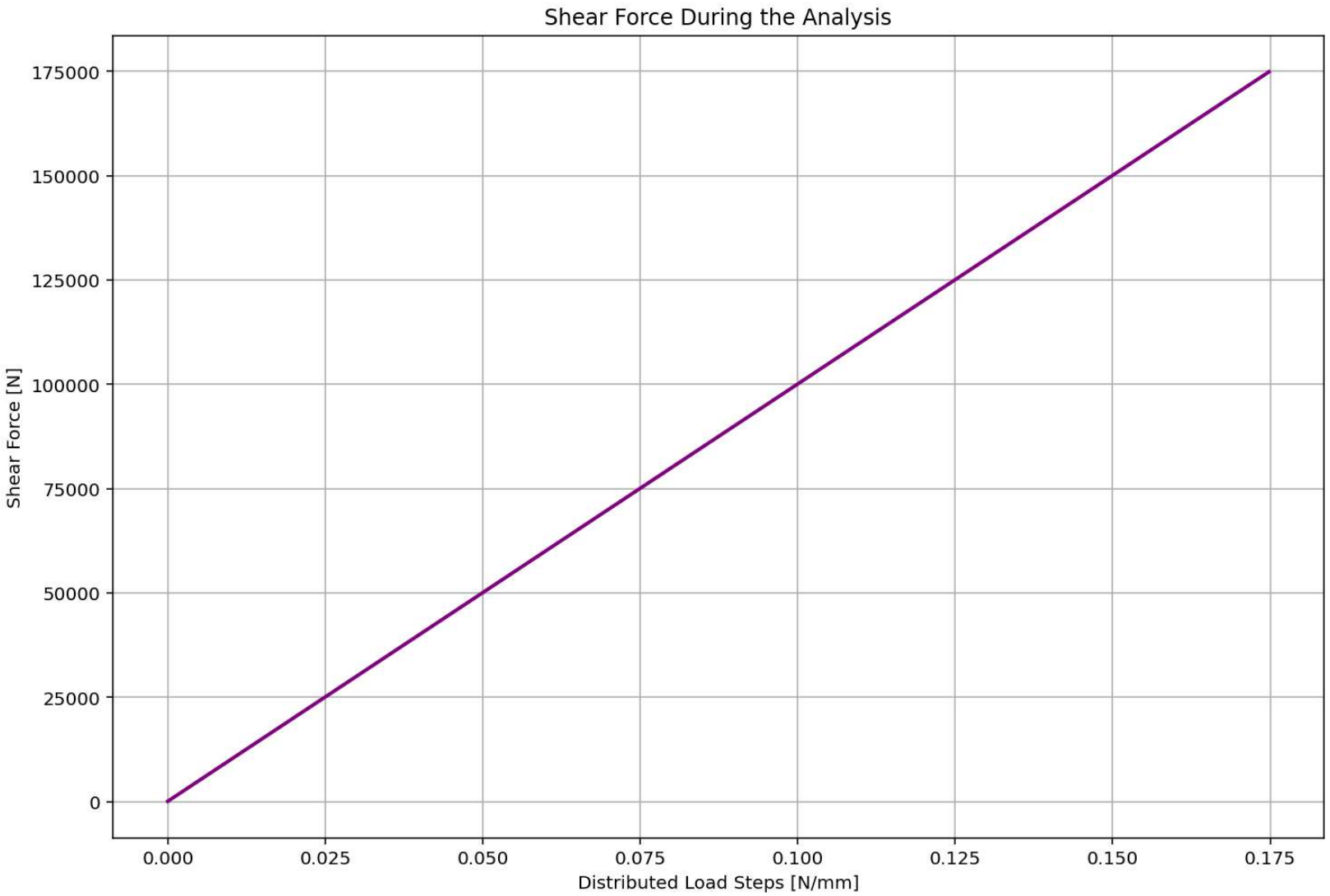

AXIAL FORCE-DISPLACEMENT DIAGRAM
100000
80000
60000
40000
20000
0
Axial Force [N]
0.0
0.2
0.4
0.6
0.8
Displacement in Y [mm] in Middle of Beam

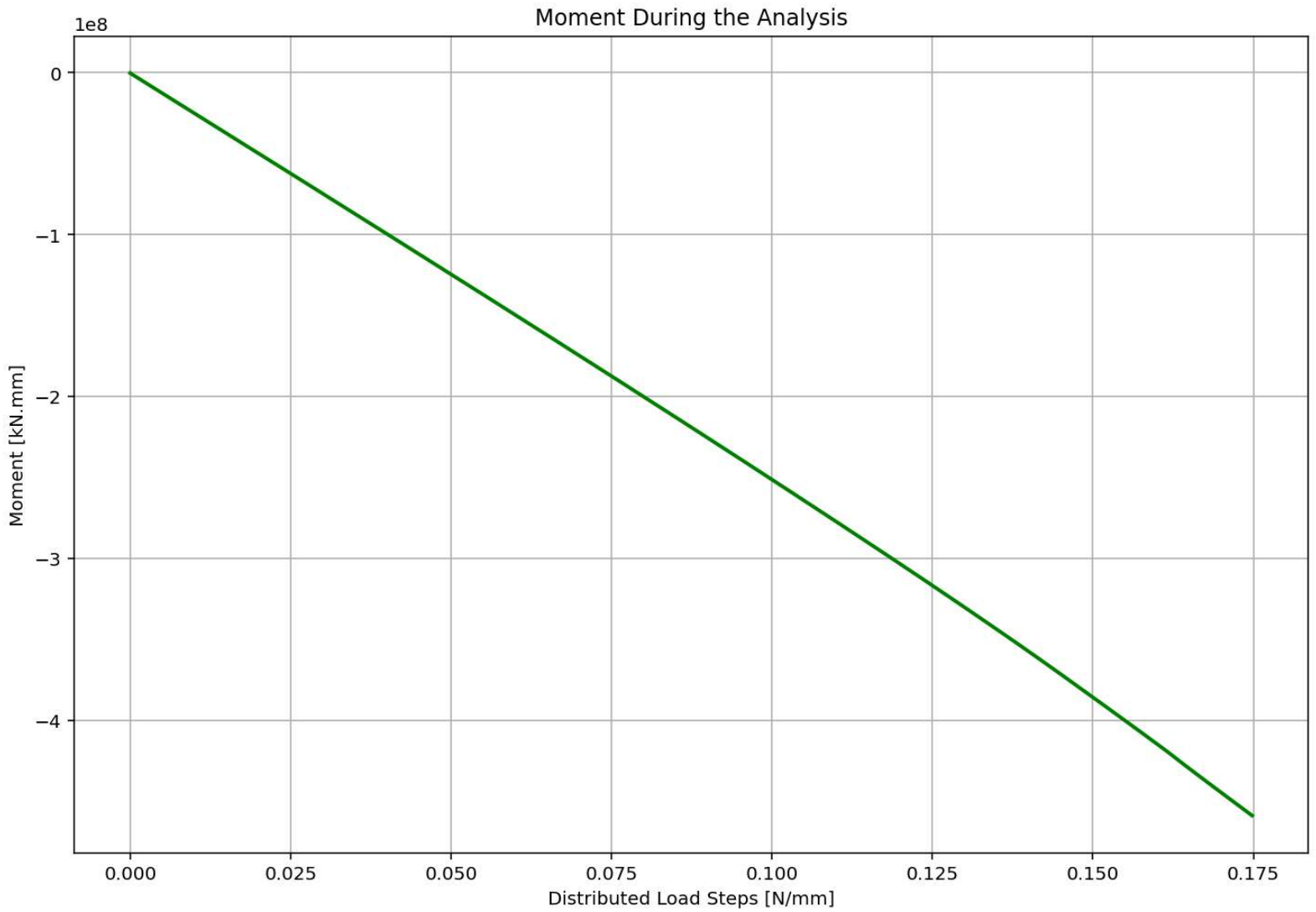

MOMENT-ROTATION DIAGRAM
1e8
0
−1
−2
−3
−4
Moment [kN.mm]
0.000
0.002
0.004
0.006
0.008
Rotation [rad]

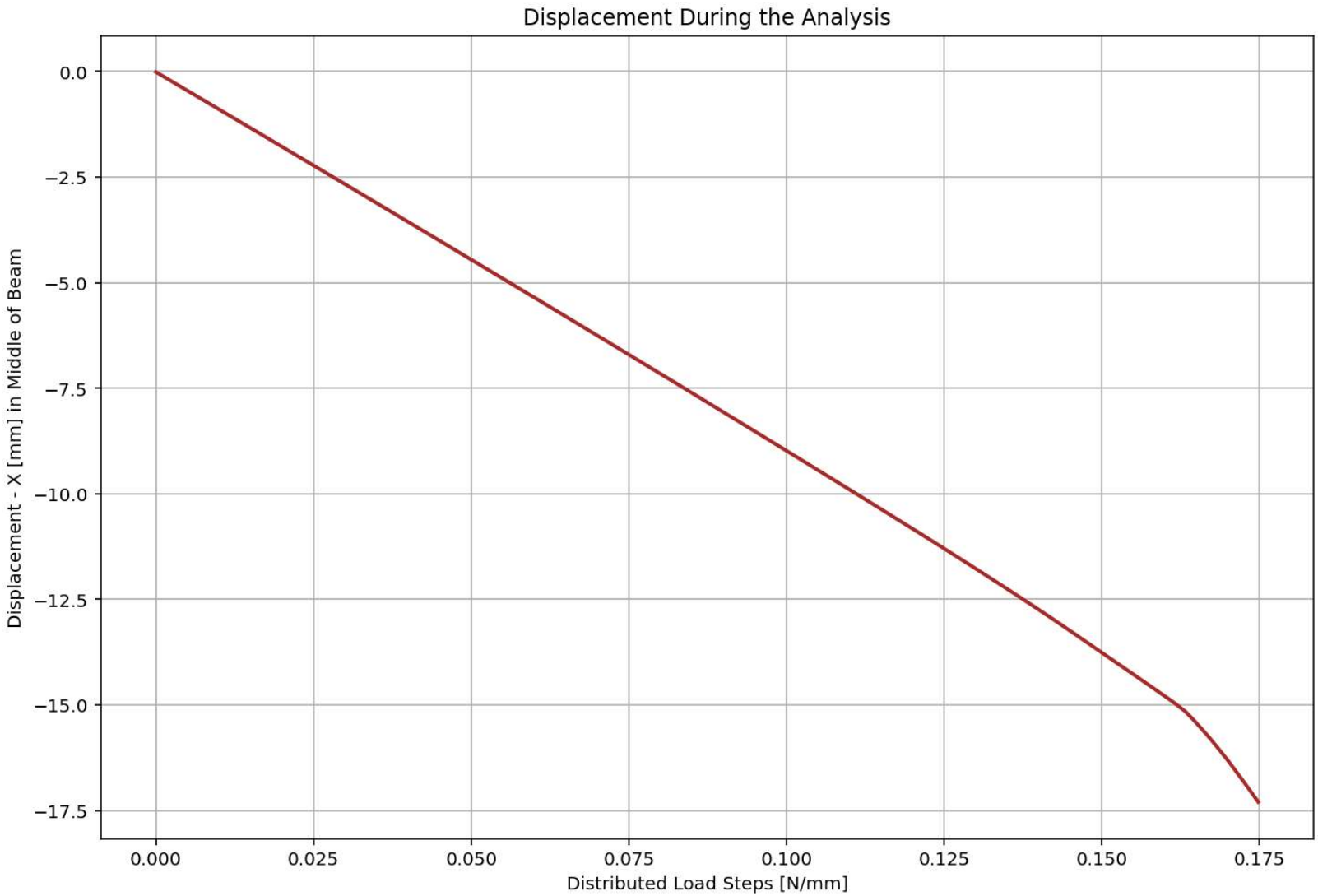

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Rotational Stiffness [N.mm/Rad]
1.12 × 10^4
1.1 × 10^4
1.08 × 10^4
1.06 × 10^4
1.04 × 10^4
1.02 × 10^4
5 × 10^10
6 × 10^10
Lateral Stiffness in X Dir. [N/mm]

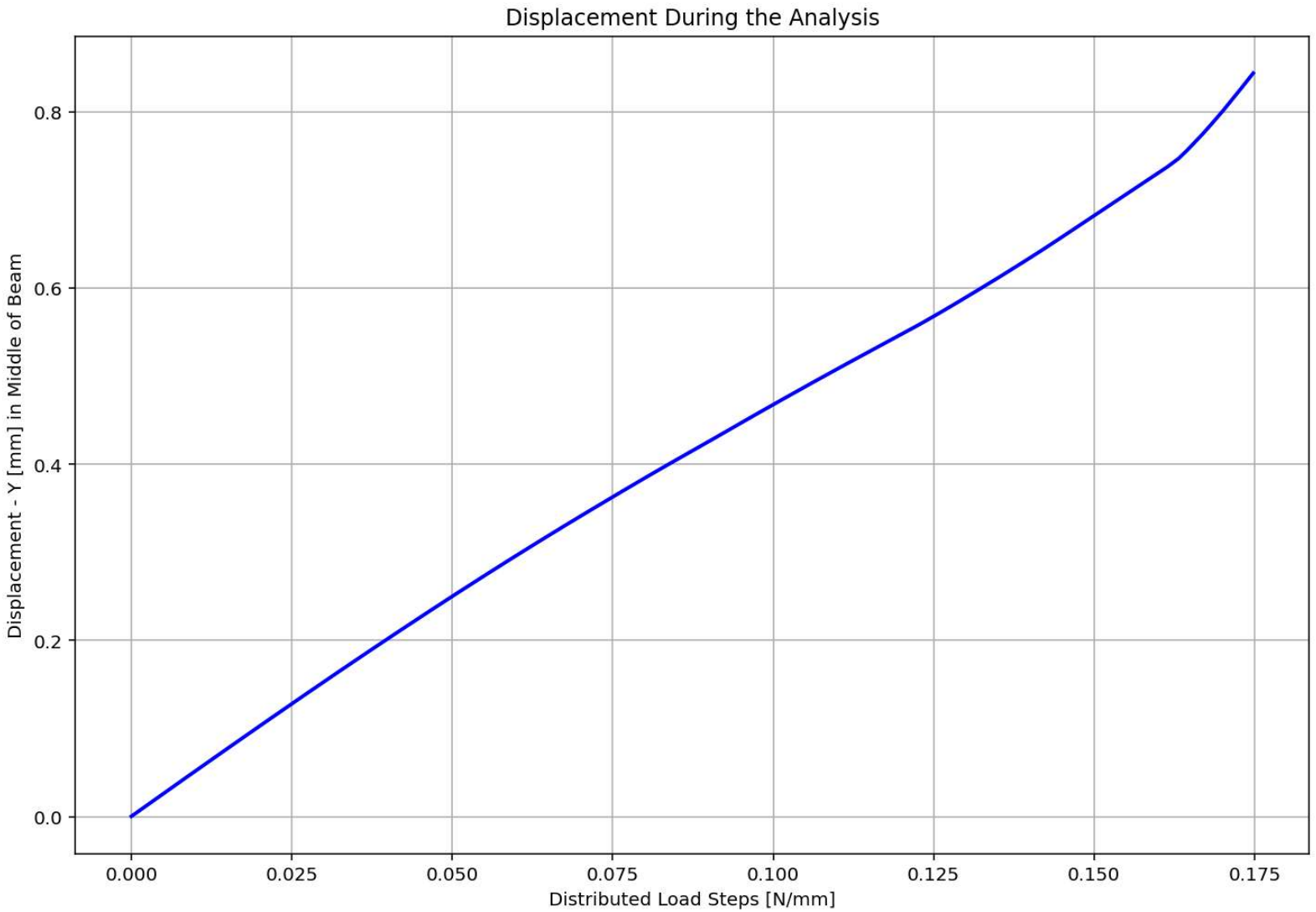

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Rotational Stiffness [N.mm/Rad]
10^5
10^4
10^3
10^2
5×10^{10}
6×10^{10}
Lateral Stiffness in Y Dir. [N/mm]

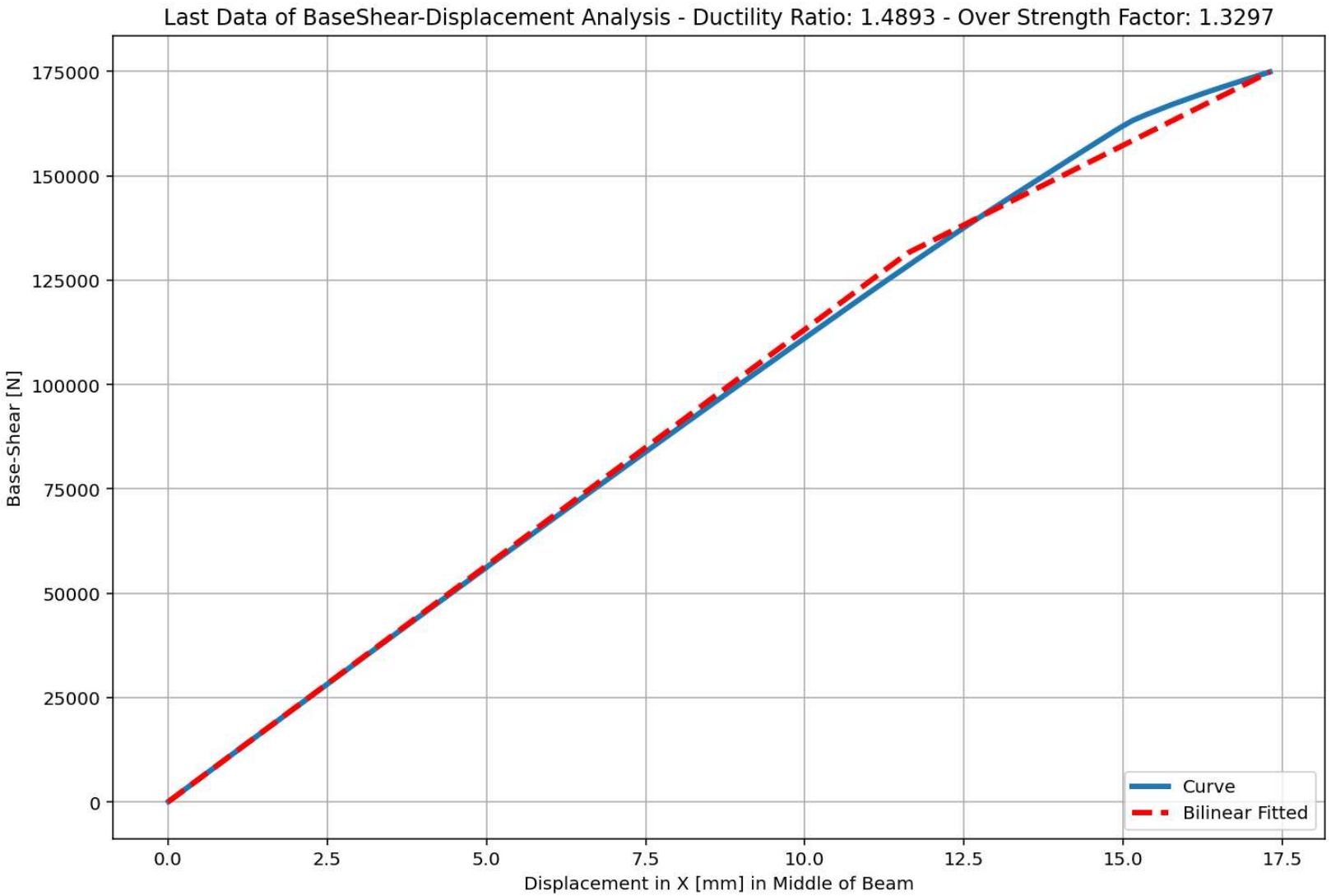

Axial Force During the Analysis
Axial Force [N]
100000
80000
60000
40000
20000
0
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Distributed Load Steps [N/mm]

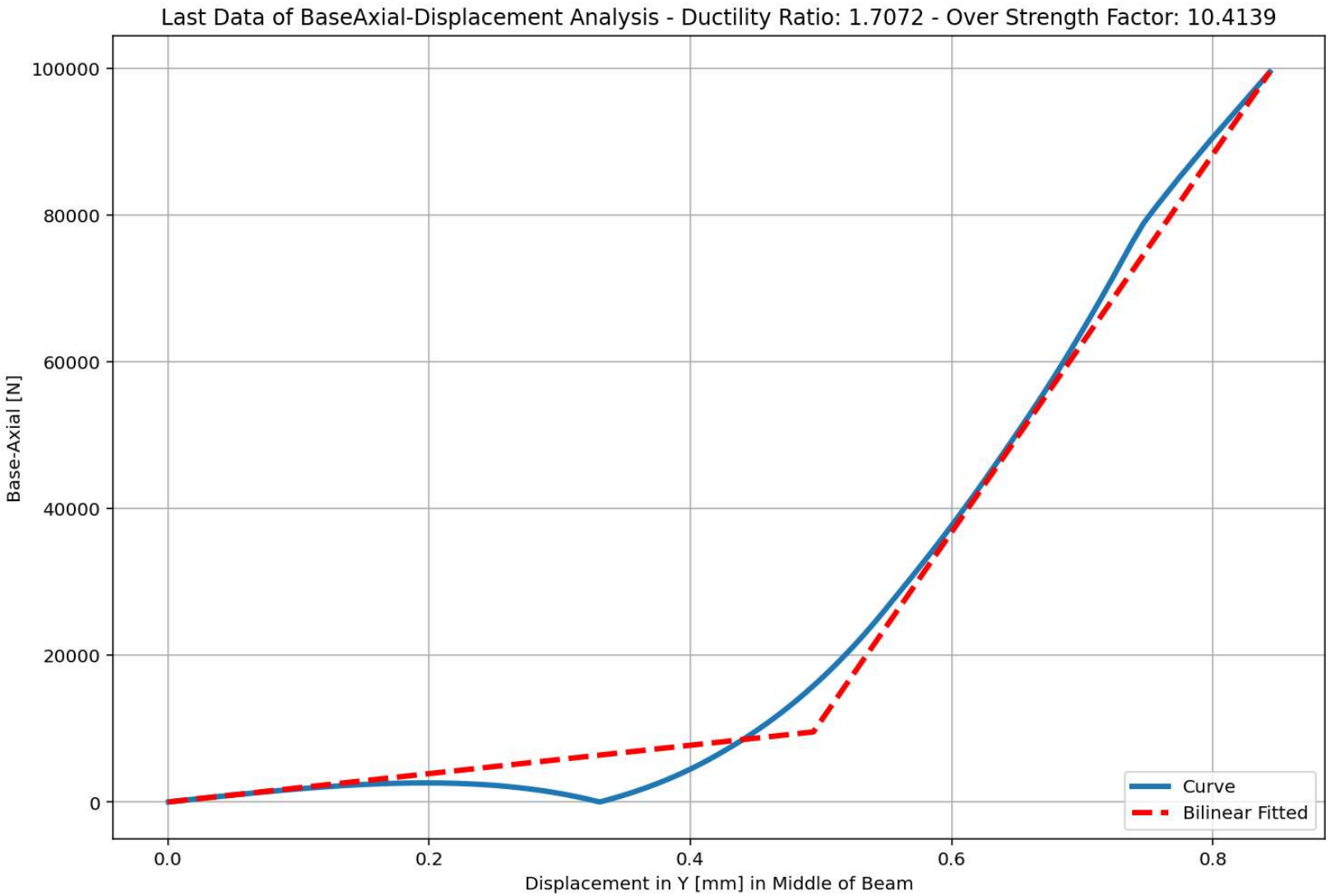

Shear Force During the Analysis
Shear Force [N]
175000
150000
125000
100000
75000
50000
25000
0
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Distributed Load Steps [N/mm]

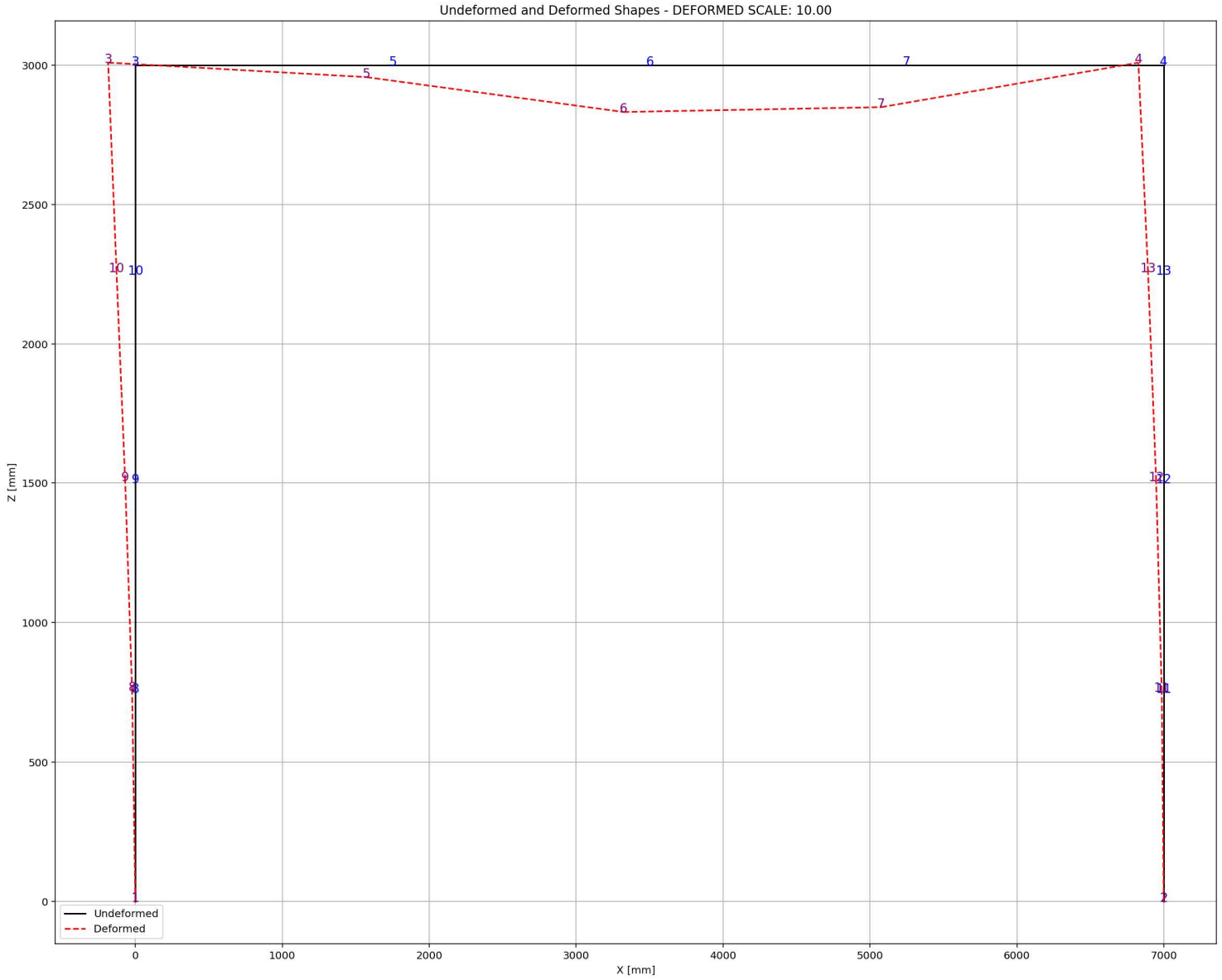

Moment During the Analysis
1e8
0
−1
−2
−3
−4
Moment [kN.mm]
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Distributed Load Steps [N/mm]


Displacement During the Analysis
Displacement - X [mm] in Middle of Beam
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
−15.0
−17.5
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Distributed Load Steps [N/mm]

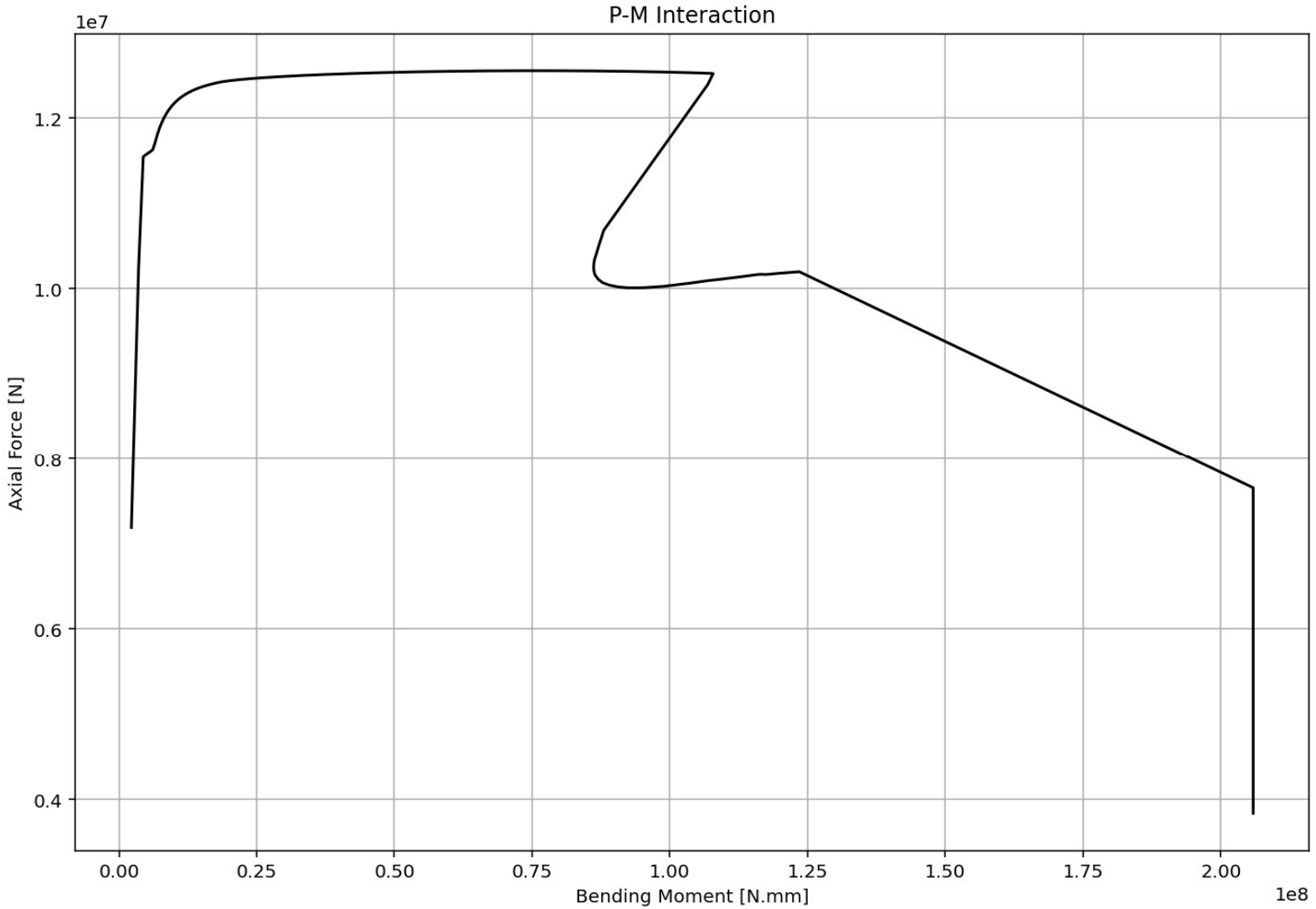

Displacement During the Analysis
Displacement - Y [mm] in Middle of Beam
0.0
0.2
0.4
0.6
0.8
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Distributed Load Steps [N/mm]

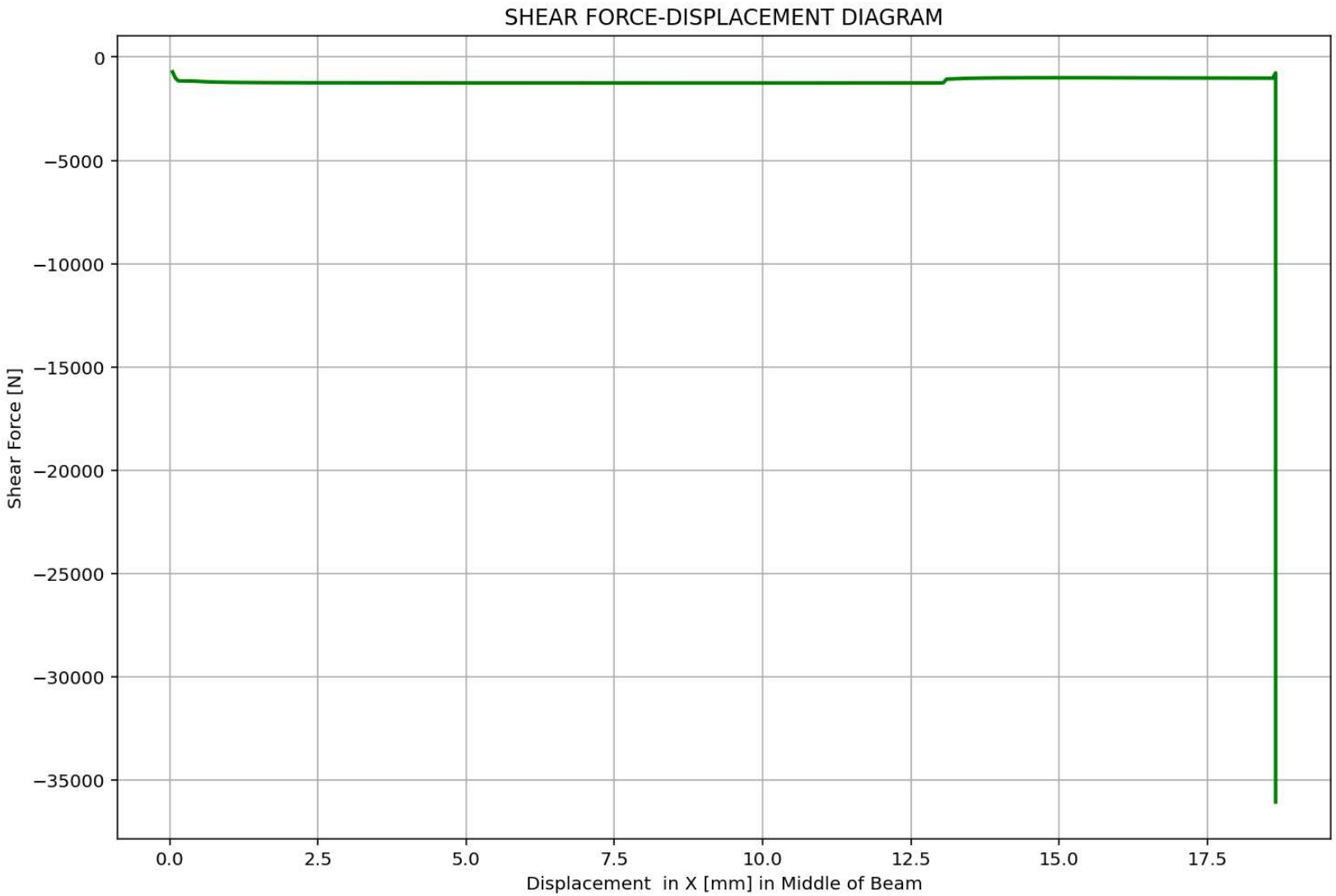

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 1.4893 - Over Strength Factor: 1.3297
Base-Shear [N]
175000
150000
125000
100000
75000
50000
25000
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Displacement in X [mm] in Middle of Beam
Curve
Bilinear Fitted

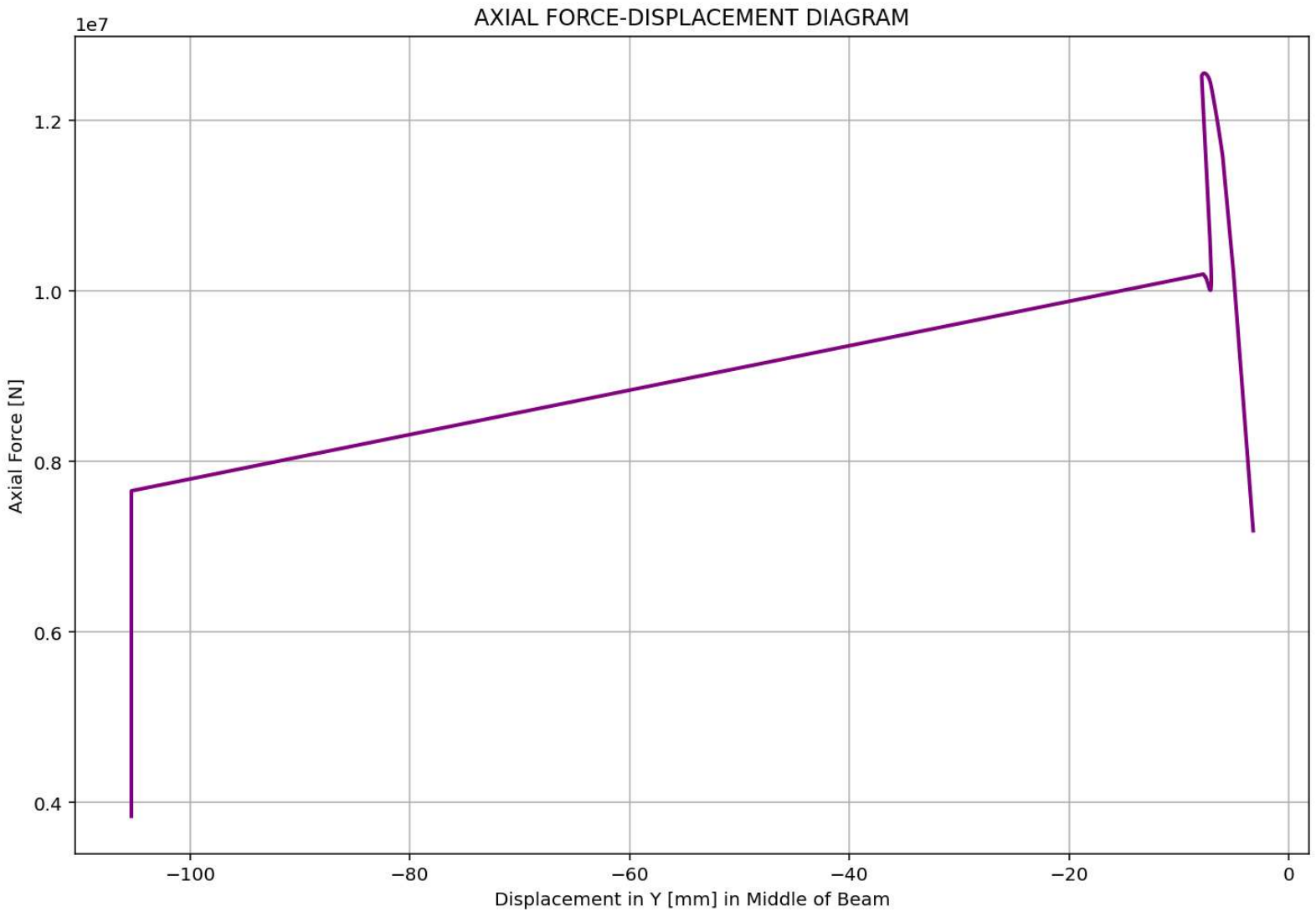

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 1.7072 - Over Strength Factor: 10.4139
100000
80000
60000
40000
20000
0
Base-Axial [N]
0.0
0.2
0.4
0.6
0.8
Displacement in Y [mm] in Middle of Beam
Curve
Bilinear Fitted

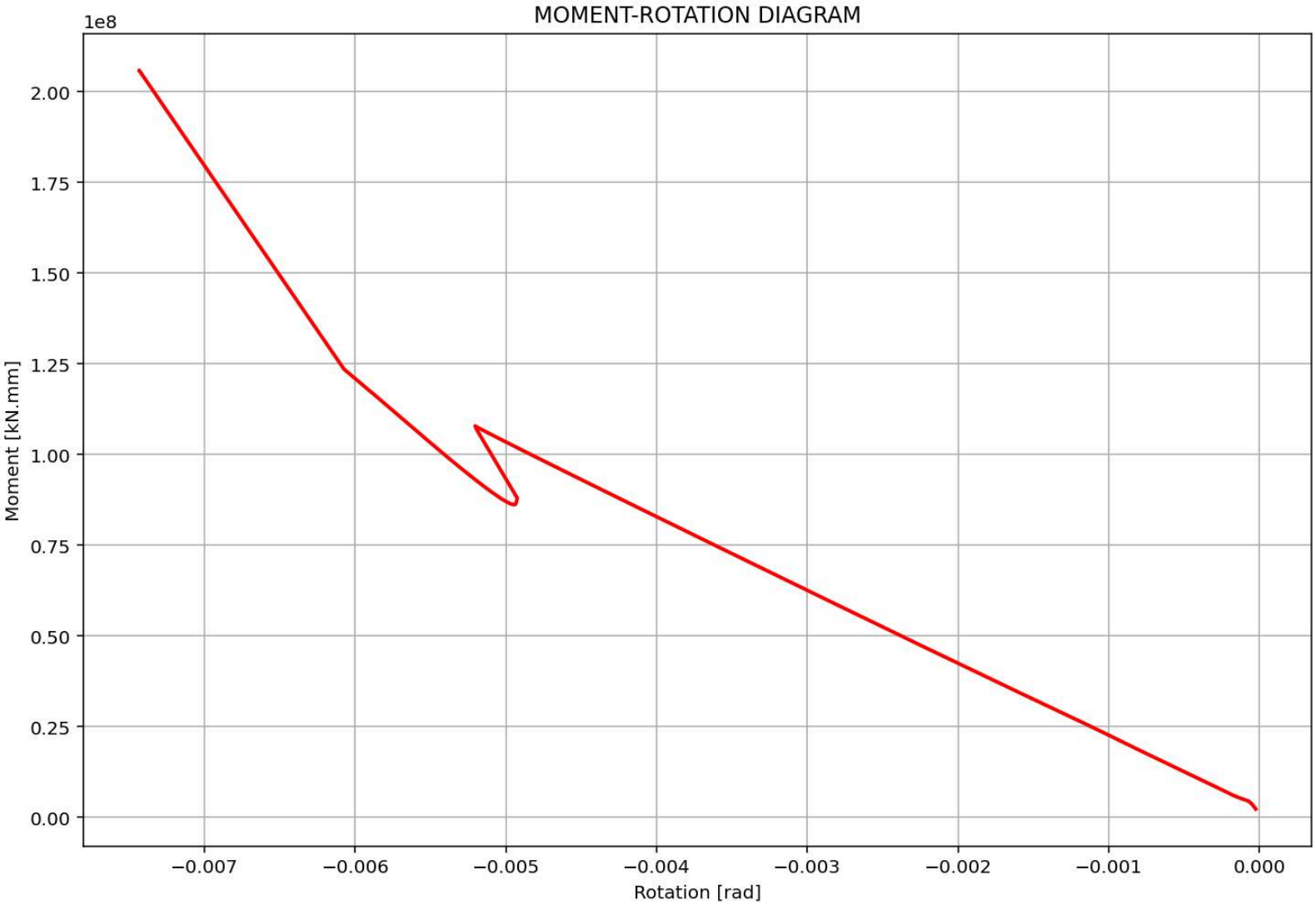

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Z [mm]
X [mm]
Undeformed
Deformed
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000

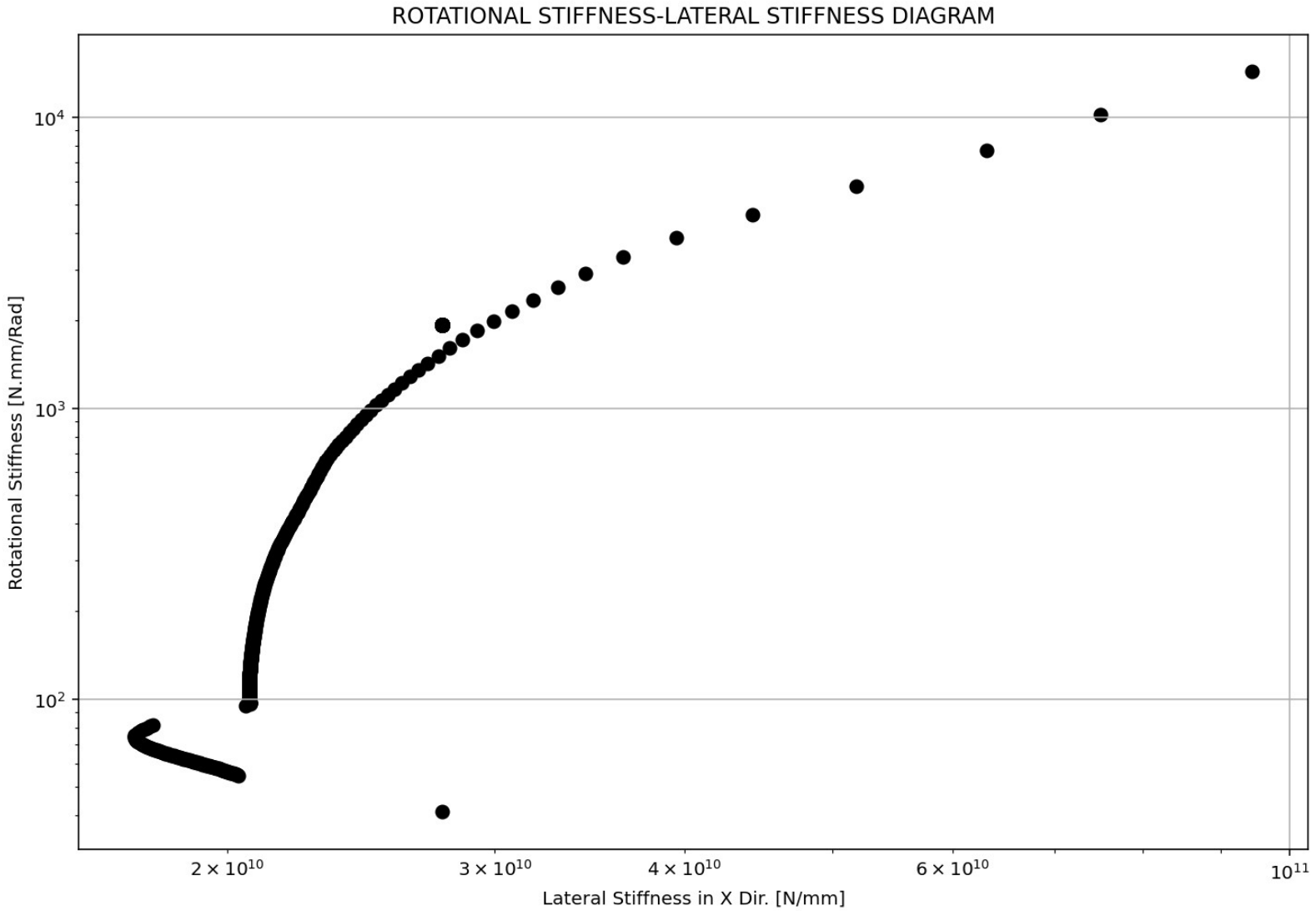
DISPLACEMENT CONTROL

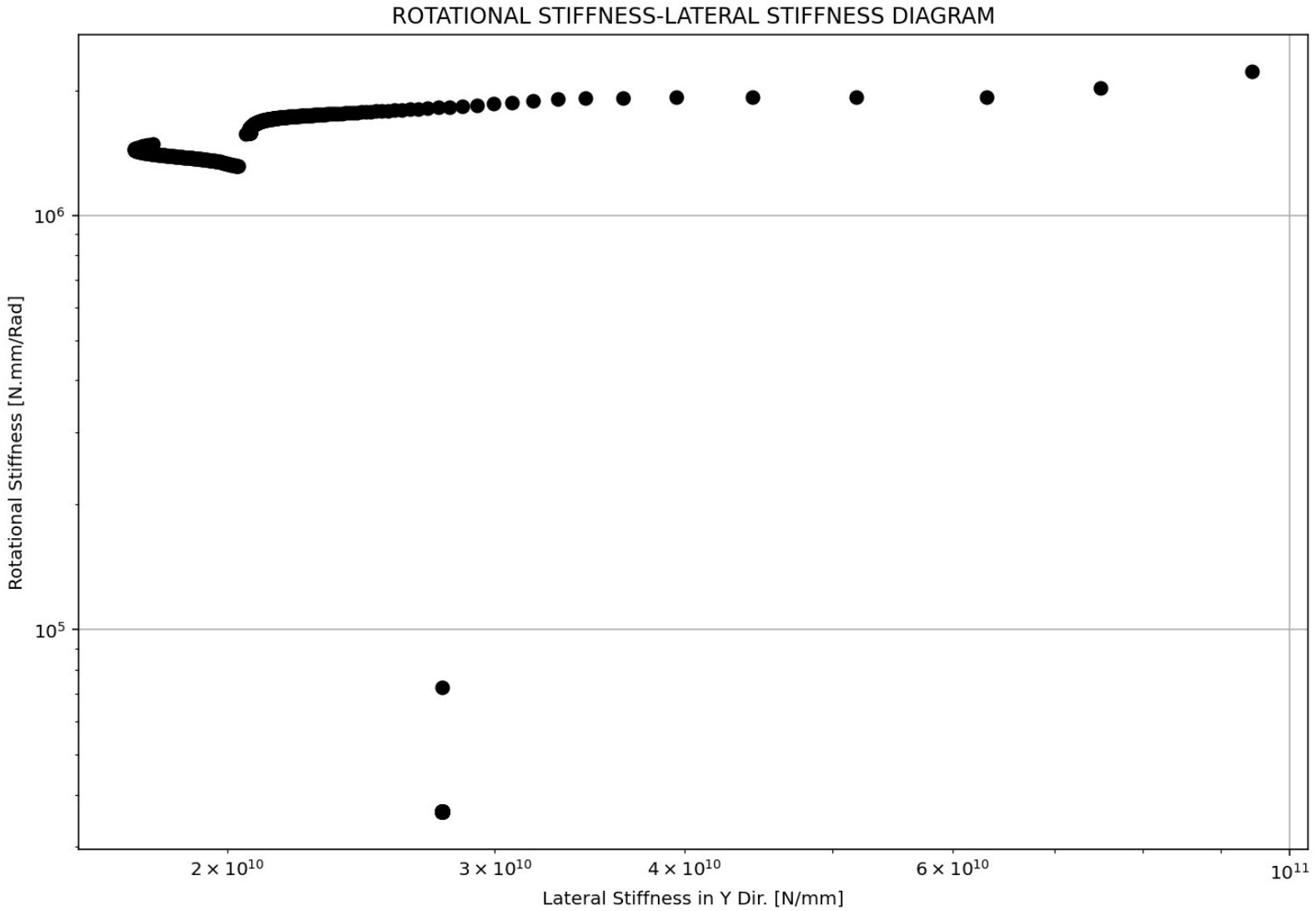

P-M Interaction
1e7
1.2
1.0
0.8
0.6
0.4
Axial Force [N]
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
1e8
Bending Moment [N.mm]

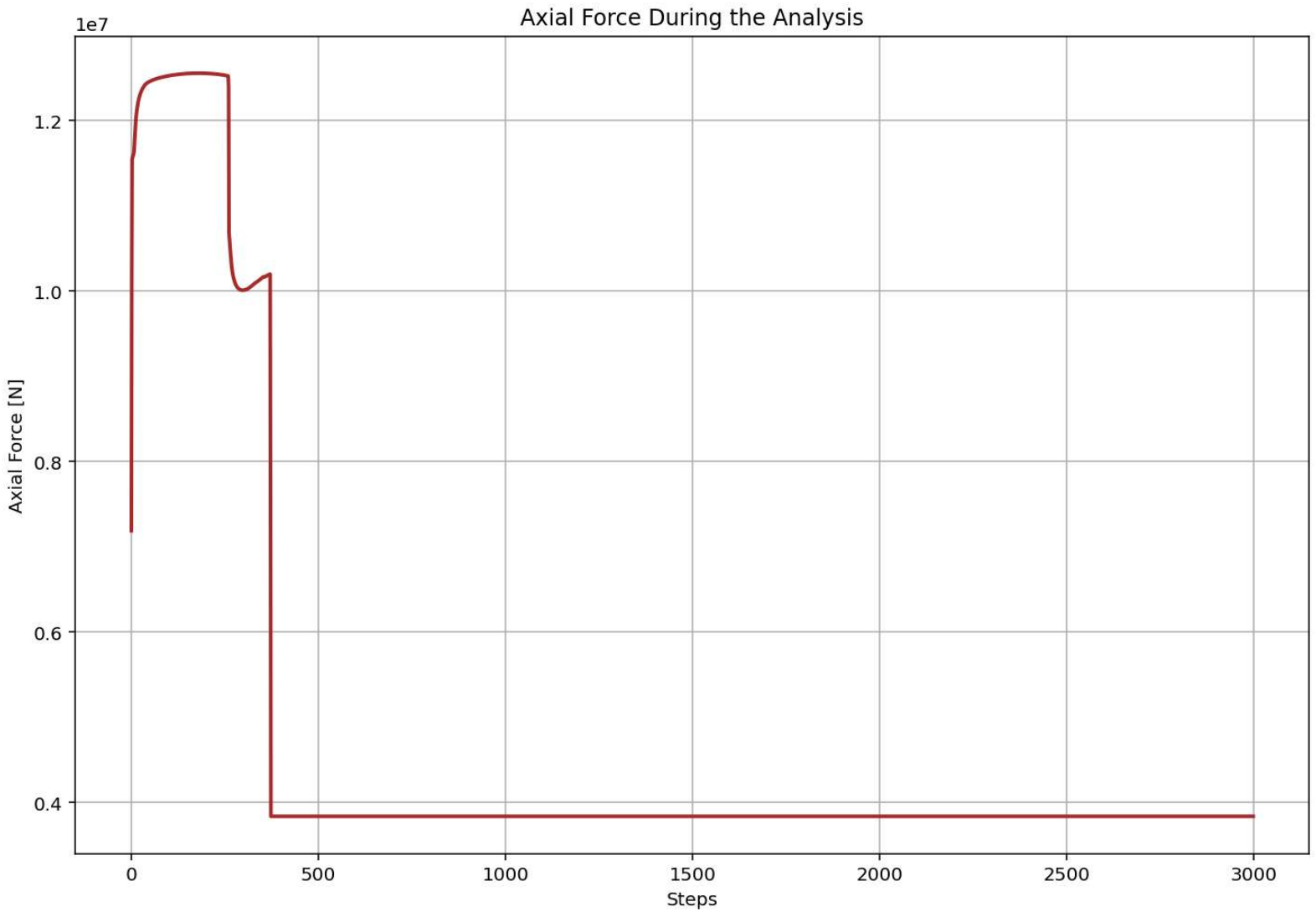

SHEAR FORCE-DISPLACEMENT DIAGRAM
0
−5000
−10000
−15000
−20000
−25000
−30000
−35000
Shear Force [N]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Displacement in X [mm] in Middle of Beam

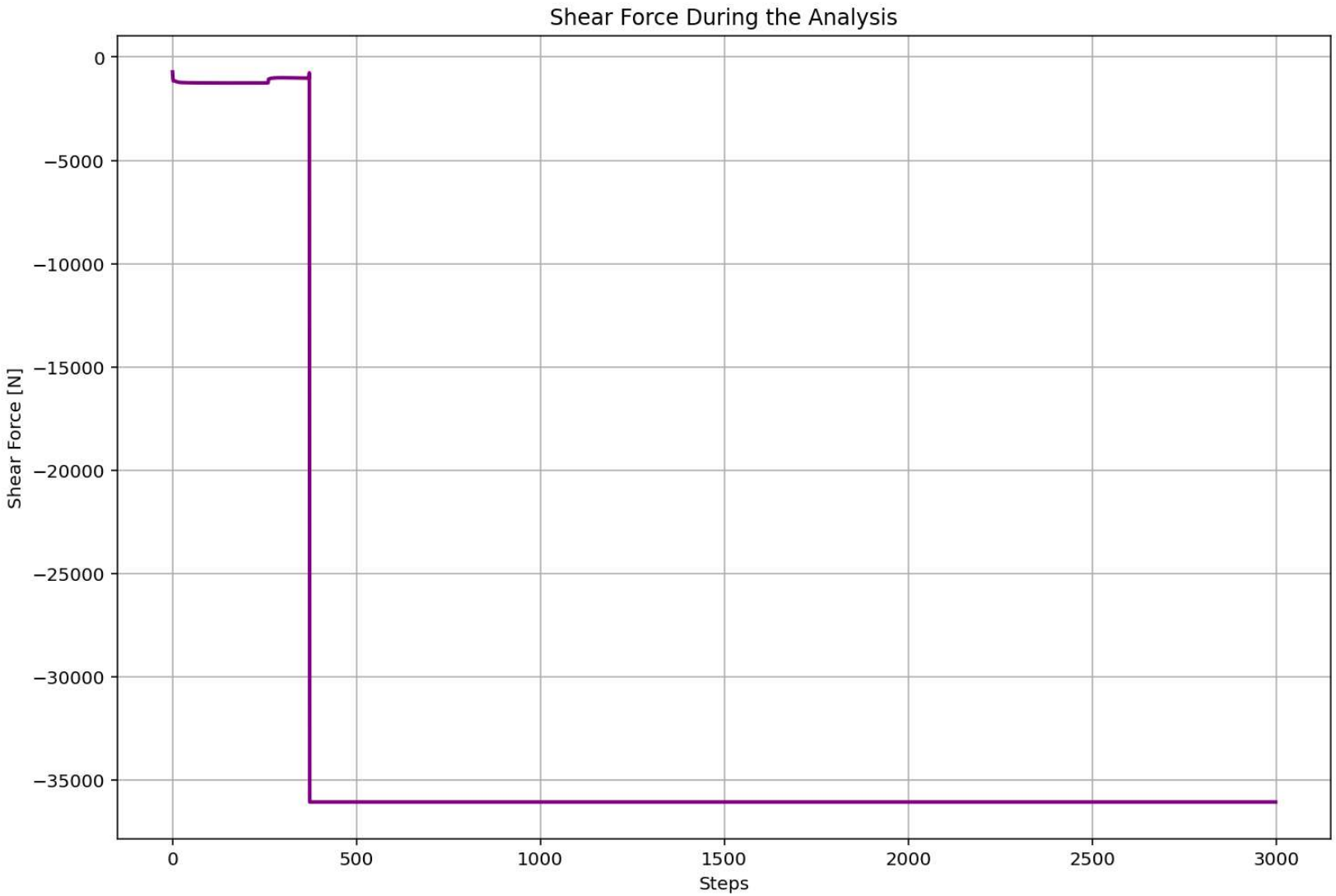

AXIAL FORCE-DISPLACEMENT DIAGRAM
1e7
1.2
1.0
0.8
0.6
0.4
Axial Force [N]
−100
−80
−60
−40
−20
0
Displacement in Y [mm] in Middle of Beam

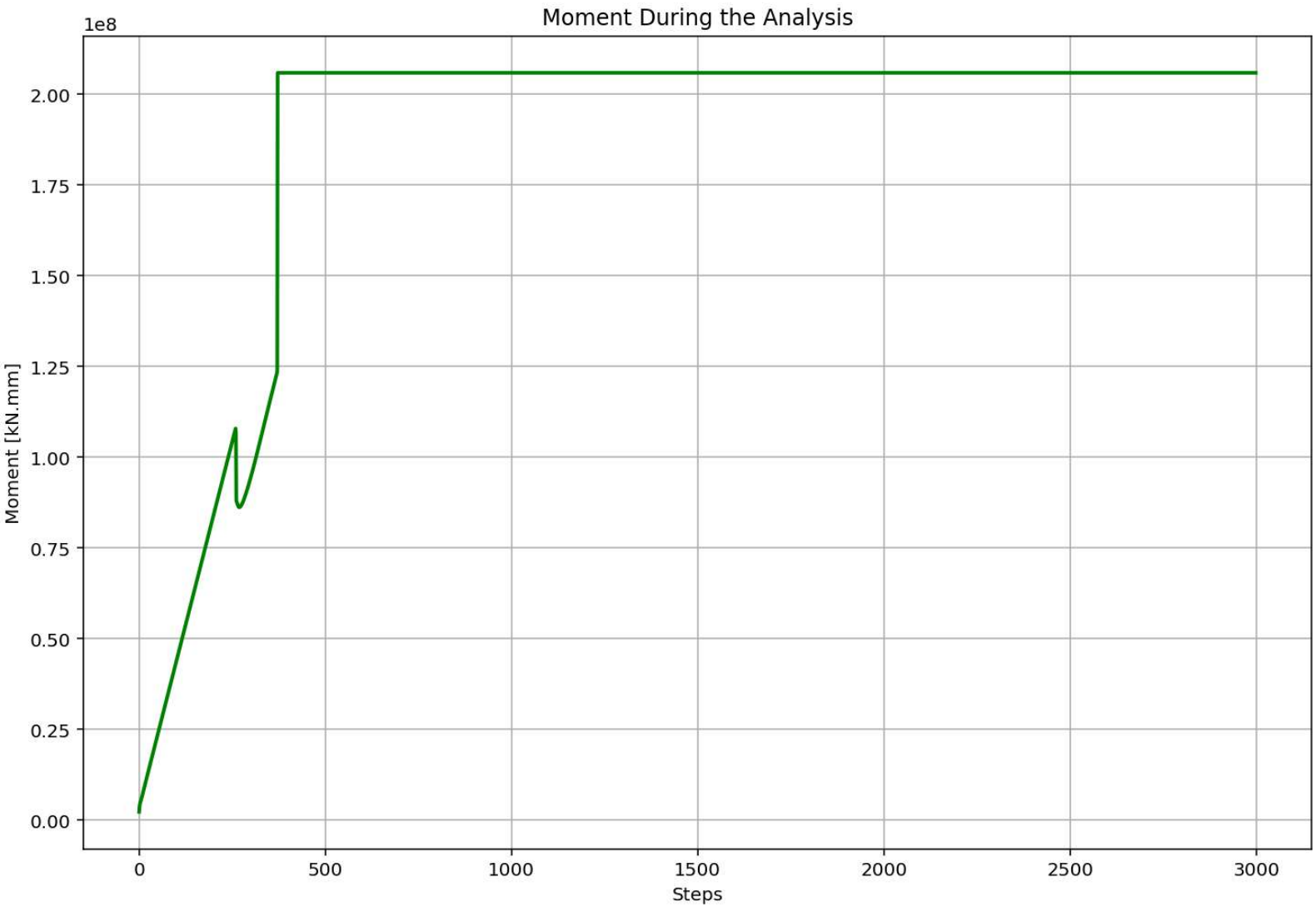

MOMENT-ROTATION DIAGRAM
1e8
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Moment [kN.mm]
−0.007
−0.006
−0.005
−0.004
−0.003
−0.002
−0.001
0.000
Rotation [rad]

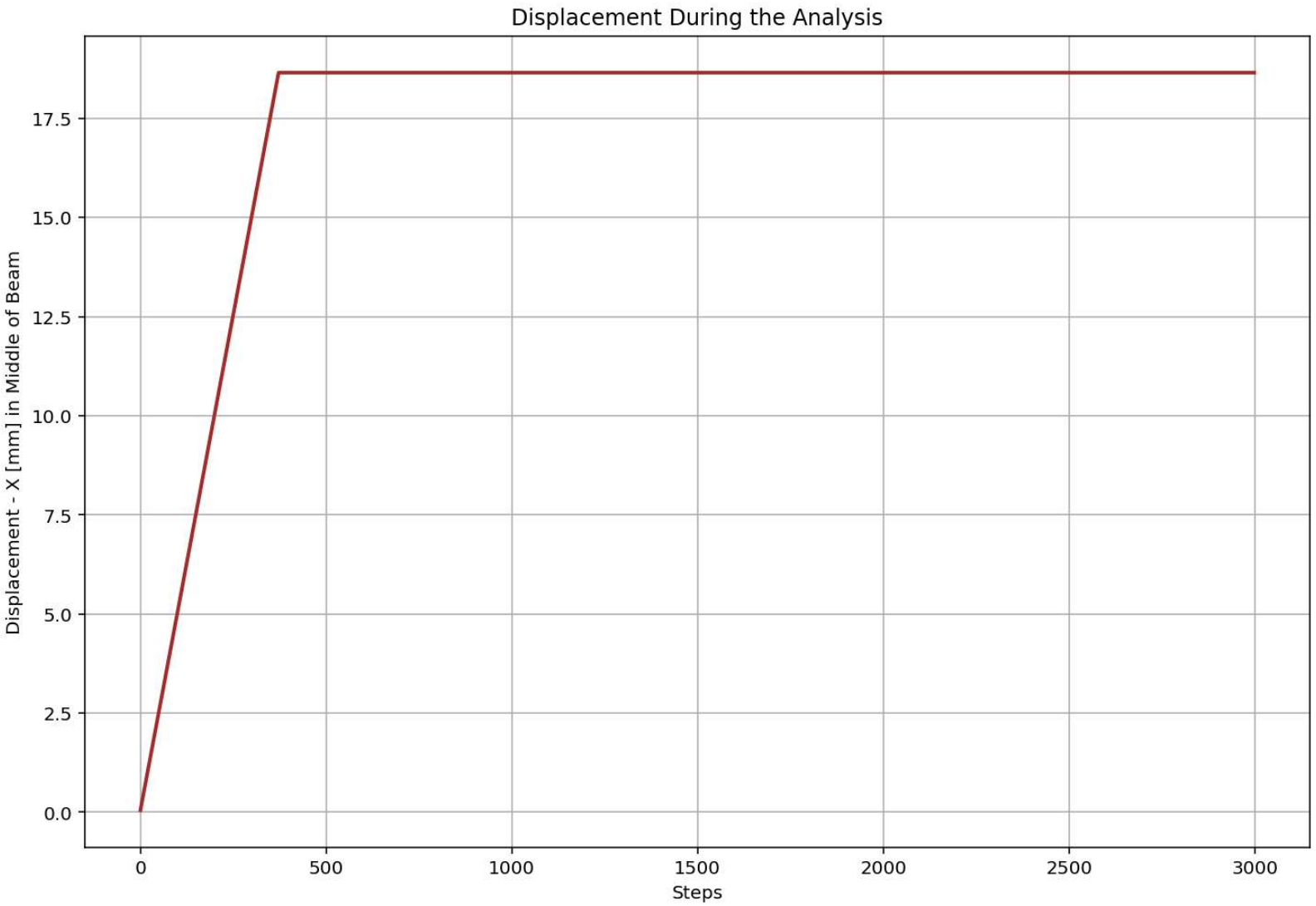

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Rotational Stiffness [N.mm/Rad]
10^4
10^3
10^2
2×10^{10}
3×10^{10}
4×10^{10}
6×10^{10}
10^{11}
Lateral Stiffness in X Dir. [N/mm]

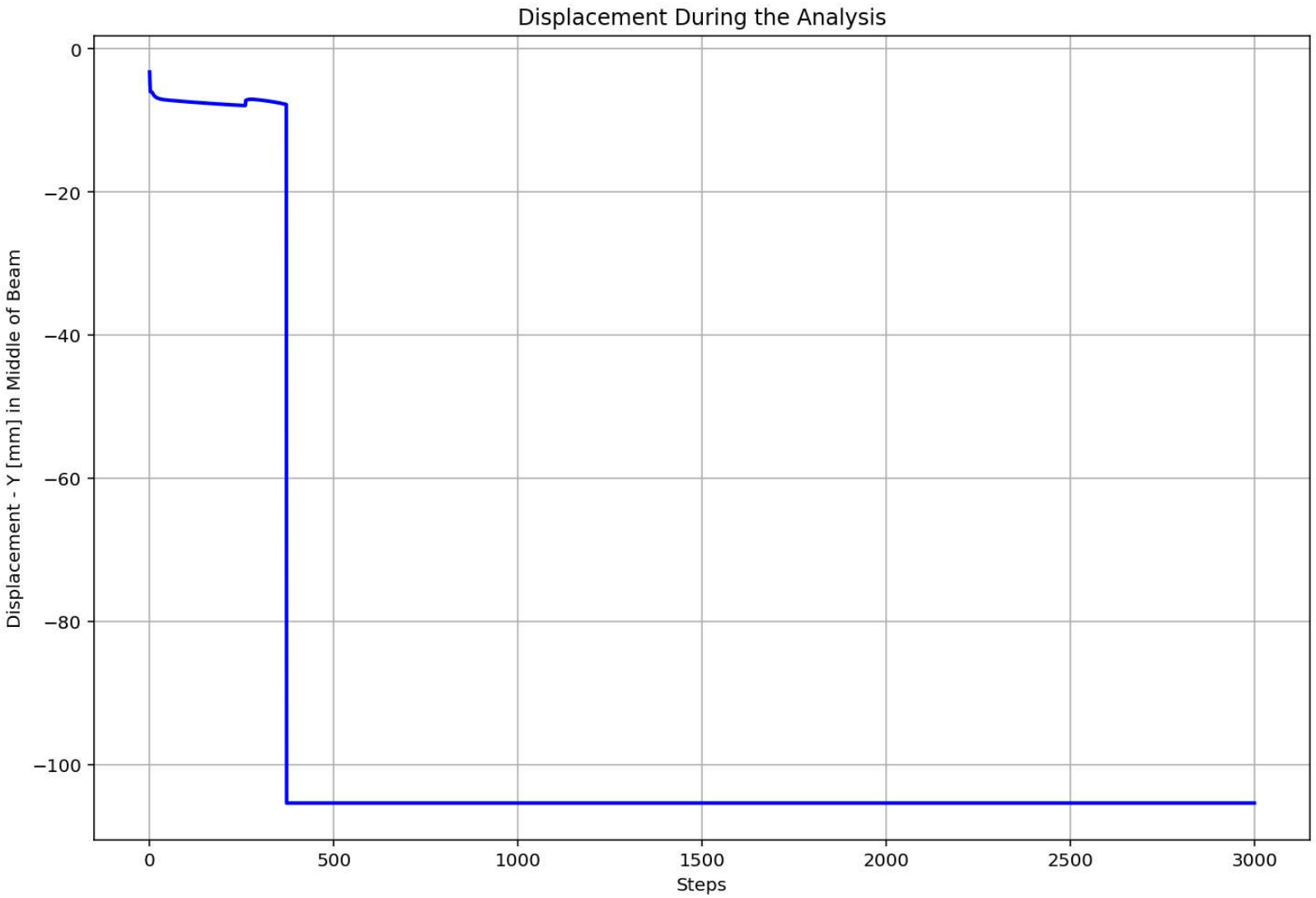

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Rotational Stiffness [N.mm/Rad]
10^6
10^5
2×10^{10}
3×10^{10}
4×10^{10}
6×10^{10}
10^{11}
Lateral Stiffness in Y Dir. [N/mm]

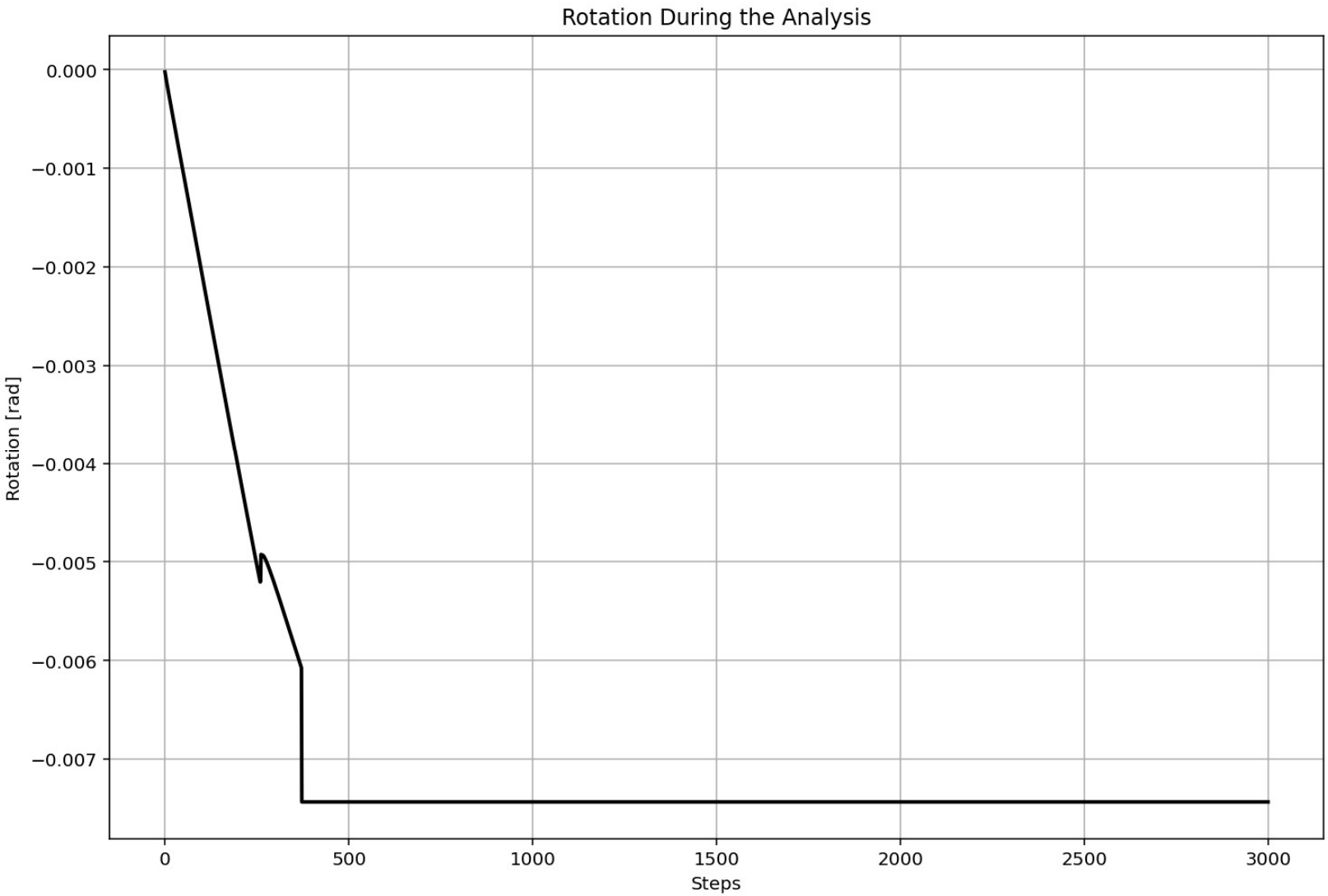

Axial Force During the Analysis
1e7
1.2
1.0
0.8
0.6
0.4
Axial Force [N]
0
500
1000
1500
2000
2500
3000
Steps

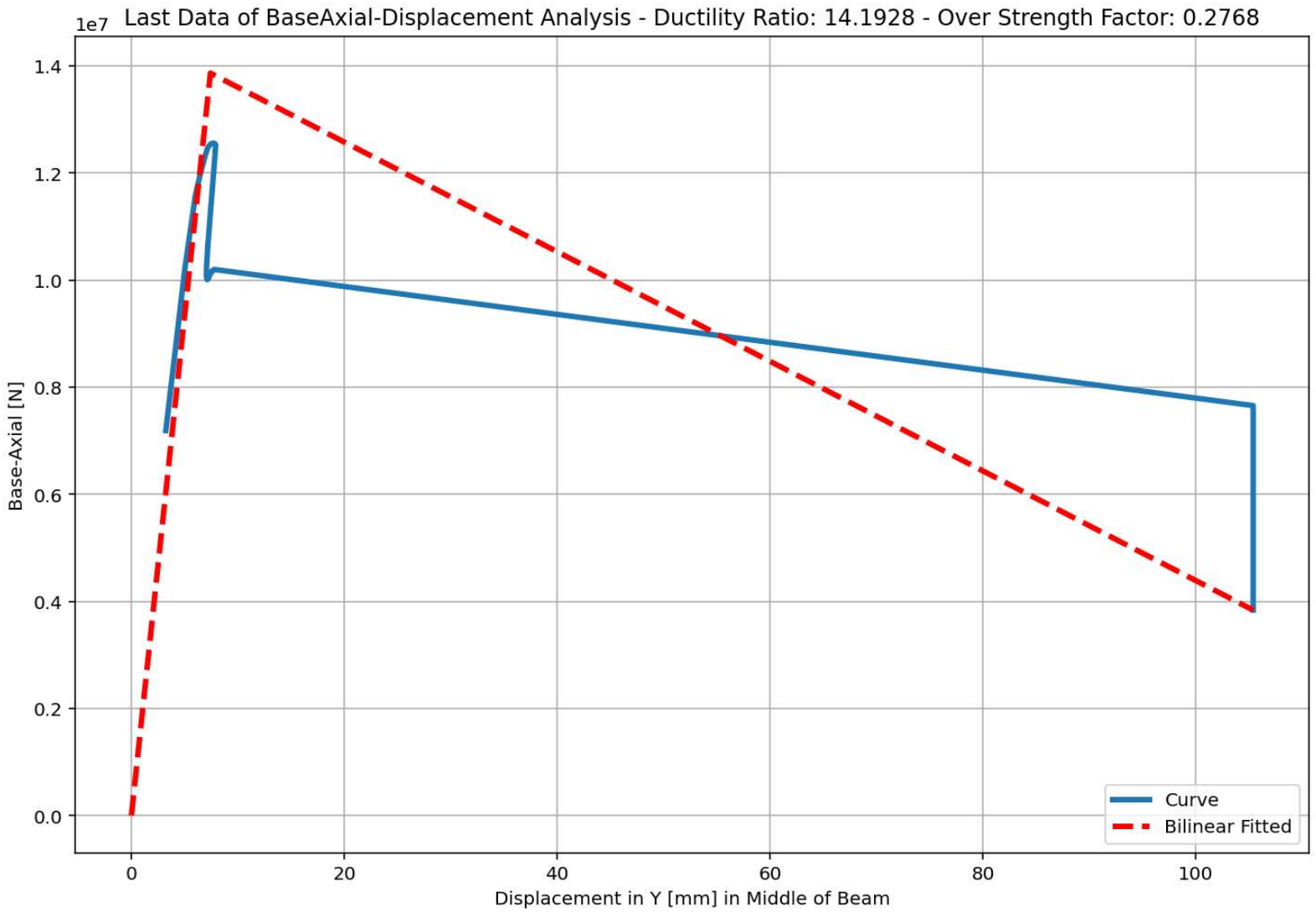

Shear Force During the Analysis
Shear Force [N]
0
−5000
−10000
−15000
−20000
−25000
−30000
−35000
0
500
1000
1500
2000
2500
3000
Steps

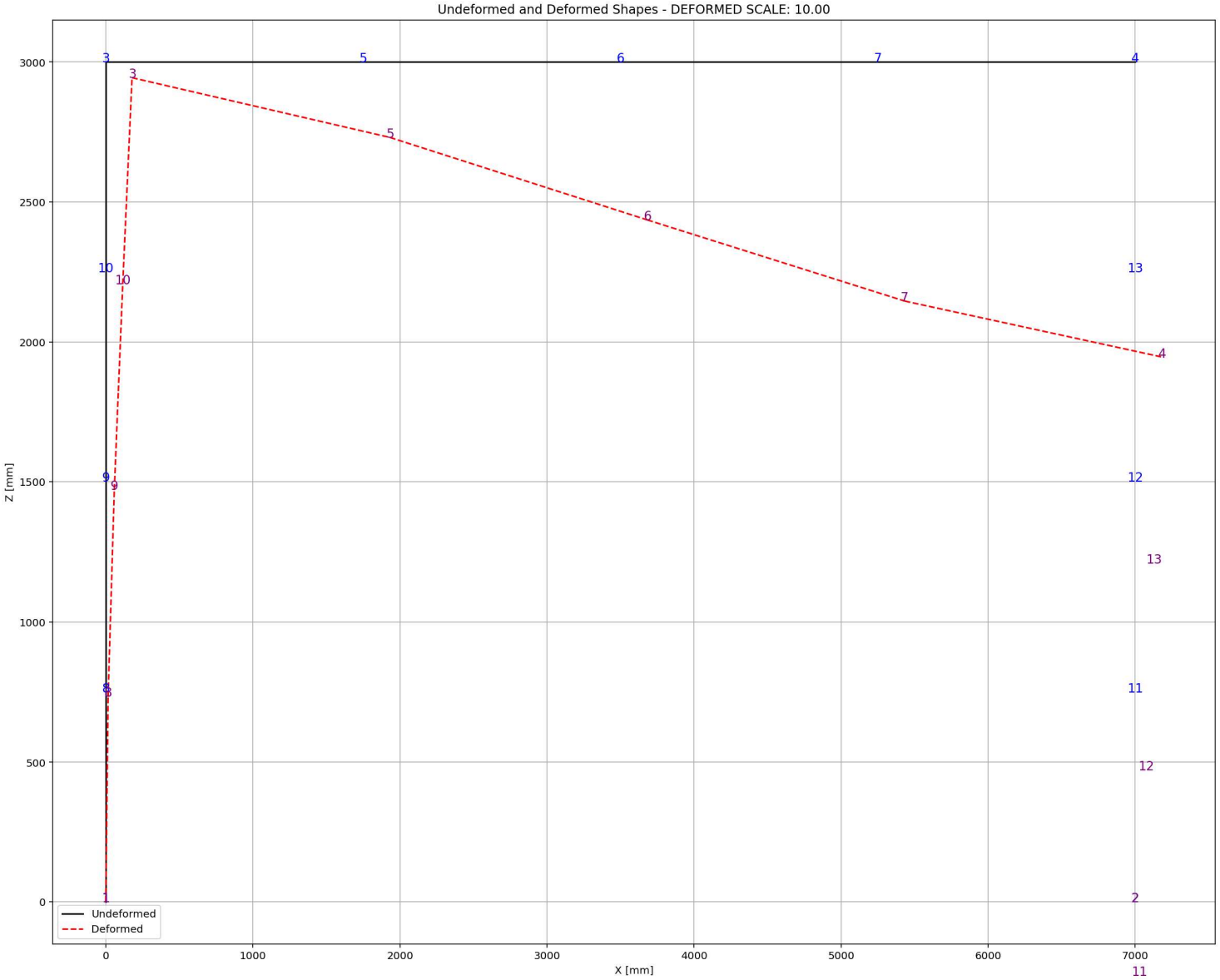

Moment During the Analysis
1e8
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Moment [kN.mm]
0
500
1000
1500
2000
2500
3000
Steps


Displacement During the Analysis
Displacement - X [mm] in Middle of Beam
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
500
1000
1500
2000
2500
3000
Steps


Displacement During the Analysis
Displacement - Y [mm] in Middle of Beam
0
−20
−40
−60
−80
−100
0
500
1000
1500
2000
2500
3000
Steps


Rotation During the Analysis
0.000
−0.001
−0.002
−0.003
−0.004
−0.005
−0.006
−0.007
Rotation [rad]
0
500
1000
1500
2000
2500
3000
Steps


Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 14.1928 - Over Strength Factor: 0.2768
1e7
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Base-Axial [N]
0
20
40
60
80
100
Displacement in Y [mm] in Middle of Beam
Curve
Bilinear Fitted


Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Z [mm]
X [mm]
Undeformed
Deformed
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000