>> IN THE NAME OF GOD <<

Moment-Curvature Analysis of Double I steel sections with Plates on Flanges, with Compression Axial Load effect in MATLAB and SAP2000

The MATLAB Program is Verified by SAP2000 v.15.1.0 (Linear and Nonlinear Structural Analysis Program)
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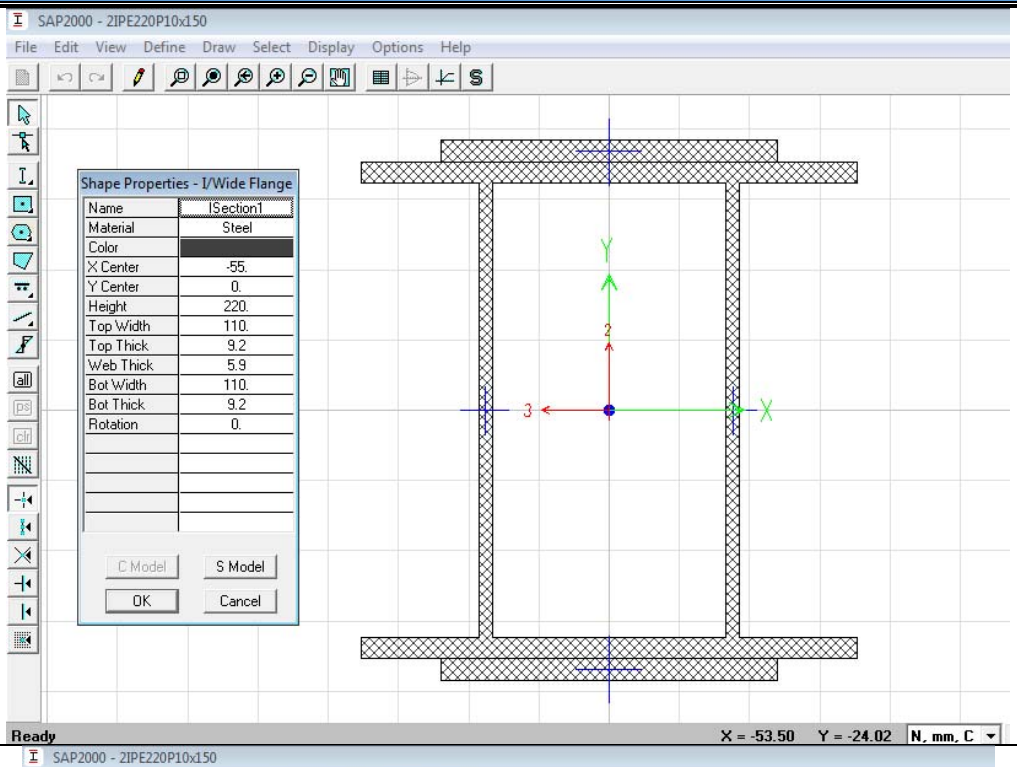
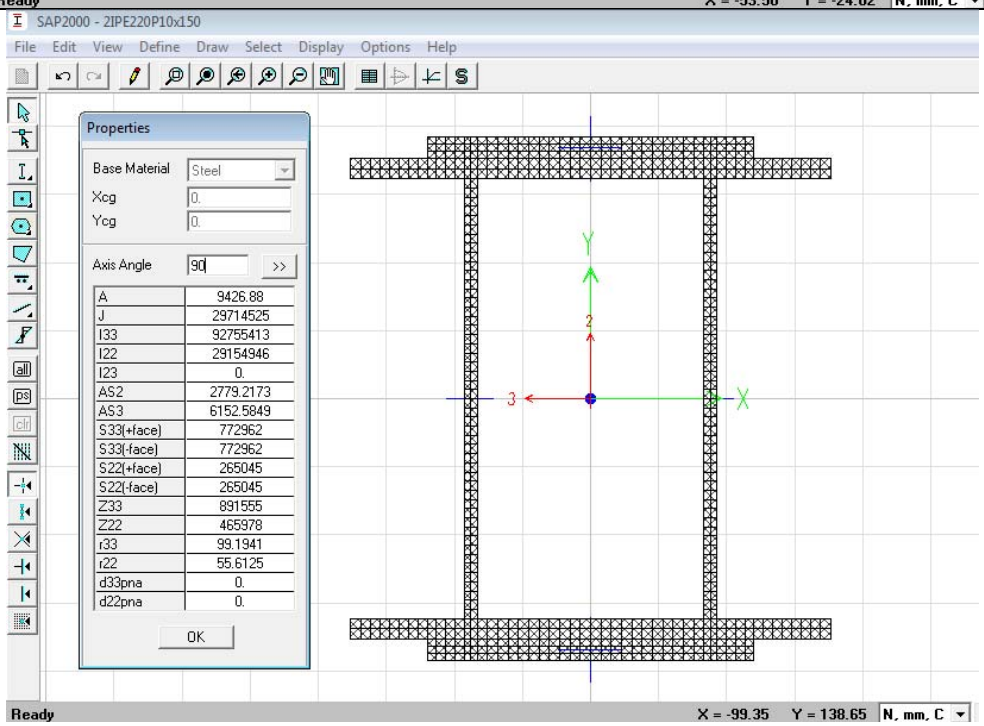
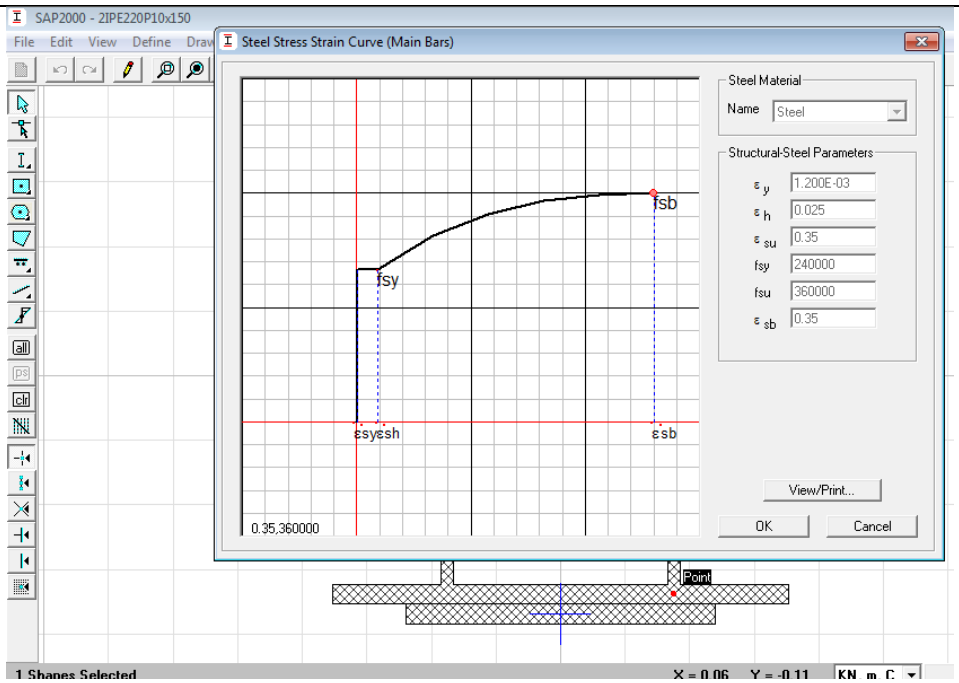
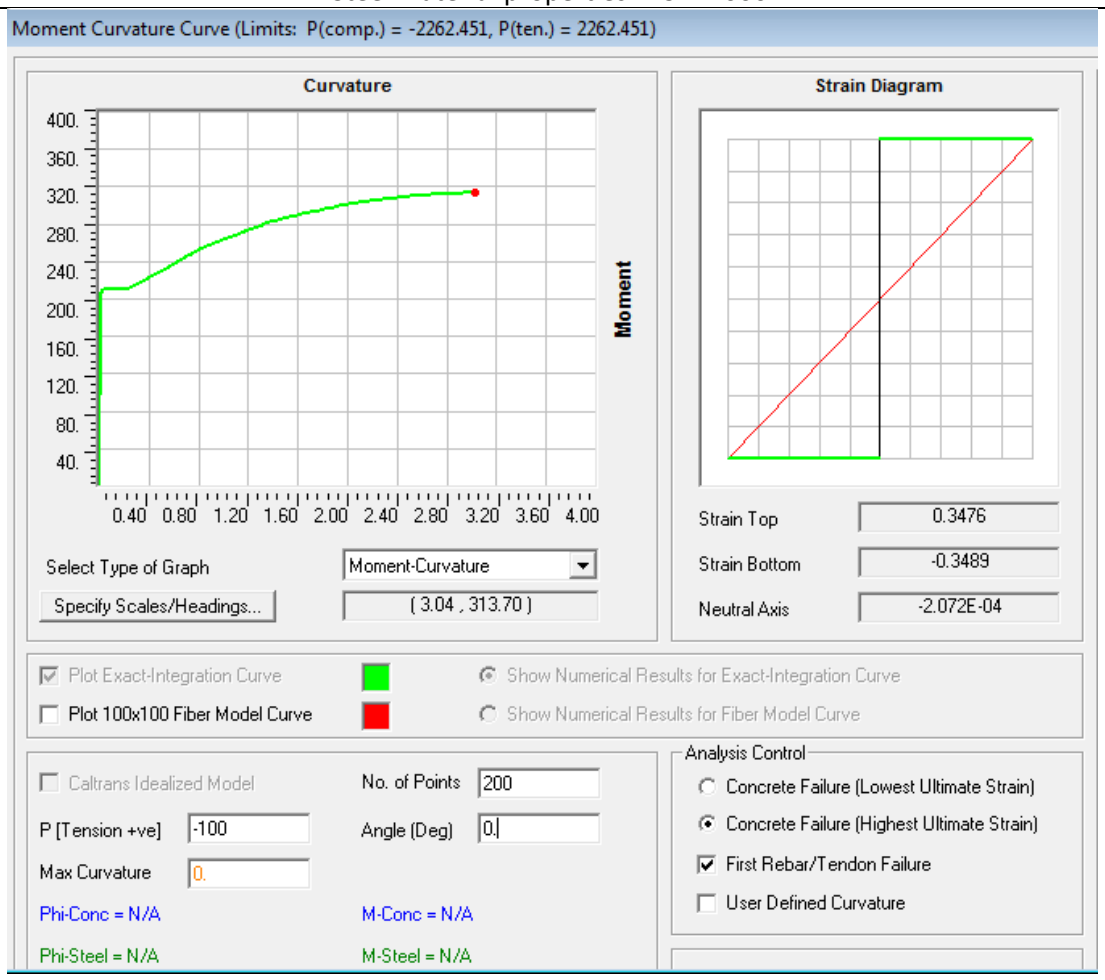




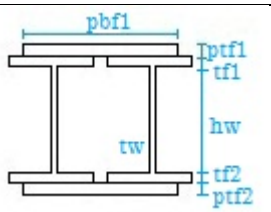
Steel section properties in SAP2000



Steel material properties in SAP2000



Moment curvature analysis in SAP2000

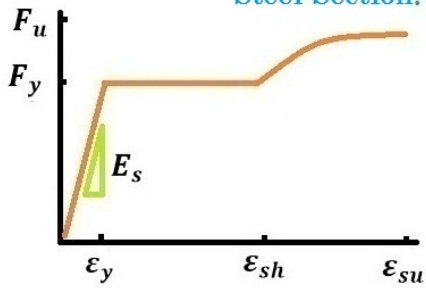


Section Properties:

```
Ptarget =+100000;% [N] Target axial load [+ : Compression]
%% Section Properties
tf1=9.2;% [mm] I section thickness on Top flange
bf1=110;% [mm] I section width on Top flange
tw=5.9;% [mm] I section thickness of Web
hw=201.6;% [mm] Height of web
tf2=9.2;% [mm] I section thickness on Bottom flange
bf2=110;% [mm] I section width on Bottom flange
ptf1=10;% [mm] Plate section thickness on Top flange
pbf1=150;% [mm] Plate section width on Top flange
ptf2=10;% [mm] Plate section thickness on Bottom flange
pbf2=150;% [mm] Plate section width on Bottom flange
```

Stress-Strain of materials

Steel Section: Stress-Strain Relationship (Curve strain hardening)



$$\begin{cases} \varepsilon_s \le \varepsilon_y & f_s = E_s\varepsilon_s \\ \varepsilon_y < \varepsilon_s \le \varepsilon_{sh} & f_s = F_y \\ \varepsilon_{sh} < \varepsilon_s \le \varepsilon_{su} & f_s = F_u + (F_u - F_y)\left(\frac{\varepsilon_{su}-\varepsilon_s}{\varepsilon_{su}-\varepsilon_{sh}}\right)^2 \end{cases}$$

Steel Properties:

```
fy =240;% [N/mm^2] Yield strength of steel section
Es =2e5;% [N/mm^2] Modulus of elasticity of steel section
fu=1.5*fy;% Ultimate steel stress
ey=fy/Es;% Yeild steel strain
esh=0.025;% Strain at steel strain-hardening
esu=0.35;% Ultimate steel strain
Esh=(fu-fy)/(esu-esh);
```

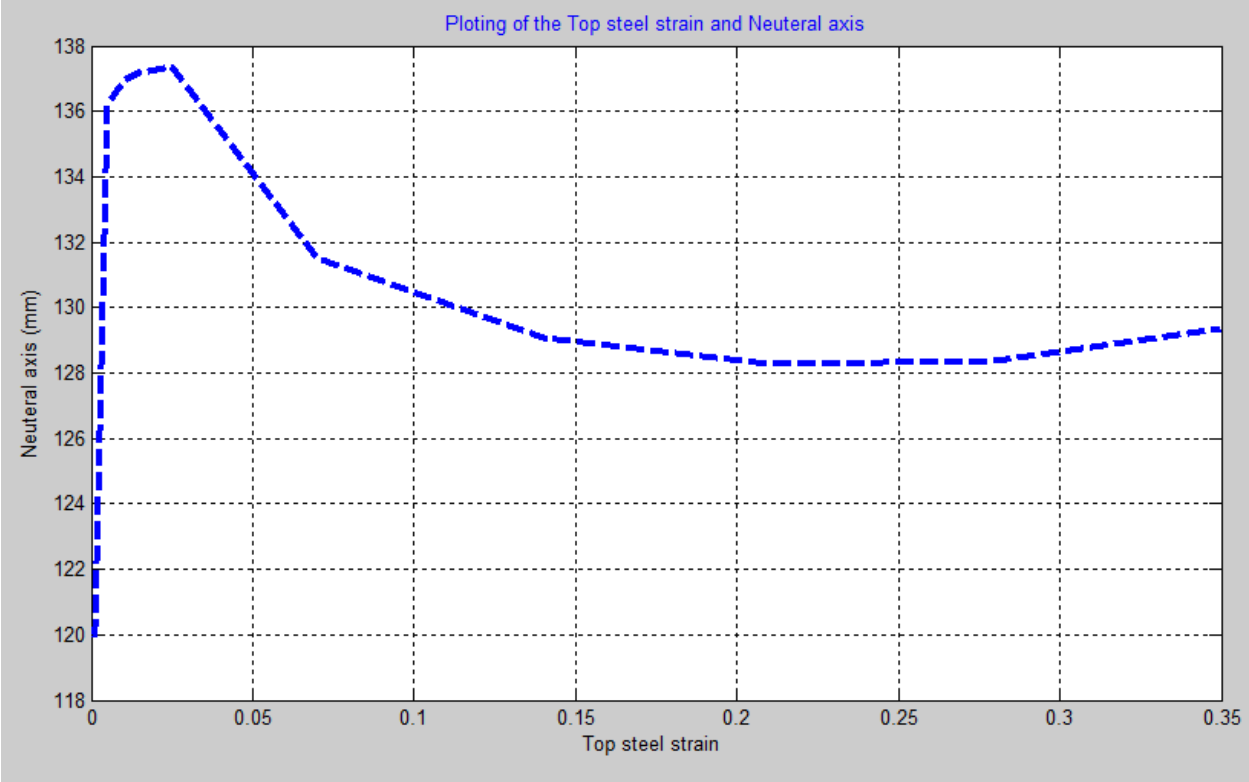
Analysis Report:

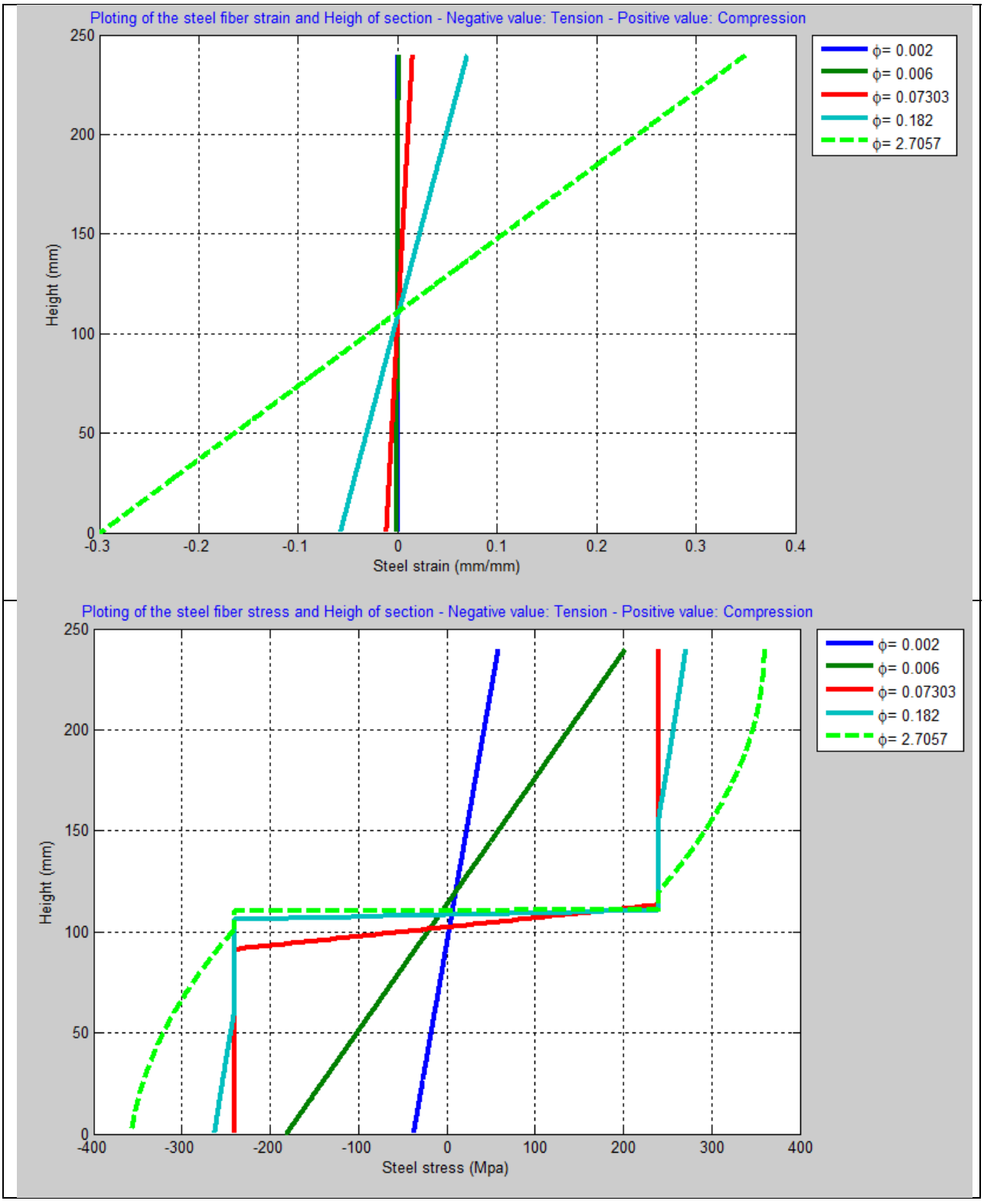
################################
 # SECTION WITH AXIAL LOAD EFFECT #
################################
(+)It is converged in 2 iterations - Initial axial strain: 0.000053 - Initial axial stress: 10.608 (N/mm^2)
Target applied axial load: 100.000 (kN) - Yield strength axial force capacity of the section: 1586.611 (kN) - Ultimate strength axial force capacity of the section: 2379.917 (kN)

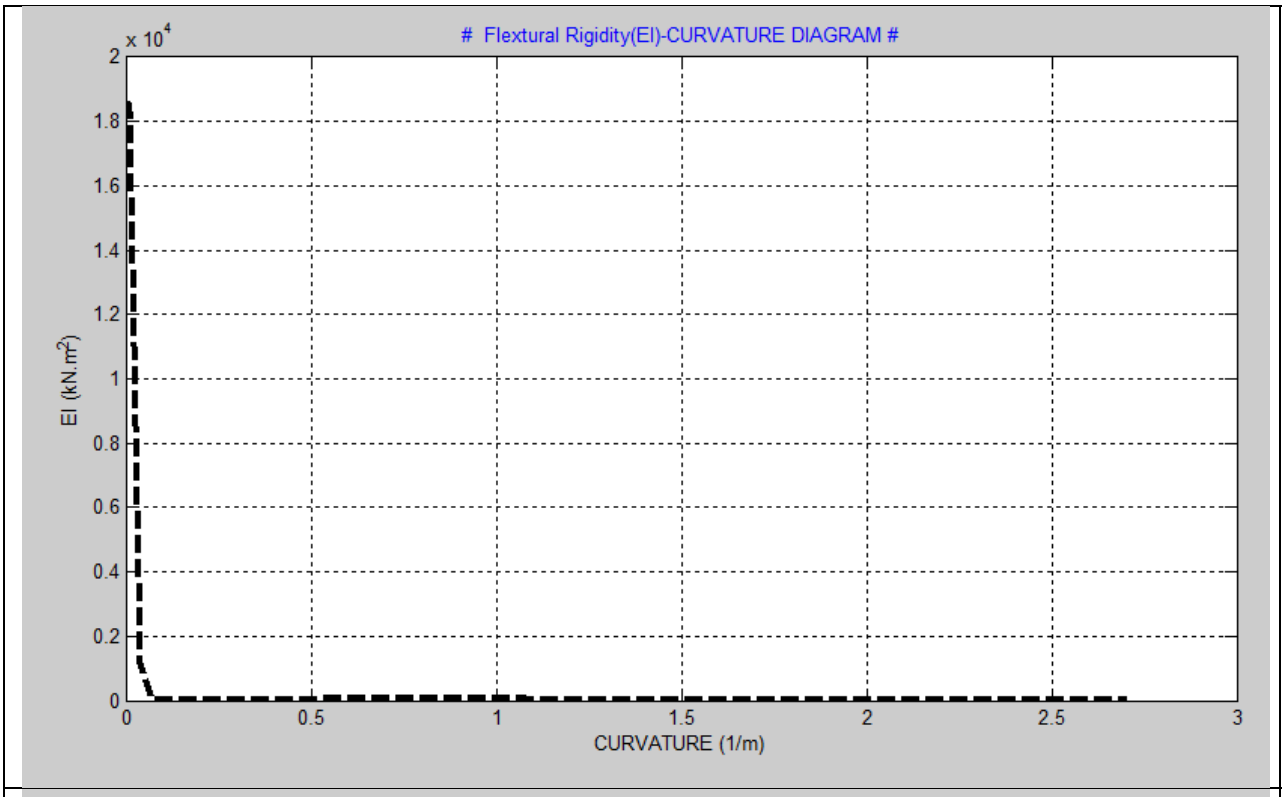
(+)Increment 1 : It is converged in 7 iterations - strain: 0.00024 - x: 120.00 - Phi: 0.00200 - Moment: 37.10
(+)Increment 2 : It is converged in 1 iterations - strain: 0.00048 - x: 120.00 - Phi: 0.00400 - Moment: 74.20
(+)Increment 3 : It is converged in 1 iterations - strain: 0.00072 - x: 120.00 - Phi: 0.00600 - Moment: 111.31
(+)Increment 4 : It is converged in 1 iterations - strain: 0.00096 - x: 120.00 - Phi: 0.00800 - Moment: 148.41
(+)Increment 5 : It is converged in 4 iterations - strain: 0.00120 - x: 120.22 - Phi: 0.00998 - Moment: 184.71
(+)Increment 6 : It is converged in 5 iterations - strain: 0.00500 - x: 136.21 - Phi: 0.03671 - Moment: 215.32
(+)Increment 7 : It is converged in 4 iterations - strain: 0.01000 - x: 136.93 - Phi: 0.07303 - Moment: 216.22

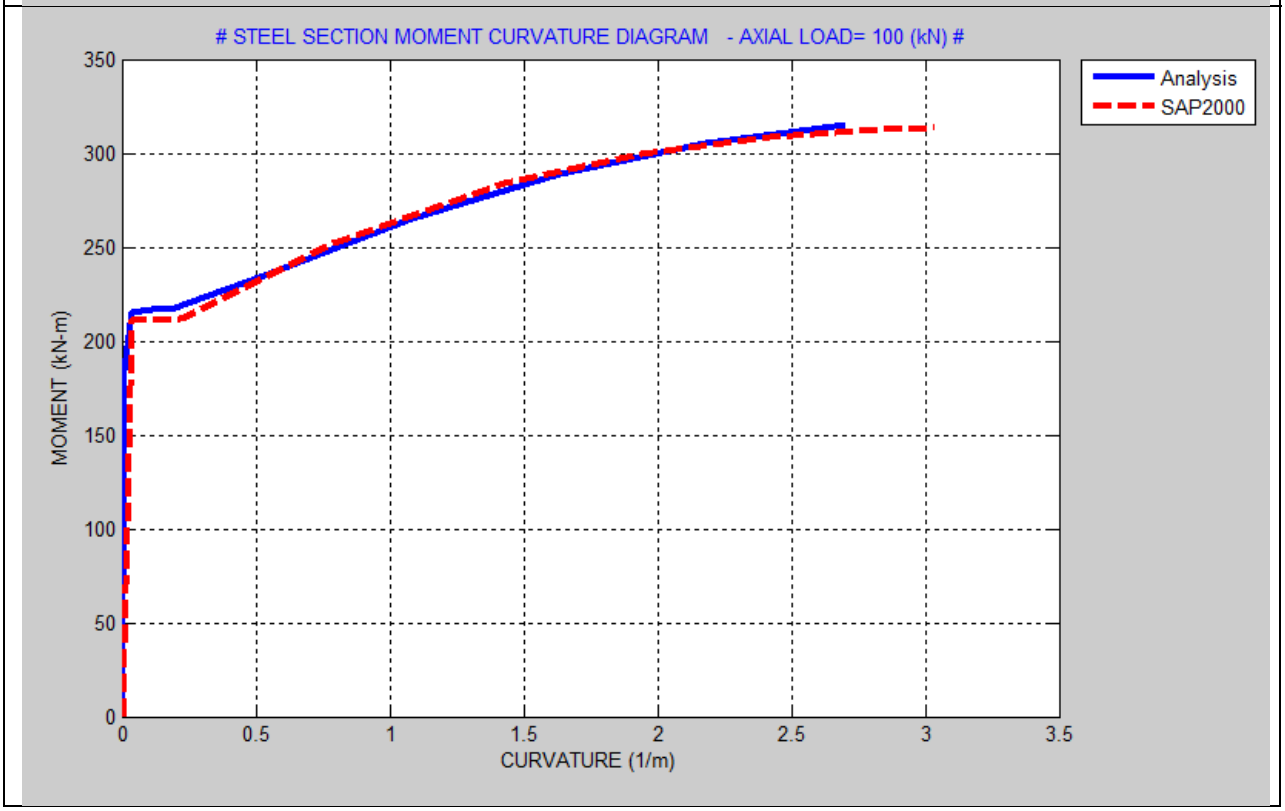
```
(+)Increment 8 : It is converged in 4 iterations - strain: 0.01500 - x: 137.17 - Phi: 0.10935 - Moment: 216.41
(+)Increment 9 : It is converged in 4 iterations - strain: 0.02000 - x: 137.29 - Phi: 0.14568 - Moment: 216.48
(+)Increment 10 : It is converged in 4 iterations - strain: 0.02500 - x: 137.36 - Phi: 0.18200 - Moment: 216.52
(+)Increment 11 : It is converged in 14 iterations - strain: 0.07000 - x: 131.49 - Phi: 0.53236 - Moment: 235.02
(+)Increment 12 : It is converged in 23 iterations - strain: 0.14000 - x: 129.08 - Phi: 1.08461 - Moment: 265.15
(+)Increment 13 : It is converged in 32 iterations - strain: 0.21000 - x: 128.26 - Phi: 1.63731 - Moment: 288.72
(+)Increment 14 : It is converged in 41 iterations - strain: 0.28000 - x: 128.36 - Phi: 2.18129 - Moment: 305.27
(+)Increment 15 : It is converged in 75 iterations - strain: 0.35000 - x: 129.36 - Phi: 2.70568 - Moment: 314.88

    ## Strain Reached to Ultimate Strain: 0.3500 ##

+=======================+
= Steel Section curve fitted  =
   Curvature    Moment
    (1/m)     (kN.m)
-----------------------------------------
      0       0
   0.0123  227.7248
   2.7057  314.8806
+=======================+
+-------------------------------------------------------------------------+
 Elastic EI (Analysis): 18551.08 (kN.m^2)
 Plastic EI (Analysis): 32.36 (kN.m^2)
 Steel Material Ductility Rito : 14.00
 Steel Section Ductility Rito (Analysis) : 220.41
 Steel Section Over Strength Factor (Analysis) :  1.38
+-------------------------------------------------------------------------+
```

Plot :




Ploting of the steel fiber strain and Heigh of section - Negative value: Tension - Positive value: Compression
Height (mm)
Steel strain (mm/mm)
ϕ= 0.002
ϕ= 0.006
ϕ= 0.07303
ϕ= 0.182
ϕ= 2.7057
Ploting of the steel fiber stress and Heigh of section - Negative value: Tension - Positive value: Compression
Height (mm)
Steel stress (Mpa)
ϕ= 0.002
ϕ= 0.006
ϕ= 0.07303
ϕ= 0.182
ϕ= 2.7057


Flextural Rigidity(EI)-CURVATURE DIAGRAM
x 10^4
EI (kN.m^2)
CURVATURE (1/m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0.5
1.5
2.5
3


STEEL SECTION MOMENT CURVATURE DIAGRAM - AXIAL LOAD= 100 (kN)
Analysis
SAP2000
MOMENT (kN-m)
CURVATURE (1/m)
0
50
100
150
200
250
300
350
0.5
1
1.5
2
2.5
3
3.5