>> IN THE NAME OF GOD <<

Moment-Curvature Analysis of Confined Concrete Composite Beam Section in MATLAB

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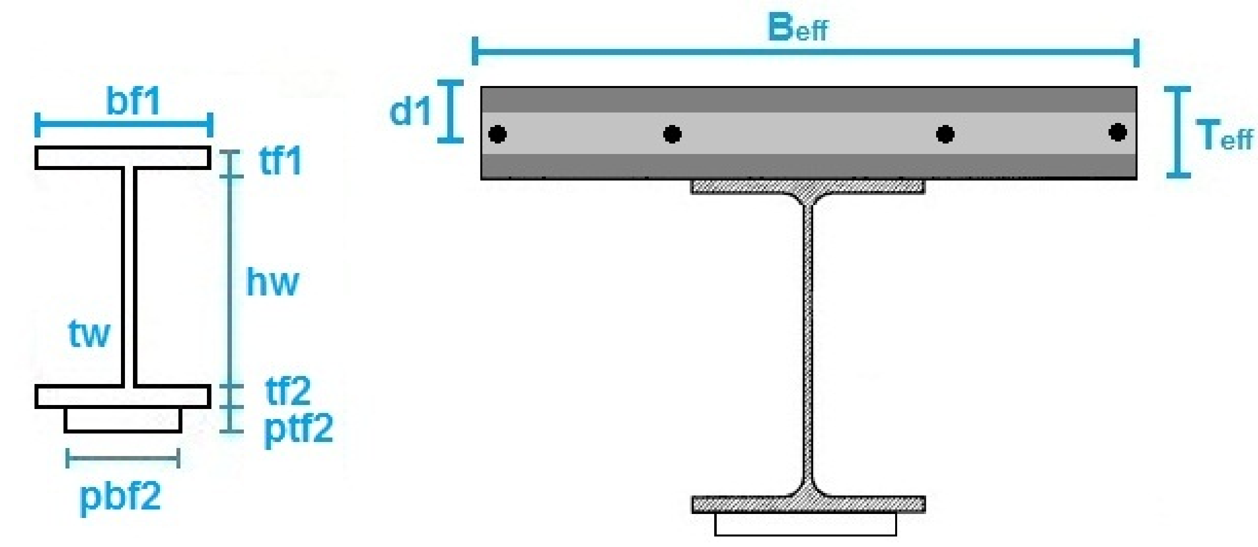


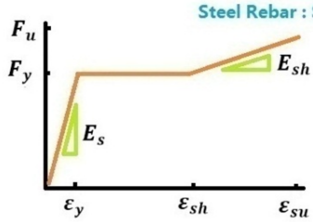
Confined concrete composite beam section

Section Properties:

```
Beff=1000; % Width of deck
Teff=100; % Depth of deck
%As:  As1       As2
As=[1000 1000];
%d:d1  d2
d=[30 60];
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
ptf2=10;% [mm] Plate section thickness on Bottom flange
pbf2=80;% [mm] Plate section width on Bottom flange
```

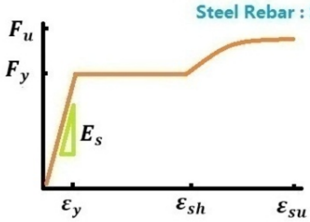
Stress-Strain of materials

Steel Rebar : Stress-Strain Relationship (Linear strain hardening)



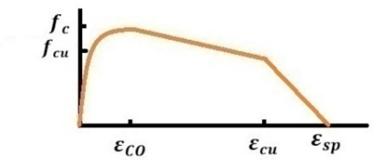
$$\begin{cases} \varepsilon_s \le \varepsilon_y & f_s = E_s\varepsilon_s \\ \varepsilon_y < \varepsilon_s \le \varepsilon_{sh} & f_s = F_y \\ \varepsilon_{sh} < \varepsilon_s \le \varepsilon_{su} & f_s = F_y + E_{sh}(\varepsilon_s - \varepsilon_{sh}) \end{cases}$$

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



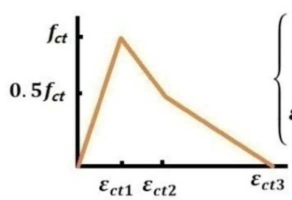
$$\begin{cases} \varepsilon_s \le \varepsilon_y & f_s = E_s\varepsilon_s \\ \varepsilon_y < \varepsilon_s \le \varepsilon_{sh} & f_s = F_y \\ \varepsilon_{sh} < \varepsilon_s \le \varepsilon_{su} & f_s = F_u + (F_u - F_y)\left(\frac{\varepsilon_{su}-\varepsilon_s}{\varepsilon_{su}-\varepsilon_{sh}}\right)^2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

Unconfined Concrete compressive : Stress-Strain Relationship (Mander Model)



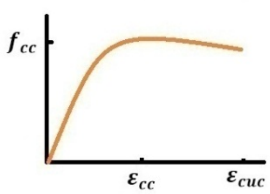
$$\begin{cases} f_c = \dfrac{f_c\left(\frac{\varepsilon_c}{\varepsilon_{C0}}\right)R}{R-1+\left(\frac{\varepsilon_c}{\varepsilon_{C0}}\right)^R} & 0 < \varepsilon_c \le \varepsilon_{cu} \\ f_c = f_{cu}\left(1 - \frac{\varepsilon_c-\varepsilon_{cu}}{\varepsilon_{sp}-\varepsilon_{cu}}\right) & \varepsilon_{cu} < \varepsilon_c \le \varepsilon_{sp} \end{cases}$$

Unconfined Concrete Tensile: Stress-Strain Relationship



$$\begin{cases} \varepsilon_c \le \varepsilon_{ct1} & f_{ct} = 0.5E_c\varepsilon_c \\ \varepsilon_{ct1} < \varepsilon_c \le \varepsilon_{ct2} & f_{ct} = f_{ct} - \left[\frac{0.5f_{ct}}{\varepsilon_{ct2}-\varepsilon_{ct1}}\right](\varepsilon_c - \varepsilon_{ct1}) \\ \varepsilon_{ct2} < \varepsilon_c \le \varepsilon_{ct3} & f_{ct} = 0.5f_{ct} - \left[\frac{0.5f_{ct}}{\varepsilon_{ct3}-\varepsilon_{ct2}}\right](\varepsilon_c - \varepsilon_{ct2}) \end{cases}$$

Confined concrete compressive: Stress-strain Relationship (Mander Model)



$$f_c = \frac{f_{cc}\left(\frac{\varepsilon_c}{\varepsilon_{cc}}\right)r}{r-1+\left(\frac{\varepsilon_c}{\varepsilon_{cc}}\right)^r} \quad 0 \le \varepsilon_c \le \varepsilon_{cuc}$$

Steel Section 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);
```

Concrete Properties:

```
fc =25;% [N/mm^2] Unconfined concrete strength
ecu=0.004;% Ultimate concrete strain
Ec=5000*sqrt(fc);
ec0=(2*fc)/Ec;
```

```
fct=-0.7*sqrt(fc);% Concrete tension stress
ect1=(2*fct)/Ec;ect2=(2.625*fct)/Ec;ect3=(9.292*fct)/Ec;% Concrete tension strain
```

Steel Reinforcing Properties:

```
fys =400;% Yield strength of steel reinforcing (N/mm^2)
Ess =2e5;% Modulus of elasticity of steel (N/mm^2)
fus=1.5*fys;% Ultimate steel stress
eys=fys/Ess;% Yield steel strain
eshs=0.01;% Strain at steel strain-hardening
esus=0.09;% Ultimate steel strain
stp= 2;% Kind of strain hardening:  1:linear   2:curve
Eshs=(fus-fys)/(esus-eshs);
```

Stirrup Reinforcing Properties:

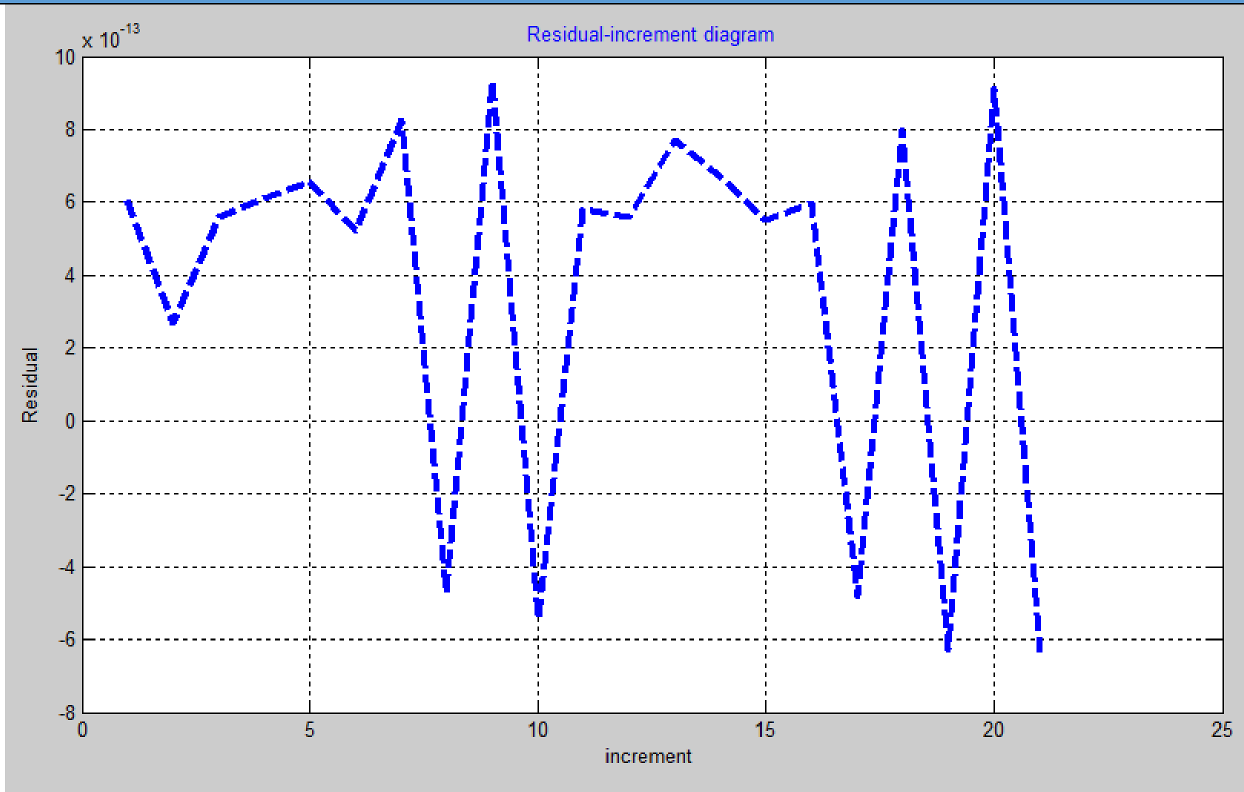
```
fyh =300;% [MPa] Transverse Reinforcing Bar (stirrup) Yield Stress
Nx=2;% Total of transverse hoop legs in the X
Ny=4;% Total of transverse hoop legs in the Y
diastirrup=8;% [mm] Cross-sectional hoop diameter
wi=6.4e+9;% [mm^2] Define total summation of confined reinforcing steel in power.2
s =100;% [mm] Tie Spacing Along Member
```

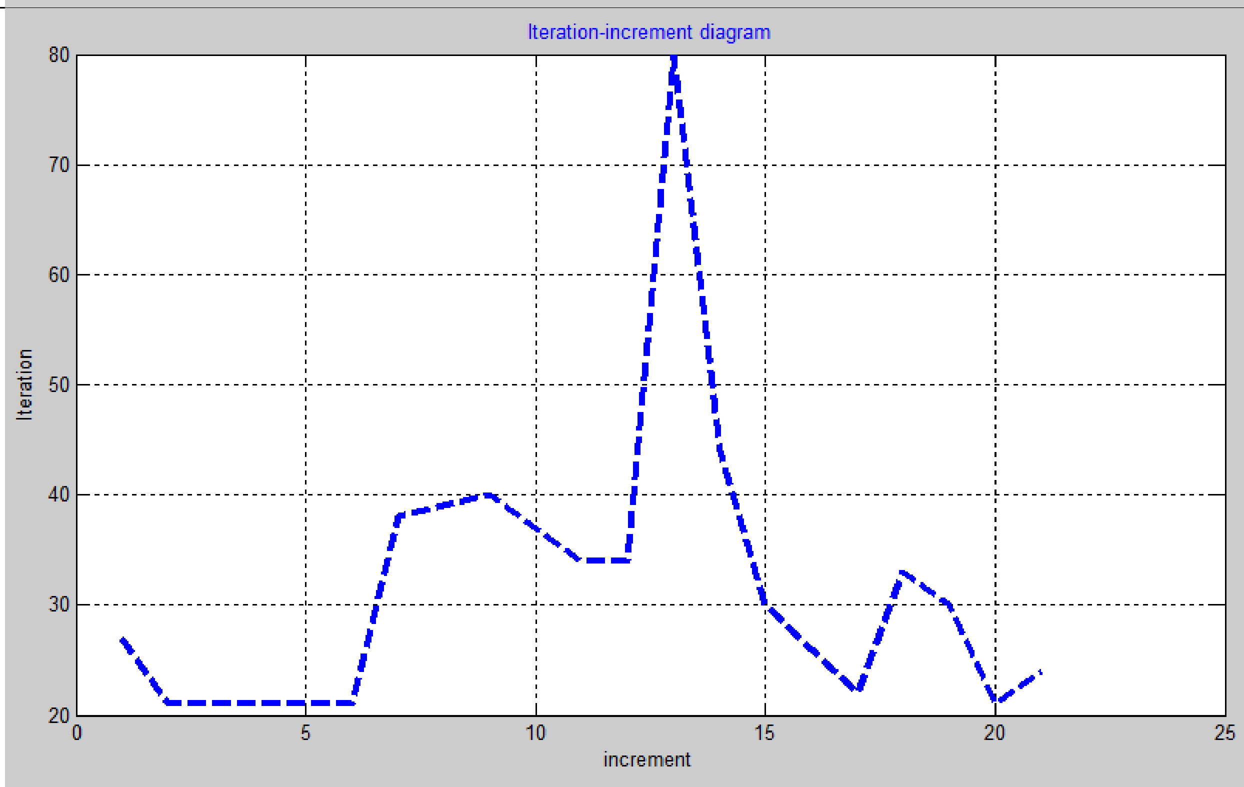
Analysis Report:

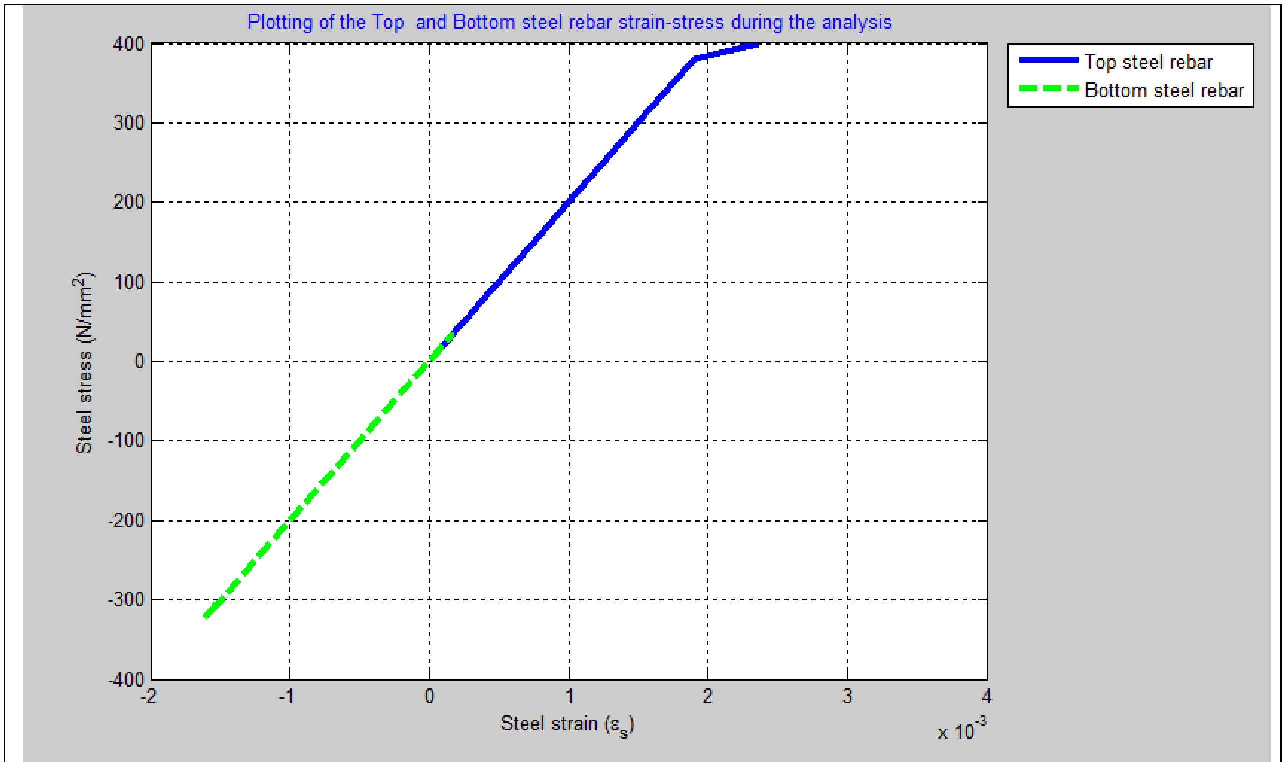
```
(+)Increment 1 : It is converged in 27 iterations - strain: 0.00003 - x: 89.54 - Phi: 0.00031 - Moment: 9.46
(+)Increment 2 : It is converged in 21 iterations - strain: 0.00009 - x: 89.62 - Phi: 0.00103 - Moment: 31.18
(+)Increment 3 : It is converged in 21 iterations - strain: 0.00019 - x: 89.80 - Phi: 0.00209 - Moment: 63.09
(+)Increment 4 : It is converged in 21 iterations - strain: 0.00028 - x: 90.06 - Phi: 0.00311 - Moment: 93.71
(+)Increment 5 : It is converged in 21 iterations - strain: 0.00037 - x: 90.35 - Phi: 0.00407 - Moment: 122.31
(+)Increment 6 : It is converged in 21 iterations - strain: 0.00043 - x: 90.59 - Phi: 0.00474 - Moment: 142.23
(+)Increment 7 : It is converged in 38 iterations - strain: 0.00065 - x: 80.55 - Phi: 0.00808 - Moment: 174.05
(+)Increment 8 : It is converged in 39 iterations - strain: 0.00087 - x: 72.62 - Phi: 0.01200 - Moment: 186.23
(+)Increment 9 : It is converged in 40 iterations - strain: 0.00104 - x: 67.81 - Phi: 0.01535 - Moment: 192.33
(+)Increment 10 : It is converged in 37 iterations - strain: 0.00117 - x: 64.95 - Phi: 0.01802 - Moment: 196.17
(+)Increment 11 : It is converged in 34 iterations - strain: 0.00130 - x: 62.70 - Phi: 0.02075 - Moment: 199.55
(+)Increment 12 : It is converged in 34 iterations - strain: 0.00134 - x: 62.14 - Phi: 0.02153 - Moment: 200.44
(+)Increment 13 : It is converged in 80 iterations - strain: 0.00178 - x: 55.79 - Phi: 0.03198 - Moment: 206.59
(+)Increment 14 : It is converged in 44 iterations - strain: 0.00268 - x: 48.78 - Phi: 0.05485 - Moment: 209.72
(+)Increment 15 : It is converged in 30 iterations - strain: 0.00357 - x: 46.64 - Phi: 0.07649 - Moment: 211.74
(+)Increment 16 : It is converged in 26 iterations - strain: 0.00446 - x: 46.02 - Phi: 0.09691 - Moment: 213.39
(+)Increment 17 : It is converged in 22 iterations - strain: 0.00535 - x: 46.52 - Phi: 0.11505 - Moment: 214.40
(+)Increment 18 : It is converged in 33 iterations - strain: 0.00624 - x: 48.20 - Phi: 0.12954 - Moment: 213.13
(+)Increment 19 : It is converged in 30 iterations - strain: 0.00714 - x: 49.46 - Phi: 0.14425 - Moment: 213.07
(+)Increment 20 : It is converged in 21 iterations - strain: 0.00803 - x: 50.13 - Phi: 0.16011 - Moment: 214.62
(+)Increment 21 : It is converged in 24 iterations - strain: 0.00892 - x: 50.73 - Phi: 0.17582 - Moment: 216.16
+=====================+
= Steel Section curve fitted  =
   Curvature    Moment
     (1/m)     (kN.m)
-------------------------------
      0       0
   0.0067  202.6954
   0.1758  216.1590
+=====================+
+--------------------------------------------------------+
 Elastic EI : 30260.35 (kN.m^2)
 Plastic EI : 79.61 (kN.m^2)
 Steel Material Ductility Rito : 14.00
 Steel Section Ductility Rito : 26.25
 Steel Section Over Strength Factor :  1.07
+--------------------------------------------------------+
+==============================================================================+
 Increment    Top strain   Neuteral axis(x)    Curvature   Flextural Rigidity(EI)
===============================================================================
   (i)           (1)           (mm)              (1/m)            (kN.m^2)
```

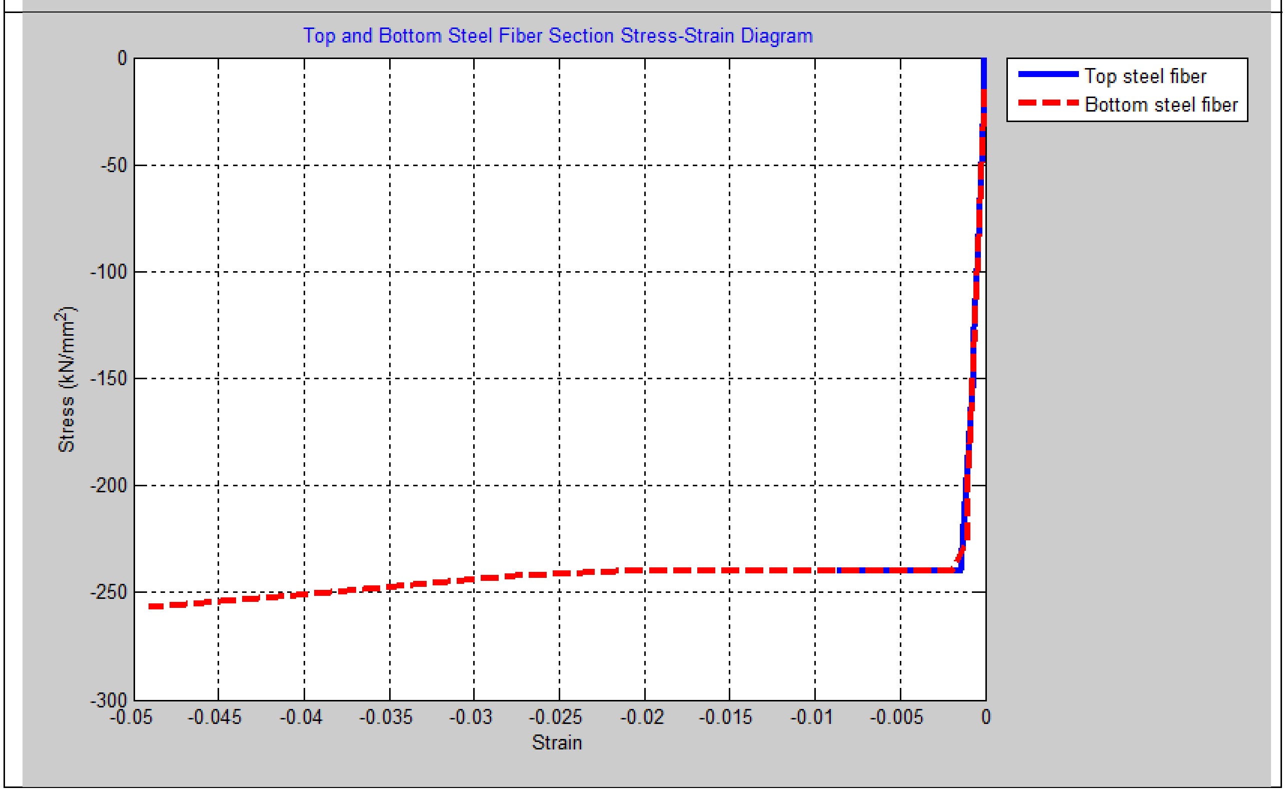
1	0.00003	89.54	0.000313	30260.35
2	0.00009	89.62	0.001031	30235.92
3	0.00019	89.80	0.002089	30156.82
4	0.00028	90.06	0.003109	30017.34
5	0.00037	90.35	0.004067	29842.18
6	0.00043	90.59	0.004739	29670.17
7	0.00065	80.55	0.008075	9537.39
8	0.00087	72.62	0.012002	3100.82
9	0.00104	67.81	0.015348	1825.60
10	0.00117	64.95	0.018025	1435.21
11	0.00130	62.70	0.020748	1239.49
12	0.00134	62.14	0.021529	1142.64
13	0.00178	55.79	0.031976	588.56
14	0.00268	48.78	0.054848	136.77
15	0.00357	46.64	0.076486	93.33
16	0.00446	46.02	0.096912	80.89
17	0.00535	46.52	0.115046	55.78
18	0.00624	48.20	0.129541	-87.52
19	0.00714	49.46	0.144250	-4.31
20	0.00803	50.13	0.160113	97.77
21	0.00892	50.73	0.175820	97.85

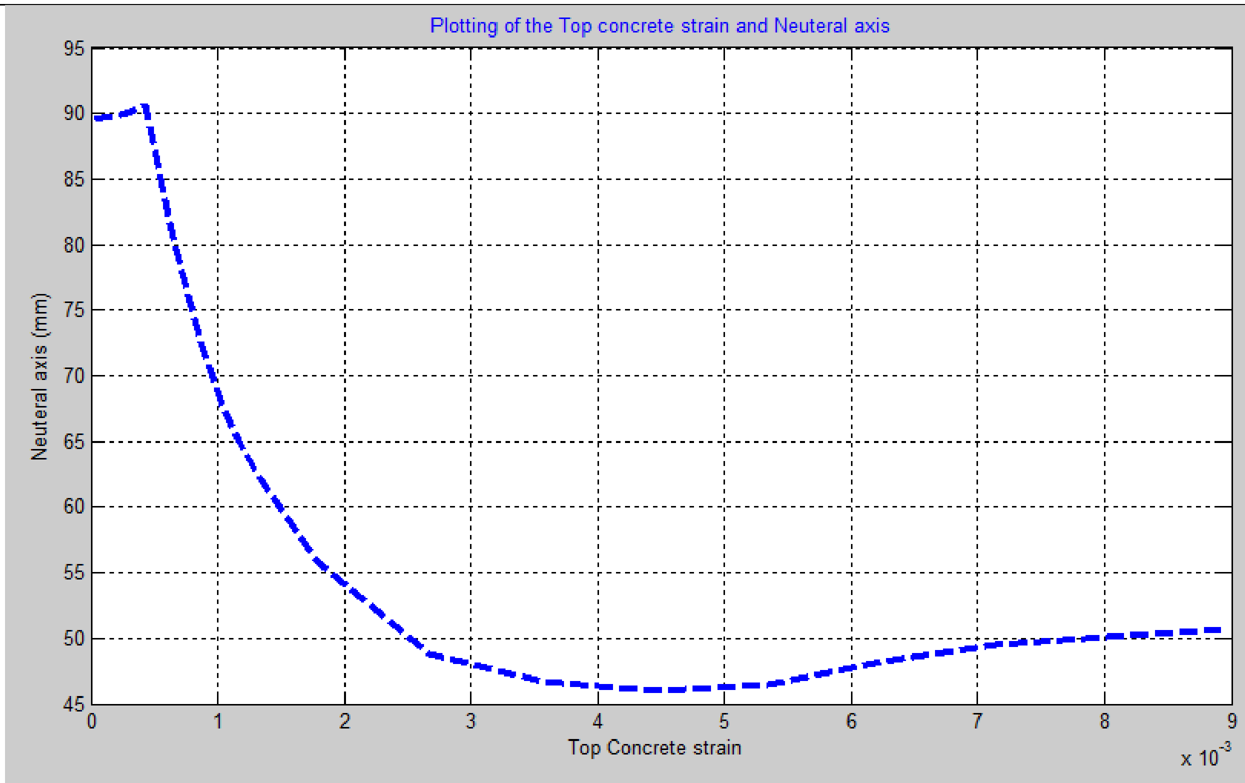
Plot :

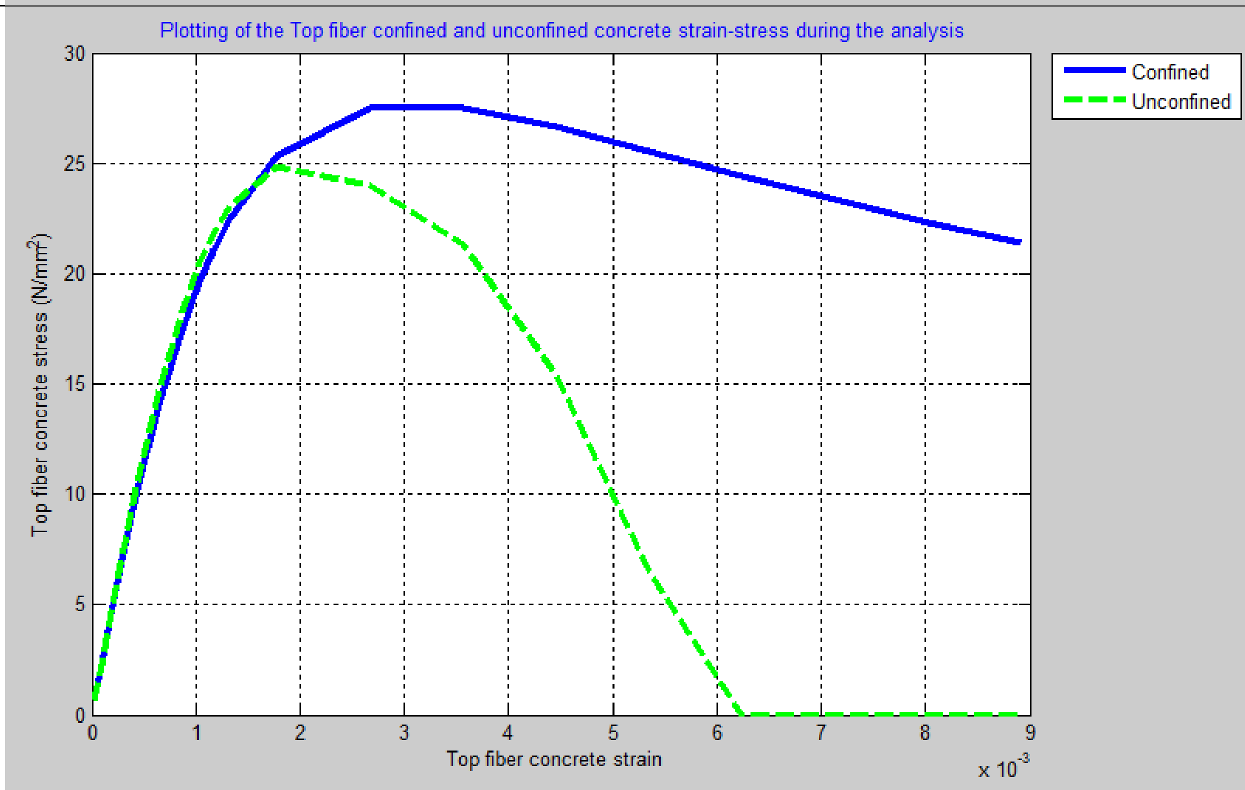

Residual-increment diagram
x 10^-13
Residual
increment
10
8
6
4
2
0
-2
-4
-6
-8
0
5
10
15
20
25

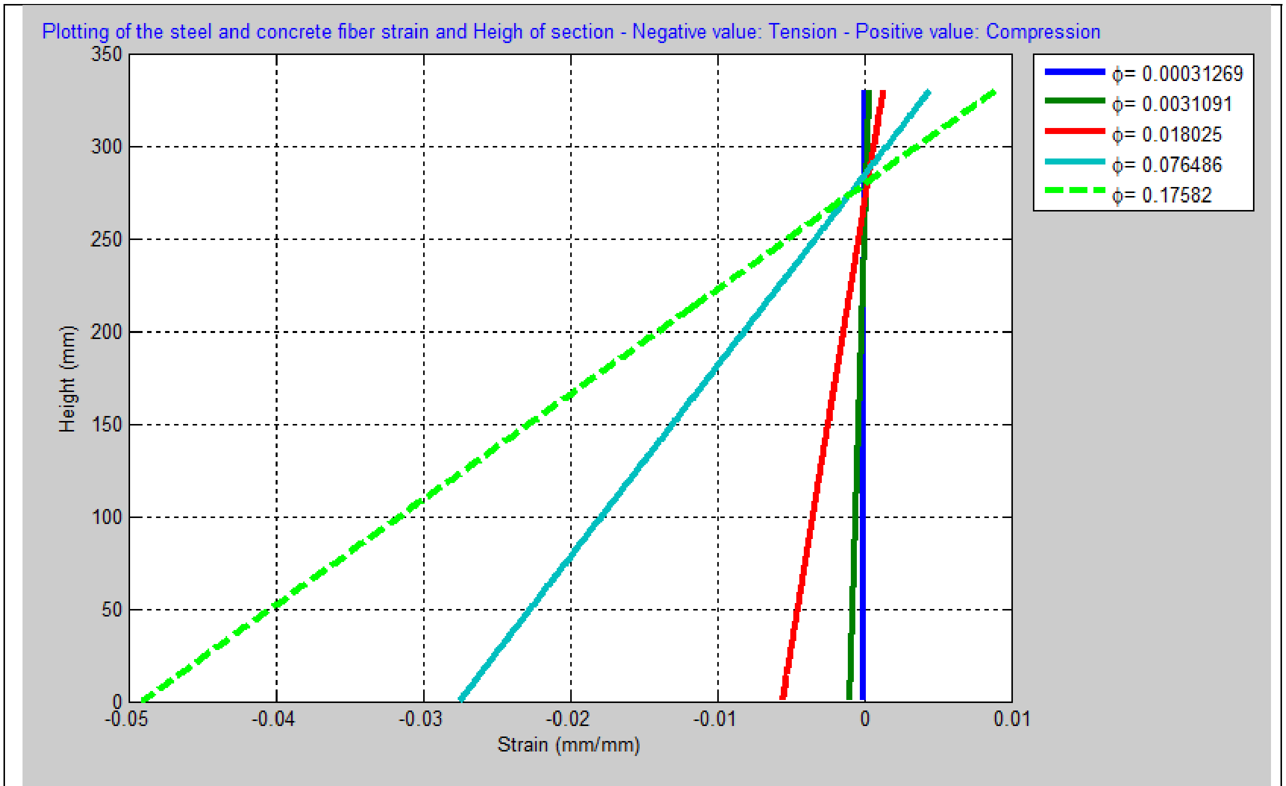

Iteration-increment diagram
Iteration
increment
80
70
60
50
40
30
20
0
5
10
15
20
25

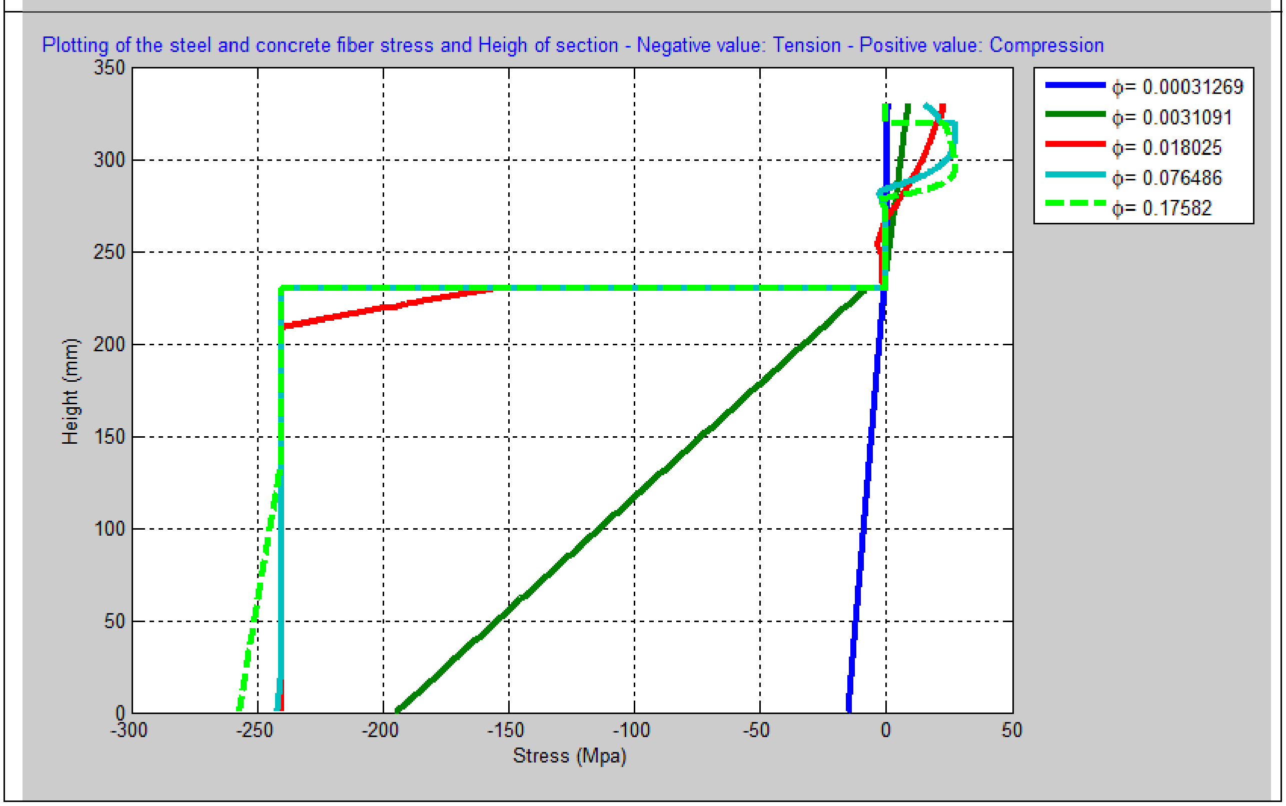

Plotting of the Top and Bottom steel rebar strain-stress during the analysis
Steel stress (N/mm2)
Steel strain (εs)
x 10-3
400
300
200
100
0
-100
-200
-300
-400
-2
-1
0
1
2
3
4
Top steel rebar
Bottom steel rebar

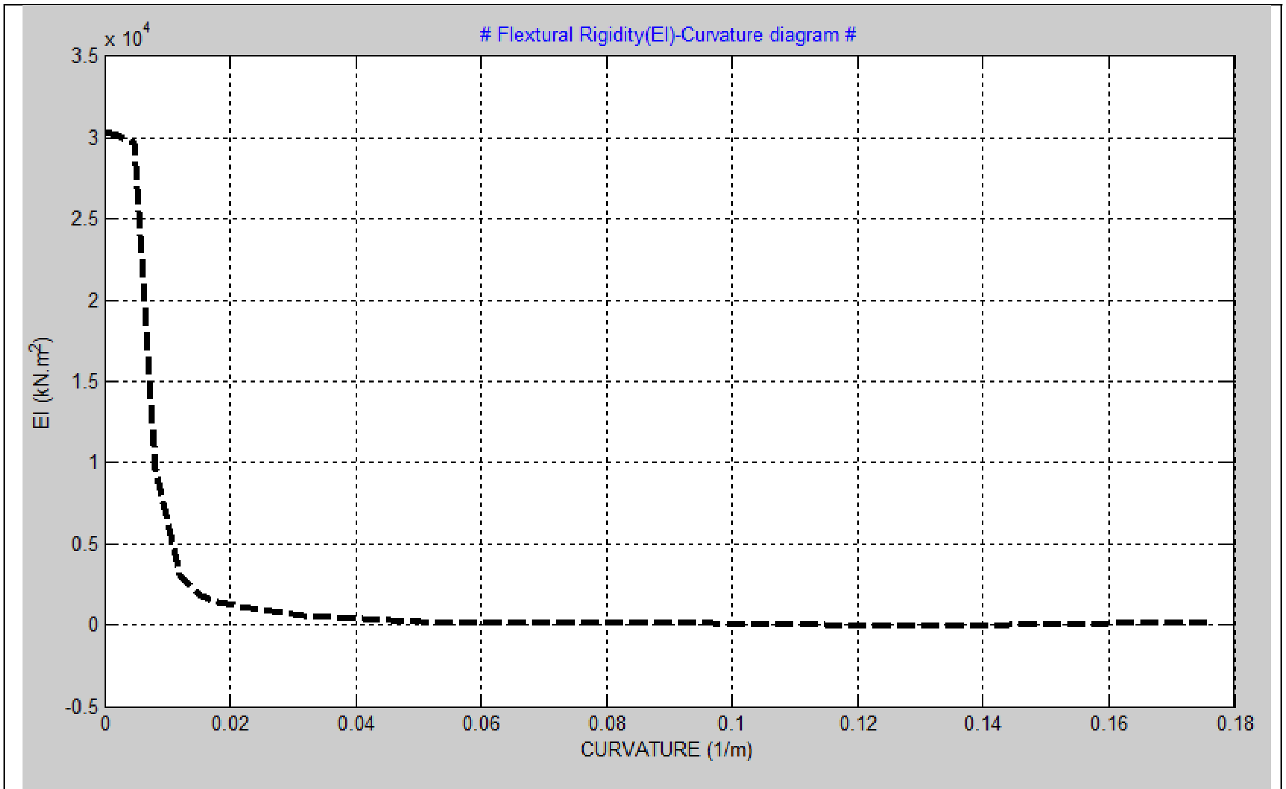

Top and Bottom Steel Fiber Section Stress-Strain Diagram
Stress (kN/mm2)
Strain
0
-50
-100
-150
-200
-250
-300
-0.05
-0.045
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0
Top steel fiber
Bottom steel fiber


Plotting of the Top concrete strain and Neuteral axis
Neuteral axis (mm)
Top Concrete strain
x 10^-3

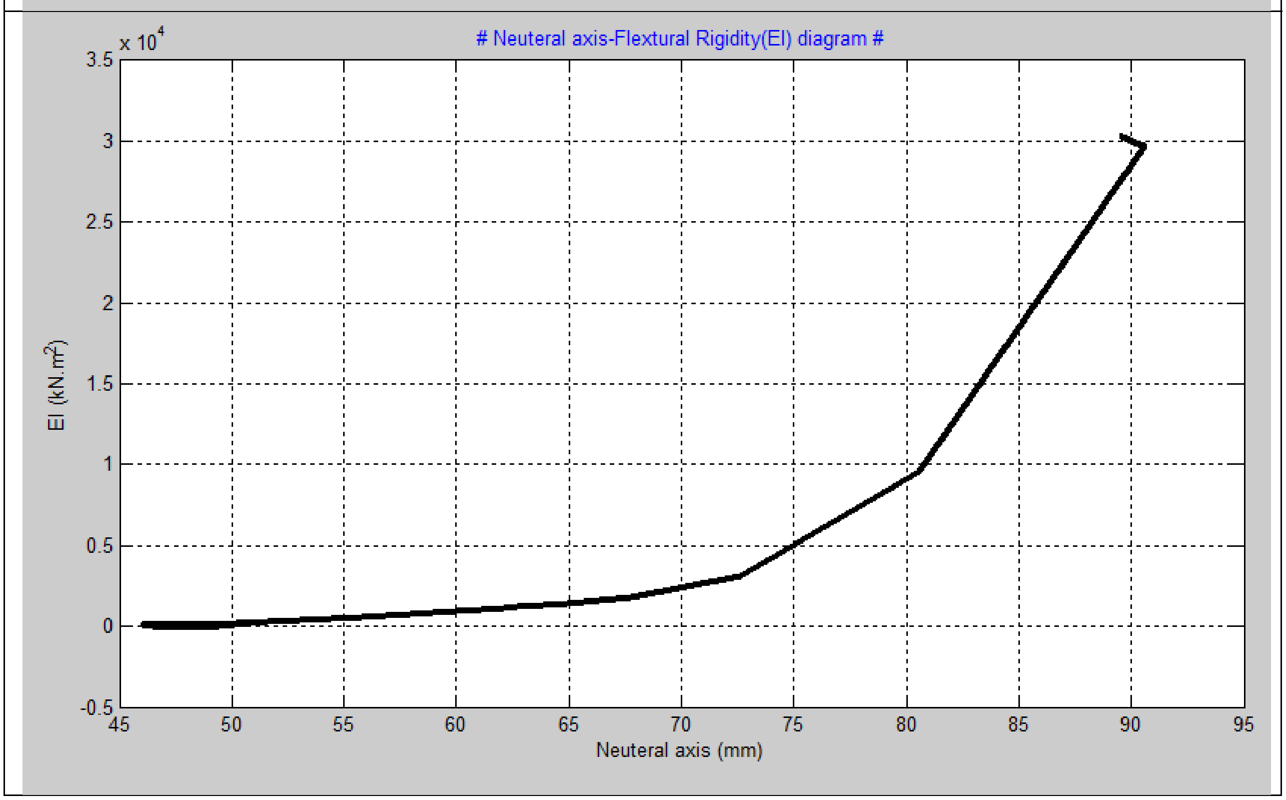

Plotting of the Top fiber confined and unconfined concrete strain-stress during the analysis
Top fiber concrete stress (N/mm^2)
Top fiber concrete strain
x 10^-3
Confined
Unconfined


Plotting of the steel and concrete fiber strain and Heigh of section - Negative value: Tension - Positive value: Compression
Height (mm)
Strain (mm/mm)
ϕ= 0.00031269
ϕ= 0.0031091
ϕ= 0.018025
ϕ= 0.076486
ϕ= 0.17582

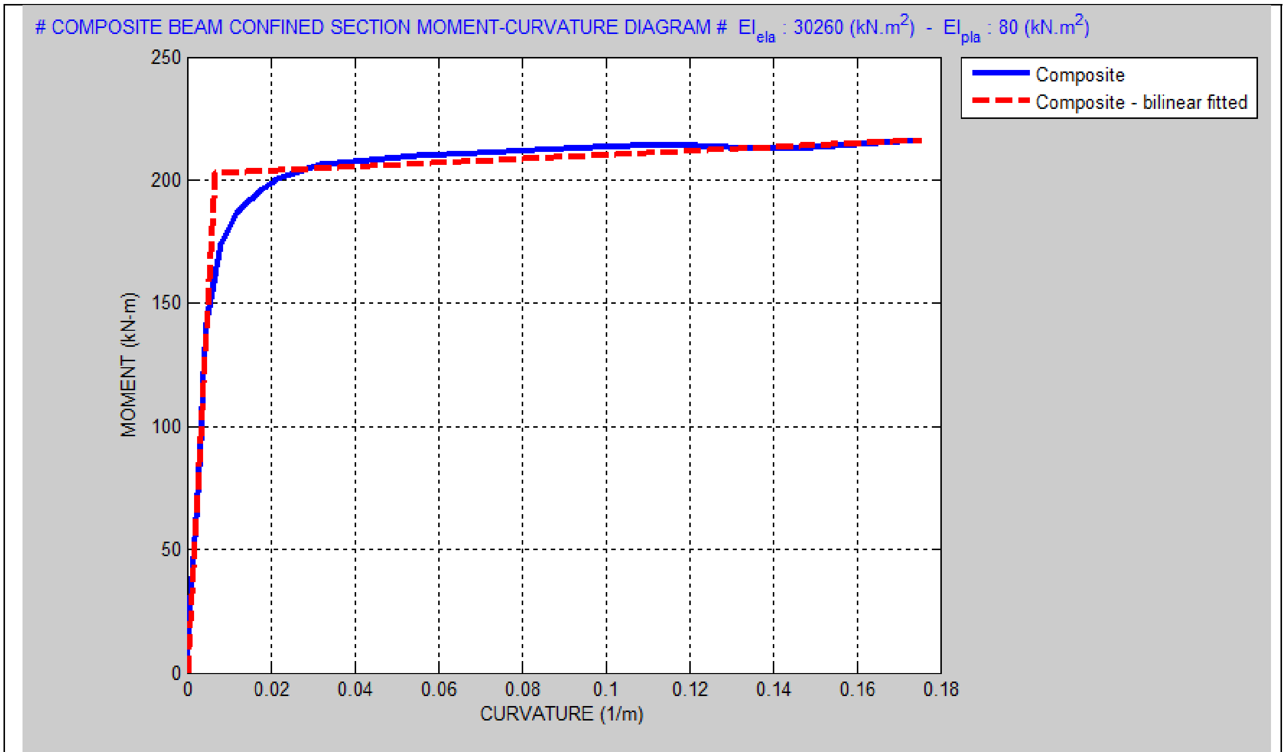

Plotting of the steel and concrete fiber stress and Heigh of section - Negative value: Tension - Positive value: Compression
Height (mm)
Stress (Mpa)
ϕ= 0.00031269
ϕ= 0.0031091
ϕ= 0.018025
ϕ= 0.076486
ϕ= 0.17582



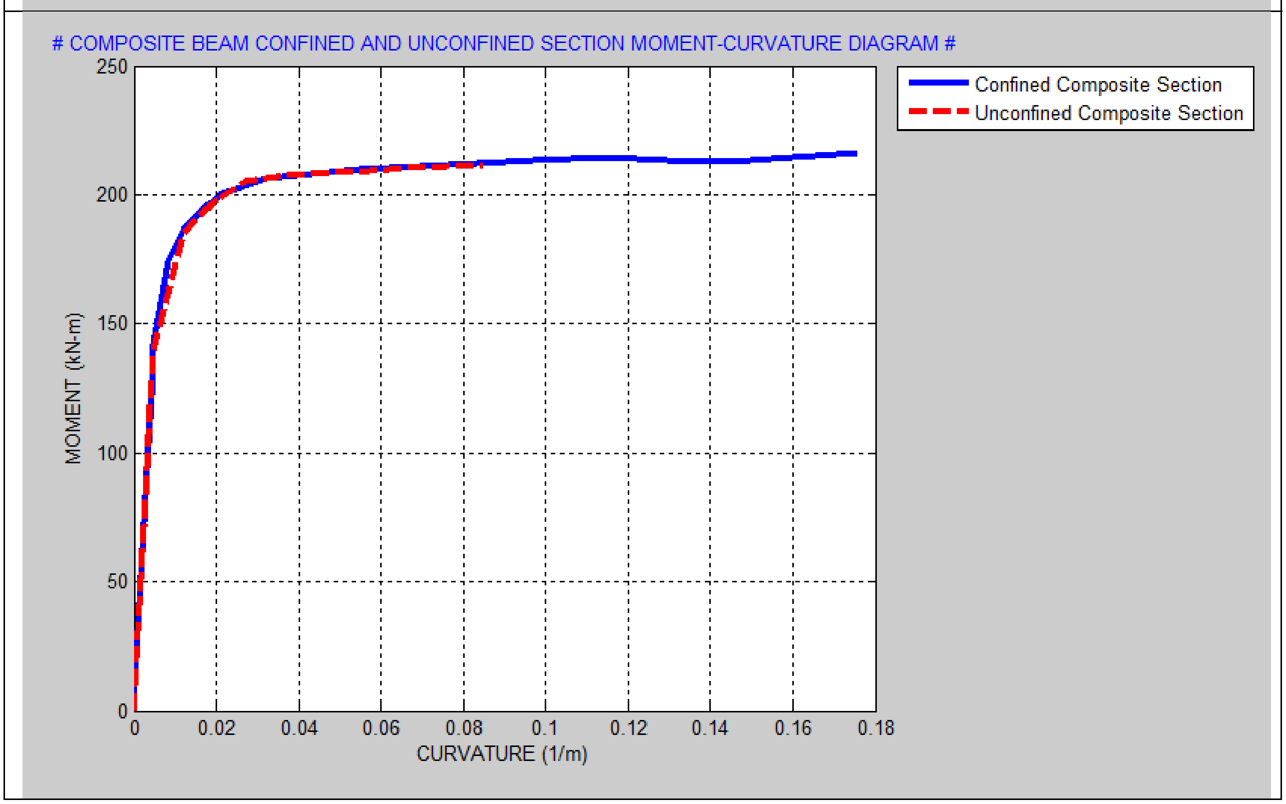
Flextural Rigidity(EI)-Curvature diagram
x 10^4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
EI (kN.m2)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
CURVATURE (1/m)



Neuteral axis-Flextural Rigidity(EI) diagram
x 10^4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
EI (kN.m2)
45
50
55
60
65
70
75
80
85
90
95
Neuteral axis (mm)



COMPOSITE BEAM CONFINED SECTION MOMENT-CURVATURE DIAGRAM # EIela : 30260 (kN.m2) - EIpla : 80 (kN.m2)
Composite
Composite - bilinear fitted
MOMENT (kN-m)
CURVATURE (1/m)
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18



COMPOSITE BEAM CONFINED AND UNCONFINED SECTION MOMENT-CURVATURE DIAGRAM
Confined Composite Section
Unconfined Composite Section
MOMENT (kN-m)
CURVATURE (1/m)
0
50
100
150
200
250
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18