>> IN THE NAME OF GOD <<

Moment-Curvature Analysis of Composite Beam Section In MATLAB

This program is written by salar delavar ghashghaei -2015.05.12

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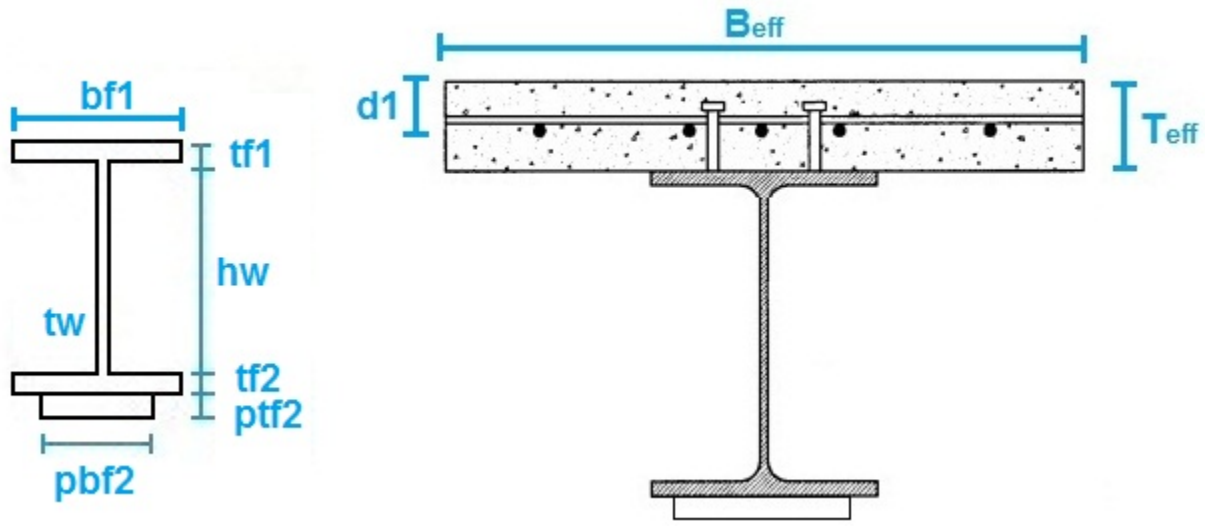



```
%*************************************************************%
%   _     _____________________________________               %
%   |    |                                     |              %
%        |     #     #     #     #     #     #     |        %
%        |     #                             #     |        %
% Beff   |    As1   As2   As3   As4   As5   As6   |        %
%        |     #                             #     |        %
%   |    |     #     #     #     #     #     #     |        %
%   _    |_____________________________________|              %
%        |<-                Teff                ->|        %
%        |<-d1->|                                            %
%        |<-  d2   ->|                                       %
%        |<-     d3      ->|                                 %
%        |<-        d4          ->|                          %
%        |<-            d5          ->|                      %
%        |<-               d6             >|                %
%    X                                                      %
%    ^                                                      %
%    |             (Moment - Curvature along X axis)        %
%    |                                                      %
%    +----> Y                                               %
%*************************************************************%
```

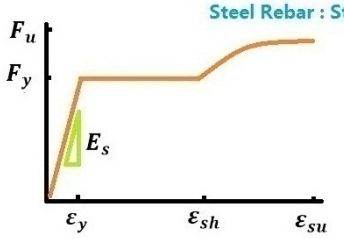
Section Properties:

```
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
```

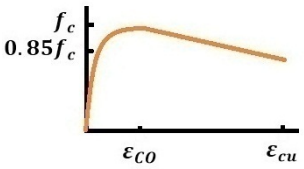
Stress-Strain of materials

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



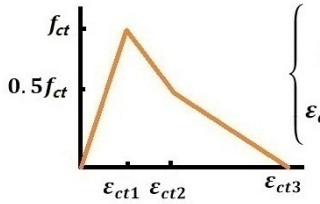
$$\begin{cases} \varepsilon_s \le \varepsilon_y & f_s = E_s\varepsilon_s \\ \varepsilon_y < \varepsilon_s \le \varepsilon_{sh} & f_s = F_y \\ \varepsilon_{sh} < \varepsilon_s \le \varepsilon_{su} & f_s = F_u + (F_u - F_y)\left(\frac{\varepsilon_{su}-\varepsilon_s}{\varepsilon_{su}-\varepsilon_{sh}}\right)^2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

Unconfined Concrete compressive : Stress-Strain Relationship



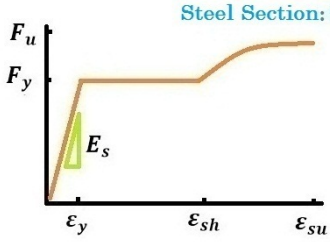
$$\begin{cases} \varepsilon_c < \varepsilon_{C0} & f_c = f_c\left[\left(\frac{2\varepsilon_c}{\varepsilon_{C0}}\right) - \left(\frac{\varepsilon_c}{\varepsilon_{C0}}\right)^2\right] \\ \varepsilon_{C0} \le \varepsilon_c < \varepsilon_{cu} & f_c\left[1 - \left(\frac{0.15(\varepsilon_c-\varepsilon_{C0})}{\varepsilon_{cu}-\varepsilon_{C0}}\right)\right] \end{cases}$$

Unconfined Concrete Tensile: Stress-Strain Relationship



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

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 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;% Yeild steel strain
eshs=0.01;% Strain at steel strain-hardening
esus=0.09;% Ultimate steel strain
Eshs=(fus-fys)/(esus-eshs);
```

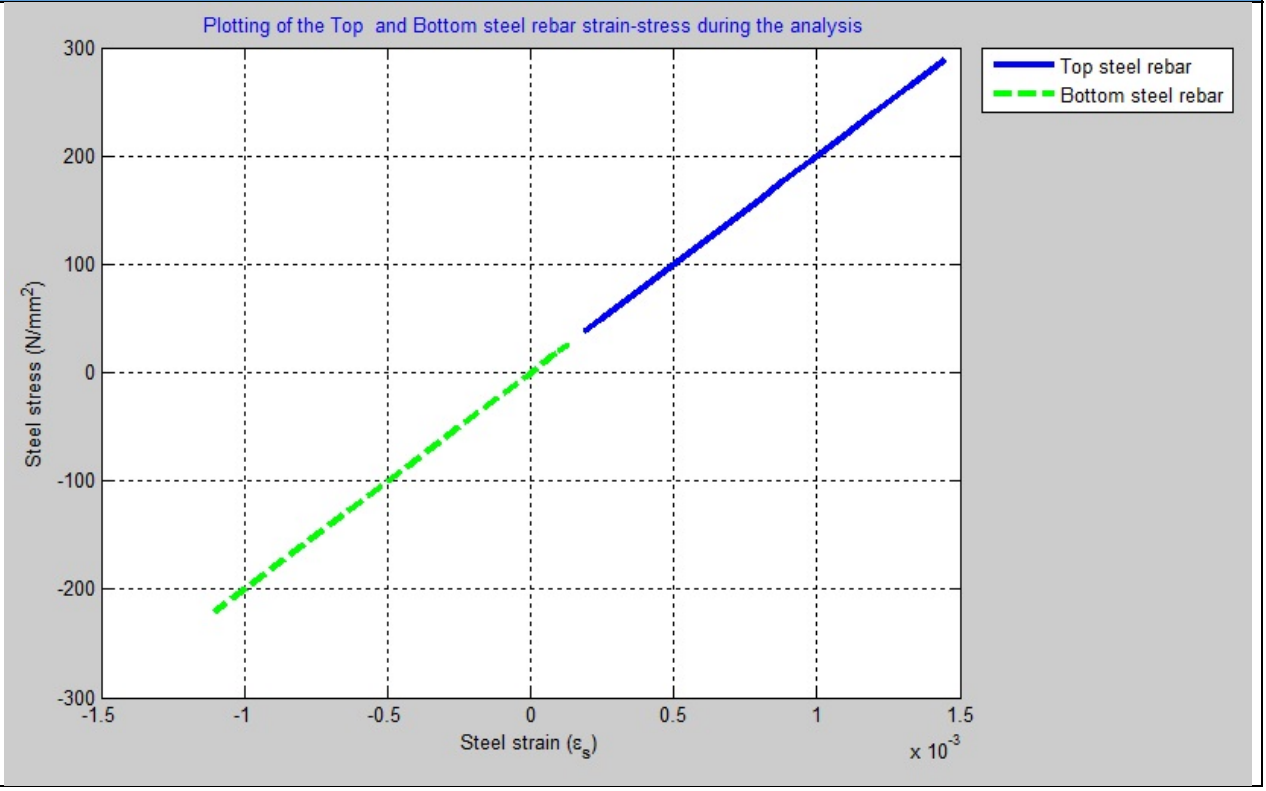
Analysis Report:

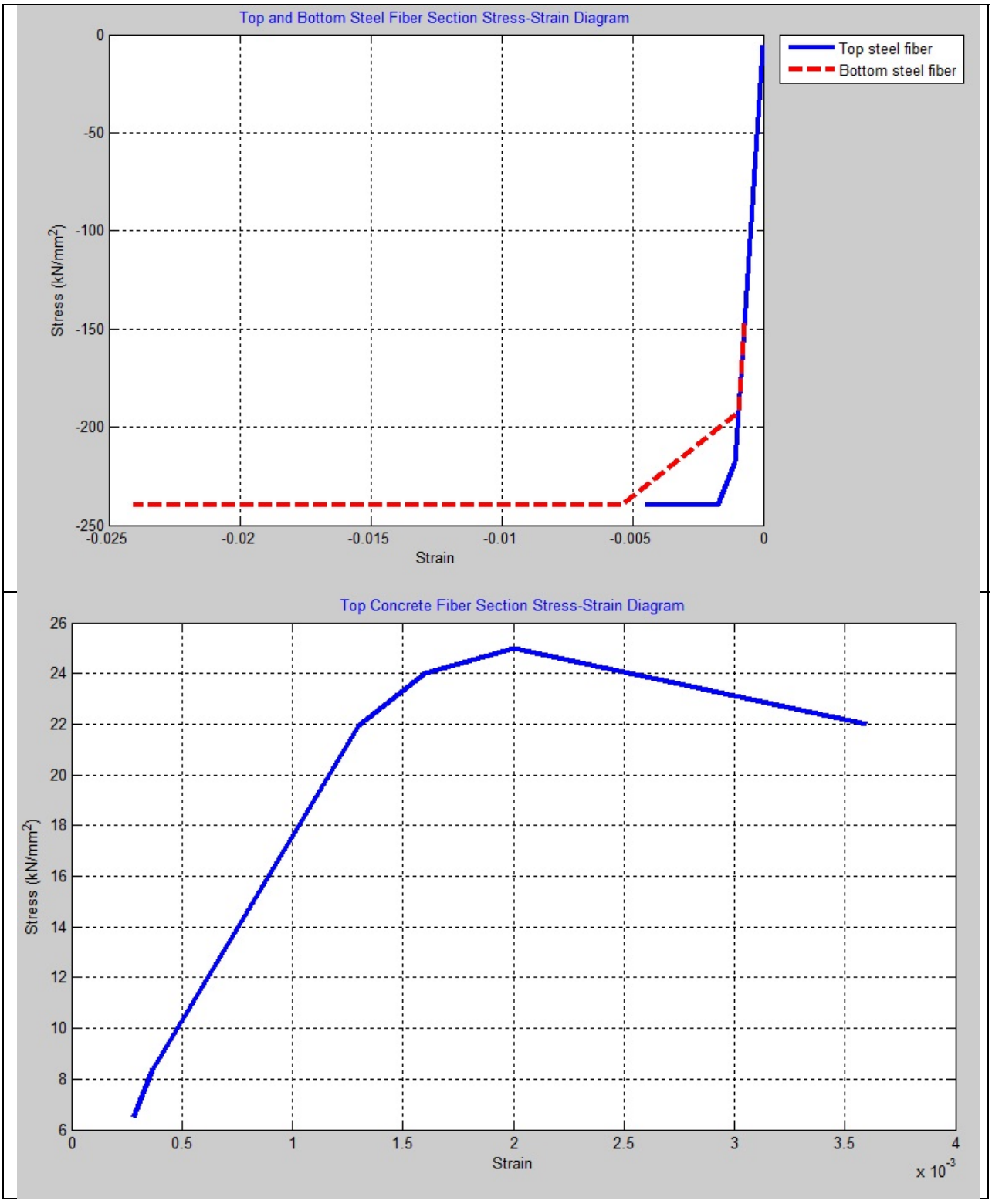
```
(+)Increment 1 : It is converged in 10 iterations - strain: 0.00028 - x: 90.87 - Phi: 0.00308 - Moment: 92.27
(+)Increment 2 : It is converged in 10 iterations - strain: 0.00037 - x: 91.30 - Phi: 0.00403 - Moment: 120.12
(+)Increment 3 : It is converged in 21 iterations - strain: 0.00130 - x: 63.71 - Phi: 0.02042 - Moment: 198.44
(+)Increment 4 : It is converged in 24 iterations - strain: 0.00160 - x: 59.55 - Phi: 0.02687 - Moment: 205.02
(+)Increment 5 : It is converged in 30 iterations - strain: 0.00200 - x: 53.70 - Phi: 0.03724 - Moment: 207.28
(+)Increment 6 : It is converged in 33 iterations - strain: 0.00240 - x: 50.57 - Phi: 0.04746 - Moment: 208.58
(+)Increment 7 : It is converged in 36 iterations - strain: 0.00280 - x: 48.92 - Phi: 0.05724 - Moment: 209.51
(+)Increment 8 : It is converged in 38 iterations - strain: 0.00320 - x: 47.96 - Phi: 0.06672 - Moment: 210.23
(+)Increment 9 : It is converged in 41 iterations - strain: 0.00360 - x: 47.39 - Phi: 0.07597 - Moment: 210.82
(+)Increment 10 : It is converged in 42 iterations - strain: 0.00400 - x: 47.03 - Phi: 0.08505 - Moment: 211.33

    ##  Concrete Strain Reached to Ultimate Strain: 0.0040 ##

+==============================+
= Steel Section curve fitted  =
   Curvature    Moment
    (1/m)     (kN.m)
--------------------------------
      0       0
   0.0063  187.9370
   0.0850  211.3304
+==============================+
+------------------------------------------------------+
 Elastic EI : 29946.32 (kN.m^2)
 Plastic EI : 296.97 (kN.m^2)
 Steel Material Ductility Rito : 14.00
 Steel Section Ductility Rito : 13.55
 Steel Section Over Strength Factor :  1.12
+------------------------------------------------------+
+==============================+
=Steel Section Moment-Curvature=
   Curvature    Moment
    (1/m)     (kN.m)
--------------------------------
  0.00000     0.000
  0.00308    92.274
  0.00403   120.122
  0.02042   198.441
  0.02687   205.024
  0.03724   207.279
  0.04746   208.578
  0.05724   209.506
  0.06672   210.227
  0.07597   210.822
  0.08505   211.330
+==============================+
= Steel Section curve fitted  =
   Curvature    Moment
```

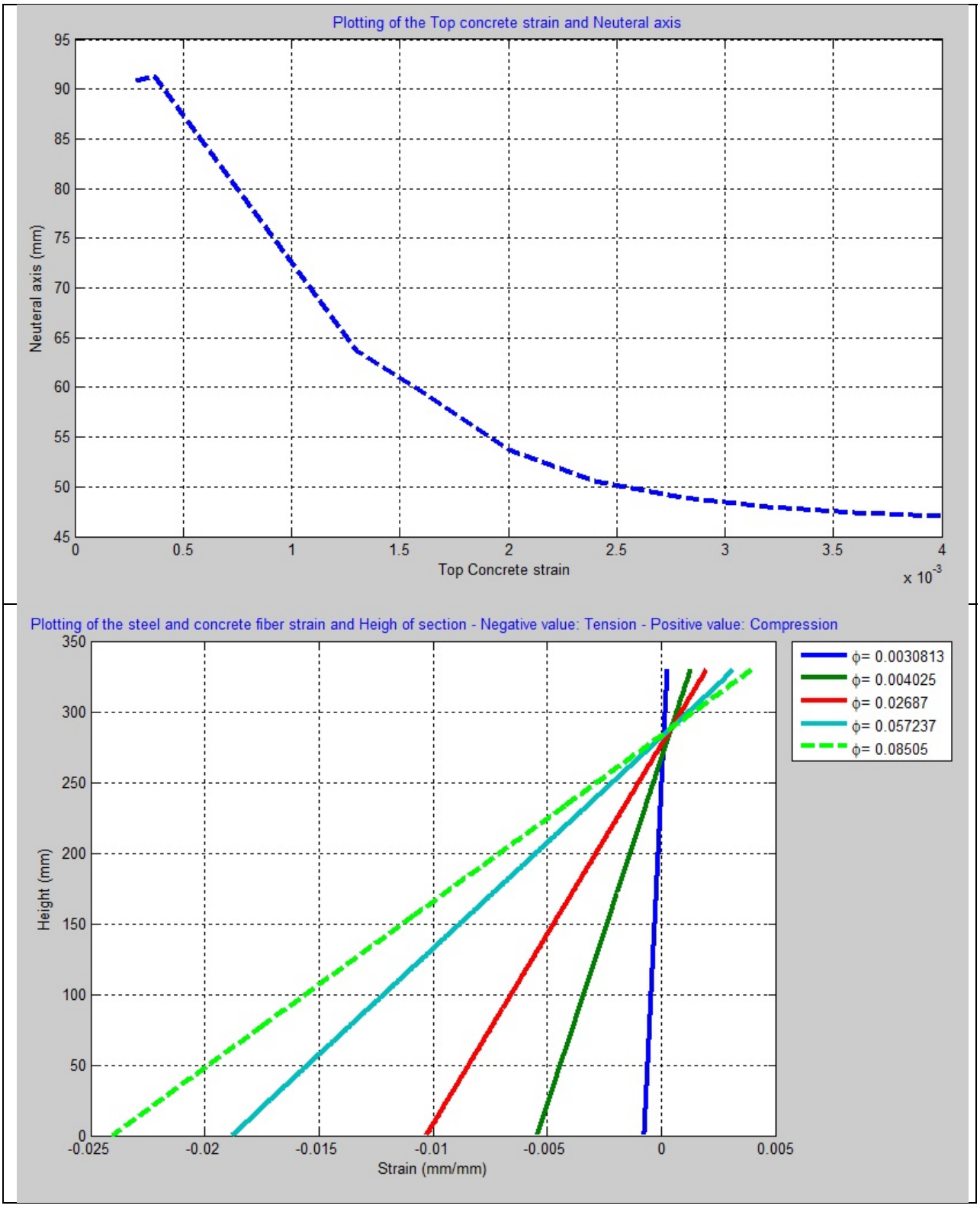
(1/m)	(kN.m)
0.0000	0.000
0.0063	187.937
0.0850	211.330

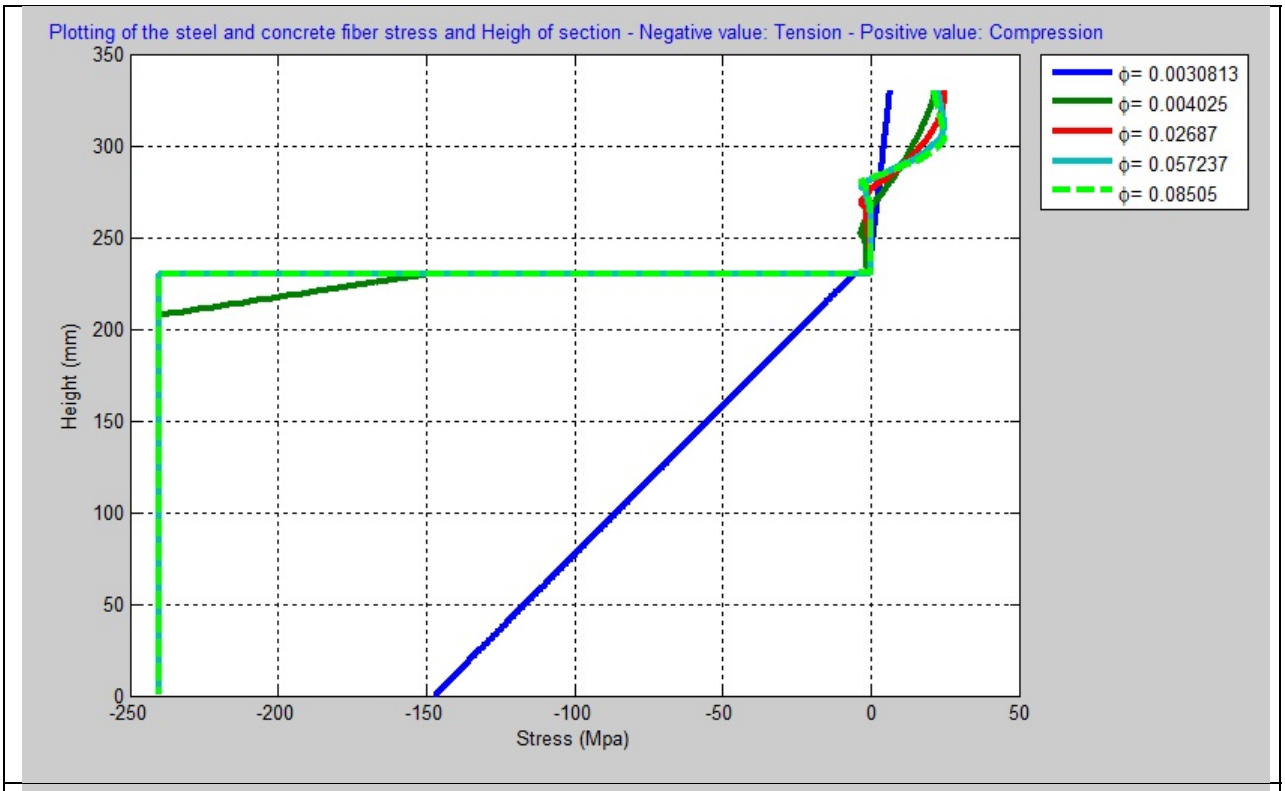
Increment (i)	Top strain (1)	Neuteral axis(x) (mm)	Curvature (1/m)	Flextural Rigidity(EI) (kN.m^2)
1	0.00028	90.87	0.003081	29946.32
2	0.00037	91.30	0.004025	29509.74
3	0.00130	63.71	0.020419	4777.26
4	0.00160	59.55	0.026870	1020.54
5	0.00200	53.70	0.037244	217.31
6	0.00240	50.57	0.047457	127.26
7	0.00280	48.92	0.057237	94.80
8	0.00320	47.96	0.066718	76.05
9	0.00360	47.39	0.075967	64.36
10	0.00400	47.03	0.085050	56.00

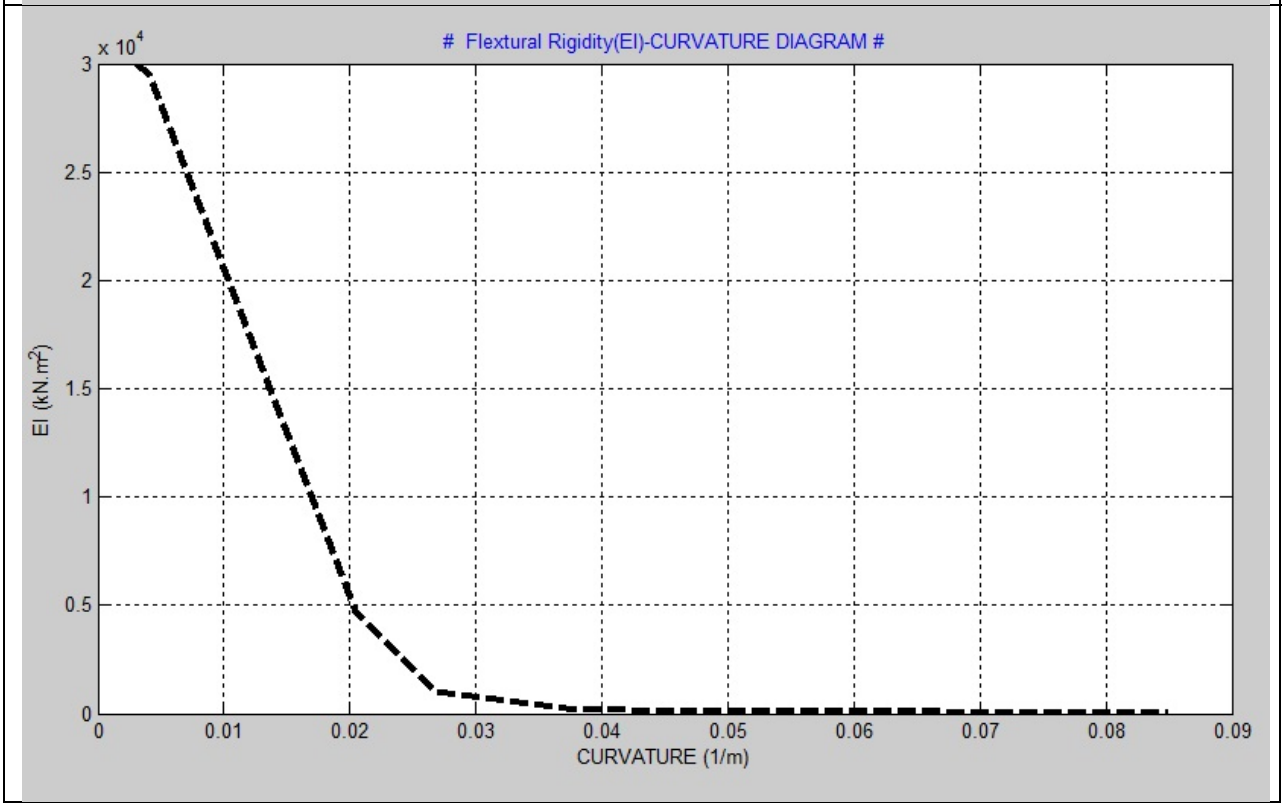
Plotting :

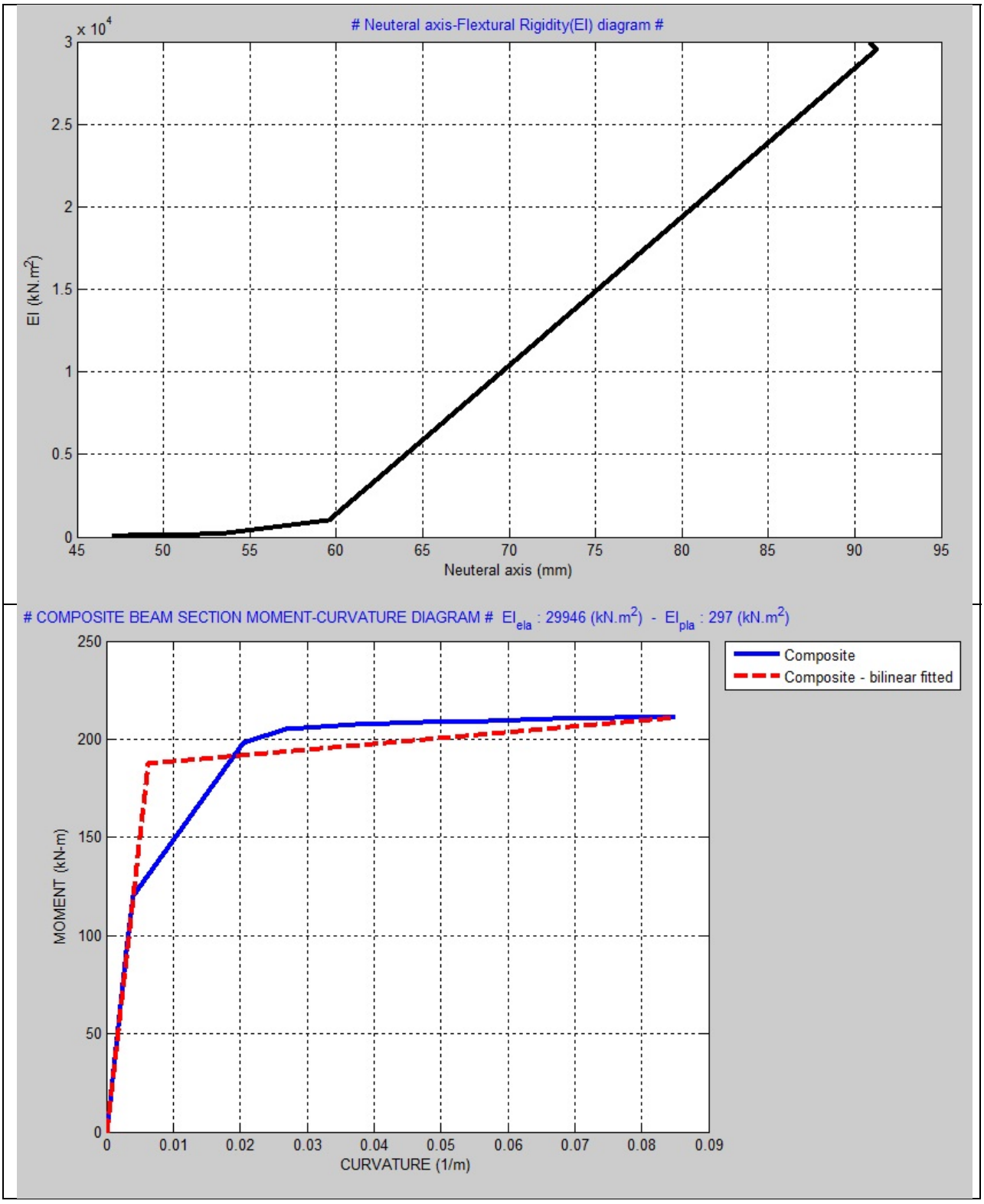



Top and Bottom Steel Fiber Section Stress-Strain Diagram
Top steel fiber
Bottom steel fiber
Stress (kN/mm2)
Strain
0
-50
-100
-150
-200
-250
-0.025
-0.02
-0.015
-0.01
-0.005
0
Top Concrete Fiber Section Stress-Strain Diagram
Stress (kN/mm2)
Strain
x 10-3
26
24
22
20
18
16
14
12
10
8
6
0
0.5
1
1.5
2
2.5
3
3.5
4


Plotting of the Top concrete strain and Neuteral axis
Neuteral axis (mm)
Top Concrete strain
x 10^-3
95
90
85
80
75
70
65
60
55
50
45
0
0.5
1
1.5
2
2.5
3
3.5
4
Plotting of the steel and concrete fiber strain and Heigh of section - Negative value: Tension - Positive value: Compression
Height (mm)
Strain (mm/mm)
350
300
250
200
150
100
50
0
-0.025
-0.02
-0.015
-0.01
-0.005
0
0.005
ϕ= 0.0030813
ϕ= 0.004025
ϕ= 0.02687
ϕ= 0.057237
ϕ= 0.08505


Plotting of the steel and concrete fiber stress and Heigh of section - Negative value: Tension - Positive value: Compression
ϕ= 0.0030813
ϕ= 0.004025
ϕ= 0.02687
ϕ= 0.057237
ϕ= 0.08505
Height (mm)
Stress (Mpa)
350
300
250
200
150
100
50
0
-250
-200
-150
-100
-50
0
50


Flextural Rigidity(EI)-CURVATURE DIAGRAM
x 10^4
EI (kN.m^2)
CURVATURE (1/m)
3
2.5
2
1.5
1
0.5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09


Neuteral axis-Flextural Rigidity(EI) diagram
x 10^4
EI (kN.m^2)
Neuteral axis (mm)
COMPOSITE BEAM SECTION MOMENT-CURVATURE DIAGRAM # EI_ela : 29946 (kN.m^2) - EI_pla : 297 (kN.m^2)
Composite
Composite - bilinear fitted
MOMENT (kN-m)
CURVATURE (1/m)