>> IN THE NAME OF GOD <<

Analysis of 1st order and 2nd order Nonlinear Semi-Rigid Connection Frame subjected to Pushover lateral displacement (Displacement Control) In MATLAB

This program is written by Salar Delavar Ghashghaei -2015.05.19
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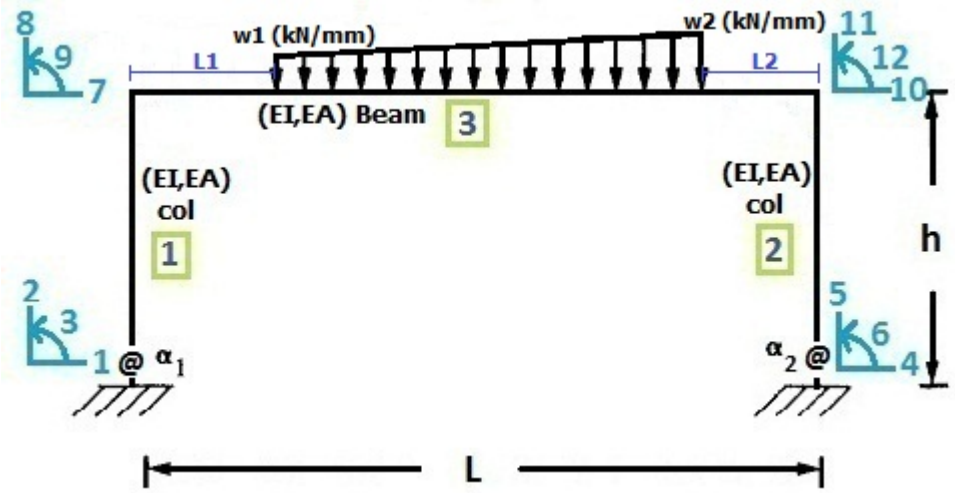


Define Parameters:

```
W1=.003; % [kN/mm] % Distributed load Value (+ : Down)
W2=.005; % [kN/mm] % Distributed load Value (+ : Down)
h= 3000; % [mm]
L = 6000; % [mm]
L1 = 1000; % [mm] % Distance of Distributed load from edge
L2 = 1000; % [mm] % Distance of Distributed load from edge
EIc = 200*100^4/12; % [kN.mm^2] column
EAc = 200*10000; % [kN] column
EIb = 200*50^4/12; % [kN.mm^2] beam
EAb = 200*(50)^2; % [kN] beam
D7=.1;% [mm] Initial Displacement  [DOF (7)]Incremantal Displacement
```

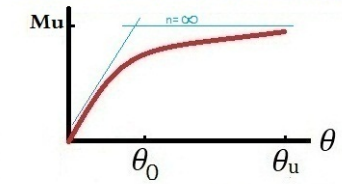
Nonlinear Rotational Spring of columns:

```
tyc=.001; % Yield rotation
Myc=40e+3; % Yield moment
tuc=.025;  % Ultimate rotation
Muc=1.25*Myc;  % Ultimate moment
nc = 9; % Moment-rotation shape parameter
Rkic=Myc/tyc;
Rkpc=(Muc-Myc)/(tuc-tyc);
% Notice: Semi-Rigid Spring for column Connection Number 2
```

Semi-Rigid Connection Number 1

Elastic Perfect Plastic

Nonlinear Moment-Rotation Relation



$$M(\theta) = \frac{R_{ki}\theta}{\left(1+\left(\left|\frac{R_{ki}\theta}{M_u}\right|\right)^n\right)^{\frac{1}{n}}} \quad \therefore R_{ki} = \frac{M_u}{\theta_0}$$

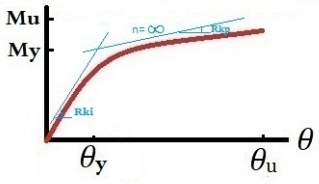
Nonlinear stiffness-Rotation Relation

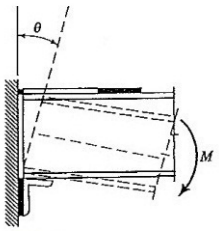
$$K(\theta) = \frac{R_{ki}}{\left(1+\left(\left|\frac{R_{ki}\theta}{M_u}\right|\right)^n\right)^{\frac{1}{n}}}$$

Semi-Rigid Connection Number 2

Elasto–plastic with hardening

Nonlinear Moment-Rotation Relation





$$M(\theta) = \frac{(R_{ki}-R_{kp})\theta}{(1+(\left|\frac{R_{ki}\theta}{M_y}\right|)^n)^{\frac{1}{n}}} + R_{kp}\theta \quad \therefore R_{ki} = \frac{M_y}{\theta_y} \quad \therefore R_{kp} = \frac{M_u - M_y}{\theta_u - \theta_y}$$

Nonlinear stiffness-Rotation Relation

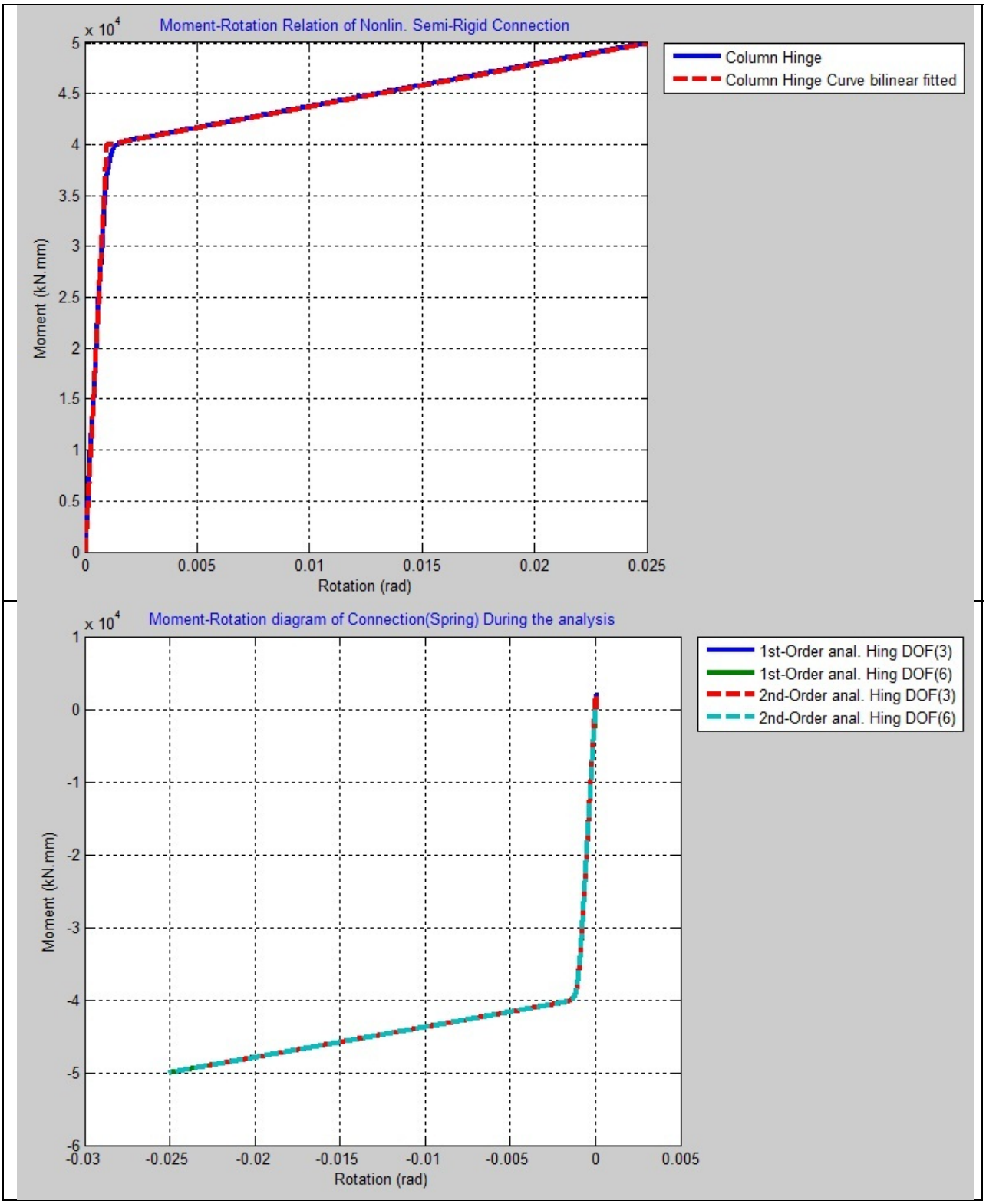
$$K(\theta) = \frac{(R_{ki}-R_{kp})}{(1+(\left|\frac{R_{ki}\theta}{M_y}\right|)^n)^{\frac{1}{n}}} + R_{kp}$$

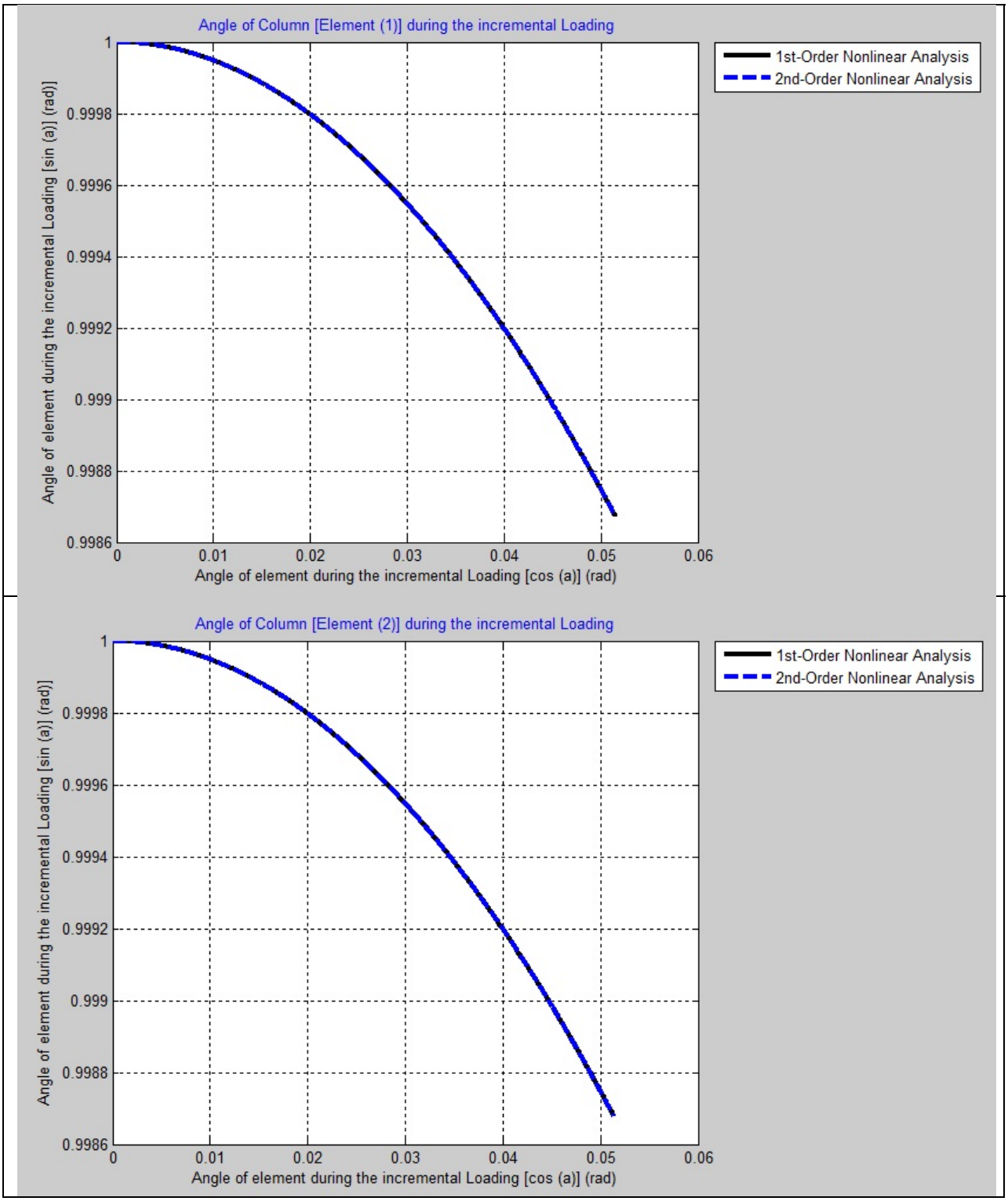
Analysis Report:

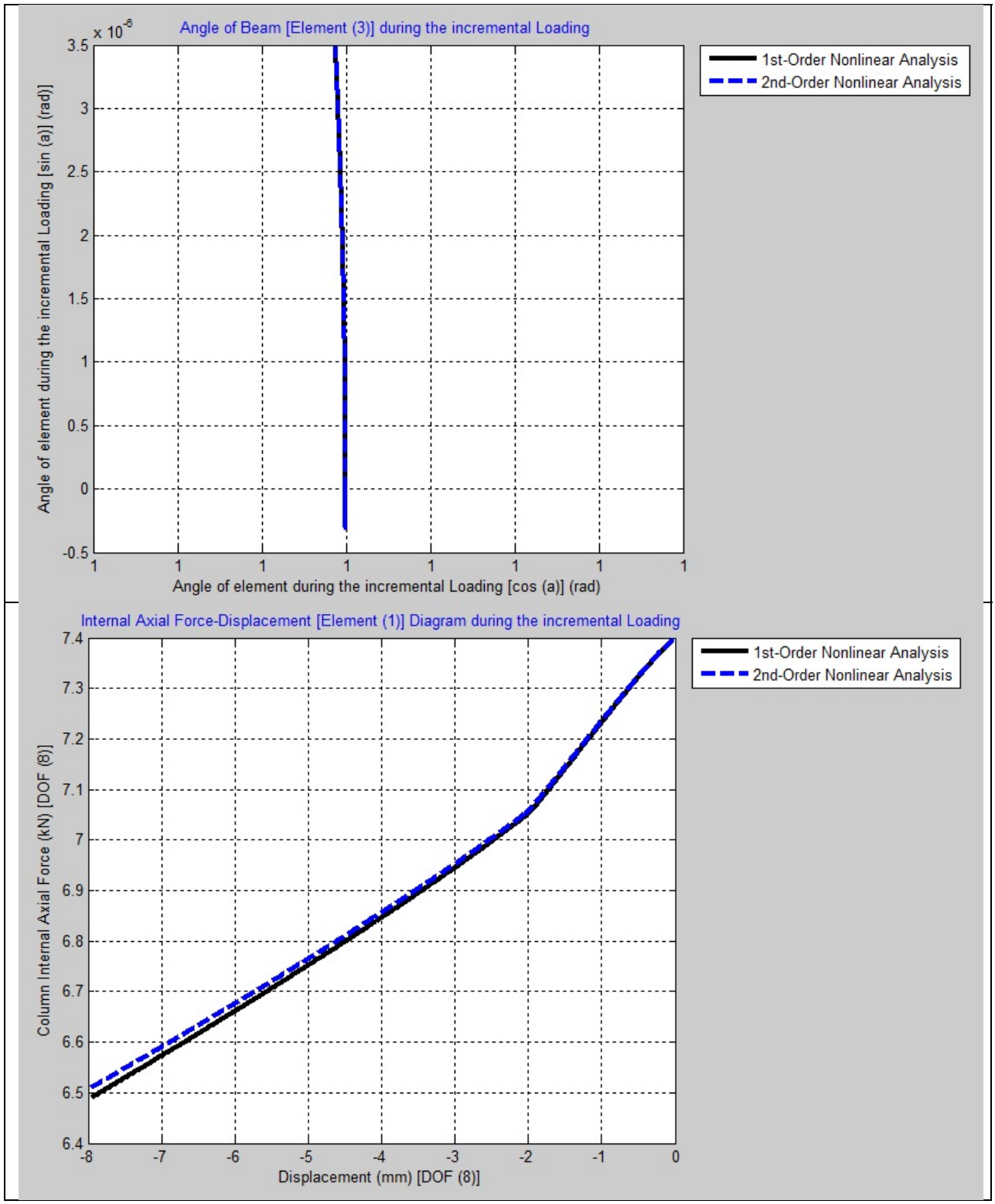
```
 ###################################
#       First-order Nonlinear Analysis      #
###################################
(+)It is converged in 4 iterations for increment 1
(+)It is converged in 4 iterations for increment 2
(+)It is converged in 4 iterations for increment 3
(+)It is converged in 4 iterations for increment 4
(+)It is converged in 5 iterations for increment 5
(+)It is converged in 5 iterations for increment 6
(+)It is converged in 5 iterations for increment 7
(+)It is converged in 5 iterations for increment 8
(+)It is converged in 5 iterations for increment 9
(+)It is converged in 5 iterations for increment 10
.
.
.
(+)It is converged in 24 iterations for increment 1539
(+)It is converged in 23 iterations for increment 1540
(+)It is converged in 24 iterations for increment 1541
    ## spring at support [DOF (6)] reached to Ultimate Rotation ##
####################################
#       Second-order Nonlinear Analysis      #
####################################
(+)It is converged in 4 iterations for increment 1
(+)It is converged in 4 iterations for increment 2
(+)It is converged in 4 iterations for increment 3
(+)It is converged in 4 iterations for increment 4
(+)It is converged in 5 iterations for increment 5
(+)It is converged in 5 iterations for increment 6
(+)It is converged in 5 iterations for increment 7
(+)It is converged in 5 iterations for increment 8
(+)It is converged in 5 iterations for increment 9
(+)It is converged in 5 iterations for increment 10
.
.
.
(+)It is converged in 24 iterations for increment 1541
(+)It is converged in 24 iterations for increment 1542
(+)It is converged in 23 iterations for increment 1543
    ## spring at support [DOF (6)] reached to Ultimate Rotation ##
====================== Result ========================
=== 1st-Order Nonlinear ==+== 2nd-Order Nonlinear =====
Disp.(D7) Base Shear(D1+D4) Disp.(D7) Base Shear(D1+D4)
=======================================================
```

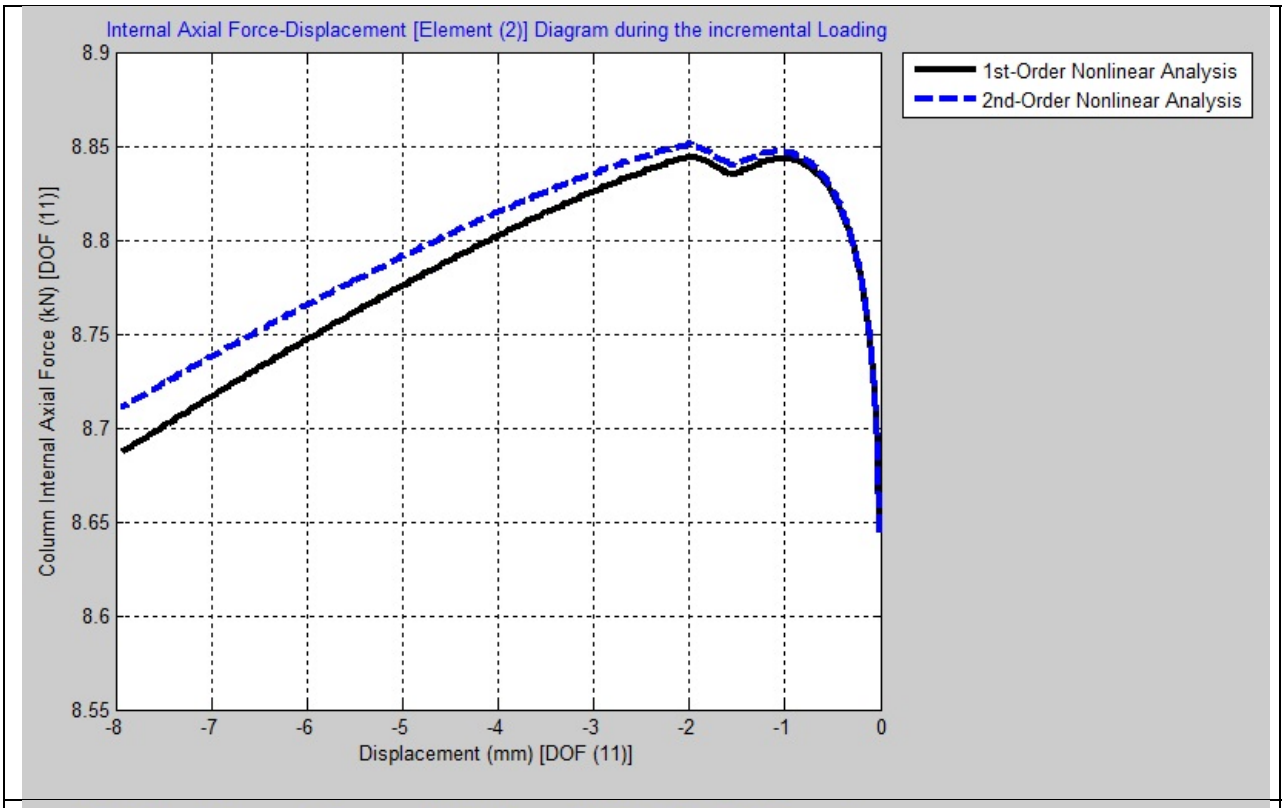
```
 (mm)      (kN)      (mm)      (kN)
-----------------------------------------------------
    0     0     0     0
  9.2513  14.2470   9.2535  14.1810
 154.1000  37.6640 154.3000  36.8470
=====================================================
==================== Internal Moment for each degree of freedom ====================
+ ============================== 1st-order Nonlinear ============================== +
  step(i)     (f3)       (f9)       (f13)       (f14)       (f6)        (f12)
-------------------------------------------------------------------------------------
         1     53.335     -0.002   5000.002   5000.002     53.225     -0.000
         2    106.669     -0.000   5000.002   4999.992    106.450     -0.000
         3    160.004     -0.000   5000.002   4999.992    159.675     -0.000
         4    213.338     -0.000   5000.002   4999.992    212.900     -0.000
         5    266.673     -0.000   5000.002   4999.992    266.125     -0.000
         6    320.007     -0.000   5000.001   4999.992    319.350     -0.000
         7    373.342     -0.000   5000.001   4999.992    372.575     -0.000
         8    426.676     -0.000   5000.001   4999.992    425.800     -0.000
         9    480.011     -0.000   5000.000   4999.992    479.025     -0.000
        10    533.345     -0.000   5000.000   4999.992    532.251     -0.000
         .
         .
         .
      1107  20068.909     -0.606   4999.992   4999.992  20108.135     -0.000
      1108  20013.140     -0.607   4999.992   4999.992  20052.236     -0.000
      1109  19957.370     -0.609   4999.992   4999.992  19996.336     -0.000
+ ============================== 2nd-order Nonlinear ============================== +
  step(i)     (f3)       (f9)       (f13)       (f14)       (f6)        (f12)
-------------------------------------------------------------------------------------
         1     53.056      0.001   5000.392   4999.613     52.953     -0.000
         2    106.112      0.002   5000.382   4999.603    105.905     -0.000
         3    159.168      0.002   5000.381   4999.604    158.858     -0.000
         4    212.224      0.003   5000.381   4999.604    211.810     -0.000
         5    265.280      0.004   5000.380   4999.605    264.763     -0.000
         6    318.337      0.005   5000.380   4999.605    317.715     -0.000
         7    371.393      0.006   5000.380   4999.605    370.668     -0.000
         8    424.449      0.007   5000.380   4999.605    423.620     -0.000
         9    477.505      0.007   5000.380   4999.605    476.573     -0.000
        10    530.561      0.008   5000.380   4999.605    529.526     -0.000
         .
         .
         .
      1109  20010.679    166.932   5070.793   4929.192  20101.804      0.000
      1110  19954.353    167.384   5070.921   4929.064  20045.594      0.000
      1111  19898.026    167.837   5071.049   4928.936  19989.385      0.000
+ ================================================================================== +

+-------------------------------------------------------------------------------------+
 Semi-Rigid Column Connection Ductility Rito is (Tu/Ty): 25.037
 1st-order Nonlinear Ductility Rito is (Du/Dy): 16.657
 2nd-order Nonlinear Ductility Rito is (Du/Dy): 16.675
 1st-order Nonlinear Over Strength Ratio is (Fu/Fy):  2.644
 2nd-order Nonlinear Over Strength Ratio is (Fu/Fy): 2.598
 1st-order Nonlinear Initial Strucural stiffness is (Ke):  1.540 [kN/mm]
 1st-order Nonlinear Tangent Strucural stiffness is (Kt): 0.162 [kN/mm]
 2nd-order Nonlinear Initial Strucural stiffness is (Ke):  1.533 [kN/mm]
 2nd-order Nonlinear Tangent Strucural stiffness is (Kt): 0.156 [kN/mm]
+-------------------------------------------------------------------------------------+
```

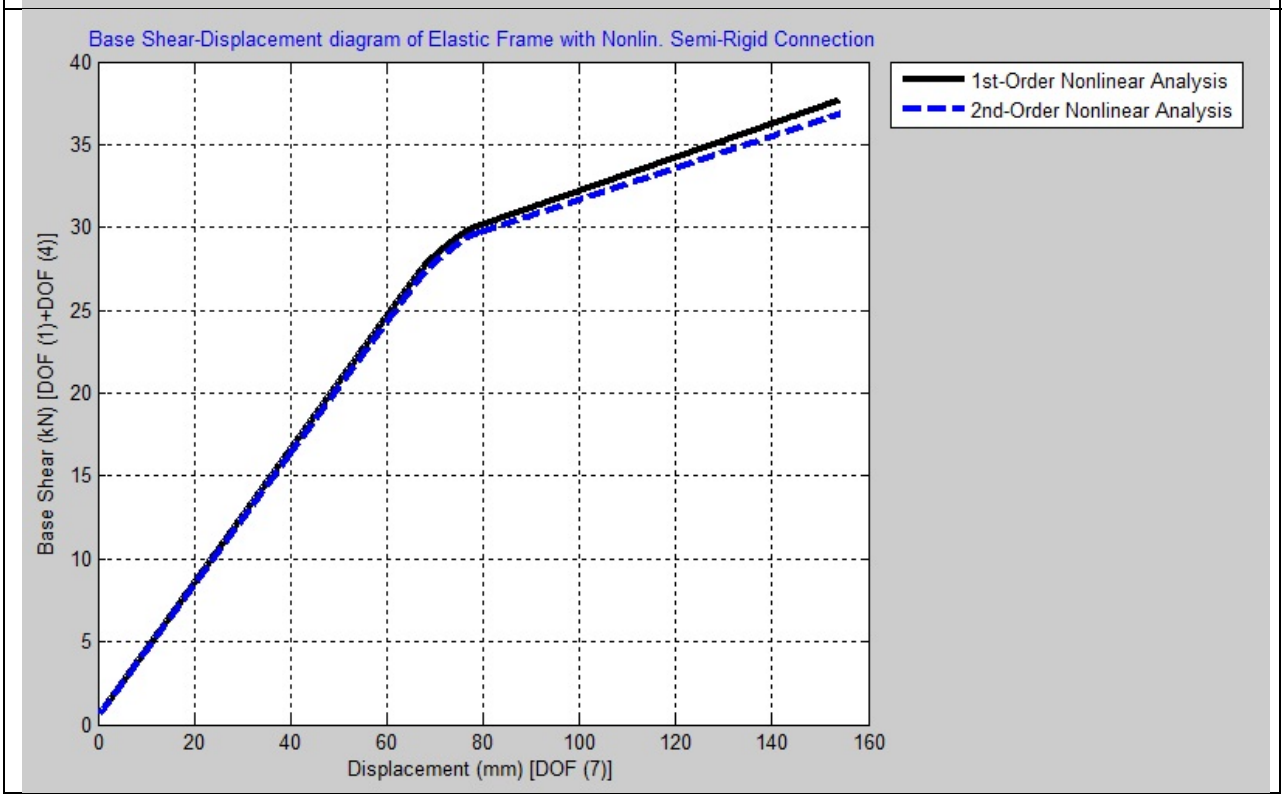
Plotting :

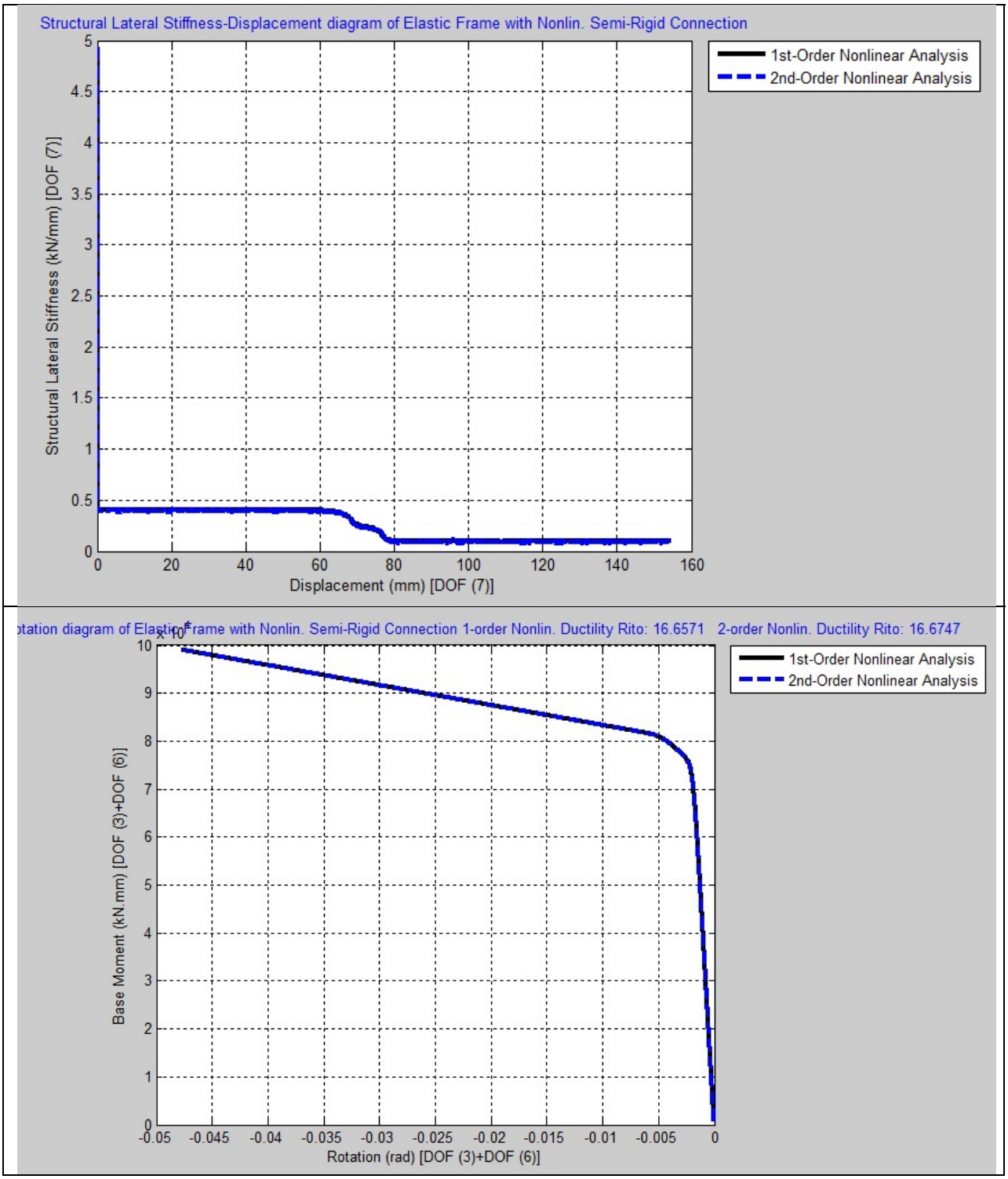

Moment-Rotation Relation of Nonlin. Semi-Rigid Connection
x 10^4
Moment (kN.mm)
Rotation (rad)
Column Hinge
Column Hinge Curve bilinear fitted
Moment-Rotation diagram of Connection(Spring) During the analysis
x 10^4
Moment (kN.mm)
Rotation (rad)
1st-Order anal. Hing DOF(3)
1st-Order anal. Hing DOF(6)
2nd-Order anal. Hing DOF(3)
2nd-Order anal. Hing DOF(6)

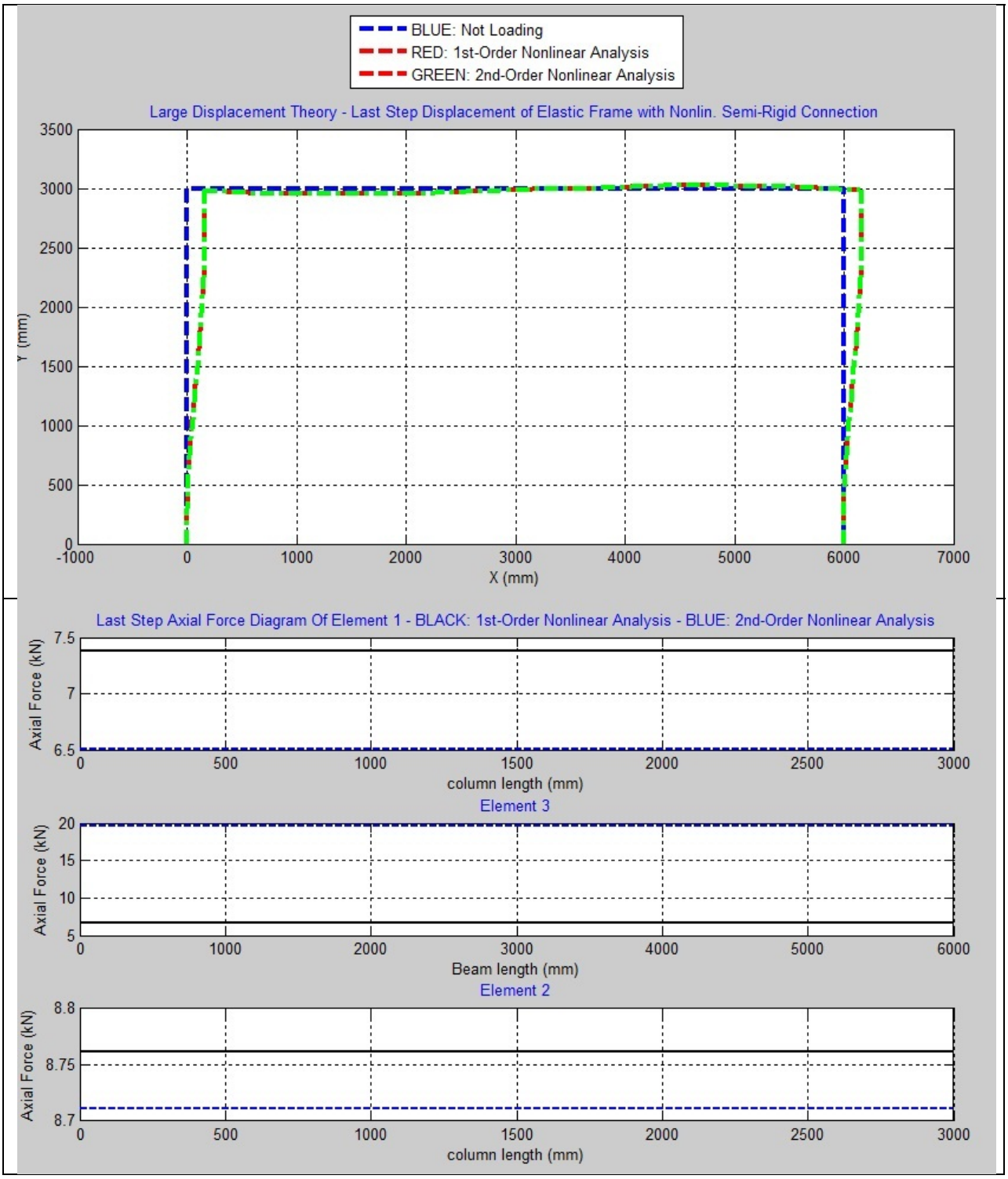

Angle of Column [Element (1)] during the incremental Loading
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Angle of element during the incremental Loading [sin (a)] (rad)]
Angle of element during the incremental Loading [cos (a)] (rad)
1
0.9998
0.9996
0.9994
0.9992
0.999
0.9988
0.9986
0
0.01
0.02
0.03
0.04
0.05
0.06
Angle of Column [Element (2)] during the incremental Loading
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Angle of element during the incremental Loading [sin (a)] (rad)]
Angle of element during the incremental Loading [cos (a)] (rad)
1
0.9998
0.9996
0.9994
0.9992
0.999
0.9988
0.9986
0
0.01
0.02
0.03
0.04
0.05
0.06

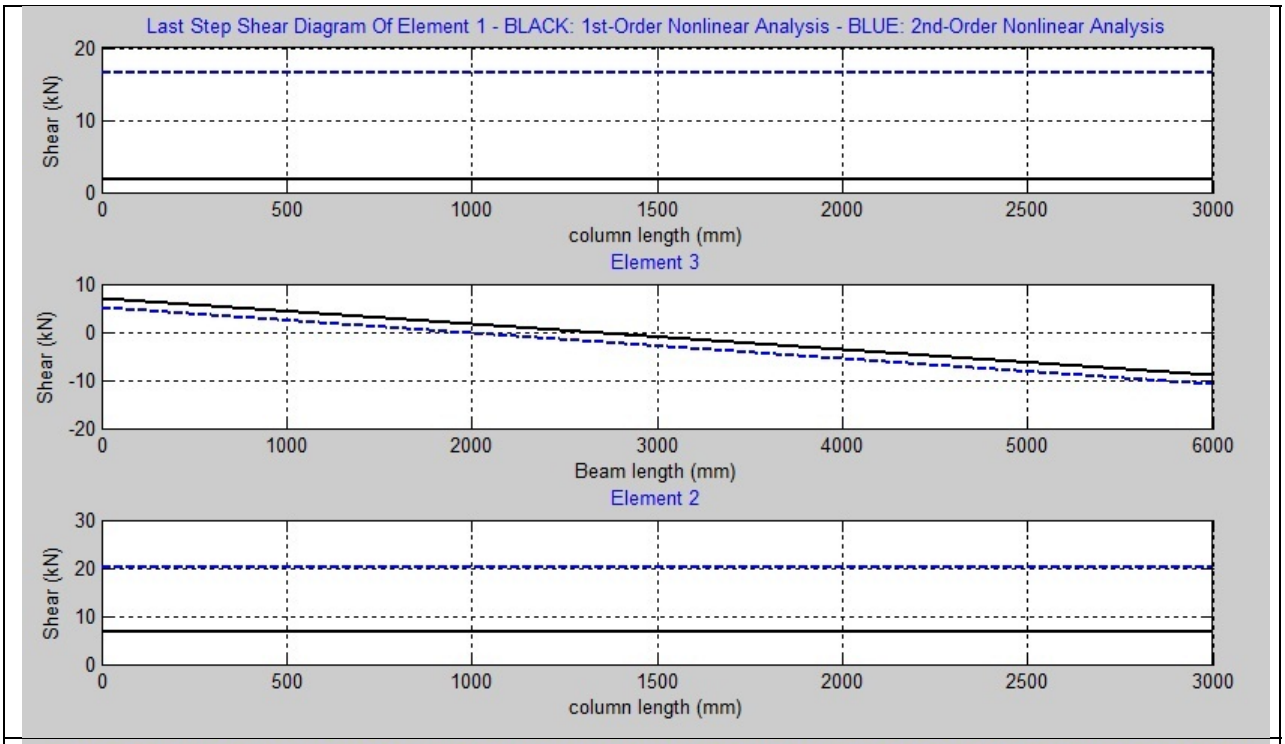

Angle of Beam [Element (3)] during the incremental Loading
x 10^-6
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Angle of element during the incremental Loading [sin (a)] (rad)
1
Angle of element during the incremental Loading [cos (a)] (rad)
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Internal Axial Force-Displacement [Element (1)] Diagram during the incremental Loading
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
Column Internal Axial Force (kN) [DOF (8)]
-8
-7
-6
-5
-4
-3
-2
-1
0
Displacement (mm) [DOF (8)]
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis

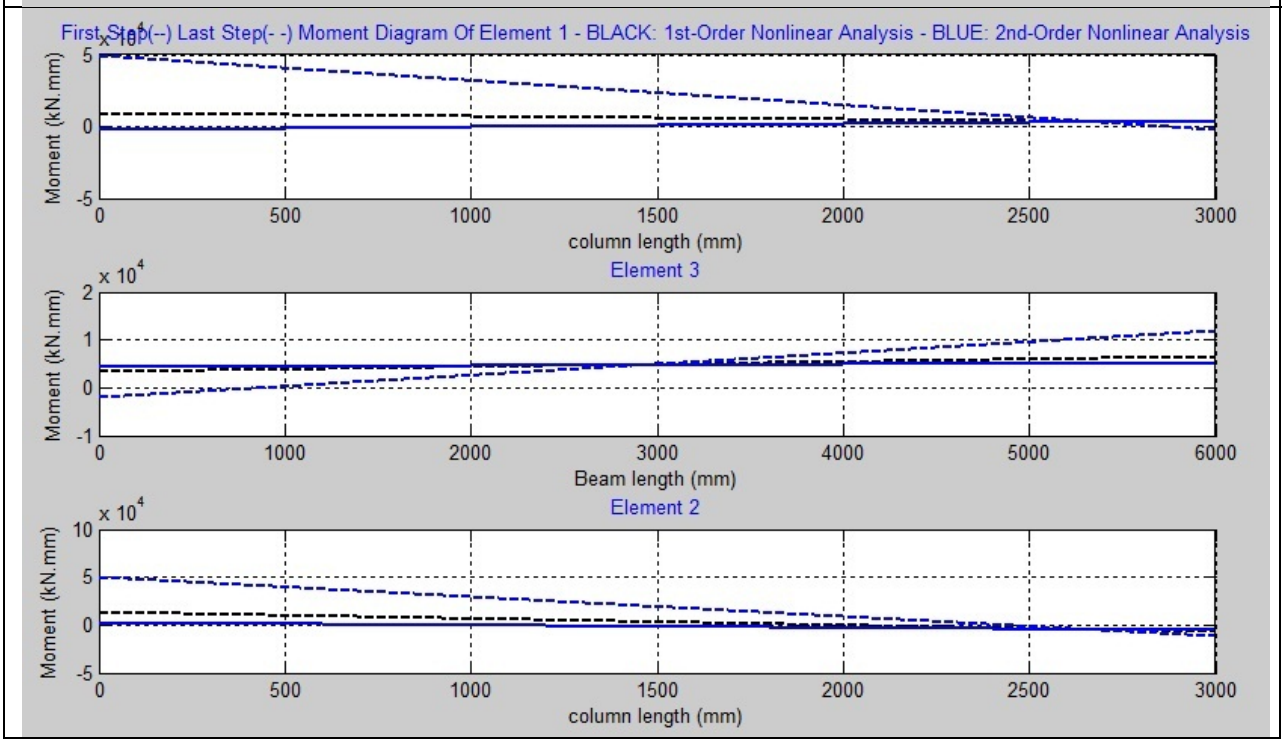

Internal Axial Force-Displacement [Element (2)] Diagram during the incremental Loading
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Column Internal Axial Force (kN) [DOF (11)]
Displacement (mm) [DOF (11)]
8.9
8.85
8.8
8.75
8.7
8.65
8.6
8.55
-8
-7
-6
-5
-4
-3
-2
-1
0


Base Shear-Displacement diagram of Elastic Frame with Nonlin. Semi-Rigid Connection
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Base Shear (kN) [DOF (1)+DOF (4)]
Displacement (mm) [DOF (7)]
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160


Structural Lateral Stiffness-Displacement diagram of Elastic Frame with Nonlin. Semi-Rigid Connection
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Structural Lateral Stiffness (kN/mm) [DOF (7)]
Displacement (mm) [DOF (7)]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
20
40
60
80
100
120
140
160
tation diagram of Elastic Frame with Nonlin. Semi-Rigid Connection 1-order Nonlin. Ductility Rito: 16.6571 2-order Nonlin. Ductility Rito: 16.6747
x 10^4
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Base Moment (kN.mm) [DOF (3)+DOF (6)]
Rotation (rad) [DOF (3)+DOF (6)]
0
1
2
3
4
5
6
7
8
9
10
-0.05
-0.045
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0


BLUE: Not Loading
RED: 1st-Order Nonlinear Analysis
GREEN: 2nd-Order Nonlinear Analysis
Large Displacement Theory - Last Step Displacement of Elastic Frame with Nonlin. Semi-Rigid Connection
Y (mm)
X (mm)
Last Step Axial Force Diagram Of Element 1 - BLACK: 1st-Order Nonlinear Analysis - BLUE: 2nd-Order Nonlinear Analysis
Axial Force (kN)
column length (mm)
Element 3
Axial Force (kN)
Beam length (mm)
Element 2
Axial Force (kN)
column length (mm)


Last Step Shear Diagram Of Element 1 - BLACK: 1st-Order Nonlinear Analysis - BLUE: 2nd-Order Nonlinear Analysis
Shear (kN)
column length (mm)
Element 3
Shear (kN)
Beam length (mm)
Element 2
Shear (kN)
column length (mm)


First Step(--) Last Step(- -) Moment Diagram Of Element 1 - BLACK: 1st-Order Nonlinear Analysis - BLUE: 2nd-Order Nonlinear Analysis
Moment (kN.mm)
column length (mm)
Element 3
Moment (kN.mm)
Beam length (mm)
Element 2
Moment (kN.mm)
column length (mm)