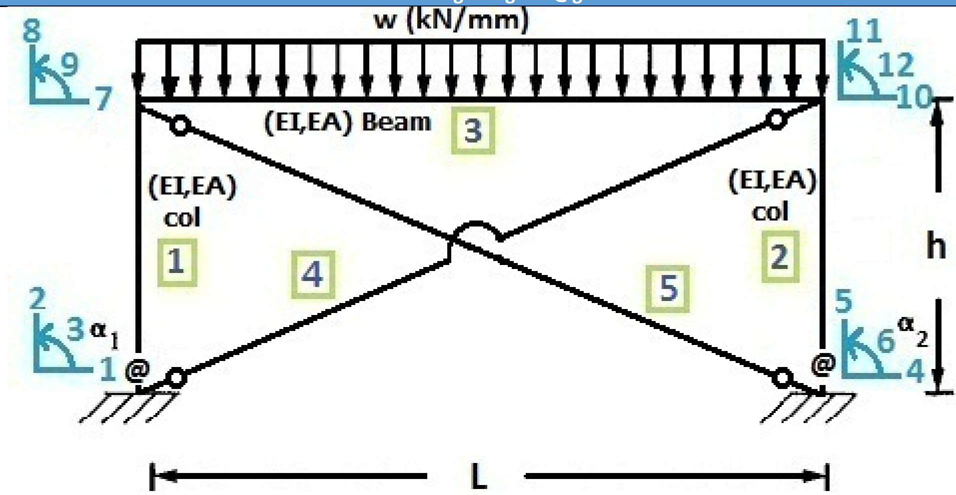
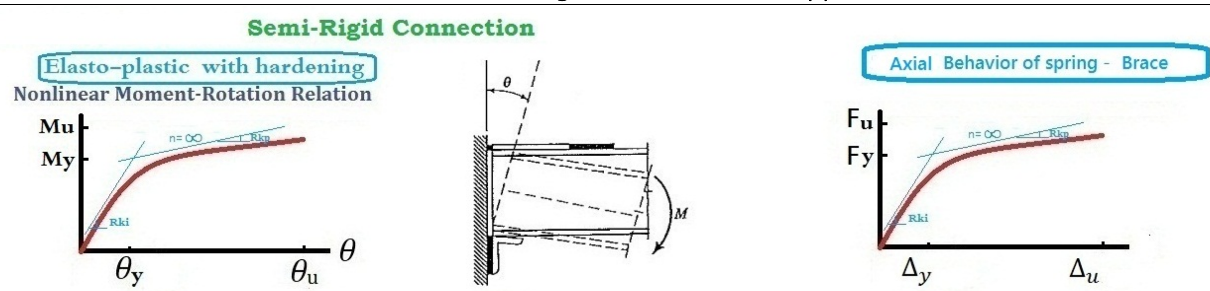
>> IN THE NAME OF GOD <<

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

This program is written by Salar Delavar Ghashghaei -2015.06.02
E-mail: salar.d.ghashghaei@gmail.com



a1 and a2 are Semi-rigid connections at supports



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

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

Nonlinear stiffness-Rotation Relation

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

Nonlinear siffness-Displacement

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

Define Parameters:

```
% Define Parameters in mm,kN
W=.03; % [kN/mm] % Distributed load Value (+ : Down)
h= 3000; % [mm] % column length
L = 6000; % [mm] % beam length
EIc = 200*100^4/12; % [kN.mm^2] column
EAc = 200*10000; % [kN]
EIb = 200*50^4/12; % [kN.mm^2] beam
EAb = 200*(50)^2; % [kN]
```

Nonlinear Rotational Spring of columns:

```
tyc=.08; % Yield rotaion
Myc=40e+3; % Yield moment
```

```
tuc=.25;  % Ultimate rotation
Muc=1.25*Myc;  % Ultimate moment
nc = 9; % Moment-rotation shape parameter
Rkic=Myc/tyc;
Rkpc=(Muc-Myc)/(tuc-tyc);
```

Nonlinear Axial displacement Spring of Brace:

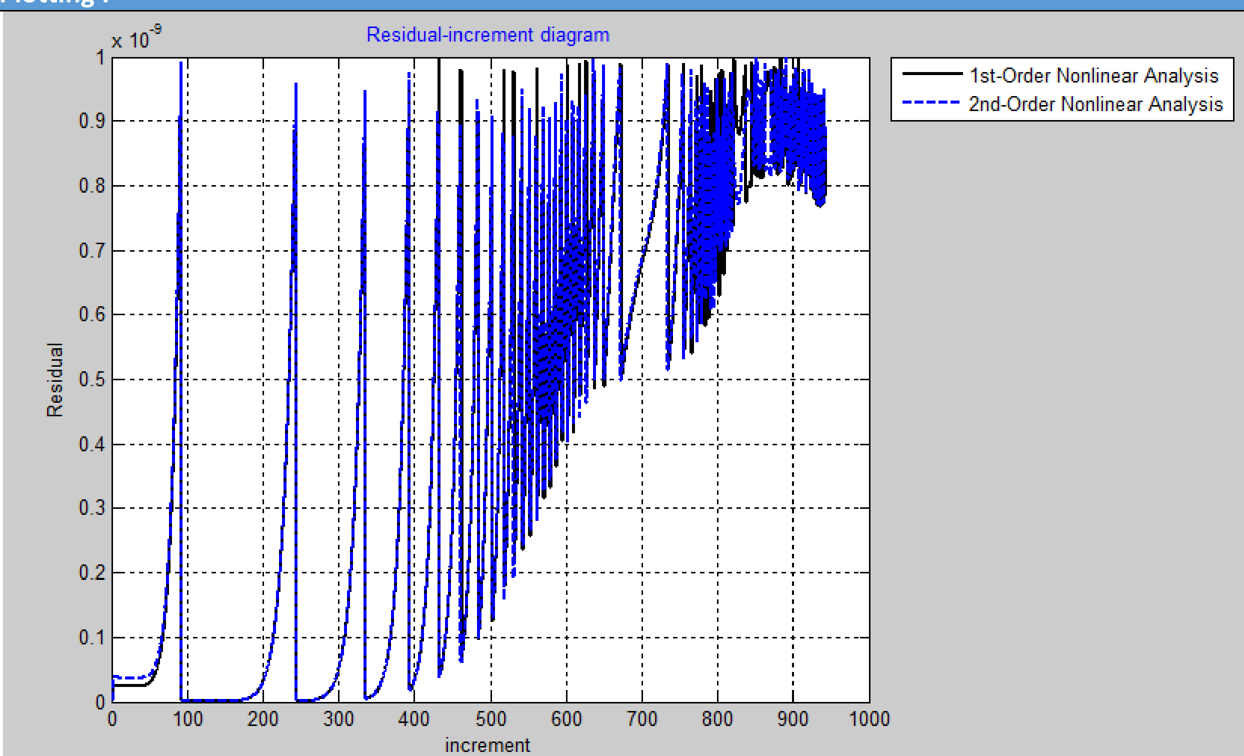
```
dyb=10; % Yield displacement [mm]
Fyb=1000; % Yield Shear Force [kN]
dub=35;  % Ultimate displacement [mm]
Fub=1.25*Fyb;  % Ultimate Shear Force [kN]
n = 9; % Shear Force-displacement shape parameter
Rki=Fyb/dyb;
Rkp=(Fub-Fyb)/(dub-dyb);
```

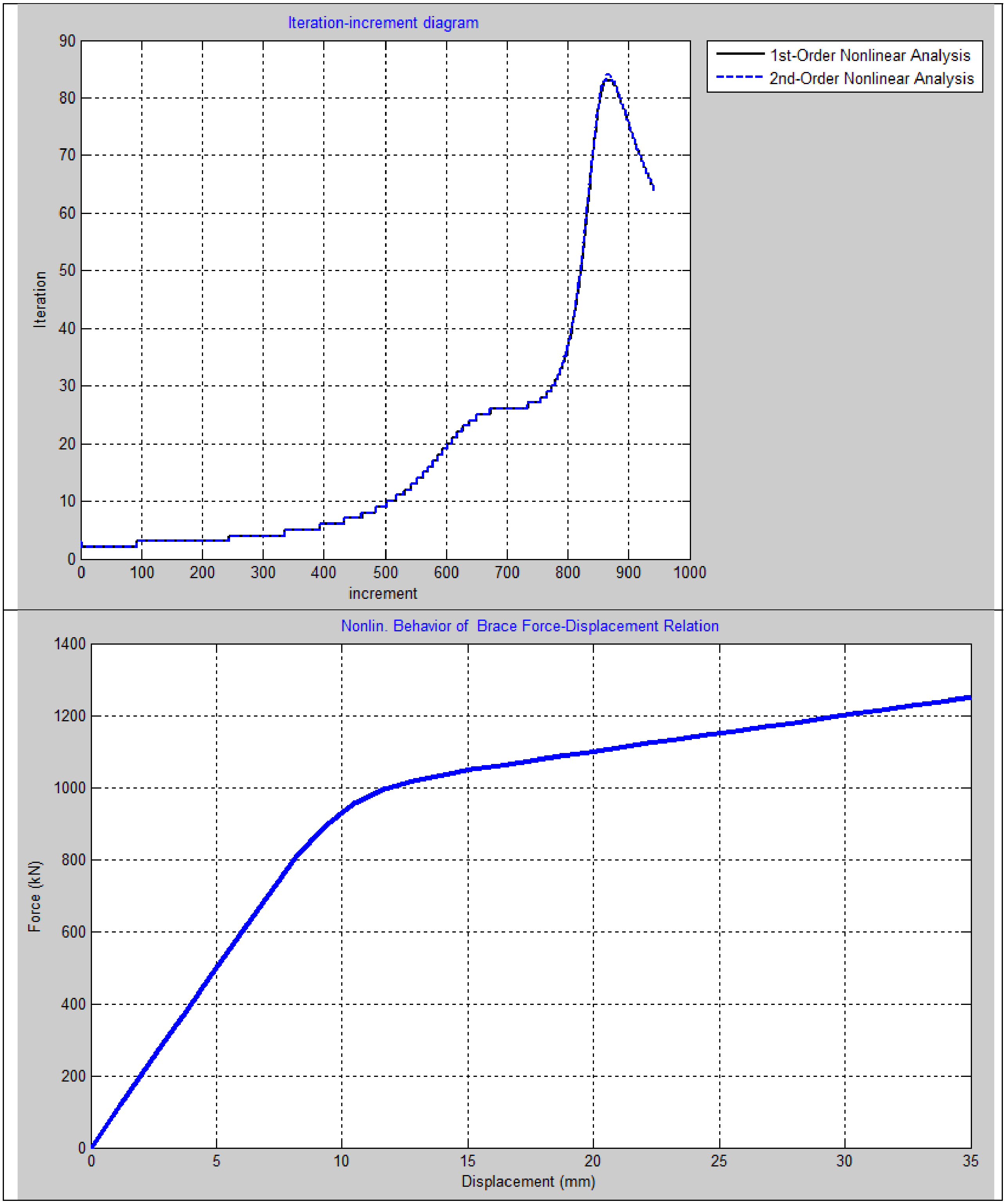
Analysis Report:

```
####################################
#       First-order Nonlinear Analysis      #
####################################
(+)It is converged in 3 iterations for increment 1
(+)It is converged in 2 iterations for increment 2
(+)It is converged in 2 iterations for increment 3
(+)It is converged in 2 iterations for increment 4
(+)It is converged in 2 iterations for increment 5
(+)It is converged in 2 iterations for increment 6
(+)It is converged in 2 iterations for increment 7
(+)It is converged in 2 iterations for increment 8
(+)It is converged in 2 iterations for increment 9
(+)It is converged in 2 iterations for increment 10
.
.
.
(+)It is converged in 66 iterations for increment 934
(+)It is converged in 66 iterations for increment 935
(+)It is converged in 66 iterations for increment 936
(+)It is converged in 65 iterations for increment 937
(+)It is converged in 65 iterations for increment 938
(+)It is converged in 65 iterations for increment 939
(+)It is converged in 65 iterations for increment 940
(+)It is converged in 64 iterations for increment 941
(+)It is converged in 64 iterations for increment 942
(+)It is converged in 64 iterations for increment 943
(+)It is converged in 64 iterations for increment 944
    ## Brace displacement reached to Ultimate displacement ##
######################################
#      Second-order Nonlinear Analysis       #
######################################
(+)It is converged in 3 iterations for increment 1
(+)It is converged in 2 iterations for increment 2
(+)It is converged in 2 iterations for increment 3
(+)It is converged in 2 iterations for increment 4
(+)It is converged in 2 iterations for increment 5
(+)It is converged in 2 iterations for increment 6
(+)It is converged in 2 iterations for increment 7
(+)It is converged in 2 iterations for increment 8
(+)It is converged in 2 iterations for increment 9
(+)It is converged in 2 iterations for increment 10
.
.
.
(+)It is converged in 66 iterations for increment 933
(+)It is converged in 66 iterations for increment 934
(+)It is converged in 66 iterations for increment 935
(+)It is converged in 66 iterations for increment 936
(+)It is converged in 65 iterations for increment 937
```

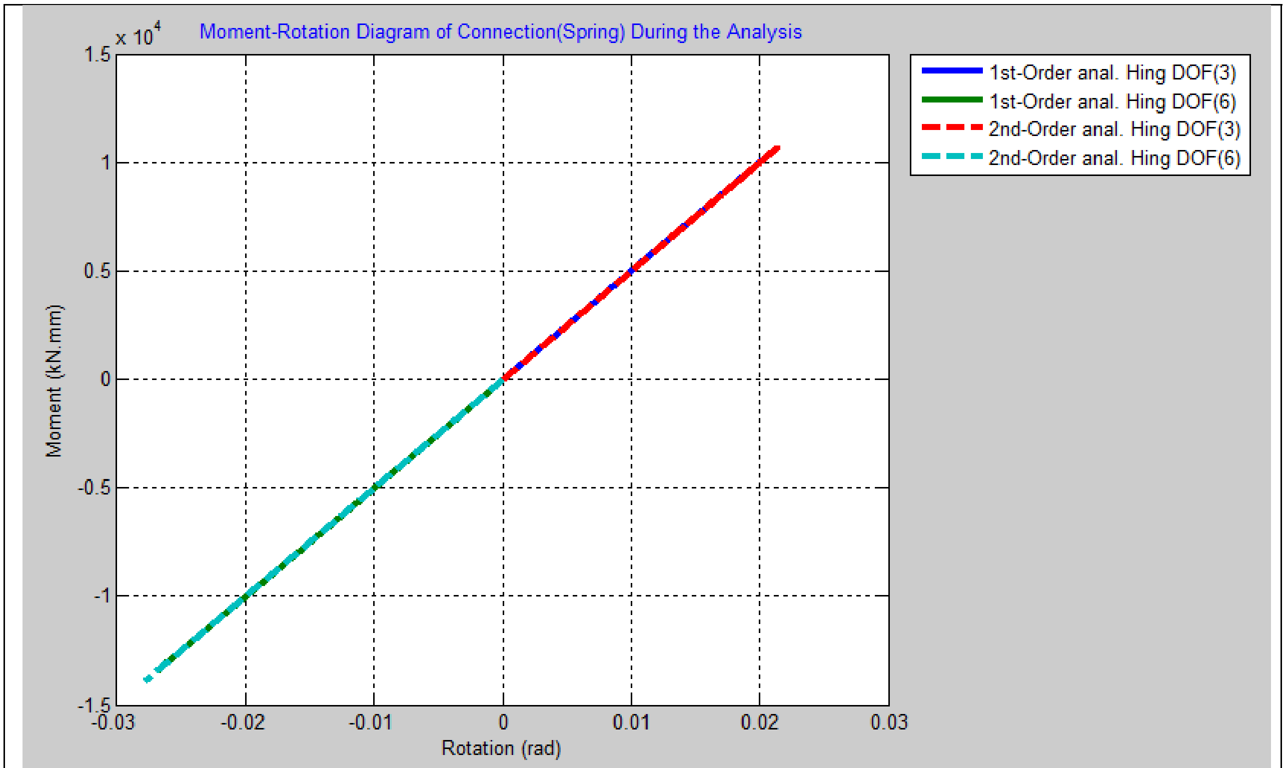
```
(+)It is converged in 65 iterations for increment 938
(+)It is converged in 65 iterations for increment 939
(+)It is converged in 65 iterations for increment 940
(+)It is converged in 64 iterations for increment 941
(+)It is converged in 64 iterations for increment 942
(+)It is converged in 64 iterations for increment 943
    ## Brace displacement reached to Ultimate displacement ##
===================== Result ====================
=== 1st-Order Nonlinear ==+== 2nd-Order Nonlinear =====
Disp.(D7) Base Shear(D1+D4) Disp.(D7) Base Shear(D1+D4)
==============================================
 (mm)      (kN)      (mm)      (kN)
--------------------------------------------------
 1.0e+003 *
      0        0        0        0
   0.0122   1.4269   0.0122   1.4264
   0.0351   1.8880   0.0351   1.8860
==============================================
+-----------------------------------------------------------------------------+
 Semi-Rigid Column Connection Ductility Rito is:  3.183
 1st-order Nonlinear Ductility Rito is (Du/Dy):  2.870
 2nd-order Nonlinear Ductility Rito is (Du/Dy): 2.869
 1st-order Nonlinear Over Strength Ratio is (Fu/Fy):  1.323
 2nd-order Nonlinear Over Strength Ratio is (Fu/Fy): 1.322
 1st-order Nonlinear Initial Strucural stiffness is (Ke): 116.606 [kN/mm]
 1st-order Nonlinear Tangent Strucural stiffness is (Kt): 20.147 [kN/mm]
 2nd-order Nonlinear Initial Strucural stiffness is (Ke): 116.561 [kN/mm]
 2nd-order Nonlinear Tangent Strucural stiffness is (Kt): 20.100 [kN/mm]
+------------------------------------------------------------------------------+
```

Plotting :

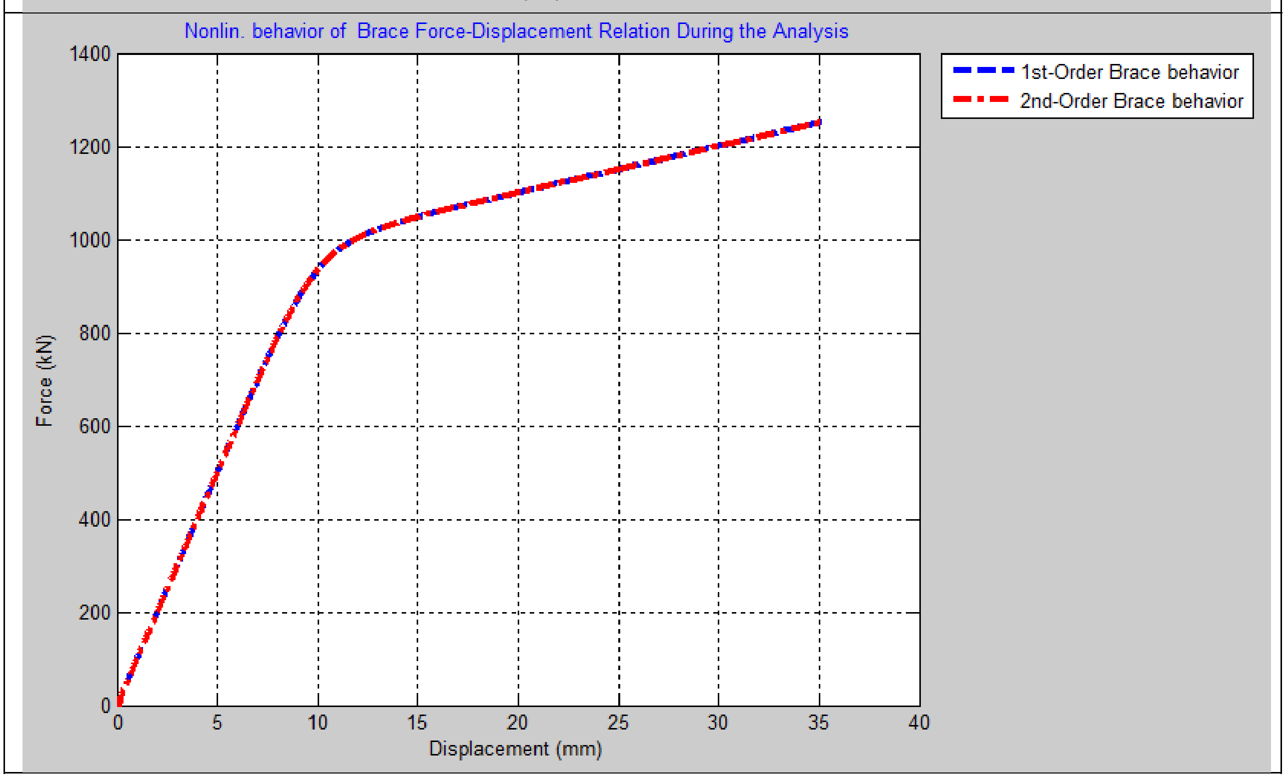




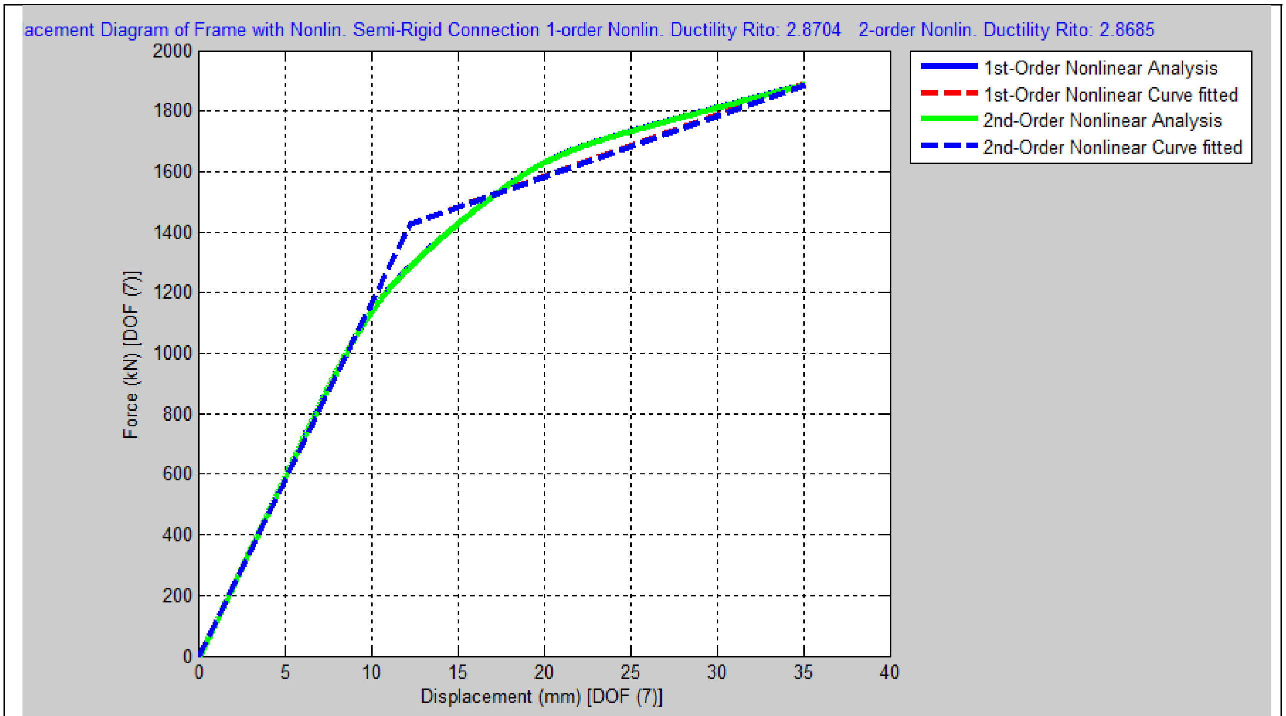
Iteration-increment diagram
1st-Order Nonlinear Analysis
2nd-Order Nonlinear Analysis
Iteration
increment
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
800
900
1000
Nonlin. Behavior of Brace Force-Displacement Relation
Force (kN)
Displacement (mm)
0
200
400
600
800
1000
1200
1400
0
5
10
15
20
25
30
35



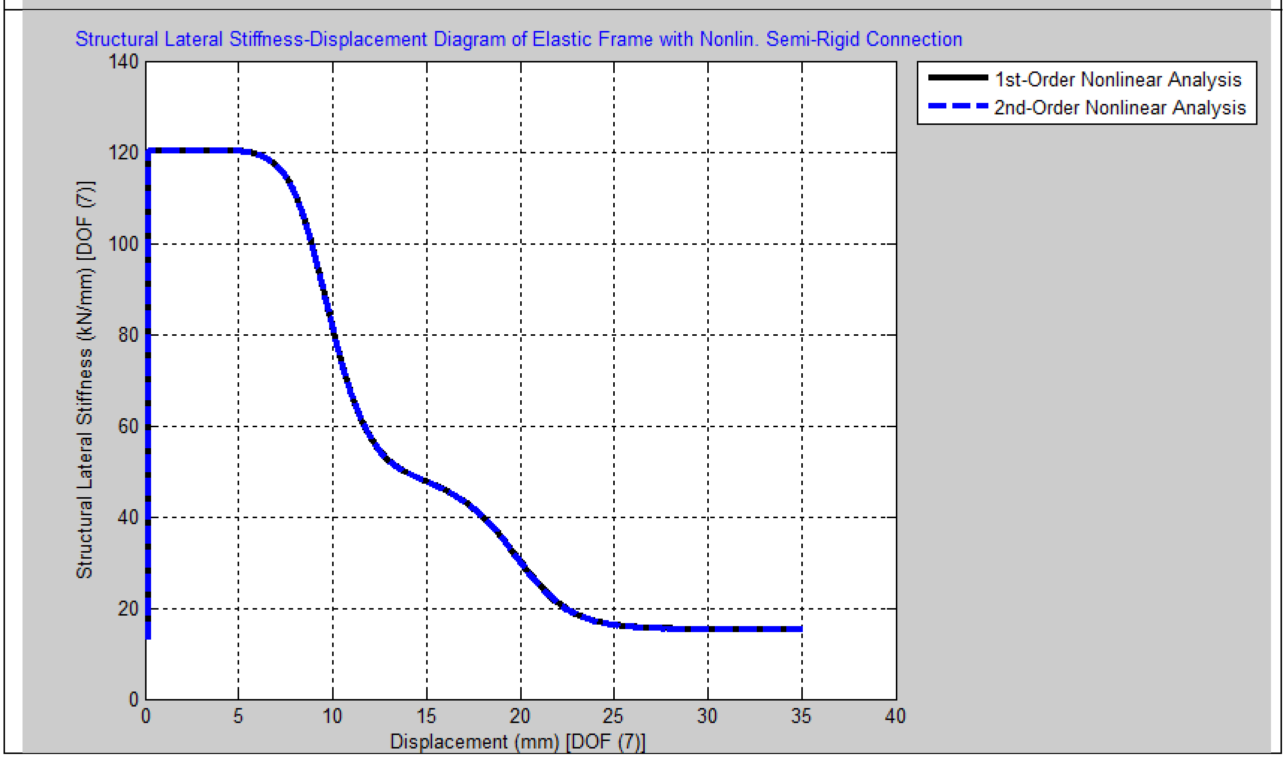
Moment-Rotation Diagram of Connection(Spring) During the Analysis
x 10^4
1.5
1
0.5
0
-0.5
-1
-1.5
Moment (kN.mm)
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
Rotation (rad)
1st-Order anal. Hing DOF(3)
1st-Order anal. Hing DOF(6)
2nd-Order anal. Hing DOF(3)
2nd-Order anal. Hing DOF(6)



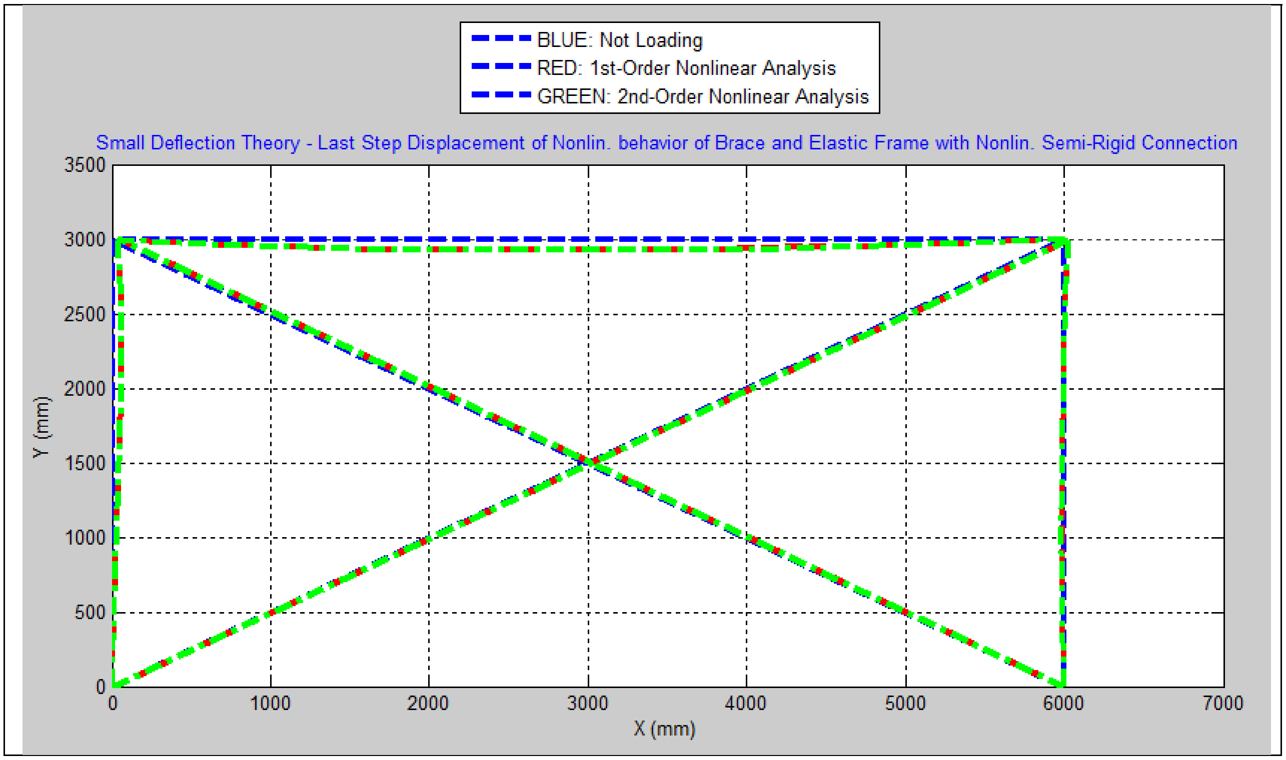
Nonlin. behavior of Brace Force-Displacement Relation During the Analysis
1400
1200
1000
800
600
400
200
0
Force (kN)
0
5
10
15
20
25
30
35
40
Displacement (mm)
1st-Order Brace behavior
2nd-Order Brace behavior



acement Diagram of Frame with Nonlin. Semi-Rigid Connection 1-order Nonlin. Ductility Rito: 2.8704 2-order Nonlin. Ductility Rito: 2.8685
1st-Order Nonlinear Analysis
1st-Order Nonlinear Curve fitted
2nd-Order Nonlinear Analysis
2nd-Order Nonlinear Curve fitted
Force (kN) [DOF (7)]
Displacement (mm) [DOF (7)]



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)]



BLUE: Not Loading
RED: 1st-Order Nonlinear Analysis
GREEN: 2nd-Order Nonlinear Analysis
Small Deflection Theory - Last Step Displacement of Nonlin. behavior of Brace and Elastic Frame with Nonlin. Semi-Rigid Connection
Y (mm)
X (mm)
0
500
1000
1500
2000
2500
3000
3500
0
1000
2000
3000
4000
5000
6000
7000