>> IN THE NAME OF GOD <<

Plastic kinematic link analysis in MATLAB and SAP2000

The MATLAB Program is Verified by SAP2000 v.15.1.0 – SAP2000 Verification Report – Example : Problem 6-009
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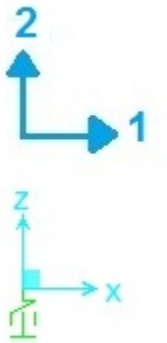
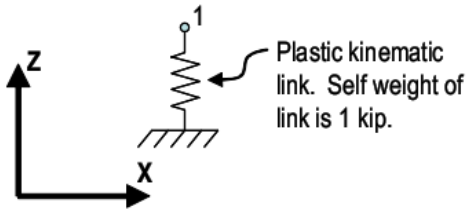


GEOMETRY, PROPERTIES AND LOADING



Loading

Self weight is applied as a gravity load

Active Degrees of Freedom

U_z only

Link Properties (U_1 DOF)

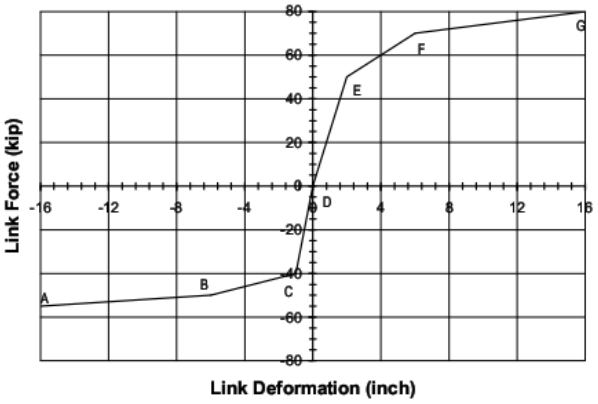
Linear Properties

Not used

Shear Distance

Not used for zero length link

Nonlinear Properties



Point	Deformation (in)	Force (kip)
A	-16	-55
B	-6	-50
C	-1	-40
D	0	0
E	2	50
F	6	70
G	16	80

See force-deformation chart to left

Plastic kinematic link model in SAP2000 (verification example: Problem 6-009)

Define Parameters:

```
% Define Parameters in unit: [mm,kN]
P1 = 0.0; % [kN]
P2 = 0.5; % [kN] Incremantal loading [DOF (2)]
lanX = 0.0;lanY = 1.0;
```

```
Dmax = 304.8; % [mm] Max displacement
```

Plastic kinematic Link Properties:

```
d1=50.8; % [mm] Yield displacement
F1=222.4111; % [kN] Yield force
d2=152.4; % [mm]
F2=311.3755; % [kN]
d3=406.4; % [mm] Ultimate displacement
F3=355.8578;  % [kN] Ultimate force
Rk1=(F1-0)/(d1-0);
Rk2=(F2-F1)/(d2-d1);
Rk3=(F3-F2)/(d3-d2);
```

Analysis Report:

```
####################################
#      Plastic Kinematic Link Analysis     #
####################################
(+)Increment 1 : It is converged in 2 iterations
(+)Increment 2 : It is converged in 2 iterations
(+)Increment 3 : It is converged in 2 iterations
(+)Increment 4 : It is converged in 2 iterations
(+)Increment 5 : It is converged in 2 iterations
(+)Increment 6 : It is converged in 2 iterations
(+)Increment 7 : It is converged in 2 iterations
(+)Increment 8 : It is converged in 2 iterations
(+)Increment 9 : It is converged in 2 iterations
(+)Increment 10 : It is converged in 2 iterations
(+)Increment 11 : It is converged in 2 iterations.
.
.
(+)Increment 664 : It is converged in 177 iterations
(+)Increment 665 : It is converged in 175 iterations
(+)Increment 666 : It is converged in 174 iterations
(+)Increment 667 : It is converged in 172 iterations
(+)Increment 668 : It is converged in 171 iterations
(+)Increment 669 : It is converged in 169 iterations
(+)Increment 670 : It is converged in 168 iterations
(+)Increment 671 : It is converged in 166 iterations
(+)Increment 672 : It is converged in 165 iterations
(+)Increment 673 : It is converged in 163 iterations
(+)Increment 674 : It is converged in 162 iterations
(+)Increment 675 : It is converged in 161 iterations
(+)Increment 676 : It is converged in 159 iterations
(+)Increment 677 : It is converged in 158 iterations
 ## Link reached to ultimate displacement ##
```

SAP2000 Analysis Report:

```
B E G I N   A N A L Y S I S                              2016/04/21  22:24:54


 RUNNING ANALYSIS WITHIN THE GUI PROCESS
 USING THE ADVANCED SOLVER (PROVIDES LIMITED INSTABILITY INFORMATION)

 NUMBER OF JOINTS                          =           1
    WITH MASS                              =           1
 NUMBER OF LINK/SUPPORT ELEMENTS           =           1
 NUMBER OF LOAD PATTERNS                   =           1
 NUMBER OF ACCELERATION LOADS              =           6
 NUMBER OF LOAD CASES                      =           2


 N O N L I N E A R   S T A T I C   A N A L Y S I S                    22:24:54

 CASE: NLSTAT1
 STARTING FROM ZERO (UNSTRESSED) INITIAL CONDITIONS
 LOAD CONTROL TYPE                         = CONJUGATE DISPLACEMENT
```

NUMBER OF STAGES = 0
TYPE OF GEOMETRIC NONLINEARITY = NONE
INCLUDE ELASTIC MATERIAL NONLINEARITY = NO
INCLUDE INELASTIC MATERIAL NONLINEARITY = NO
METHOD TO USE WHEN HINGES DROP LOAD = UNLOAD ENTIRE STRUCTURE
SAVE POSITIVE INCREMENTS ONLY = YES
RELATIVE FORCE CONVERGENCE TOLERANCE = 0.000100
RELATIVE EVENT TOLERANCE = 0.010000

E L E M E N T F O R M A T I O N 22:24:54

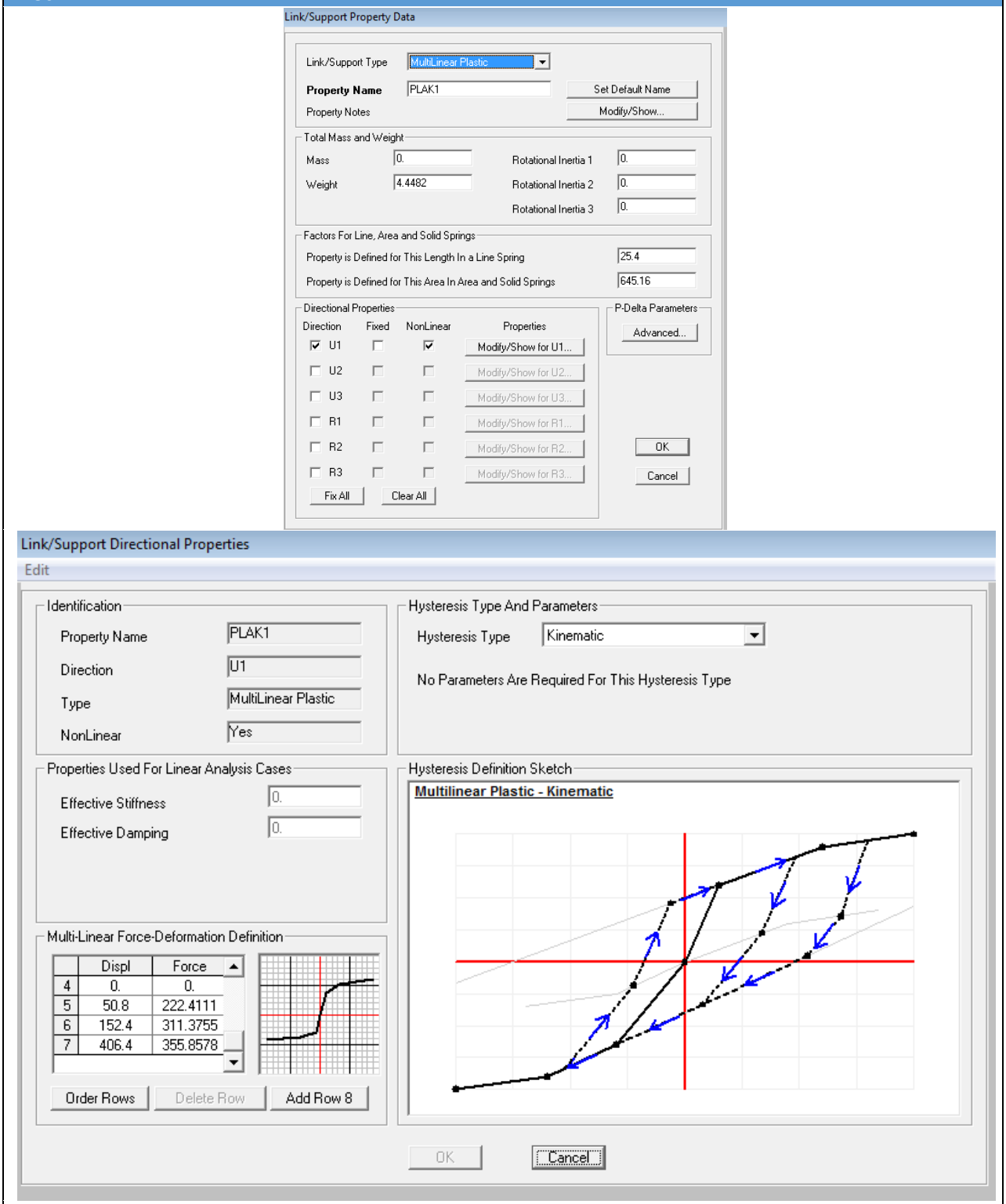
Saved Steps (200	Null Steps 50	Total Steps 200	Iteration this Step 10/10		Relative Unbalance 1.000000	Curr Step Size 0.010000	Curr Sum of Steps 1.000000	Max Sum of Steps 1.000000)
0	0	1		1	37.500000	0.010000	.000000	.000000
1	0	1	Conv	2	.000000	0.010000	0.010000	0.010000
2	0	2	Conv	1	.000000	0.010000	0.020000	0.020000
3	0	3	Conv	1	.000000	0.010000	0.030000	0.030000
4	0	4	Conv	1	.000000	0.010000	0.040000	0.040000
5	0	5	Conv	1	.000000	0.010000	0.050000	0.050000
6	0	6	Conv	1	.000000	0.010000	0.060000	0.060000
7	0	7	Conv	1	7.40E-14	0.010000	0.070000	0.070000
8	0	8	Conv	1	.000000	0.010000	0.080000	0.080000
9	0	9	Conv	1	.000000	0.010000	0.090000	0.090000
10	0	10	Conv	1	7.40E-14	0.010000	0.100000	0.100000
11	0	11	Conv	1	1.48E-13	0.010000	0.110000	0.110000
12	0	12	Conv	1	2.96E-13	0.010000	0.120000	0.120000
13	0	13	Conv	1	2.96E-13	0.010000	0.130000	0.130000
14	0	14	Conv	1	2.96E-13	0.010000	0.140000	0.140000
15	0	15	Conv	1	2.96E-13	0.010000	0.150000	0.150000
16	0	16	Conv	1	4.44E-13	0.010000	0.160000	0.160000
16	0	17		1	16.666667	0.010000	0.160000	0.160000
17	0	17	Conv	2	.000000	0.010000	0.170000	0.170000
18	0	18	Conv	1	1.48E-13	0.010000	0.180000	0.180000
19	0	19	Conv	1	1.48E-13	0.010000	0.190000	0.190000
20	0	20	Conv	1	1.48E-13	0.010000	0.200000	0.200000
21	0	21	Conv	1	1.48E-13	0.010000	0.210000	0.210000
22	0	22	Conv	1	1.48E-13	0.010000	0.220000	0.220000
23	0	23	Conv	1	1.48E-13	0.010000	0.230000	0.230000
24	0	24	Conv	1	1.48E-13	0.010000	0.240000	0.240000
25	0	25	Conv	1	1.48E-13	0.010000	0.250000	0.250000
26	0	26	Conv	1	1.48E-13	0.010000	0.260000	0.260000
27	0	27	Conv	1	1.48E-13	0.010000	0.270000	0.270000
28	0	28	Conv	1	1.48E-13	0.010000	0.280000	0.280000
29	0	29	Conv	1	1.48E-13	0.010000	0.290000	0.290000
30	0	30	Conv	1	1.48E-13	0.010000	0.300000	0.300000
31	0	31	Conv	1	1.48E-13	0.010000	0.310000	0.310000
32	0	32	Conv	1	1.48E-13	0.010000	0.320000	0.320000
33	0	33	Conv	1	1.48E-13	0.010000	0.330000	0.330000
34	0	34	Conv	1	1.48E-13	0.010000	0.340000	0.340000
35	0	35	Conv	1	1.48E-13	0.010000	0.350000	0.350000
36	0	36	Conv	1	1.48E-13	0.010000	0.360000	0.360000
37	0	37	Conv	1	1.48E-13	0.010000	0.370000	0.370000
38	0	38	Conv	1	1.48E-13	0.010000	0.380000	0.380000
39	0	39	Conv	1	1.48E-13	0.010000	0.390000	0.390000
40	0	40	Conv	1	.000000	0.010000	0.400000	0.400000
41	0	41	Conv	1	.000000	0.010000	0.410000	0.410000
42	0	42	Conv	1	.000000	0.010000	0.420000	0.420000
43	0	43	Conv	1	.000000	0.010000	0.430000	0.430000
44	0	44	Conv	1	.000000	0.010000	0.440000	0.440000
45	0	45	Conv	1	2.96E-13	0.010000	0.450000	0.450000
46	0	46	Conv	1	2.96E-13	0.010000	0.460000	0.460000
47	0	47	Conv	1	2.96E-13	0.010000	0.470000	0.470000
48	0	48	Conv	1	5.92E-13	0.010000	0.480000	0.480000
49	0	49	Conv	1	5.92E-13	0.010000	0.490000	0.490000
50	0	50	Conv	1	2.96E-13	0.010000	0.500000	0.500000
51	0	51	Conv	1	2.96E-13	0.010000	0.510000	0.510000
52	0	52	Conv	1	2.96E-13	0.010000	0.520000	0.520000

53	0	53	Conv	1	2.96E-13	0.010000	0.530000	0.530000
54	0	54	Conv	1	2.96E-13	0.010000	0.540000	0.540000
55	0	55	Conv	1	2.96E-13	0.010000	0.550000	0.550000
56	0	56	Conv	1	2.96E-13	0.010000	0.560000	0.560000
57	0	57	Conv	1	2.96E-13	0.010000	0.570000	0.570000
58	0	58	Conv	1	2.96E-13	0.010000	0.580000	0.580000
59	0	59	Conv	1	2.96E-13	0.010000	0.590000	0.590000
60	0	60	Conv	1	2.96E-13	0.010000	0.600000	0.600000
61	0	61	Conv	1	2.96E-13	0.010000	0.610000	0.610000
62	0	62	Conv	1	2.96E-13	0.010000	0.620000	0.620000
63	0	63	Conv	1	2.96E-13	0.010000	0.630000	0.630000
64	0	64	Conv	1	2.96E-13	0.010000	0.640000	0.640000
65	0	65	Conv	1	2.96E-13	0.010000	0.650000	0.650000
66	0	66	Conv	1	2.96E-13	0.010000	0.660000	0.660000
67	0	67	Conv	1	2.96E-13	0.010000	0.670000	0.670000
68	0	68	Conv	1	2.96E-13	0.010000	0.680000	0.680000
69	0	69	Conv	1	2.96E-13	0.010000	0.690000	0.690000
70	0	70	Conv	1	2.96E-13	0.010000	0.700000	0.700000
71	0	71	Conv	1	2.96E-13	0.010000	0.710000	0.710000
72	0	72	Conv	1	2.96E-13	0.010000	0.720000	0.720000
73	0	73	Conv	1	2.96E-13	0.010000	0.730000	0.730000
74	0	74	Conv	1	2.96E-13	0.010000	0.740000	0.740000
75	0	75	Conv	1	2.96E-13	0.010000	0.750000	0.750000
76	0	76	Conv	1	2.96E-13	0.010000	0.760000	0.760000
77	0	77	Conv	1	2.96E-13	0.010000	0.770000	0.770000
78	0	78	Conv	1	2.96E-13	0.010000	0.780000	0.780000
79	0	79	Conv	1	.000000	0.010000	0.790000	0.790000
80	0	80	Conv	1	2.96E-13	0.010000	0.800000	0.800000
81	0	81	Conv	1	5.92E-13	0.010000	0.810000	0.810000
82	0	82	Conv	1	8.88E-13	0.010000	0.820000	0.820000
83	0	83	Conv	1	8.88E-13	0.010000	0.830000	0.830000
84	0	84	Conv	1	8.88E-13	0.010000	0.840000	0.840000
85	0	85	Conv	1	1.18E-12	0.010000	0.850000	0.850000
86	0	86	Conv	1	1.48E-12	0.010000	0.860000	0.860000
87	0	87	Conv	1	1.48E-12	0.010000	0.870000	0.870000
88	0	88	Conv	1	1.48E-12	0.010000	0.880000	0.880000
89	0	89	Conv	1	1.48E-12	0.010000	0.890000	0.890000
90	0	90	Conv	1	1.78E-12	0.010000	0.900000	0.900000
91	0	91	Conv	1	2.07E-12	0.010000	0.910000	0.910000
92	0	92	Conv	1	2.07E-12	0.010000	0.920000	0.920000
93	0	93	Conv	1	2.07E-12	0.010000	0.930000	0.930000
94	0	94	Conv	1	2.07E-12	0.010000	0.940000	0.940000
95	0	95	Conv	1	2.37E-12	0.010000	0.950000	0.950000
96	0	96	Conv	1	2.37E-12	0.010000	0.960000	0.960000
97	0	97	Conv	1	2.37E-12	0.010000	0.970000	0.970000
98	0	98	Conv	1	2.66E-12	0.010000	0.980000	0.980000
99	0	99	Conv	1	2.96E-12	0.010000	0.990000	0.990000
100	0	100	Conv	1	2.96E-12	0.010000	1.000000	1.000000

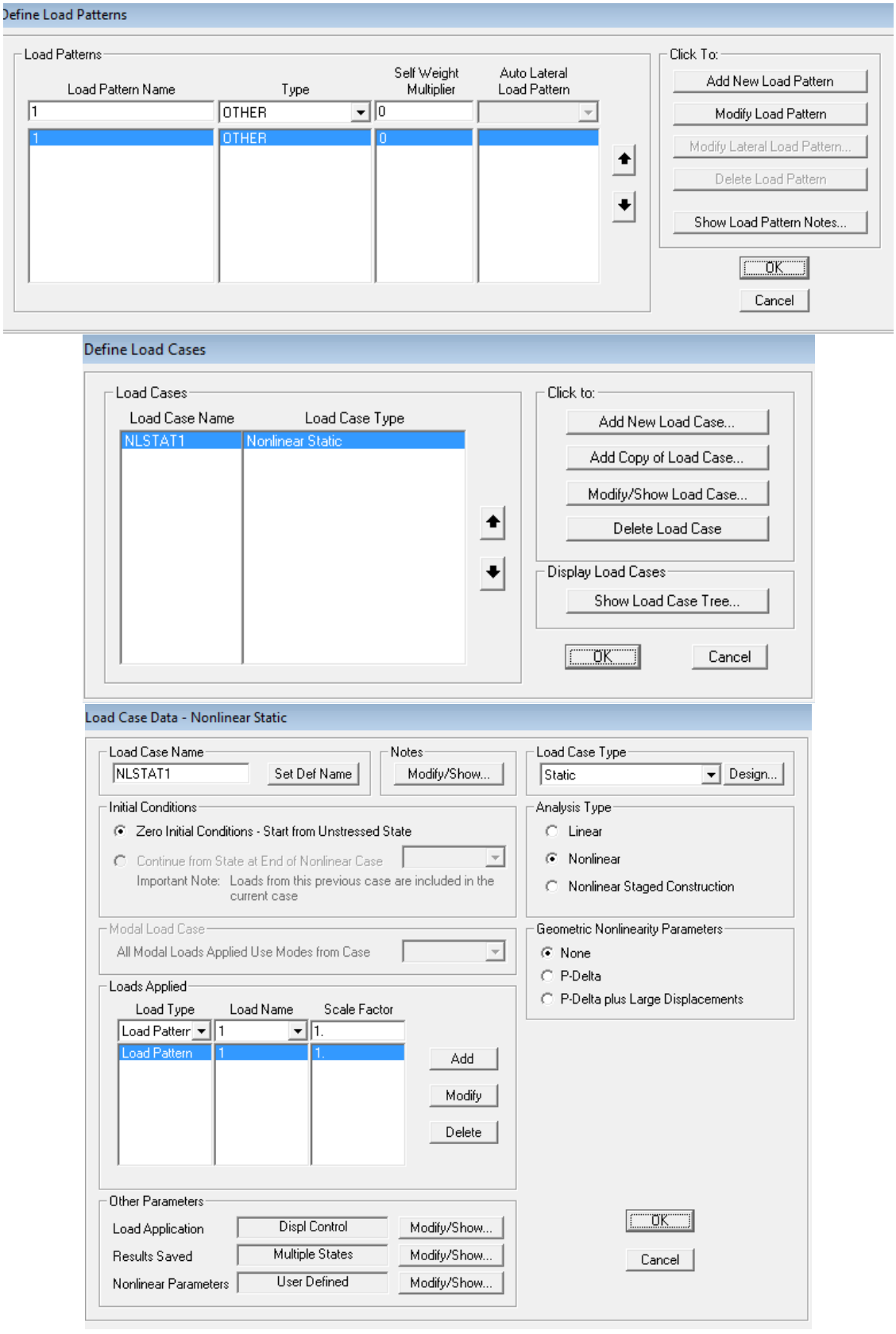
```
TIME FOR INITIALIZING ANALYSIS           =        0.25
TIME FOR CONTROLLING ANALYSIS            =        0.14
TIME FOR UPDATING LOADS AND STATE        =        0.06
TIME FOR FORMING STIFFNESS MATRIX        =        0.34
TIME FOR SOLVING STIFFNESS MATRIX        =        3.20
TIME FOR CALCULATING DISPLACEMENTS       =        0.62
TIME FOR DETERMINING EVENTS              =        0.00
TIME FOR SAVING RESULTS                  =        0.69
                                           ----------
TOTAL TIME FOR THIS ANALYSIS             =        5.30


A N A L Y S I S   C O M P L E T E                        2016/04/21  22:25:04
```

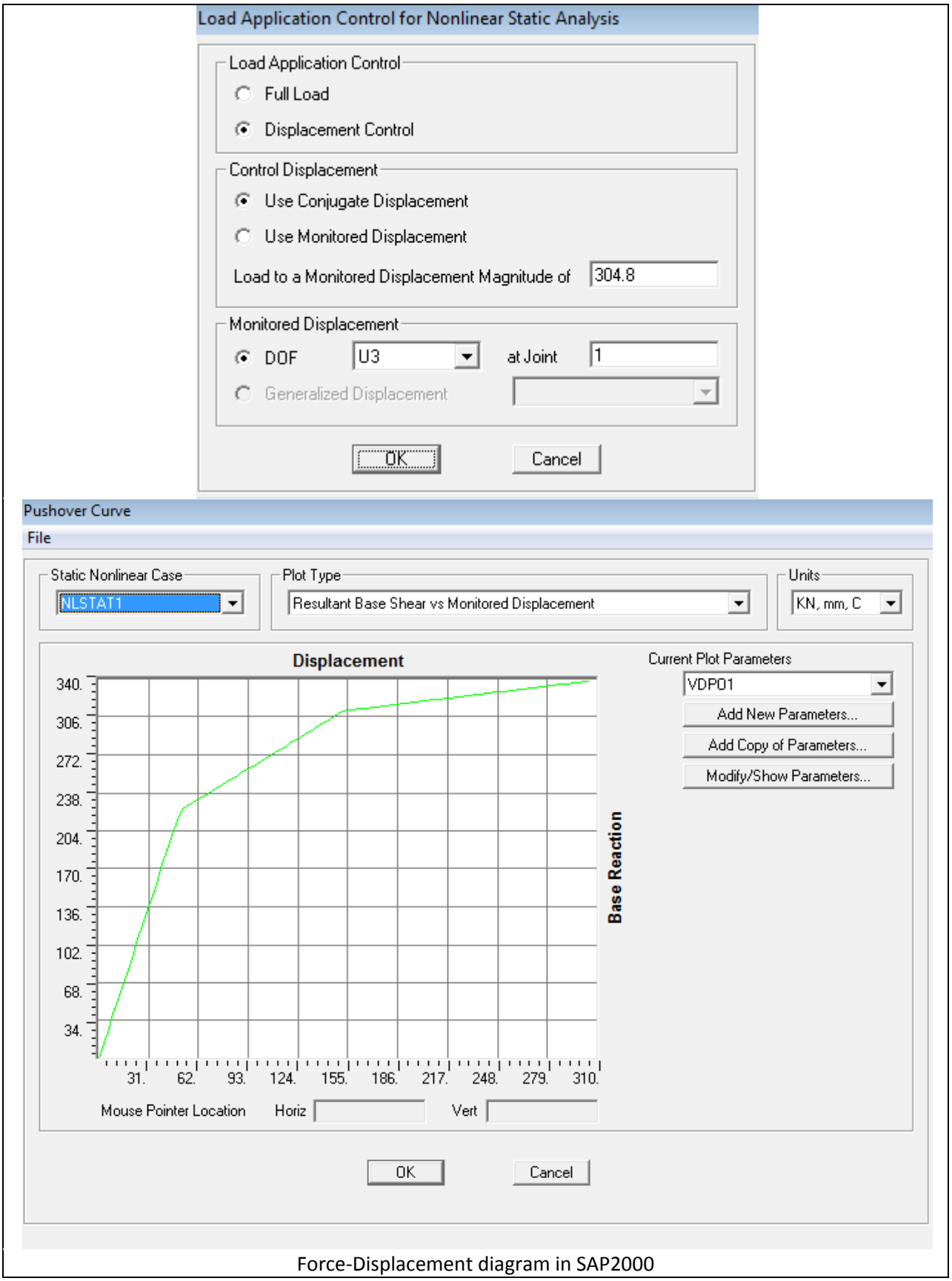
Plot :



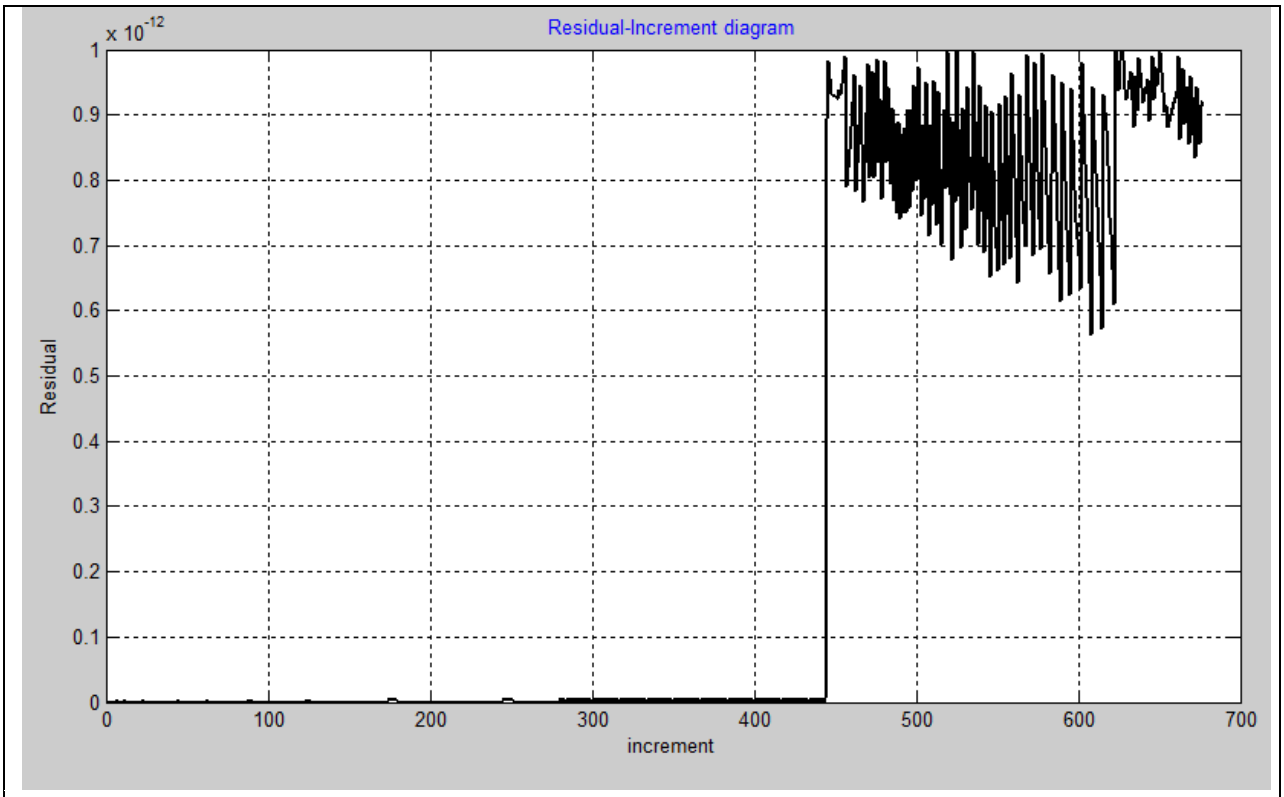
Plastic kinematic link properties in SAP2000



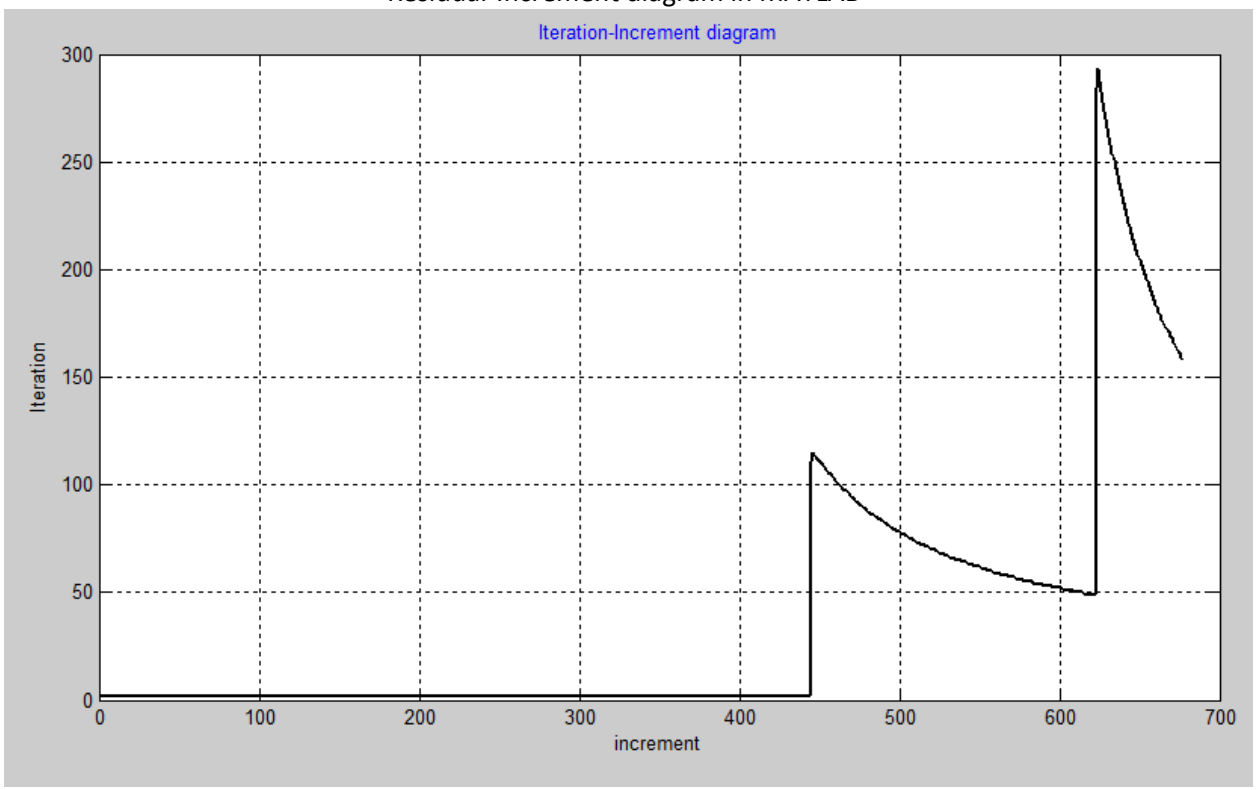
load patterns and load cases in SAP2000



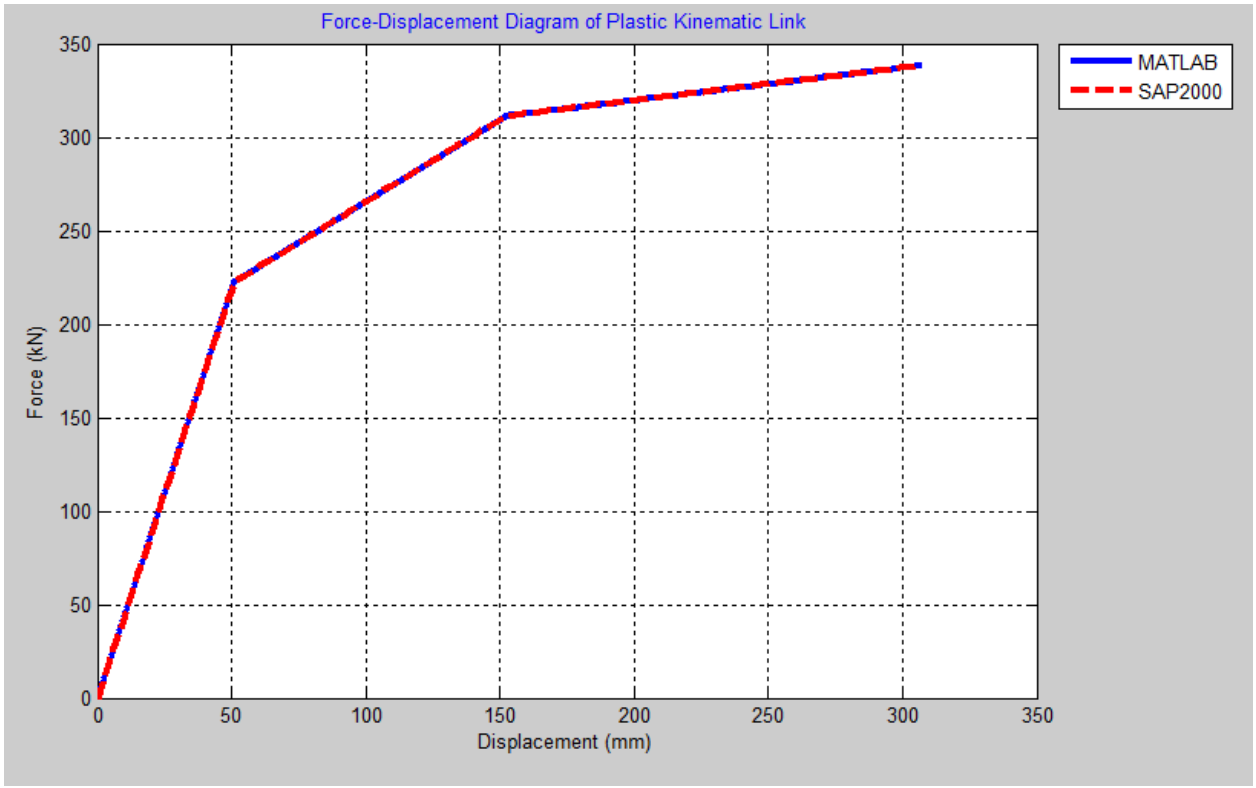
Force-Displacement diagram in SAP2000



Residual-Increment diagram in MATLAB



Iteration-Increment diagram in MATLAB



Force-displacement diagram of kinematic link in SAP2000 and MATLAB