EngiLab Beam.2D ML

Linear Static Analysis of Plane Frames Program

BENCHMARK TESTS

v1.00 Oct. 25, 2004

Introduction

The purpose of this study is to investigate the accuracy of EngiLab Beam.2D ML Linear static analysis results. EngiLab Beam.2D ML version 1.10 has been used for all the analyses.

Three different models are examined:

❶ A continuous beam model

❷ A Frame model

❸ A truss model

MSC.Nastran[1] by MSC.Software, a general Finite Element Analysis software, has been used as a benchmark program. The analysis results of EngiLab Beam.2D ML are presented together with the analysis results of MSC.Nastran for comparison purposes.

[1] NASTRAN is a registered trademark of the National Aeronautics Space Administration (NASA). MSC is a registered trademark of MSC Software, Inc.

Contents

Figures index

Tables index

Test Example 1

1. *Continuous beam model*

1.1 Model description

This model is a continuous beam that consists of **6 Nodes** and **5 Elements**, as shown in the figure below.

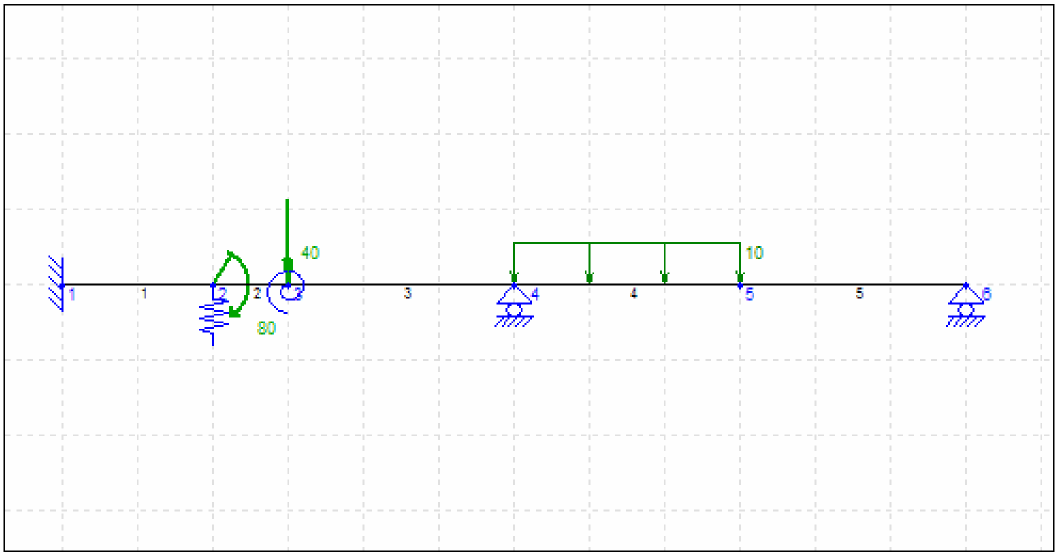

Figure 1. Continuous beam model

1.2 Model data

1.2.1 Material – Section (E,A,I Group)

Young's Modulus E	Sect. area A	Sect. moment of inertia I
210,000,000	0.02	0.00005

Table 1. Material – Section data for example 1

1.2.2 Nodes

Node ID	x - Coordinate	y - Coordinate
1	0	0
2	2	0
3	3	0
4	6	0
5	9	0
6	12	0

Table 2. Nodes data for example 1

1.2.3 Constraints

Node	Description (Type)
1	Fixed (xxx)
4	x-Roller (oxo)
6	x-Roller (oxo)

Table 3. Constraints for example 1

1.2.4 Springs (elastic nodes)

Node	Direction (Type)	Stiffness
2	y (Translational spring)	20,000
3	Z (Rotational spring)	10,000

Table 4. Springs (elastic nodes) for example 1

1.2.5 Elements

Element ID	Node i	Node j	Type
1	1	2	P2
2	2	3	P2
3	3	4	P2
4	4	5	P2
5	5	6	P2

Table 5. Elements for example 1

All elements have the same section and material (E,A,I) properties, described in paragraph 1.2.1.

1.2.6 Nodal (point) loads

Node	Direction (Type)	Value
2	z (Moment)	-80
3	y (Force)	-40

Table 6. Nodal (point) loads for example 1

1.2.7 Elemental (Uniform) loads

Element	Direction	Value
4	y	-10

Table 7. Elemental (uniform) loads for example 1

1.3 EngiLab Beam.2D ML Analysis Results

1.3.1 Node displacements

Node	x-Displacement	y-Displacement	z-Rotation
1	0	0	0
2	0	-2.33986367713817E-03	-4.21137719671309E-03
3	0	-4.92326101732249E-03	-6.80481997791127E-04
4	0	0	7.22789667833522E-04
5	0	-1.79846876654443E-03	-1.57312994193476E-04
6	0	0	9.77890880368953E-04

Table 8. EngiLab Beam.2D ML Node displacements for example 1

1.3.2 Element forces

Element	i, j	Axial force	Shear force	Moment
1	1	0	-29.4763379333049	-7.36660765056124
	2	0	29.4763379333049	-51.5860682160487
2	2	0	17.3209356094585	-28.4139317839513
	3	0	-17.3209356094585	45.7348673934098
3	3	0	-22.6790643905415	-38.9300474154985
	4	0	22.6790643905415	-29.107145756126
4	4	0	27.3511909593543	29.107145756126
	5	0	2.64880904064567	7.946427121937
5	5	0	-2.64880904064567	-7.946427121937
	6	0	2.64880904064567	-1.77635683940025E-15

Table 9. EngiLab Beam.2D ML Element forces for example 1

1.3.3 Constraint - Spring reactions

Node	Force Fx	Force Fy	Moment M
1	0	-29.4763379333049	-7.36660765056124
2		46.7972735427634	
3			6.80481997791127
4		50.0302553498958	
6		2.64880904064567	

Table 10. EngiLab Beam.2D ML Constraint – Spring reactions for example 1

1.4 MSC.Nastran Analysis Results

In the MSC.Nastran model, beam elements have been used for the continuous beam and two spring elements (axial, torsional) for the two springs.

1.4.1 Node displacements

Node	T1 (x-Displ.)	T2 (y-Displ.)	R3 (z-Rot.)
1	0	0	0
2	0	-0.0023399	-0.0042114
3	0	-0.0049233	-0.00068048
4	0	0	0.00072279
5	0	-0.0017985	-0.00015731
6	0	0	0.00097789

Table 11. MSC.Nastran Node displacements for example 1

1.4.2 Element forces

Element	i, j	Axial force	Shr. Plane 1	Mom. Plane 1
1	1	0	29.4763	7.36661
	2	0	29.4763	-51.5861
2	2	0	-17.3209	28.4139
	3	0	-17.3209	45.7349
3	3	0	22.6791	38.93
	4	0	22.6791	-29.1071
4	4	0	-27.3512	-29.1071
	5	0	2.64881	7.94643
5	5	0	2.64881	7.94643
	6	0	2.64881	0

Table 12. MSC.Nastran Element forces for example 1

1.4.3 Constraint - Spring reactions

Node	T1 (Force Fx)	T2 (Force Fy)	R3 (Moment M)
1	0	-29.4763	-7.36661
2		46.7973	
3			6.80482
4		50.0303	
6		2.64881	

Table 13. MSC.Nastran Constraint – Spring reactions for example 1

Test Example 2

2. Frame model

2.1 Model description

This is a frame model that consists of **13 Nodes** and **16 Elements**, as shown in the figure below.

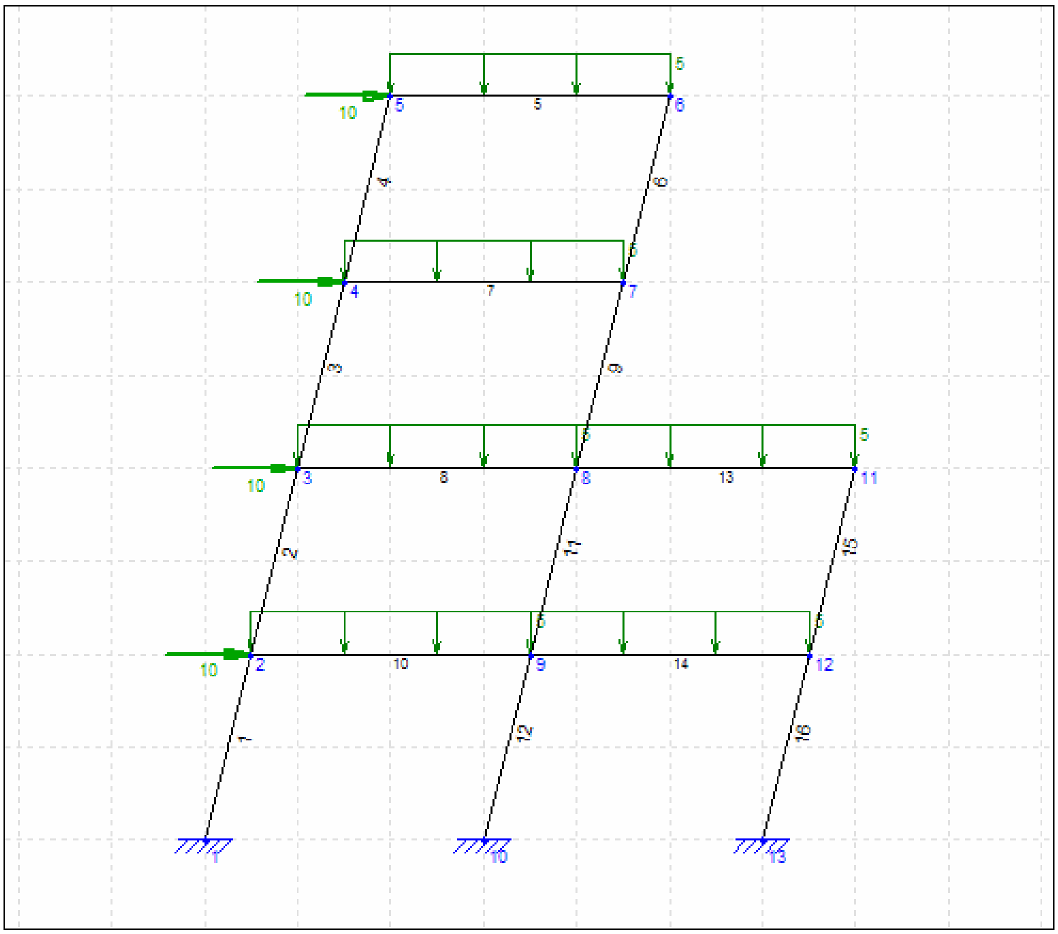

Figure 2. Frame model

2.2 Model data

2.2.1 Material – Section (E,A,I Group)

Young's Modulus E	Sect. area A	Sect. moment of inertia I
210,000,000	0.02	0.00005

Table 14. Material – Section data for example 2

2.2.2 Nodes

Node ID	x - Coordinate	y - Coordinate
1	0	0
2	0.5	2
3	1	4
4	1.5	6
5	2	8
6	5	8
7	4.5	6
8	4	4
9	3.5	2
10	3	0
11	7	4
12	6.5	2
13	6	0

Table 15. Nodes data for example 2

2.2.3 Constraints

Node	Description (Type)
1	Fixed (xxx)
10	Fixed (xxx)
13	Fixed (xxx)

Table 16. Constraints for example 2

2.2.4 Springs (elastic nodes)

There are no springs in the model.

2.2.5 Elements

Element ID	Node i	Node j	Type
1	1	2	P2
2	2	3	P2
3	3	4	P2
4	4	5	P2
5	5	6	P2
6	6	7	P2
7	4	7	P2
8	3	8	P2
9	7	8	P2
10	2	9	P2
11	8	9	P2
12	9	10	P2
13	8	11	P2
14	9	12	P2
15	11	12	P2
16	12	13	P2

Table 17. Elements for example 2

All elements have the same section and material (E,A,I) properties, described in paragraph 2.2.1.

2.2.6 Nodal (point) loads

Node	Direction (Type)	Value
2	x (Force)	10
3	x (Force)	10
4	x (Force)	10
5	x (Force)	10

Table 18. Nodal (point) loads for example 2

2.2.7 Elemental (Uniform) loads

Element	Direction	Value
5	y	-5
7	y	-5
8	y	-5
10	y	-5
13	y	-5

Table 19. Elemental (uniform) loads for example 2

2.3 EngiLab Beam.2D ML Analysis Results

2.3.1 Node displacements

Node	x-Displacement	y-Displacement	z-Rotation
1	0	0	0
2	0.00247186011252515	-0.00060672194619835	-0.00127397359836608
3	0.00548217963574199	-0.00135298422985483	-0.00118986528593972
4	0.00832688042286974	-0.00206090835789954	-0.00093923170162155
5	0.01017361818521380	-0.00252273554750382	-0.00060270681435891
6	0.01016955772280710	-0.00262024177752716	-0.00033806010677258
7	0.00832511124141448	-0.00215313733234963	-0.00091274512109716
8	0.00547434210663795	-0.00142492283222298	-0.00085674681347263
9	0.00247308315696515	-0.00065006542872795	-0.00084158218612421
10	0.00000000000000000	0.00000000000000000	0.00000000000000000
11	0.00546571458705395	-0.00139268910306570	-0.00067743726066709
12	0.00247521574342228	-0.00063752005092678	-0.00122346011570756
13	0	0	0

Table 20. EngiLab Beam.2D ML Node displacements for example 2

2.3.2 Element forces

Element	i, j	Axial force	Shear force	Moment
1	1	-22.22162076156910	17.71769134971990	24.75164186139650
	2	22.22162076156910	-17.71769134971990	11.77431457709730
2	2	-12.48654495080370	8.07873674453277	7.89898672519015
	3	12.48654495080370	-8.07873674453277	8.75575573444344
3	3	-6.42564173946181	10.59643460226870	9.64601574644415
	4	6.42564173946181	-10.59643460226870	12.19909381360780
4	4	0.28213923608978	4.51869848592447	2.94376303562327
	5	-0.28213923608978	-4.51869848592447	6.37177253826933
5	5	5.68464736943133	1.36966062552183	-6.37177253826940
	6	-5.68464736943133	13.63033937447820	-12.01924558516510
6	6	11.84464201572740	8.82076089107255	12.01924558516510
	7	-11.84464201572740	-8.82076089107255	6.16521884093967
7	4	2.47685403735886	-5.03343587826383	-15.14285684923110
	7	-2.47685403735886	20.03343587826380	-22.45745078556040
8	3	10.97254074566810	-6.49057121816850	-18.40177148088760
	8	-10.97254074566810	21.49057121816850	-23.56994217361790
9	7	30.67920424309540	16.08248415172910	16.29223194462070
	8	-30.67920424309540	-16.08248415172910	16.86265849532970
10	2	-1.71226221600318	-7.10662090629391	-19.67330130228740
	9	1.71226221600318	22.10662090629390	-24.14656141659430
11	8	48.50785765773620	19.39962253816890	19.91943599567560
	9	-48.50785765773620	-19.39962253816890	20.07391041531610
12	9	62.84116980892420	24.29549880859920	20.75684006157800
	10	-62.84116980892420	-24.29549880859920	29.32961384588330
13	8	12.07852741759510	-3.38971258837864	-13.21215231738740
	11	-12.07852741759510	18.38971258837860	-19.45698544774850
14	9	-2.98562103997165	-7.01384120922778	-16.68418906029990
	12	2.98562103997165	22.01384120922780	-26.85733456738340
15	11	14.91116855069860	16.17805322384070	19.45698544774850
	12	-14.91116855069860	-16.17805322384070	13.89492568163130
16	12	36.99185096427170	18.62071610076690	12.96240888575210
	13	-36.99185096427170	-18.62071610076690	25.42518076829870

Table 21. EngiLab Beam.2D ML Element forces for example 2

2.3.3 Constraint - Spring reactions

Node	Force Fx	Force Fy	Moment M
1	-22.5782200635481	-17.2609673772049	24.7516418613965
10	-8.32887355883062	66.8574135796002	29.3296138458833
13	-9.09290637762396	40.4035537976056	25.4251807682987

Table 22. EngiLab Beam.2D ML Constraint – Spring reactions for example 2

2.4 MSC.Nastran Analysis Results for Example 2

In the MSC.Nastran model, beam elements have been used for the frame.

2.4.1 Node displacements

Node	T1 (x-Displ.)	T2 (y-Displ.)	R3 (z-Rot.)
1	0	0	0
2	0.002472	-0.00061	-0.00127
3	0.005482	-0.00135	-0.00119
4	0.008327	-0.00206	-0.00094
5	0.010174	-0.00252	-0.0006
6	0.01017	-0.00262	-0.00034
7	0.008325	-0.00215	-0.00091
8	0.005474	-0.00142	-0.00086
9	0.002473	-0.00065	-0.00084
10	0	0	0
11	0.005466	-0.00139	-0.00068
12	0.002475	-0.00064	-0.00122
13	0	0	0

Table 23. MSC.Nastran Node displacements for example 2

2.4.2 Element forces

Element	i, j	Axial force	Shr. Plane 1	Mom. Plane 1
1	1	22.2216	-17.7177	-24.7516
	2	22.2216	-17.7177	11.7743
2	2	12.4865	-8.07874	-7.89899
	3	12.4865	-8.07874	8.75576
3	3	6.42564	-10.5964	-9.64602
	4	6.42564	-10.5964	12.1991
4	4	-0.28214	-4.5187	-2.94376
	5	-0.28214	-4.5187	6.37177
5	5	-5.68465	-1.36966	6.37177
	6	-5.68465	13.6303	-12.0192
6	6	-11.8446	8.82076	12.0192
	7	-11.8446	8.82076	-6.16522
7	4	-2.47685	5.03344	15.1429
	7	-2.47685	20.0334	-22.4575
8	3	-10.9725	6.49057	18.4018
	8	-10.9725	21.4906	-23.5699
9	7	-30.6792	16.0825	16.2922
	8	-30.6792	16.0825	-16.8627
10	2	1.71226	7.10662	19.6733
	9	1.71226	22.1066	-24.1466
11	8	-48.5079	19.3996	19.9194
	9	-48.5079	19.3996	-20.0739
12	9	-62.8412	24.2955	20.7568
	10	-62.8412	24.2955	-29.3296
13	8	-12.0785	3.38971	13.2122
	11	-12.0785	18.3897	-19.457

14	9	2.98562	7.01384	16.6842
	12	2.98562	22.0138	-26.8573
15	11	-14.9112	16.1781	19.457
	12	-14.9112	16.1781	-13.8949
16	12	-36.9919	18.6207	12.9624
	13	-36.9919	18.6207	-25.4252

Table 24. MSC.Nastran Element forces for example 2

2.4.3 Constraint - Spring reactions

Node	T1 (Force Fx)	T2 (Force Fy)	R3 (Moment M)
1	-22.5782	-17.261	24.7516
10	-8.32887	66.8574	29.3296
13	-9.09291	40.4036	25.4252

Table 25. MSC.Nastran Constraint – Spring reactions for example 2

Test Example 3

3. Truss model

3.1 Model description

This is a truss model that consists of **6 Nodes** and **9 Elements**, as shown in the figure below.

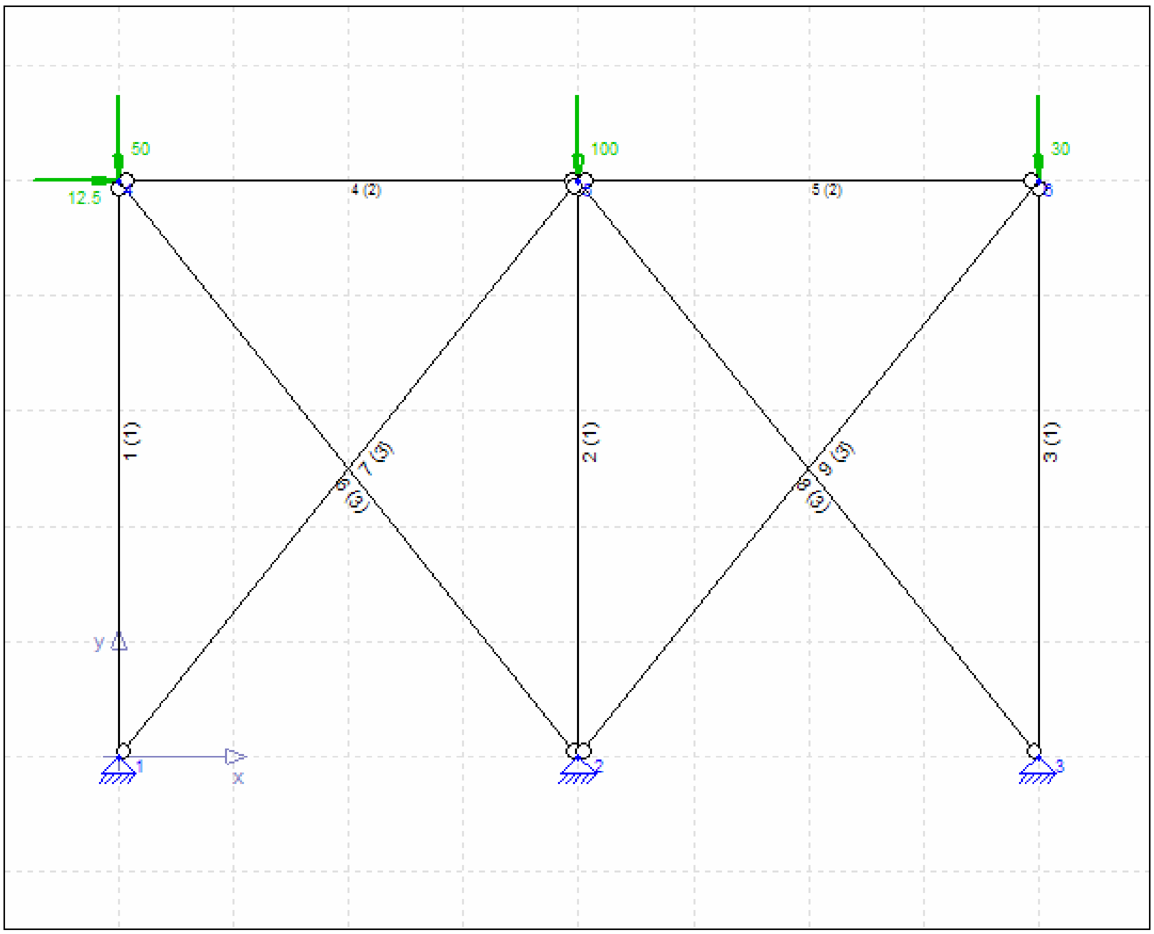

Figure 3. Truss model

3.2 Model data

3.2.1 Material – Section (E,A,I Group)

E,A,I Group	Young's Modulus E	Sect. area A	Sect. moment of inertia I
1	210000000	.00118	.00001*
2	210000000	.000797	.00001*
3	210000000	.00103	.00001*

Table 26. Material – Section data for example 3

* Section moment of inertia does not affect the results of a truss analysis, as elements are stressed only axially (no bending)

3.2.2 Nodes

Node ID	x - Coordinate	y - Coordinate
1	0	0
2	4	0
3	8	0
4	0	5
5	4	5
6	8	5

Table 27. Nodes data for example 3

3.2.3 Constraints

Node	Description (Type)
1	Pinned (xxo)
2	Pinned (xxo)
3	Pinned (xxo)

Table 28. Constraints for example 3

3.2.4 Springs (elastic nodes)

There are no springs in the model.

3.2.5 Elements

Element ID	Node i	Node j	E,A,I Group	Type	Hinges at end
1	1	4	1	P2'	j
2	2	5	1	P2'	j
3	3	6	1	P2'	j
4	4	5	2	P1	i, j
5	5	6	2	P1	i, j
6	4	2	3	P2'	j
7	1	5	3	P1	i, j
8	5	3	3	P2'	j
9	2	6	3	P2'	i

Table 29. Elements for example 3

3.2.6 Nodal (point) loads

Node	Direction (Type)	Value
4	x (Force)	12.5
4	y (Force)	-50
5	y (Force)	-100
6	y (Force)	-30

Table 30. Nodal (point) loads for example 3

3.3 EngiLab Beam.2D ML Analysis Results

3.3.1 Node displacements

Node	x-Displacement	y-Displacement	z-Rotation
1	0	0	-2.80550747335865E-05
2	0	0	-3.06838837454512E-05
3	0	0	-5.26467685385537E-05
4	1.40275373667933E-04	-6.79732150287663E-04	4.92085788490485E-05
5	1.53419418727256E-04	-1.10186048920333E-03	8.87888991018788E-05
6	2.63233842692768E-04	-4.89434270712849E-04	-7.98513730808595E-05

Table 31. EngiLab Beam.2D ML Node displacements for example 3

3.3.2 Element forces

Element	i, j	Axial force	Shear force	Moment
1	1	33.6875253682566	8.67361737988404E-19	0
	4	-33.6875253682566	-8.67361737988404E-19	0
2	2	54.6082058449169	8.67361737988404E-19	0
	5	-54.6082058449169	-8.67361737988404E-19	0
3	3	24.2563624565288	1.73472347597681E-18	0
	6	-24.2563624565288	-1.73472347597681E-18	0
4	4	-.549979705394735	0	0
	5	.549979705394735	0	0
5	5	-4.59491003477695	0	0
	6	4.59491003477695	0	0
6	4	20.890160337405	8.67361737988404E-19	0
	2	-20.890160337405	-8.67361737988404E-19	0
7	1	25.8274058046482	0	0
	5	-25.8274058046482	0	0
8	5	32.3024536623468	1.73472347597681E-18	0
	3	-32.3024536623468	-1.73472347597681E-18	0
9	2	7.35544495312593	-1.73472347597681E-18	0
	6	-7.35544495312593	1.73472347597681E-18	0

Table 32. EngiLab Beam.2D ML Element forces for example 3

3.3.3 Constraint - Spring reactions

Node	Force Fx	Force Fy	Moment M
1	16.1342524973421	53.8553409899342	
2	-8.45506967061778	76.6643180201315	
3	-20.1791828267243	49.4803409899342	

Table 33. EngiLab Beam.2D ML Constraint – Spring reactions for example 3

3.4 MSC.Nastran Analysis Results for Example 3

In the MSC.Nastran model, rod elements have been used for the truss.

3.4.1 Node displacements

Node	T1 (x-Displ.)	T2 (y-Displ.)
1	0	0
2	0	0
3	0	0
4	0.00014028	-0.00067973
5	0.00015342	-0.0011019
6	0.00026323	-0.00048943

Table 34. MSC.Nastran Node displacements for example 3

3.4.2 Element forces

Element	Axial force
1	-33.6875
2	-54.6082
3	-24.2564
4	0.54998
5	4.59491
6	-20.8902
7	-25.8274
8	-32.3025
9	-7.35544

Table 35. MSC.Nastran Element forces for example 3

3.4.3 Constraint - Spring reactions

Node	T1 (Force Fx)	T2 (Force Fy)	R3 (Moment M)
1	16.1343	53.8553	
2	-8.45507	76.6643	
3	-20.1792	49.4803	

Table 36. MSC.Nastran Constraint – Spring reactions for example 3

Conclusions

4. Conclusions

The purpose of this study was to investigate the accuracy of EngiLab Beam.2D ML Linear static analysis results Three different models were examined; a beam model, a frame model and a truss model. MSC.Nastran by MSC.Software, a general Finite Element Analysis software, has been used as a benchmark program. It turned out that the analysis results of the two programs coincide for all models that were tested, which validates the accuracy of EngiLab Beam.2D ML Linear static analysis results.

All the corresponding files needed for this study, input files, results (output) files as well as further details on the methodology or any other information, are at the user's disposal upon their request via email at support@engilab.com.