Appendix to report:

SBJ-33-C5-OON-22-RE-021

K12 - DESIGN OF MOORING AND ANCHORING

Appendix title:

APPENDIX B – INTERLINK STIFFNESS MODELL

Contract no:	18/91094
Project number:	5187772/12777
Document number:	SBJ-33-C5-OON-22-RE-021 App. B
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Controlled by:	Håkon S. Andersen
Approved by:	Kolbjørn Høyland

CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

Norconsult

DR. TECHN. OLAV OLSEN

Prodtex IFE Pure Logic HEYERDAHL ARKITEKTER AS H&BB MIKO MARINE AS BUKSÉR OG BERGING FORCE TECHNOLOGY SWERIM

Table of Content

1 REPORT ANALYSIS MODELL

1.1 Materials

Materials

Mat	Classification
1	STEEL

Cross-sections static properties

SNo	Mat	A[m2]	Ay[m2]	Iy[m4]	yc[mm]	ysc[mm]	E[N/mm2]	g[kg/m]	I-1[m4]
	MRf	It[m4]	Az[m2]	Iz[m4]	zc[mm]	zsc[mm]	G[N/mm2]		I-2[m4]
			Ayz[m2]	Iyz[m4]					α[°]
1	1	1.6741E-02		4.461E-05	0.0	0.0	210000	41.9	1.029E-03
		1.853E-06		1.029E-03	0.0	0.0	80769		4.461E-05
	▪ Link 1								
2	1	1.6741E-02		1.029E-03	0.0	0.0	210000	41.9	
		1.853E-06		4.461E-05	0.0	0.0	80769		
	▪ Link 2								

SNo section number
Mat material number
A[m2] sectional area
Ay[m2],Az[m2],Ayz[m2] transverse shear deformation area
Iy[m4],Iz[m4],Iyz[m4] bending moment of inertia
I-1[m4],I-2[m4],α[°] principal moments of inertia and angle of the principal axes
MRf reinforcement material number
It[m4] torsional moment of inertia
G[N/mm2] Shear modulus
yc[mm],zc[mm] ordinate of elastic centroid
ysc[mm],zsc[mm] ordinate of shear centre
E[N/mm2] Young's modulus
g[kg/m] weight per length

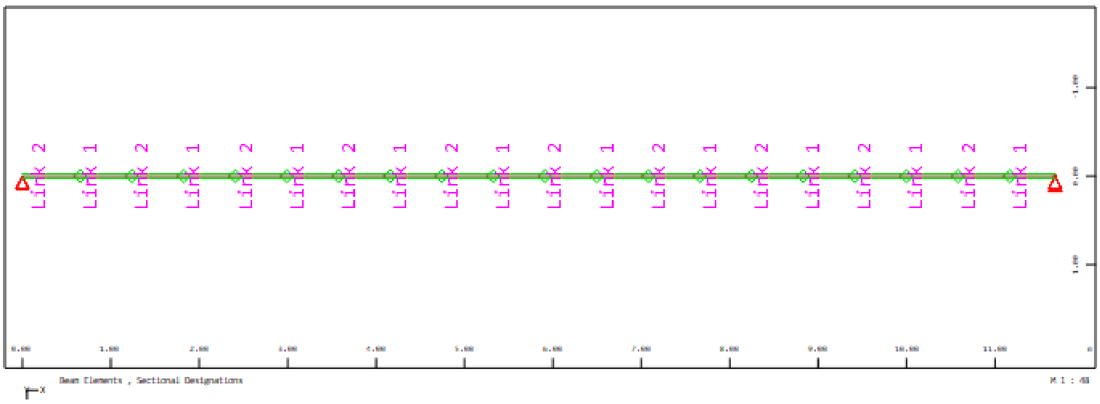
Spring Material 111

Connection type: 'Implicit Hinge' work law(s)

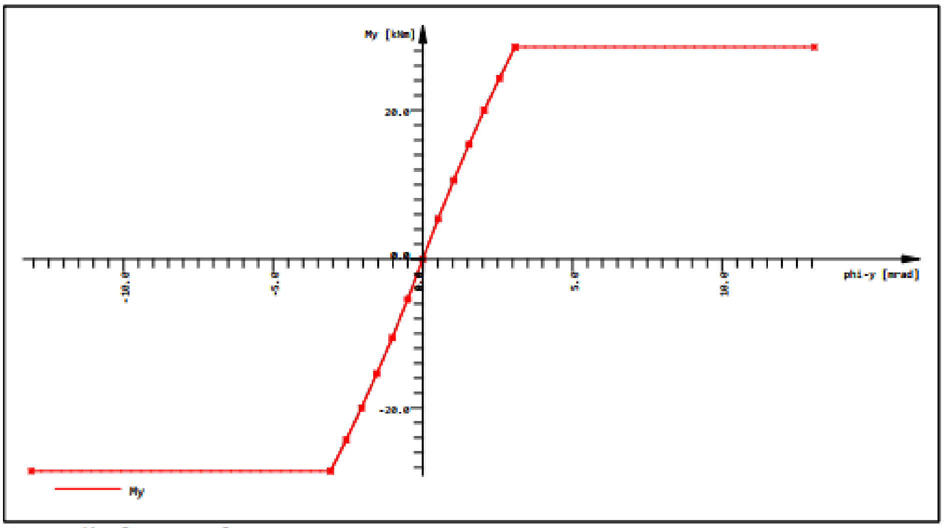
Material type: Elastoplastic, anisotropic hardening

Force-displacement law My

Number		Sur[kNm/rad]	u[mrad]	My[kNm]	S[kNm/rad]
111	My	10588.23	-13.080	-28.50	0.00
			-3.080	-28.50	8076.92
			-2.560	-24.30	8431.37
			-2.050	-20.00	9019.61
			-1.540	-15.40	9230.77
			-1.020	-10.60	10196.08
			-0.510	-5.40	10588.23
			0.000	0.00	10588.23
			0.510	5.40	10000.00
			1.030	10.60	9411.76
			1.540	15.40	9019.61
			2.050	20.00	8431.37
			2.560	24.30	8076.92
			3.080	28.50	0.00
			13.080	28.50	0.00



material and hinge definition

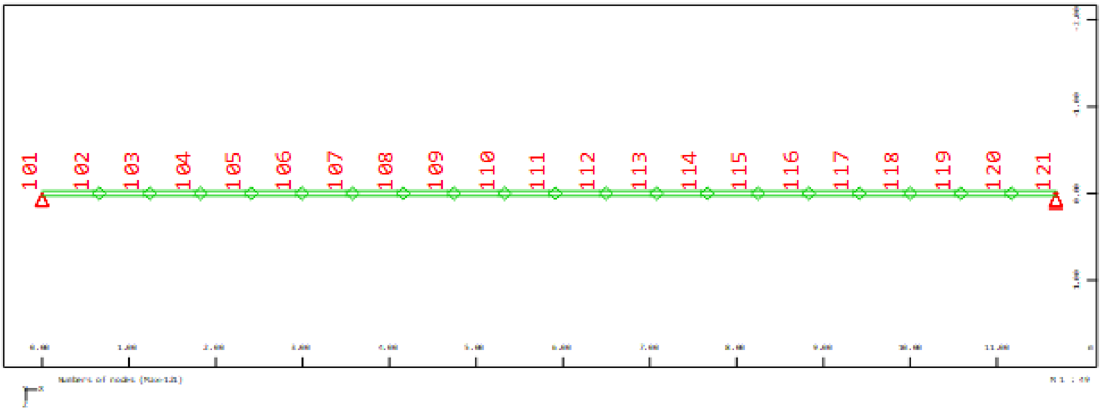


Force-displacement law My

1.2 Nodes

Nodes

Number	X[m]	Y[m]	Z[m]	eq.PX	eq.PY	eq.PZ	eq.MX	eq.MY	eq.MZ
101	0.000	0.000	0.000	PX	PY	PZ	1	2	3
102	0.584	0.000	0.000	4	5	6	7	8	9
103	1.168	0.000	0.000	11	12	13	14	15	16
104	1.752	0.000	0.000	18	19	20	21	22	23
105	2.336	0.000	0.000	25	26	27	28	29	30
106	2.920	0.000	0.000	32	33	34	35	36	37
107	3.504	0.000	0.000	39	40	41	42	43	44
108	4.088	0.000	0.000	46	47	48	49	50	51
109	4.672	0.000	0.000	53	54	55	56	57	58
110	5.256	0.000	0.000	60	61	62	63	64	65
111	5.840	0.000	0.000	67	68	69	70	71	72
112	6.424	0.000	0.000	74	75	76	77	78	79
113	7.008	0.000	0.000	81	82	83	84	85	86
114	7.592	0.000	0.000	88	89	90	91	92	93
115	8.176	0.000	0.000	95	96	97	98	99	100
116	8.760	0.000	0.000	102	103	104	105	106	107
117	9.344	0.000	0.000	109	110	111	112	113	114
118	9.928	0.000	0.000	116	117	118	119	120	121
119	10.512	0.000	0.000	123	124	125	126	127	128
120	11.096	0.000	0.000	130	131	132	133	134	135
121	11.680	0.000	0.000	137	PY	PZ	MX	138	MZ
MIN	0.000	0.000	0.000						
MAX	11.680	0.000	0.000	138					



1.3 Loads

Load Case 101 3rd Order Theory (UPD.LAGRANGIAN) NONLINEAR
Factor forces and moments 1.000

Loads acting on Nodes

Node	WX[mm]	WY[mm]	WZ[mm]	DX[mrad]	DY[mrad]	DZ[mrad]	
101					8.730		
Node	**PX[kN]**	**PY[kN]**	**PZ[kN]**	**MX[kNm]**	**MY[kNm]**	**MZ[kNm]**	**MB[kNm2]**
121	1300.0						

Beam Forces and Moments Loadcase 101 NONLINEAR

Grp	Number	x [m]	N [kN]	Vy [kN]	Vz [kN]	Mt [kNm]	My [kNm]	Mz [kNm]
0	1	0.000	1299.9	0.00	13.86	0.00	-29.86	0.00
		0.584	1299.9	0.00	13.86	0.00	-21.76	0.00
0	2	0.000	1300.4	0.00	9.73	0.00	-21.62	0.00
		0.584	1300.4	0.00	9.73	0.00	-15.94	0.00
0	3	0.000	1300.8	0.00	7.17	0.00	-15.84	0.00
		0.584	1300.8	0.00	7.17	0.00	-11.66	0.00
0	4	0.000	1300.6	0.00	5.38	0.00	-11.65	0.00
		0.584	1300.6	0.00	5.38	0.00	-8.51	0.00
0	5	0.000	1300.3	0.00	3.92	0.00	-8.53	0.00
		0.584	1300.3	0.00	3.92	0.00	-6.24	0.00
0	6	0.000	1300.0	0.00	2.87	0.00	-6.27	0.00
		0.584	1300.0	0.00	2.87	0.00	-4.60	0.00
0	7	0.000	1299.9	0.00	2.12	0.00	-4.60	0.00
		0.584	1299.9	0.00	2.12	0.00	-3.36	0.00
0	8	0.000	1299.8	0.00	1.54	0.00	-3.38	0.00
		0.584	1299.8	0.00	1.54	0.00	-2.48	0.00
0	9	0.000	1299.9	0.00	1.16	0.00	-2.48	0.00
		0.584	1299.9	0.00	1.16	0.00	-1.80	0.00
0	10	0.000	1299.9	0.00	0.83	0.00	-1.83	0.00
		0.584	1299.9	0.00	0.83	0.00	-1.34	0.00
0	11	0.000	1300.0	0.00	0.62	0.00	-1.34	0.00
		0.584	1300.0	0.00	0.62	0.00	-0.98	0.00
0	12	0.000	1300.0	0.00	0.45	0.00	-0.99	0.00
		0.584	1300.0	0.00	0.45	0.00	-0.72	0.00
0	13	0.000	1300.1	0.00	0.32	0.00	-0.72	0.00
		0.584	1300.1	0.00	0.32	0.00	-0.54	0.00
0	14	0.000	1300.1	0.00	0.24	0.00	-0.54	0.00
		0.584	1300.1	0.00	0.24	0.00	-0.39	0.00
0	15	0.000	1300.1	0.00	0.16	0.00	-0.39	0.00
		0.584	1300.1	0.00	0.16	0.00	-0.30	0.00
0	16	0.000	1300.1	0.00	0.14	0.00	-0.29	0.00

Load Case 101 3rd Order Theory (UPD.LAGRANGIAN) NONLINEAR
Factor forces and moments 1.000

Loads acting on Nodes

Node	WX[mm]	WY[mm]	WZ[mm]	DX[mrad]	DY[mrad]	DZ[mrad]	
101					8.730		
Node	**PX[kN]**	**PY[kN]**	**PZ[kN]**	**MX[kNm]**	**MY[kNm]**	**MZ[kNm]**	**MB[kNm2]**
121	1300.0						

Beam Forces and Moments Loadcase 101 NONLINEAR

Grp	Number	x [m]	N [kN]	Vy [kN]	Vz [kN]	Mt [kNm]	My [kNm]	Mz [kNm]
0	1	0.000	1299.9	0.00	13.86	0.00	-29.86	0.00
		0.584	1299.9	0.00	13.86	0.00	-21.76	0.00
0	2	0.000	1300.4	0.00	9.73	0.00	-21.62	0.00
		0.584	1300.4	0.00	9.73	0.00	-15.94	0.00
0	3	0.000	1300.8	0.00	7.17	0.00	-15.84	0.00
		0.584	1300.8	0.00	7.17	0.00	-11.66	0.00
0	4	0.000	1300.6	0.00	5.38	0.00	-11.65	0.00
		0.584	1300.6	0.00	5.38	0.00	-8.51	0.00
0	5	0.000	1300.3	0.00	3.92	0.00	-8.53	0.00
		0.584	1300.3	0.00	3.92	0.00	-6.24	0.00
0	6	0.000	1300.0	0.00	2.87	0.00	-6.27	0.00
		0.584	1300.0	0.00	2.87	0.00	-4.60	0.00
0	7	0.000	1299.9	0.00	2.12	0.00	-4.60	0.00
		0.584	1299.9	0.00	2.12	0.00	-3.36	0.00
0	8	0.000	1299.8	0.00	1.54	0.00	-3.38	0.00
		0.584	1299.8	0.00	1.54	0.00	-2.48	0.00
0	9	0.000	1299.9	0.00	1.16	0.00	-2.48	0.00
		0.584	1299.9	0.00	1.16	0.00	-1.80	0.00
0	10	0.000	1299.9	0.00	0.83	0.00	-1.83	0.00
		0.584	1299.9	0.00	0.83	0.00	-1.34	0.00
0	11	0.000	1300.0	0.00	0.62	0.00	-1.34	0.00
		0.584	1300.0	0.00	0.62	0.00	-0.98	0.00
0	12	0.000	1300.0	0.00	0.45	0.00	-0.99	0.00
		0.584	1300.0	0.00	0.45	0.00	-0.72	0.00
0	13	0.000	1300.1	0.00	0.32	0.00	-0.72	0.00
		0.584	1300.1	0.00	0.32	0.00	-0.54	0.00
0	14	0.000	1300.1	0.00	0.24	0.00	-0.54	0.00
		0.584	1300.1	0.00	0.24	0.00	-0.39	0.00
0	15	0.000	1300.1	0.00	0.16	0.00	-0.39	0.00
		0.584	1300.1	0.00	0.16	0.00	-0.30	0.00
0	16	0.000	1300.1	0.00	0.14	0.00	-0.29	0.00
		0.584	1300.1	0.00	0.14	0.00	-0.21	0.00

1.4 Results

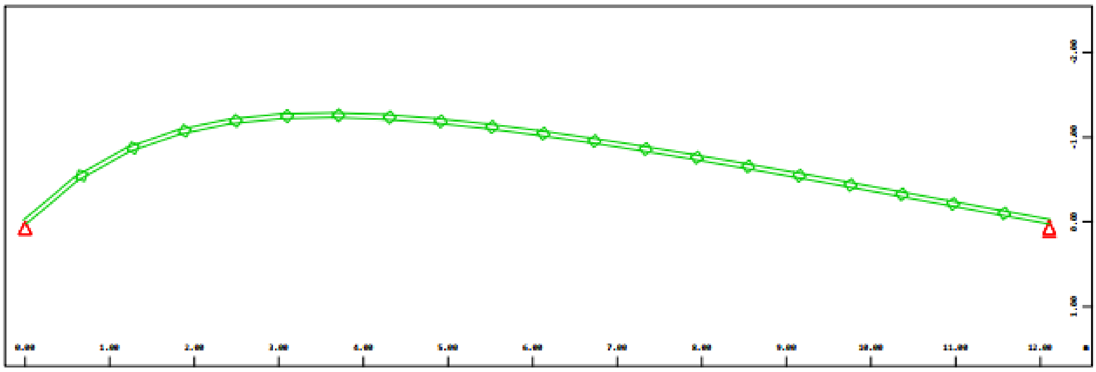
Beam Forces and Moments Loadcase 101 NONLINEAR

Grp	Number	x [m]	N [kN]	Vy [kN]	Vz [kN]	Mt [kNm]	My [kNm]	Mz [kNm]
0	16	0.584	1300.1	0.00	0.14	0.00	-0.21	0.00
0	17	0.000	1300.1	0.00	0.07	0.00	-0.21	0.00
		0.584	1300.1	0.00	0.07	0.00	-0.17	0.00
0	18	0.000	1300.1	0.00	0.09	0.00	-0.14	0.00
		0.584	1300.1	0.00	0.09	0.00	-0.09	0.00
0	19	0.000	1300.1	0.00	0.03	0.00	-0.09	0.00
		0.584	1300.1	0.00	0.03	0.00	-0.07	0.00
0	20	0.000	1300.1	0.00	0.07	0.00	-0.04	0.00
		0.584	1300.1	0.00	0.07	0.00	-0.00	0.00

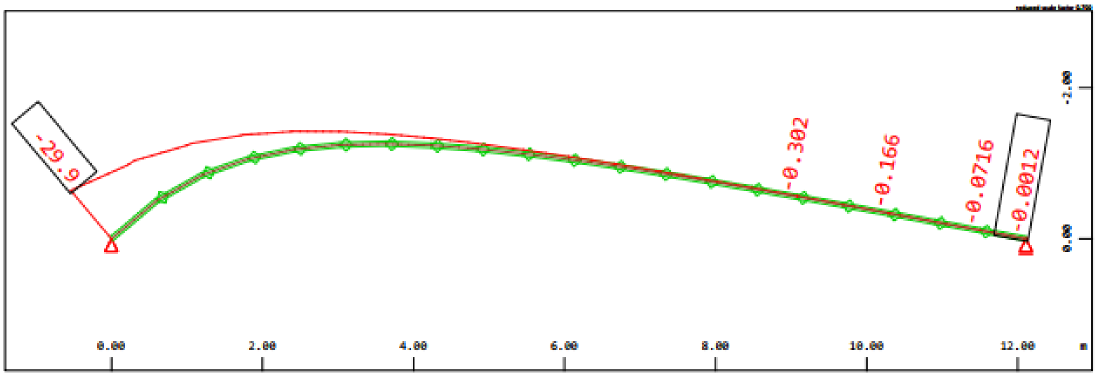
Grp primary group number
Number element number

Nodal Displacements Loadcase 101 NONLINEAR

Node No	u-X [mm]	u-Y [mm]	u-Z [mm]	phi-X [mrad]	phi-Y [mrad]	phi-Z [mrad]
101	0.000	0.000	0.000	0.000	8.730	0.000
102	0.194	0.000	-5.079	0.000	8.660	0.000
103	0.400	0.000	-8.469	0.000	5.247	0.000
104	0.612	0.000	-10.594	0.000	3.620	0.000
105	0.827	0.000	-11.853	0.000	1.858	0.000
106	1.043	0.000	-12.455	0.000	1.020	0.000
107	1.259	0.000	-12.599	0.000	0.086	0.000
108	1.474	0.000	-12.392	0.000	-0.359	0.000
109	1.690	0.000	-11.940	0.000	-0.861	0.000
110	1.906	0.000	-11.298	0.000	-1.101	0.000
111	2.121	0.000	-10.524	0.000	-1.372	0.000
112	2.336	0.000	-9.647	0.000	-1.502	0.000
113	2.552	0.000	-8.699	0.000	-1.649	0.000
114	2.767	0.000	-7.695	0.000	-1.719	0.000
115	2.982	0.000	-6.653	0.000	-1.798	0.000
116	3.197	0.000	-5.580	0.000	-1.836	0.000
117	3.412	0.000	-4.486	0.000	-1.879	0.000
118	3.627	0.000	-3.377	0.000	-1.899	0.000
119	3.841	0.000	-2.257	0.000	-1.920	0.000
120	4.056	0.000	-1.130	0.000	-1.929	0.000
121	4.271	0.000	0.000	0.000	-1.935	0.000



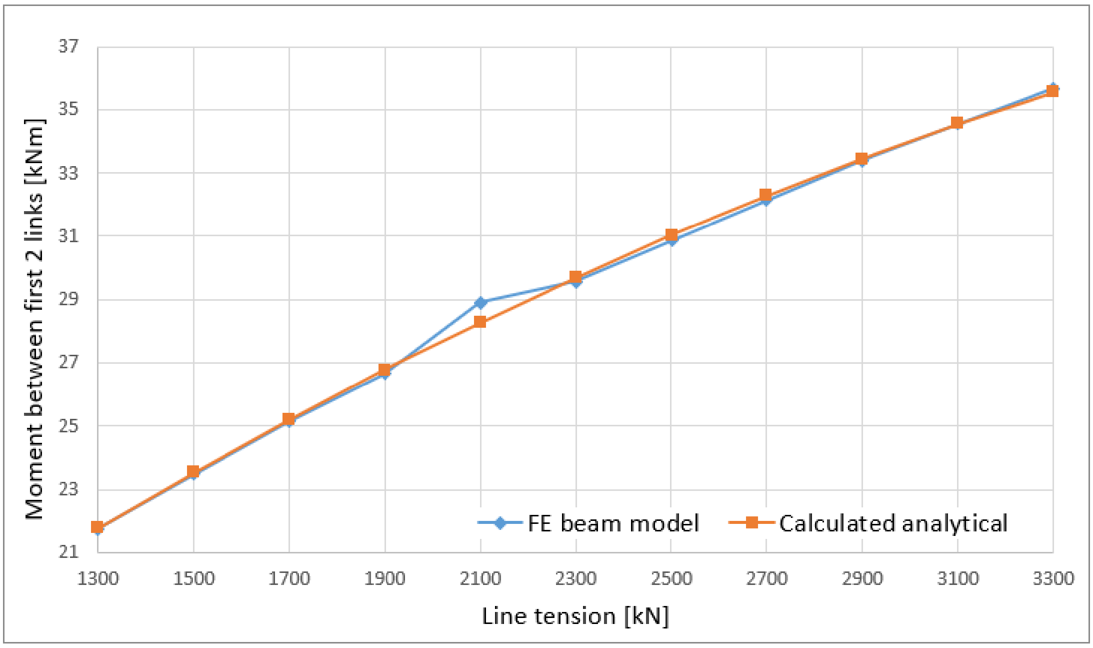
Deformed Structure from LC 101 NONLINEAR Enlarged by 100.0 M 1 : 50



Deformed Structure from LC 101 NONLINEAR Enlarged by 100.0 M 1 : 56
Beam Elements , Bending moment My, nonlinear Loadcase 101 NONLINEAR , 1 cm 3D = 20.0 kNm

2 CURVE FITTING

The figure and formula below show the results from curve fitting for D=146mm. The beam model as described in section 1 has been run for tensions between 1300kN and 3300kN. Interlink moment between the first two links has been recorded and is plotted with the blue line in the figure below. By means of the recorded values a curve function Mi has been established. The curve is plotted in orange in the figure below.



$$M_i = f_\alpha * (\quad 8.43 \ + \ 1.16E\text{-}02 * F_t \ + \ -1.03E\text{-}06 * F_t^2)$$

$f_\alpha = 0.5deg/\alpha_{timeseries}$

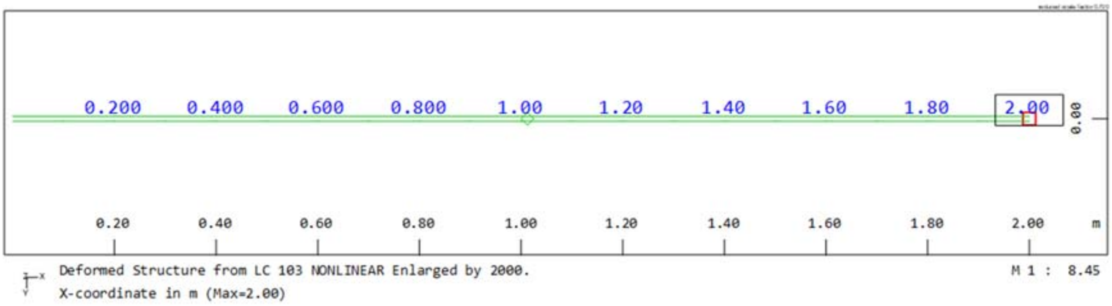
3 CONTROLL OF ANALYSIS MODELL

3.1 Case 1 – Cantilever with Stiff hinge

Cantilever beam with high spring stiffness which means stiff connection between links.
Applied loads are moment, point load and rotation.
Both links have same Crossection properties.

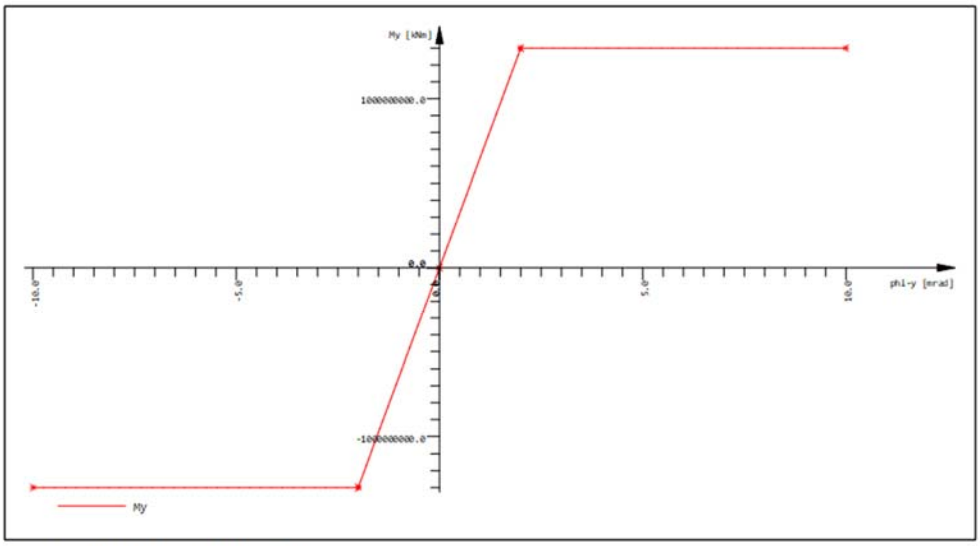
3.1.1 Input geometry and cross section

Two chain links modelled with a total length of 2m (1m per link). Hinge applied between both links (at 1m). Force displacement law My defined for this hinge, see figure. Hinge for case 1 is modelled with high stiffness such that the two links perform as a stiff beam together. Fixed support applied at end of link 2. The system performs similar to a cantilever beam.



Force-displacement law My

Number		Sur[kNm/rad]	u[mrad]	My[kNm]	S[kNm/rad]
111	My	6.500E+11	-10.000	-1300000000.	0.00
			-2.000	-1300000000.	6.500E+11
			0.000	0.00	6.500E+11
			2.000	1300000000.	0.00
			10.000	1300000000.	0.00



Force-displacement law My

Crossection properties such as Iy and Iz for the links are calculated separately and given as in put to calculation.

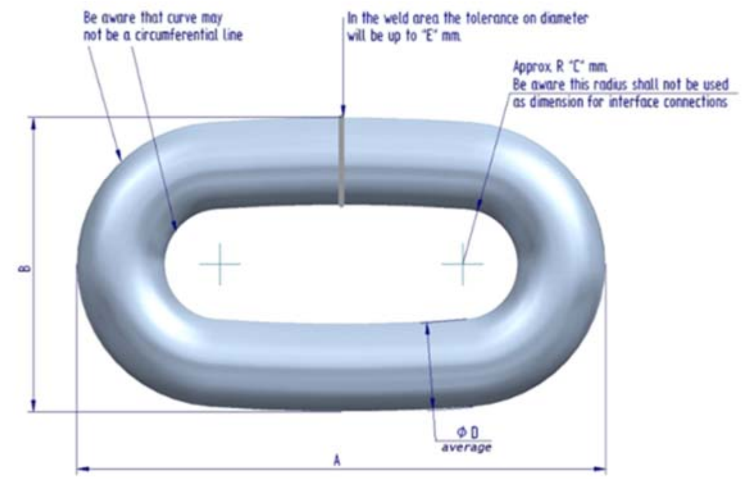
CALCULATION LINK PROPERTIES

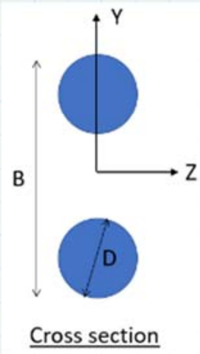
1. Input

Maximum rotation Rz from global analyses:

Maximum Tension Ft incl. pretension and tension from pontoon displacement:

> COMMON LINK FOR 111 mm. STUDLESS CHAIN
> Material Quality: GL-R3
> Project:





DIMENSIONS IN mm. (Approx.)

A	B	C	D	E
666	372	69	111	122

Chain diameter $D := 111\ mm$

Link length $A := 666\ mm$

Link width $B := 372\ mm$

2. Calculation properties

Radius $R := \frac{D}{2} = 55.5\ mm$

Cross section area $A := \pi \cdot R^2 = (9.67689 \cdot 10^{-3})\ m^2$

Momenet of Inertia $I_{yy} := 2 \cdot \left[\frac{1}{4} \cdot \pi \cdot R^4\right] = \left[1.49036 \cdot 10^{-5}\right]\ m^4$

$$I_{zz} := 2 \cdot \left[\frac{1}{4} \cdot \pi \cdot R^4 + \left(\frac{B}{2} - \frac{D}{2}\right)^2 \cdot A\right] = \left[3.44503 \cdot 10^{-4}\right]\ m^4$$

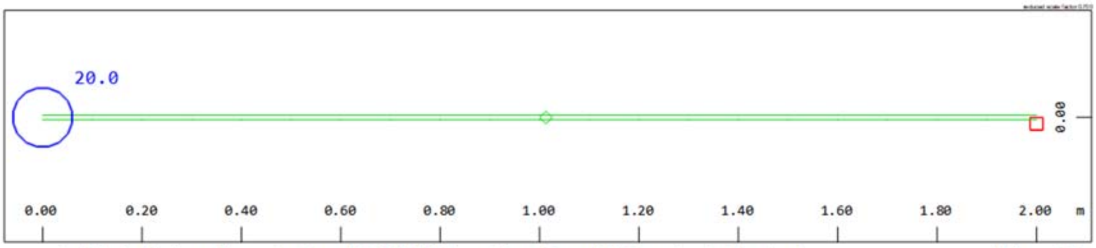
Cross-sections static properties

SNo	Mat MRf	A[m2] It[m4]	Ay[m2] Az[m2] Ayz[m2]	Iy[m4] Iz[m4] Iyz[m4]	yc[mm] zc[mm]	ysc[mm] zsc[mm]	E[N/mm2] G[N/mm2]	g[kg/m]	I-1[m4] I-2[m4] α[°]
1	1	9.6769E-03		1.490E-05	0.0	0.0	210000	24.2	3.445E-04
		6.180E-07		3.445E-04	0.0	0.0	79300		1.490E-05
	= Link 1								
2	1	9.6769E-03		3.445E-04	0.0	0.0	210000	24.2	
		6.180E-07		1.490E-05	0.0	0.0	79300		
	= Link 2								

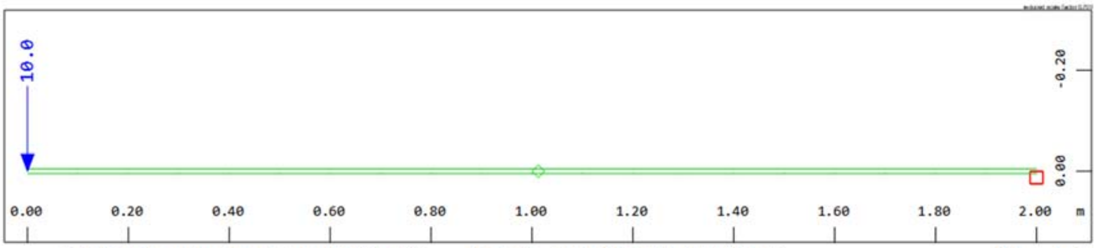
SNo	section number	yc[mm],zc[mm]	ordinate of elastic centroid
Mat	material number	ysc[mm],zsc[mm]	ordinate of shear centre
A[m2]	sectional area	E[N/mm2]	Young's modulus
Ay[m2],Az[m2],Ayz[m2]	transverse shear deformation area	g[kg/m]	weight per length
Iy[m4],Iz[m4],Iyz[m4]	bending moment of inertia		
I-1[m4],I-2[m4],α[°]	principal moments of inertia and angle of the principal axes		
MRf	reinforcement material number		
It[m4]	torsional moment of inertia		
G[N/mm2]	Shear modulus		

3.1.2 Input loads

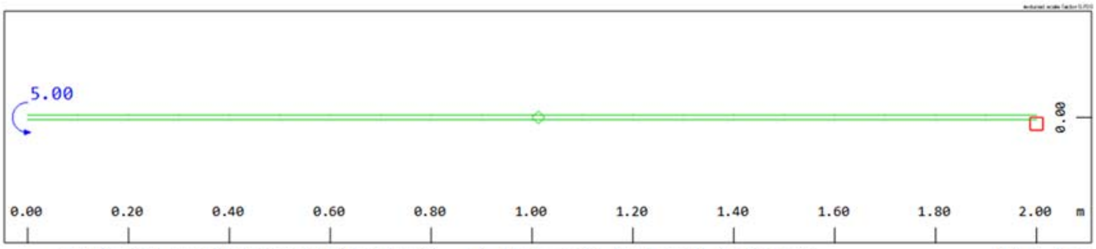
LC101 = Rotation 20 mrad
LC102 = Point load 10 kN
LC103 = Moment 5 kNm



Load (rotation), nonlinear Loadcase 101 NONLINEAR , (1 cm 3D = unit) Support rotation about global Y (Unit=10.0 mrad) (Max=20.0) M 1 : 8.51

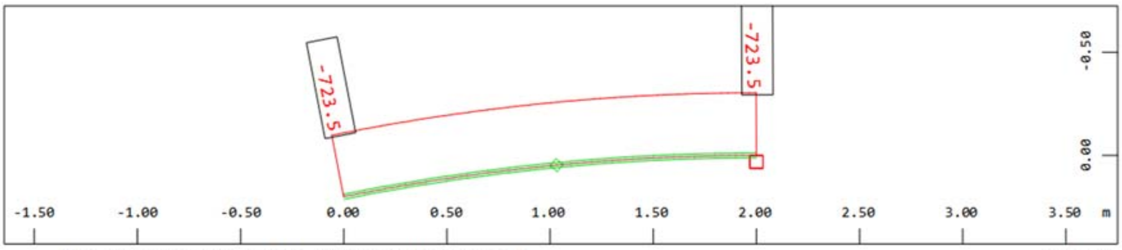


Load (force), nonlinear Loadcase 102 NONLINEAR , (1 cm 3D = unit) in global Z (Unit=5.00 kN) (Max=10.0) (total: 10.0) M 1 : 8.39

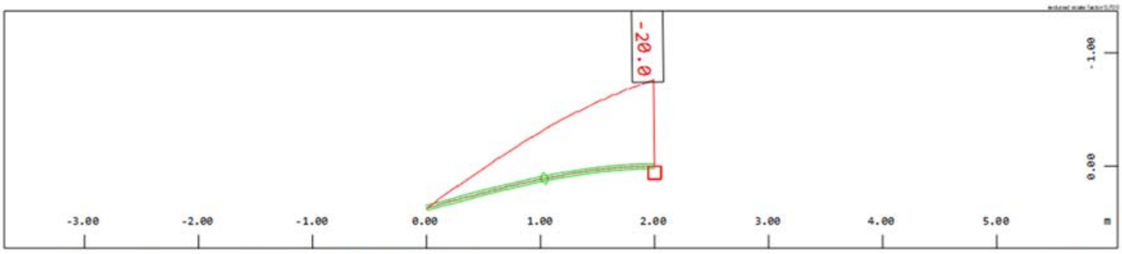


Load (moment), nonlinear Loadcase 103 NONLINEAR , (1 cm 3D = unit) about global Y (Unit=5.00 kN) (Max=5.00) (total: 5.00) M 1 : 8.39

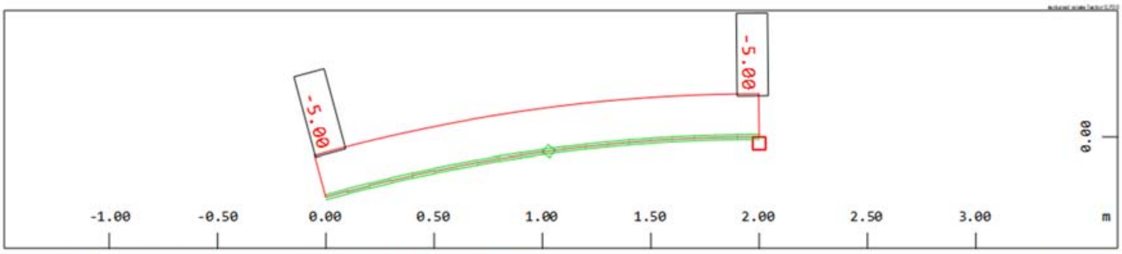
3.1.3 Results - Moments



Deformed Structure from LC 101 NONLINEAR Enlarged by 10.0 M 1 : 21
Beam Elements , Bending moment My, nonlinear Loadcase 101 NONLINEAR , 1 cm 3D = 500.0 kNm



Deformed Structure from LC 102 NONLINEAR Enlarged by 1000. M 1 : 38
Beam Elements , Bending moment My, nonlinear Loadcase 102 NONLINEAR , 1 cm 3D = 10.0 kNm



Deformed Structure from LC 103 NONLINEAR Enlarged by 2000. M 1 : 20
Beam Elements , Bending moment My, nonlinear Loadcase 103 NONLINEAR , 1 cm 3D = 5.00 kNm

Control Moment for LC101
E = 210000 N/mm^2
Iy = $3.445*10^{-4}$ m^4 (Section SNo 2 is used in this check, both links have same stiffness in)
M = α * EI/L = 20mrad/1000 * 210000000 kN/m^2 * $3.445*10^{-4}$ m^4/2 = <u>723.5 kNm</u>

→ Moment calculation is correct.

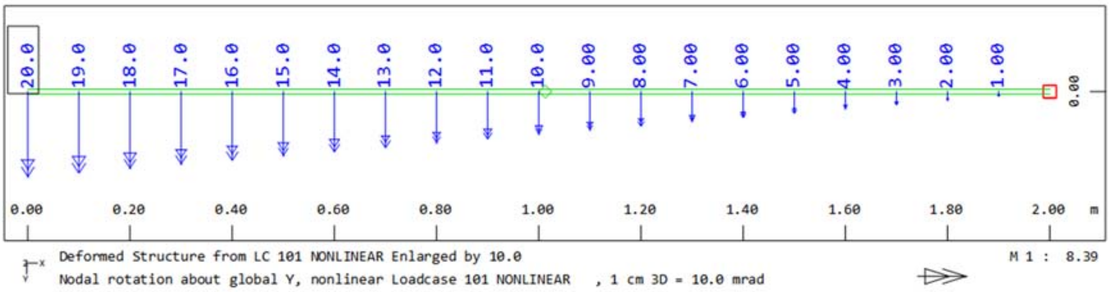
Control Moment for LC102
M = P*L = 10kN*2m = <u>20 kNm</u>

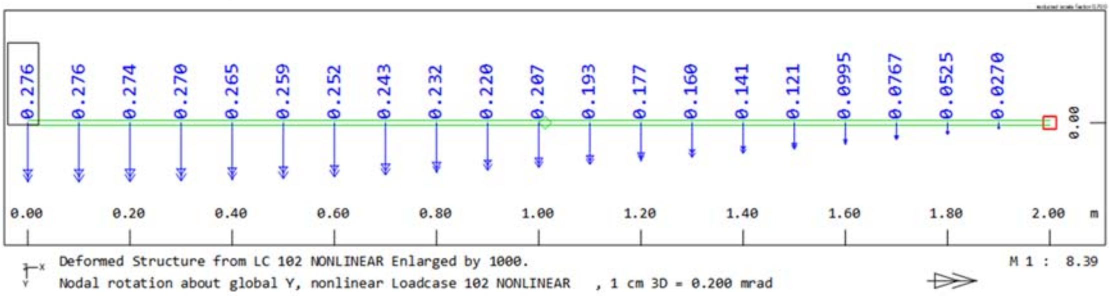
→ Moment calculation is correct.

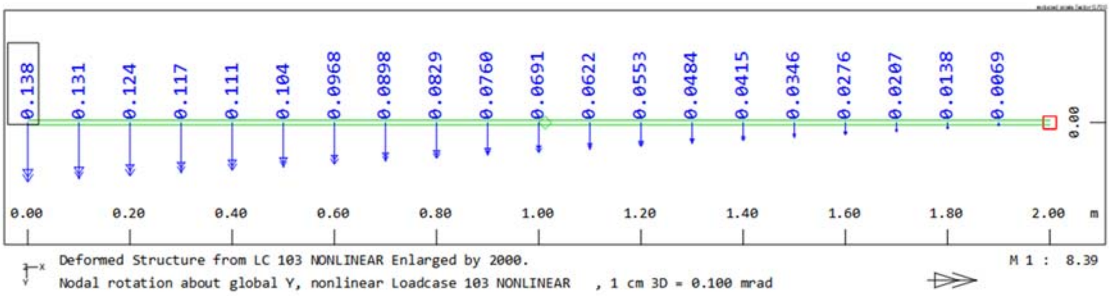
Control Moment for LC103
M = <u>5 kNm</u>

→ Moment calculation is correct.

3.1.4 Results - Rotations







Control Rotation for LC101

α_{max} = 20 mrad,

α_{min} = 0 mrad,

→ Rotation calculation is correct.

Control Rotation for LC102

E = 210000 N/mm^2

Iy = 3.445*10^{-4} m^4 (Section SNo 2 is used in this check, both links have same stiffness in)

α_{max} = P*L^2/(2*E*I)*1000 =

10 kN*(2m)^2 /(2*210000000 kN/m^2 * 3.445*10^{-4} m^4)*1000 = 0.276 mrad

→ Rotation calculation is correct.

Control Rotation for LC103

E = 210000 N/mm^2

Iy = 3.445*10^{-4} m^4 (Section SNo 2 is used in this check, both links have same stiffness in)

α_{max} = M*L/(E*I)*1000 =

5 kNm*2m /(210000000 kN/m^2 * 3.445*10^{-4} m^4)*1000 = 0.138 mrad

→ Rotation calculation is correct.

3.2 Case 2 – As Case 1 with variable Iy and Iz for links

3.2.1 Input geometry and cross section

Same input as for case 1. However, Crossection stiffness for link2 is 90deg rotated in regard with link 1 (due to chain characteristic).

Cross-sections static properties

SNo	Mat	A[m2]	Ay[m2]	Iy[m4]	yc[mm]	ysc[mm]	E[N/mm2]	g[kg/m]	I-1[m4]
	MRf	It[m4]	Az[m2]	Iz[m4]	zc[mm]	zsc[mm]	G[N/mm2]		I-2[m4]
			Ayz[m2]	Iyz[m4]					α[°]
1	1	9.6769E-03		1.490E-05	0.0	0.0	210000	24.2	3.445E-04
		6.180E-07		3.445E-04	0.0	0.0	79300		1.490E-05
	= Link 1								
2	1	9.6769E-03		3.445E-04	0.0	0.0	210000	24.2	
		6.180E-07		1.490E-05	0.0	0.0	79300		
	= Link 2								

SNo	section number	yc[mm],zc[mm]	ordinate of elastic centroid
Mat	material number	ysc[mm],zsc[mm]	ordinate of shear centre
A[m2]	sectional area	E[N/mm2]	Young's modulus
Ay[m2],Az[m2],Ayz[m2]	transverse shear deformation area	g[kg/m]	weight per length
Iy[m4],Iz[m4],Iyz[m4]	bending moment of inertia		
I-1[m4],I-2[m4],α[°]	principal moments of inertia and angle of the principal axes		
MRf	reinforcement material number		
It[m4]	torsional moment of inertia		
G[N/mm2]	Shear modulus		

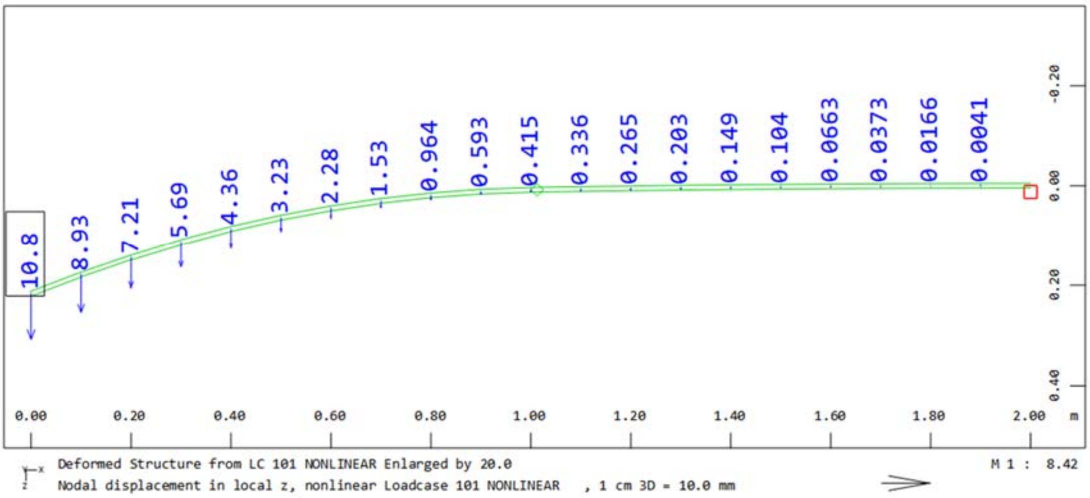
```
+PROG SOFIMSHA
$ Dat : C:\...\Interlinkstiffness_02.dat  (#002)              11.04.2019
$ Job : NX-C1D9E-007:000281                                       10:43
HEAD GEOMETRY DEFINITION
ECHO VAL NO
UNIT 5 ; SYST SPAC GDIV 1000

NODE NO  X   Y  Z  FIX
    201  0      0  0
    102  1.0    0  0
    202  2.0    0  0   PPMM

BEAM FIT 201 102 NCS 1 DIV 10 $EHIN 111
BEAM FIT 102 202 NCS 2 DIV 10 AHIN 111

END
```

3.2.2 Input loads

Input loads are the same as for case 1.

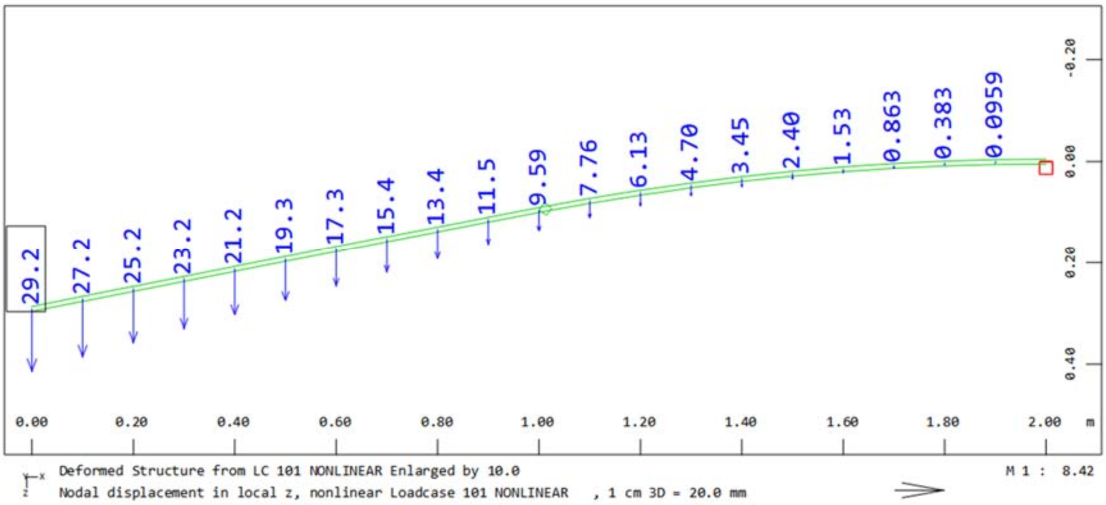
3.2.3 Results deformation

Link 2 stiffer than link 1



The deformation plot shows parabolic deformation in the weaker link (link 1) and rather linear deformation in the stronger link (link 2).

Link 1 stiffer than link 2



The deformation plot shows parabolic deformation in the weaker link (link 2) and rather linear deformation in the stronger link (link 1).

Conclusion
The results above appear reasonable.

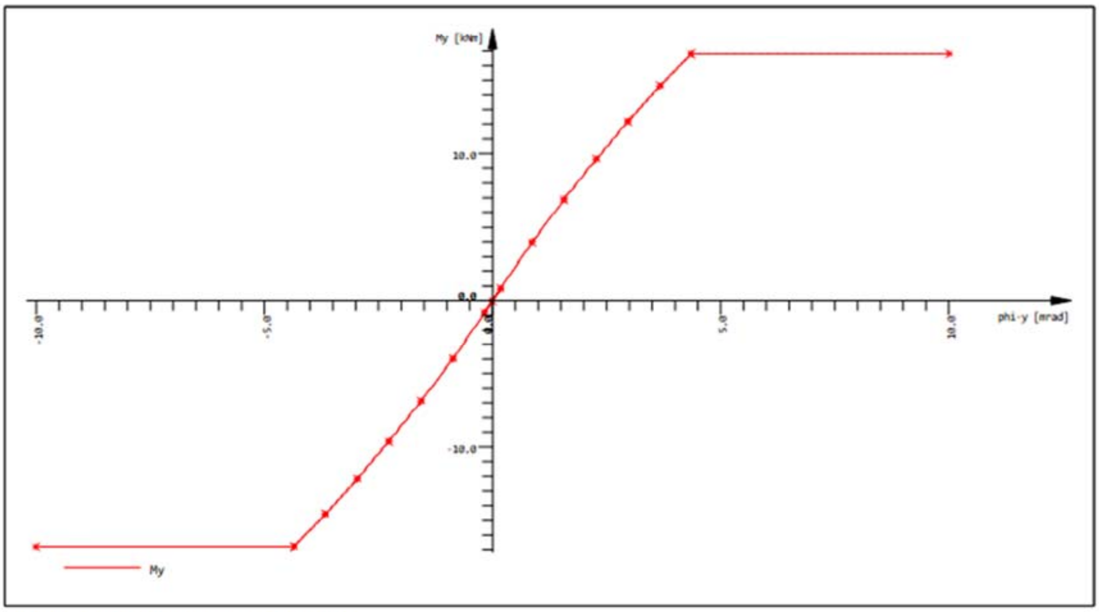
3.3 Case 3 – As Case 1 with Interlink stiffness for spring between links

3.3.1 Input geometry and cross section

Same input as for case 1. However, force displacement law at spring between links is defined according to interlink stiffness.

Force-displacement law My

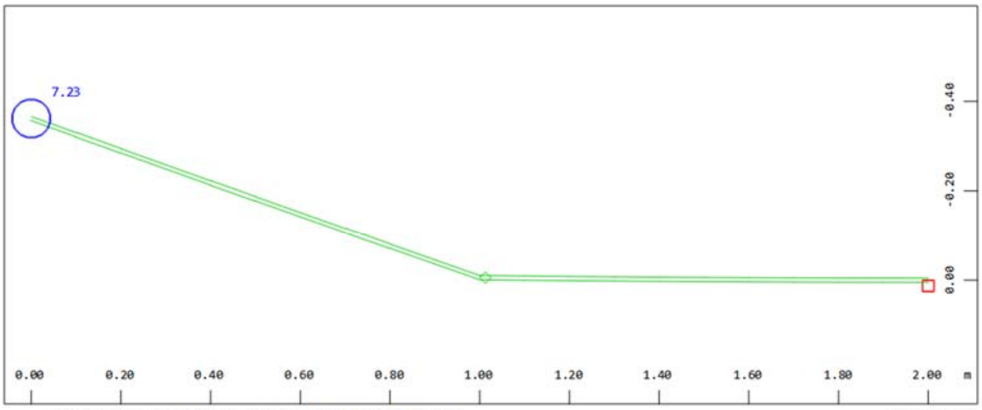
Number		Sur[kNm/rad]	u[mrad]	My[kNm]	S[kNm/rad]
111	My	4705.88	-10.000	-16.80	0.00
			-4.360	-16.80	3188.40
			-3.670	-14.60	3428.57
			-2.970	-12.20	3714.28
			-2.270	-9.60	3857.14
			-1.570	-6.90	4142.86
			-0.870	-4.00	4571.43
			-0.170	-0.80	4705.88
			0.000	0.00	4705.88
			0.170	0.80	4571.43
			0.870	4.00	4142.86
			1.570	6.90	3857.14
			2.270	9.60	3714.28
			2.970	12.20	3428.57
			3.670	14.60	3188.40
			4.360	16.80	0.00
			10.000	16.80	0.00



Force-displacement law My

3.3.2 Input loads

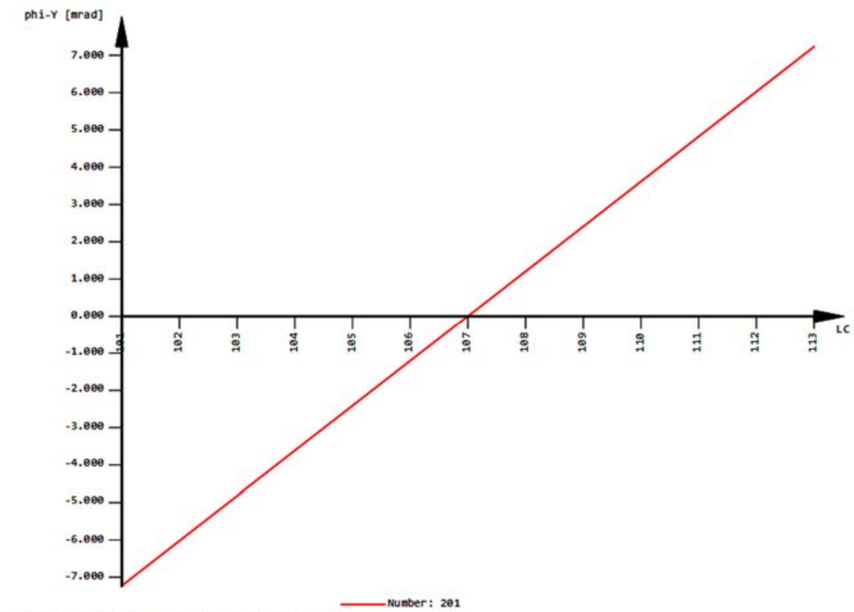
Rotation applied on free end. Rotation increased in with equal steps over 13 load cases.



Deformed Structure from LC 101 NONLINEAR Enlarged by 50.0 M 1 : 8.44
All loads, nonlinear Loadcase 101 NONLINEAR , (1 cm 3D = unit) Support rotation vector

LC	LC-title	Number	phi-Y [mrad]
101	NONLINEAR	201	-7.230
102	NONLINEAR		-6.025
103	NONLINEAR		-4.820
104	NONLINEAR		-3.615
105	NONLINEAR		-2.410
106	NONLINEAR		-1.205
107	NONLINEAR		0.000
108	NONLINEAR		1.205
109	NONLINEAR		2.410
110	NONLINEAR		3.615
111	NONLINEAR		4.820
112	NONLINEAR		6.025
113	NONLINEAR		7.230

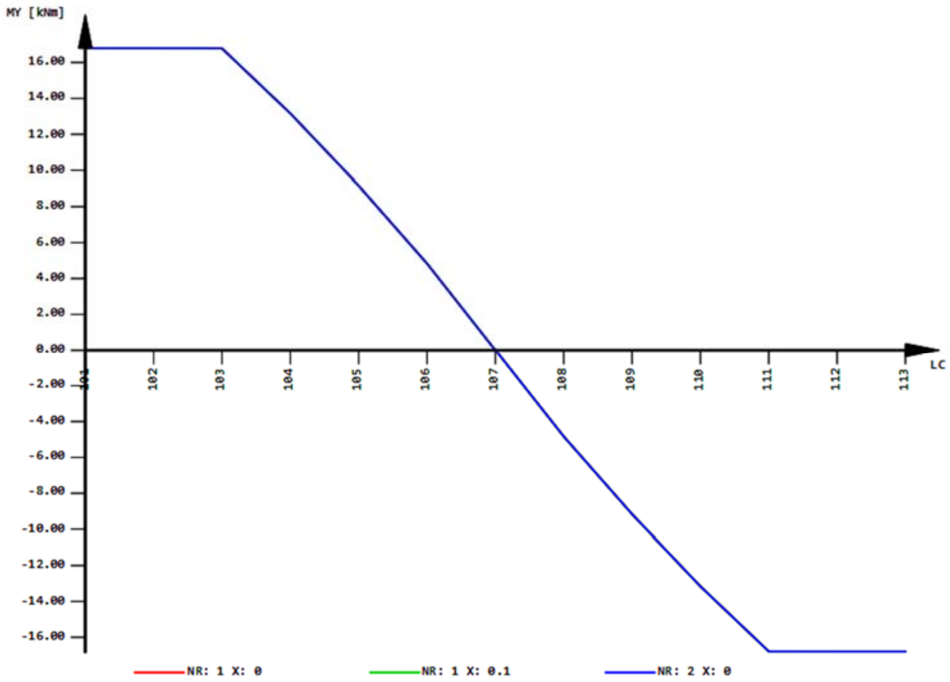
LC Load Case
LC-title Load case description
Number Node (Filter: =201)
phi-Y Nodal Displacements



LC: 101-113, Nodal rotation about global Y

3.3.3 Results Moment

Moment in beam plotted over loadcases, see figure below.



LC: 101-113, Beam Elements Bending moment My

LC: 101-113, Nodal rotation about global Y

LC	LC-title	Number	phi-Y [mrad]
101	NONLINEAR	102	-6.998
102	NONLINEAR		-5.793
103	NONLINEAR		-4.588
104	NONLINEAR		-3.433
105	NONLINEAR		-2.283
106	NONLINEAR		-1.138
107	NONLINEAR		0.000
108	NONLINEAR		1.138
109	NONLINEAR		2.283
110	NONLINEAR		3.433
111	NONLINEAR		4.588
112	NONLINEAR		5.793
113	NONLINEAR		6.998

LC Load Case
LC-title Load case description
Number Node (Filter: =102)
phi-Y Nodal Displacements

The moment curve shows maximum moment of 16.8 kNm. This is correct with respect to the defined displacement law. Moment is constant 16.8 kNm for load cases 101-103 and 111-113. For these load cases the hinge rotation is larger than 4.36mrad (see table above). With respect to the defined displacement law the moment plot is reasonable.

3.4 Conclusion

Modelling of geometry, Crossection properties and hinge works as required. Basic model verified.