STRUCTURAL ANALYSIS

PROJECT

Beam

CLIENT

Course code

CREATED BY

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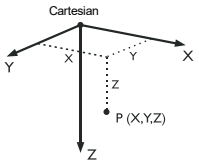
MODEL - GENERAL DATA

General	Model name	:	Beam	
	Project name	:	Assignment Week 5	
	Type of model	:	3D	
	Positive direction of global axis Z	:	Downward	
	Classification of load cases and combinations	:	According to Standard: EN 1990 National Annex: SFS - Finland	
Options	☐ RF-FORM-FINDING - Find initial equilibrium shapes of membrane and cable structures			
	☐ RF-CUTTING-PATTERN			
	☐ Piping analysis			
	☐ Use CQC Rule			
	☐ Enable CAD/BIM model			
	Standard Gravity			
	g	:	10.00 m/s²	

FE MESH SETTINGS

General	Target length of finite elements	l_{FE}	:	0.500 m
	Maximum distance between a node and a line to integrate it into the line	ε	:	0.001 m
	Maximum number of mesh nodes (in thousands)		:	500
Members	Number of divisions of members with cable, elastic foundation, taper, or plastic characteristic		:	10
	☒ Activate member divisions for large deformation or post-critical analysis			
	☒ Use division for members with node lying on them			
Surfaces	Maximum ratio of FE rectangle diagonals	Δ_D	:	1.800
	Maximum out-of-plane inclination of two finite elements	α	:	0.50 °
	Shape direction of finite elements		:	Triangles and quadrangles ☒ Same squares where possible



1.1 NODES

Node No.	Node Type	Reference Node	Coordinate System	Node Coordinates X [m]	Y [m]	Z [m]	Comment
1	Standard	-	Cartesian	0.000	0.000	0.000	
2	Standard	-	Cartesian	4.000	0.000	0.000	
3	Standard	-	Cartesian	1.000	0.000	0.000	
4	Standard	-	Cartesian	2.000	0.000	0.000	
5	Standard	-	Cartesian	3.000	0.000	0.000	

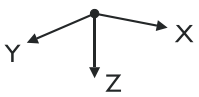
1.2 LINES

Line No.	Line Type	Nodes No.	Line Length L [m]		Comment
1	Polyline	3,1	1.000	X	
2	Polyline	4,3	1.000	X	
3	Polyline	5,4	1.000	X	
4	Polyline	2,5	1.000	X	

1.3 MATERIALS

Matl. No.	Modulus E [MN/m²]	Modulus G [MN/m²]	Poisson's Ratio ν [-]	Spec. Weight γ [kN/m³]	Coeff. of Th. Exp. α [1/K]	Partial Factor γ_M [-]	Material Model
1	Steel S 235 | SFS EN 1993-1-1:2005						
	210000.000	80769.200	0.300	78.50	1.20E-05	1.00	Isotropic Linear Elastic
2	Steel A992 | ANSI/AISC 360-16:2016						
	199948.000	77221.300	0.295	78.49	1.20E-05	1.00	Isotropic Linear Elastic
3	E = 1000 MN/m^2						
	1000.000	500.000	0.000	10.00	0.00E+00	1.00	Isotropic Linear Elastic

1.7 NODAL SUPPORTS



Support No.	Nodes No.	Axis System	Column in Z	Support Conditions $u_{X'}$	$u_{Y'}$	$u_{Z'}$	$\varphi_{X'}$	$\varphi_{Y'}$	$\varphi_{Z'}$
1	1	User Defined X',Y',Z'	☐	☒	☒	☒	☒	☐	☒
2	2	User Defined X',Y',Z'	☐	☐	☒	☒	☒	☐	☒

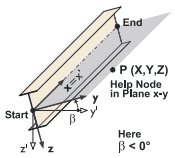
1.7.10 NODAL SUPPORTS - USER-DEFINED AXIS SYSTEM

Support No.	Direction Type	Sequence	Rotation [°] about X	about Y	about Z	Coordinate System	1st axis	Node 1 No.	Node 2 No.	2nd axis	Referen Node	Member/Line No.
1	Rotated	ZYX	-90.00	0.00	0.00							
2	Rotated	ZYX	-90.00	0.00	0.00							

1.13 CROSS-SECTIONS

Section No.	Matl. No.	J [cm⁴] / A [cm²]	I_y [cm⁴] / A_y [cm²]	I_z [cm⁴] / A_z [cm²]	Principal Axes α [°]	Rotation α' [°]	Overall Dimensions [m] Width b	Height h
1	Rectangle 0.3/0.1							
	3	7902.14 300.00	2500.00 250.00	22500.00 250.00	0.00	0.00	0.300	0.100

1.17 MEMBERS

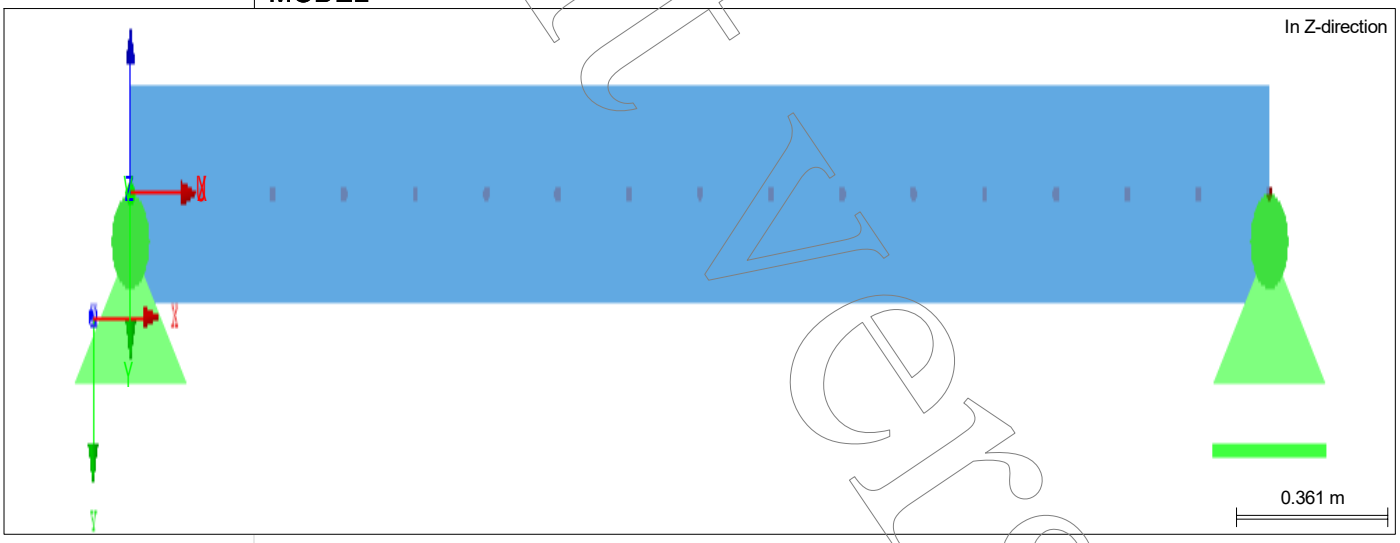


Mbr. No.	Line No.	Member	Rotation Type	β[¡¿½]	Cross-Section Start	End	Hinge No. Start	End	Ecc. No.	Div. No.	Length L [m]	
1	1	Beam	Angle	0.00	1	1	-	-	-	-	1.000	X
2	2	Beam	Angle	0.00	1	1	-	-	-	-	1.000	X
3	3	Beam	Angle	0.00	1	1	-	-	-	-	1.000	X
4	4	Beam	Angle	0.00	1	1	-	-	-	-	1.000	X

1.23 FE MESH REFINEMENTS

Refinem. No.	FE Mesh Refinement applied to	Nodes No.	Number Divisions	Sphere Radius [m]	Target FE Length [m] Inner	Outer	Comment
1	Lines via division	1-4	4				

MODEL



2.1 LOAD CASES

Load Case	Load Case Description	EN 1990 | SFS Action Category	Self-Weight - Factor in Direction Active	X	Y	Z
LC1	Self-weight	Permanent	☒	0.000	1.000	0.000
LC2	Point Load	Permanent/Imposed	☐			
LC3	Point Moment	Permanent/Imposed	☐			

2.1.1 LOAD CASES - CALCULATION PARAMETERS

Load Case	Load Case Description	Calculation Parameters		
LC1	Self-weight	Method of analysis	: ◉	Geometrically linear analysis
		Method for solving system of nonlinear algebraic equations	: ◉	Newton-Raphson
		Activate stiffness factors of:	: ☒	Cross-sections (factor for J, I_y, I_z, A, A_y, A_z)
			: ☒	Members (factor for GJ, EI_y, EI_z, EA, GA_y, GA_z)
LC2	Point Load	Method of analysis	: ◉	Geometrically linear analysis
		Method for solving system of nonlinear algebraic equations	: ◉	Newton-Raphson
		Activate stiffness factors of:	: ☒	Cross-sections (factor for J, I_y, I_z, A, A_y, A_z)
			: ☒	Members (factor for GJ, EI_y, EI_z, EA, GA_y, GA_z)
LC3	Point Moment	Method of analysis	: ◉	Geometrically linear analysis

2.1.1 LOAD CASES - CALCULATION PARAMETERS

Load Case	Load Case Description	Calculation Parameters		
		Method for solving system of nonlinear algebraic equations	:	Newton-Raphson
		Activate stiffness factors of:	:	Cross-sections (factor for J, I_y, I_z, A, A_y, A_z)
			:	Members (factor for GJ, EI_y, EI_z, EA, GA_y, GA_z)

2.5 LOAD COMBINATIONS

Load Combin.	DS	Load Combination Description	No.	Factor	Load Case	
CO1		Permanent Loads	1	1.00	LC1	Self-weight
			2	1.00	LC2	Point Load
			3	1.00	LC3	Point Moment

2.5.2 LOAD COMBINATIONS - CALCULATION PARAMETERS

Load Combin.	Description	Calculation Parameters		
CO1	Permanent Loads	Method of analysis	:	Second order analysis (P-Delta)
		Method for solving system of nonlinear algebraic equations	:	Picard
		Options	:	Consider favorable effects due to tension
			:	Refer internal forces to deformed system for:
				Normal forces N
				Shear forces V_y and V_z
				Moments M_y, M_z and M_T
		Activate stiffness factors of:	:	Materials (partial factor γM)
			:	Cross-sections (factor for J, I_y, I_z, A, A_y, A_z)
			:	Members (factor for GJ, EI_y, EI_z, EA, GA_y, GA_z)

3.1 NODAL LOADS - BY COMPONENTS - COORDINATE SYSTEM

LC2
Point Load

LC2: Point Load

No.	On Nodes No.	Coordinate System	Force [kN] P_X / P_U	P_Y / P_V	P_Z / P_W	Moment [kNm] M_X / M_U	M_Y / M_V	M_Z / M_W
1	3	0 | Global XYZ	0.000	1.000	0.000	0.000	0.000	0.000

3.1 NODAL LOADS - BY COMPONENTS - COORDINATE SYSTEM

LC3
Point Moment

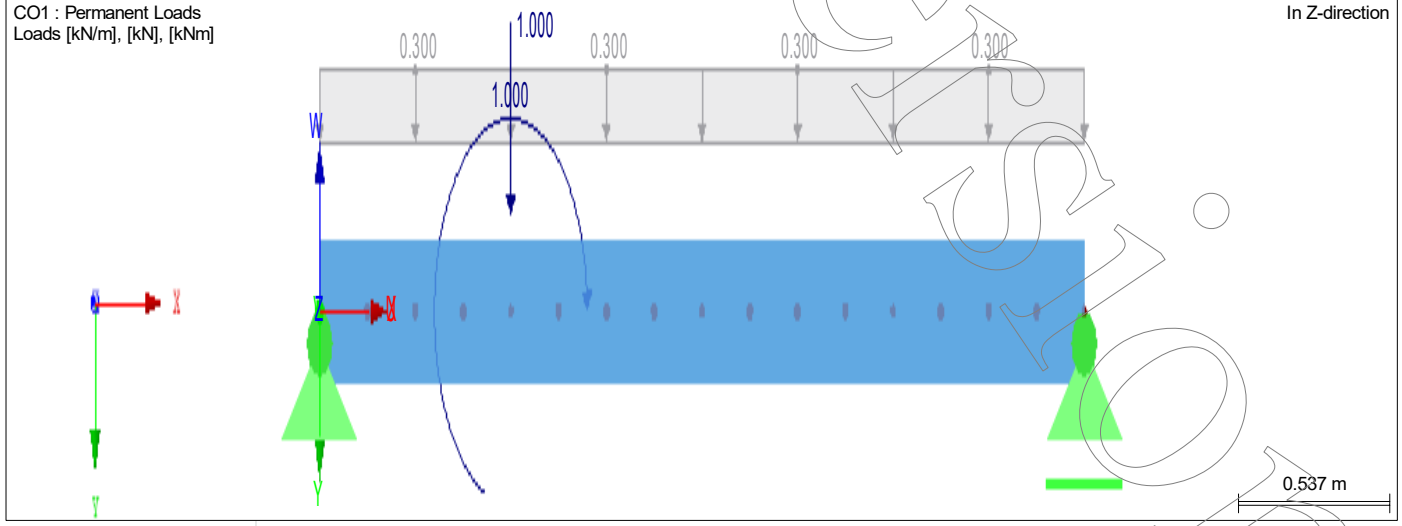
LC3: Point Moment

No.	On Nodes No.	Coordinate System	Force [kN] P_X / P_U	P_Y / P_V	P_Z / P_W	Moment [kNm] M_X / M_U	M_Y / M_V	M_Z / M_W
2	3	0 | Global XYZ	0.000	0.000	0.000	0.000	0.000	1.000

CO1: PERMANENT LOADS

CO1 : Permanent Loads
Loads [kN/m], [kN], [kNm]

In Z-direction



4.0 RESULTS - SUMMARY

Description	Value	Unit	Comment
Load Case LC1 - Self-weight			
Sum of loads in X	0.00	kN	
Sum of support reactions in X	0.00	kN	
Sum of loads in Y	1.20	kN	
Sum of support reactions in Y	1.20	kN	Deviation 0.00%
Sum of loads in Z	0.00	kN	
Sum of support reactions in Z	0.00	kN	
Resultant of reactions about X	0.000	kNm	At center of gravity of model (X:2.000, Y:0.000, Z:0.000 m)
Resultant of reactions about Y	0.000	kNm	At center of gravity of model
Resultant of reactions about Z	0.000	kNm	At center of gravity of model
Max. displacement in X	0.00	mm	
Max. displacement in Y	4.49	mm	Member No. 2, x: 0.000 m
Max. displacement in Z	0.00	mm	
Max. vector displacement	4.49	mm	Member No. 2, x: 0.000 m
Max. rotation about X	0.0	mrad	
Max. rotation about Y	0.0	mrad	
Max. rotation about Z	3.6	mrad	Member No. 1, x: 1.000 m
Maximum member strain	0.00000	-	Member No. 0, x: 0.000 m
Method of analysis	Linear		Geometrically linear analysis
Reduction of stiffness			Cross-sections, Members, Surfaces
Number of load increments	1		
Number of iterations	1		
Maximum value of element of stiffness matrix on diagonal	2.4E+08		
Minimum value of element of stiffness matrix on diagonal	3.161E+05		
Stiffness matrix determinant	1.415E+613		
Infinity Norm	4.8E+08		
Load Case LC2 - Point Load			
Sum of loads in X	0.00	kN	
Sum of support reactions in X	0.00	kN	
Sum of loads in Y	1.00	kN	
Sum of support reactions in Y	1.00	kN	Deviation 0.00%
Sum of loads in Z	0.00	kN	
Sum of support reactions in Z	0.00	kN	
Resultant of reactions about X	0.000	kNm	At center of gravity of model (X:2.000, Y:0.000, Z:0.000 m)
Resultant of reactions about Y	0.000	kNm	At center of gravity of model
Resultant of reactions about Z	-1.000	kNm	At center of gravity of model
Max. displacement in X	0.00	mm	
Max. displacement in Y	4.19	mm	Member No. 2, x: 0.250 m
Max. displacement in Z	0.00	mm	
Max. vector displacement	4.19	mm	Member No. 2, x: 0.250 m
Max. rotation about X	0.0	mrad	
Max. rotation about Y	0.0	mrad	
Max. rotation about Z	3.9	mrad	Member No. 1, x: 1.000 m
Maximum member strain	0.00000	-	Member No. 0, x: 0.000 m
Method of analysis	Linear		Geometrically linear analysis
Reduction of stiffness			Cross-sections, Members, Surfaces
Number of load increments	1		
Number of iterations	1		
Maximum value of element of stiffness matrix on diagonal	2.4E+08		
Minimum value of element of stiffness matrix on diagonal	3.161E+05		
Stiffness matrix determinant	1.415E+613		
Infinity Norm	4.8E+08		
Load Case LC3 - Point Moment			
Sum of loads in X	0.00	kN	
Sum of support reactions in X	0.00	kN	
Sum of loads in Y	0.00	kN	
Sum of support reactions in Y	0.00	kN	
Sum of loads in Z	0.00	kN	
Sum of support reactions in Z	0.00	kN	
Resultant of reactions about X	0.000	kNm	At center of gravity of model (X:2.000, Y:0.000, Z:0.000 m)
Resultant of reactions about Y	0.000	kNm	At center of gravity of model
Resultant of reactions about Z	1.000	kNm	At center of gravity of model
Max. displacement in X	0.00	mm	
Max. displacement in Y	3.34	mm	Member No. 2, x: 0.125 m
Max. displacement in Z	0.00	mm	
Max. vector displacement	3.34	mm	Member No. 2, x: 0.125 m
Max. rotation about X	0.0	mrad	
Max. rotation about Y	0.0	mrad	
Max. rotation about Z	2.6	mrad	Member No. 1, x: 0.000 m
Maximum member strain	0.00000	-	Member No. 0, x: 0.000 m
Method of analysis	Linear		Geometrically linear analysis
Reduction of stiffness			Cross-sections, Members, Surfaces
Number of load increments	1		
Number of iterations	1		
Maximum value of element of stiffness matrix on diagonal	2.4E+08		
Minimum value of element of stiffness matrix on diagonal	3.161E+05		
Stiffness matrix determinant	1.415E+613		
Infinity Norm	4.8E+08		
Load Combination CO1 - Permanent Loads			
Sum of loads in X	0.00	kN	
Sum of support reactions in X	0.00	kN	
Sum of loads in Y	2.20	kN	
Sum of support reactions in Y	2.20	kN	Deviation 0.00%
Sum of loads in Z	0.00	kN	
Sum of support reactions in Z	0.00	kN	

4.0 RESULTS - SUMMARY

	Description	Value	Unit	Comment
	Resultant of reactions about X	0.0	kNm	At center of gravity of model (X:2.0, Y:0.0, Z:0.0 m)
	Resultant of reactions about Y	0.0	kNm	At center of gravity of model
	Resultant of reactions about Z	0.0	kNm	At center of gravity of model
	Max. displacement in X	0.00	mm	
	Max. displacement in Y	11.98	mm	Member No. 2, x: 0.125 m
	Max. displacement in Z	0.00	mm	
	Max. vector displacement	11.98	mm	Member No. 2, x: 0.125 m
	Max. rotation about X	0.0	mrad	
	Max. rotation about Y	0.0	mrad	
	Max. rotation about Z	9.5	mrad	Member No. 1, x: 1.000 m
	Maximum member strain	0.00000	-	Member No. 0, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear, Timoshenko)
	Internal forces referred to deformed system for...	☒		N, V_y, V_z, M_y, M_z, M_T
	Reduction of stiffness			Materials, Cross-sections, Members, Surfaces
	Consider favorable effects of tensile forces	☒		
	Divide results by CO factor	☐		
	Number of load increments	1		
	Number of iterations	2		
	Maximum value of element of stiffness matrix on diagonal	2.4E+08		
	Minimum value of element of stiffness matrix on diagonal	3.161E+05		
	Stiffness matrix determinant	1.415E+613		
	Infinity Norm	4.8E+08		
Summary				
	Max. displacement in X	0.00		
	Max. displacement in Y	11.98	mm	CO1, Member No. 2, x: 0.125 m
	Max. displacement in Z	0.00		
	Max. vector displacement	11.98	mm	CO1, Member No. 2, x: 0.125 m
	Max. rotation about X	0.0		
	Max. rotation about Y	0.0		
	Max. rotation about Z	9.5	mrad	CO1, Member No. 1, x: 1.000 m
	Other Settings:			
	Number of 1D finite elements	16		
	Number of 2D finite elements	0		
	Number of 3D finite elements	0		
	Number of FE mesh nodes	17		
	Number of equations	102		
	Internal forces referred to deformed system for...:			
	Max. number of iterations	100		
	Number of divisions for member results	10		
	Division of cable/foundation/tapered members	10		
	Number of member divisions for searching maximum values	10		
	Subdivisions of FE mesh for graphical results	3		
	Percentage of iterations according to Picard method in combination with Newton-Raphson method	5	%	
	Options:			
	Activate shear stiffness of members (Ay, Az)	☒		
	Activate member divisions for large deformation or post-critical analysis	☒		
	Activate entered stiffness modifications	☒		
	Ignore rotational degrees of freedom	☐		
	Check of critical forces of members	☒		
	Nonsymmetric direct solver if demanded by nonlinear model	☐		
	Method for the system of equations	Direct		
	Plate bending theory	Mindlin		
	Solver version	64-bit		
	Precision and Tolerance:			
	Change default setting	☐		

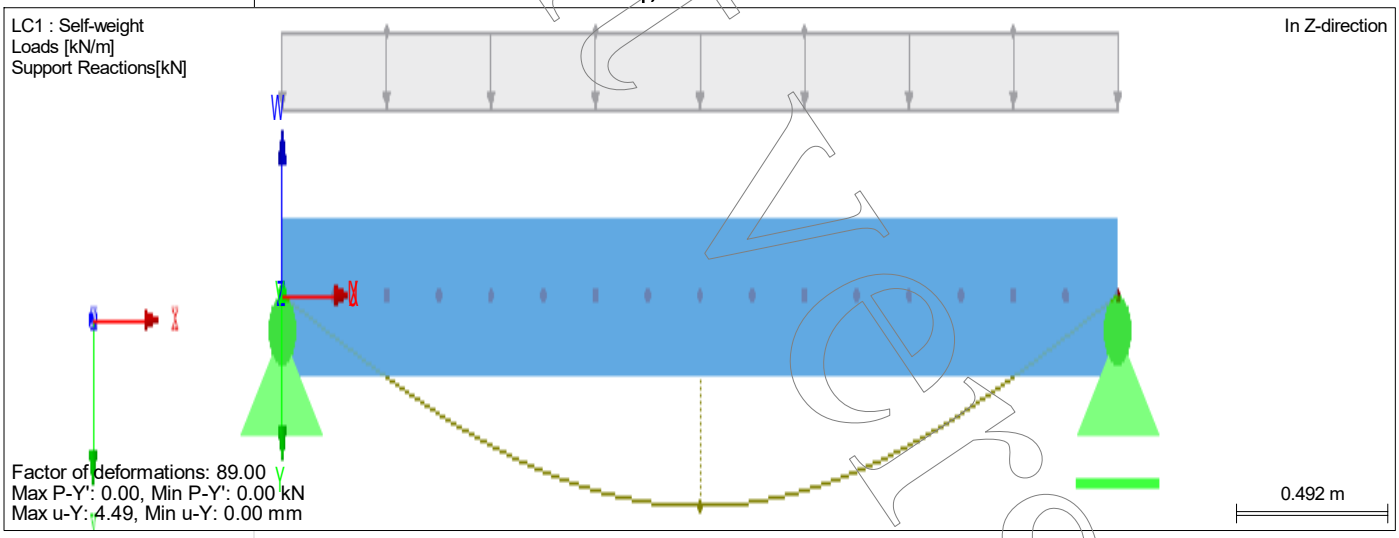
4.1 NODES - SUPPORT FORCES

Node No.	LC/CO	Support Forces [kN] P_X	P_Y	P_Z	Support Moments [kNm] M_X	M_Y	M_Z	
1*	LC1	0.00	0.00	0.60	0.00	0.00	0.00	Self-weight
	LC2	0.00	0.00	0.75	0.00	0.00	0.00	Point Load
	LC3	0.00	0.00	-0.25	0.00	0.00	0.00	Point Moment
	CO1	0.00	0.00	1.10	0.00	0.00	0.00	Permanent Loads
2*	LC1	0.00	0.00	0.60	0.00	0.00	0.00	Self-weight
	LC2	0.00	0.00	0.25	0.00	0.00	0.00	Point Load
	LC3	0.00	0.00	0.25	0.00	0.00	0.00	Point Moment
	CO1	0.00	0.00	1.10	0.00	0.00	0.00	Permanent Loads
Σ Supp.	LC1	0.00	1.20	0.00				
Σ Loads	LC1	0.00	1.20	0.00				
Σ Supp.	LC2	0.00	1.00	0.00				
Σ Loads	LC2	0.00	1.00	0.00				
Σ Supp.	LC3	0.00	0.00	0.00				
Σ Loads	LC3	0.00	0.00	0.00				
Σ Supp.	CO1	0.00	2.20	0.00				
Σ Supp.	CO1	0.00	2.20	0.00				

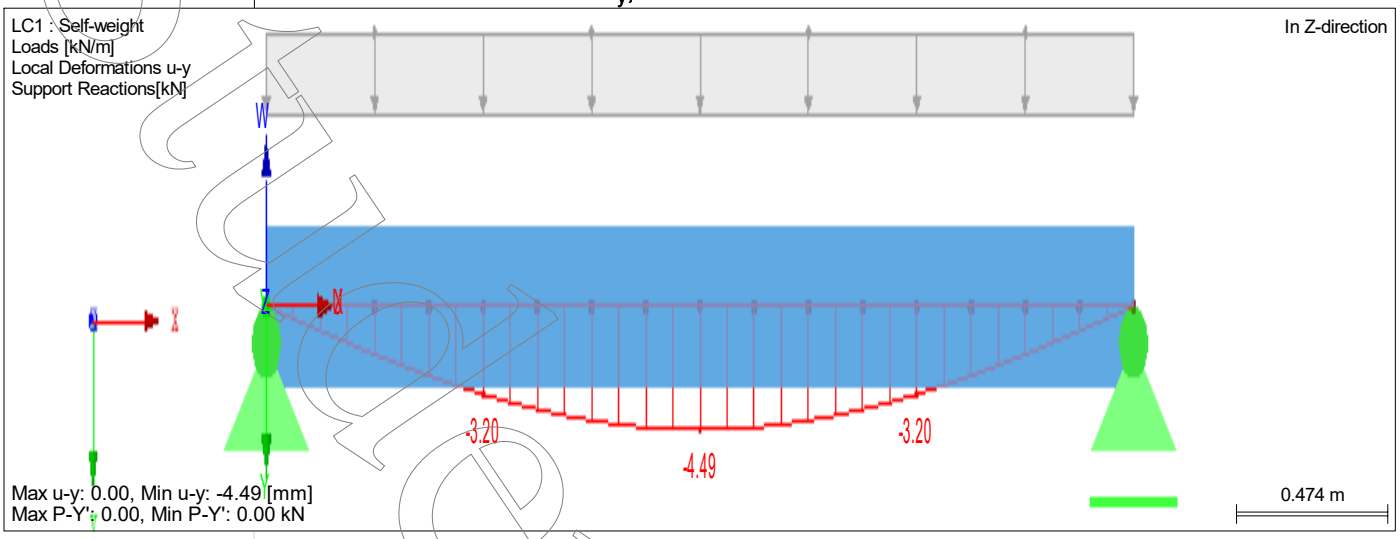
4.12 CROSS-SECTIONS - INTERNAL FORCES

Member No.	LC/CO	Node No.	Location x [m]	Forces [kN] N	V_y	V_z	Moments [kNm] M_T	M_y	M_z
	Section No. 1: Rectangle 0.3/0.1								
1	LC1	3	0.000	0.00	0.30	0.00	0.00	0.00	0.45
		1	1.000	0.00	0.60	0.00	0.00	0.00	0.00
	LC2	3	0.000	0.00	0.75	0.00	0.00	0.00	0.75
		1	1.000	0.00	0.75	0.00	0.00	0.00	0.00
	LC3	3	0.000	0.00	-0.25	0.00	0.00	0.00	-0.25
		1	1.000	0.00	-0.25	0.00	0.00	0.00	0.00
	CO1	3	0.000	0.01	0.80	0.00	0.00	0.00	0.95
		1	1.000	0.01	1.10	0.00	0.00	0.00	0.00
2	LC1	4	0.000	0.00	0.00	0.00	0.00	0.00	0.60
		3	1.000	0.00	0.30	0.00	0.00	0.00	0.45
	LC2	4	0.000	0.00	-0.25	0.00	0.00	0.00	0.50
		3	1.000	0.00	-0.25	0.00	0.00	0.00	0.75
	LC3	4	0.000	0.00	-0.25	0.00	0.00	0.00	0.50
		3	1.000	0.00	-0.25	0.00	0.00	0.00	0.75
	CO1	4	0.000	0.00	-0.50	0.00	0.00	0.00	1.60
		3	1.000	0.00	-0.20	0.00	0.00	0.00	1.95
3	LC1	5	0.000	0.00	-0.30	0.00	0.00	0.00	0.45
		4	1.000	0.00	0.00	0.00	0.00	0.00	0.60
	LC2	5	0.000	0.00	-0.25	0.00	0.00	0.00	0.25
		4	1.000	0.00	-0.25	0.00	0.00	0.00	0.50
	LC3	5	0.000	0.00	-0.25	0.00	0.00	0.00	0.25
		4	1.000	0.00	-0.25	0.00	0.00	0.00	0.50
	CO1	5	0.000	0.01	-0.80	0.00	0.00	0.00	0.95
		4	1.000	0.00	-0.50	0.00	0.00	0.00	1.60
4	LC1	2	0.000	0.00	-0.60	0.00	0.00	0.00	0.00
		5	1.000	0.00	-0.30	0.00	0.00	0.00	0.45
	LC2	2	0.000	0.00	-0.25	0.00	0.00	0.00	0.00
		5	1.000	0.00	-0.25	0.00	0.00	0.00	0.25
	LC3	2	0.000	0.00	-0.25	0.00	0.00	0.00	0.00
		5	1.000	0.00	-0.25	0.00	0.00	0.00	0.25
	CO1	2	0.000	0.01	-1.10	0.00	0.00	0.00	0.00
		5	1.000	0.01	-0.80	0.00	0.00	0.00	0.95

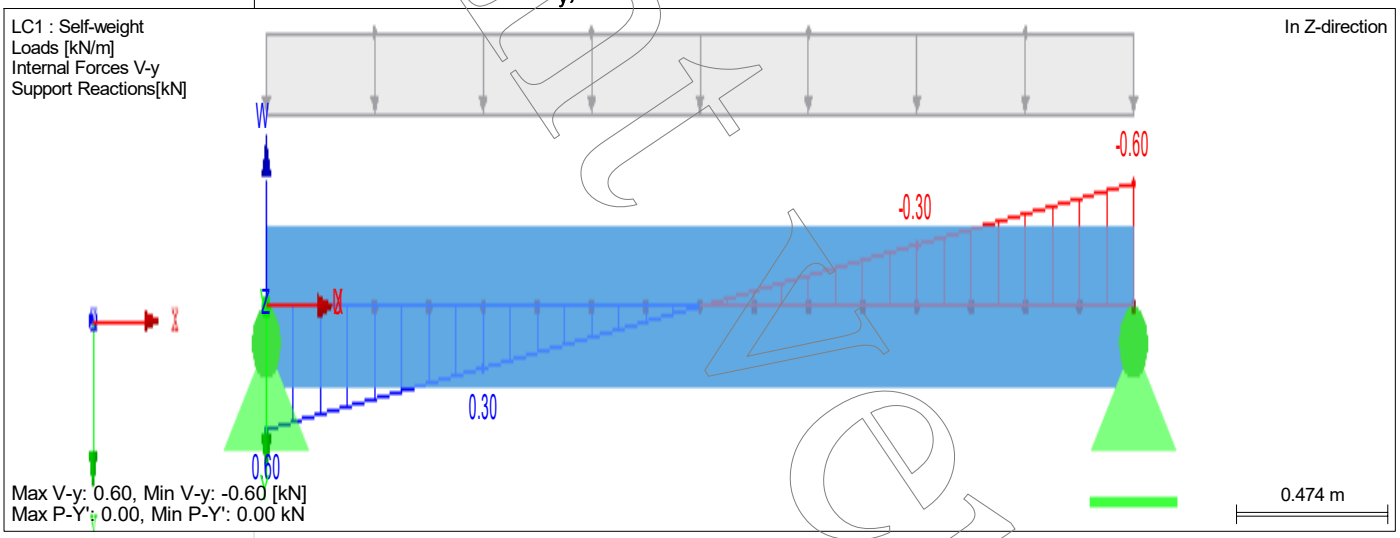
GLOBAL DEFORMATIONS u_Y, SUPPORT REACTIONS



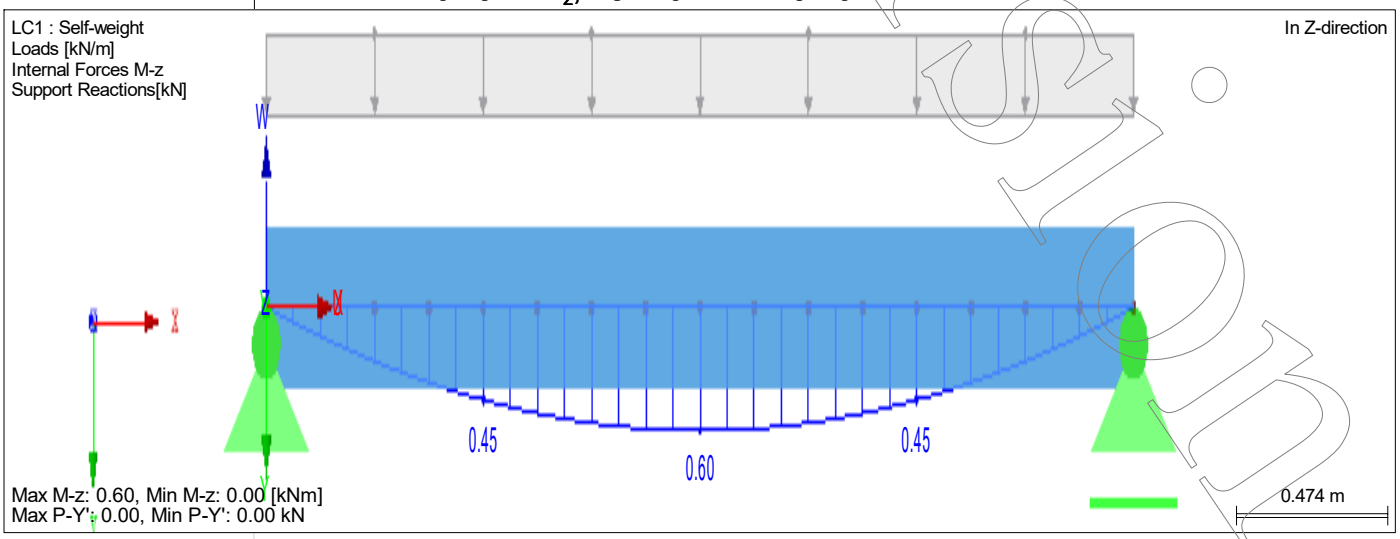
LOCAL DEFORMATIONS u_y, SUPPORT REACTIONS



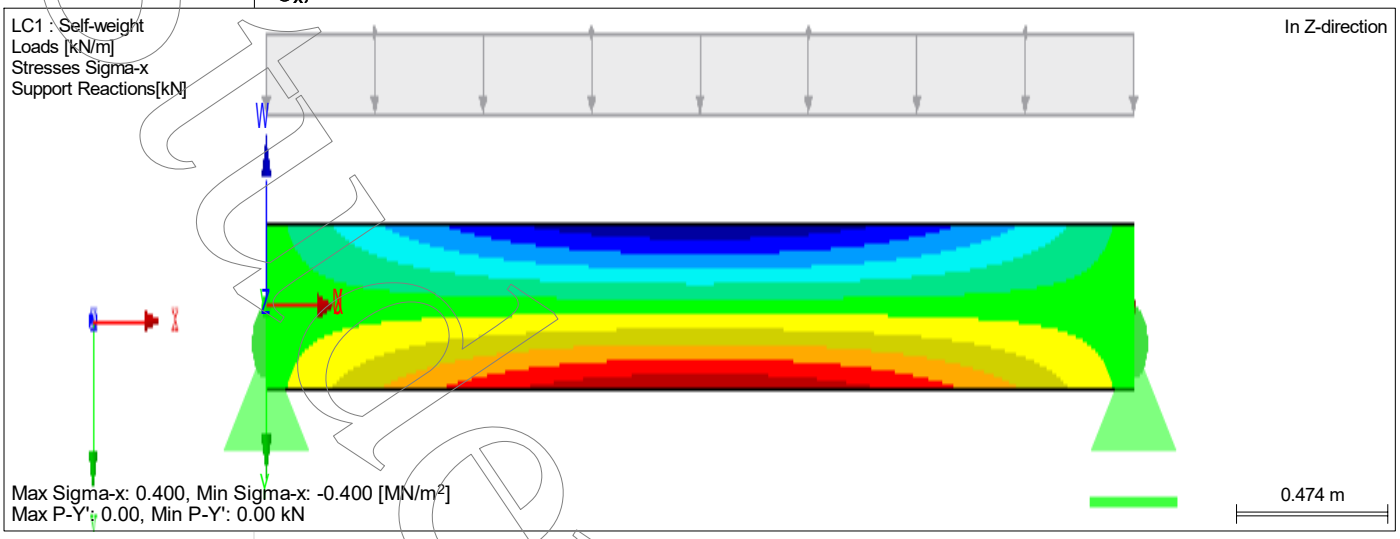
INTERNAL FORCES V_y, SUPPORT REACTIONS



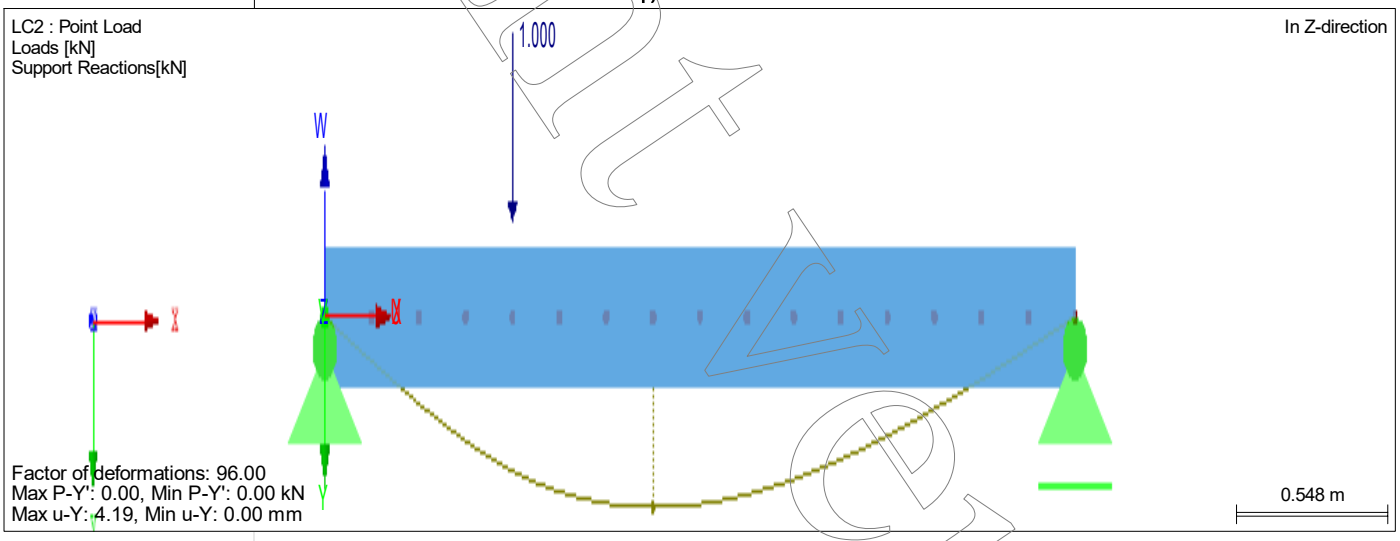
INTERNAL FORCES M_z, SUPPORT REACTIONS



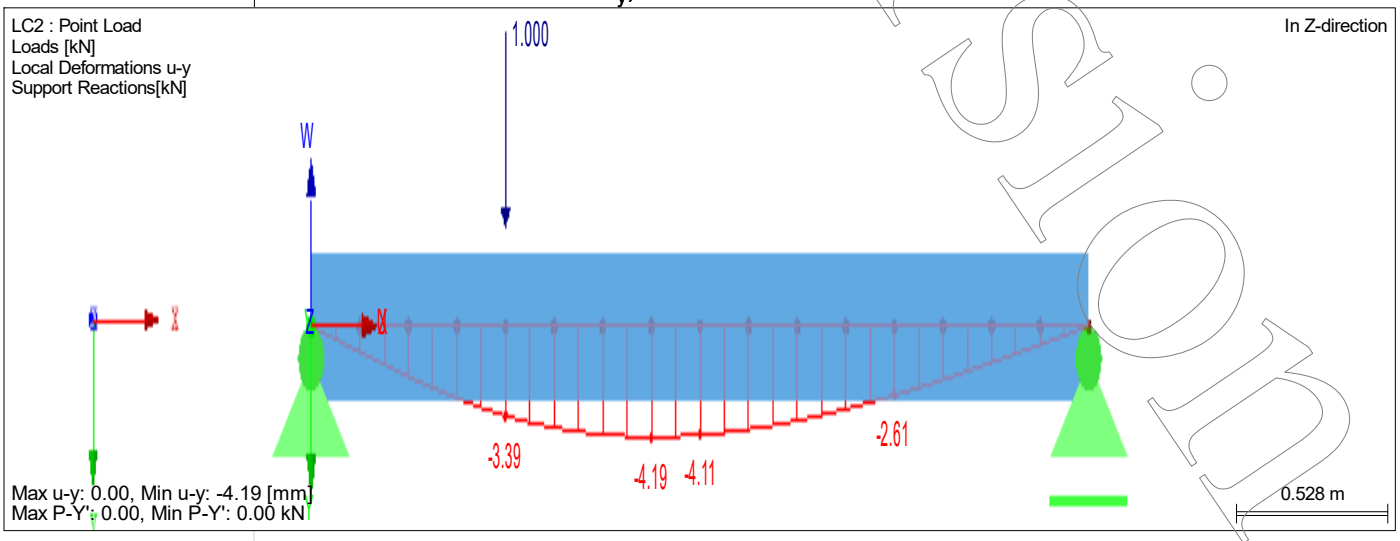
σ_x, SUPPORT REACTIONS



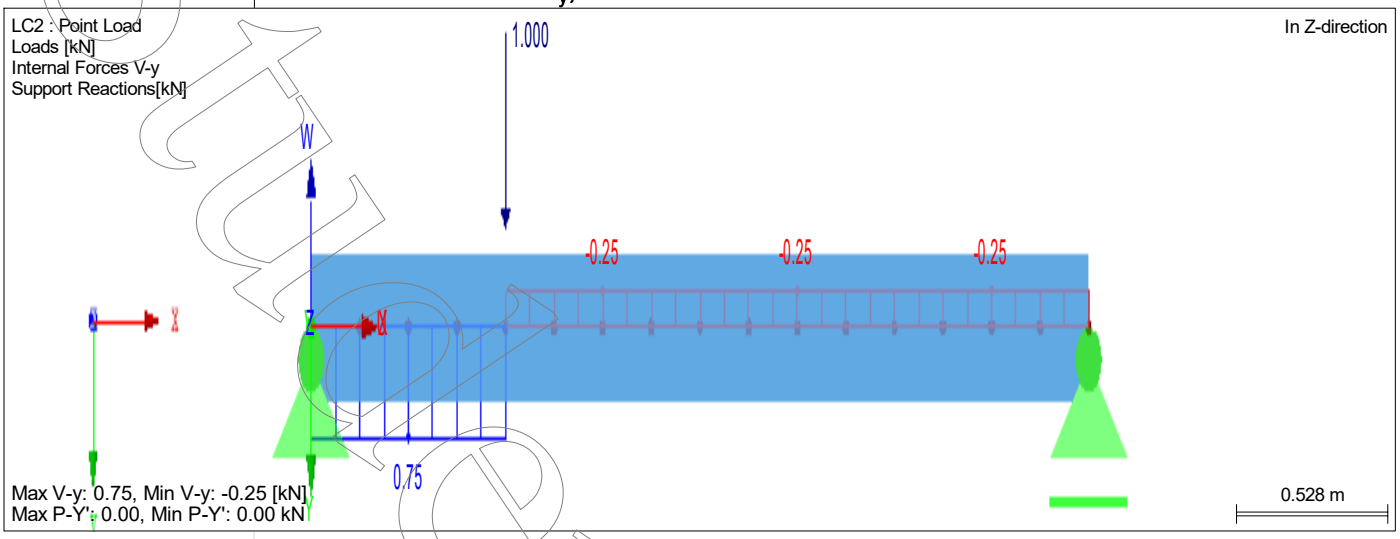
GLOBAL DEFORMATIONS u_Y, SUPPORT REACTIONS



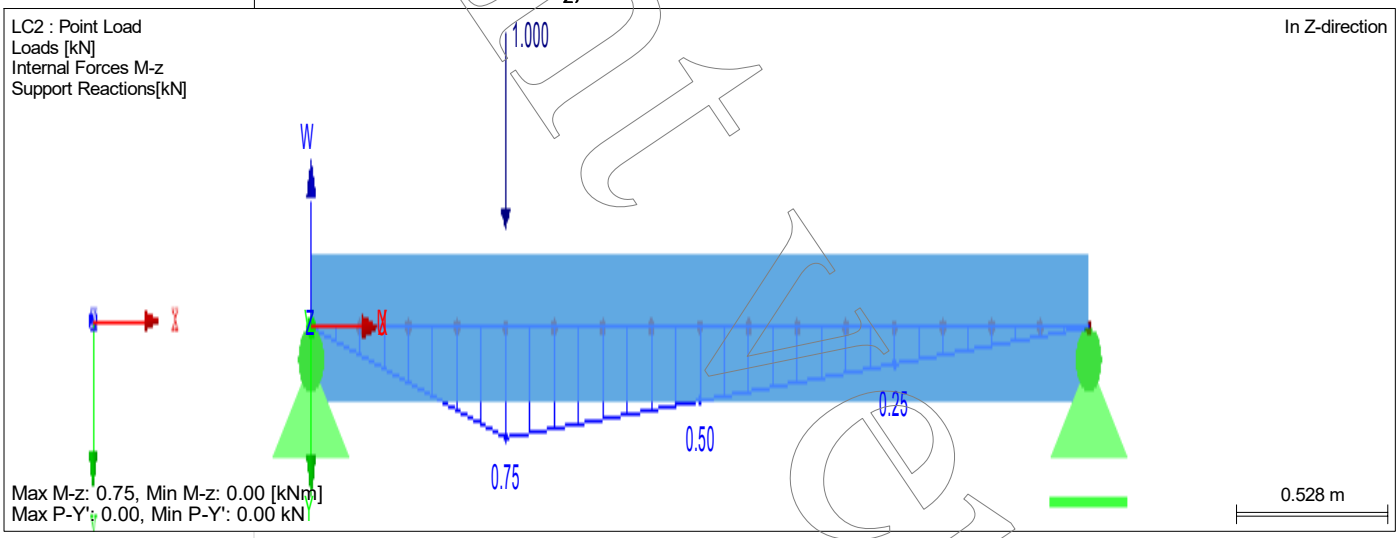
LOCAL DEFORMATIONS u_y, SUPPORT REACTIONS



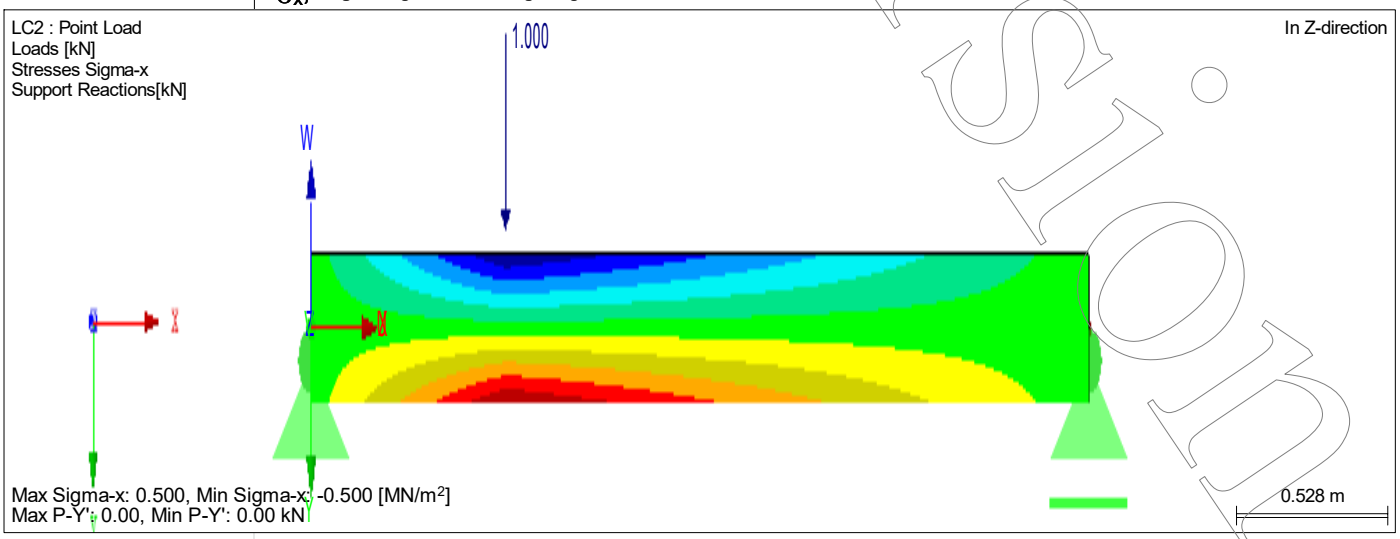
INTERNAL FORCES V_y, SUPPORT REACTIONS



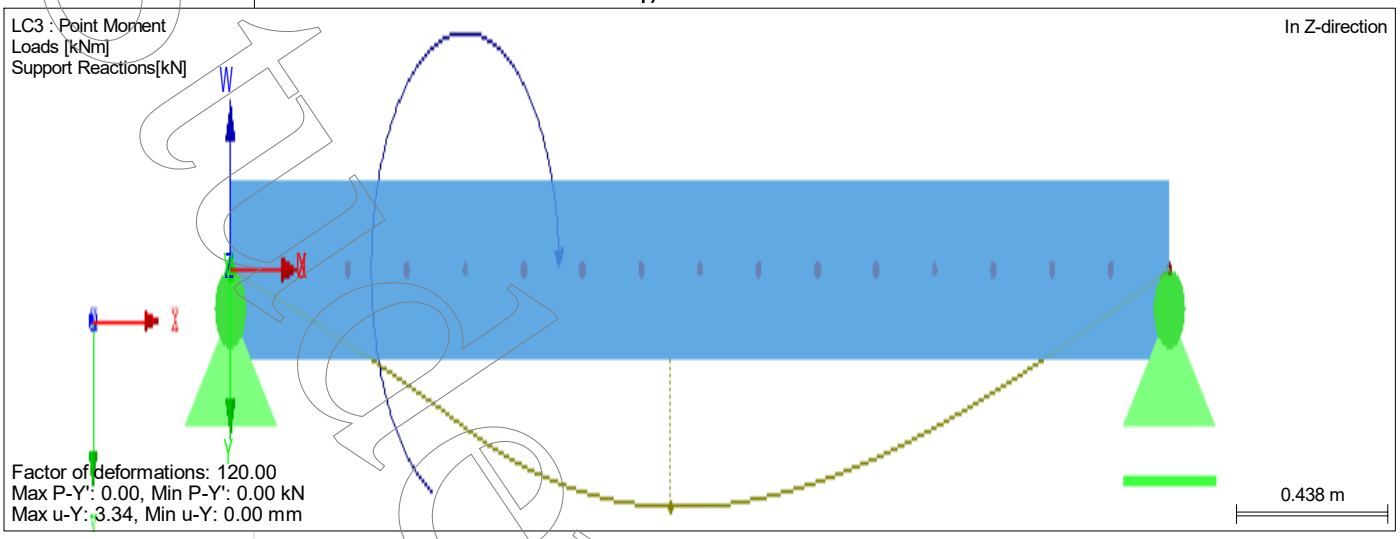
INTERNAL FORCES M_z, SUPPORT REACTIONS



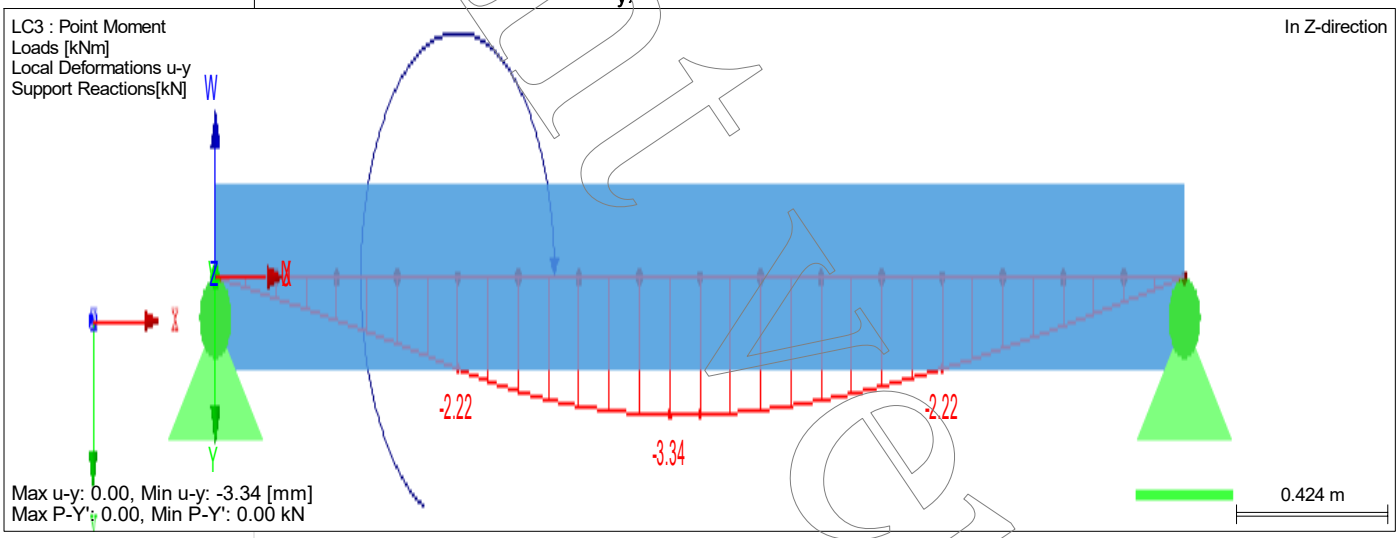
σ_x, SUPPORT REACTIONS



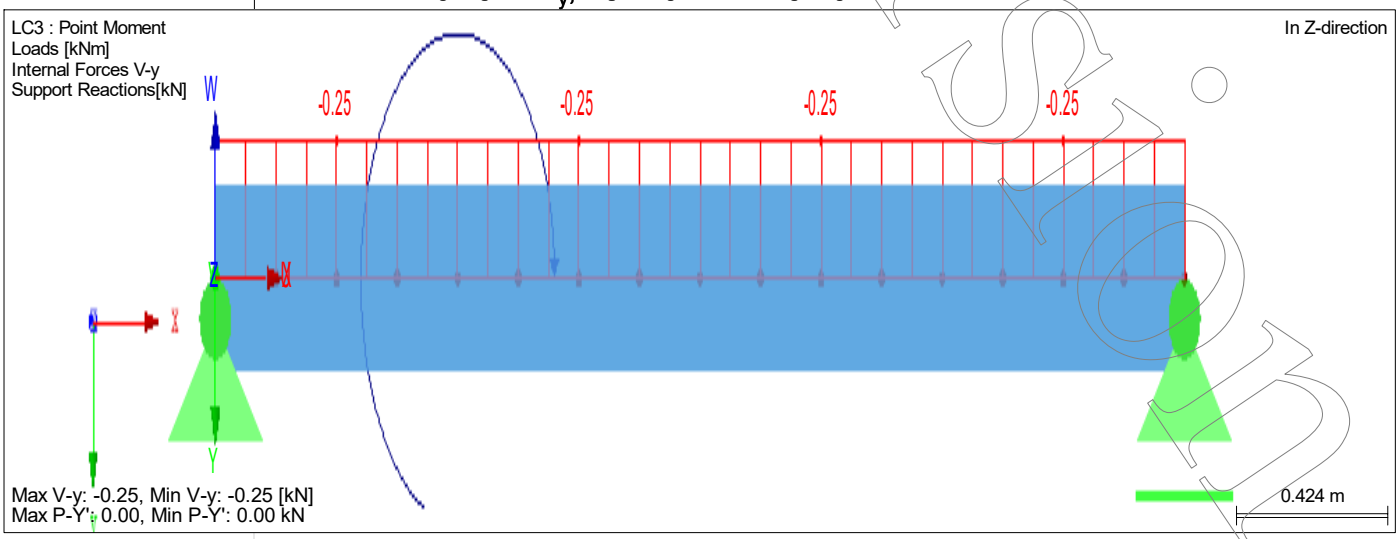
GLOBAL DEFORMATIONS u_Y, SUPPORT REACTIONS



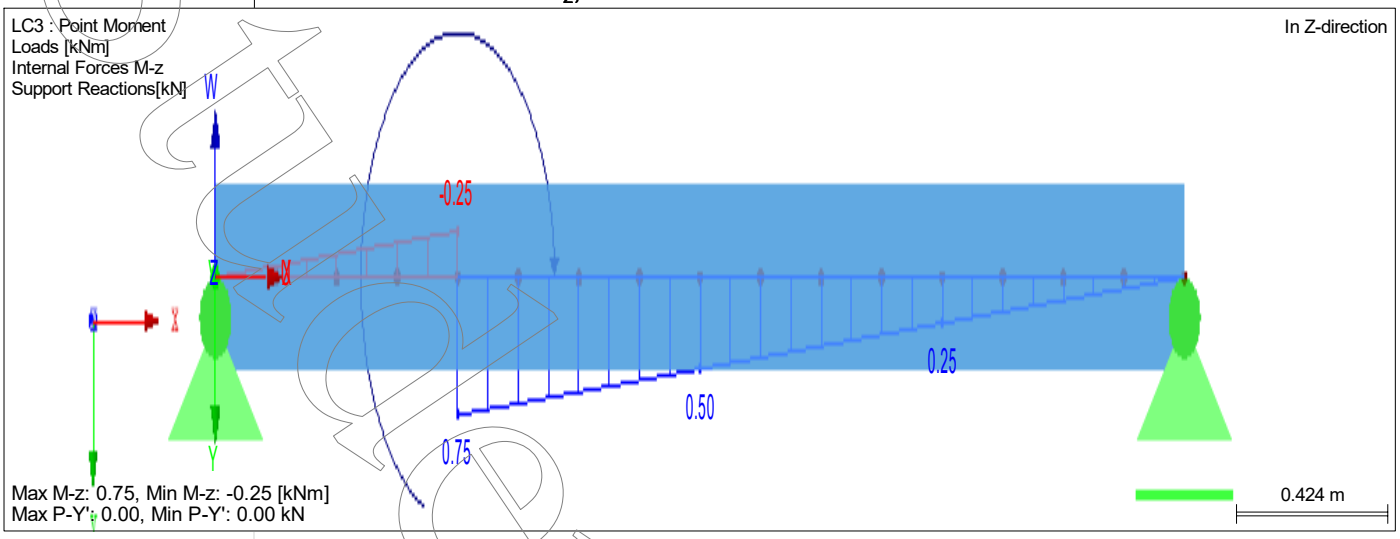
LOCAL DEFORMATIONS u_y, SUPPORT REACTIONS



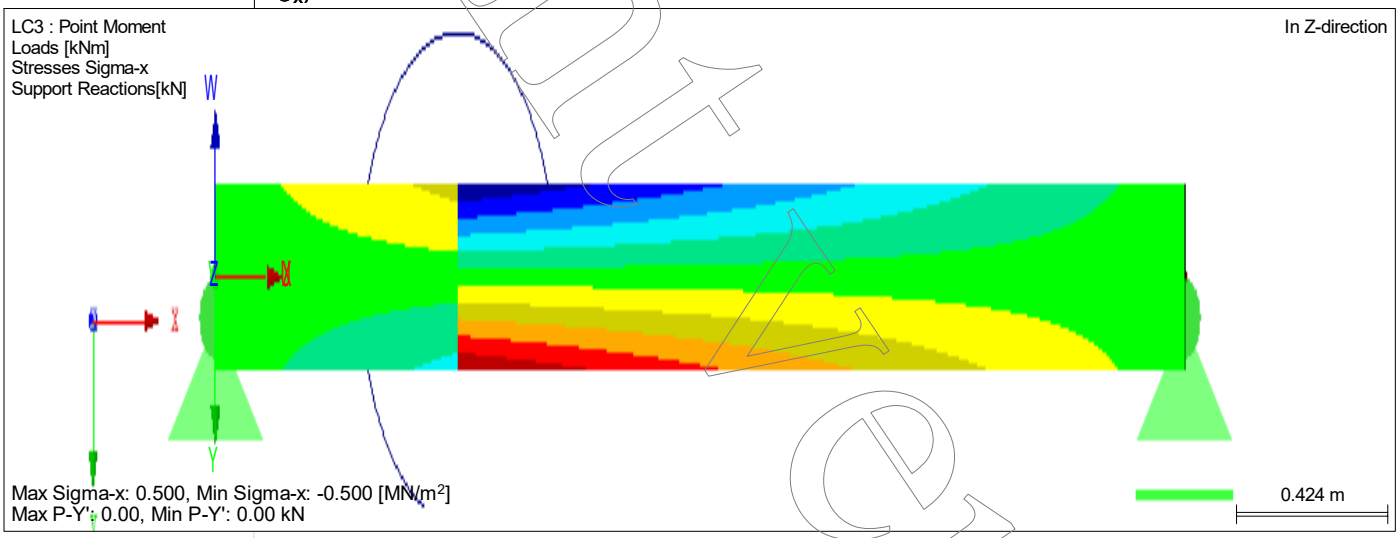
INTERNAL FORCES V_y, SUPPORT REACTIONS



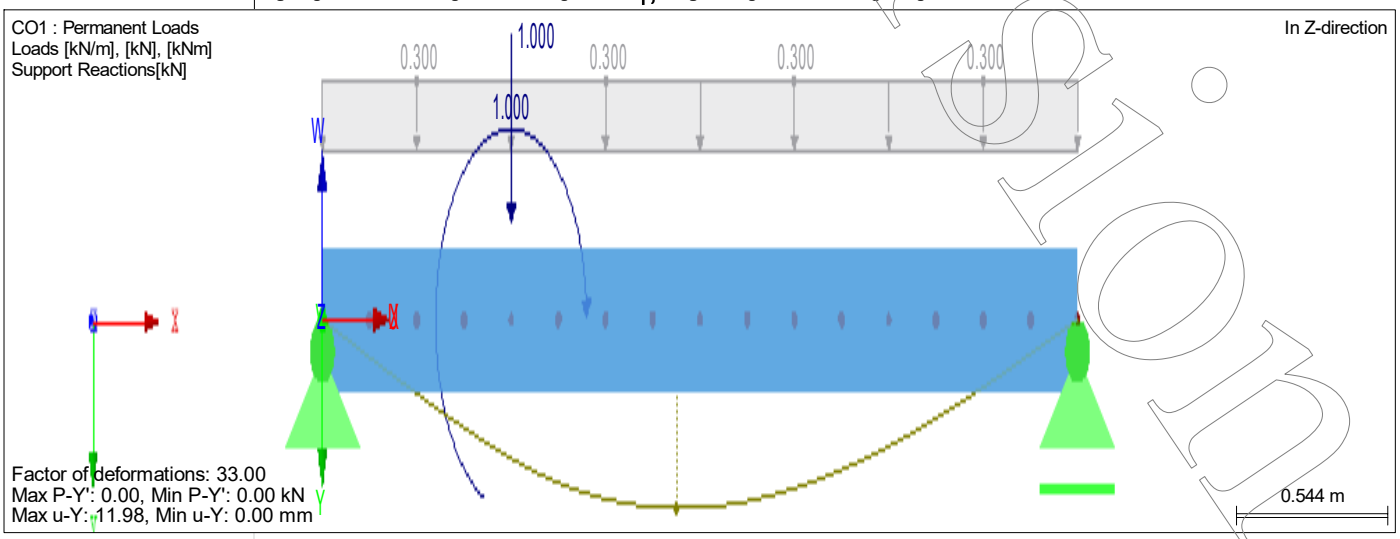
INTERNAL FORCES M_z, SUPPORT REACTIONS



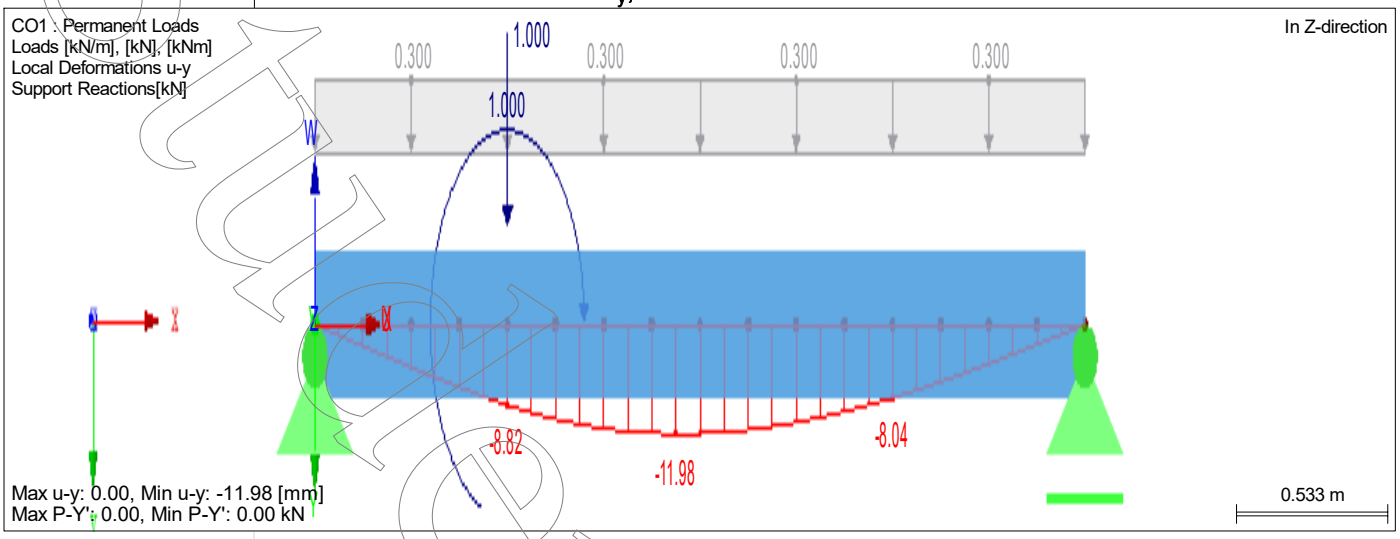
σ_x, SUPPORT REACTIONS



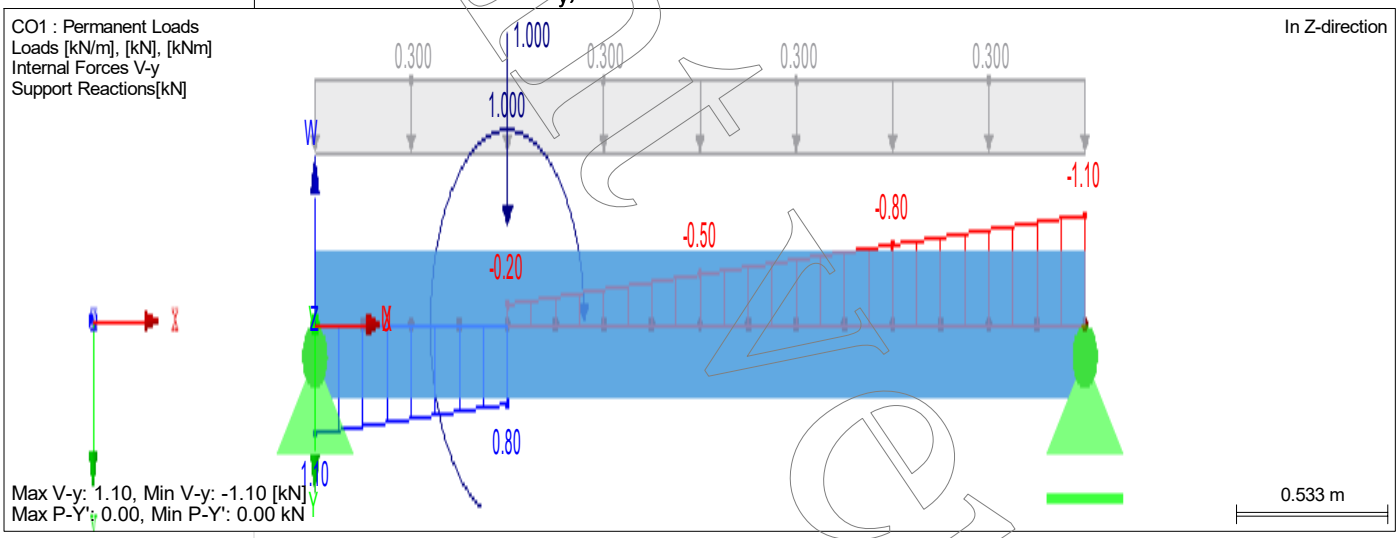
GLOBAL DEFORMATIONS u_Y, SUPPORT REACTIONS



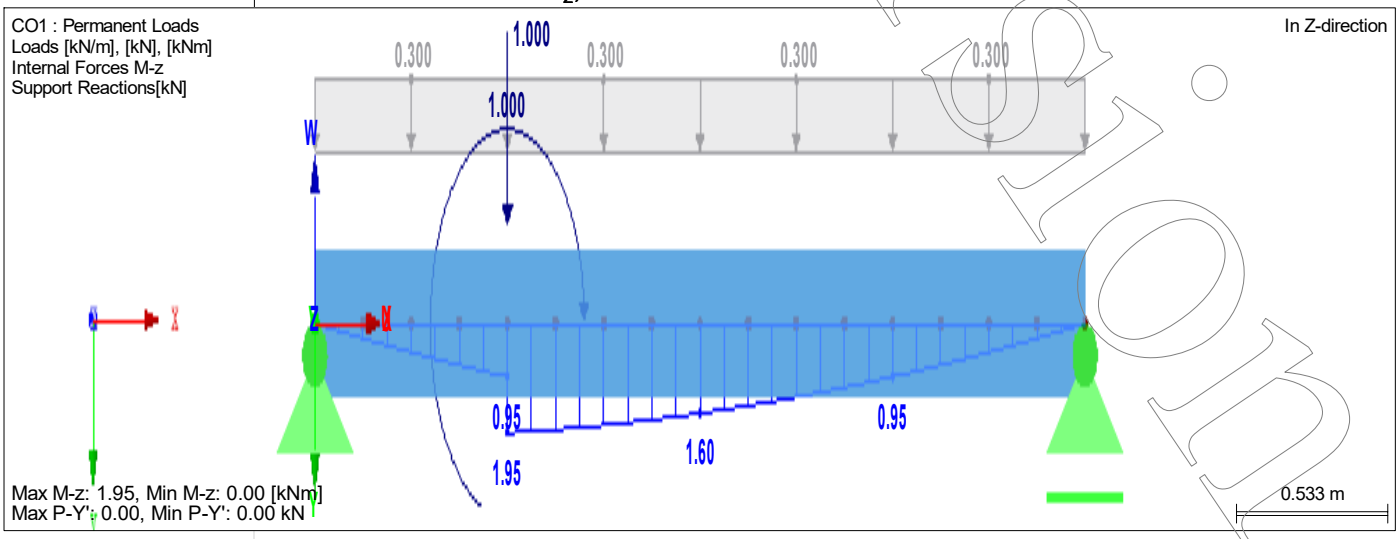
LOCAL DEFORMATIONS u_y, SUPPORT REACTIONS



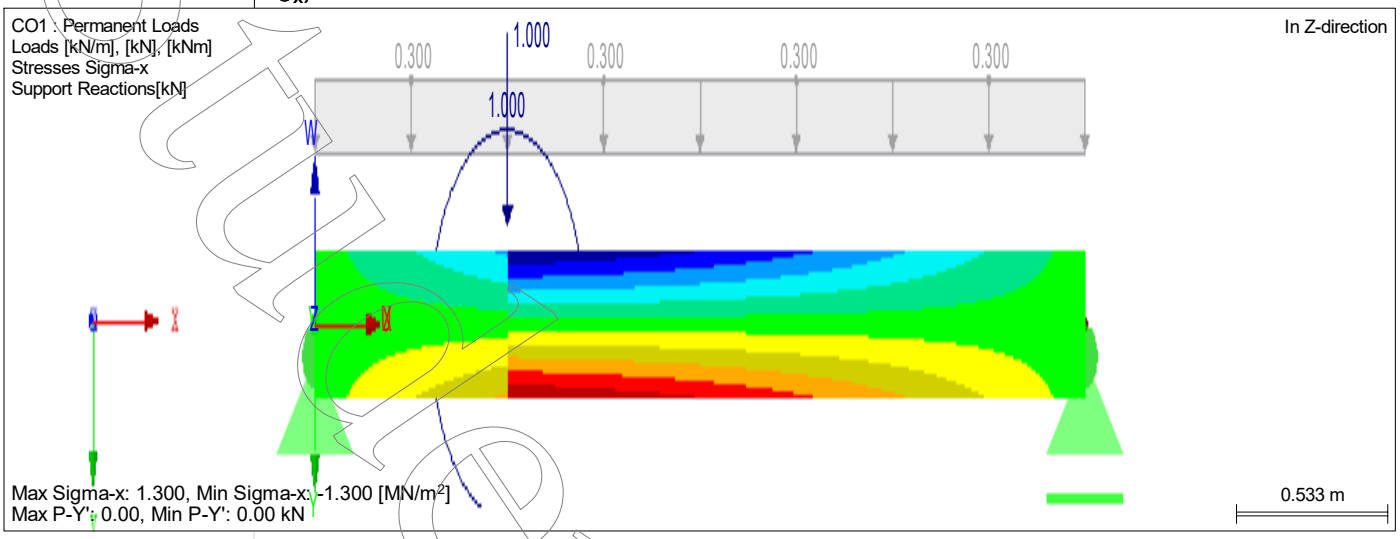
INTERNAL FORCES V_y, SUPPORT REACTIONS



INTERNAL FORCES M_z, SUPPORT REACTIONS



σ_x, SUPPORT REACTIONS



NOTES OF BENDING MOMENTS

Bending moment graphs have opposite signs than in Finnish practice