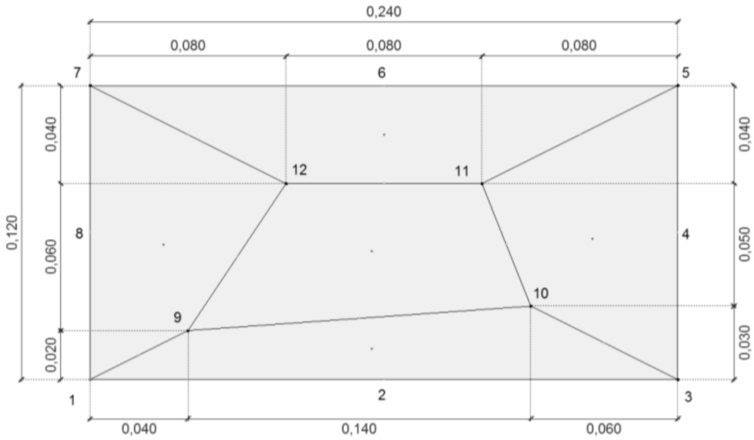
Patch tests

AXISVM

2023

Software Release Number: X7r1c
Date: 19. 04. 2023.
Tested by: InterCAD
Page number:
File name: PatchMcNeal_Rigid-T1.axs

Topic	Rigid body motion
Analysis Type	Non-linear static
Geometry	(see below)



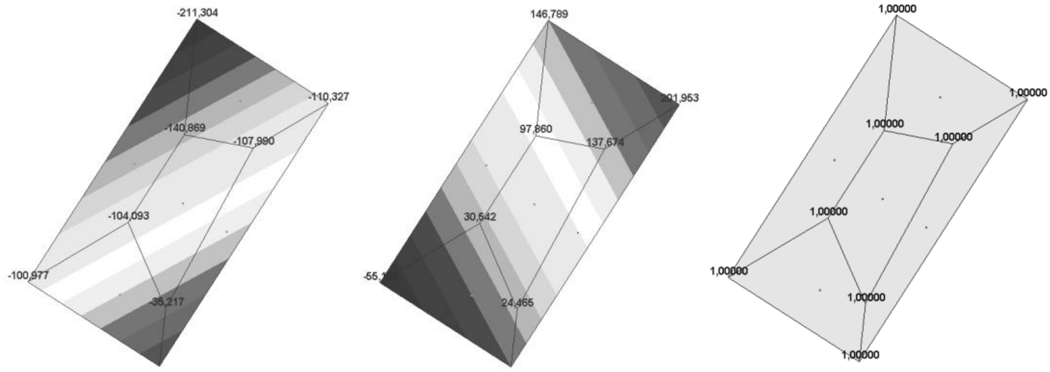
t= 1 mm
a = 240 mm
b = 120 mm

Node	x [m]	y [m]	Node	x [m]	y [m]
1	0	0	7	0	0,12
2	0,12	0	8	0	0,06
3	0,24	0	9	0,04	0,02
4	0,24	0,06	10	0,18	0,03
5	0,24	0,12	11	0,16	0,08
6	0,12	0,12	12	0,08	0,08

Loads	Prescribed displacement: $\varphi_z = 1{,}0$ radian at node 1
Boundary Conditions	$e_x = e_y = e_z = \varphi_x = \varphi_y = 0$ at node 1
Material Properties	E = 100 kN / cm^2 ρ = 1000 kg / m^3 ν = 0,25
Element types	Shell elements
Target	Check displacements of node 3 and prove that all stresses are zero.
Results	

Reference:
Richard H. MacNeal and Robert L. Harder, “A Proposed Standard Set of Problems to Test Finite Element Accuracy”, Finite Elements in Analysis and Design 1, pp. 3-20, 1985.

Displacements of node 3	AxisVM	Analytical	error [%]
e_x [mm]	-110,327	-110,327	0,0
e_y [mm]	201,953	201,953	0,0
φ_z [rad]	1,00000	1,00000	0,0

	 e_x [mm] e_y [mm] φ_z [rad]
	All the stresses are zero up to eleven digits.

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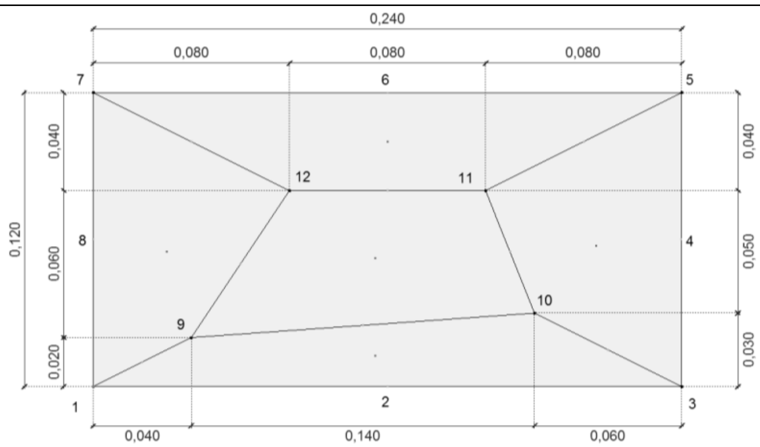
File name: PatchMacNeel_Membrane.axs

<table>
<tr><td>Topic</td><td>Patch test – membrane plate</td></tr>
<tr><td>Analysis Type</td><td>Linear static</td></tr>
<tr><td>Geometry</td><td>



t= 1 mm
a = 240 mm
b = 120 mm

<table>
<tr><th>Node</th><th>x [m]</th><th>y [m]</th><th>Node</th><th>x [m]</th><th>y [m]</th></tr>
<tr><td>1</td><td>0</td><td>0</td><td>7</td><td>0</td><td>0,12</td></tr>
<tr><td>2</td><td>0,12</td><td>0</td><td>8</td><td>0</td><td>0,06</td></tr>
<tr><td>3</td><td>0,24</td><td>0</td><td>9</td><td>0,04</td><td>0,02</td></tr>
<tr><td>4</td><td>0,24</td><td>0,06</td><td>10</td><td>0,18</td><td>0,03</td></tr>
<tr><td>5</td><td>0,24</td><td>0,12</td><td>11</td><td>0,16</td><td>0,08</td></tr>
<tr><td>6</td><td>0,12</td><td>0,12</td><td>12</td><td>0,08</td><td>0,08</td></tr>
</table>

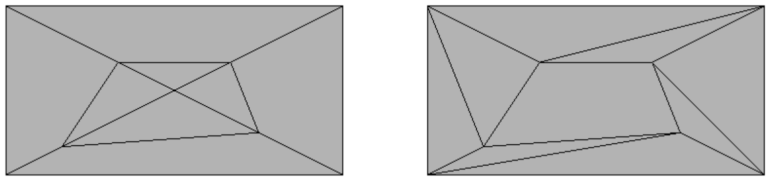
</td></tr>
<tr><td>Loads</td><td>

Prescribed displacements:
$e_x = x + y/2$ $e_y = y + x/2$

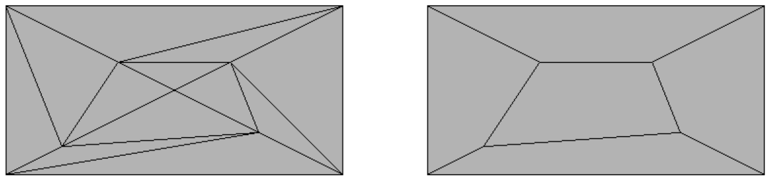
<table>
<tr><th>Node</th><th>e_x [m]</th><th>e_y [m]</th></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>2</td><td>0,12</td><td>0,06</td></tr>
<tr><td>3</td><td>0,24</td><td>0,12</td></tr>
<tr><td>4</td><td>0,27</td><td>0,18</td></tr>
<tr><td>5</td><td>0,30</td><td>0,24</td></tr>
<tr><td>6</td><td>0,18</td><td>0,18</td></tr>
<tr><td>7</td><td>0,06</td><td>0,12</td></tr>
<tr><td>8</td><td>0,03</td><td>0,06</td></tr>
</table>

</td></tr>
<tr><td>Boundary Conditions</td><td>-</td></tr>
<tr><td></td><td></td></tr>
</table>

Material Properties	$E = 100$ kN / cm^2 $\rho = 1000$ kg / m^3 $\nu = 0,25$
Element types	Shell elements – 4 mesh cases



rectangular and triangular elements mixed



triangular elements only   rectangular elements only

Target	Determine forces and displacements of inner nodes.
Results	

Reference:

Richard H. MacNeal and Robert L. Harder, “A Proposed Standard Set of Problems to Test Finite Element Accuracy”, Finite Elements in Analysis and Design 1, pp. 3-20, 1985.

Forces

Node	AxisVM results in four mesh cases			Analytical solution		
	n_x [kN/m]	n_y [kN/m]	n_{xy} [kN/m]	n_x [kN/m]	n_y [kN/m]	n_{xy} [kN/m]
9	1333,33	1333,33	400,00	1333,33	1333,33	400,00
10	1333,33	1333,33	400,00	1333,33	1333,33	400,00
11	1333,33	1333,33	400,00	1333,33	1333,33	400,00
12	1333,33	1333,33	400,00	1333,33	1333,33	400,00

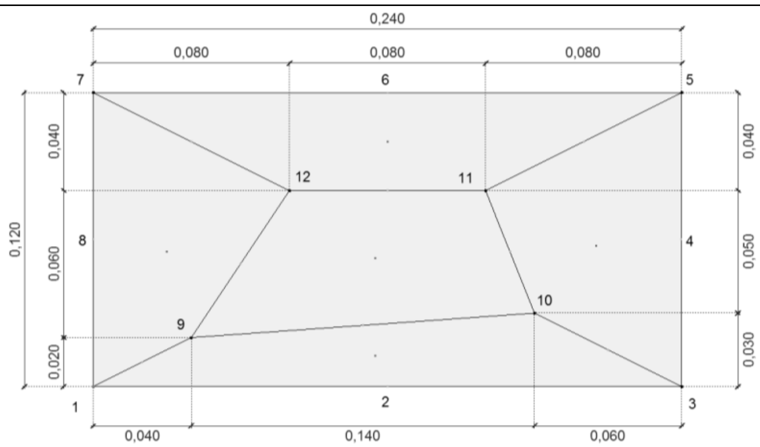
Displacements

Node	AxisVM results in four mesh cases		Analytical solutions	
	e_x [m]	e_y [m]	e_x [m]	e_y [m]
9	0,05	0,04	0,05	0,04
10	0,195	0,12	0,195	0,12
11	0,20	0,16	0,20	0,16
12	0,12	0,12	0,12	0,12

Calculated displacements and forces are the same in each mesh case as the results in AxisVM.

Software Release Number: X7r1c
Date: 19. 04. 2023.
Tested by: InterCAD
Page number:
File name: PatchMacNeel_Bending plate.axs

Topic	Constant curvature patch test – bending plate
Analysis Type	Linear static
Geometry	



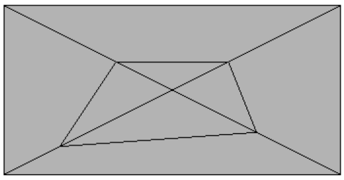
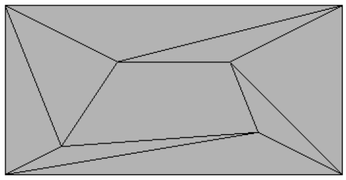
t= 1 mm
a = 240 mm
b = 120 mm

Node	x [m]	y [m]	Node	x [m]	y [m]
1	0	0	7	0	0,12
2	0,12	0	8	0	0,06
3	0,24	0	9	0,04	0,02
4	0,24	0,06	10	0,18	0,03
5	0,24	0,12	11	0,16	0,08
6	0,12	0,12	12	0,08	0,08

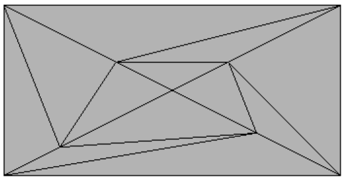
Loads	-
Boundary Conditions	Prescribed displacements:

Node	e_z [m]	φ_x [rad]	φ_y [rad]
1	0	0	0
2	0,0072	0,06	-0,12
3	0,0288	0,12	-0,24
4	0,0378	0,18	-0,27
5	0,0504	0,24	-0,30
6	0,0216	0,18	-0,18
7	0,0072	0,12	-0,06
8	0,0018	0,06	-0,03

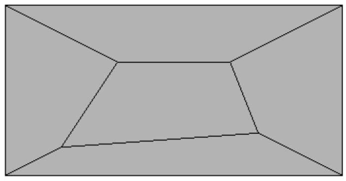
<table>
<tr><td>Material Properties</td><td>E = 100 kN / cm^2
ρ = 1000 kg / m^3
ν = 0,25</td></tr>
<tr><td>Element types</td><td>Shell elements – 4 mesh cases:

rectangular and triangular elements mixed



triangular elements only



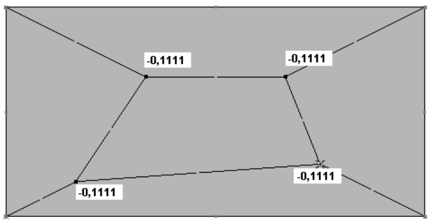
rectangular elements only</td></tr>
<tr><td>Target</td><td>Determine moments and displacements of inner nodes.</td></tr>
<tr><td>Results</td><td></td></tr>
<tr><td></td><td>Reference:

Richard H. MacNeal and Robert L. Harder, “A Proposed Standard Set of Problems to Test Finite Element Accuracy”, Finite Elements in Analysis and Design 1, pp. 3-20, 1985.

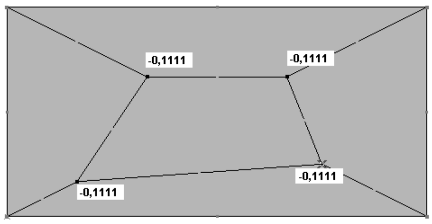
<u>Moments</u>

Analytical solution at each inner node:
$m_x = m_y = -\ 0,1111$ kNmm/m
$m_{xy} = -\ 0,0333$ kNmm/m

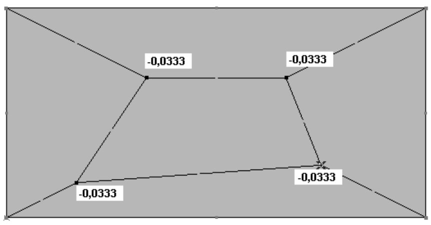
Results in AxisVM:



m_x [kNmm/m]



m_y [kNmm/m]



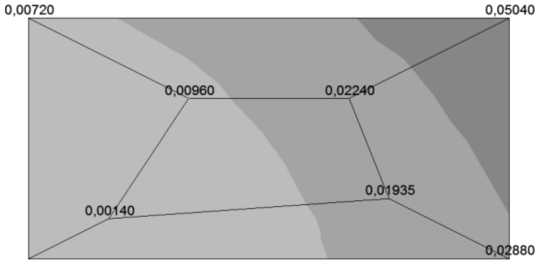
m_{xy} [kNmm/m]</td></tr>
</table>

Displacements

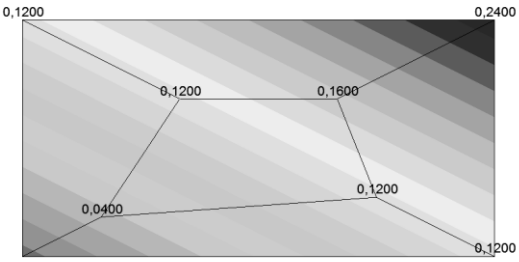
Analytical solution:

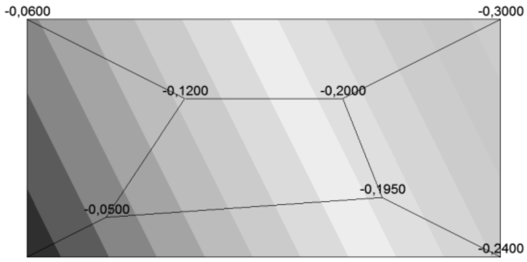
Node	x [m]	y [m]	e_z [m]	φ_x [rad]	φ_y [rad]
9	0,04	0,02	0,00140	0,0400	0,0500
10	0,18	0,03	0,01935	0,1200	0,1950
11	0,16	0,08	0,02240	0,1600	0,2000
12	0,08	0,08	0,00960	0,1200	0,1200

Results in AxisVM:



e_z [m]



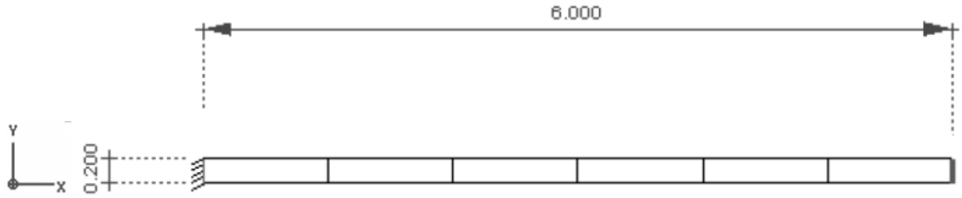
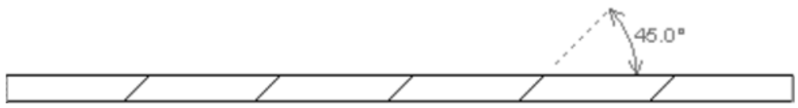


φ_x [m]

φ_y [m]

Calculated displacements and moments are the same in each mesh case as the results in AxisVM.

Software Release Number: X7r1c
Date: 19. 04. 2023.
Tested by: InterCAD
Page number:
File name: Cantilever.axs

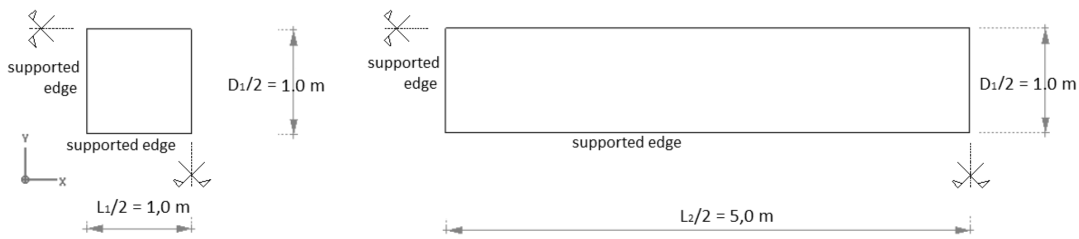
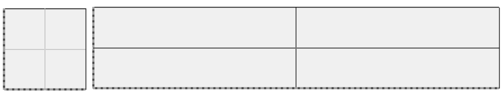
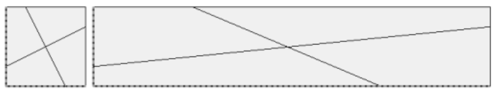
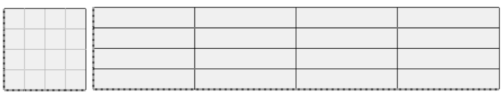
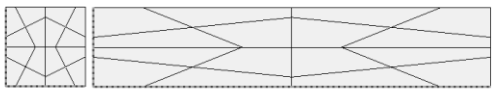
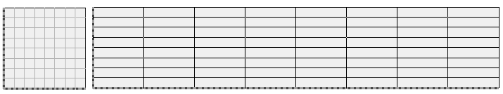
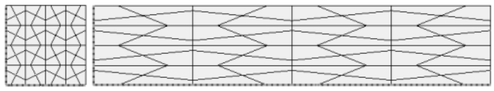
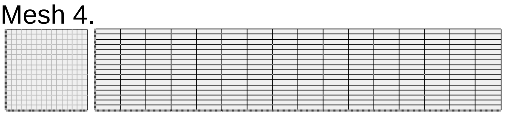
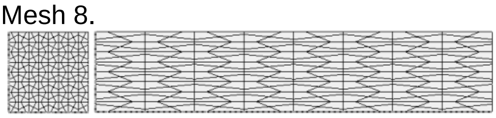
Topic	In-plane and out-of-plane shear and bending patch test of shell element
Analysis Type	Linear static
Geometry	 length: h = 6,0 m width: w = 0,20 m depth: d = 0,10 m
Loads	Unit forces on the free end of the beam, each as a different load case: A unit force in y direction, distributed on the edge: 5 kN/m A unit force in z direction, distributed on the edge: 5 kN/m A unit moment about axis x
Boundary Conditions	Left edge is clamped: $e_x = e_y = e_z = \varphi_x = \varphi_y = \varphi_z = 0$
Material Properties	E = 1000 kN / cm^2 ν = 0,30
Element types	Shell elements – 3 mesh cases: mesh a.)  rectangular elements mesh b.)  parallelogram + trapezoidal elements mesh c.)  trapezoidal elements
Target	Determine the displacements of the free end of the beam.
Results	
	Analytical solution: Reference: Richard H. MacNeal and Robert L. Harder, “A Proposed Standard Set of Problems to Test Finite Element Accuracy”, Finite Elements in Analysis and Design 1, pp. 3-20, 1985. e_y = 0,1081 m e_z = 0,4321 m φ_x = 0,03411 rad *

	Mesh case	AxisVM results	Analytical solution	e [%]
e_y [mm]	a	108,087	108,1	-0,01
	b	108,015		-0,08
	c	105,716		-2,21
e_z [mm]	a	428,189	432,1	-0,91
	b	428,743		-0,78
	c	427,531		-1,06
φ_x [rad]	a	0,03012	0,03411*	-11,7
	b	0,03006		-11,87
	c	0,03011		-11,73

* In our opinion, the φ_x rotation result for torsion is the following:

$$\varphi_x = \int \frac{M_x}{GI_x} dx = 0{,}03411 \text{ [rad]}$$

Software Release Number: X7r1c
Date: 19. 04. 2023.
Tested by: InterCAD
Page number:
File name: Plate_Distorted elements.axs

Topic	Shell element test
Analysis Type	Linear static
Geometry	The analyzed rectangular plates are of 2*2 and 2*10 meters. Only one quarter of the plates are modeled:  length: L_1 = 2,0 m, L_2 = 10,0 m width: $D_1 = D_2$ = 2,0 m depth: $t_1 = t_2$ = 0,01 m
Loads	Case 1: Distributed load on the whole plate: 0,1 kN/m^2 Case 2: Point load in z direction in the center of the plate: 0,4 kN (0,1 kN on the modeled quarter plate)
Boundary Conditions	At the left and bottom edge of the modeled plate: Case 1: clamped edge: $e_x = e_y = e_z = \varphi_x = \varphi_y = \varphi_z = 0$ Case 2: simple support: $e_x = e_y = e_z = \varphi_z = 0$ In each case - because only one quarter of the original plate is modeled – symmetry conditions are applied to the symmetry lines.
Material Properties	E = 1747,2 kN / cm^2 ν = 0,30
Element types	Shell elements: arrangement of orthogonal and distorted elements, with different mesh density: Mesh 1.  Mesh 5.  Mesh 2.  Mesh 6.  Mesh 3.  Mesh 7.  Mesh 4.  Mesh 8. 

Target	Determine the deflection in z direction in the center of the plate.
Results	

Reference:

Richard H. MacNeal and Robert L. Harder, “A Proposed Standard Set of Problems to Test Finite Element Accuracy”, Finite Elements in Analysis and Design 1, pp. 3-20, 1985.

Analytic results	e_z deflection [mm]			
	Distributed load		Concentrated load	
	b/a=1	b/a=5	b/a=1	b/a=5
Clamped support	1,26	2,56	5,60	7,23
Simple support	4,06	12,97	11,60	16,96

Results in AxisVM

Clamped support		e_z deflection [mm]			
		Distributed load		Concentrated load	
		b/a=1	b/a=5	b/a=1	b/a=5
Analytic results		1,26	2,56	5,60	7,23
Mesh cases	1	1,24	2,62	5,40	6,31
	2	1,26	2,61	5,57	7,07
	3	1,27	2,60	5,61	7,10
	4	1,27	2,61	5,62	7,24
Error of last row		0,8%	1,9%	0,4%	0,1%

Simple support		e_z deflection [mm]			
		Distributed load		Concentrated load	
		b/a=1	b/a=5	b/a=1	b/a=5
Analytic results		4,06	12,97	11,60	16,96
Mesh cases	1	4,17	12,79	11,70	16,78
	2	4,09	12,30	11,64	16,33
	3	4,08	12,97	11,64	16,88
	4	4,08	12,97	11,64	16,97
Error of last row		0,5%	0%	0,3%	0,1%

Clamped support distorted elements		e_z deflection [mm]			
		Distributed load		Concentrated load	
		b/a=1	b/a=5	b/a=1	b/a=5
Analytic results		1,26	2,56	5,60	7,23
Mesh cases	5	1,00	2,98	3,95	2,50
	6	1,16	2,57	5,07	5,47
	7	1,25	2,60	5,51	5,81
	8	1,26	2,60	5,60	6,59
Error of last row		0%	1,5%	0%	9,7%

Simple support distorted elements		e_z deflection [mm]			
		Distributed load		Concentrated load	
		b/a=1	b/a=5	b/a=1	b/a=5
Analytic results		4,06	12,97	11,60	16,96
Mesh cases	5	3,95	14,25	10,93	12,40
	6	4,07	12,95	11,36	13,83
	7	4,08	12,98	11,58	14,79
	8	4,08	12,97	11,63	16,15
Error of last row		0,5%	0%	0,3%	4,8%