

Finite Element Analysis of Flat Slab

Using numerical formulation of Bogner-Fox-Schmit (BFS) plate element

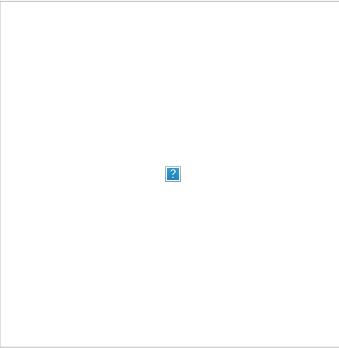
Input data

Span lengths

$$l = \text{hp}([3.6; 4.2; 4.2; 3.6]) = [3.6 \ 4.2 \ 4.2 \ 3.6] \text{ m}$$

$$l = \text{hp}([3; 3.6; 3]) = [3 \ 3.6 \ 3] \text{ m}$$

Number of axes - $n_{\text{sa}} = \text{len}(l) + 1 = 5$, $n_{\text{sb}} = \text{len}(l) + 1 = 4$



Axis coordinates $\mathbf{x}_s = [0 \ 3.6 \ 7.8 \ 12 \ 15.6]$, $\mathbf{m}_{v_s} = [0 \ 3 \ 6.6 \ 9.6]$ m

Slab dimensions - $l_a = \mathbf{x}_{s,5} = 15.6$ m, $l_b = \mathbf{x}_{s,4} = 9.6$ m

Thickness - $t = 0.2$ m

Load - $q = 10$ kN/m²

Modulus of elasticity - $E = 35000$ MPa

Poisson's ratio - $\nu = 0.2$

Finite element mesh

We will use Bogner-Fox-Schmit rectangular finite element with $n_{\text{DOFs}} = 16$

Element dimensions - $a_1 = 0.6$ m, $b_1 = 0.6$ m

Number of elements and joints along a and b -

$$n_a = \text{ceiling}\left(\frac{a}{a_1}\right) = \text{ceiling}\left(\frac{a}{0.6}\right) = [6 \ 7 \ 7 \ 6], n_{ea} = \text{sum}(n_a) = 26, n_{ja} = n_{ea} + 1 = 26 + 1 = 27$$

$$n_b = \text{ceiling}\left(\frac{b}{b_1}\right) = \text{ceiling}\left(\frac{b}{0.6}\right) = [5 \ 6 \ 5], n_{eb} = \text{sum}(n_b) = 16, n_{jb} = n_{eb} + 1 = 16 + 1 = 17$$

Total number of elements - $n_e = n_{ea} \cdot n_{eb} = 26 \cdot 16 = 416$

Total number of joints - $n_j = n_{ja} \cdot n_{jb} = 27 \cdot 17 = 459$

Supported joints count - $n_s = n_{sa} \cdot n_{sb} = 5 \cdot 4 = 20$

Joint coordinates

$$\mathbf{j} = [0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0.6 \ 0.6 \ 0.6 \ \dots \ 15.6] \text{ m}$$

$$\mathbf{j} = [0 \ 0.6 \ 1.2 \ 1.8 \ 2.4 \ 3 \ 3.6 \ 4.2 \ 4.8 \ 5.4 \ 6 \ 6.6 \ 7.2 \ 7.8 \ 8.4 \ 9 \ 9.6 \ 0 \ 0.6 \ 1.2 \ \dots \ 9.6] \text{ m}$$

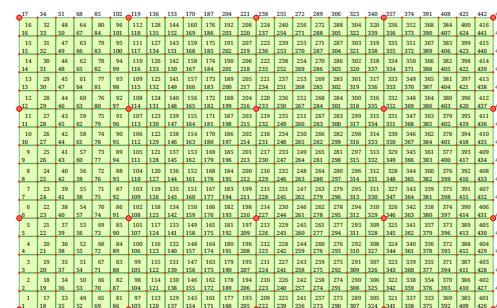
Numbers of joints at elements' corners

$$\text{transp}(\mathbf{e}_j) = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 & \dots & 441 \\ 18 & 19 & 20 & 21 & 22 & 23 & 24 & 25 & 26 & 27 & 28 & 29 & 30 & 31 & 32 & 33 & 35 & 36 & 37 & 38 & 39 & 458 \\ 19 & 20 & 21 & 22 & 23 & 24 & 25 & 26 & 27 & 28 & 29 & 30 & 31 & 32 & 33 & 34 & 36 & 37 & 38 & 39 & 459 \\ 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 19 & 20 & 21 & 22 & 442 \end{bmatrix}$$

Supported joints

$$\mathbf{j} = [1 \ 6 \ 12 \ 17 \ 103 \ 108 \ 114 \ 119 \ 222 \ 227 \ 233 \ 238 \ 341 \ 346 \ 352 \ 357 \ 443 \ 448 \ 454 \ 459]$$

Joints for element $e - j_e(\mathbf{e}) = \text{row}(\mathbf{e}_j, \mathbf{e})$



Finite element formulation

Shape functions

Along dimension a

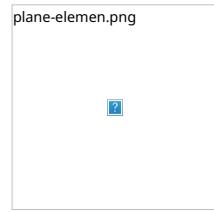
Base functions	First derivatives	Second derivatives
$\Phi_{1a}(\xi) = 1 - \xi^2 \cdot (3 - 2 \cdot \xi)$	$\Phi'_{1a}(\xi) = -6 \cdot \frac{\xi}{a_1} \cdot (1 - \xi)$	$\Phi''_{1a}(\xi) = -\frac{6}{a_1^2} \cdot (1 - 2 \cdot \xi)$
$\Phi_{2a}(\xi) = \xi \cdot a_1 \cdot (1 - \xi) \cdot (2 - \xi)$	$\Phi'_{2a}(\xi) = 1 - \xi \cdot (4 - 3 \cdot \xi)$	$\Phi''_{2a}(\xi) = -\frac{2}{a_1} \cdot (2 - 3 \cdot \xi)$
$\Phi_{3a}(\xi) = \xi^2 \cdot (3 - 2 \cdot \xi)$	$\Phi'_{3a}(\xi) = 6 \cdot \frac{\xi}{a_1} \cdot (1 - \xi)$	$\Phi''_{3a}(\xi) = \frac{6}{a_1^2} \cdot (1 - 2 \cdot \xi)$
$\Phi_{4a}(\xi) = \xi^2 \cdot a_1 \cdot (-1 + \xi)$	$\Phi'_{4a}(\xi) = -\xi \cdot (2 - 3 \cdot \xi)$	$\Phi''_{4a}(\xi) = -\frac{2}{a_1} \cdot (1 - 3 \cdot \xi)$

Along dimension b

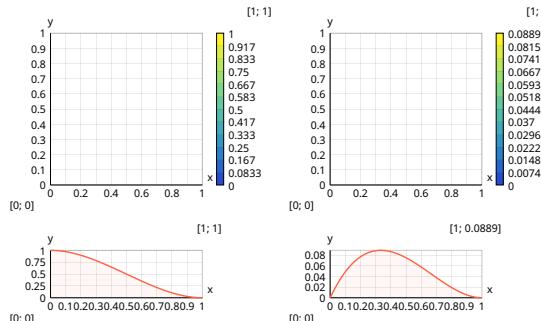
Base functions	First derivatives	Second derivatives
$\Phi_{1b}(\eta) = 1 - \eta^2 \cdot (3 - 2 \cdot \eta)$	$\Phi'_{1b}(\eta) = -6 \cdot \frac{\eta}{b_1} \cdot (1 - \eta)$	$\Phi''_{1b}(\eta) = -\frac{6}{b_1^2} \cdot (1 - 2 \cdot \eta)$
$\Phi_{2b}(\eta) = \eta \cdot b_1 \cdot (1 - \eta) \cdot (2 - \eta)$	$\Phi'_{2b}(\eta) = 1 - \eta \cdot (4 - 3 \cdot \eta)$	$\Phi''_{2b}(\eta) = -\frac{2}{b_1} \cdot (2 - 3 \cdot \eta)$
$\Phi_{3b}(\eta) = \eta^2 \cdot (3 - 2 \cdot \eta)$	$\Phi'_{3b}(\eta) = 6 \cdot \frac{\eta}{b_1} \cdot (1 - \eta)$	$\Phi''_{3b}(\eta) = \frac{6}{b_1^2} \cdot (1 - 2 \cdot \eta)$
$\Phi_{4b}(\eta) = \eta^2 \cdot b_1 \cdot (-1 + \eta)$	$\Phi'_{4b}(\eta) = -\eta \cdot (2 - 3 \cdot \eta)$	$\Phi''_{4b}(\eta) = -\frac{2}{b_1} \cdot (1 - 3 \cdot \eta)$

$$\begin{array}{lll}
\text{For vertical displacements } w \quad \text{For rotations } \theta_x & & \text{For rotations } \theta_y \\
\begin{array}{lll}
N_{1,w}(\xi, \eta) = \Phi_{1a}(\xi) \cdot \Phi_{1b}(\eta) & N_{1,0}(\xi, \eta) = \Phi_{2a}(\xi) \cdot \Phi_{1b}(\eta) & N_{1,0}(\xi, \eta) = \Phi_{1a}(\xi) \cdot \Phi_{2b}(\eta) \\
N_{2,w}(\xi, \eta) = \Phi_{3a}(\xi) \cdot \Phi_{1b}(\eta) & N_{2,0}(\xi, \eta) = \Phi_{4a}(\xi) \cdot \Phi_{1b}(\eta) & N_{2,0}(\xi, \eta) = \Phi_{3a}(\xi) \cdot \Phi_{2b}(\eta) \\
N_{3,w}(\xi, \eta) = \Phi_{3a}(\xi) \cdot \Phi_{3b}(\eta) & N_{3,0}(\xi, \eta) = \Phi_{4a}(\xi) \cdot \Phi_{3b}(\eta) & N_{3,0}(\xi, \eta) = \Phi_{3a}(\xi) \cdot \Phi_{4b}(\eta) \\
N_{4,w}(\xi, \eta) = \Phi_{1a}(\xi) \cdot \Phi_{3b}(\eta) & N_{4,0}(\xi, \eta) = \Phi_{2a}(\xi) \cdot \Phi_{3b}(\eta) & N_{4,0}(\xi, \eta) = \Phi_{1a}(\xi) \cdot \Phi_{4b}(\eta)
\end{array} & &
\end{array}$$

$$\begin{aligned} \text{For twist } \psi \\ N_{1,\psi}(\xi; \eta) &= \Phi_{2a}(\xi) \cdot \Phi_{2b}(\eta) \\ N_{2,\psi}(\xi; \eta) &= \Phi_{4a}(\xi) \cdot \Phi_{2b}(\eta) \\ N_{3,\psi}(\xi; \eta) &= \Phi_{4a}(\xi) \cdot \Phi_{4b}(\eta) \\ N_{4,\psi}(\xi; \eta) &= \Phi_{2a}(\xi) \cdot \Phi_{4b}(\eta) \end{aligned}$$



$N_{1,w}$ shape function plot



N_{1,θ_x} shape function plot

Shape functions vector

$$N(\vec{r}; \xi; \eta) = \text{take}(\vec{r}; N_{1,w}(\xi; \eta); N_{1,\theta_1}(\xi; \eta); N_{1,\theta_2}(\xi; \eta); N_{1,\psi}(\xi; \eta); N_{2,w}(\xi; \eta); N_{2,\theta_1}(\xi; \eta); N_{2,\theta_2}(\xi; \eta); N_{2,\psi}(\xi; \eta); N_{3,w}(\xi; \eta); N_{3,\theta_1}(\xi; \eta); N_{3,\theta_2}(\xi; \eta); N_{3,\psi}(\xi; \eta); N_{4,w}(\xi; \eta); N_{4,\theta_1}(\xi; \eta); N_{4,\theta_2}(\xi; \eta); N_{4,\psi}(\xi; \eta))$$

Constitutive matrix (stress - strain relationship)

$$D = \frac{E \cdot t^3}{12} \cdot \sin(\Gamma_{1;w,0} + \Gamma_{w,1;0} + \Gamma_{0;0})^{1-v}$$

$$D = \frac{12 \cdot (1 - 0.2^2)}{12 \cdot (1 - \frac{v^2}{r^2})} \cdot \text{mp} \left(\begin{bmatrix} 1; v; 0 & v; 1; 0 & 0; 0; \frac{1}{2} \end{bmatrix} \right) = \frac{12 \cdot (1 - 0.2^2)}{12 \cdot (1 - 0.2^2)} \cdot \text{mp} \left(\begin{bmatrix} 1; 0.2; 0 & 0.2; 1; 0 & 0; 0 \end{bmatrix} \right)$$

Strain-displacement matrix

$$B_1(j; \zeta, \eta) = \text{take}(j; \Phi_{1a}^*(\xi) \cdot \Phi_{1b}(\eta); \Phi_{2a}^*(\xi) \cdot \Phi_{1b}(\eta); \Phi_{1a}^*(\xi) \cdot \Phi_{2b}(\eta); \Phi_{2a}^*(\xi) \cdot \Phi_{2b}(\eta); \Phi_{3a}^*(\xi) \cdot \Phi_{1b}(\eta); \Phi_{4a}^*(\xi) \cdot \Phi_{1b}(\eta); \Phi_{3a}^*(\xi) \cdot \Phi_{2b}(\eta); \Phi_{4a}^*(\xi) \cdot \Phi_{2b}(\eta); \Phi_{3a}^*(\xi) \cdot \Phi_{3b}(\eta); \Phi_{4a}^*(\xi) \cdot \Phi_{3b}(\eta); \Phi_{3a}^*(\xi) \cdot \Phi_{4b}(\eta); \Phi_{4a}^*(\xi) \cdot \Phi_{4b}(\eta); \Phi_{1a}^*(\xi) \cdot \Phi_{3b}(\eta); \Phi_{2a}^*(\xi) \cdot \Phi_{3b}(\eta); \Phi_{1a}^*(\xi) \cdot \Phi_{4b}(\eta); \Phi_{2a}^*(\xi) \cdot \Phi_{4b}(\eta))$$

$$B_3(j; \xi; \eta) = 2 \cdot \text{take}(j; \Phi'_1 a(\xi) \cdot \Phi'_1 b(\eta); \Phi'_2 a(\xi) \cdot \Phi'_2 b(\eta); \Phi'_1 a(\xi) \cdot \Phi'_1 b(\eta); \Phi'_2 a(\xi) \cdot \Phi'_2 b(\eta); \Phi'_3 a(\xi) \cdot \Phi'_3 b(\eta))$$

$$\begin{aligned}
& (\eta), \Phi'_{4a}(\xi) \cdot \Phi'_{1b}(\eta), \Phi'_{3a}(\xi) \cdot \Phi'_{2b}(\eta), \Phi'_{4a}(\xi) \cdot \Phi'_{2b}(\eta), \Phi'_{3a}(\xi) \cdot \Phi'_{3b}(\eta), \Phi'_{4a}(\xi) \cdot \Phi'_{3b}(\eta), \Phi'_{3a}(\xi) \\
& \Phi'_{4b}(\eta), \Phi'_{4a}(\xi) \cdot \Phi'_{4b}(\eta), \Phi'_{1a}(\xi) \cdot \Phi'_{3b}(\eta), \Phi'_{2a}(\xi) \cdot \Phi'_{3b}(\eta), \Phi'_{1a}(\xi) \cdot \Phi'_{4b}(\eta), \Phi'_{2a}(\xi) \cdot \Phi'_{4b}(\eta)
\end{aligned}$$

$$B(j; \xi; \eta) = \mathbf{hp}([B_1(j; \xi; \eta); B_2(j; \xi; \eta); B_3(j; \xi; \eta)])$$

The coefficients of the stiffness matrix will be calculated by using the equation

$$K_{\mathbf{e},ij} = \mathbf{a}_1 \cdot \mathbf{b}_1 \cdot \int_0^1 \int_0^1 B_i(\xi; \eta)^T \cdot \mathbf{D} \cdot B_j(\xi; \eta) d\xi d\eta$$

Element stiffness matrix

Element stiffness matrix

$$RTDB_{\leq}(\vec{i}, \vec{j}; \vec{\xi}, v) = \text{transp}(R(\vec{i}; \vec{\xi}, v)) \cdot D \cdot R(\vec{j}; \vec{\xi}, v)$$

$$\begin{bmatrix} & 0 & \\ 0 & & \end{bmatrix}$$

$$F_{e,i} = a_1 \cdot b_1 \cdot \int N_i(\xi; \eta)^T \cdot q \, d\xi \, d\eta$$

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Solution

Glo

Global load vector

$$\vec{r} = [0.9 \ 0.09 \ 0.09 \ 0.009 \ 1.8 \ 0.18 \ 0 \ 0 \ 1.8 \ 0.18 \ 0 \ 0 \ 1.8 \ 0.18 \ 0 \ 0 \ 1.8 \ 0.18 \ 0 \ 0 \ \dots \ 0.009] \text{ kN}$$

Solution of the system of equations

$\mathbb{Z} = \text{slslove}(K\mathcal{F}) = [0 \ 0.5523613 \ 0.3827392 \ -0.4161287 \ 0.2028064 \ 0.3732832 \ 0.2648463 \ -0.1937261 \ 0.2989047]$

0.3091182 0.04830843 -0.02501454 0.261207 0.3426386 -0.1651493 0.1275073 0.1211489

0.4681287 -0.2671179 0.2293302 ... -0.4161286] mm

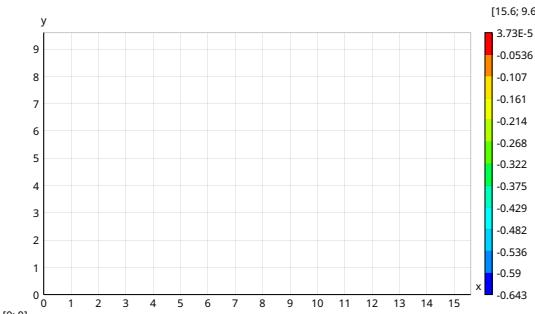
Results

Joint displacements

transp(*W_z***) =**

0	0.303	0.488	0.512	0.383	0.165	0	0.139	0.34	0.469	0.472	0.347	0.146	0	0.146	0.347	0.472	0.469	0.34	0.139	0
0.203	0.419	0.562	0.581	0.485	0.337	0.25	0.31	0.438	0.531	0.533	0.443	0.311	0.242	0.311	0.443	0.533	0.531	0.438	0.31	0.203
0.299	0.482	0.605	0.62	0.537	0.417	0.35	0.387	0.485	0.562	0.564	0.489	0.387	0.338	0.387	0.489	0.564	0.562	0.485	0.387	0.299
0.261	0.461	0.593	0.608	0.513	0.375	0.299	0.342	0.455	0.542	0.544	0.46	0.345	0.289	0.345	0.46	0.544	0.542	0.455	0.342	0.261
0.121	0.386	0.55	0.565	0.443	0.253	0.138	0.217	0.381	0.493	0.497	0.389	0.225	0.134	0.225	0.389	0.497	0.493	0.381	0.217	0.121
0	0.34	0.527	0.542	0.404	0.173	0	0.135	0.36	0.463	0.467	0.345	0.145	0	0.145	0.345	0.467	0.463	0.336	0.135	0
0.139	0.398	0.556	0.566	0.44	0.247	0.129	0.206	0.367	0.478	0.481	0.374	0.211	0.121	0.211	0.374	0.481	0.478	0.367	0.206	0.139
0.299	0.487	0.608	0.612	0.511	0.369	0.287	0.325	0.433	0.516	0.519	0.437	0.324	0.27	0.324	0.437	0.519	0.516	0.433	0.325	0.299
0.363	0.526	0.632	0.635	0.544	0.42	0.35	0.376	0.464	0.536	0.538	0.467	0.373	0.329	0.373	0.467	0.538	0.536	0.464	0.376	0.363
0.299	0.487	0.608	0.612	0.511	0.369	0.287	0.325	0.433	0.516	0.519	0.437	0.324	0.27	0.324	0.437	0.519	0.516	0.433	0.325	0.299
0.139	0.398	0.556	0.566	0.44	0.247	0.129	0.206	0.367	0.478	0.481	0.374	0.211	0.121	0.211	0.374	0.481	0.478	0.367	0.206	0.139
0	0.34	0.527	0.542	0.404	0.173	0	0.135	0.36	0.463	0.467	0.345	0.145	0	0.145	0.345	0.467	0.463	0.336	0.135	0
0.121	0.386	0.55	0.565	0.443	0.253	0.138	0.217	0.381	0.493	0.497	0.389	0.225	0.134	0.225	0.389	0.497	0.493	0.381	0.217	0.121
0.261	0.461	0.593	0.608	0.513	0.375	0.299	0.342	0.455	0.542	0.544	0.46	0.345	0.289	0.345	0.46	0.544	0.542	0.455	0.342	0.261
0.299	0.482	0.605	0.62	0.537	0.417	0.35	0.387	0.485	0.562	0.564	0.489	0.387	0.338	0.387	0.489	0.564	0.562	0.485	0.387	0.299
0.203	0.419	0.562	0.581	0.485	0.337	0.25	0.31	0.438	0.531	0.533	0.443	0.311	0.242	0.311	0.443	0.533	0.531	0.438	0.31	0.203
0	0.303	0.488	0.512	0.383	0.165	0	0.139	0.34	0.469	0.472	0.347	0.146	0	0.146	0.347	0.472	0.469	0.34	0.139	0

mm



Bending moments

$$Z(i) = \text{slice}(Z; k, (i-1)+1; k, i)$$

$$Z_1(e) = \text{hp}([Z_2(e_{-1}); Z_2(e_{-2}); Z_2(e_{-3}); Z_2(e_{-4})])$$

• $\text{E}_\text{e}(\text{c}) = \text{NP}([\text{E}](\text{c}).\text{e}, 1), [\text{E}](\text{c}).\text{e}, 2), [\text{E}](\text{c}).\text{e}, 3)$

Average

$$M_1 = \begin{pmatrix} 1.498465 & 0.3097372 & 0.2197322 & 0.1563433 & 0.1570519 & 0.9983302 & 0.1564193 & 0.1519741 & 0.19422 & 0.1519742 & 0.1564197 & 0.9983303 & 0.1570475 & 0.1563397 & 0.2197486 & 0.3098808 & 1.49858 & 8.502998 & 6.479199 & 5.777684 & \cdots & 1.498434 \\ 1.566914 & 7.805101 & 9.33778 & 7.668097 & 3.333 & -28.361735 & 3.14639 & 7.323888 & 8.895019 & 7.323888 & 3.14639 & -28.361734 & 3.332997 & 7.668093 & 9.337791 & 7.80518 & 1.566813 & 0.3205972 & 5.382201 & 7.12651 & \cdots & 1.56695 \\ 8.091391 & 3.766896 & 0.4863938 & -2.479308 & -4.459199 & 0.1550864 & 4.780359 & 2.842723 & 1.18852 \times 10^{-8} & -2.842723 & -4.780359 & -0.1550866 & 4.459199 & 2.479312 & -0.4863957 & -3.766967 & -8.09139 & 4.110857 & 2.572942 & 0.367139 & \cdots & 8.09139 \end{pmatrix}$$

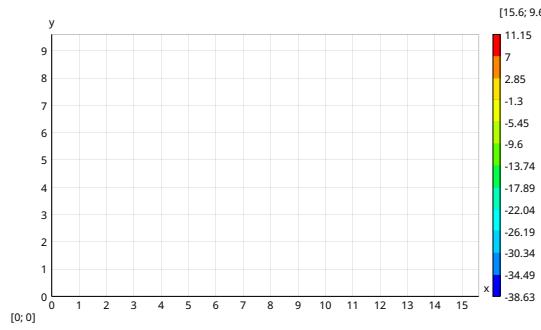
Bending moments for the plate

Bending moments - M_y

transp(Mn) =

transp	(MA)	
1.498465	8.502998	11.06652
10.47741	6.797477	0.8838727
-31.235271	0.3015017	5.644442
8.779995	8.877612	5.920011
0.685444		
0.3097372	6.479199	9.4322
8.877275	4.922637	-2.695317
-10.242892	-3.260294	3.808797
7.250425	7.361393	4.127752
-2.764349		
0.2197232	5.777684	8.176293
1.35055	4.039483	-2.257879
-6.067011	-2.819291	2.932144
6.516758	6.640543	3.291674
-2.29425		
0.1563433	5.993176	9.125993
8.492879	4.05777	-3.257751
-7.98846	-3.832677	2.913674
6.794769	6.92822	3.304597
-3.205191		
0.1570519	7.269644	10.372249
5.956604	4.972553	-5.268409
-16.118864	-5.865491	3.766832
7.713228	7.838243	4.157472
-5.9628		
0.9983302	9.038525	11.080418
10.122777	5.76385	-2.135317
-38.650059	-2.745557	4.52179
8.190804	8.315041	4.904088
-2.08841		
0.1564193	7.221047	10.282001
9.436465	4.848423	-5.358008
-16.18287	-5.96302	3.624262
7.50611	7.698815	4.05327
-5.13808		
0.1519741	5.873186	8.297255
3.773453	-3.419119	-8.032747
-4.00942	5.294529	4.649671
6.626453	3.062913	-3.26994
0.19422	5.514147	8.380213
7.692931	4.568337	-2.491105
-5.742638	-3.073384	3.210468
5.979222	6.142652	2.786902
-3.27682		
0.1519742	5.873186	8.297255
3.773453	-3.419119	-8.032747
-4.00942	5.294529	4.649671
6.626453	3.062913	-3.26994
0.1564197	7.221047	10.282001
9.436465	4.848423	-5.358008
-16.18287	-5.96302	3.624262
7.50611	7.698815	4.05327
-5.13808		
0.9983303	9.038524	11.080418
10.122777	5.76385	-2.135317
-38.650059	-2.745557	4.52179
8.190804	8.315041	4.904088
-2.08841		
0.9983303	9.038524	11.080418
10.122777	5.76385	-2.135317
-38.650059	-2.745557	4.52179
8.190804	8.315041	4.904088
-2.08841		
0.1570475	7.269646	10.372249
9.556604	4.972554	-5.268409
-16.118864	-5.865491	3.766832
7.713228	7.838243	4.157472
-5.09628		
0.1563397	5.993177	9.125994
8.492879	4.05777	-3.257751
-7.98846	-3.832677	2.913674
6.794769	6.92822	3.304597
-3.205191		
0.2197486	5.777685	8.716292
8.135052	4.039485	-2.25788
-6.067011	-2.819291	2.932144
6.516758	6.640543	3.291674
-2.29425		
0.309808	6.479177	9.432178
8.877282	4.926264	-6.2695314
-10.242892	-3.260293	3.808797
7.250426	7.361393	4.127752
-2.763439		
1.49858	8.502893	11.066537
10.477401	6.797487	0.8838683
-31.23527	0.301501	5.644443
8.779994	8.877614	5.920009
0.685445		

kNm/m

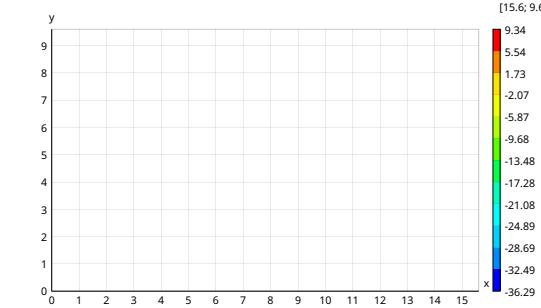


Bending moments M_y

transp(M_y) =

1.566914	0.3205972	0.2333587	0.2147852	0.1682816	0.1798035	1.015789	0.1794301	0.1669894	0.2098191	0.2091906	0.1663467	0.1776119	0.9891482	0.1776123	0.1663459	0.2091915	0.2098181	0.1669903	0.1794296	...	1.566846
7.805101	5.382201	4.308412	4.134952	4.742331	6.340395	8.230714	6.28316	4.611981	3.89228	3.867499	4.530534	6.12258	7.985896	6.12258	4.530534	3.867499	3.89228	4.611981	6.28316	...	7.805153
9.337778	7.126518	5.800074	5.553032	6.414898	8.11577	9.046666	8.014704	6.188836	5.14485	5.116777	6.090589	7.821224	8.777225	7.821225	6.090589	5.116777	5.14485	6.188836	8.014704	...	9.337789
7.668097	5.41756	4.262493	3.920413	4.233692	5.419822	6.344591	5.301204	3.979478	3.477998	3.480904	3.968582	5.222837	6.181459	5.222837	3.968582	3.480904	3.477998	3.979478	5.301104	...	7.668093
3.333	-0.3280779	0.5396346	0.405616	-1.17438	-3.412974	-0.3301829	-3.531204	-1.399574	0.09964996	0.1609008	-1.210571	-3.234664	-0.2184219	-3.234664	-1.210571	0.1609008	0.09964995	-1.399574	-3.531204	...	3.332998
-28.361735	-7.038366	-1.936162	-1.646652	-4.993974	-13.644678	-36.317523	-13.771126	-5.215881	-1.858171	-1.764027	-4.886867	-13.03174	-34.571125	-13.03174	-4.886867	-1.764027	-1.858171	-5.215881	-13.771126	...	-28.361736
3.14639	-0.5066696	0.3485146	0.1799353	-1.456247	-3.762435	-0.7233495	-3.922981	-1.765819	-0.2520091	-0.1968807	-1.596341	-3.661657	-0.6661947	-3.661657	-1.596341	-0.1968807	-0.2520091	-1.765819	-3.922981	...	3.146398
7.323888	5.094544	3.908978	3.489139	3.675468	4.685865	5.49873	4.483969	3.254199	2.794376	2.788549	3.214495	4.349964	5.243651	4.349964	3.214495	2.788549	2.794376	3.254199	4.483969	...	7.323874
8.895091	6.740122	5.350863	4.96126	5.608937	6.913063	7.572529	6.693158	5.141784	4.180525	4.149637	5.027791	6.456862	7.212973	6.456862	5.027791	4.149637	4.180525	5.141784	6.693158	...	8.895035
7.323888	5.094544	3.908978	3.489139	3.675468	4.685865	5.49873	4.483969	3.254199	2.794376	2.788549	3.214495	4.349964	5.243651	4.349964	3.214495	2.788549	2.794376	3.254199	4.483969	...	7.323874
3.14639	-0.5066695	0.3485145	0.1799354	-1.456247	-3.762435	-0.7233495	-3.922981	-1.765819	-0.2520091	-0.1968807	-1.596341	-3.661657	-0.6661947	-3.661657	-1.596341	-0.1968807	-0.2520091	-1.765819	-3.922981	...	3.146397
-28.361735	-7.038366	-1.936162	-1.646652	-4.993974	-13.644678	-36.317523	-13.771126	-5.215881	-1.858171	-1.764027	-4.886867	-13.03174	-34.571125	-13.03174	-4.886867	-1.764027	-1.858171	-5.215881	-13.771126	...	-28.361736
3.332997	-0.3280781	0.5396345	0.405616	-1.174379	-3.412974	-0.3301829	-3.531204	-1.399574	0.09964994	0.1609008	-1.210571	-3.234664	-0.2184219	-3.234664	-1.210571	0.1609008	0.09964996	-1.399574	-3.531204	...	3.333003
7.668093	5.41756	4.262493	3.920414	4.233691	5.419822	6.344591	5.301104	3.979478	3.477998	3.480904	3.968582	5.222837	6.181459	5.222837	3.968582	3.480904	3.477998	3.979478	5.301104	...	7.668093
9.337791	7.126529	5.800079	5.553029	6.414899	8.115769	9.046667	8.014704	6.188836	5.14485	5.116777	6.090589	7.821225	8.777225	7.821225	6.090589	5.116777	5.14485	6.188836	8.014704	...	9.337788
7.80518	5.382247	4.308397	4.134958	4.742326	6.340398	8.230713	6.283161	4.61198	3.892281	3.867498	4.530534	6.12258	7.985896	6.12258	4.530534	3.867499	3.89228	4.611981	6.28316	...	7.805067
1.566813	0.3204128	0.2333748	0.2147746	0.1682944	0.1797983	1.015789	0.1794292	0.1669914	0.2098169	0.2091927	0.166345	0.1776128	0.9891482	0.177612	0.1663463	0.209191	0.2098187	0.1669898	0.1794301	...	1.56695

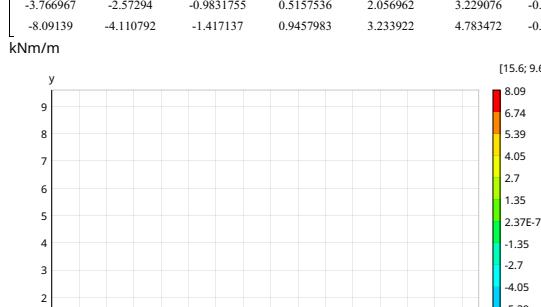
kNm/m



Bending moments M_{xy}

transp(M_{xy}) =

8.091391	4.110857	1.417137	-0.9458016	-3.233923	-4.783472	0.02175397	4.840696	3.336369	1.142106	-1.025808	-3.195694	-4.675291	8.203632×10 ⁻⁹	4.675291	3.195694	1.025808	-1.142106
3.766896	2.572942	0.9831798	-0.5157529	-2.056961	-3.229076	0.05823395	3.354953	2.213405	0.7311327	-0.6697977	-2.124616	-3.226088	-1.924384×10 ⁻⁸	3.226088	2.124615	0.6697977	-0.731132
0.4863938	0.367139	0.2104715	0.08573235	-0.1195606	-0.3138301	0.07348128	0.4612966	0.2667083	0.05683469	-0.07988453	-0.2739108	-0.4318273	4.135681×10 ⁻⁹	0.4318273	0.2739109	0.07988453	-0.0568346
-2.479308	-1.795977	-0.6012575	0.6167458	1.746893	2.092654	0.07628287	-1.948193	-1.634066	-0.5814737	0.4919345	1.536254	1.879329	-9.39927×10 ⁻¹⁰	-1.879329	-1.536254	-0.4919345	0.581473
-4.459199	-3.239942	-0.8977427	0.6826669	2.370922	4.524997	0.07578146	-4.382303	-2.264662	-0.6817699	0.6007663	2.152105	4.210878	2.347034×10 ⁻¹⁰	-4.210878	-2.152105	-0.6007663	0.681769
0.1550864	0.1611718	0.1492474	0.1245987	0.09639145	0.07797703	0.07388198	0.06988651	0.05125056	0.02105121	0.008413693	-0.02659669	-0.02344966	-6.046931×10 ⁻¹¹	0.02344966	0.02659669	0.008413693	-0.0210512
4.780359	3.565968	1.189369	-0.4505428	-2.206755	-4.399285	0.06348492	4.535454	2.37937	0.7252095	-0.6263983	-2.225358	-4.279277	1.578955×10 ⁻¹¹	4.279277	2.225358	0.6263983	-0.725209
2.842723	2.13438	0.8682924	-0.4377229	-1.679594	-2.084069	0.03778074	2.16835	1.796129	0.6296557	-0.5417072	-1.677932	-2.037682	-4.744667×10 ⁻¹²	2.037682	1.677932	0.5417072	-0.629655
1.18852×10 ⁻⁸	-6.576042×10 ⁻⁹	-7.016847×10 ⁻¹⁰	1.244056×10 ⁻¹⁰	2.191792×10 ⁻¹⁰	-7.501514×10 ⁻¹¹	1.8954×10 ⁻¹¹	-1.177769×10 ⁻¹²	3.047327×10 ⁻¹²	1.092988×10 ⁻¹²	-4.777445×10 ⁻¹²	5.435255×10 ⁻¹²	-3.554444×10 ⁻¹²	3.228026×10 ⁻¹²	-2.990397×10 ⁻¹²	1.375859×10 ⁻¹²	-1.298123×10 ⁻¹²	7.488428×10 ⁻¹²
-2.842723	-2.13438	-0.8682924	0.4377229	1.679594	2.084069	-0.03778074	-2.16835	-1.796129	-0.6296557	0.5417072	1.677932	2.037682	-7.622464×10 ⁻¹²	-2.037682	-1.677932	-0.5417072	0.629655
-4.780359	-3.565968	-1.189369	0.4505428	2.206755	4.399285	-0.06348492	-4.535454	-2.37937	-0.7252095	0.6263983	2.225358	4.279277	2.756043×10 ⁻¹¹	-4.279277	-2.225358	-0.6263983	0.725209
-0.1550866	-0.1611716	-0.1492474	-0.1245987	-0.09639145	-0.07797703	-0.07388197	-0.06988651	-0.05125056	-0.02105121	0.008413693	0.02659669	0.02344966	-1.059221×10 ⁻¹⁰	-0.02344966	0.02659669	-0.008413693	0.0210512
4.459199	3.239941	0.8977427	-0.6826669	-2.370922	-4.524997	-0.07578147	4.382303	2.264662	0.6817699	-0.6007663	-2.152105	-4.210878	4.094768×10 ⁻¹⁰	4.210878	2.152105	0.6007663	-0.681769
2.479312	1.795976	0.6012571	-0.6167458	-1.746893	-2.092654	-0.07628286	1.948193	1.634066	0.5814737	-0.4919345	-1.536254	-1.879329	-1.616467×10 ⁻⁹	1.879329	1.536254	0.4919345	-0.581473
-0.4863957	-0.3671418	-0.2104716	-0.085732185	0.1195605	0.3138302	-0.07348132	-0.4612966	-0.2667083	-0.05683469	0.07988452	0.2739109	0.4318273	6.850159×10 ⁻⁹	-0.4318273	-0.2739109	-0.07988453	0.0568346
-3.766967	-2.57294	-0.9831755	0.5157536	2.056962	3.229076	-0.05823381	-3.354953	-2.213405	-0.7311327	0.6697977	2.124615	3.226088	-3.125512×10 ⁻⁸	-3.226088	-2.124615	-0.6697977	0.731132
-0.809139	-4.110792	-1.417137	0.9457983	3.233922	4.783472	-0.02175395	-4.840696	-3.336369	-1.142106	1.025808	3.195694	4.675291	1.254052×10 ⁻⁸	-4.675291	-3.195694	-1.025808	1.142106



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