Finite Element Analysis of Deep Beam with Calcpad

|  |  |
| --- | --- |
| Input data Length - m, Height - m  Thickness - m  **Loads**  Distributed load - kN/m  Load length - m  Load function - |  |

**Supports**

Support length - m

Support elastic stiffness - MN/m²

Support function -

**Material properties**

Modulus of elasticity - MPa

Poisson`s ratio -

## Finite element mesh

We will use rectangular finite element with DOFs

Number of elements along *l* and *h* - ,

Total number of elements -

Total number of joints -

Joint coordinates

m

m

Joint numbers for elements

Coordinates of element centers

m

m

Elements along the bottom (supported) edge -

Elements along the top (loaded) edge -

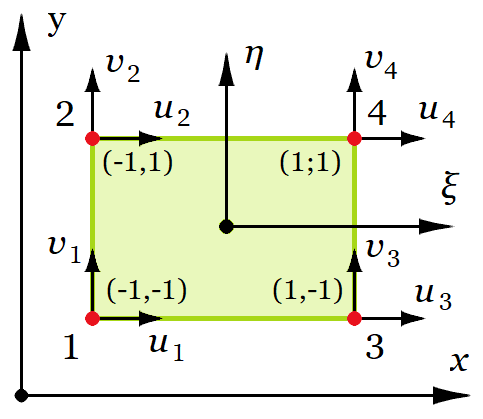
A chart with numbers and points

Description automatically generated with medium confidence

## Finite element formation

**Shape functions**

They are defined in relative coordinates to the center of the element:

⚓

Shape functions for joints at elements` corners

,

,

**Constitutive matrix** (stress-strain relationship)

**Strain-displacement matrix**

The elements of the stiffness matrix will be calculated by using direct integration

**Element stiffness matrix** (above the main diagonal only)

MN/m

**Boundary conditions**

**Supports**

Number of elements along the supported edge -

Element′s joint springs stiffness factors

Results for element 1

**Loads**

Number of elements along the loaded edge -

Element load vector

Results for element 100

## Solution

Global stiffness matrix -

Global load vector

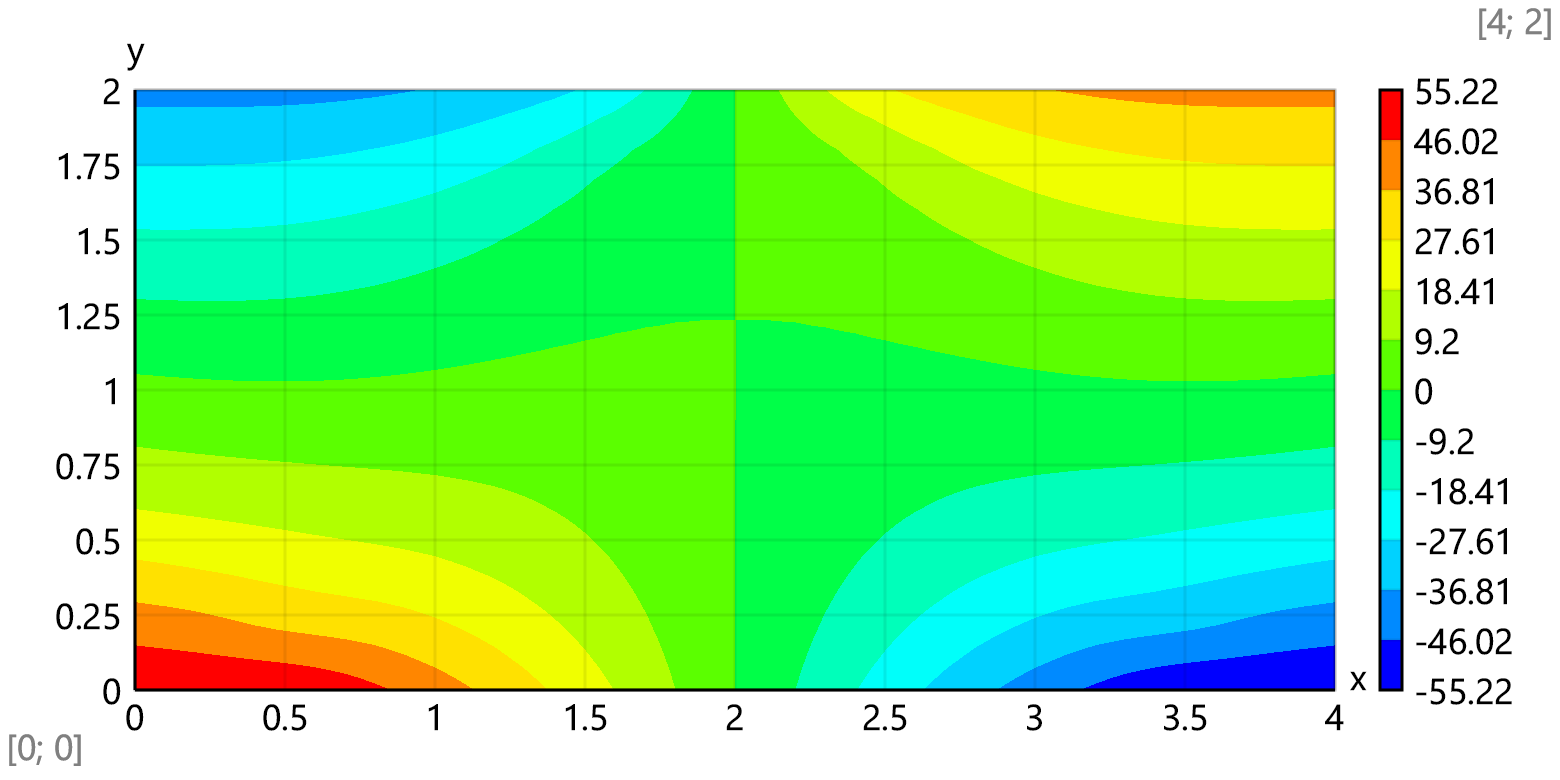
kN

Solution of the system of equations -

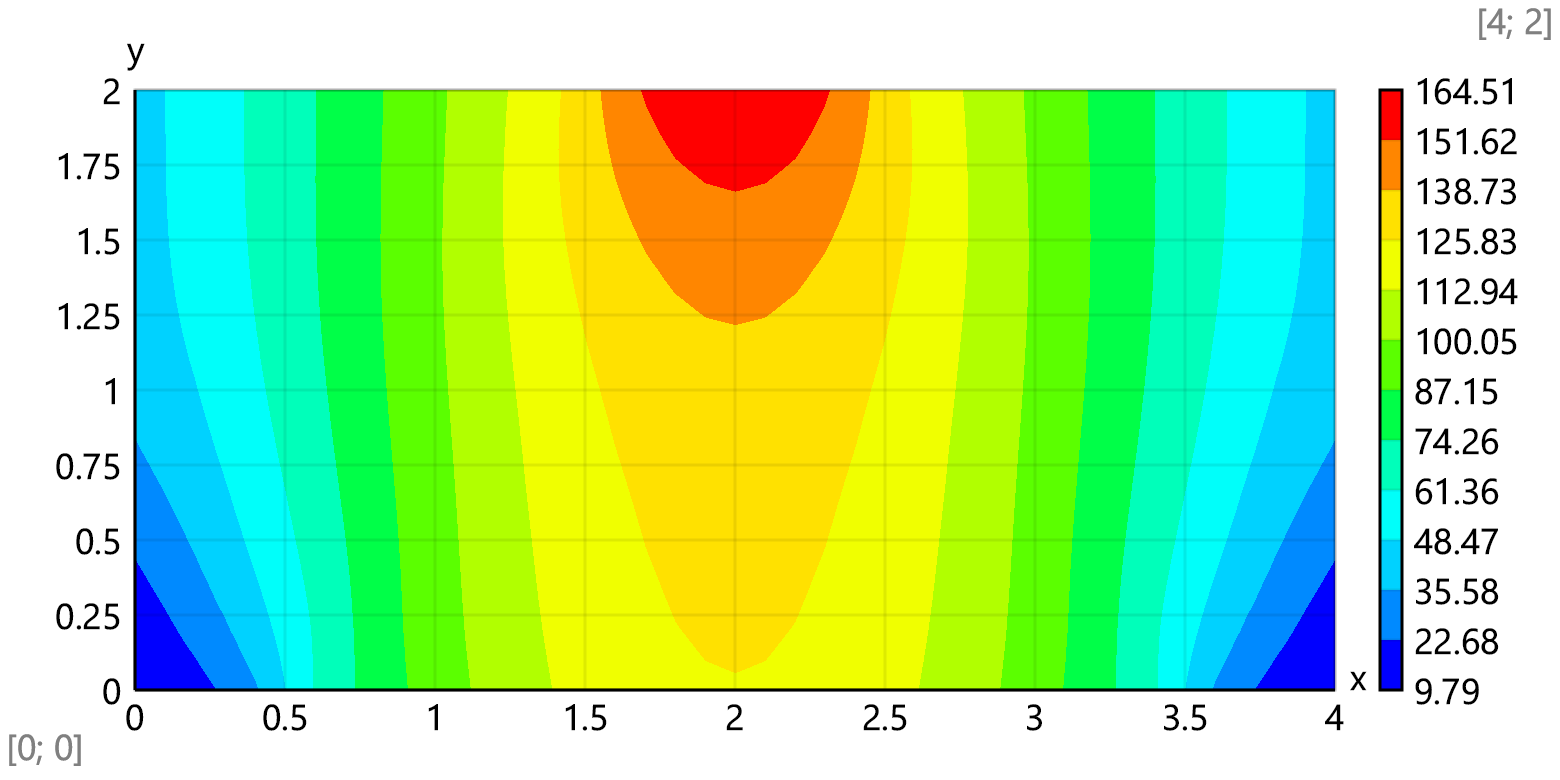
mm

## Results

Horizontal joint displacements, ·10-3mm -



Vertical joint displacements, ·10-3mm -



**Calculation of internal forces**

Displacements for joint -

Displacements for element -

Results for element 101 and joint 111:

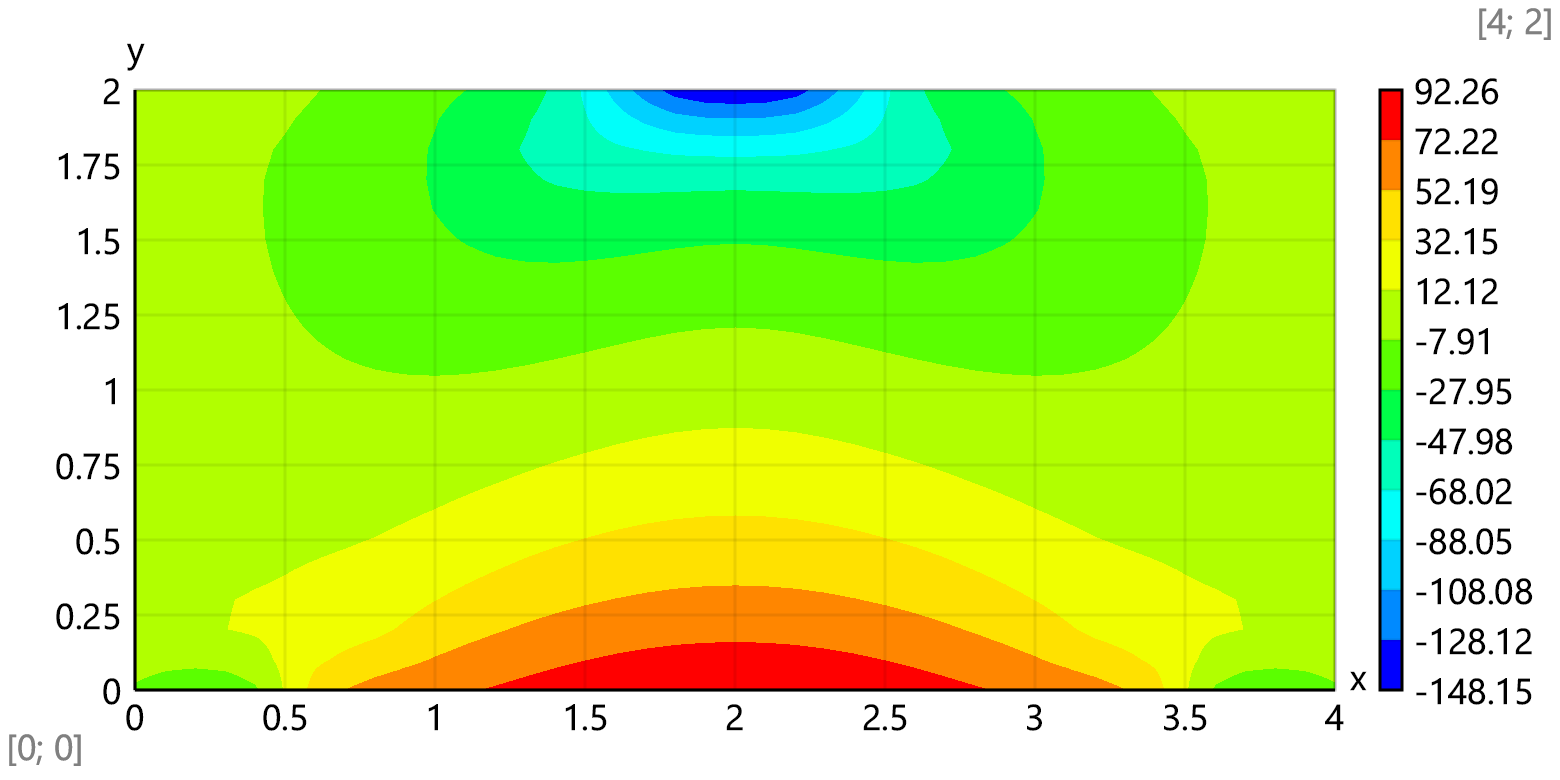
mm

kN/m

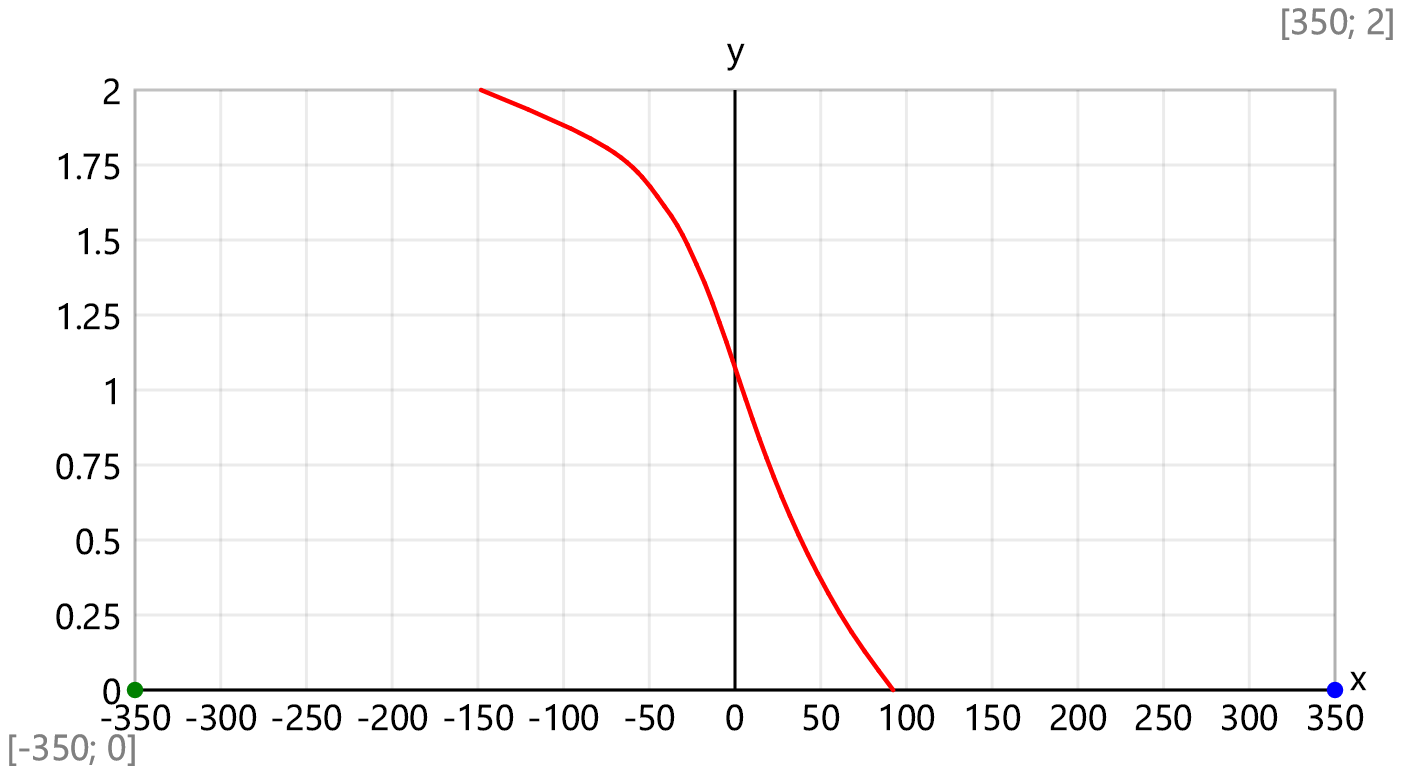
Average membrane forces at joints, kN/m -

**Membrane forces for the structure**

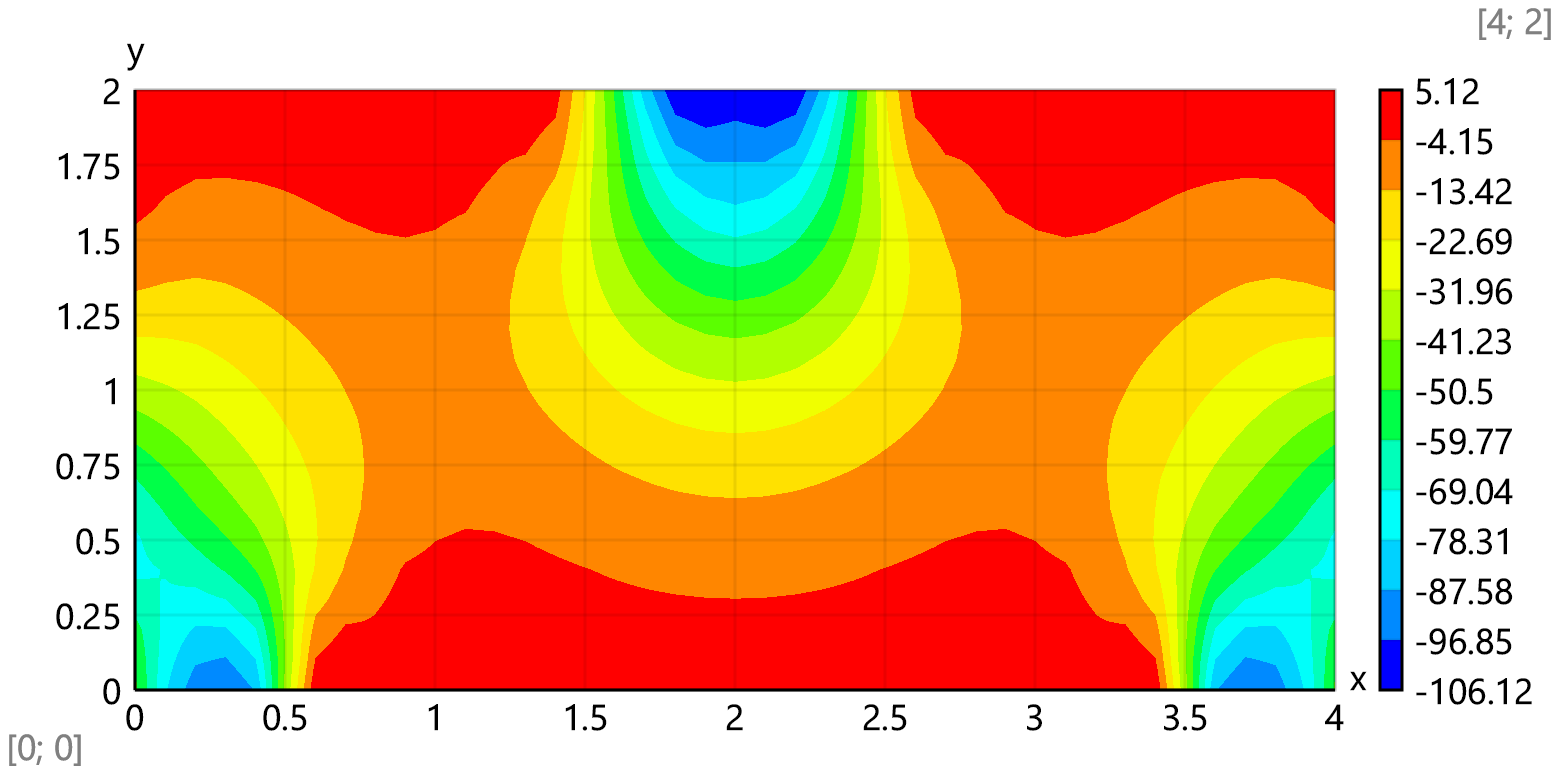
Normal membrane forces - *N*x, kN/m -

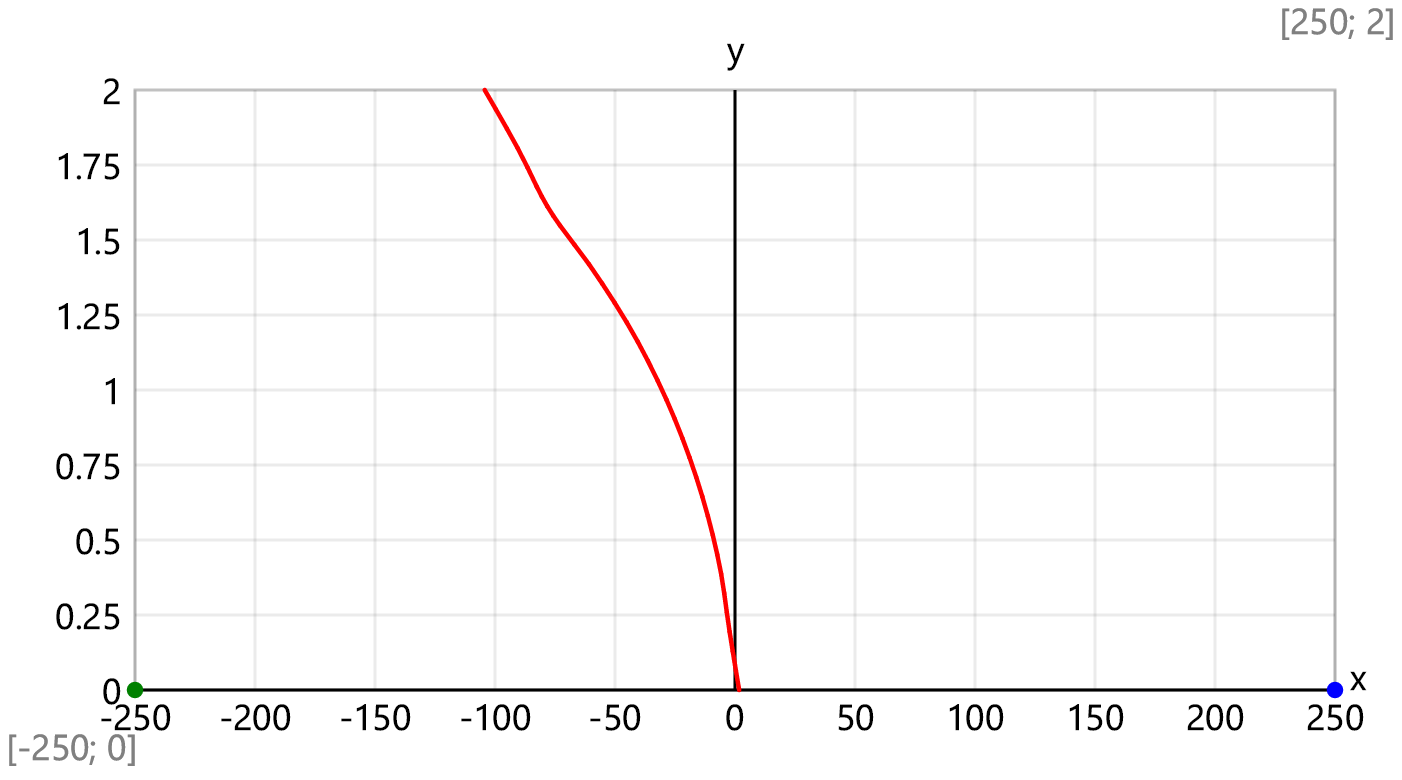


Plot for *Nx*, kN/m at *x* = *l*/2

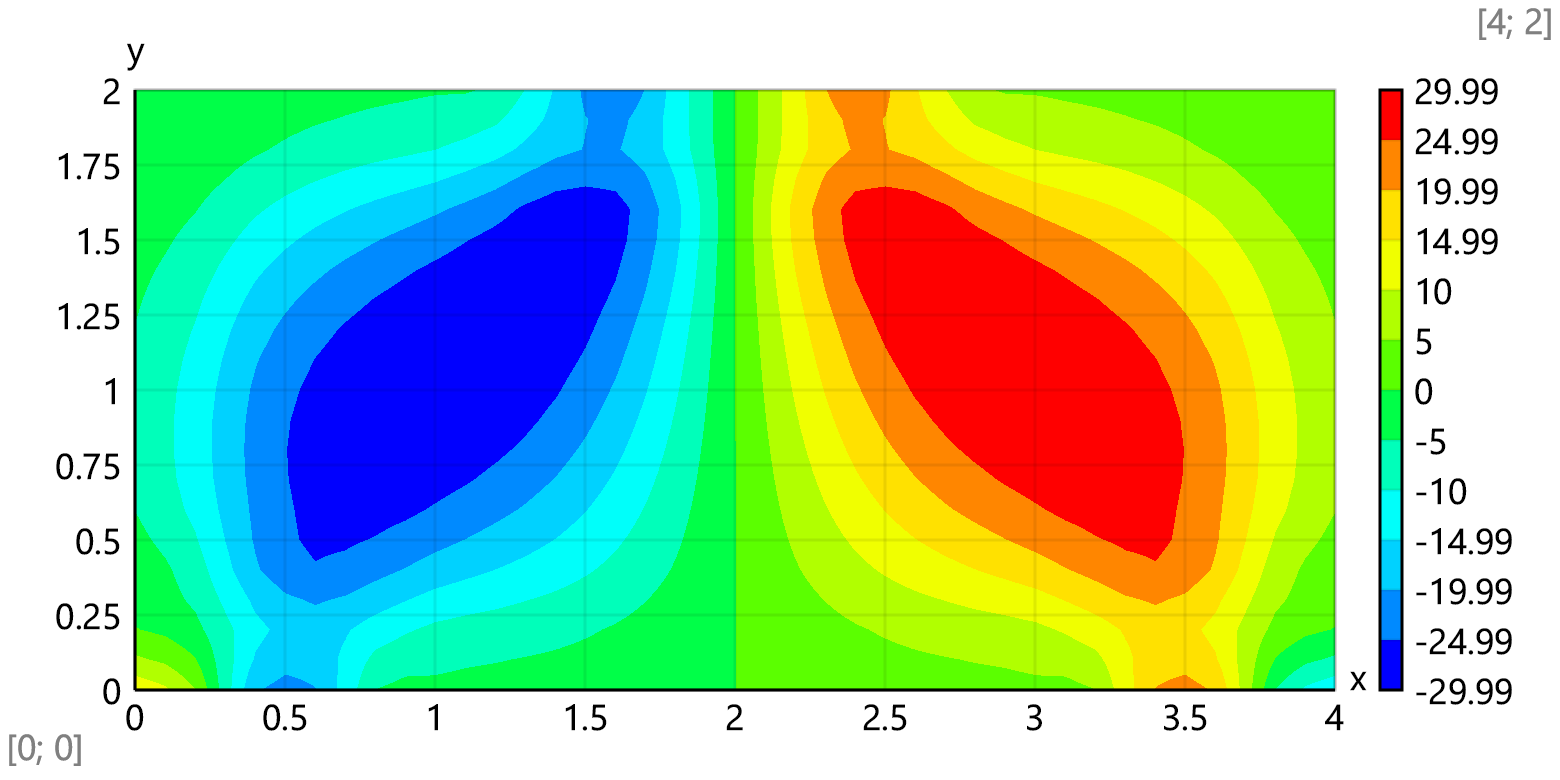


Normal membrane forces - *N*y, kN/m -



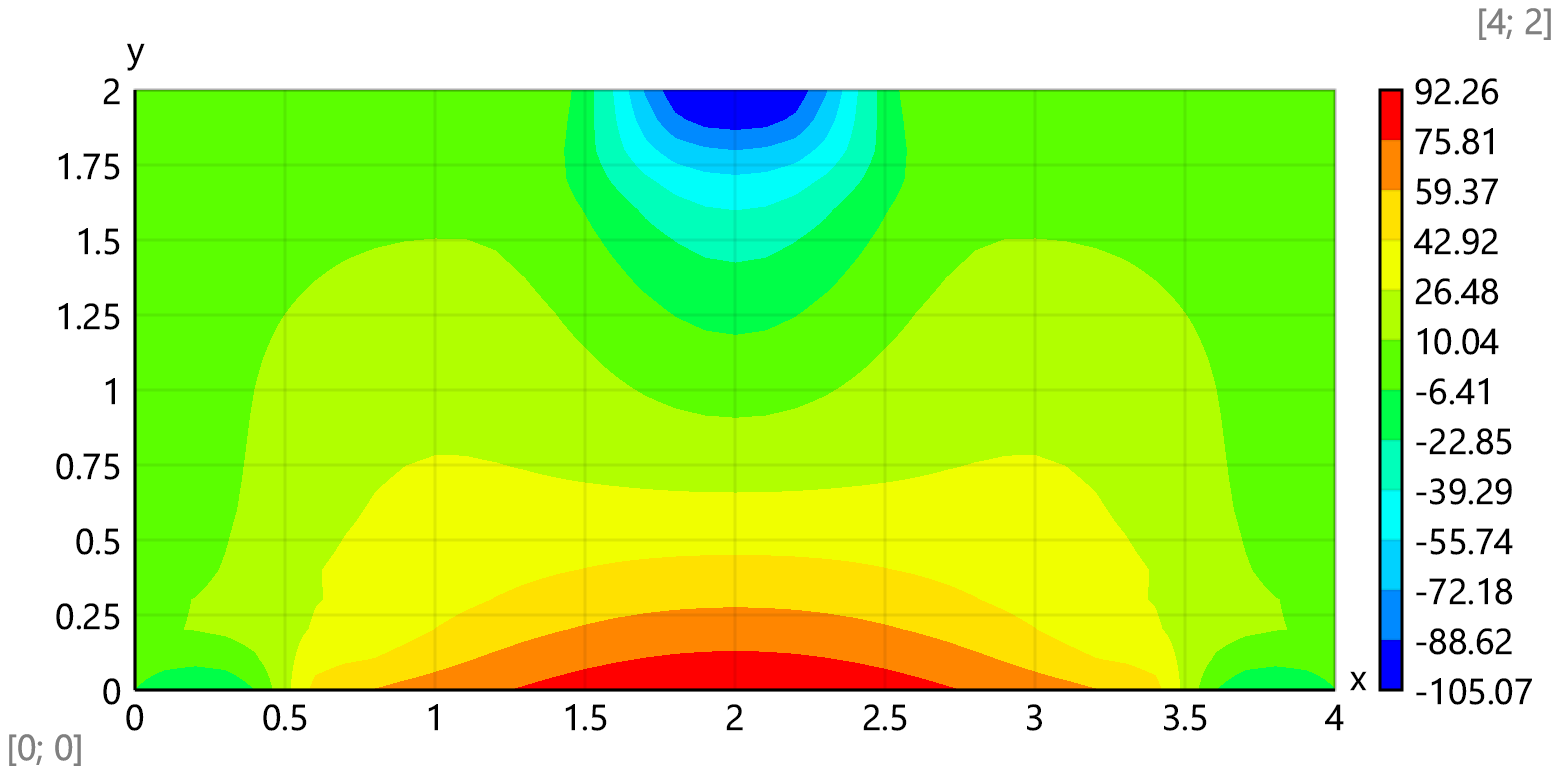


Shear membrane forces - *N*xy, kN/m -

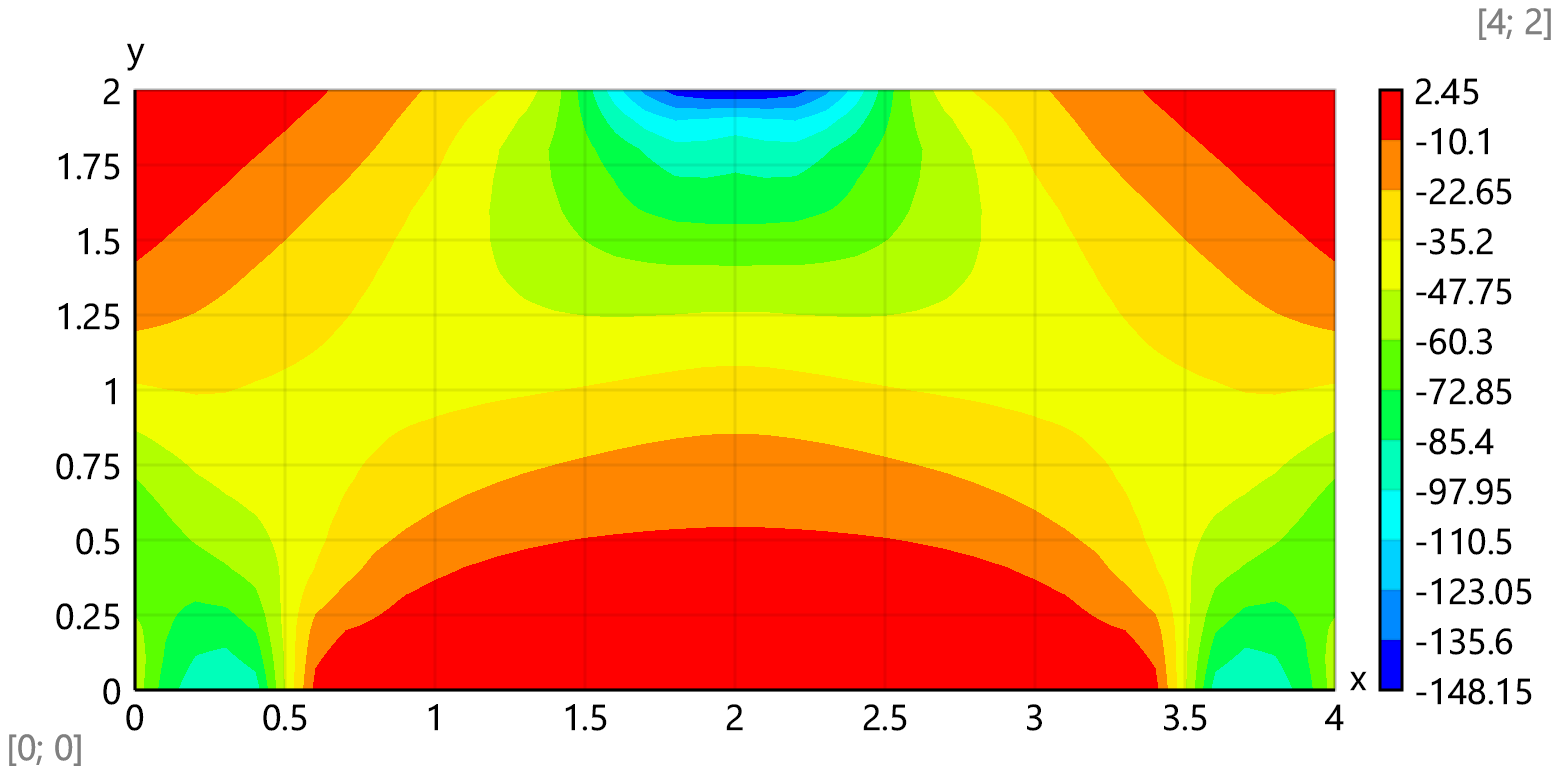


Principal membrane forces, kN/m

kN/m



kN/m



## Solution with SAP 2000

Input data

A screenshot of a computer

Description automatically generatedA red grid with yellow dots and green arrows

Description automatically generated

A screenshot of a computer

Description automatically generated

Results

Normal membrane forces - *Nx*, kN/m (F11)

A screenshot of a computer screen

Description automatically generatedA graph of a graph of a temperature

Description automatically generated with medium confidence

A purple square with black background

Description automatically generated Normal membrane forces - *Ny*, kN/m (F22)

A white square with black background

Description automatically generatedA graph of a rainbow

Description automatically generated

Shear membrane forces - *Nxy*, kN/m (F12)

A white square in a black background

Description automatically generatedA graph of a graph of a graph

Description automatically generated with medium confidence

Principal membrane forces - *N*max, kN/m (FMAX)

A graph of a rainbow colored spectrum

Description automatically generated with medium confidence

Principal membrane forces - *N*min, kN/m (FMIN)

A graph of a graph of a rainbow

Description automatically generated with medium confidence

## Analytical solution – Fourier series

Number of iterations -

Original and Fourier functions for the load

A green and red line graph

Description automatically generated

Original and Fourier functions for the reaction in supports

A black background with red and green lines

Description automatically generated

Calculation of stresses

A screen shot of a screen

Description automatically generated

Plot for *σx* at *x* = *l*/2

A red line on a black background

Description automatically generated

A screen shot of a rainbow

Description automatically generated

A screen shot of a graph

Description automatically generated

A screen shot of a screen

Description automatically generated

A screen shot of a screen

Description automatically generated

## Comparison of the results

|  |  |  |  |
| --- | --- | --- | --- |
|  | Analytical | FEA Calcpad | FEA SAP 2000 |
| *Nx*,btm, kN/m | 95,66 | 92,26 | 92,46 |
| *Nx*,top, kN/m | -147,56 | -148,15 | -150 |
| *N*y, kN/m | -92,32 | -104,3 | -103,97 |
| *Nx*y, kN/m | 29,96 | 29,95 | 30,91 |

Difference, %

|  |  |  |  |
| --- | --- | --- | --- |
|  | Analytical | FEA Calcpad | FEA SAP 2000 |
| *Nx*,btm, kN/m | 0,00% | -3,55% | -3,35% |
| *Nx*,top, kN/m | 0,00% | 0,40% | 1,65% |
| *N*y, kN/m | 0,00% | 12,98% | 12,62% |
| *Nx*y, kN/m | 0,00% | -0,03% | 3,17% |