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Supported by Croatian Science Foundation

Shape optimization of compression structures

IASS 2016 Tokyo
Spatial structures in 21st century

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Basic idea for design process of compression structures

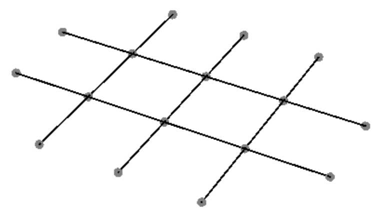
- tension – compression analogy
- kinematic constraints in force density method

$$q_{i,j}^{(k)} = q_{i,j}^{(k-1)} \frac{\overline{S}}{S_{i,j}^{(k-1)}}$$

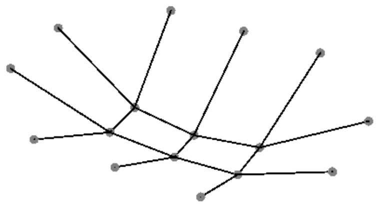
$$q_{i,j}^{(k)} = q_{i,j}^{(k-1)} \frac{\overline{S_{i,j}}}{S_{i,j}^{(k-1)}} = \frac{\overline{S_{i,j}}}{l_{i,j}^{(k-1)}}$$

$$q_{i,j}^{(k)} / q_{i,j}^{(k-1)} = l_{i,j}^{(k-1)} / l_{i,j}^{(k)}$$

$$q_{i,j}^{(k)} = \frac{S_{i,j}^{(k-1)}}{\overline{l_{i,j}}}$$



iteration



tension-compression analogy

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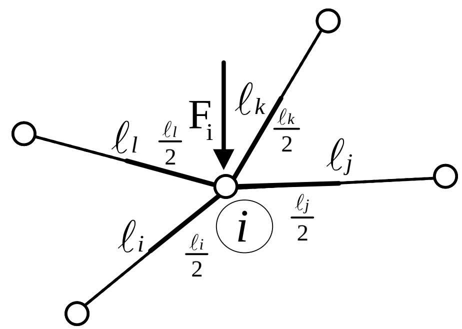
Basic idea for design process of compression structures

- vertical concentrated load in nodes

$$F_i = \frac{1}{2}\ \ell_i + \ell_j + \ell_k + \ell_l$$



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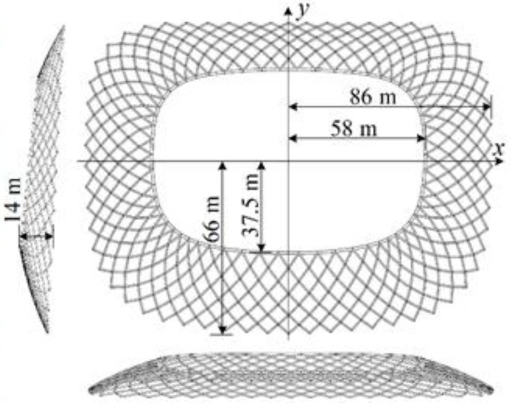
Definition of case study

- initial geometry: roof design of new stadium Kantrida in Rijeka, Croatia



- model A: target force in inner ring was set to 2100kN and in all other elements 150kN
- model B: elements of the same length (6.40m) while elements of inner ring have axial force 2000kN

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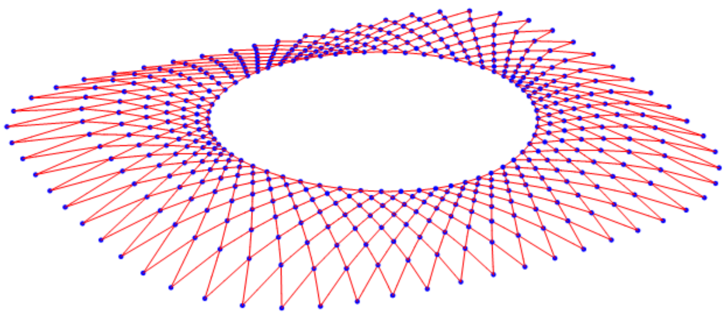
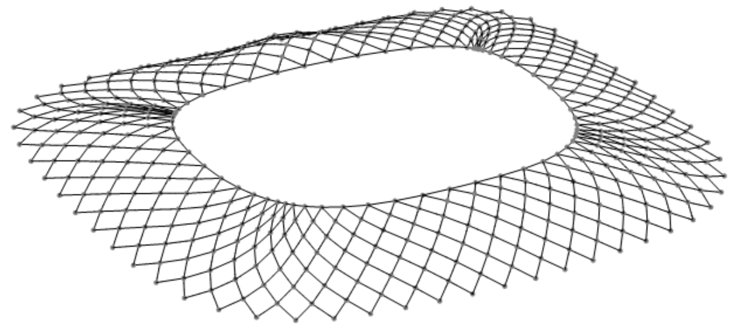
Results of form finding

model A



model B



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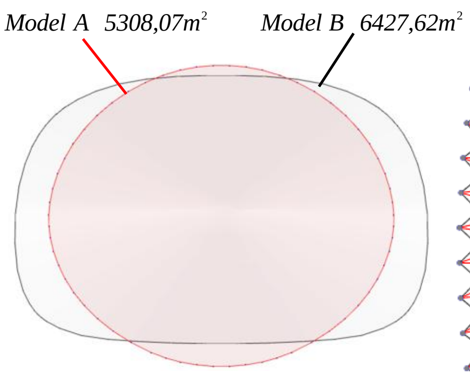
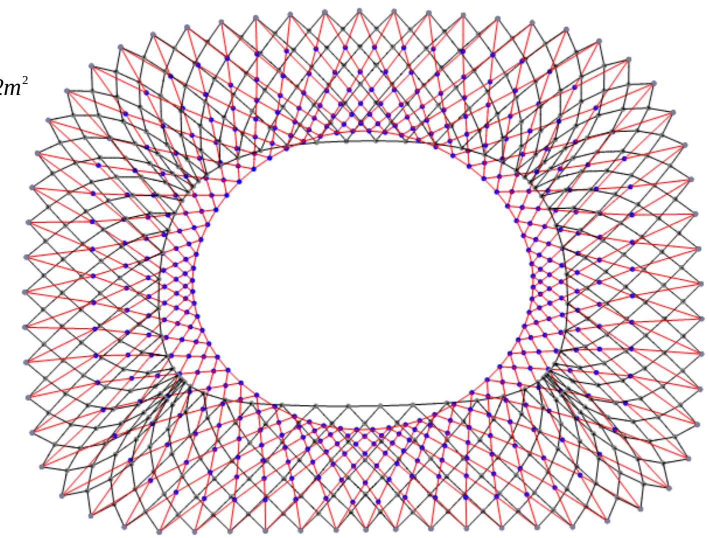
Results of form finding

- Fairly similar area closed with inner ring





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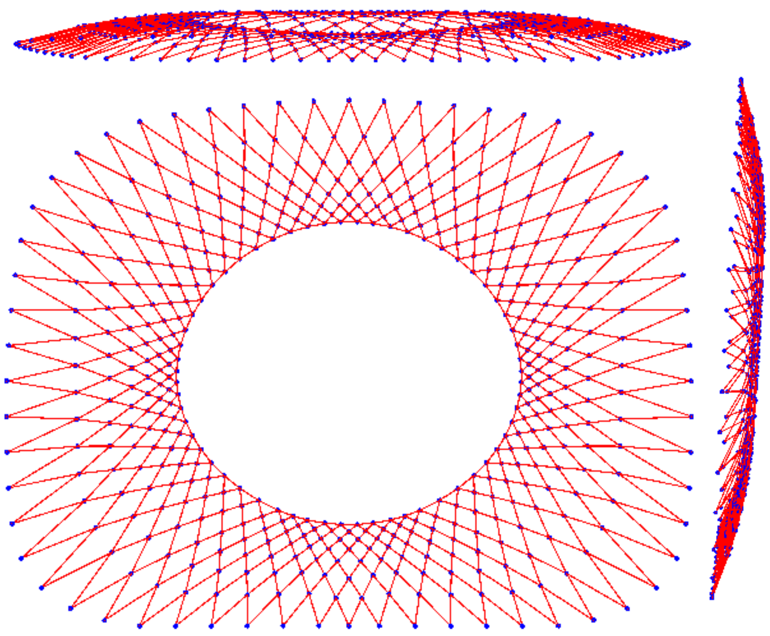
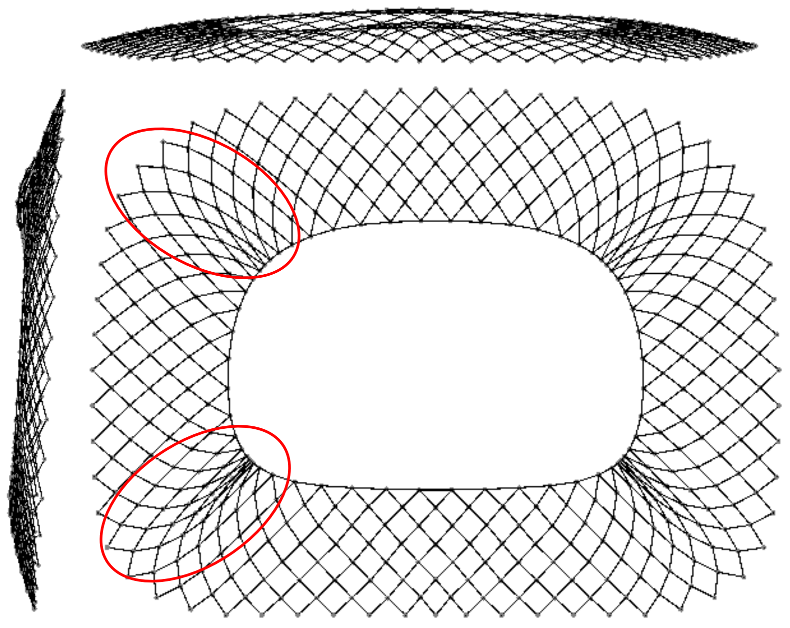
Results of form finding

- Both models are smaller in height by 2m compering then with initial geometry
- Disposition of elements in model A is favorable from the point of construction (in model B accumulation of elements occur)





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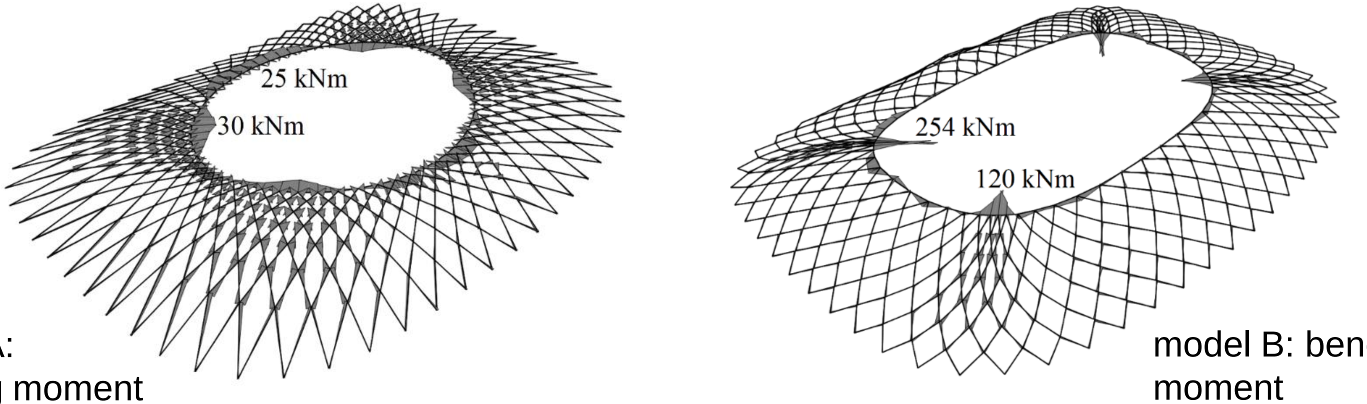
Structural analysis

- Comparisons between initial geometry (roof of new stadium Kantrida) and model A and B
- Observed parameters: displacement and distribution of internal forces
- Cross sections:
  - inner ring steel tube 813/25mm,
  - other elements tube 457/12,5mm.
- Rigid connections - bending moments in the structural analysis after optimization



model A: bending moment

model B: bending moment

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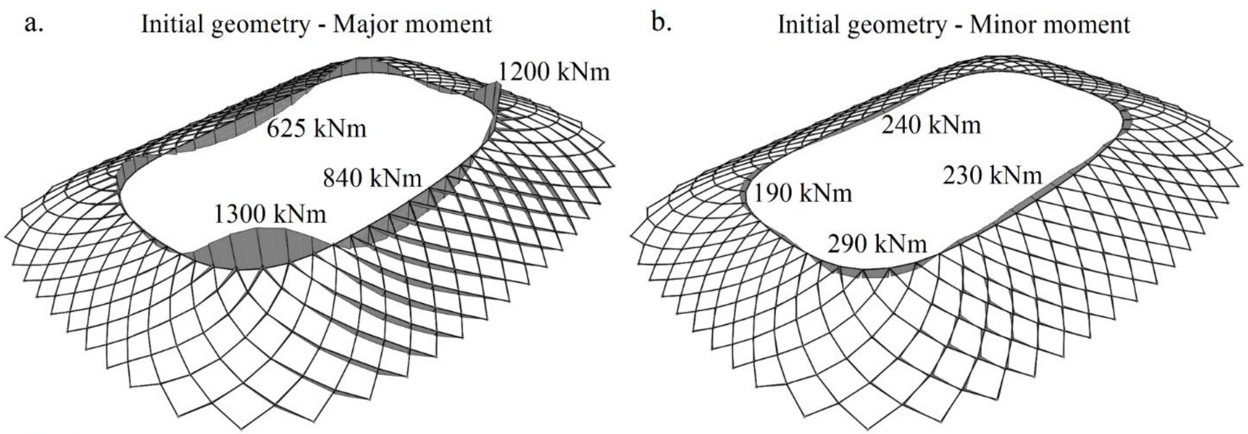

distribution of major moment in the elements of grid, $M_{major} \approx -150$ kNm $\leftrightarrow$ $M_{major} \approx 220$ kNm

distribution of minor moment in the elements of grid, $M_{\text{minor}} \approx -98$ kNm $\leftrightarrow$ $M_{\text{minor}} \approx 98$ kNm

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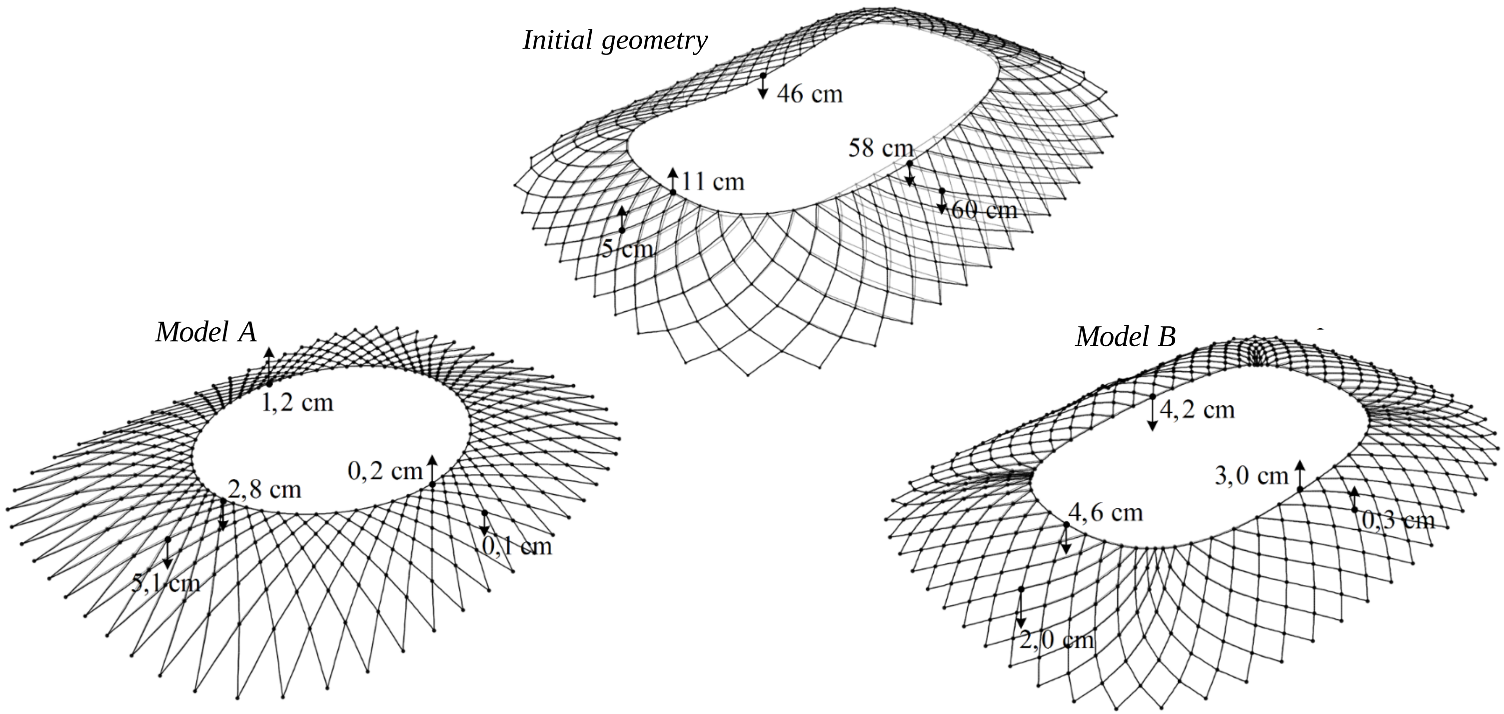
Structural analysis: displacements



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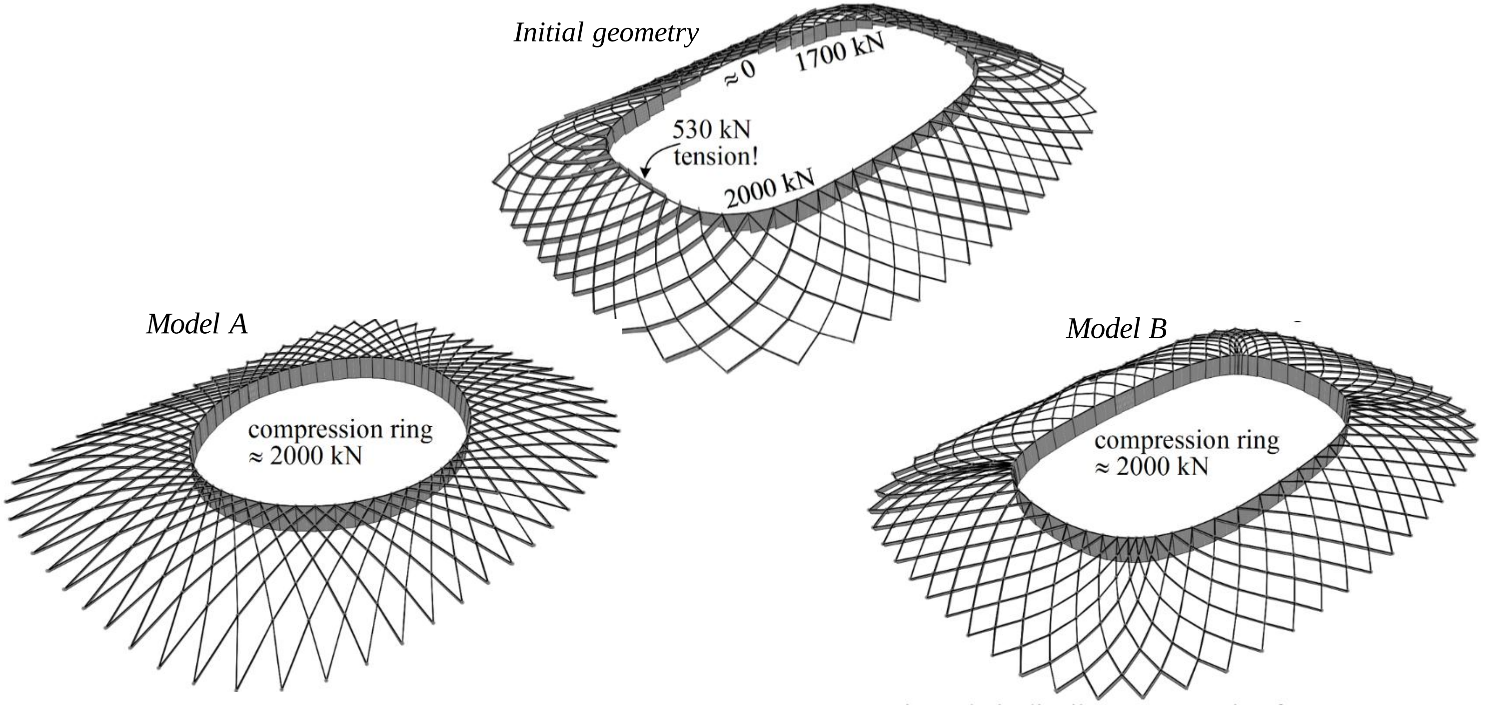
Structural analysis: axial force



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In future

- Implementation to solver: calculation of vertical concentrated load from the value of area between points
- Optimisation from stability point of view

THANK YOU

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