The University Day Ceremony

22 November 2019, Budapest

Óbuda University

Pro Scientia et Futuro

Stanislav Kmet

Thanks

Óbuda University

Pro Scientia et Futuro

Honourable Rector Magnificus, Honourable Deans Spectabilities, Honorabilities, Dear Members of the Senate of the university, Dear Members and Students of the University Community, Distinguished Guests, Dear Ladies and Gentlemen.

I can not imagine more honor than the one that is being received me from your ancient University today, whose origins date back deeply into the nineteenth century.

Óbuda University

Pro Scientia et Futuro

First of all let me say how honoured and extremely grateful I am to the Senate of the Óbuda University, the Rector Prof. Dr. Levente Kovács and Dr. h. c. professor Dr. Imre Rudás for bestowing upon me the title Professor Honoris Causa. I accept it joyfully both for myself and also on behalf of all the people with whom I have worked for the last more than 35 years.

I have been always very glad that I had an opportunity to meet and cooperate with excellent peoples and researchers from your university.

I would like to assure you that I will continue to spread the excellent prestige and reputation of your University and look forward to further cooperation. Thank you once again, Mr. Rector and professor Rudas, for this great honour.

I wish you all great success in the future. Thank you, my friends.

Allow me now present some information about my research and work of my team.

The University Day Ceremony

22 November 2019, Budapest

Óbuda University

Pro Scientia et Futuro

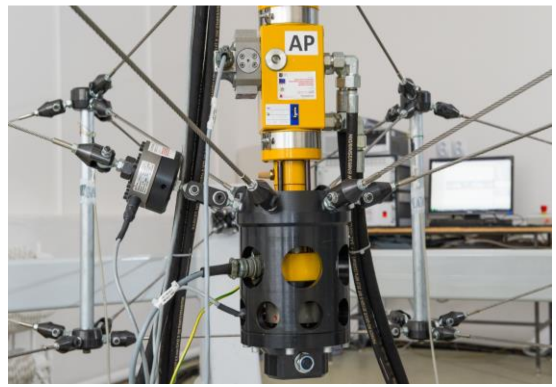
Stanislav Kmet

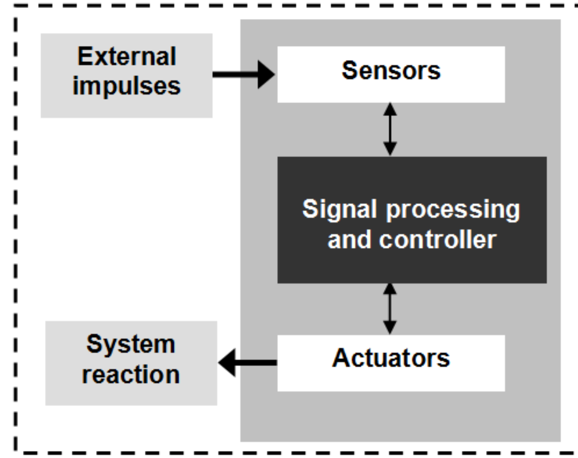
Adaptive lightweight cable, membrane and tensegrity systems controlled by artificial intelligence methods

Faculty of Civil Engineering - Institute of Structural Engineering

A scientific team for computational and experimental analysis of adaptive structures

Why adaptive structures: ***Are able to resist to the extreme loads***





Adaptive system – basic principle

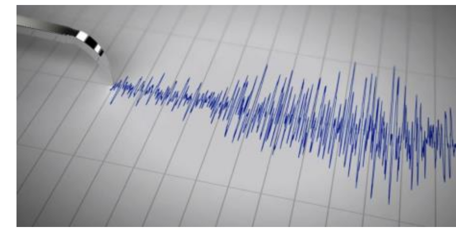
Chameleon: a Natural Adaptive System

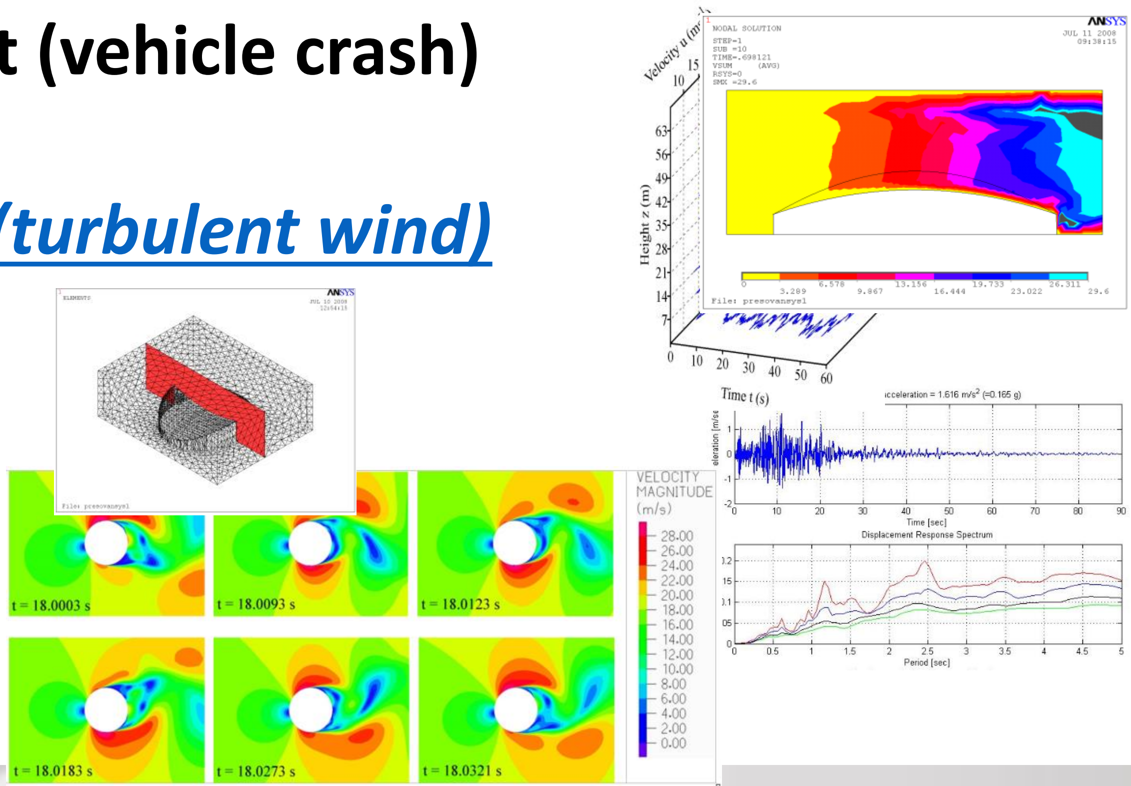
Top Scientific Teams

A scientific team for computational and experimental analysis of adaptive structures

Accidental loads = short duration but significant quantity

- **Seismic load (earthquake)**
- **Impact (vehicle crash)**
- **Snow**
- ***Wind (turbulent wind)***

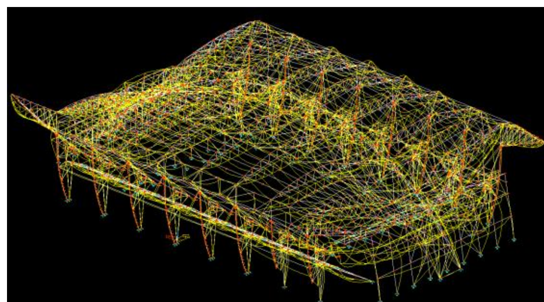




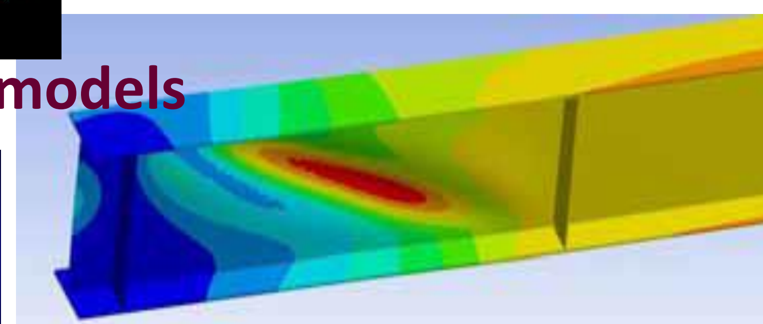
Solutions how to resist to the accidental loads: adaptive structures

A scientific team for computational and experimental analysis of adaptive structures

Experimental analysis



Computational models



INSTRON ±2500 kN testing machine (4 in Europe)

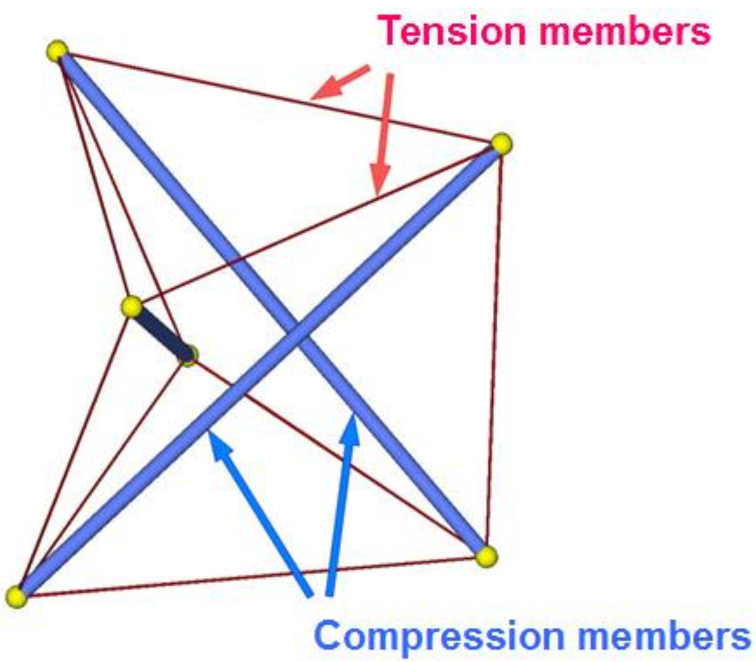
Top Scientific Teams

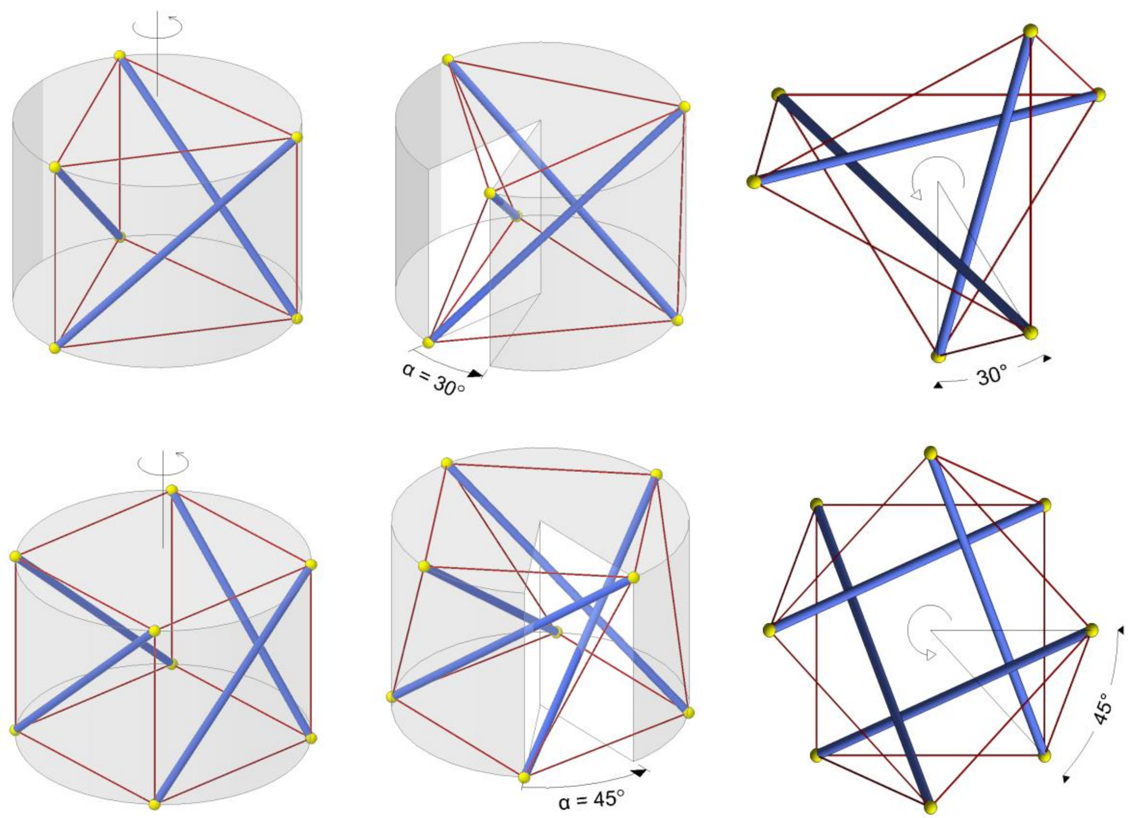
Definition – what are tensegrities?

"A tensegrity system is a system in a stable self-equilibrated state comprising a discontinuous set of compressed components inside a continuum of tensioned components." by *René Motro*

$$\alpha = \frac{\pi}{2} - \frac{\pi}{n} = 90^{\circ} - \frac{180^{\circ}}{n}$$

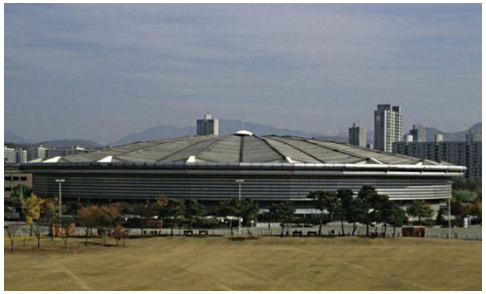
(**Rotation angle** by Tobie and Kenner)



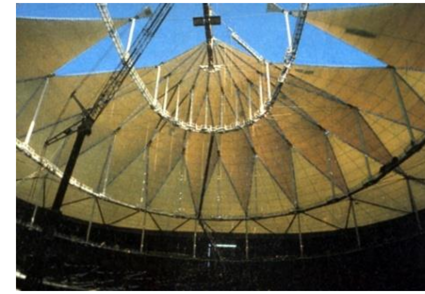


Tensegrities in civil engineering and architecture

Olympic Gymnastics Arena *- D. H. Geiger (Soul, South Korea)*

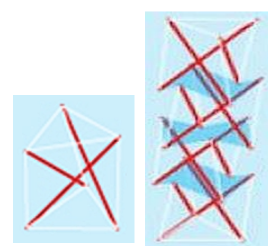


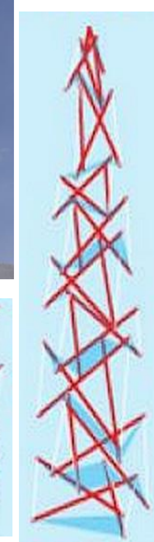
Georgia Dome *- M. P. Levy (Atlanta, USA)*

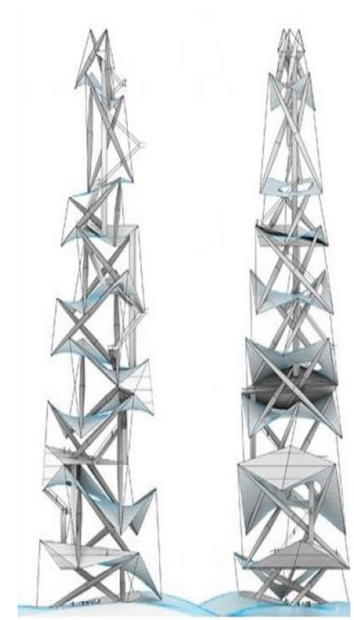


Warnow Tower *- M. Schlaich (Rostock, Germany)*

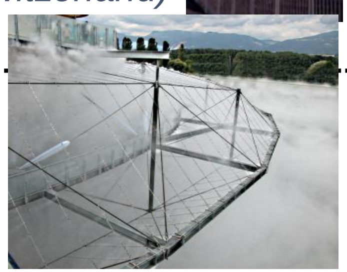
Dubai Tensegrity Tower *- A. V. Richthofen*
(Dubaj, United Arab Emirates)







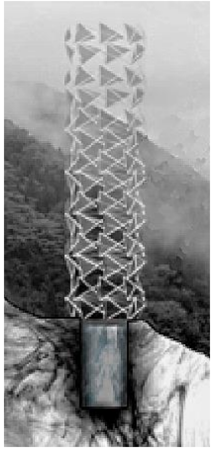
Blur Building, Expo 2002 - *Passera and*
M. Pedretti(Yverdon-les-Bains, Switzerland)



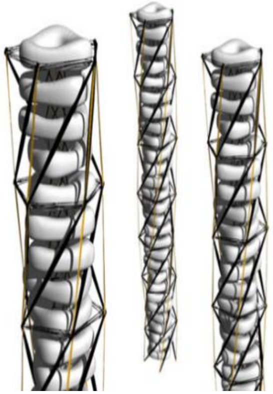
Tensegrities in civil engineering and architecture

Sky Well Tower *- P. Blicharski, et al. (Nepal)*

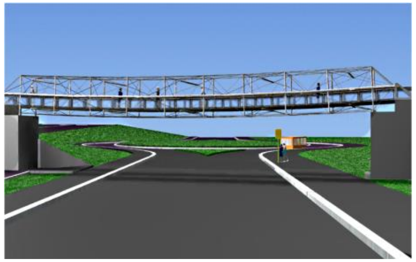




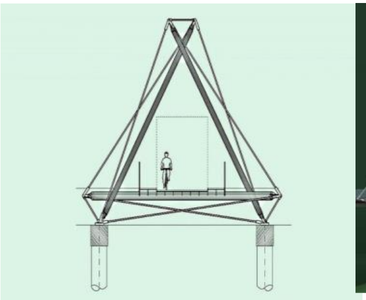
Filamentosa *- Orambra (Chicago, USA)*

Passerella Tor Vergata *- A. Micheletti (Roma, Italy)*

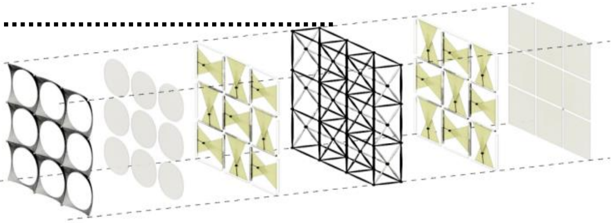



Tensegrity bridge *- Ahlbrecht Baukunst (Essen, Germany)*

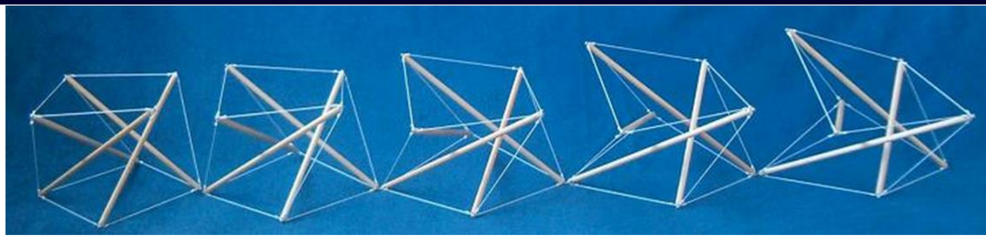



Tensegrity fasades *–*
S. Verma,
P. Devadass
(Barcelona, Spain)



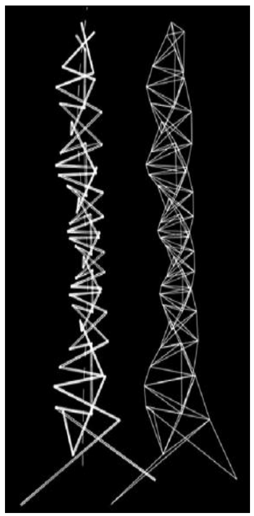


Tensegrities in civil engineering and architecture

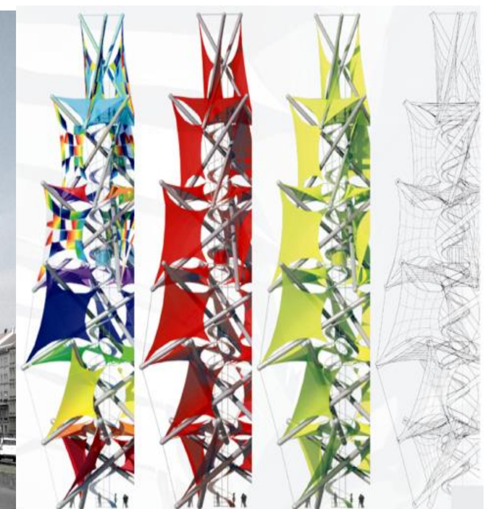


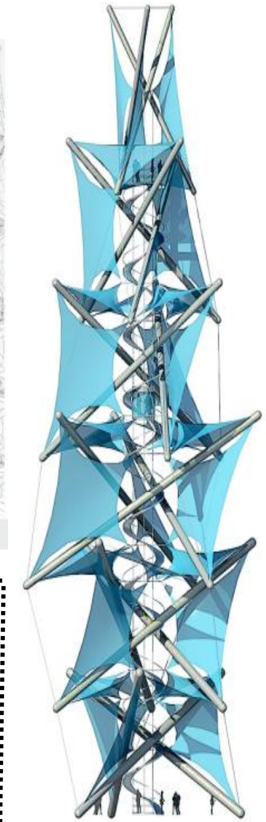
Irregular configurations of S4 T-prism

***Tensegrity Tower** - G. Fragerstrőm (Tokio, Japan)*

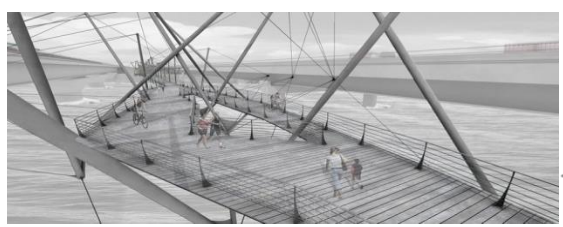


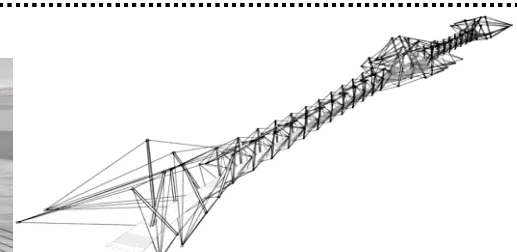
***Tensegrity Membrane Tower** - P. Borůvka (Prague, Czech Republic*





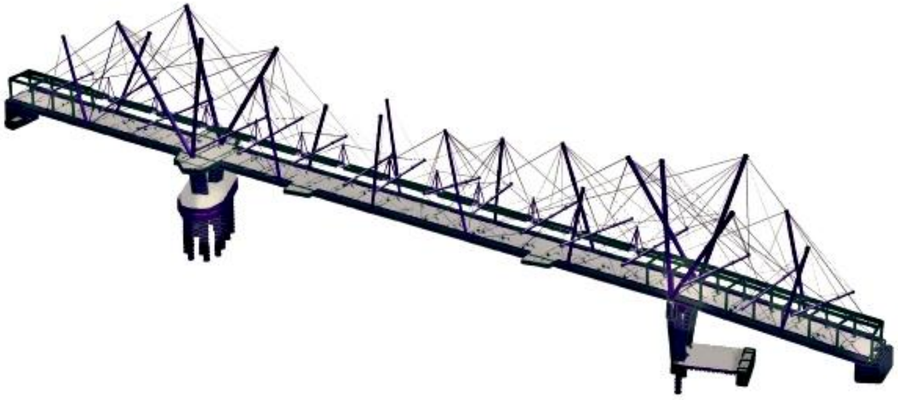
***Suspended Tensegrity Bridge** - S. Paradiso (Greggio, Italy)*





Tensegrities in civil engineering and architecture

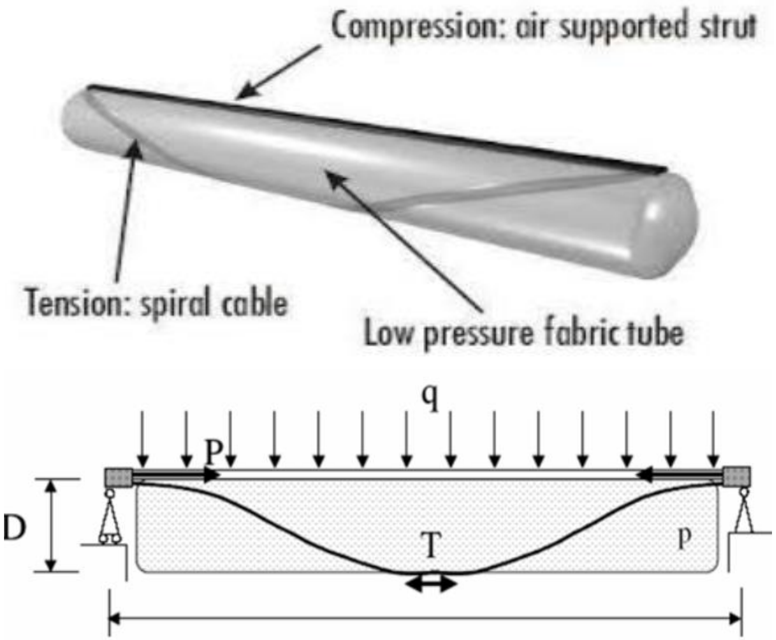
Kurilpa Bridge, tensegrity pedestrian bridge (2009) - Arup Group Limited (Brisbane, Australia)

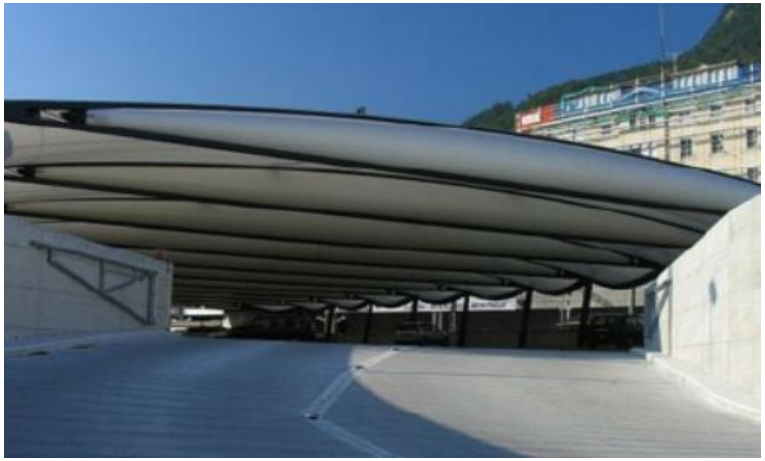


Total length = 470 m

Blur Building, Expo 2002 - *Passera and M. Pedretti (Yverdon-les-Bains, Switzerland)*

Tensairities in civil engineering and architecture



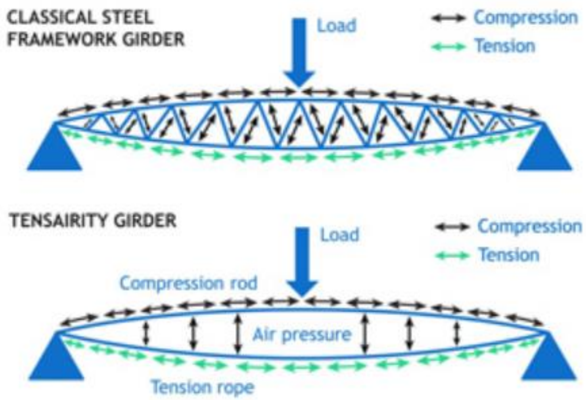


Tensairity applications:
Roof over a parking garage in Montreux

The tensairity concept (Luchsinger et al. 2004)

Basic components of the girder

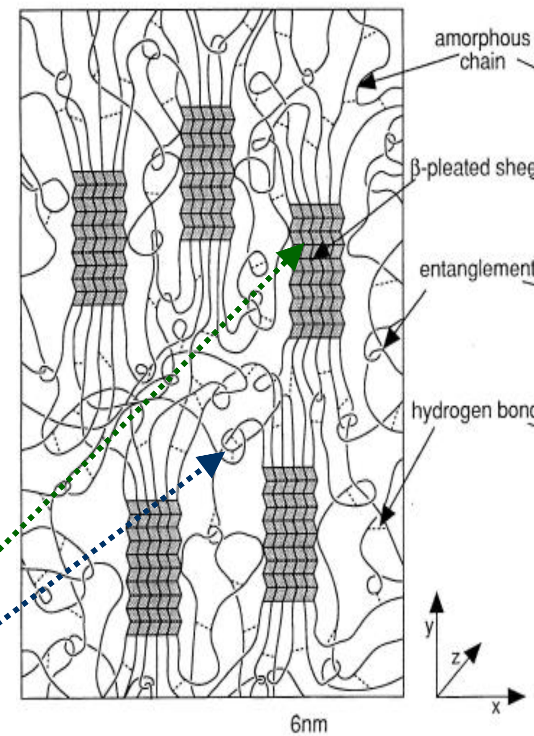
- Compression rod
- Air pressure
- Membrane – textile tube
- Tension cable



Spider fibers are tensegrities - biotensegrities

- **Tensegrity structures are motivated from biology**:

The nanostructure of the ***spider fiber is a tensegrity*** structure. ***Nature's endorsment of tensegrity structures*** warrants our attention because per unit mass, ***spider fiber is the strongest natural fiber***.



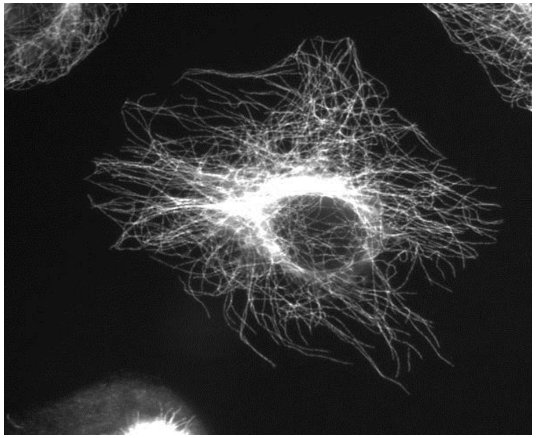
Tensegrity model: *the rigid bodies are* ***β - pleated sheets*** *and the tension members are the amorphous* ***strands*** *that connect to the rigid sheets*

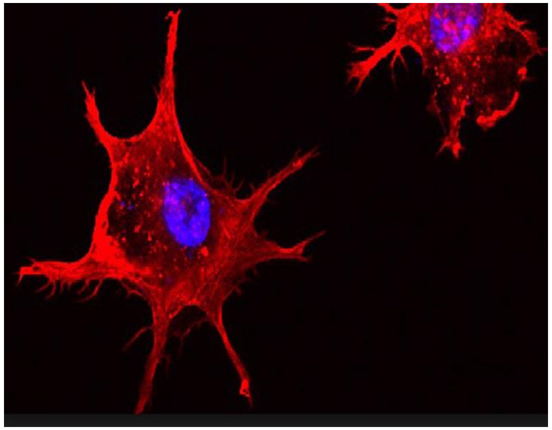
Benefits of tensegrity (*Biotensegrity*)

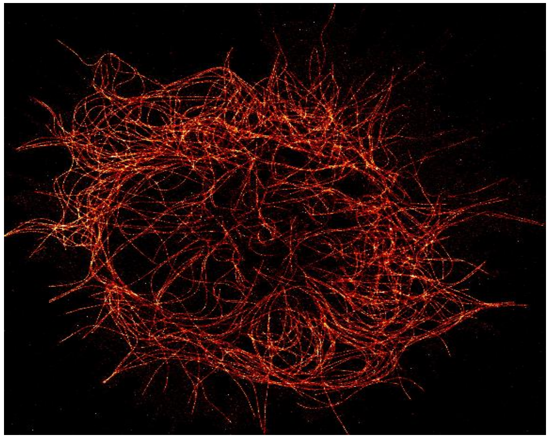
Human cells are tensegrities - biotensegrities

Articles by ***Ingber*** argue that the **tensegrity is the fundamental building architecture of life.**

His observations come from experiments in cell biology, where prestressed truss structures of the ***tensegrity type*** have been observed in ***cells***.

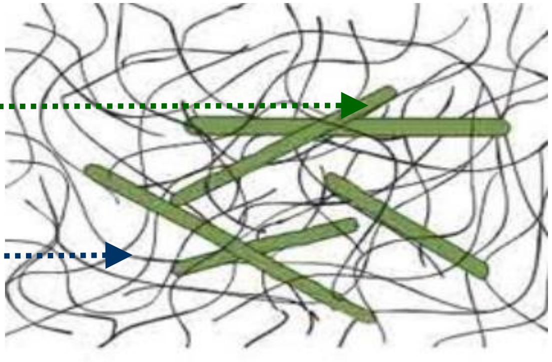






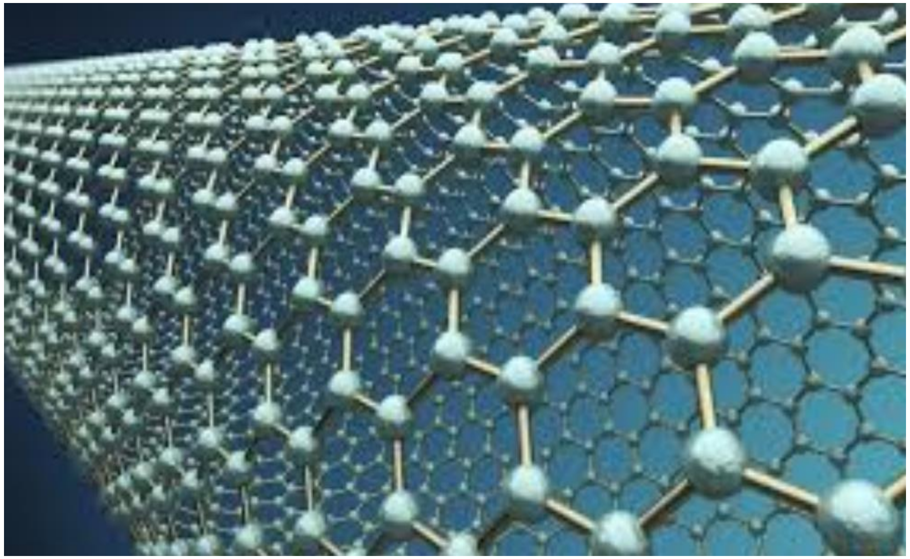
Cytoskeleton – the movers and shapers in the cell.

Microtubules (green rods) placed inside an intermediate filament network – tensegrity system.



Carbon nanotubes are tensegrities

Carbon nanotubes are the strongest and stiffest materials yet discovered in terms of ***tensile strength*** and ***elastic modulus***.

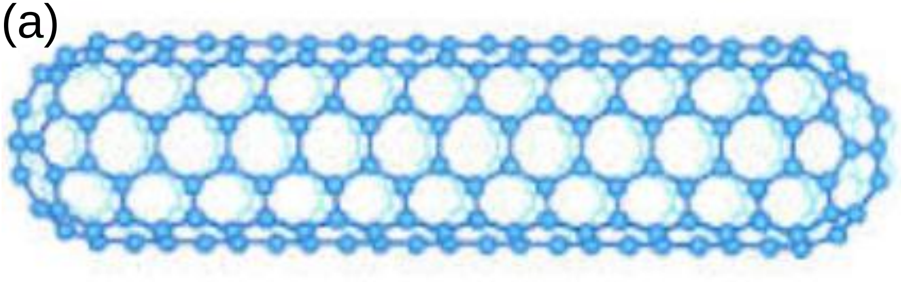


Single-walled nanotubes (*SWNT*)

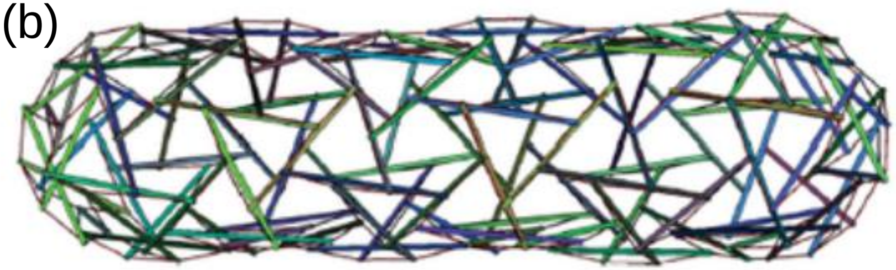
Material	Young's modulus	Tensile strength
(-)	(*MPa*)	(*MPa*)
SWNT	$1x10^6 \div 5x10^6$	$13x10^3 \div 53x10^3$
Stainless steel	$0.21x10^6$	$0.38x10^3 \div 1.55x10^3$

Capped carbon nanotube (a) topology and (b) tensegrity model by Li, Feng, Cao and Gao

(a)



(b)



Constructing tensegrity structures from one-bar elementary cells by Yue **Li**, Xi-Qiao **Feng**, Yan-Ping **Cao** and Huajian **Gao**, Proc. R. Soc. A 2010 466, 45-61, doi: 10.1098/rspa.2009.0260

Benefits of tensegrity (Carbon Nanotubes)

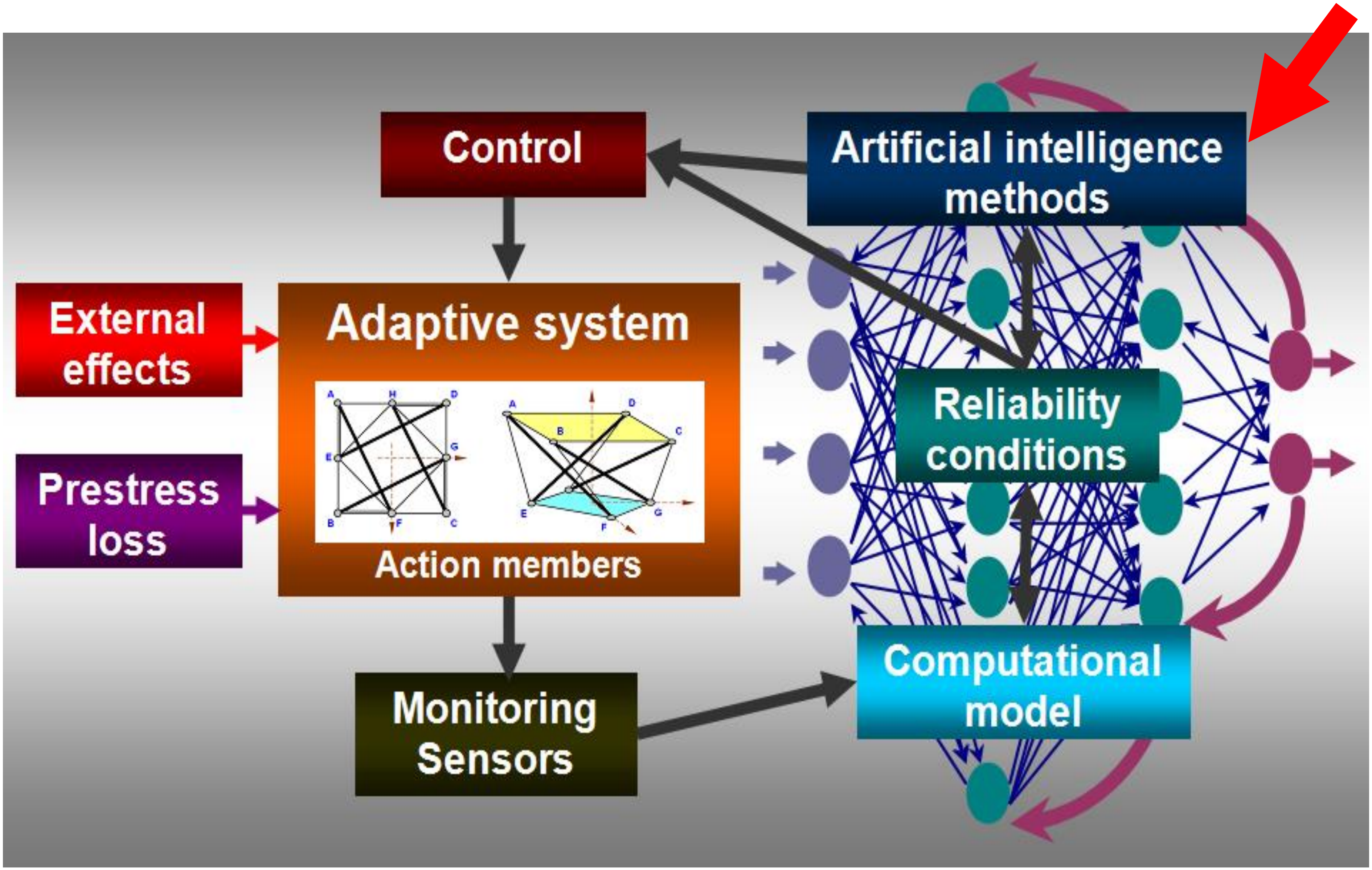
Applications of the methods of artificial intelligence in the structural engineering

►Traditional methods for modelling and optimizing complex structural systems require huge amounts of computing resources

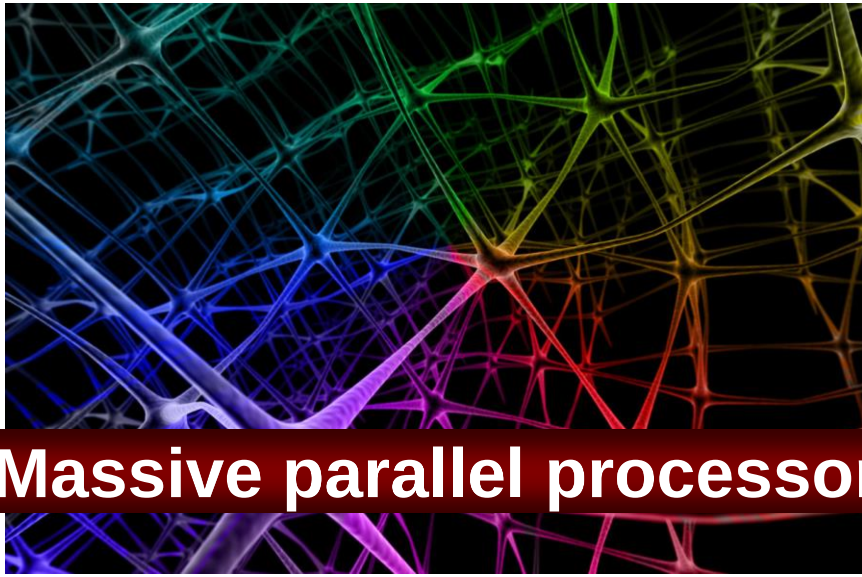
►Artificial-intelligence-based solutions can often provide valuable alternatives for efficiently solving problems in the structural engineering

►This part summarizes recently developed methods and approaches in the applications of artificial intelligence in structural engineering, **including neural networks and evolutionary computation, as well as others like chaos theory.**

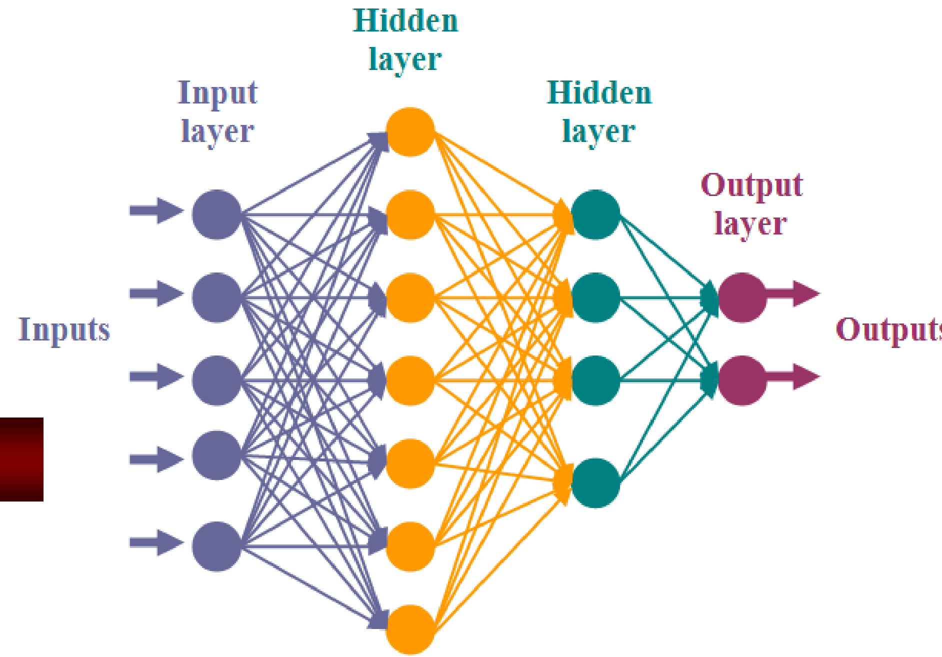
Basic scheme of the control, monitoring, computation and assessment philosophy of adaptive systems



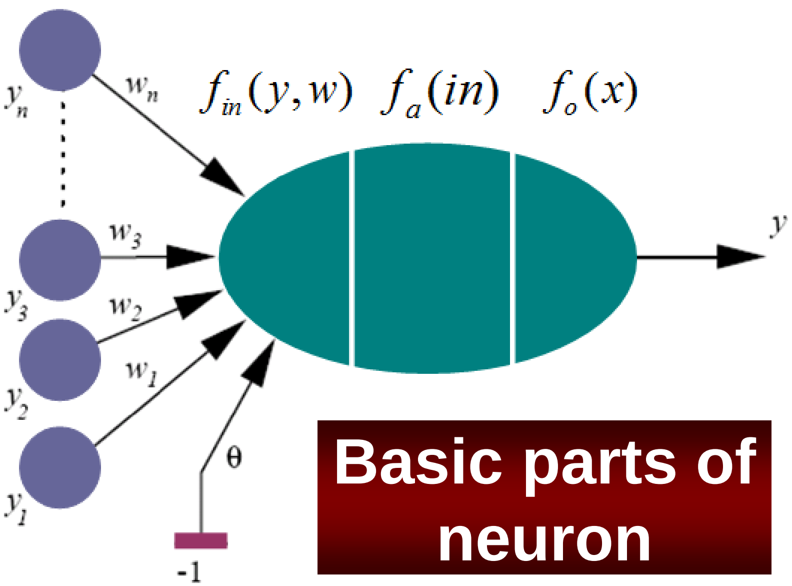
Artificial neural networks - successful uses



Massive parallel processor



Multilayer perceptron



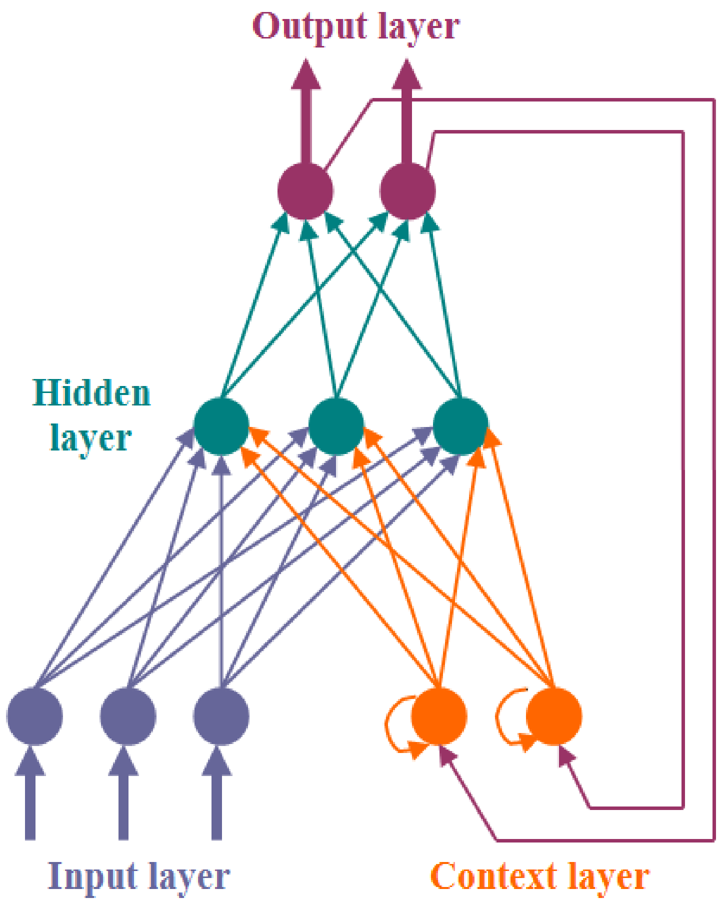
Basic parts of neuron

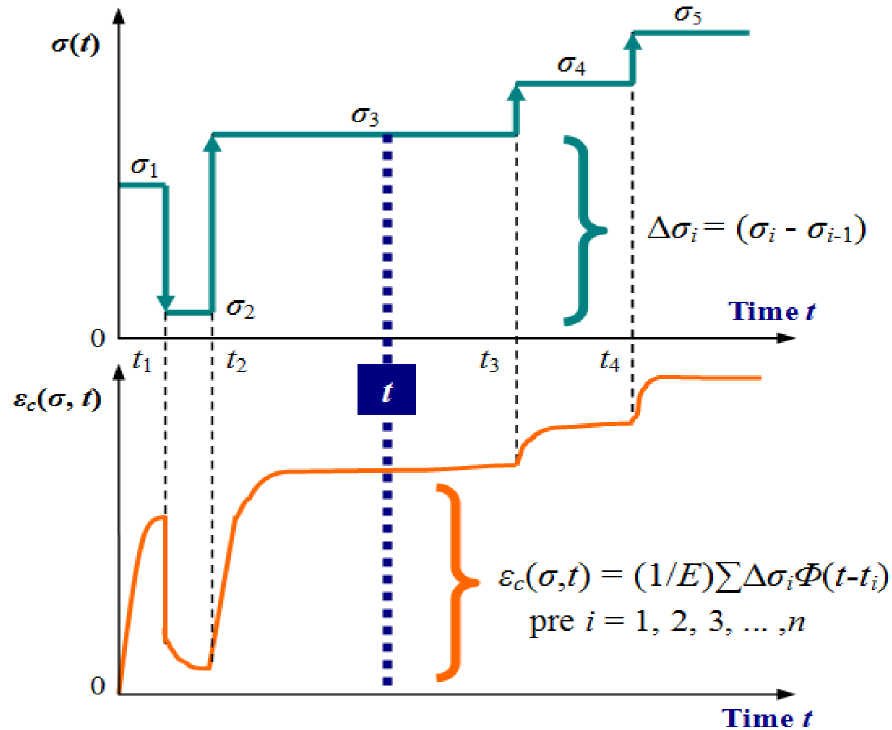
$f_{in}(y,w)$ - **Input function**

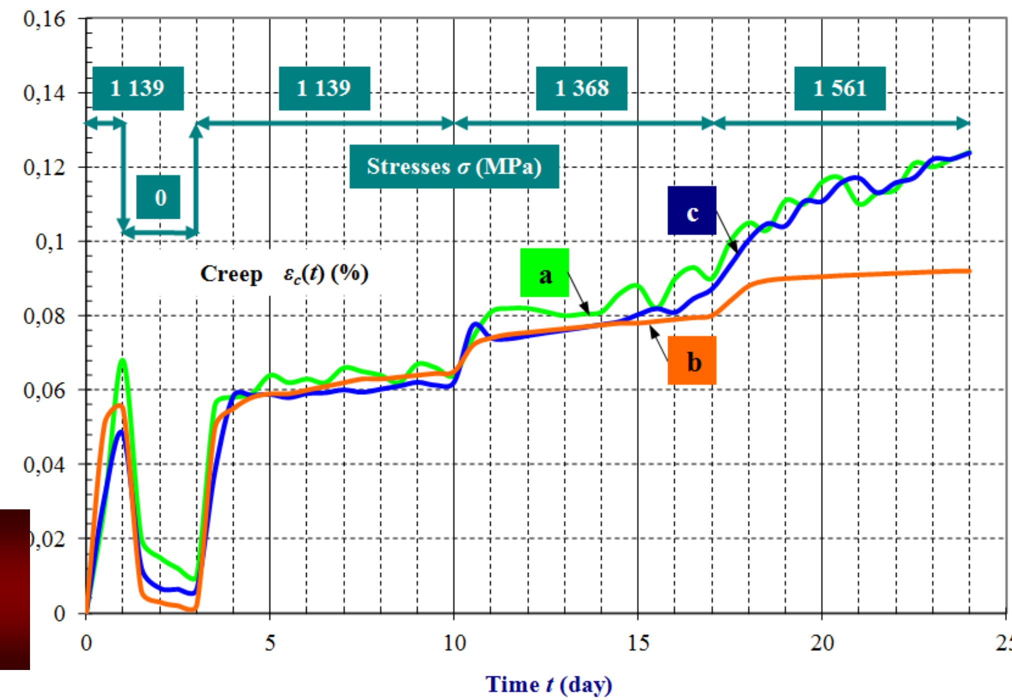
$f_a(in)$ - **Activation neuron's function**

$f_o(x)$ - **Output neuron's function**

NN as approximators and predictors



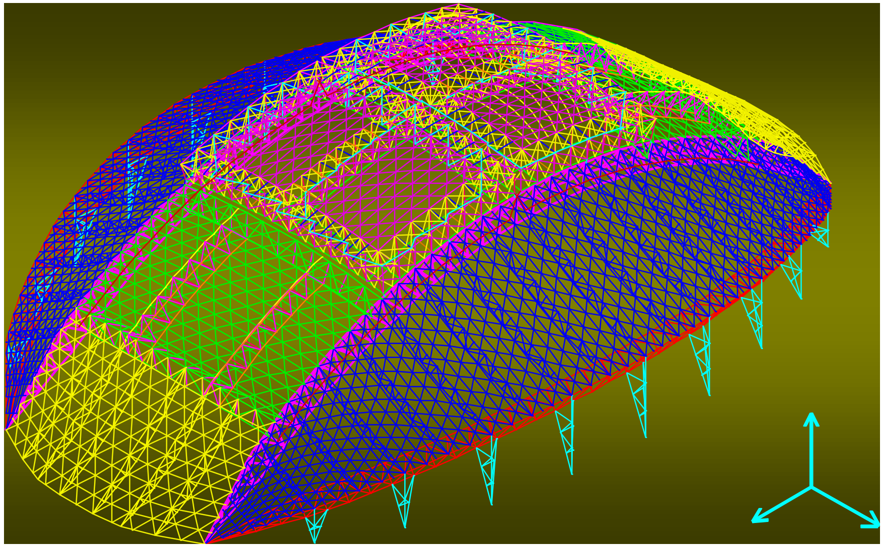




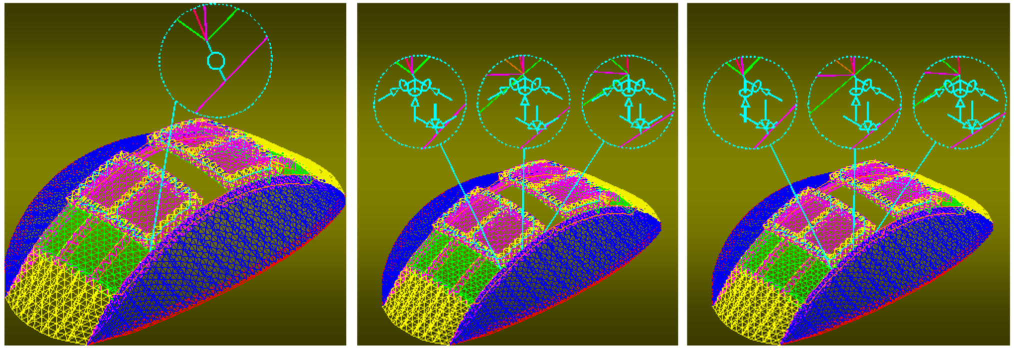
Jordan neural network (c) with a topology of 3-10-1

NN as analysers and predictors

► NN can replace analysis by means of FE Methods



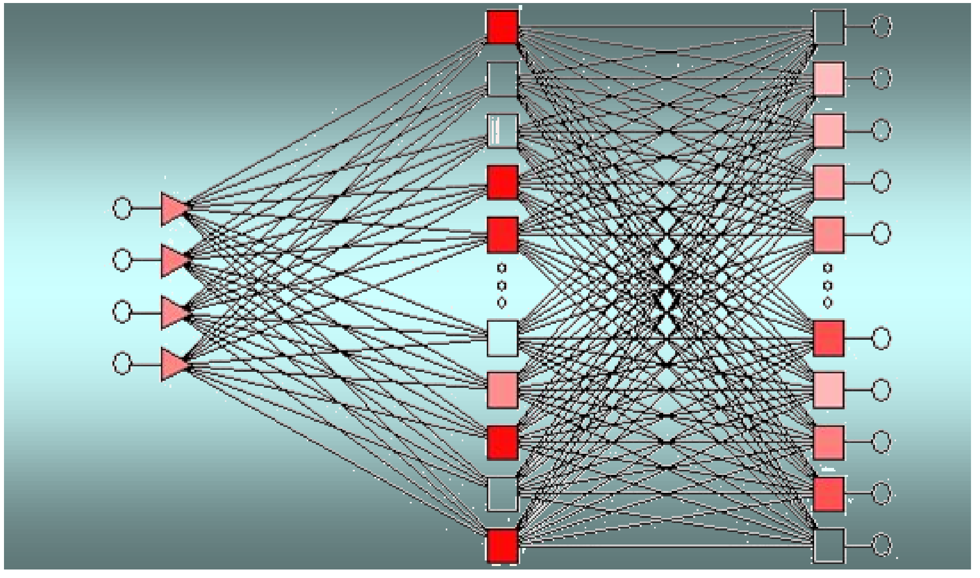
● For the behaviour prediction of retractable roof structures and **for the quick generation of the data required for the control system** the neural computing can be successfully applied.



Resulting multilayer perceptron

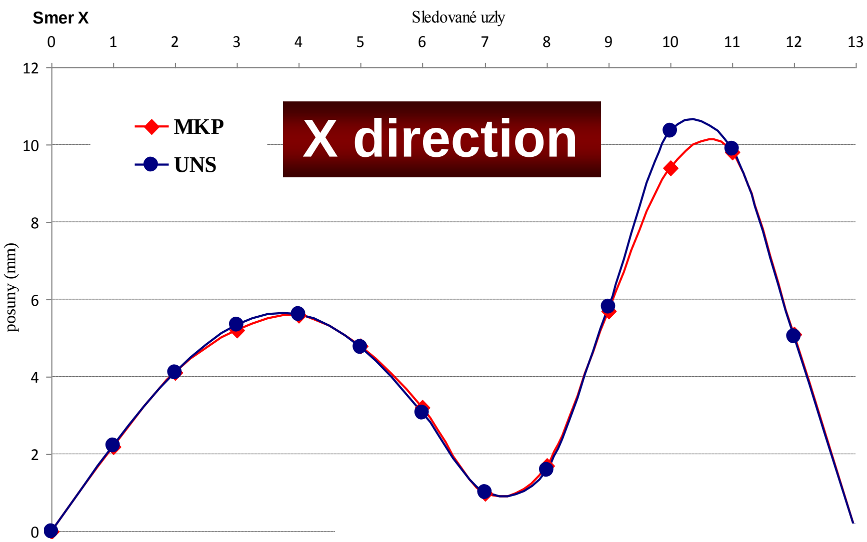
The best results were reached by the perceptron neural network with the topology 4-79-42-42 and Backpropagation learning algorithm in the combination with the conjugate gradient algorithm.

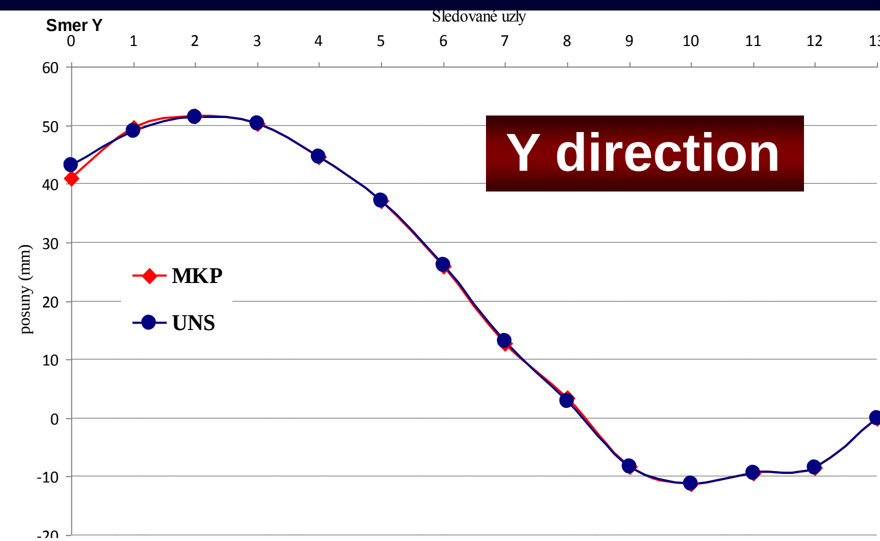
For this topology the <u>mean square error MSE = 3,3 % during the training procedure</u> and <u>MSE = 3,5 % in the testing phase were achieved</u>.

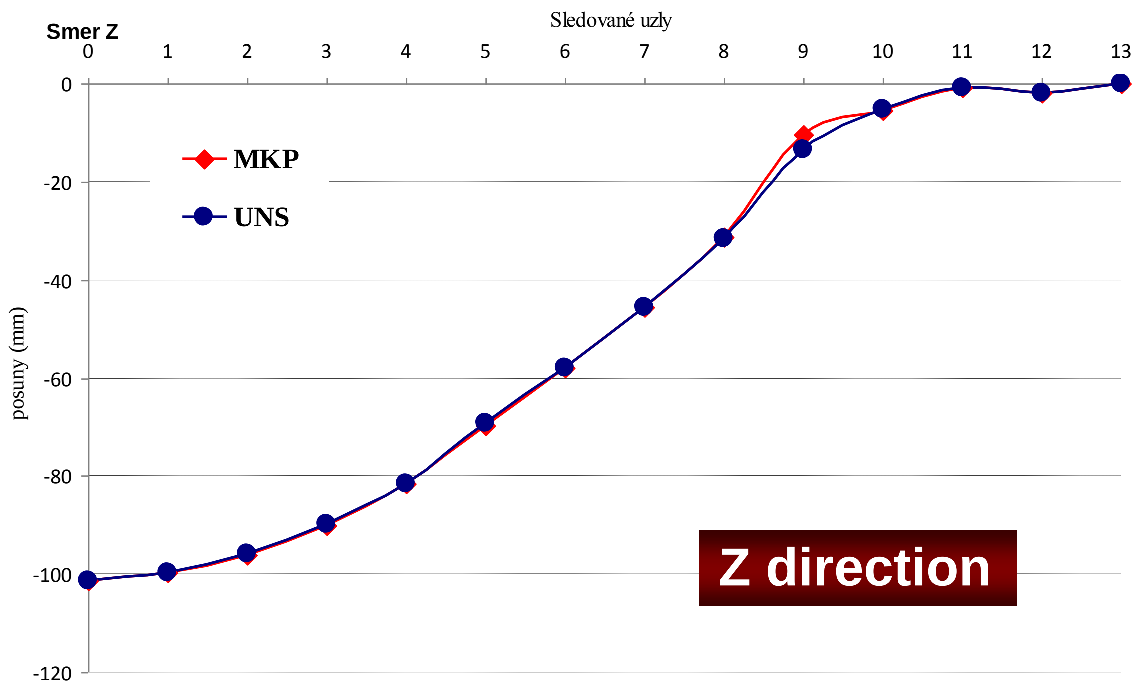


Topology of the resulting multilayer perceptron

Nodal displacements of the rail track obtained by means of ANN and FEM in the X, Y and Z directions



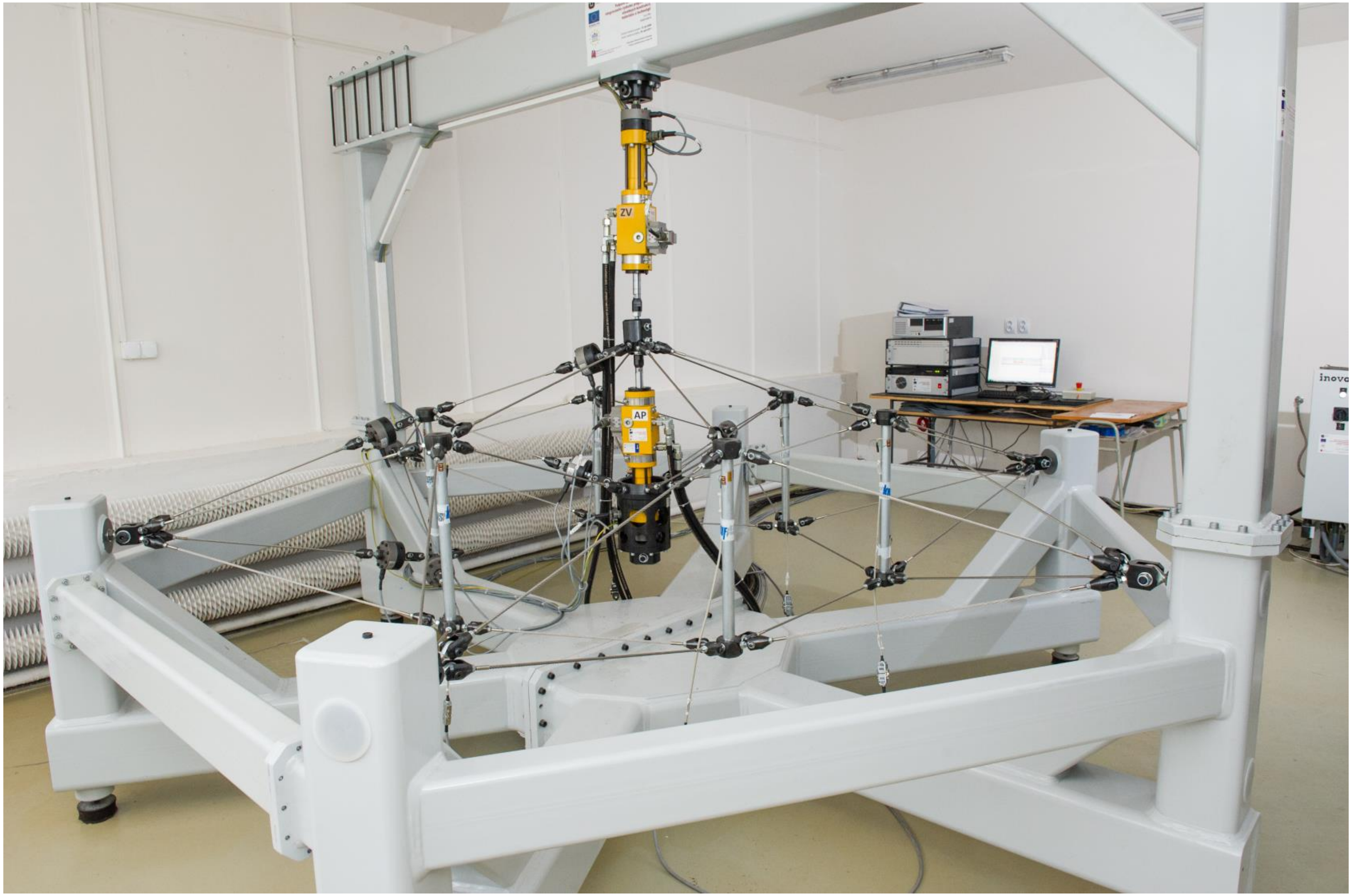




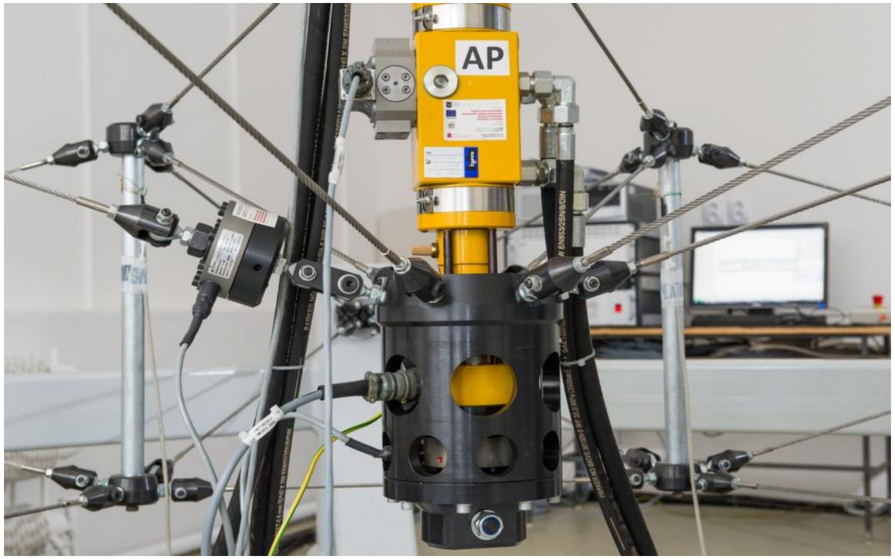
ANN

FEM

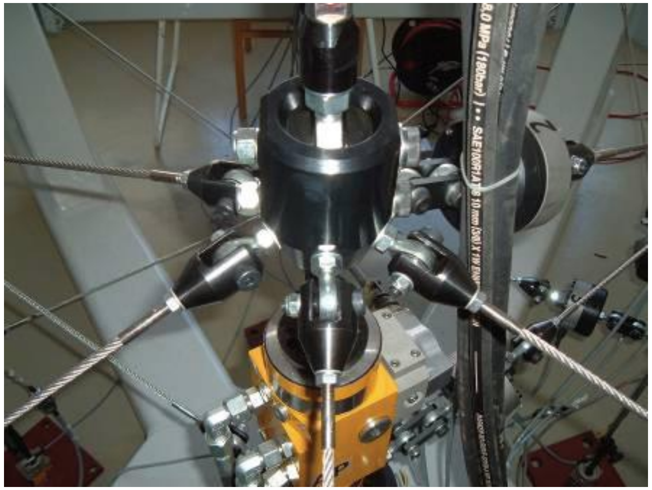
Adaptive cable dome
consists of 7 compressed struts (1 active) and 36 tensioned cables



A detailed view of the actuator and load cylinder

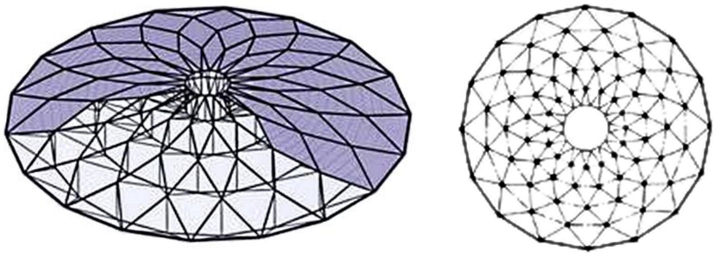


Details of connections of cable members

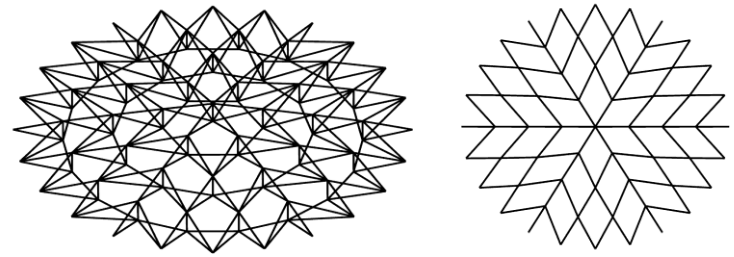


Various types of cable domes

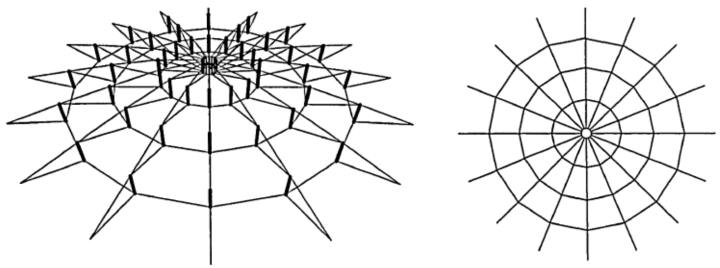
Fuller type cable dome



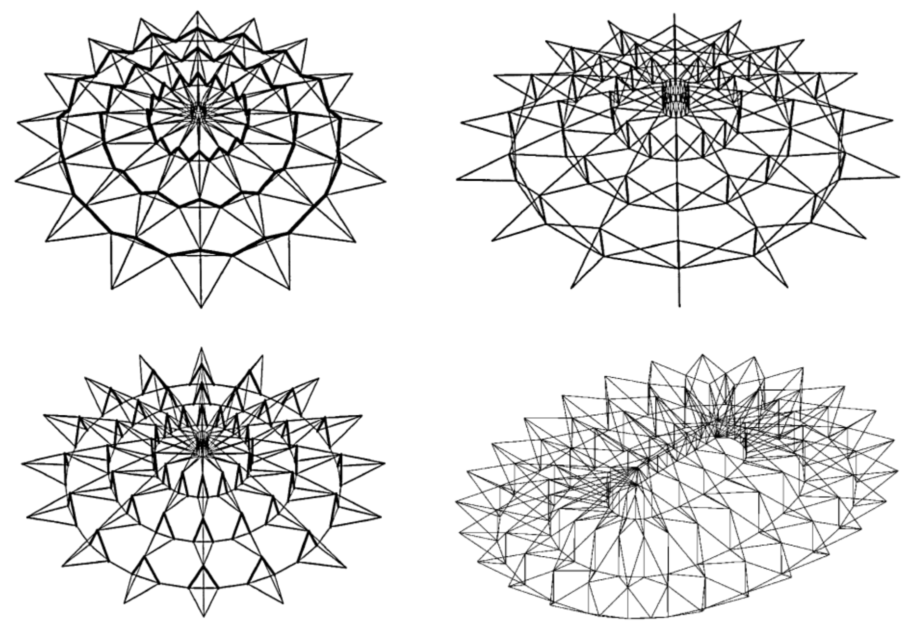
Kiewitt type cable dome



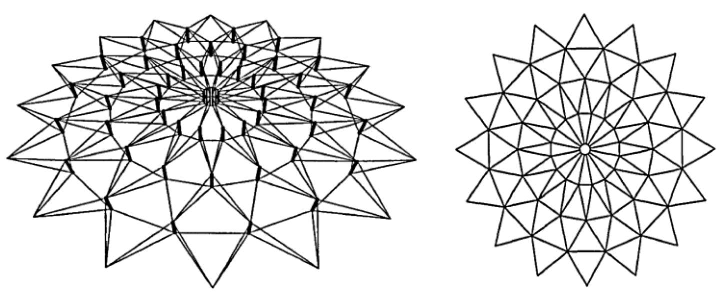
Geiger type cable dome



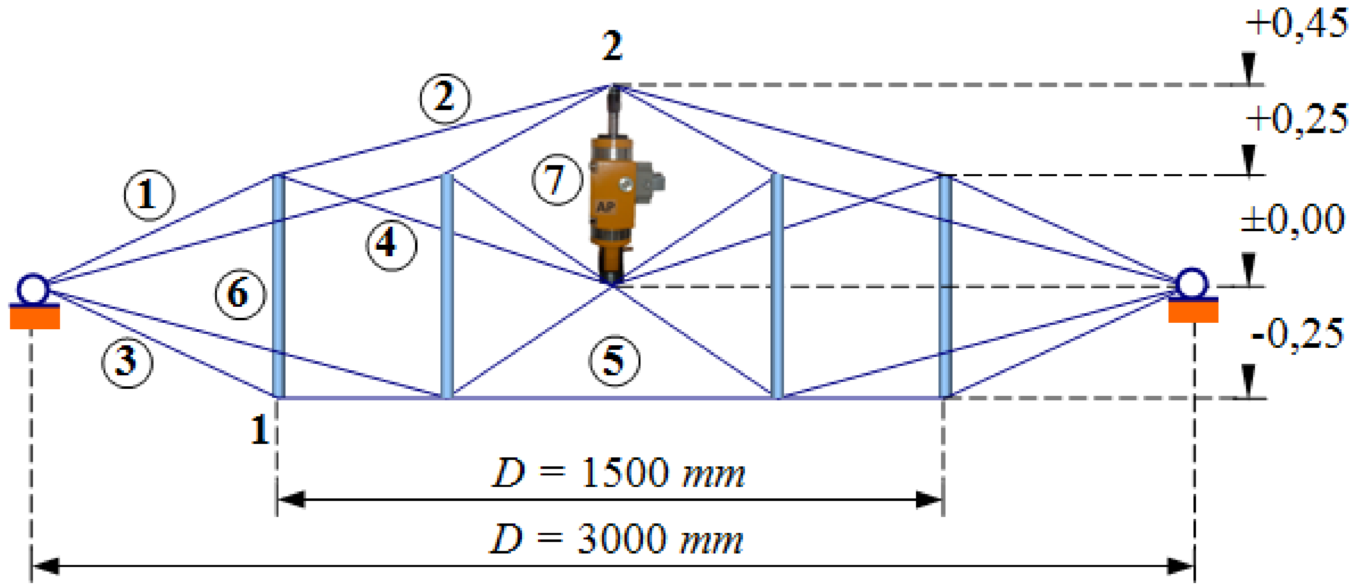
Modified cable domes

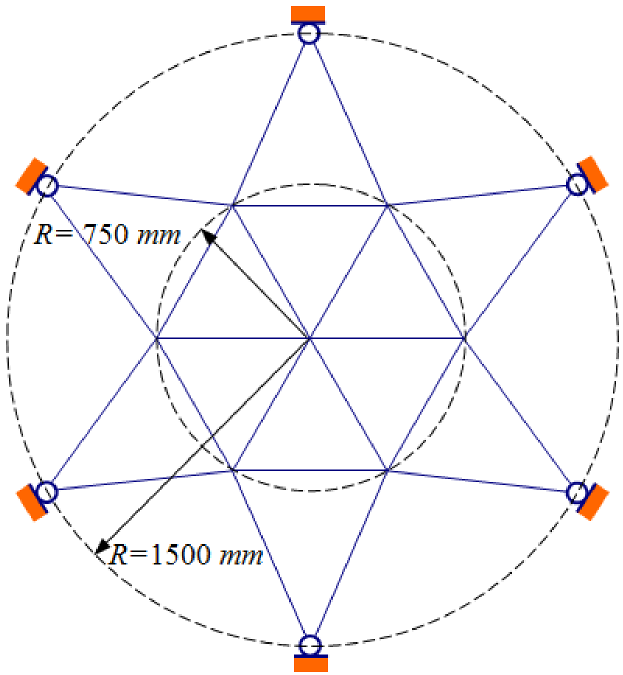


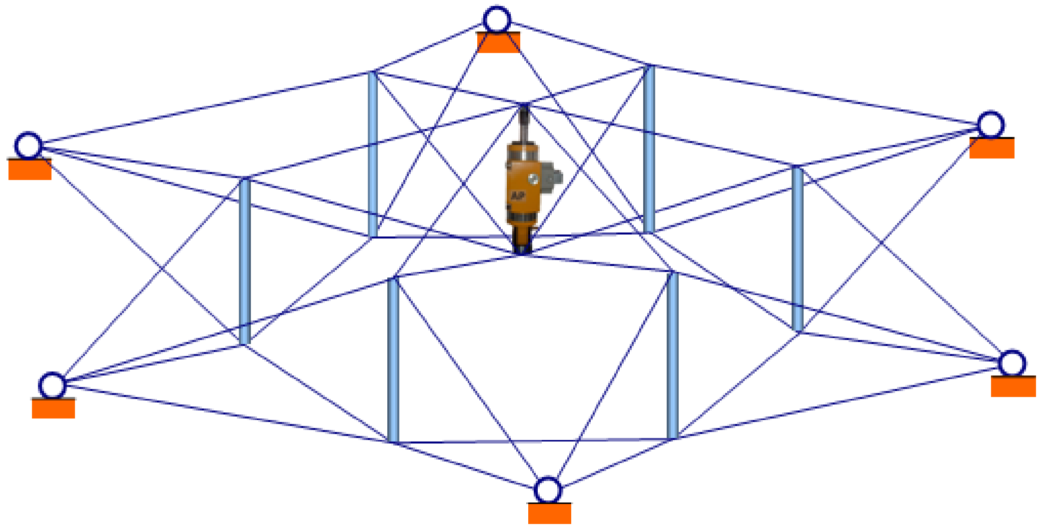
Levy type cable dome



Control of adaptive cable domes

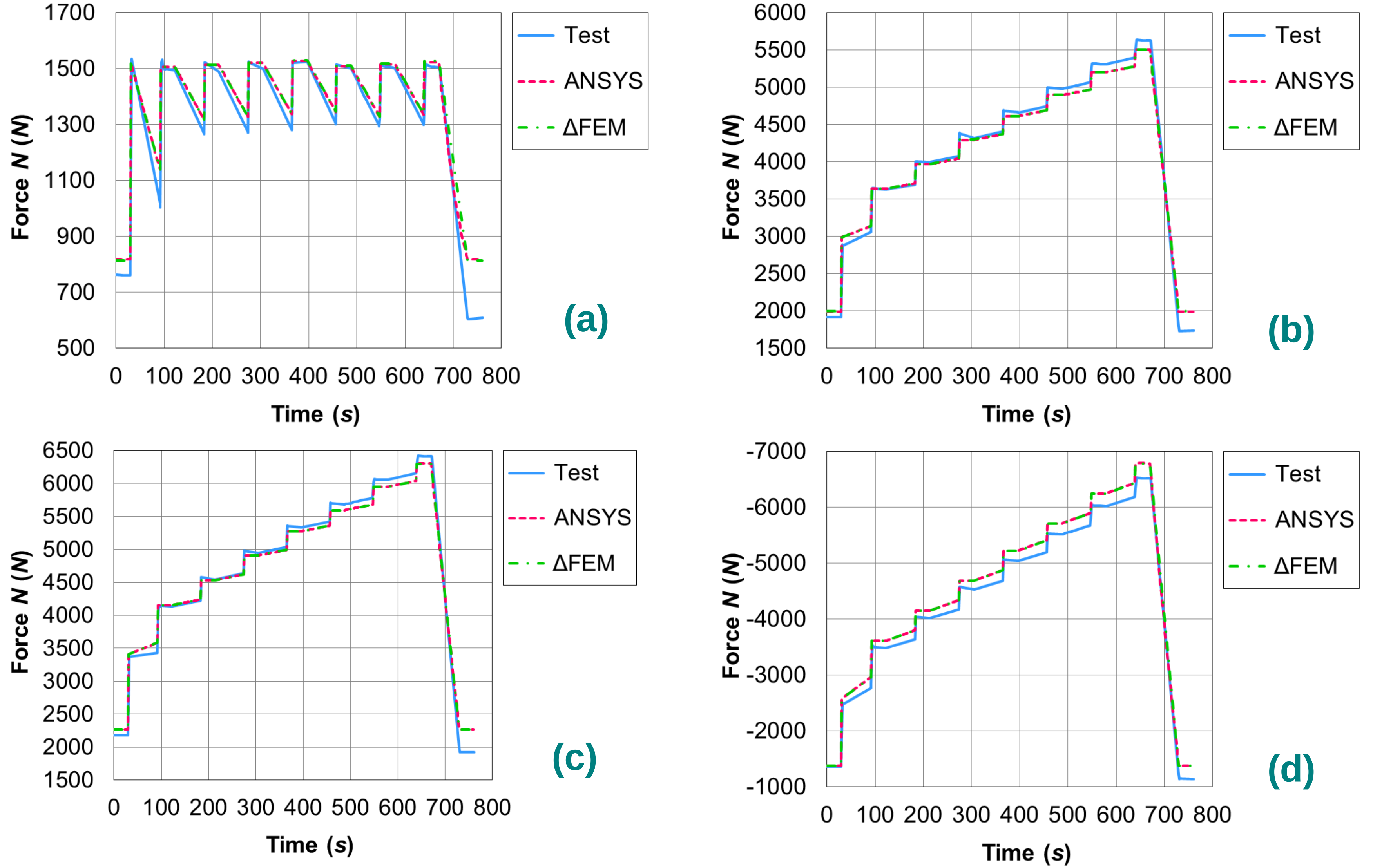






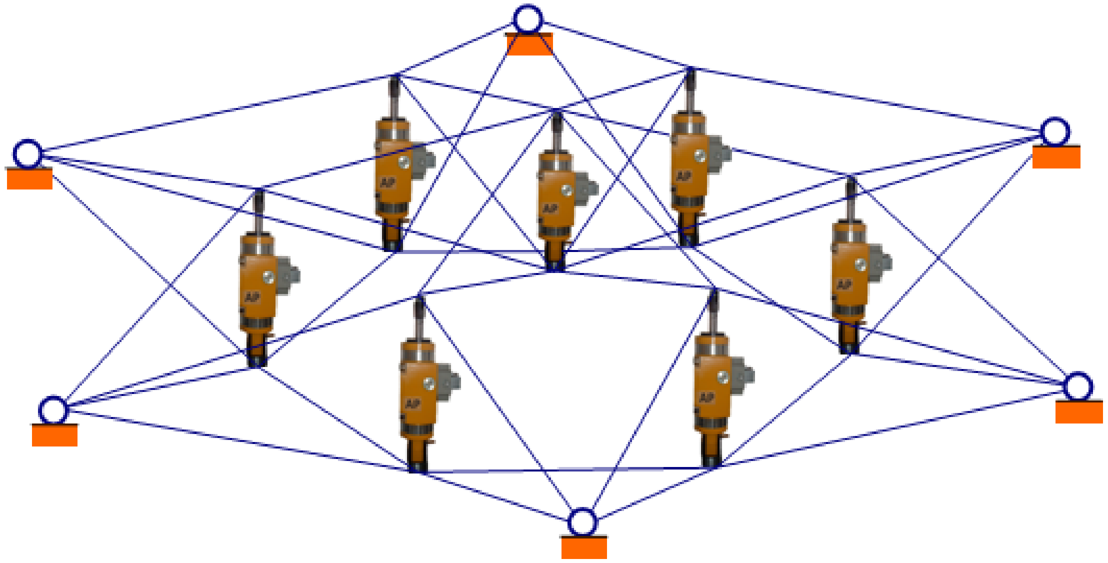
Basic reliability condition: Forces in cables > 1500 N

3
5

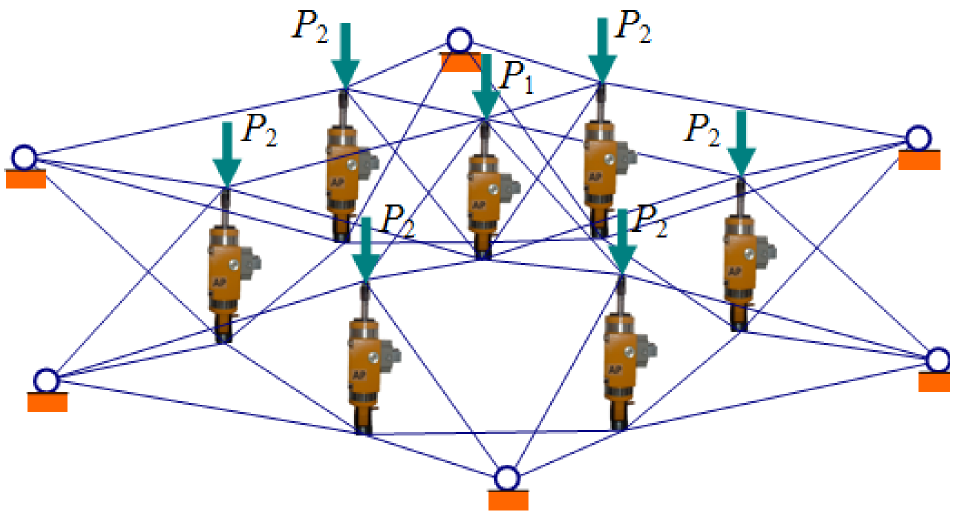


Comparison of experimentally obtained courses of forces in the cables and action member with those obtained by ANSYS and ΔFEM software: (a) ridge cable, (b) diagonal cable, (c) hooped cable and (d) action member

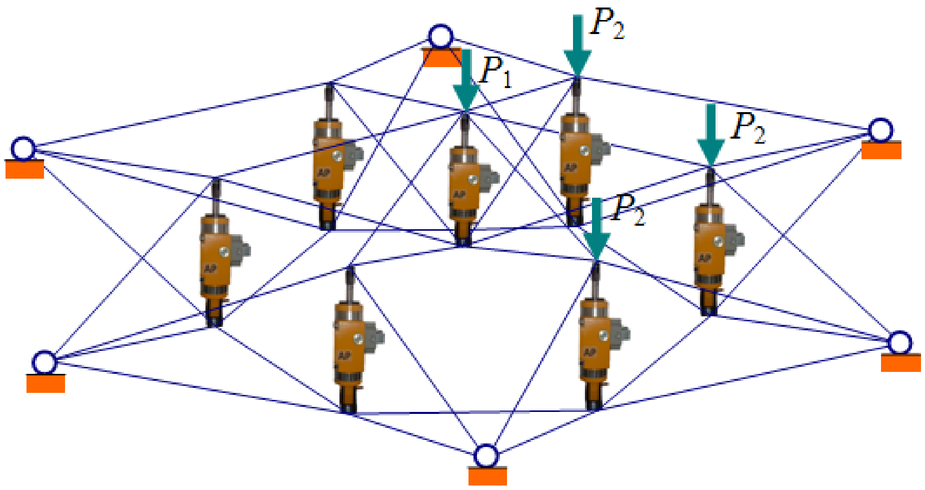
Control of the cable dome with 7 action members



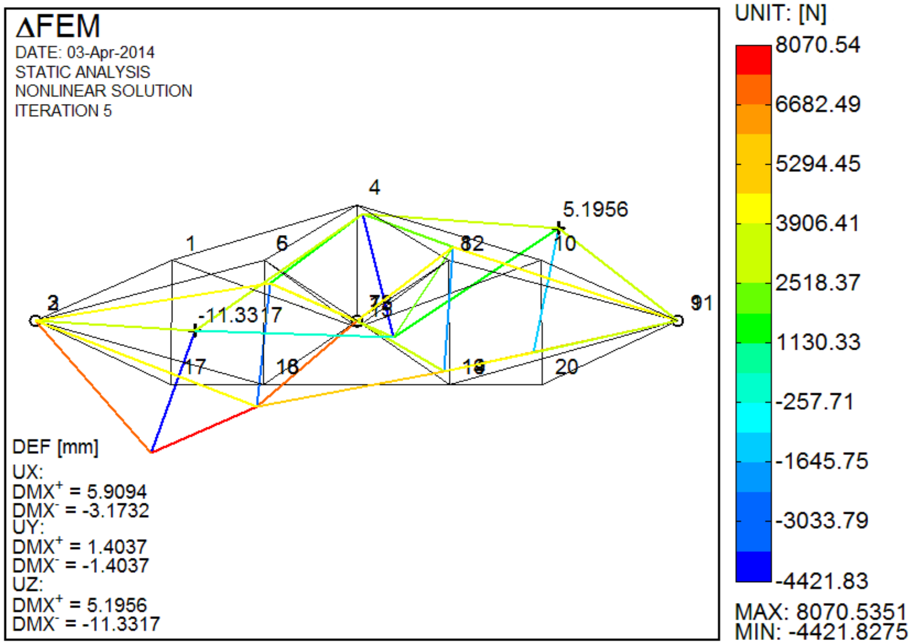
Symmetric load

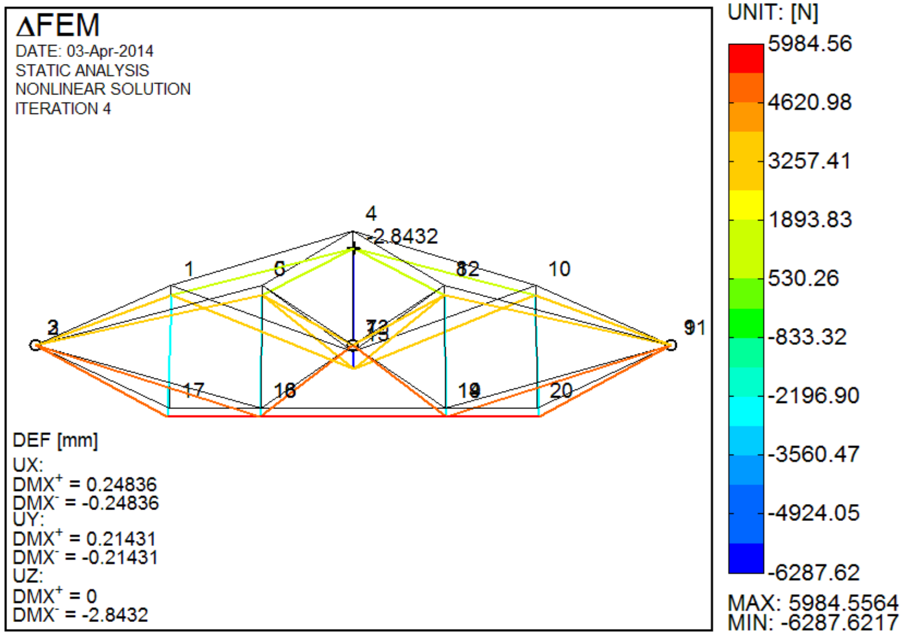


Asymmetric load



Sensitivity to an asymmetric loading





Comparison of numerically obtained internal forces and displacements of the dome (a side view) subjected: (a) to an asymmetric vertical point load of 3 500 *N* applied to one of the six non-actuated struts and (b) to a symmetric vertical point load of 3 500 *N* applied to the central node.

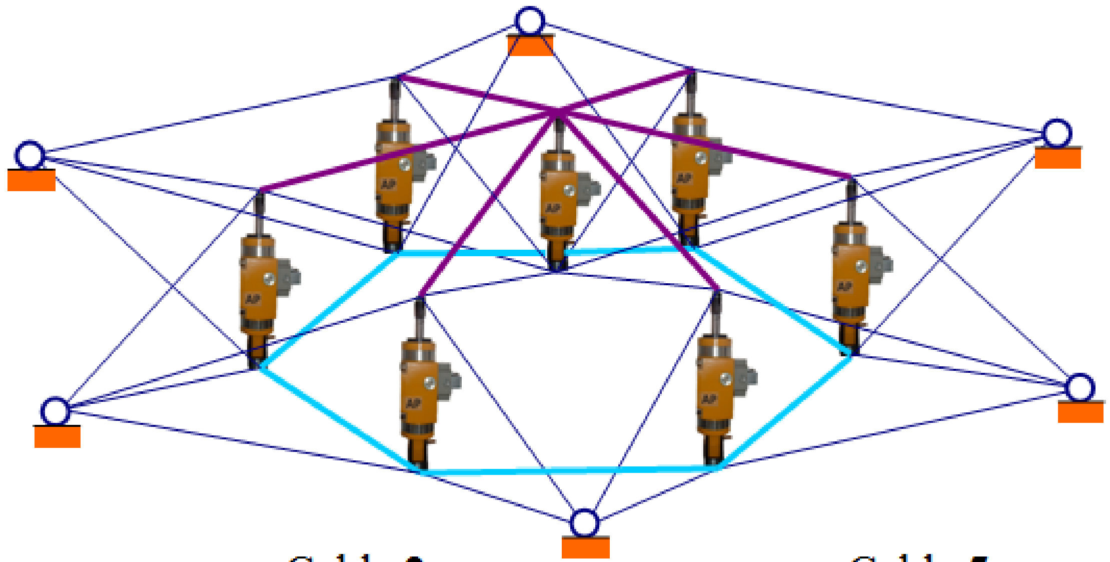
Control commands of the active cable dome using Multi-Objective Genetic Algorithms (MOGA)

Multi-objective search is used to select control commands.

An appropriate tool for the optimization of the control process is an application of **genetic algorithms.**

The Multi-Objective Genetic Algorithm (MOGA) used in Goal Driven Optimization (GDO) as a hybrid variant of the popular Non-dominated Sorted Genetic Algorithm-II (NSGA-II) based on controlled elitism concepts are used in these studies.

Objective functions in this optimization process are cable forces in two sets of cables



$$\boldsymbol{F}^{CS2}(\boldsymbol{\Delta},\boldsymbol{q})=\left(F_1^{CS2}(\Delta,q),F_2^{CS2}(\Delta,q),\mathrm{K}\,,F_6^{CS2}(\Delta,q)\right)^{\mathrm{T}}$$

$$\boldsymbol{F}^{CS5}(\boldsymbol{\Delta},\boldsymbol{q})=\left(F_1^{CS5}(\Delta,q),F_2^{CS5}(\Delta,q),\mathrm{K}\,,F_6^{CS5}(\Delta,q)\right)^{\mathrm{T}}$$

2 – Ridge cables   5 – Hooped cables

Formulation of the multi-objective task

The multi-objective task can be mathematically written as

$$\min \quad \left(\boldsymbol{F}_{min}^{CS2}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right), \boldsymbol{F}_{max}^{CS2}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right), \boldsymbol{F}_{max}^{CS5}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right) \right)$$

Subject to

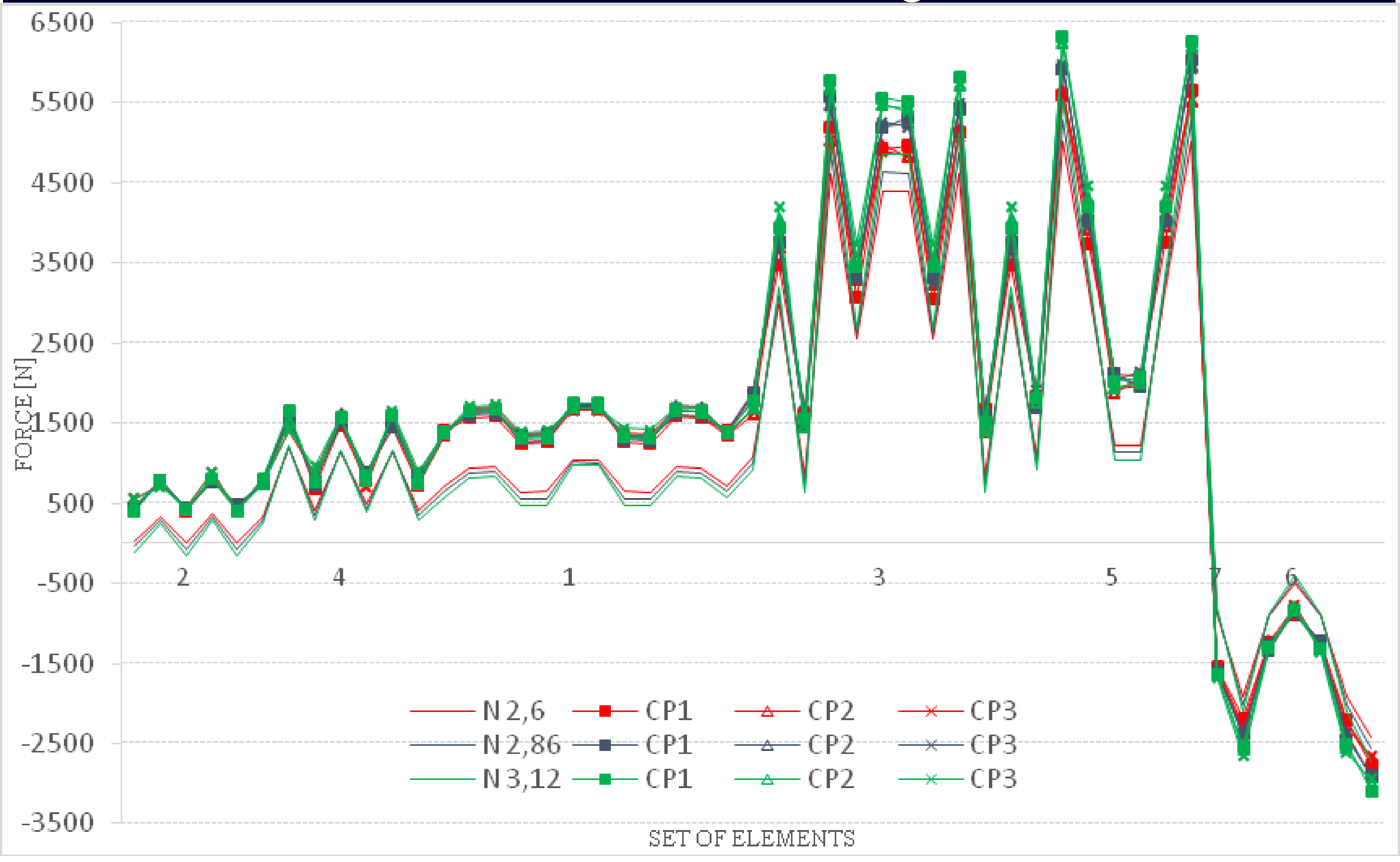
$$\boldsymbol{F}_{min}^{CS2}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right) \geq 400\, N$$

$$\boldsymbol{F}_{max}^{CS2}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right) \leq 1000\, N$$

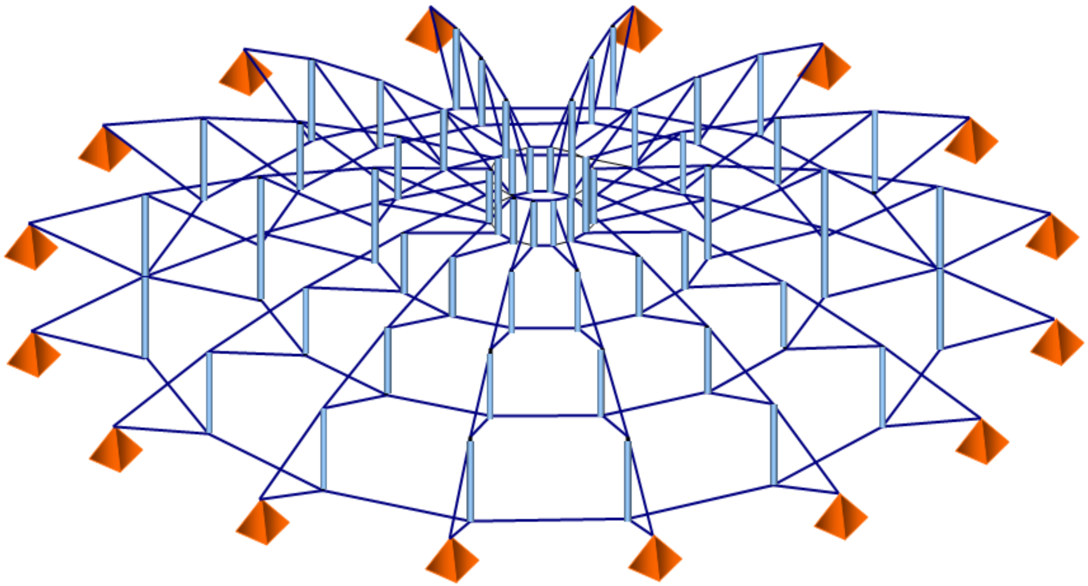
$$5500\, N \leq \boldsymbol{F}_{max}^{CS5}\left(\boldsymbol{\Delta}, \boldsymbol{q}\right) \leq 6500\, N$$

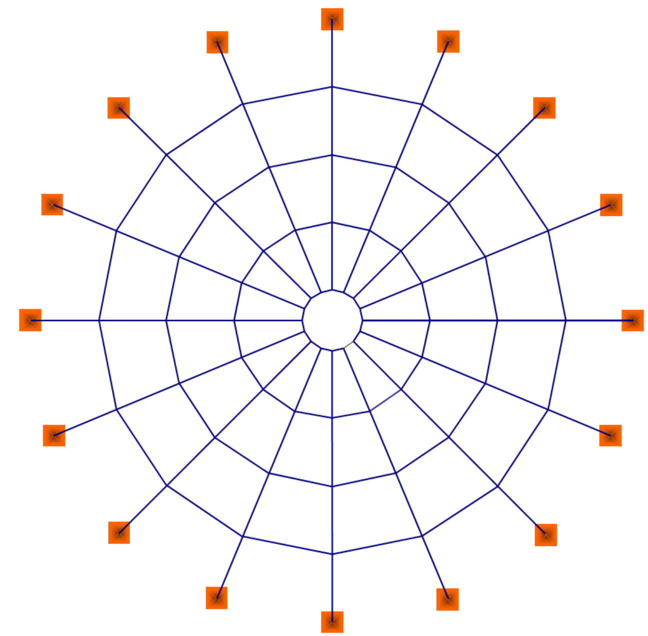
$$\Delta^{lower} = 0.001\, m \leq \boldsymbol{\Delta} \leq 0.01\, m = \Delta^{upper}$$

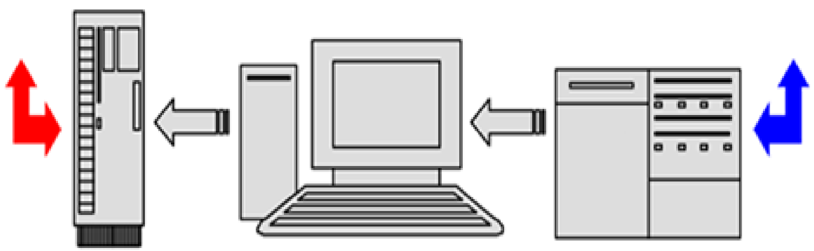
The courses of the resulting axial forces of the cable dome subjected to the asymmetric load at the optimized action member's movement configuration.



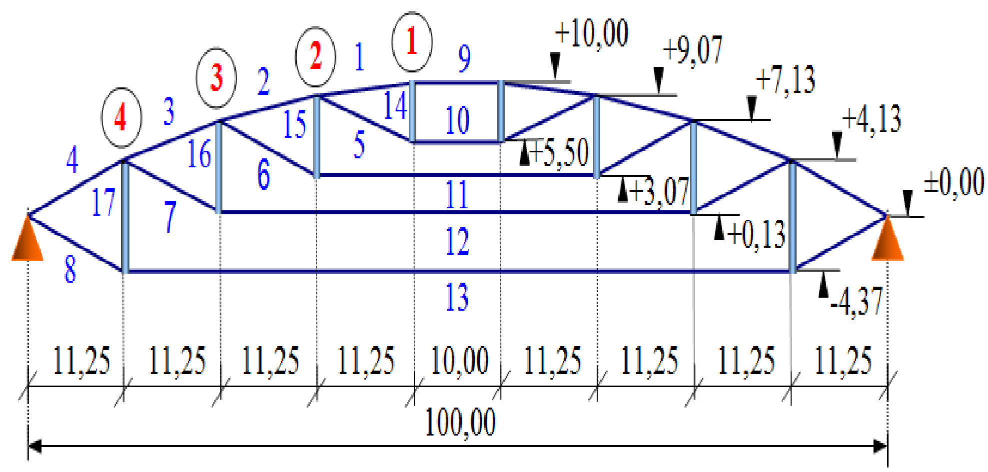
Adaptive cable dome of the Geiger type



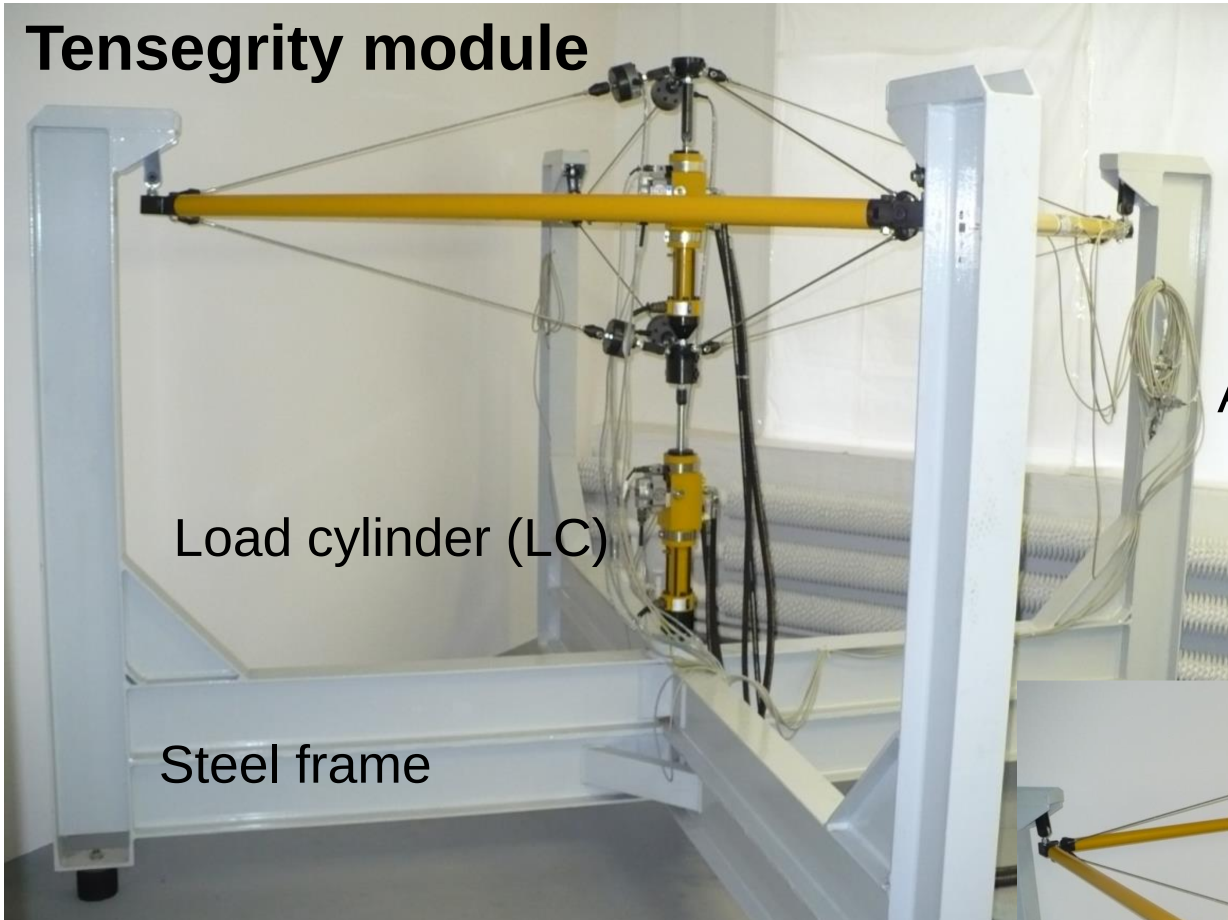




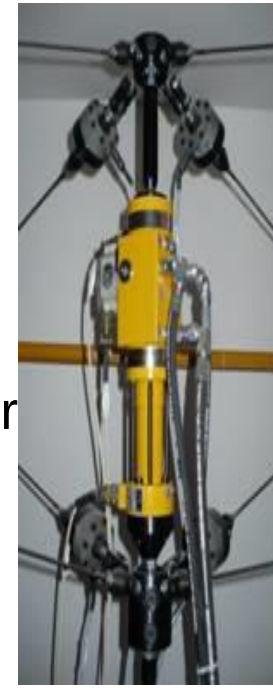
- ▸ Control electronics
- ▸ Computer system
- ▸ Device for governing the movement of action members



An adaptive tensegrity module with a load cylinder suspended in a self-supporting frame

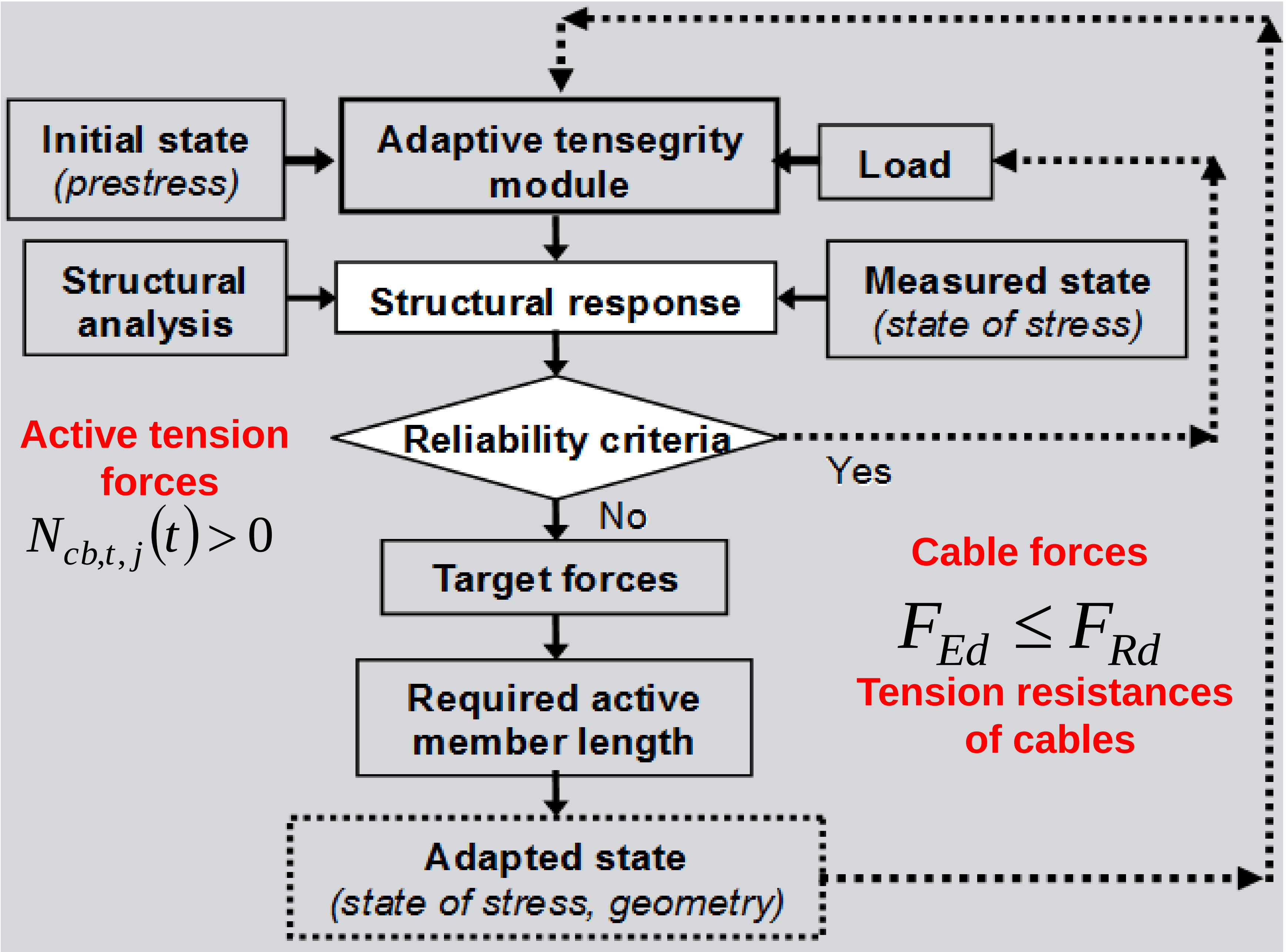


Action member

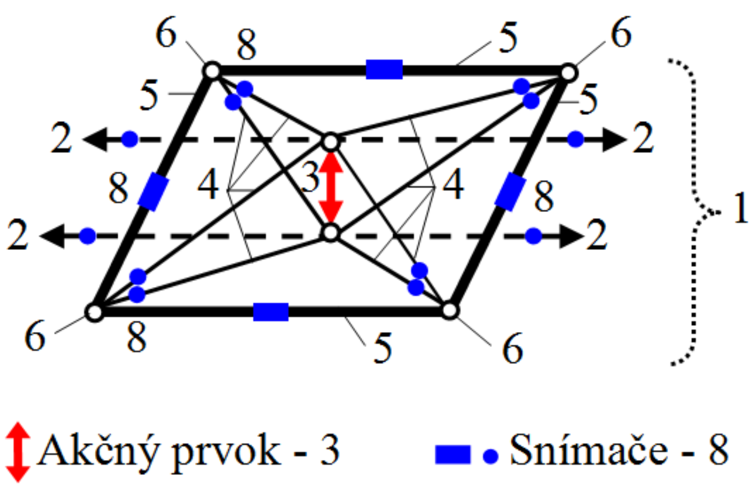


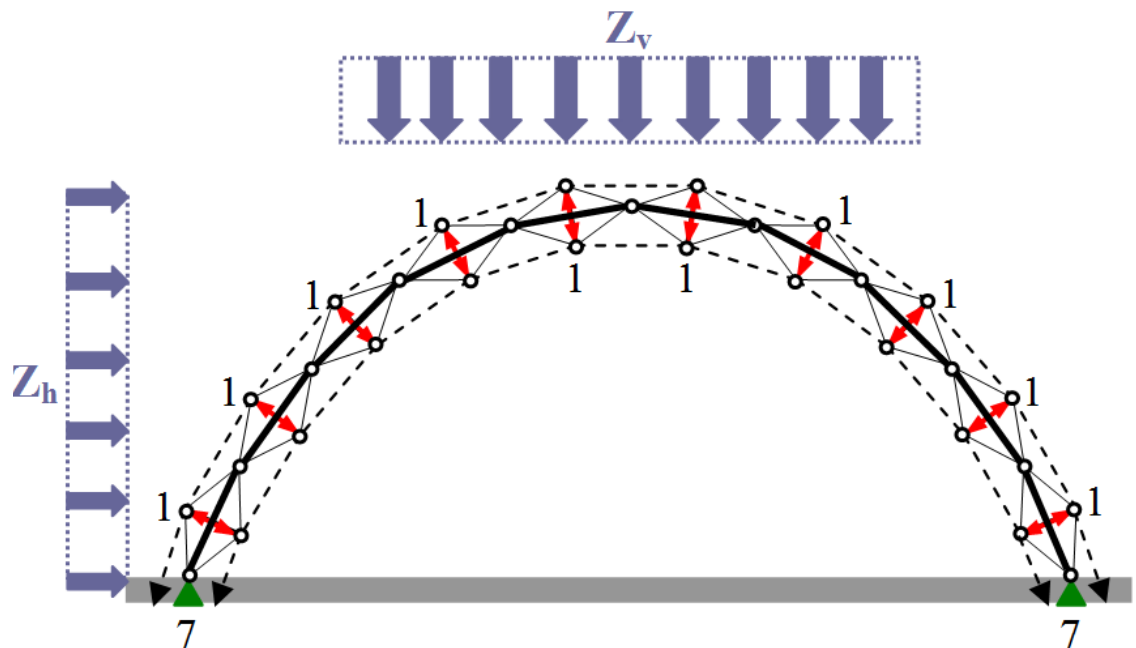
5 compressed bars (1 active in the middle) and 8 tensioned cables

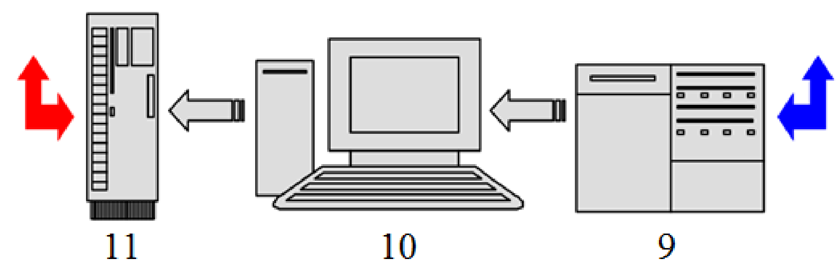
Force control loop – reliability conditions

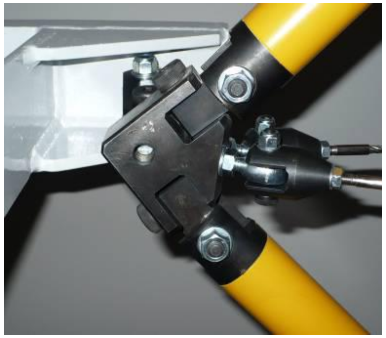


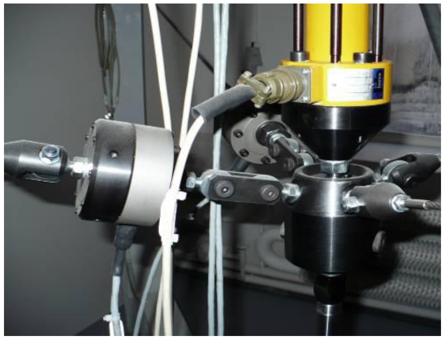
Adaptive tensegrity arch



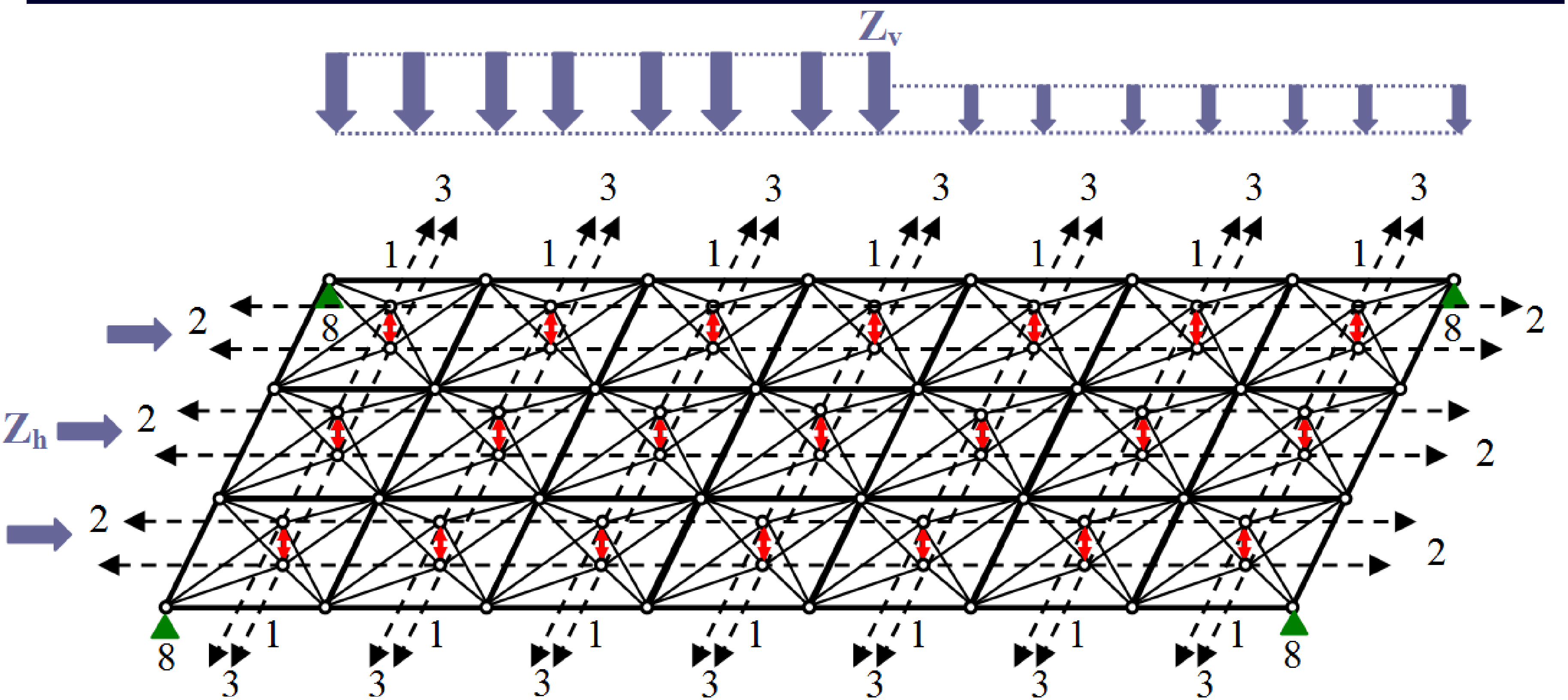


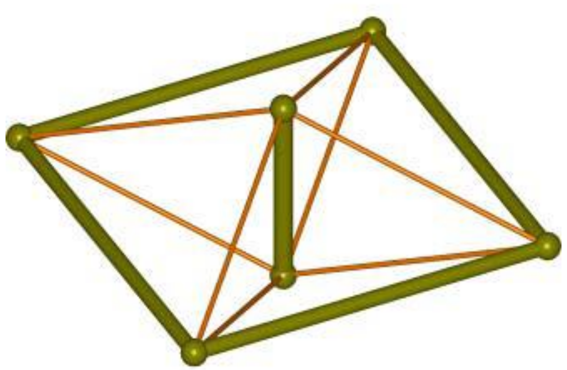


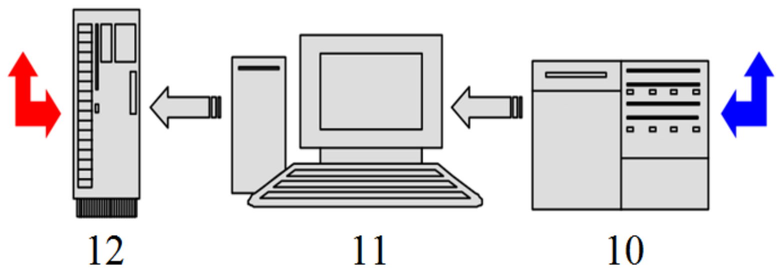




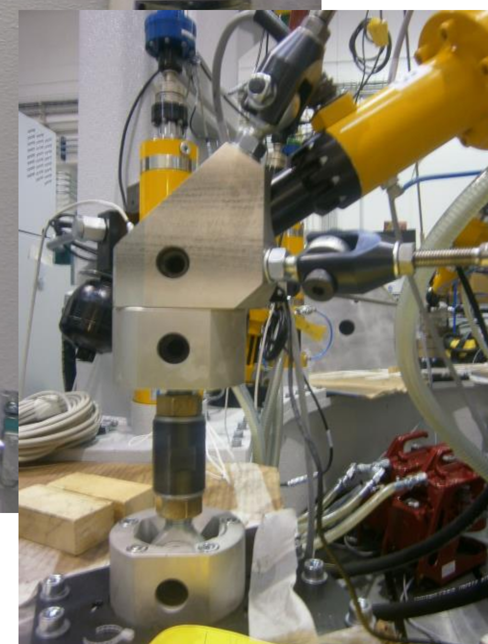
Adaptive tensegrity plate



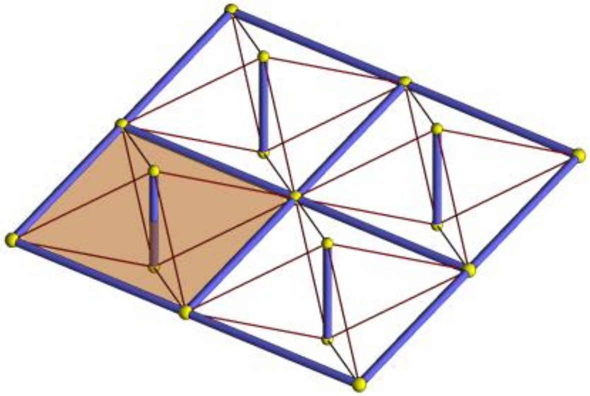


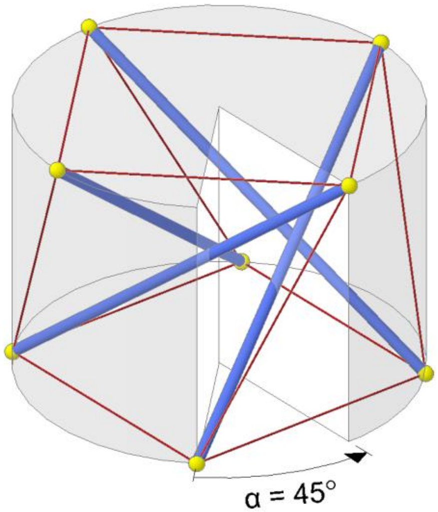


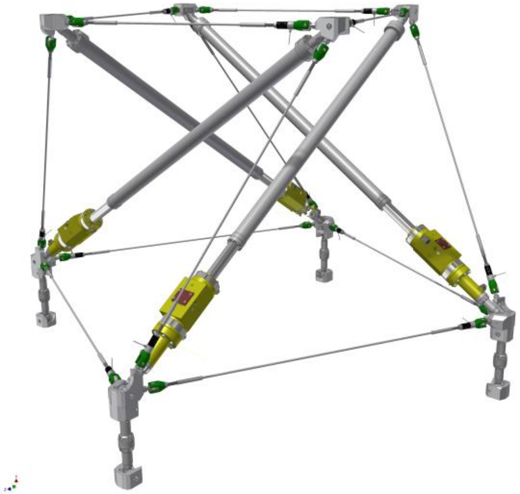
Adaptive tensegrity system

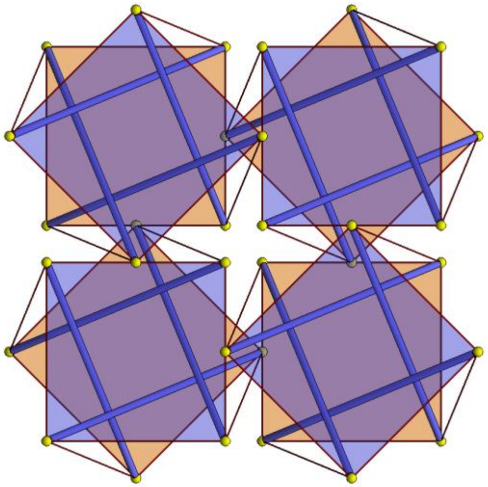


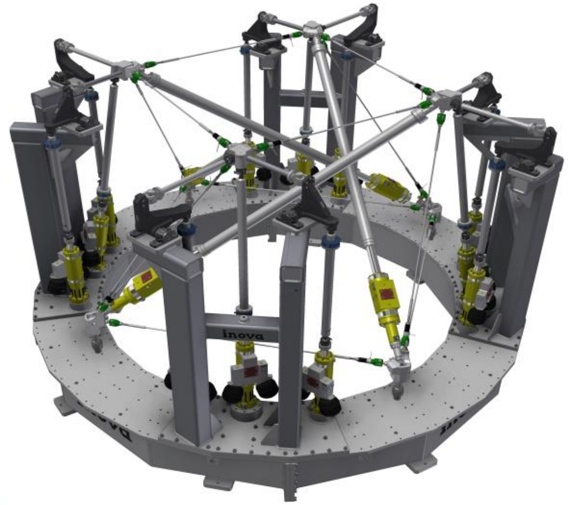
Adaptive tensegrity systems





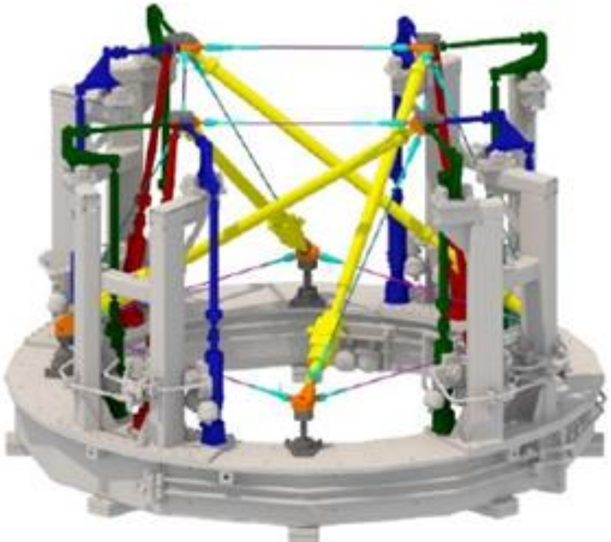




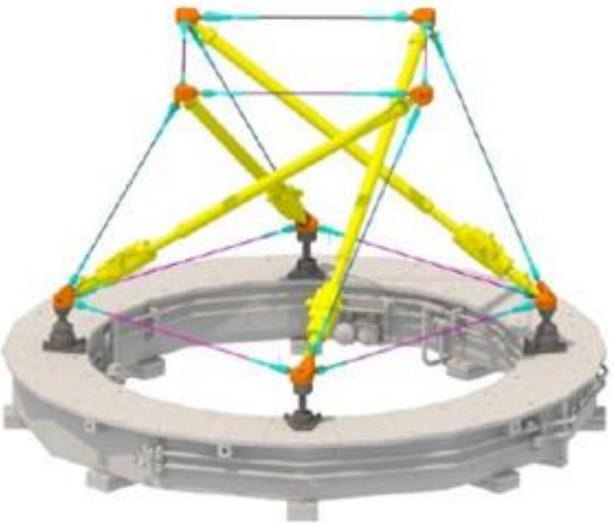


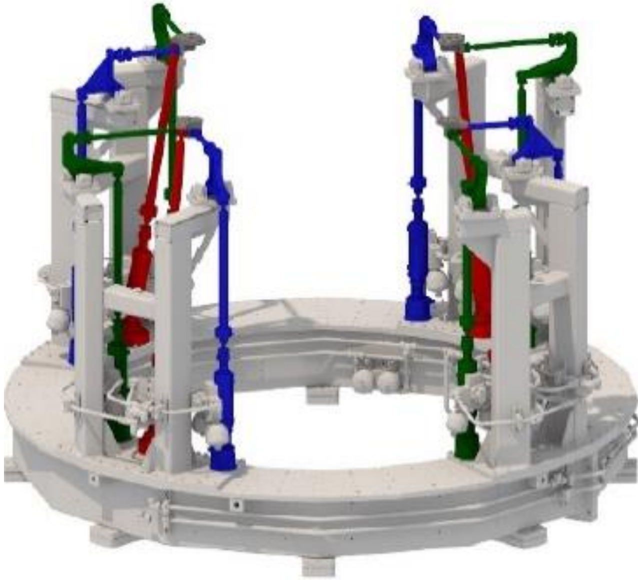
Test equipment with the spatial
self-supporting inverted steel frame

An adaptive tensegrity system

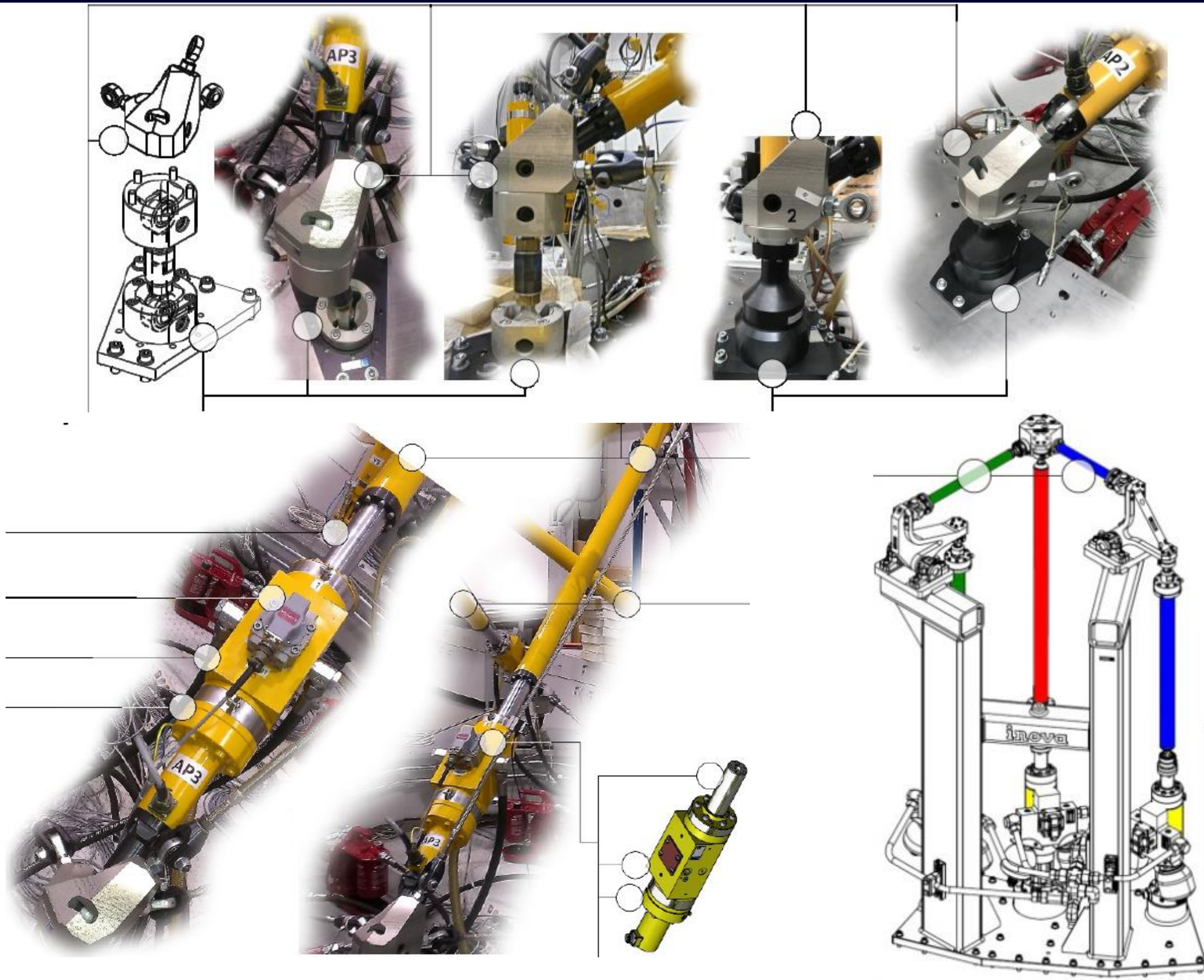


Test equipment with the self-supporting inverted steel frame





An adaptive tensegrity system - details

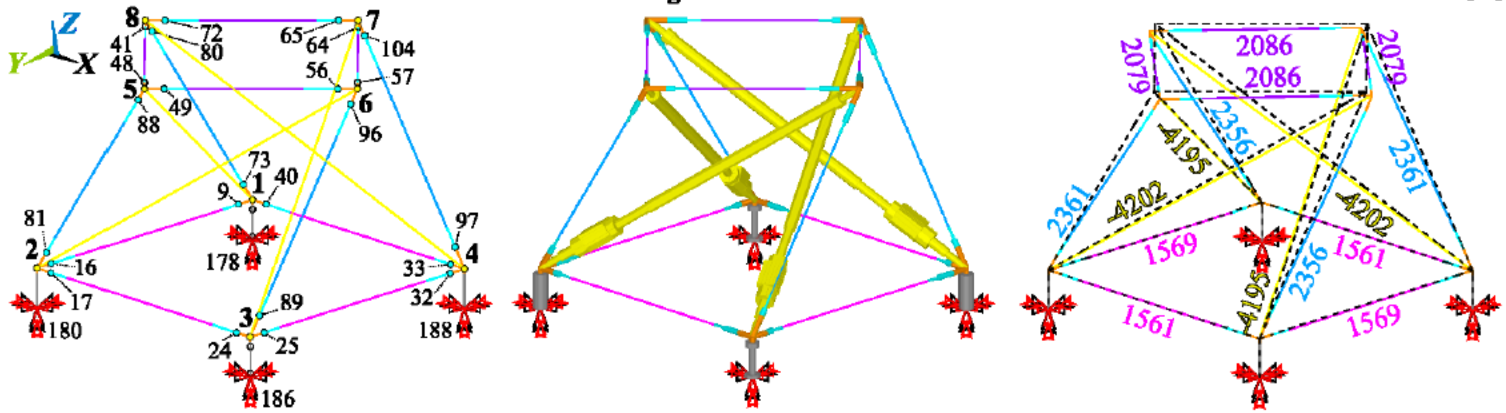


An adaptive tensegrity system – FEM analyses

FE model
truss and beam FE

FE model
assigned mass for FE

after prestress and self weight load
normal forces [N]

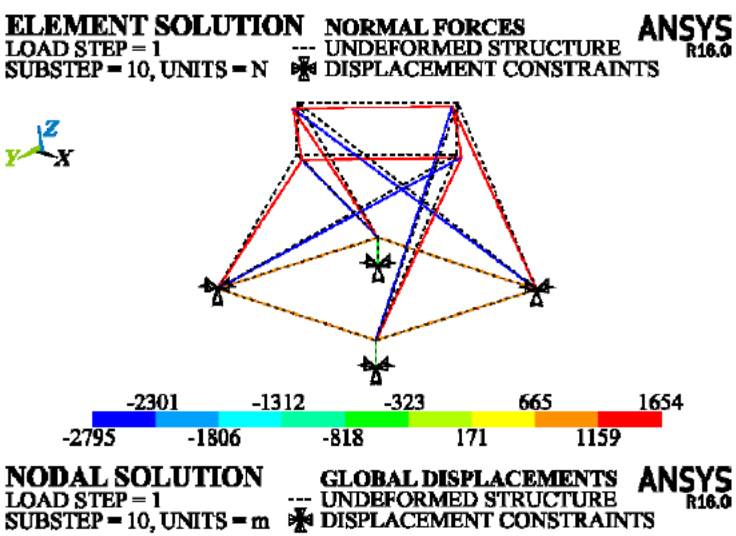


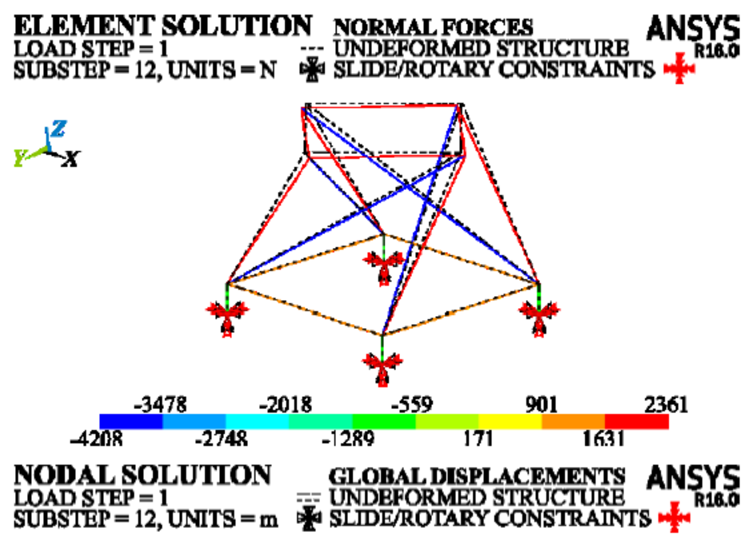
additional self weight forces applied into nodes [N]
node 1-8 = -1.9 N
spheric joint nodes = -2.2 N

truss FE
bottom cables: 4
top cables: 4
intermediate cables: 4

beam FE
active members: 11 x 4 = 44
cable anchors: 4 x 12 = 48
nodal adapters: 4 x 4 + 3 x 4 = 28
supports: 2 + 3 x 2 = 8

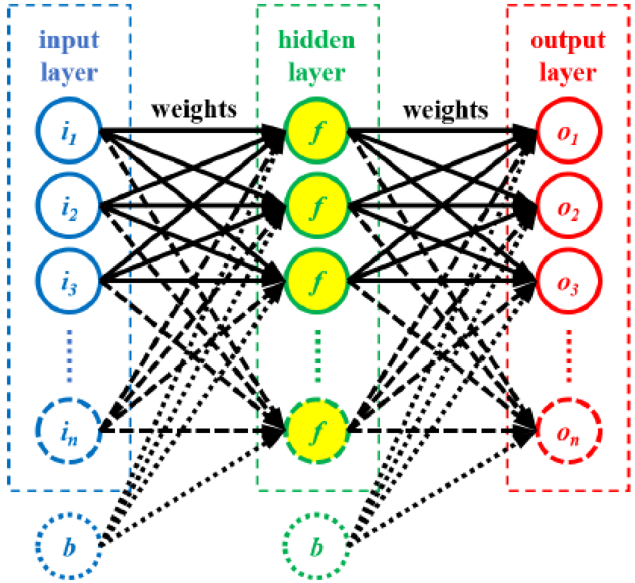
--- UNDEFORMED STRUCTURE DISPLACEMENT CONSTRAINTS ROTATIONAL CONSTRAINTS
SPHERIC JOINTS (FIXED ONLY ROTATIONS ALONG MEMBER AXES)



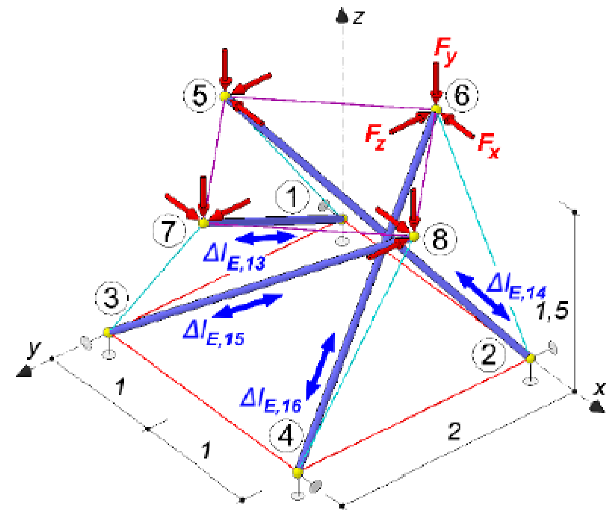


An adaptive tensegrity system – controls by NN

inputs:
- variables obtained from loaded structure (nodal displacements)

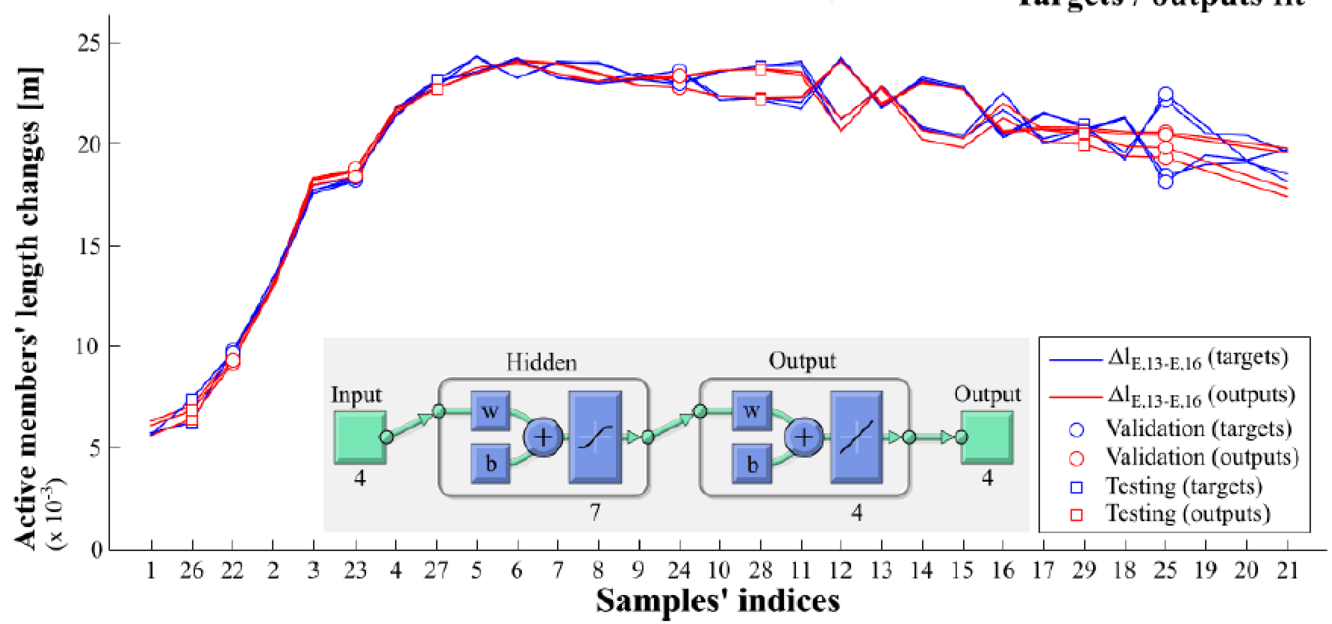


outputs:
- desired variables suitable for correction of structure's geometric-stress state (active members' length changes)

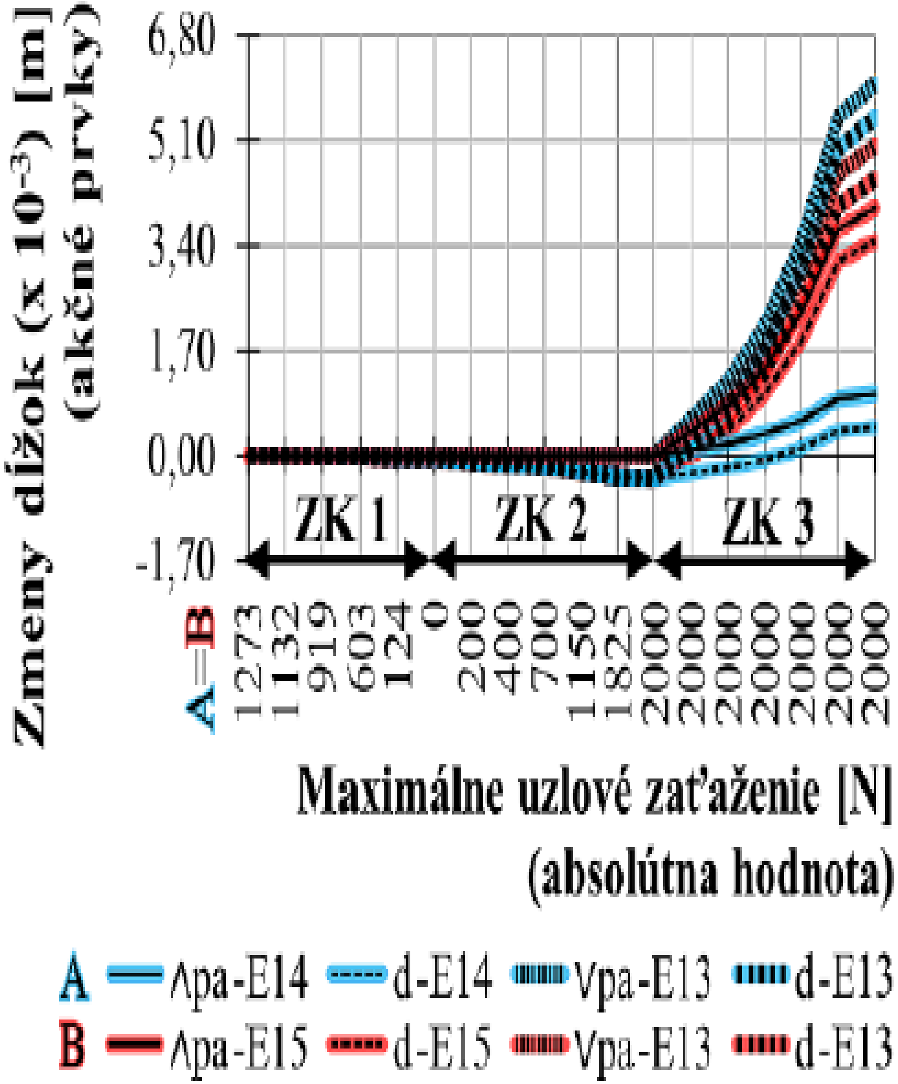


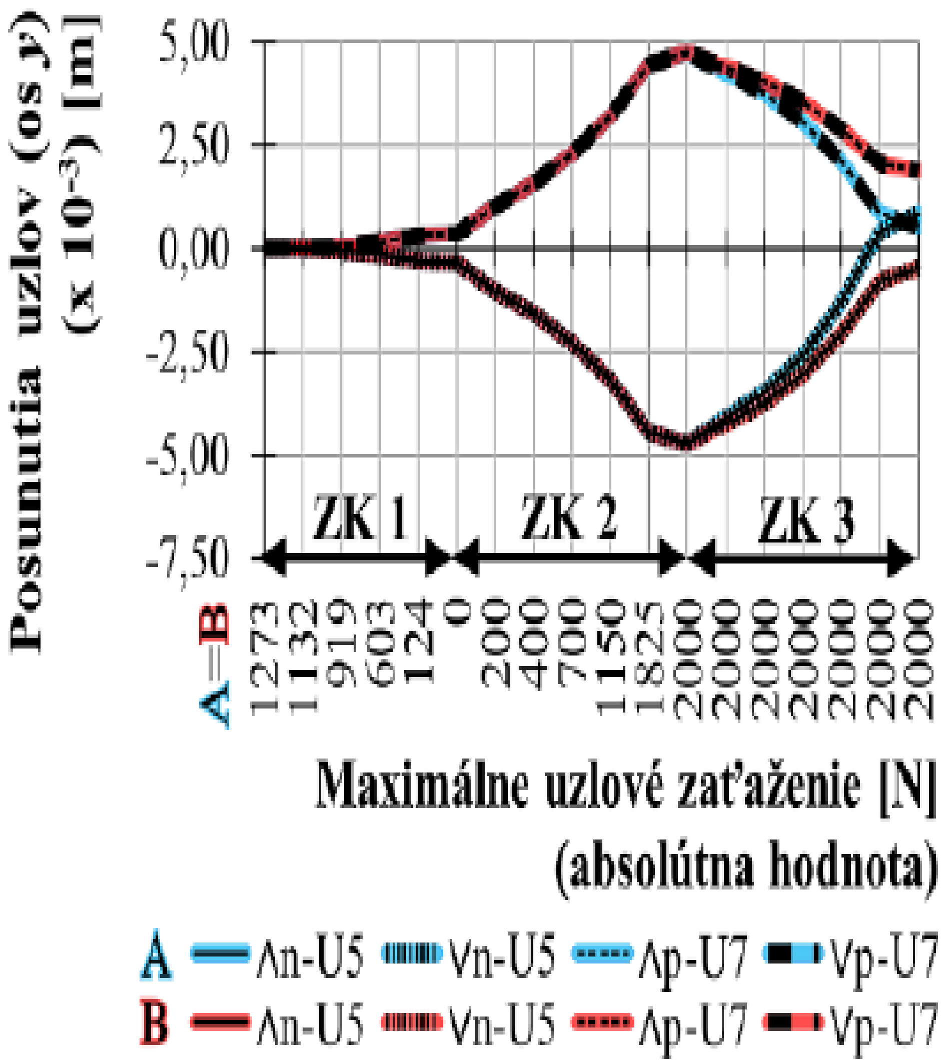
b - bias
f - activation function

Targets / outputs fit



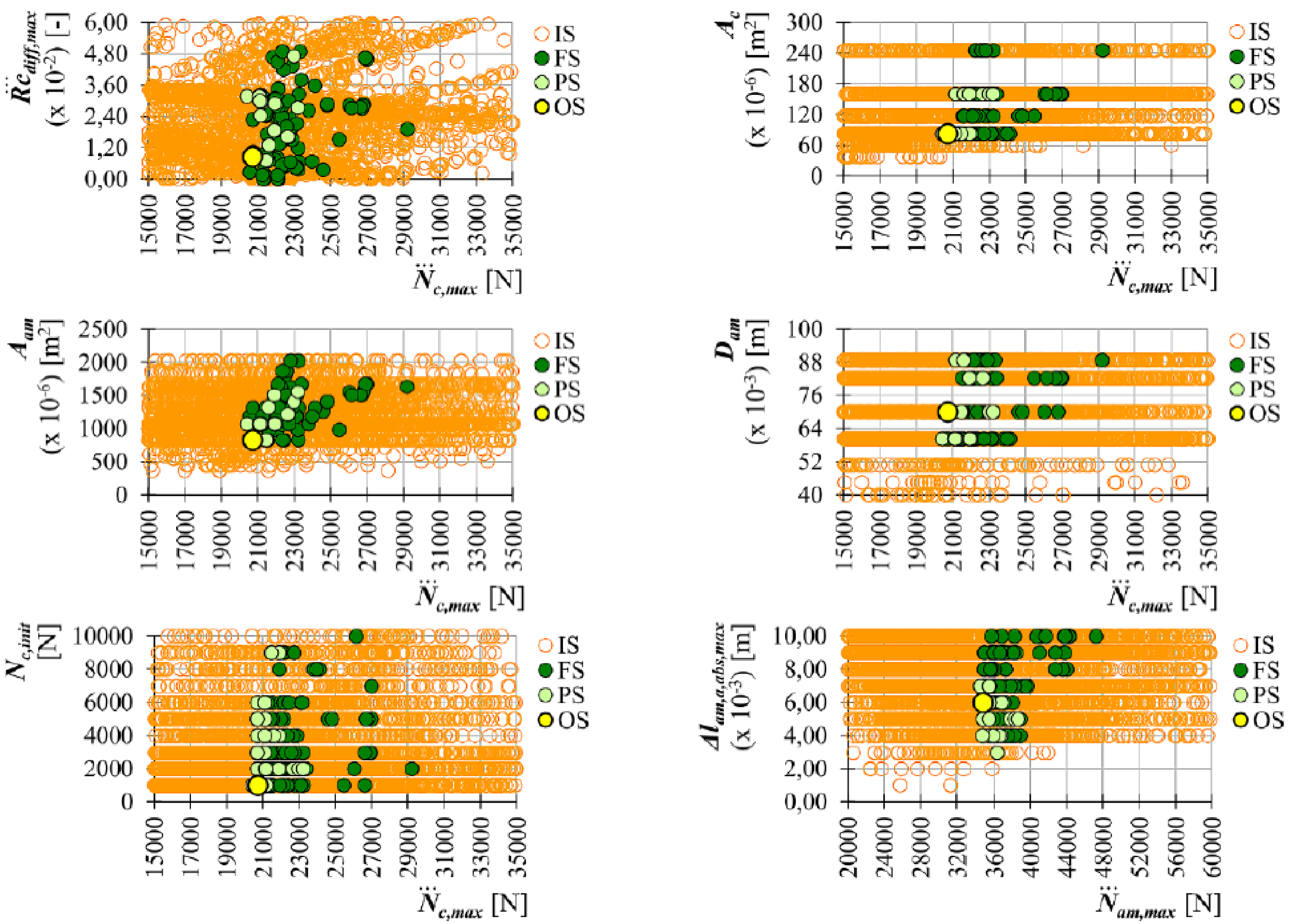
Changes in action members lengths and resulting decreases of nodal displacements



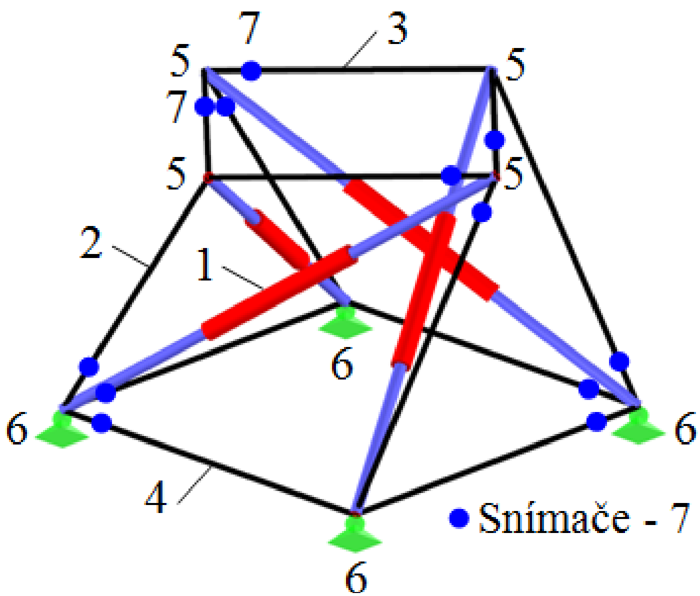


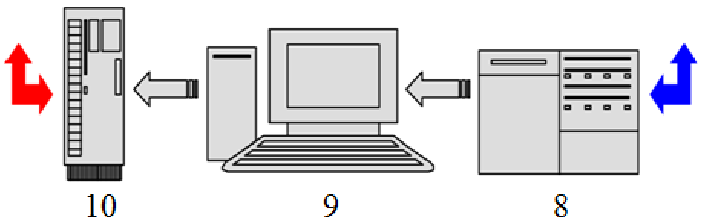
Relations between the objective functions

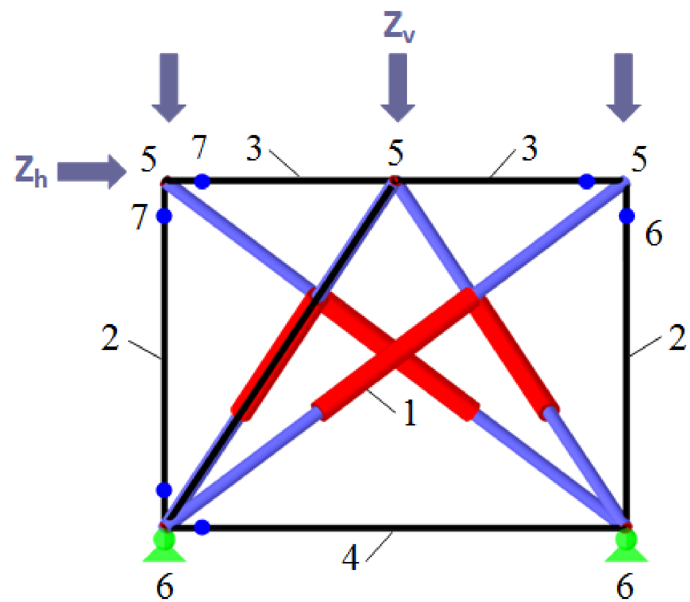
Feasible Solution - Pareto Optimal - Optimal Solution

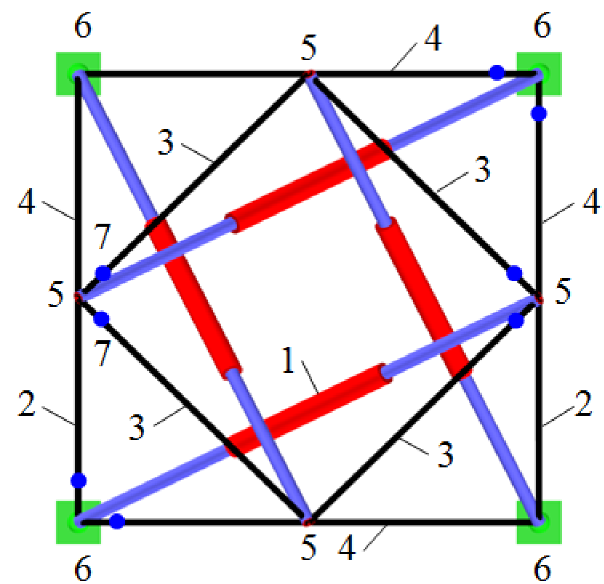


Adaptive tensegrity module

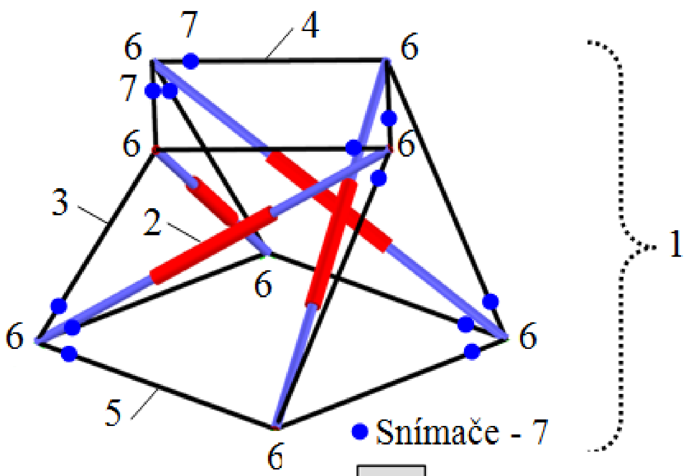


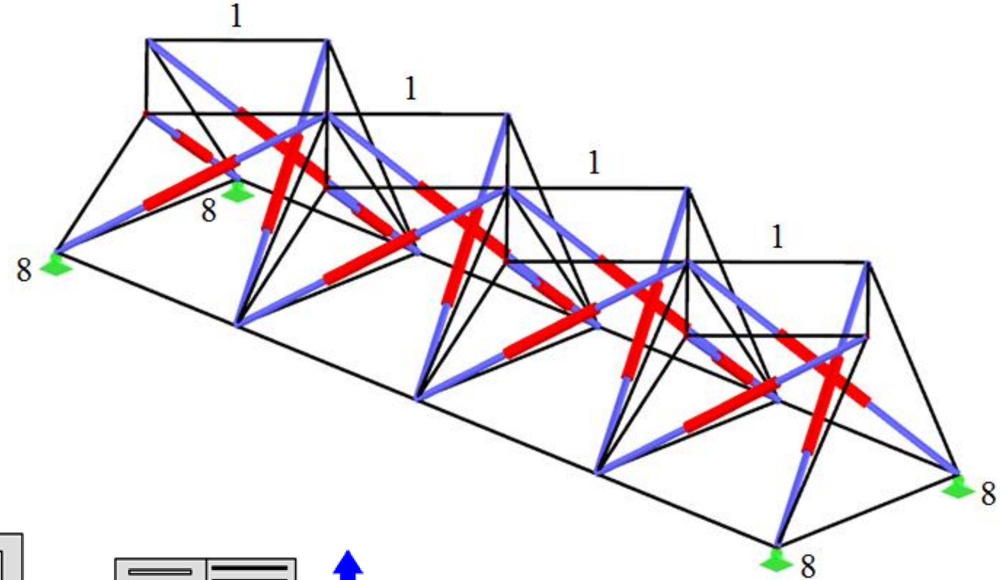


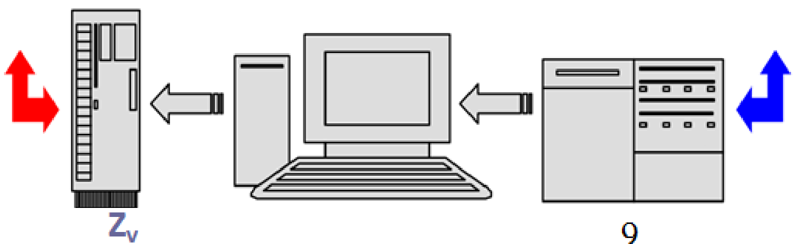


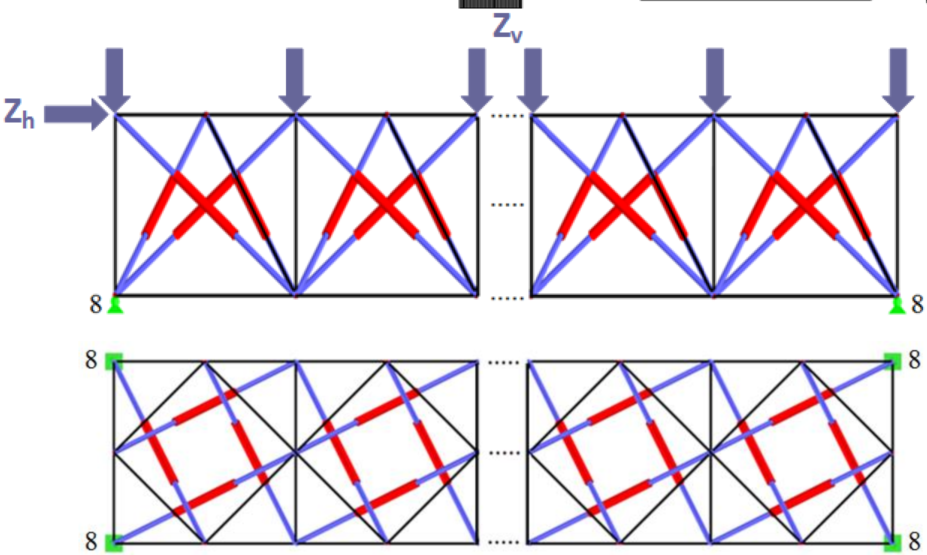


Adaptive tensegrity beam

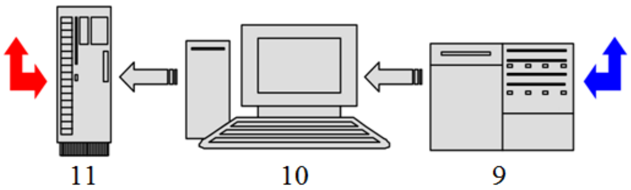


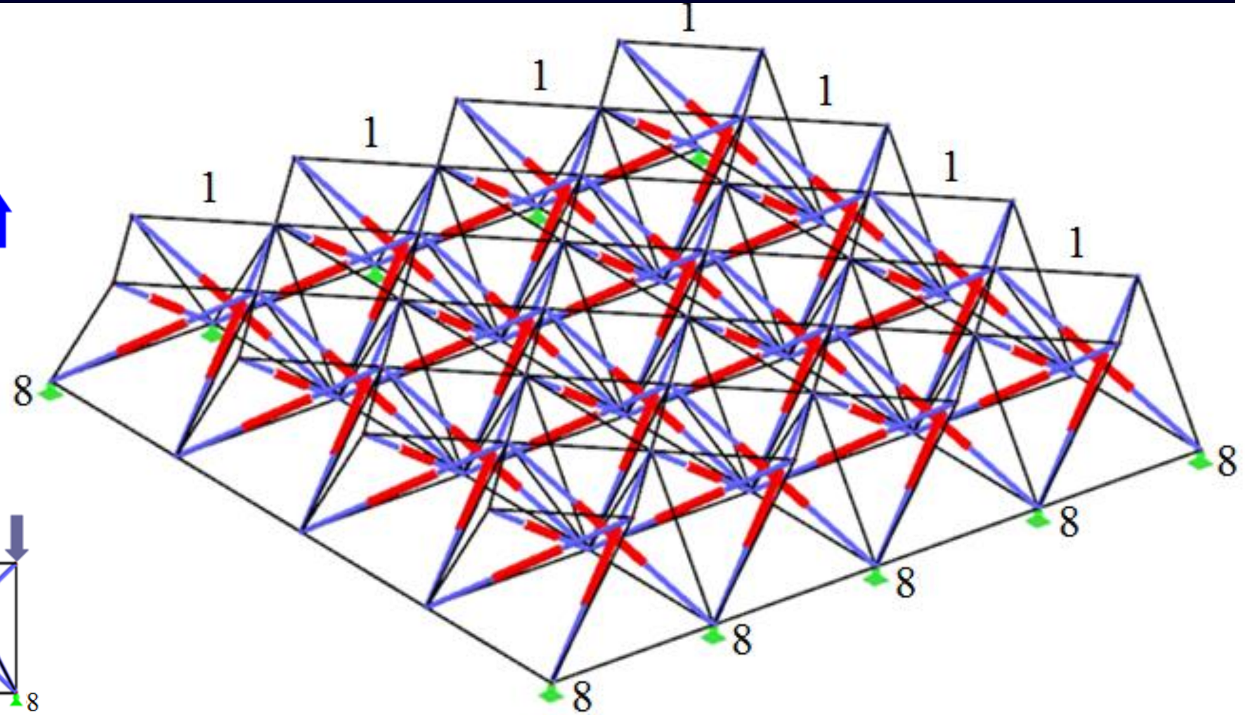


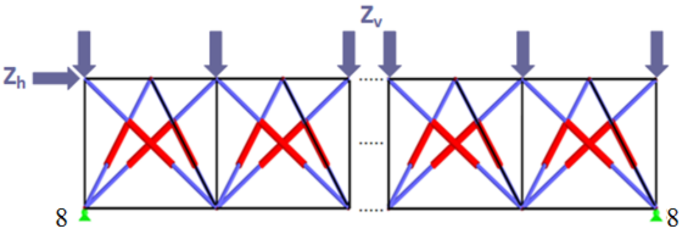


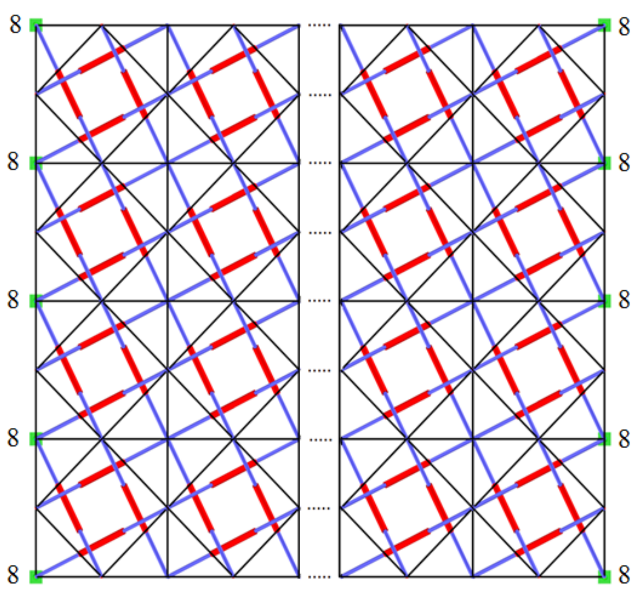


Adaptive tensegrity plate

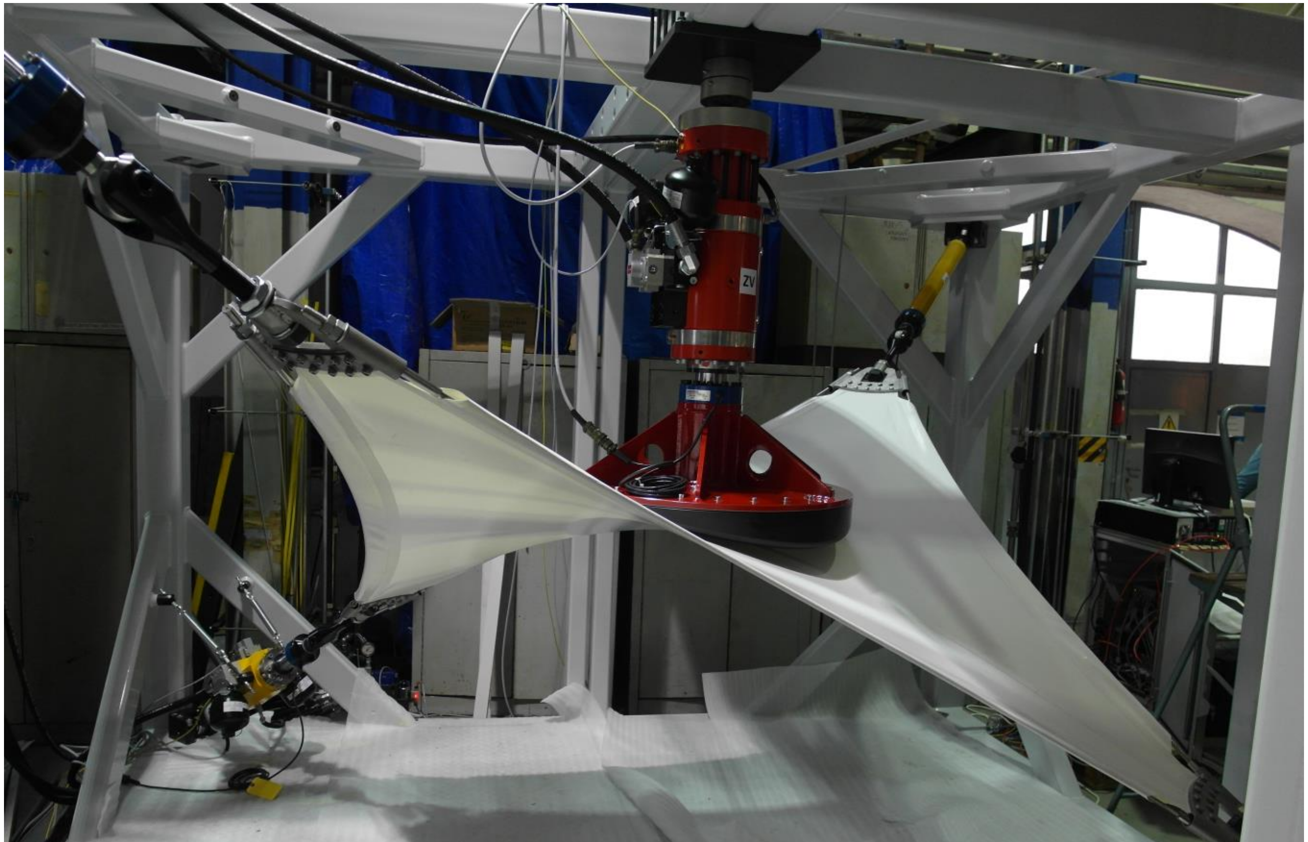


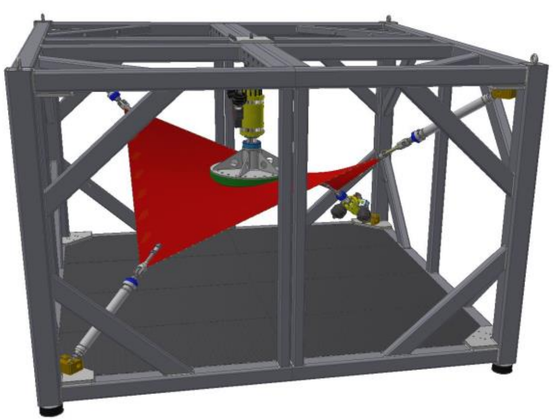


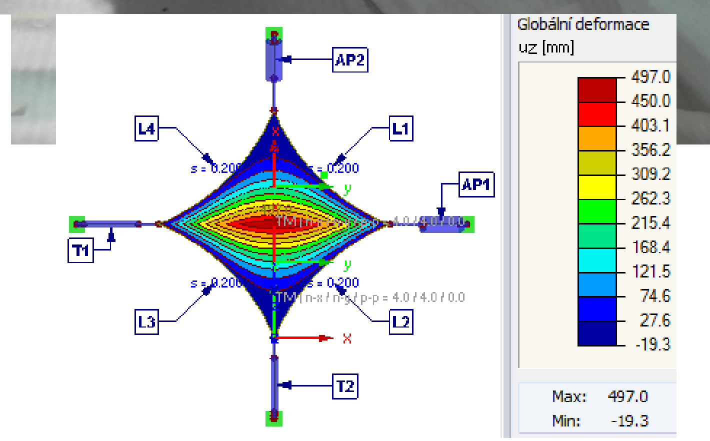


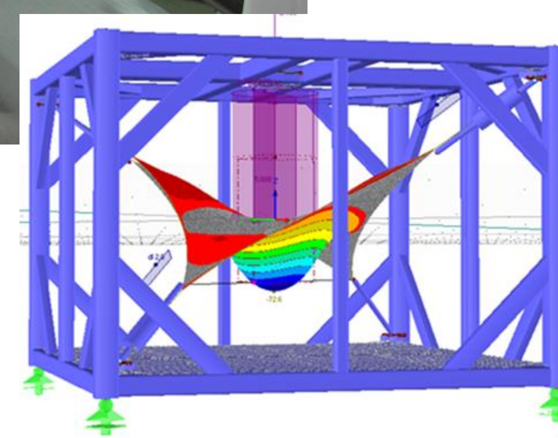


Adaptive hyperbolic-paraboloid membrane

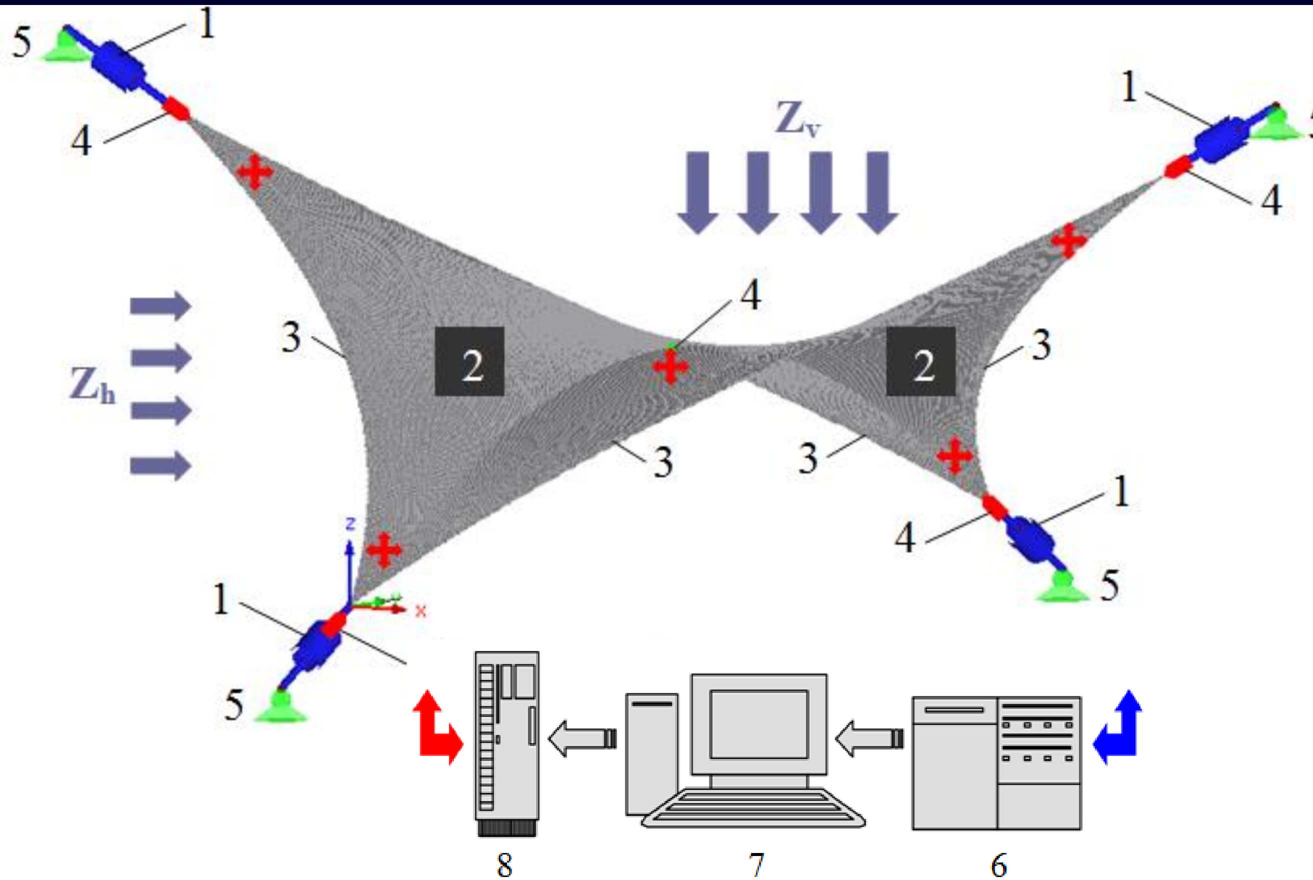


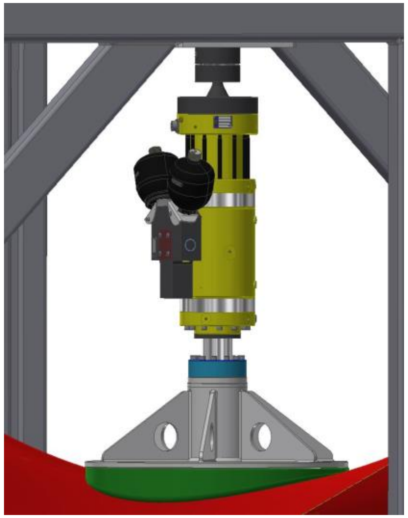


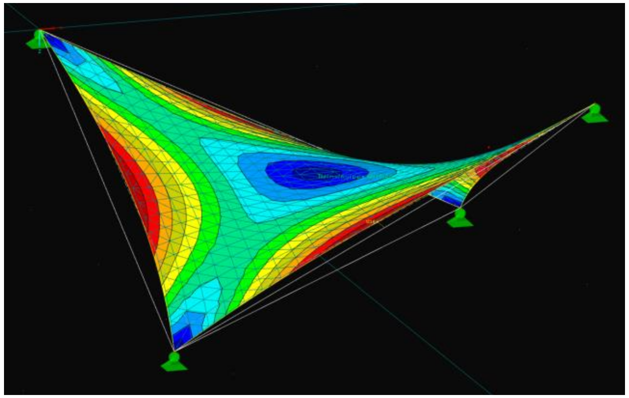


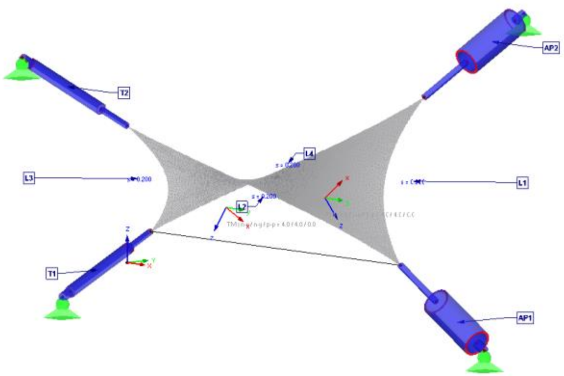


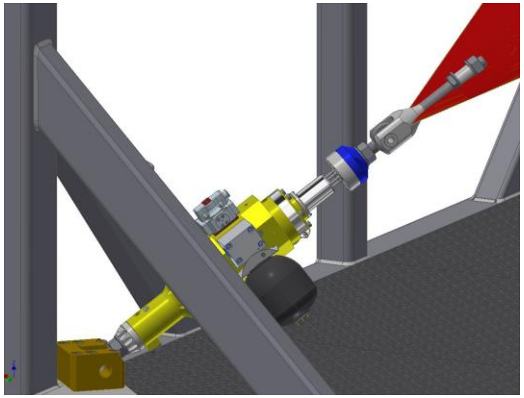
Adaptive hyperbolic-paraboloid membrane



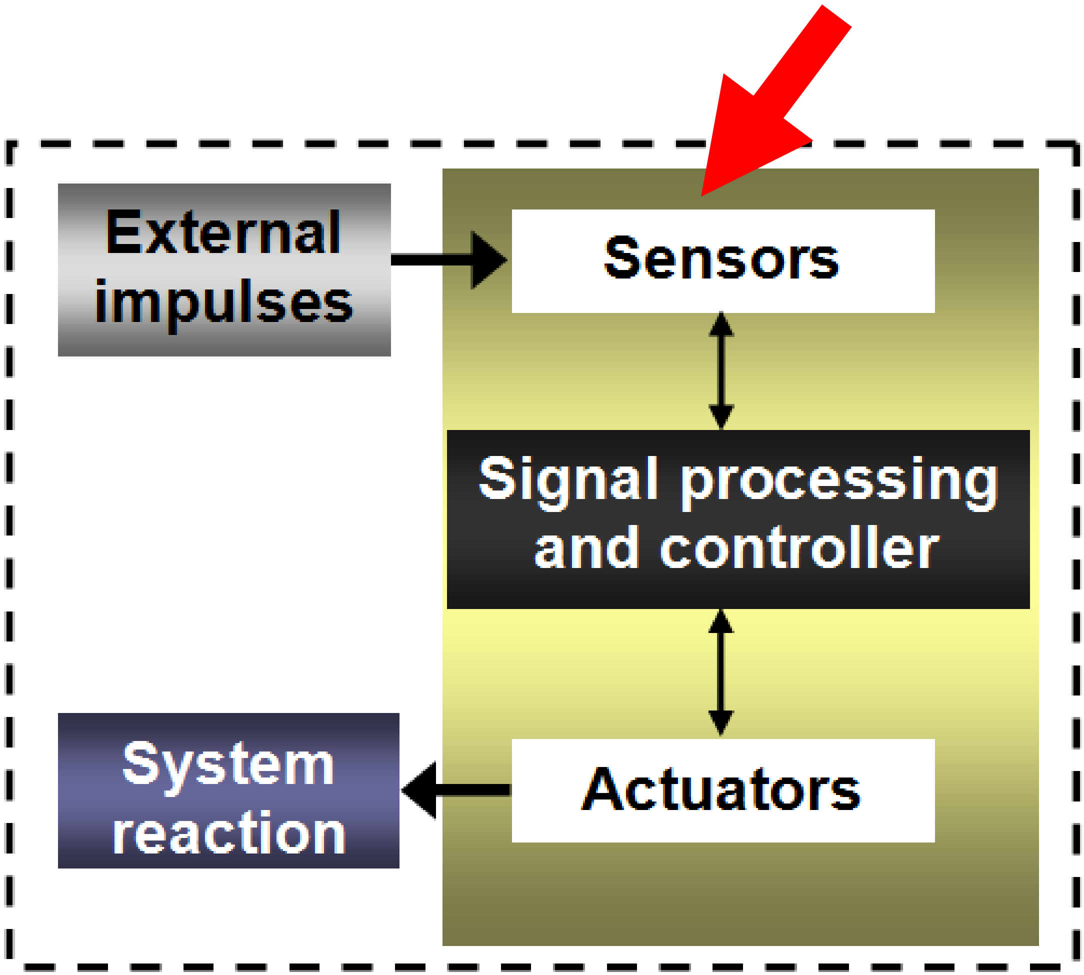








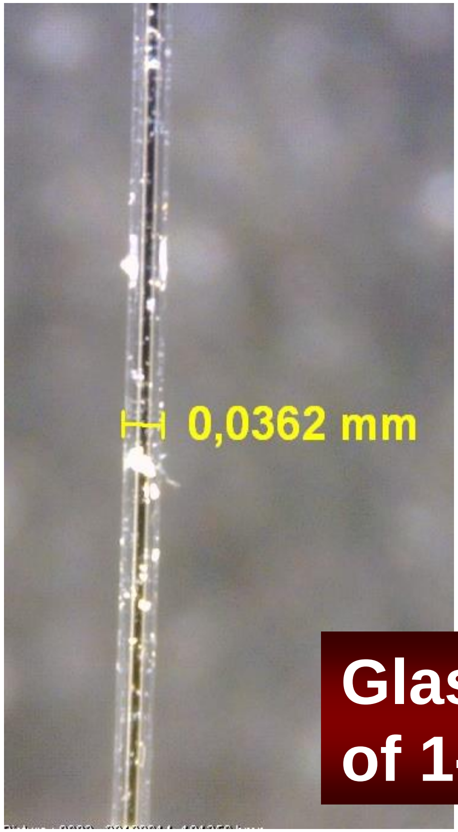
Continuous monitoring of a current state in structural members by micro-wire sensors

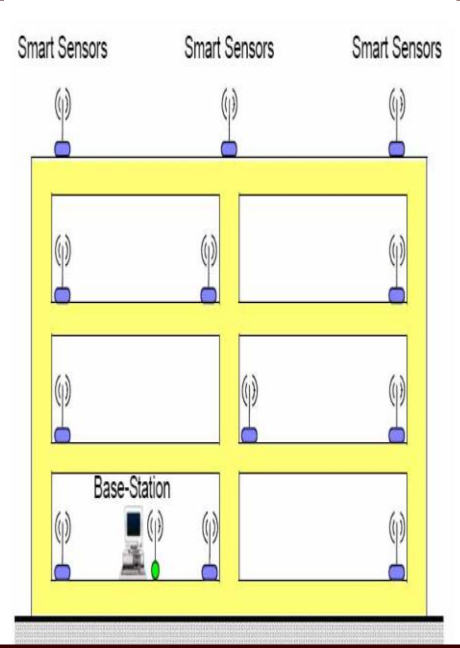


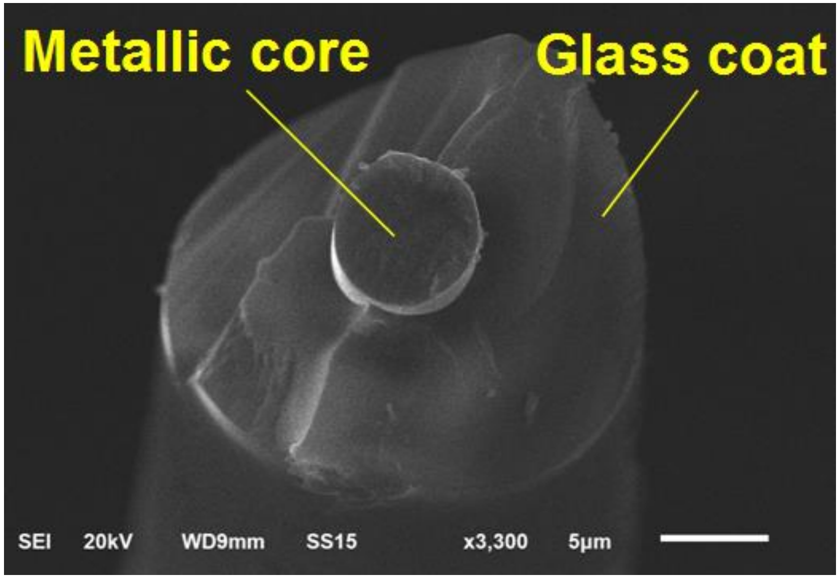
A common project with physicists from the Pavol Jozef Safarik University in Košice and RVmagnetics company

Non-contact detection and quantification of complete deformation fields in structural members by micro-wire sensors

Microwires provide information on the internal forces and the mechanism of local damage that leads to failure of the structure

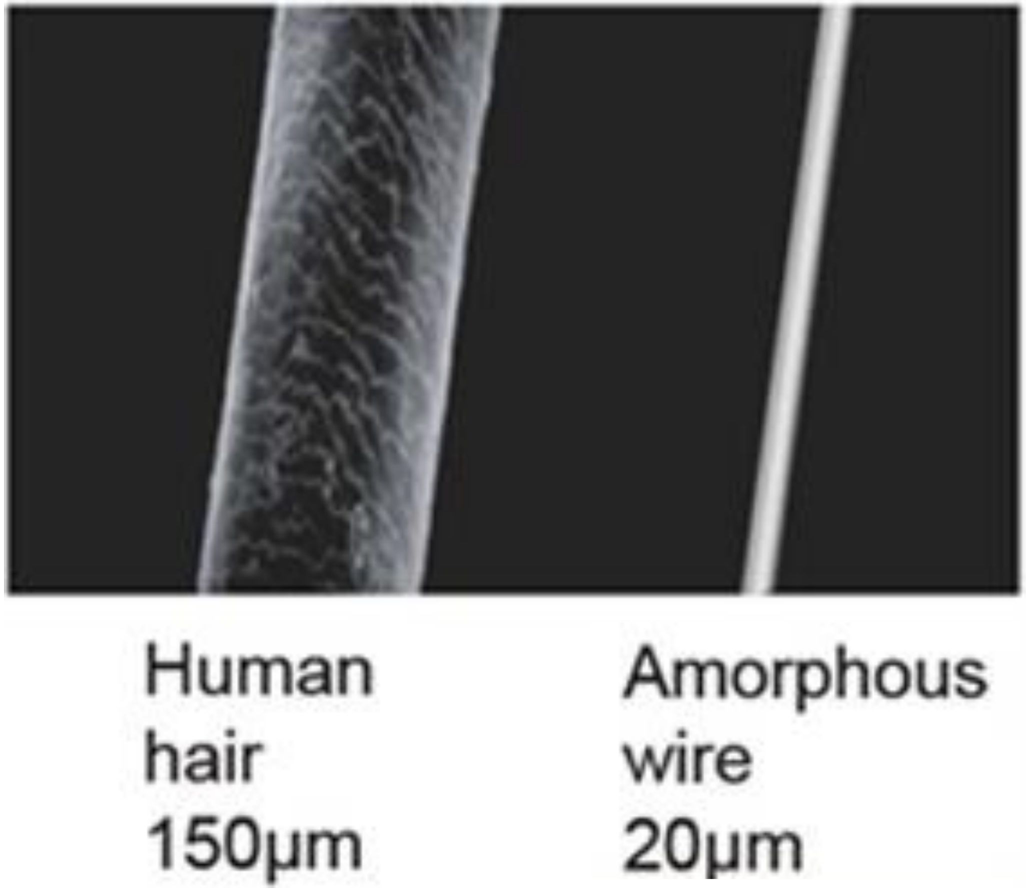


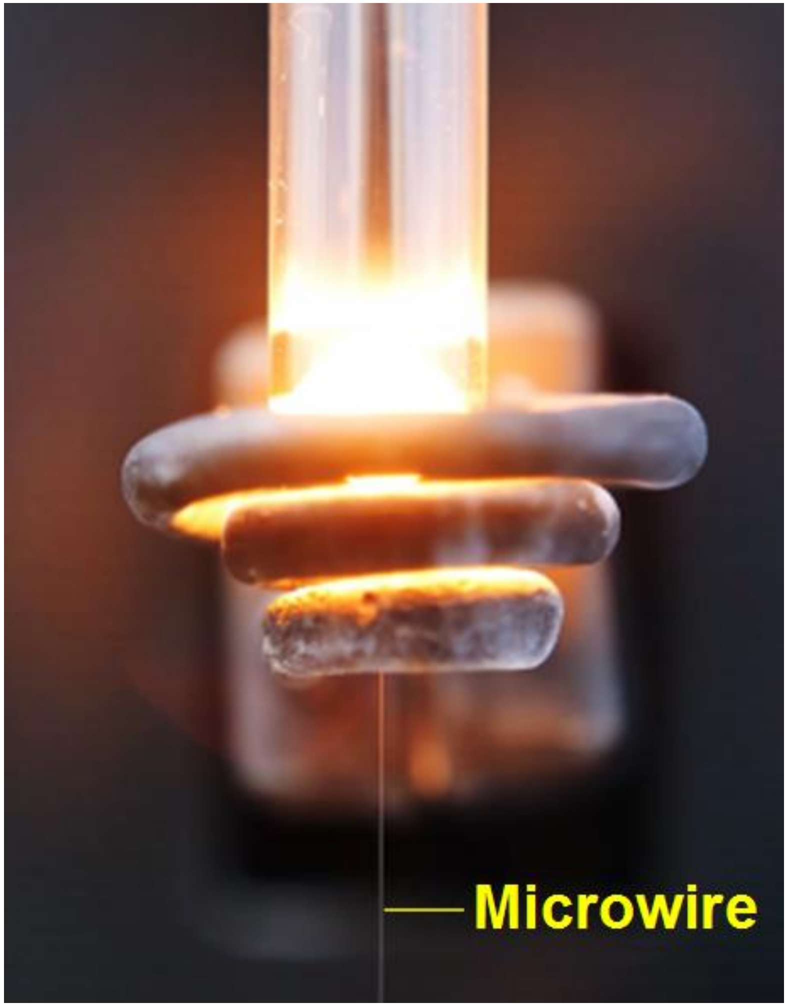




Glass coated microwires metallic core (diameter of 1-50 µm) glass-coat (thickness of 2-20 µm)

Microwire

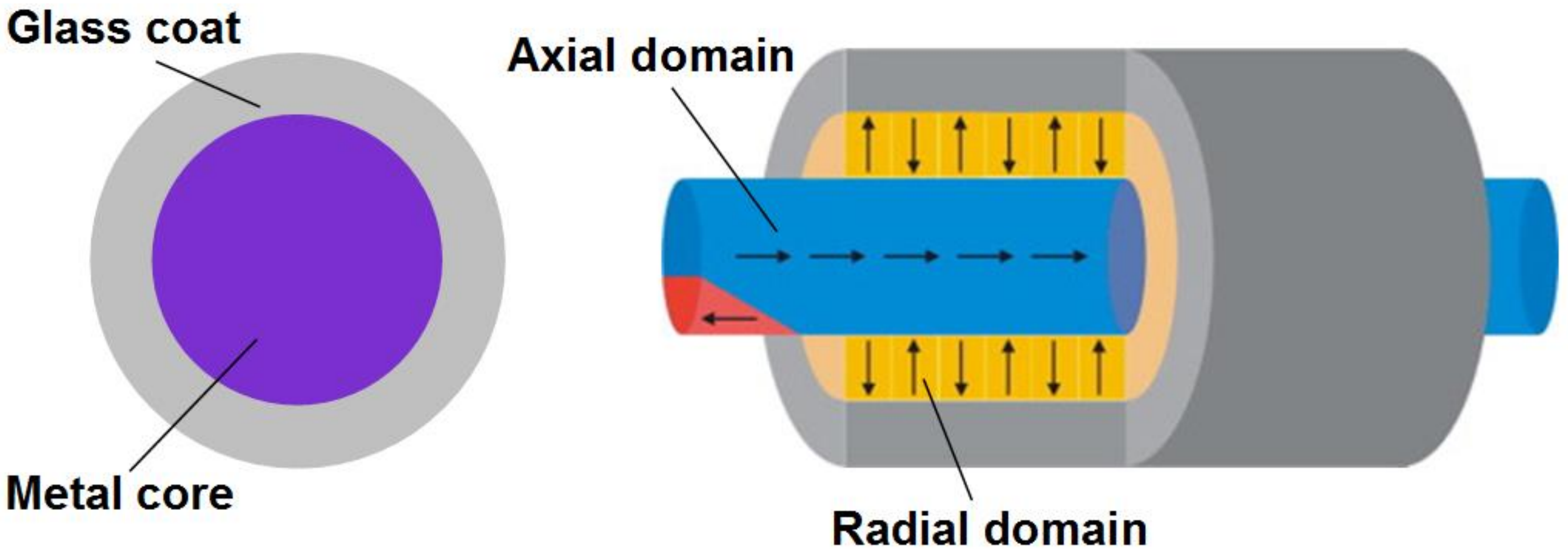


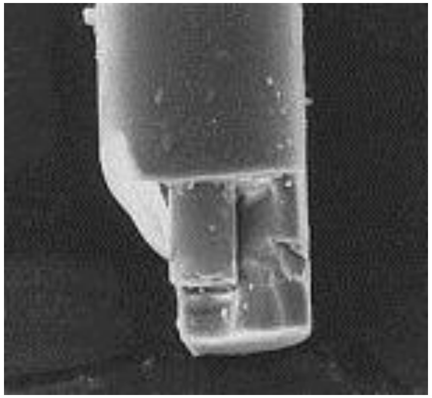


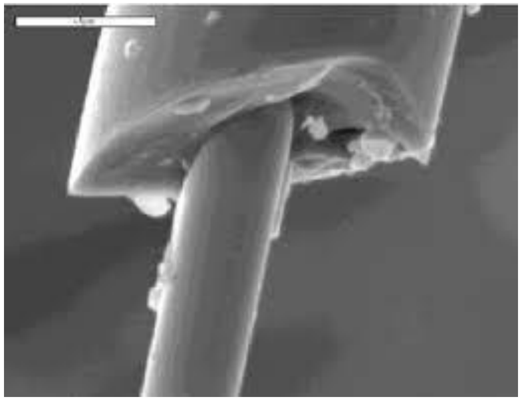
Microwires are produced by continuously drawing molten metallic alloy inside the glass capillary through the quenching liquid water or oil: (Taylor-Ulitovsky method)

Microwire – magnetisation principle

The positive magnetostriction microwires are characterized by an axial monodomain structure, implying magnetic bistability.

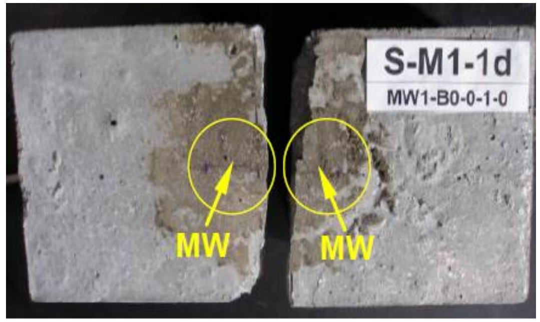


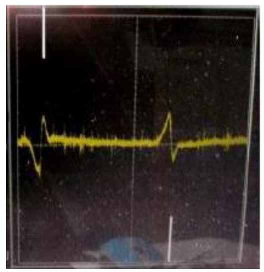


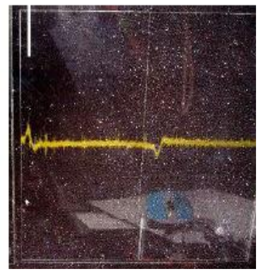


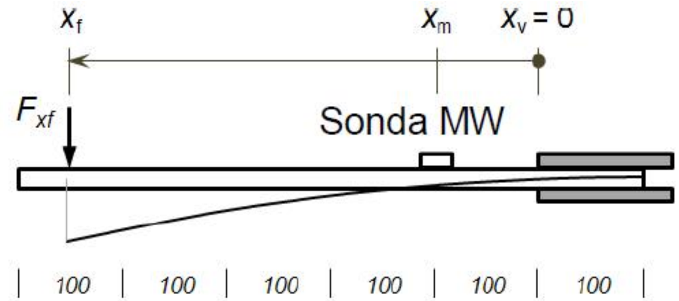
Microwire unique property magnetoelasticity with positive magnetostriction which makes them suitable elements for sensing, especially strain and temperature fields in the structures.

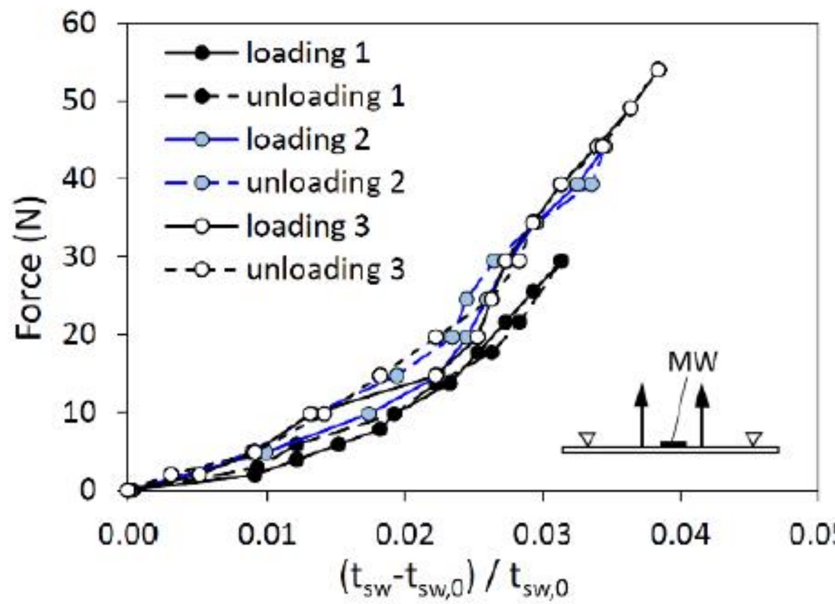
Testing on various materials and members



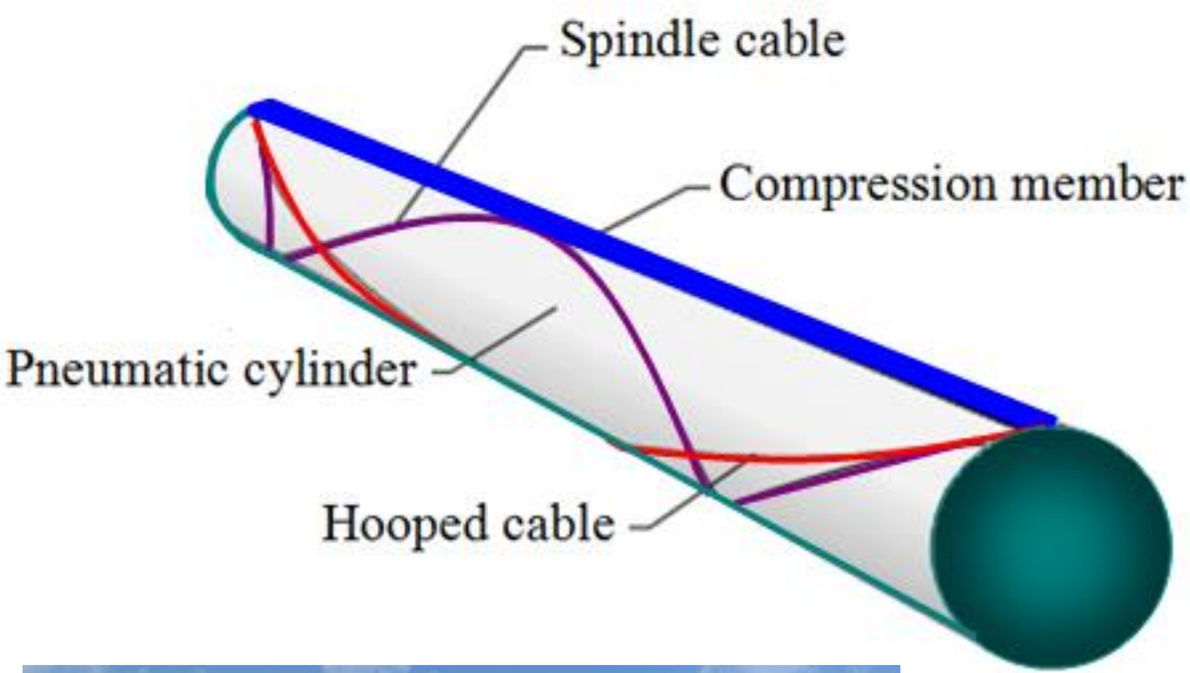






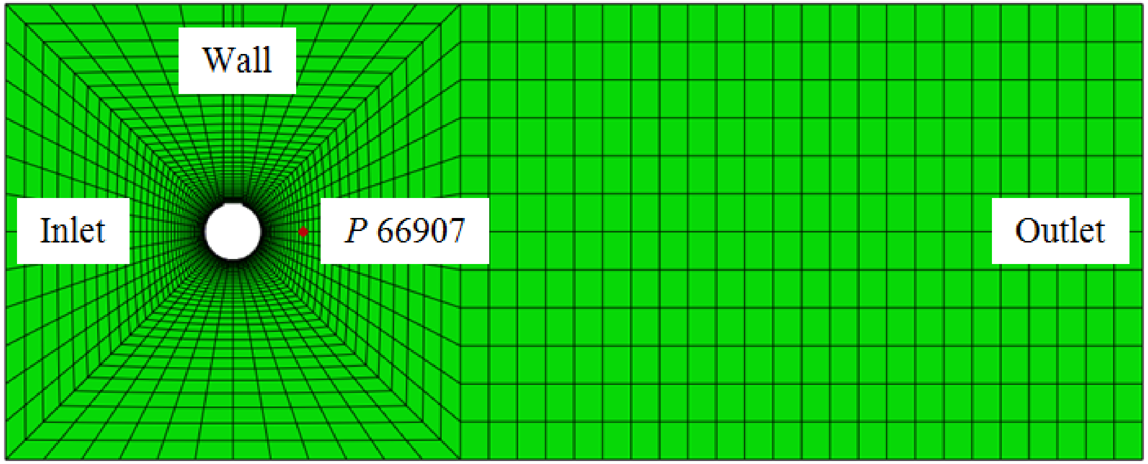


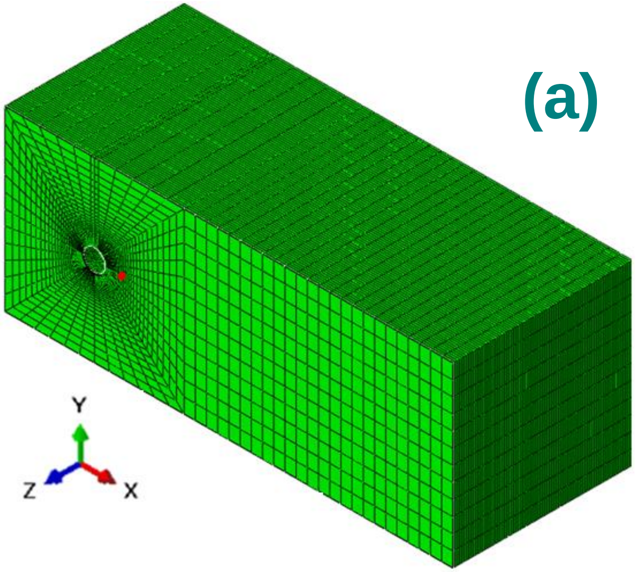
Basic structural members of the Tensairity cylindrical beam and its applications

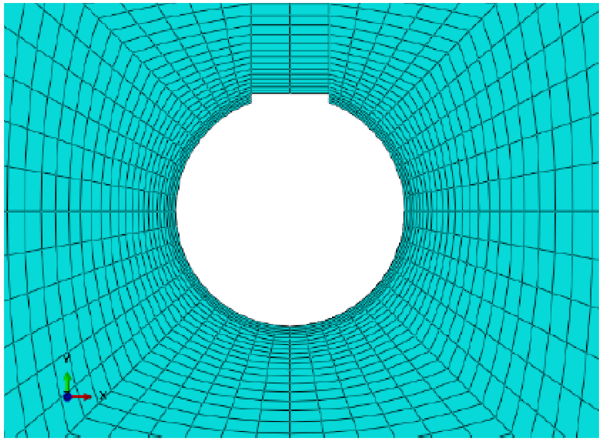


Various applications: arches, roofs, bridges etc.

Computational Fluid Dynamics (CFD) analysis of the Tensairity cylindrical beam





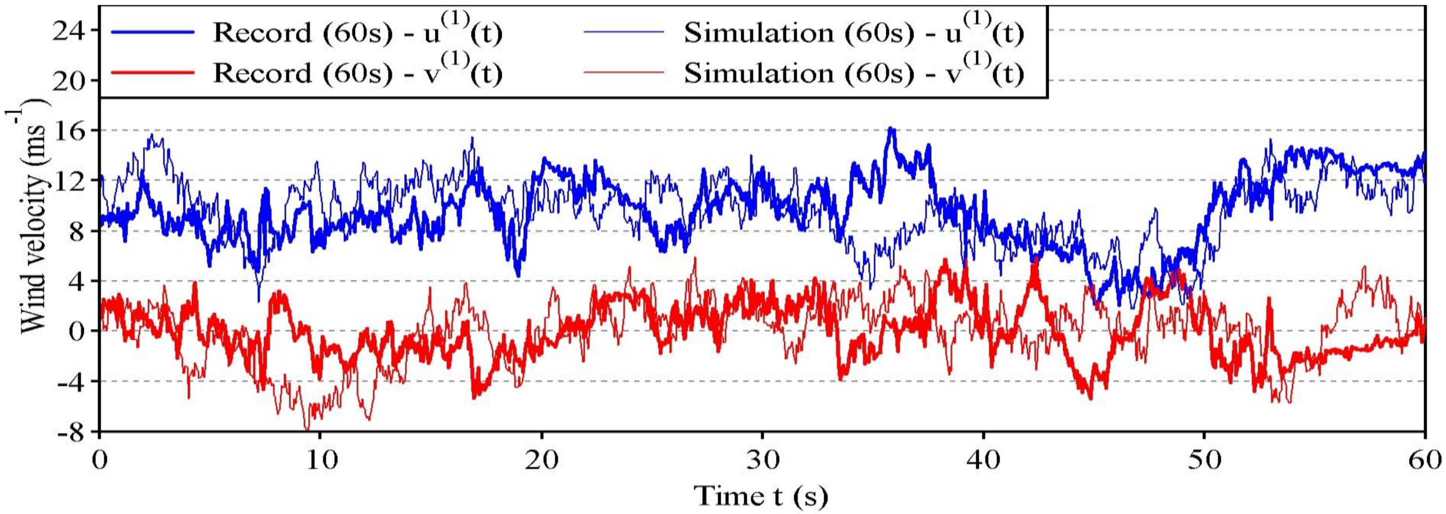


A finite element mesh of the computational fluid domain:
(a) an axonometric view with a position of the monitored point (in red) and
(b) a detail of the cross section of the Tensairity cylindrical beam.

For the fluid flow model, a one-equation turbulence Spalart-Allmaras (SA) flow model was selected (Large Eddy Simulation)

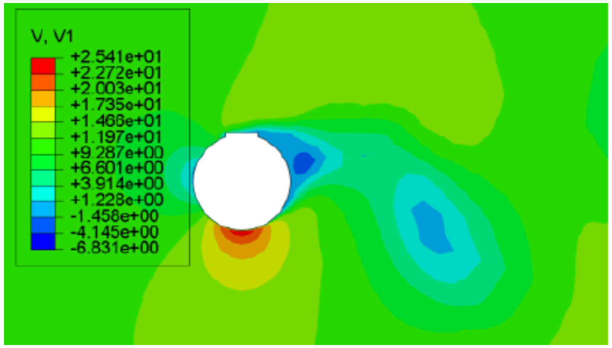
Fluid-Structure Interaction (FSI) analysis of the Tensairity cylindrical beam subjected to fluctuating wind effects

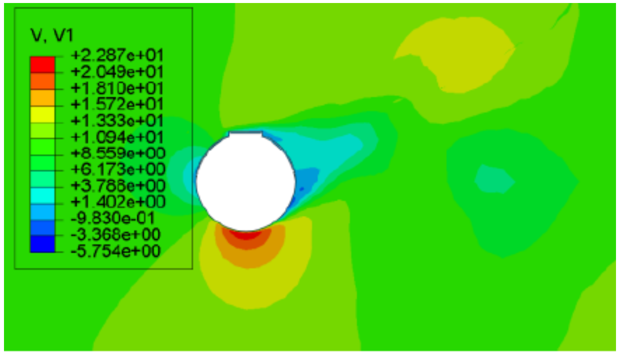
Consequently, additional boundary conditions for FSI model consist of a FSI interface in the fluid model and FSI interface in the model of the Tensairity cylindrical beam structure, which are easily defined in the Abaqus/CFD module and in the Abaqus/Explicit module

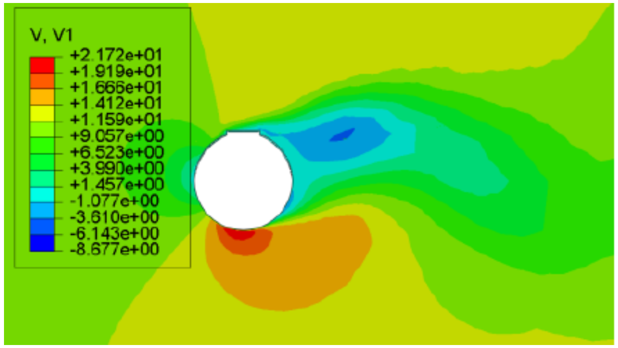


Time course of the experimentally measured and simulated wind velocity components in the longitudinal and lateral direction

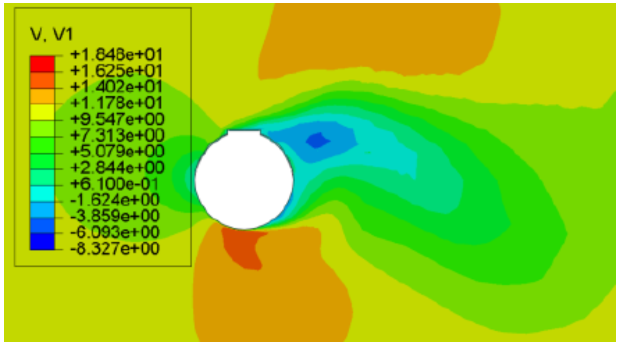
Wind flow fields (wind velocities) and shapes of waves (vortex shedding phenomena) around the Tensairity cylindrical beam subjected to fluctuating wind velocity in the selected discrete times (the FSI analysis)

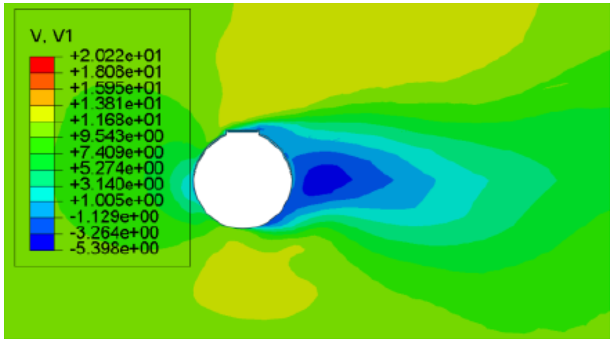


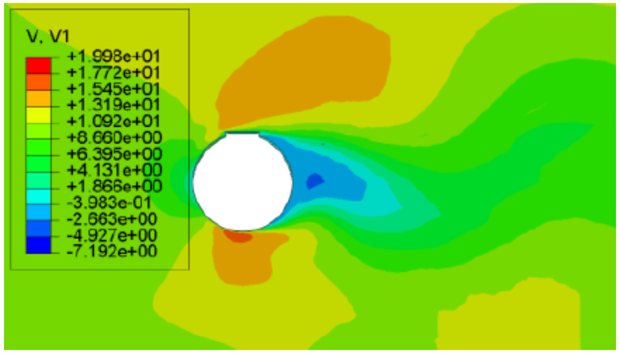




Times: (a) 0,5 *s* **(b) 1,5 *s*** **(c) 2,5 *s***

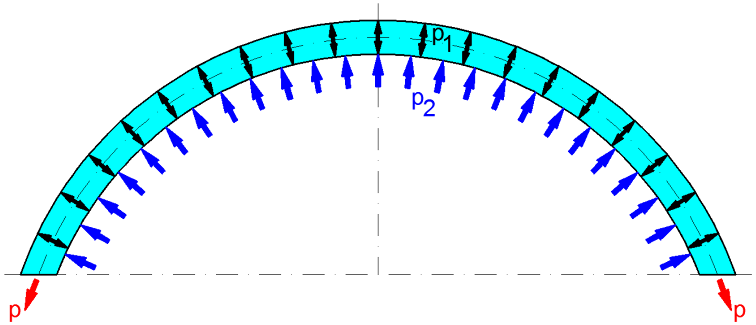


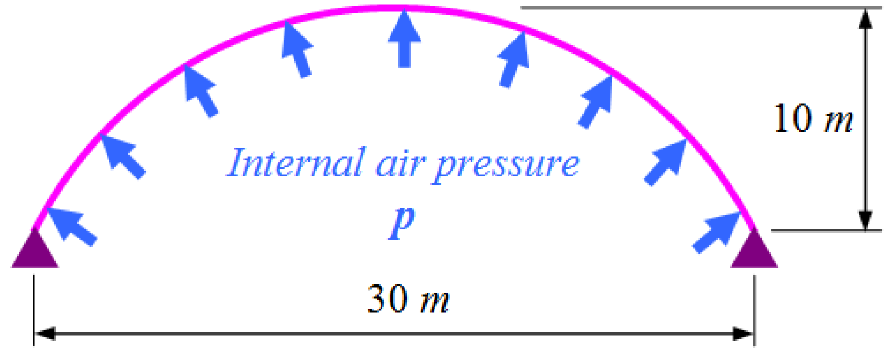


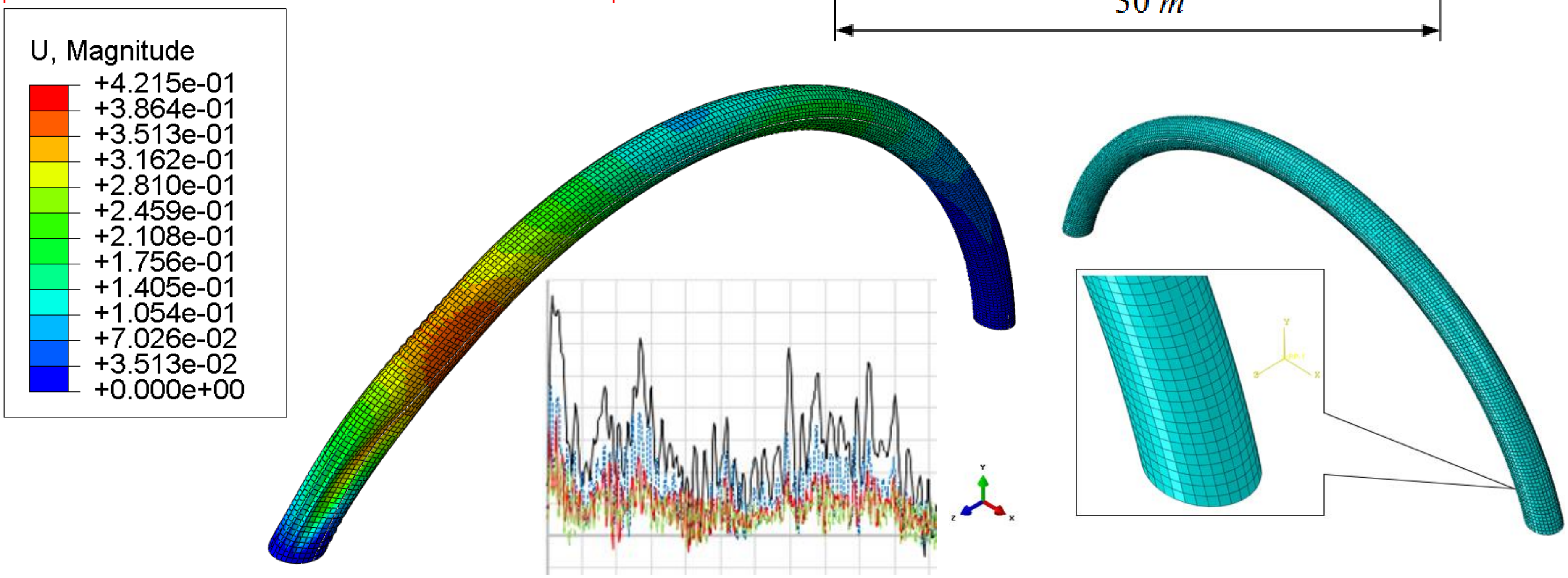


(d) 3,5 *s* **(e) 4,5 *s*** **(f) 5 *s***

Aerodynamic analysis of an air-pressurized arch subjected to turbulent wind effects







Global and local stability of the air-pressurized arch subjected to turbulent wind effects

TUKE as

► ***interdisciplinary***
► ***international***
► ***entrepreneurial*** *institution,*

with a clear conception of ***excellence***
In science, education and knowledge transfer,
able to offer
complex solutions *and* ***engaged approach****.*

The TECHNICOM University Science Park, activities for active commercialisation and spin-off firms: to improve transfer of technologies

UVP TECHNICOM

STARTUP CENTRE

VISIT OF THE PRESIDENT OF THE SLOVAK REPUBLIC

STARTUP centrum
TECHNICKÁ UNIVERZITA V KOŠICIACH

EXAMPLES OF CURRENT STARTUPS

Innovation & Technology Transfer

KOŠICE'S INNOVATION DISTRICT

The goal is KOŠICE – Science City
Concept of innovation partnership in Eastern Slovakia

PUBLIC INSTITUTIONS
- Košice Self-governing Region
- Prešov Self-governing Region
- City of Košice
- City of Prešov

SLOVAK ACADEMY OF SCIENCES
Institute of Experimental Physics, Institute of Neurobiology, Mathematical Institute, Institute of Materials Research, Institute of Parasitology, Institute of Zoology, Institute of Geotechnics, Institute of Animal Biochemistry and Genetics, Institute for Sociology, Institute of Social Sciences

PARTNER UNIVERSITIES
- Pavol Jozef Šafárik University
- University of Veterinary Medicine and Pharmacy in Košice
- University of Prešov in Prešov

Upcoming University Science Park TECHNICOM

Founder:
Technical University of Košice

Partners:
UPJŠ in Košice
PU in Prešov

- partner research and industrial associations,
- public administration,
- public sector organizations,
- financial institutions,
- commercial companies:
  U.S. Steel, s.r.o.,
  Embraco, a.s.,
  Chemosvit, a.s.,
  Nexi Fibers, a.s., etc.

SCIENCE PARKS BEING CREATED:
University Science Park MEDIPARK
Research Centre for Materials Research

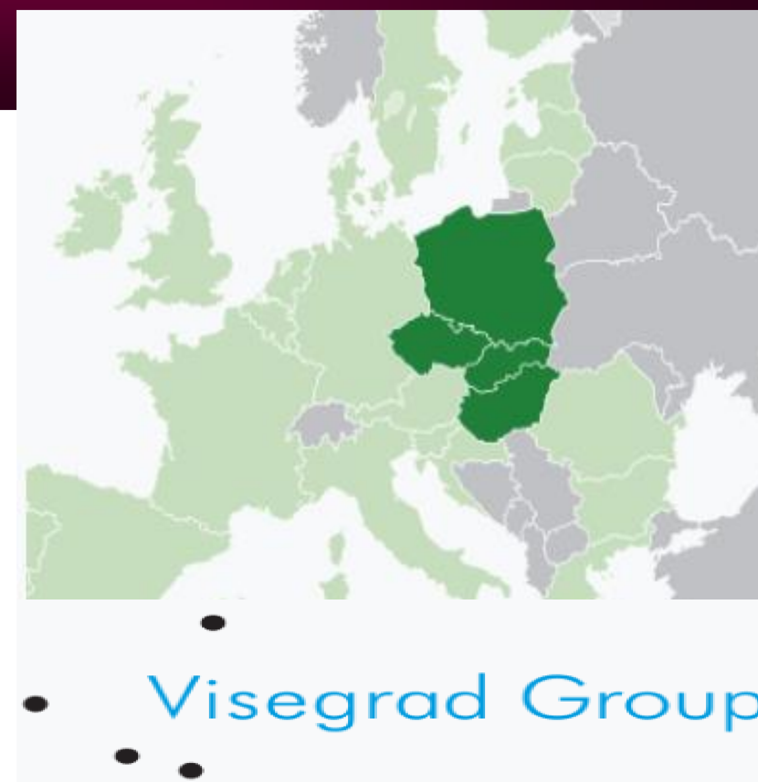
CLUSTERS:
Košice IT Valley
AT+R

Industrial park KECHNEC

and other industrial parks in the region of Eastern Slovakia

Continuing cooperation of universities from V4 countries

Excellent science based cooperation of universities in our countries is one of major assets and should be a pillar for success in FP9.



The new Framework Program for Research and Innovation 2021-2027 will be named Horizon Europe and a budget of almost € 100 billion Euros

Thank you for your kind attention !