

REAL-TIME DIGITAL TWIN DEVELOPMENT OF STRUCTURAL ASSESSMENT OF BRIDGES

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Faculty of Civil Engineering - Since 1782

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BIM OR DIGITAL TWIN ???

$BIM = 3D\ GEOMETRY + DATA$

Digital Twin = $\int_0^{100+} 3D\ GEOMETRY + DATA\ dt$



3D constructional model
Final geometry



Monitoring => Load
Laser scanning => Geometry
FEM => Explicit dynamic
Engineering decisions

TIME: 0 TO 100+ YEARS

Design

Manufacturing

Assembly,
erection

Proof testing

Service

MEASUREMENTS

FE MODEL

BUILDING THE BIM MODEL BASED ON 2D WORKSHOP DRAWINGS

MEASUREMENTS: U (LASER SCANNING), ϵ (DIC, STRAIN GAUGES), T, LOAD AND DEFLECTION

SIMULATIONS: COLD-FORMING, THERMAL CUTTING, WELDING, CONSTRUCTION STAGES,
LOADING (SLS/ULS/FAT)

3D TEKLA BIM MODEL

RESIDUAL STRESSES & DEFORMATIONS, 'REAL-TIME' DEFORMATION/STRAIN/STRESS FIELDS,
TEMPERATURES, DISP. OF BEARINGS, RESISTANCE, DAMAGE, FATIGUE LIFE

BENCHMARK: CABLE-STAYED BRIDGE IN KOMÁROM



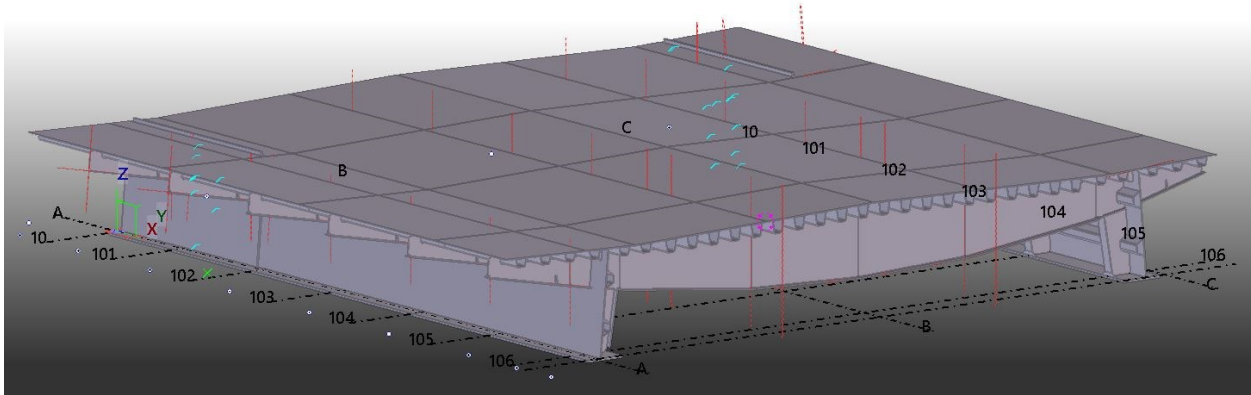
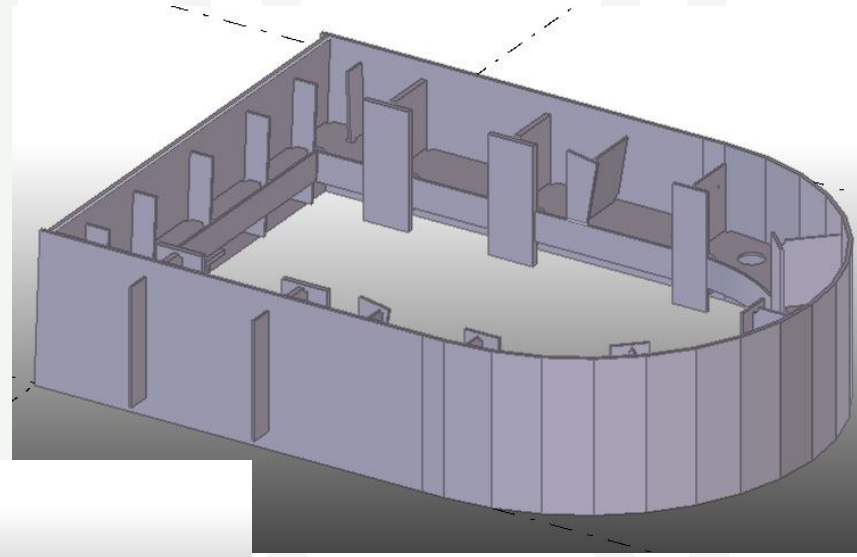
Length: 600 m
Width: 20.40 m
Spans: 66,0 + 252,0 + 120,0 + 96,0 + 66,0
Structural depth: 2.85 m
Pylon height: 80.00 m above orthotropic deck



BIM MODEL OF THE BRIDGE

Design

3D TEKLA BIM MODEL



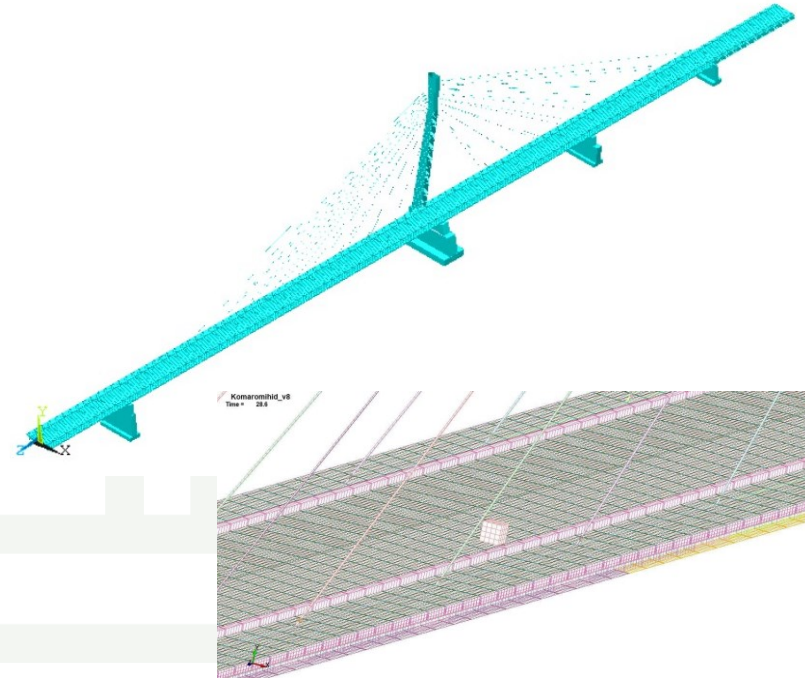
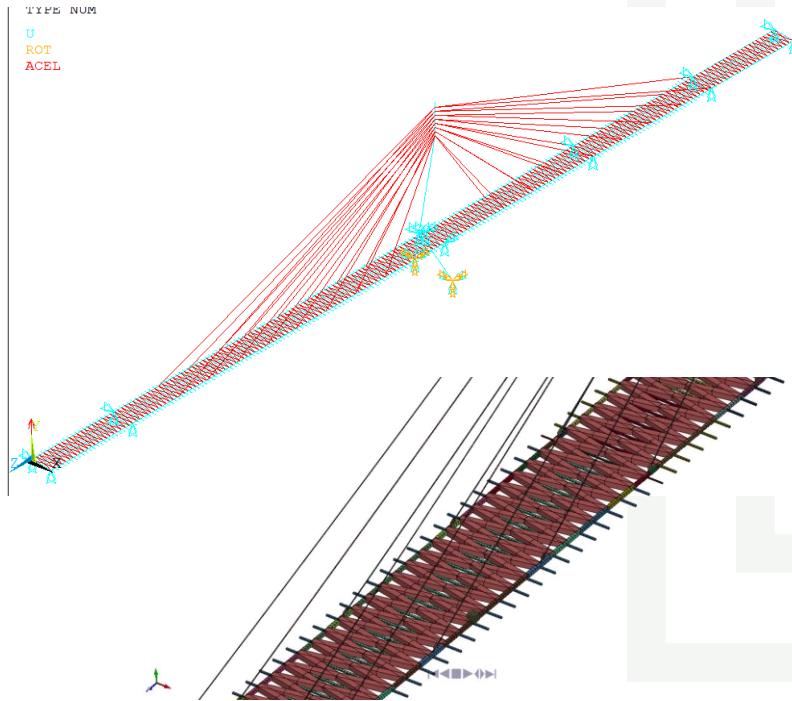
GLOBAL SHELL+BEAM MODEL FOR DESIGN

Design

FE MODEL

Beam modell

Shell modell



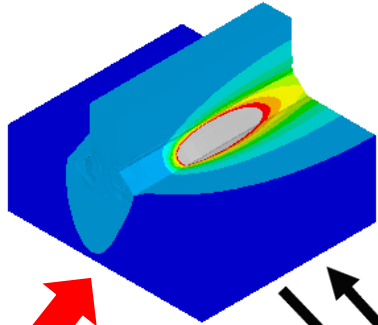
BACKGROUND OF WELDING SIMULATION

Design

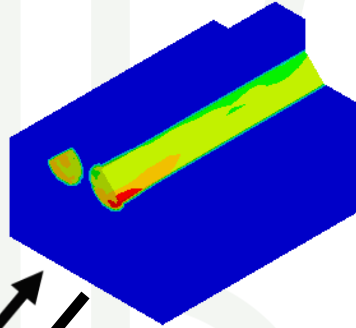
FE MODEL

- Temperature fields
- Thermal gradients
- Fusion zone
- Heat-affected zone
- Heat source model

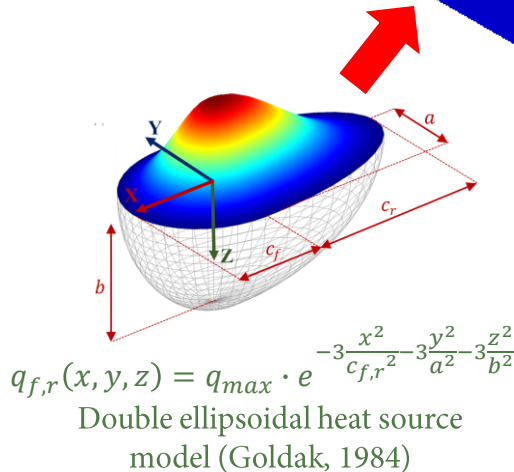
Thermal problem



Microstructure



- Phase transformations
- HV hardness
- chemical composition

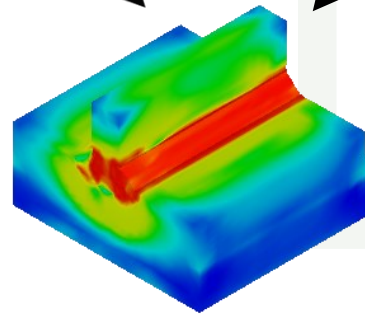


$$q_{f,r}(x, y, z) = q_{max} \cdot e^{-3\frac{x^2}{c_{f,r}^2} - 3\frac{y^2}{a^2} - 3\frac{z^2}{b^2}}$$

Double ellipsoidal heat source model (Goldak, 1984)

Uncoupled or coupled transient analysis
(local heat source, 3D)

- Deformations
- Strains
- Stresses



Mechanical problem

Application:
complex structures,
detailed analysis

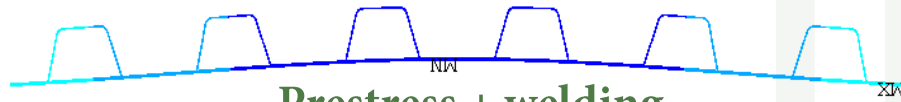
WELDING SIMULATION OF THE ORTHOTROPIC DECK

Design

FE MODEL



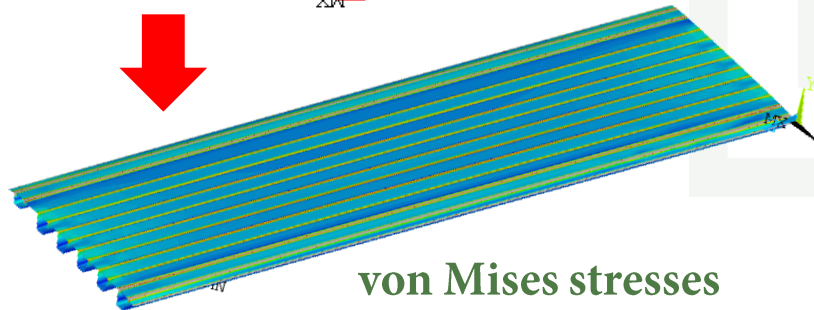
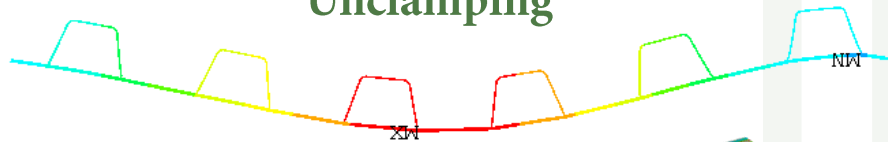
Prestress



Prestress + welding

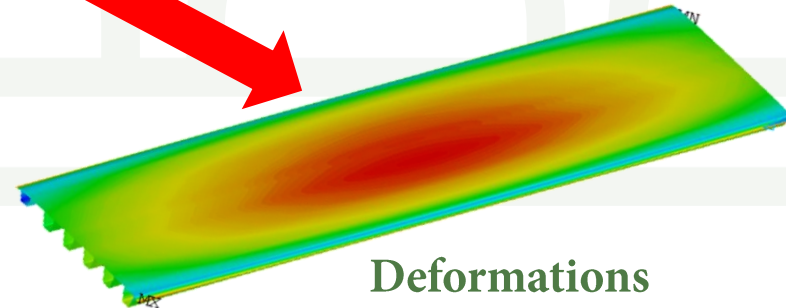


Unclamping



von Mises stresses

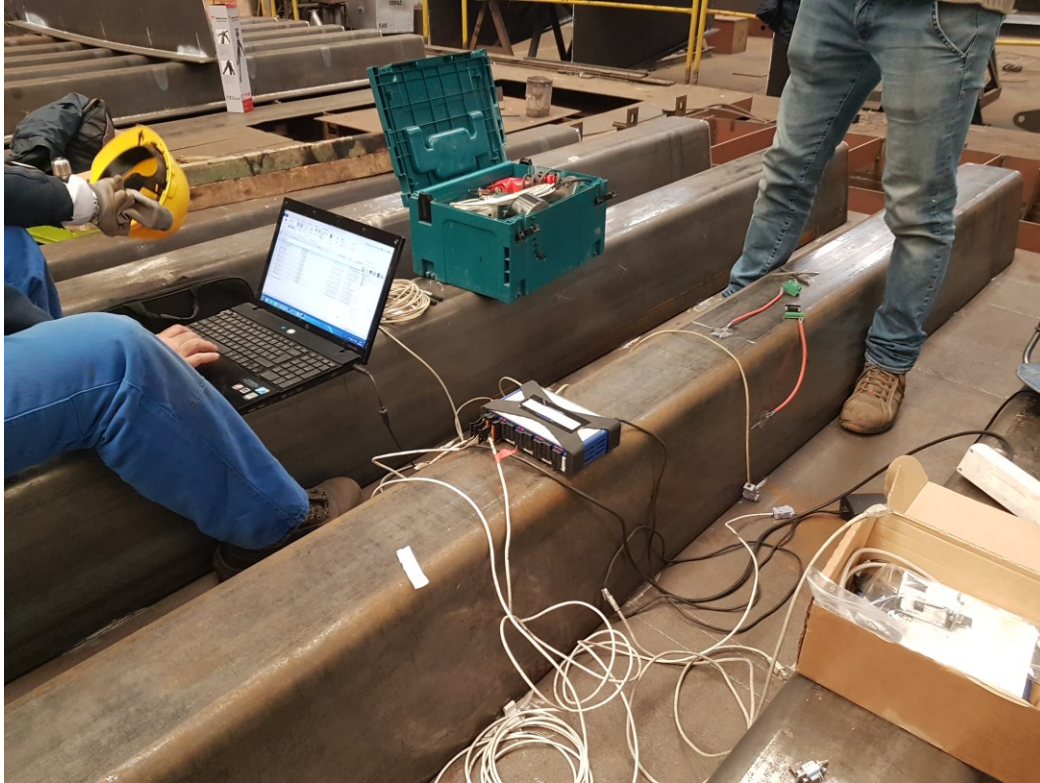
2D → 3D



Deformations

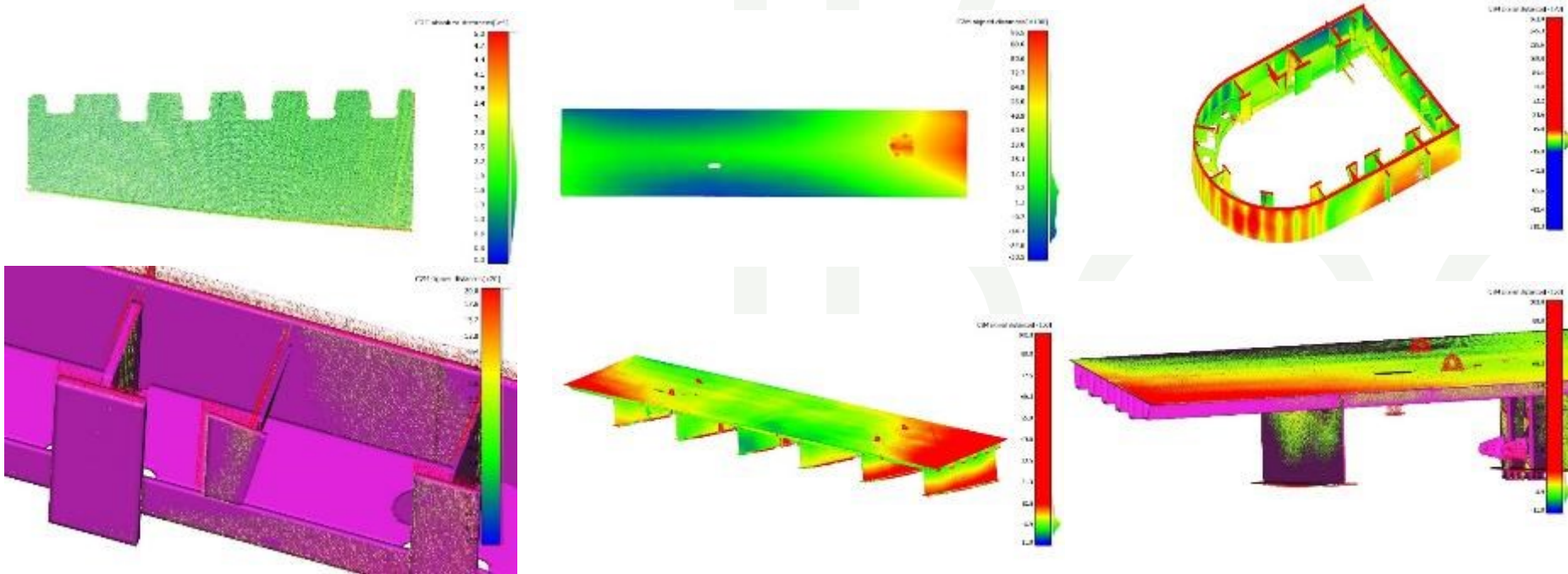
MEASUREMENTS

STRAIN GAUGES + THERMOCOUPLES



EVALUATION OF LASER SCANNING

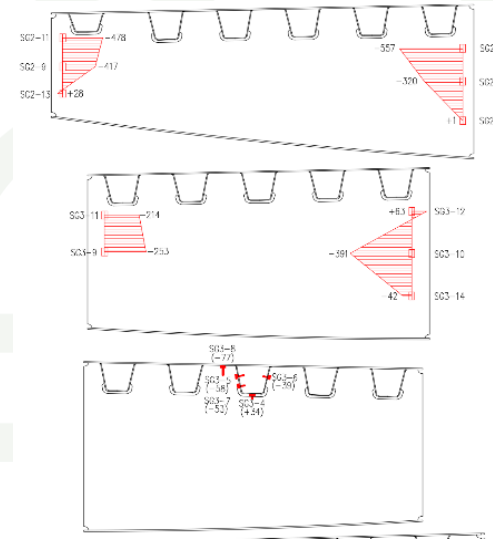
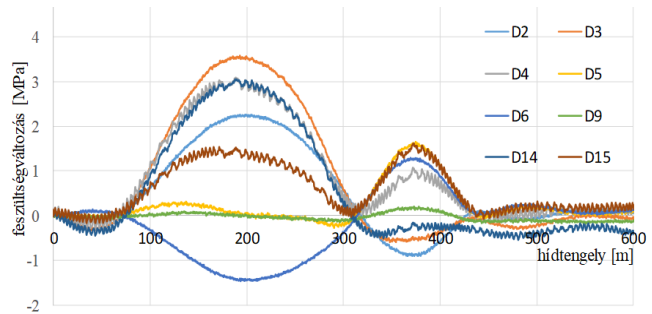
DEVIATION MAP



Assembly,
erection

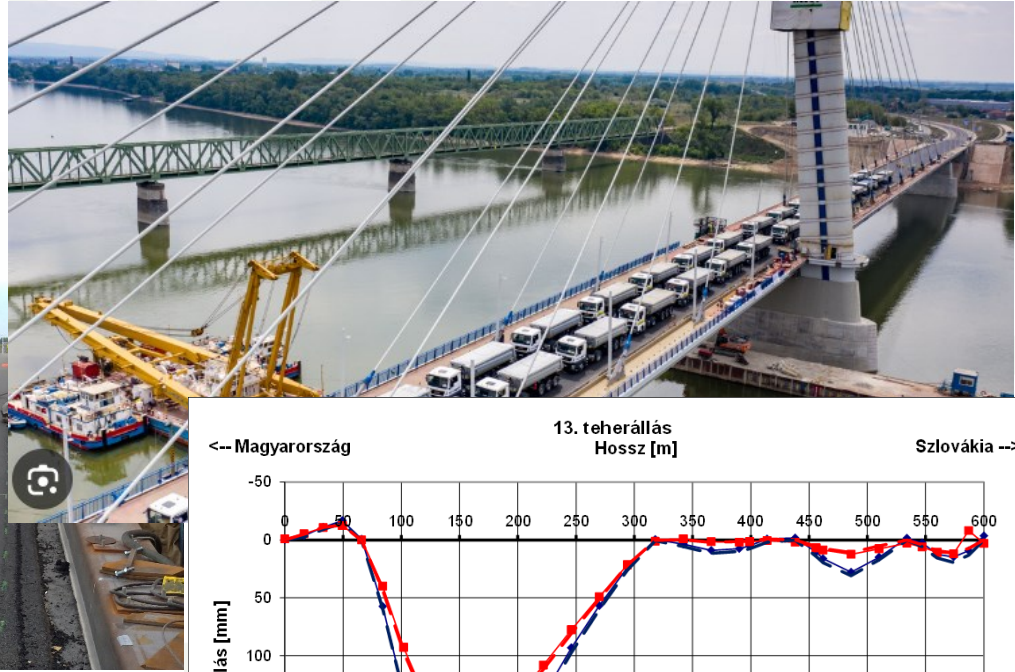
MEASUREMENTS

STRAIN GAUGES WELDING PROCESS

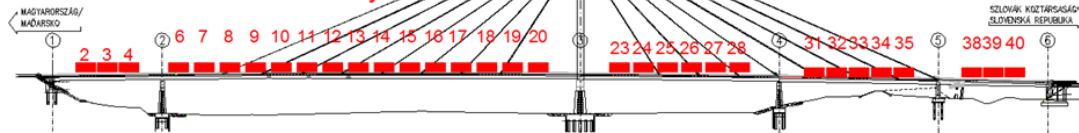


MEASURED AND FEM RESULTS

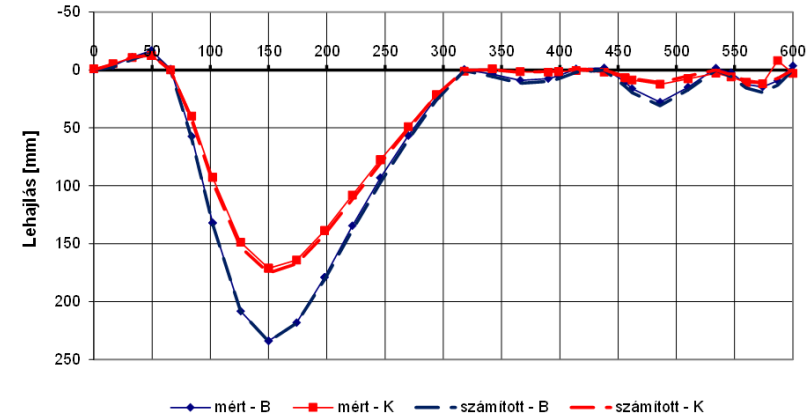
Proof testing



13. teherállás (3+15+6+5+3 db)
- féloldalas befolyási oldal



13. teherállás
Hossz [m]



SHM OR REAL-TIME DIGITAL TWIN?

Service

STRUCTURAL HEALTH MONITORING:

- *MONITORING SYSTEM*
- *STRUCTURAL DATA IN SPECIFIC POINTS*

REAL-TIME DIGITAL TWIN:

- *MONITORING SYSTEM*
- *VEHICLE WEIGHT-IN-MOTION (AI)*
- *LOAD*
- *EXPLICIT DYNAMIC ANALYSIS*
- *STRUCTURAL DATA IN ALL POINTS*

AXLE LOAD DETERMINATION

Service

MEASUREMENTS

FE MODEL

INPUT

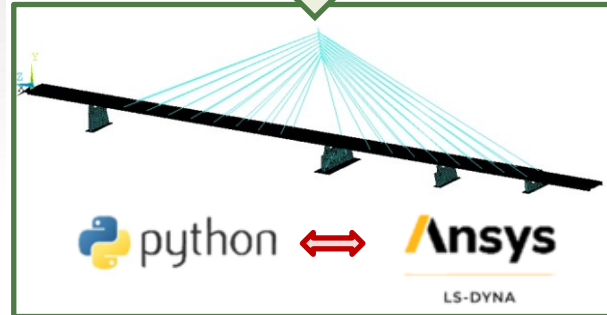
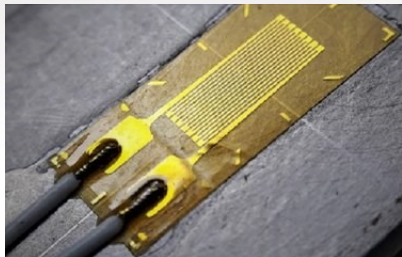
Measurements
AI deep learning
Axle weight
Load

FE model

Explicit
dynamic
analysis

OUTPUT

Stresses
Deformations



Tekla
Structures

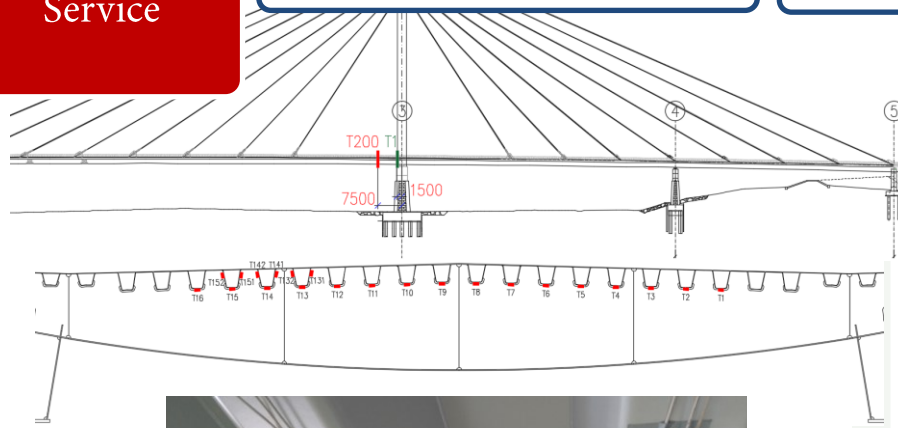


STRAIN GAUGES IN TWO CROSS-SECTIONS

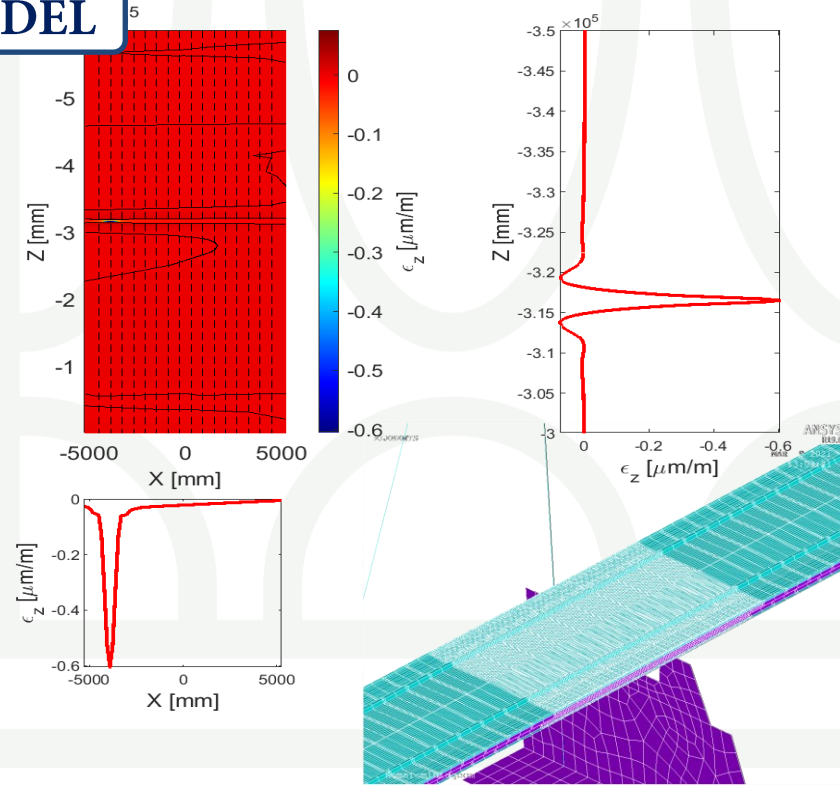
Service

MEASUREMENTS

FE MODEL



Strain gauges in two cross-sections



Impact surface data from FEM

AI DEEP LEARNING ALGORITHM FOR WEIGHT IN MOTION

Service

Effected window

Noise reduction

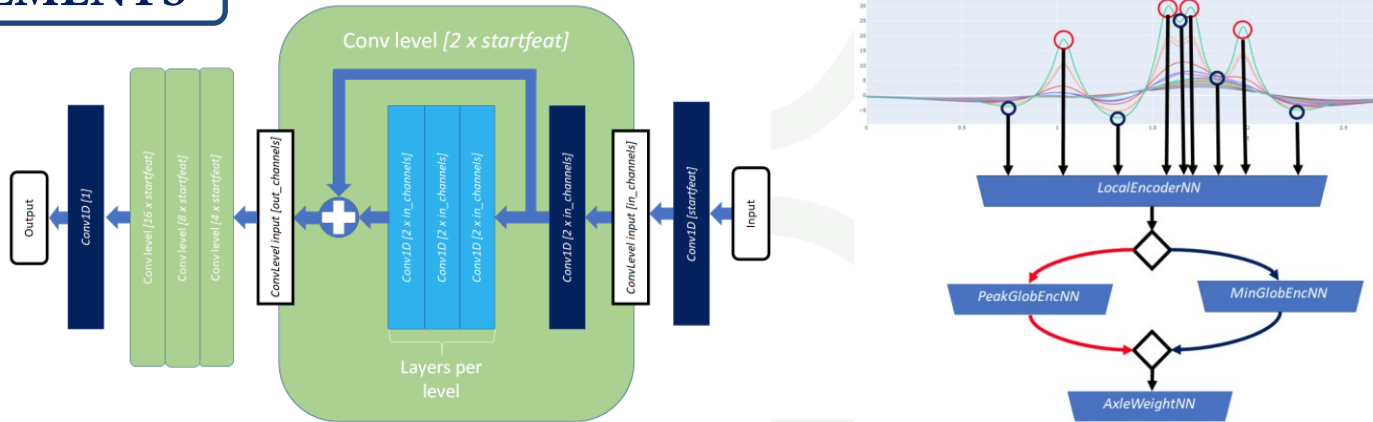
Speed

Axle #

Σ weight

Axle weight

MEASUREMENTS

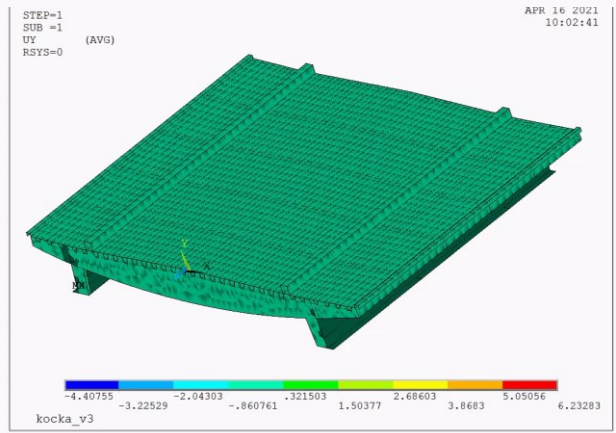
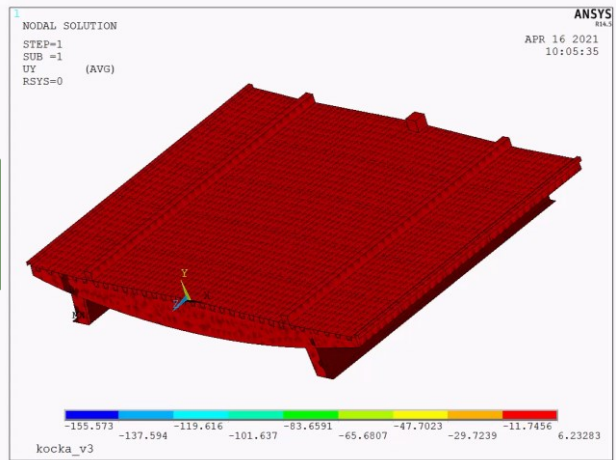
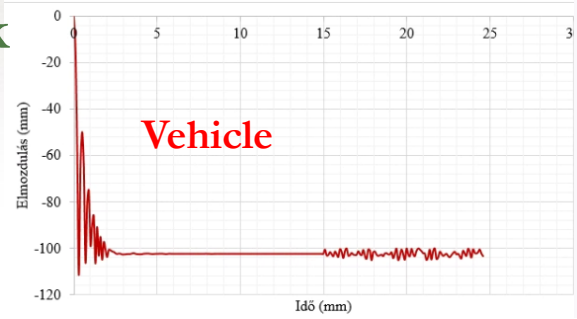
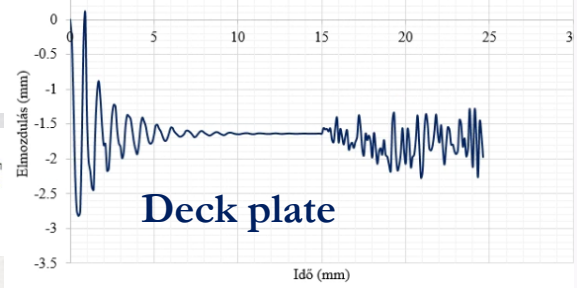
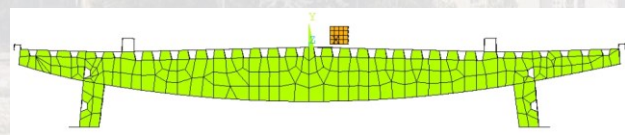
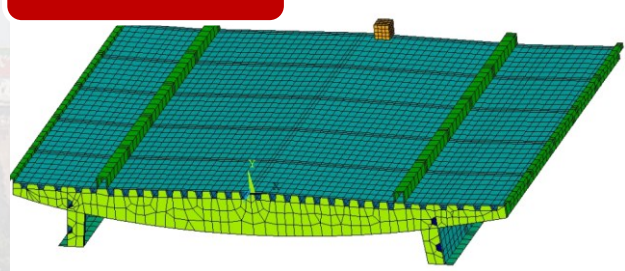


Metrika	Single-Only	Single-Convoy	Complex-Only	Complex-Convoy
<i>Axle Weight Loss</i>	2.43	2.35	3.20	3.27
σ (%)	3.61	3.56	4.60	4.66
δ (%)	7.83	6.73	9.98	8.80
<i>COST 323 (A-E)</i>	B+	A	B+	B+

EXPLICIT DYNAMIC ANALYSIS – SEGMENT TEST

Service

FE MODEL

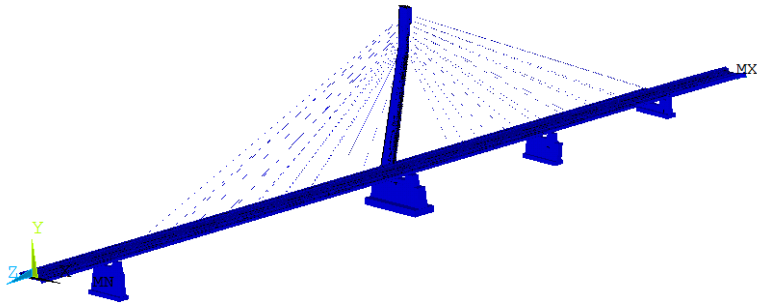


EXPLICIT DYNAMIC ANALYSIS

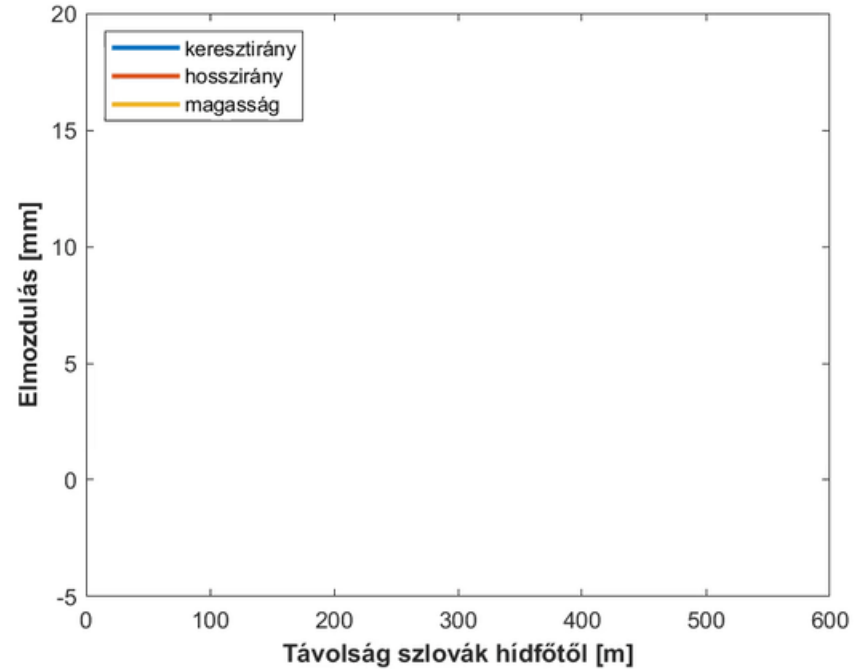
Service

FE MODEL

SHELL MODELL



PYLON TOP DISPLACEMENT



BIM APPLICATION – MEASURED AND FEM DATA

Service

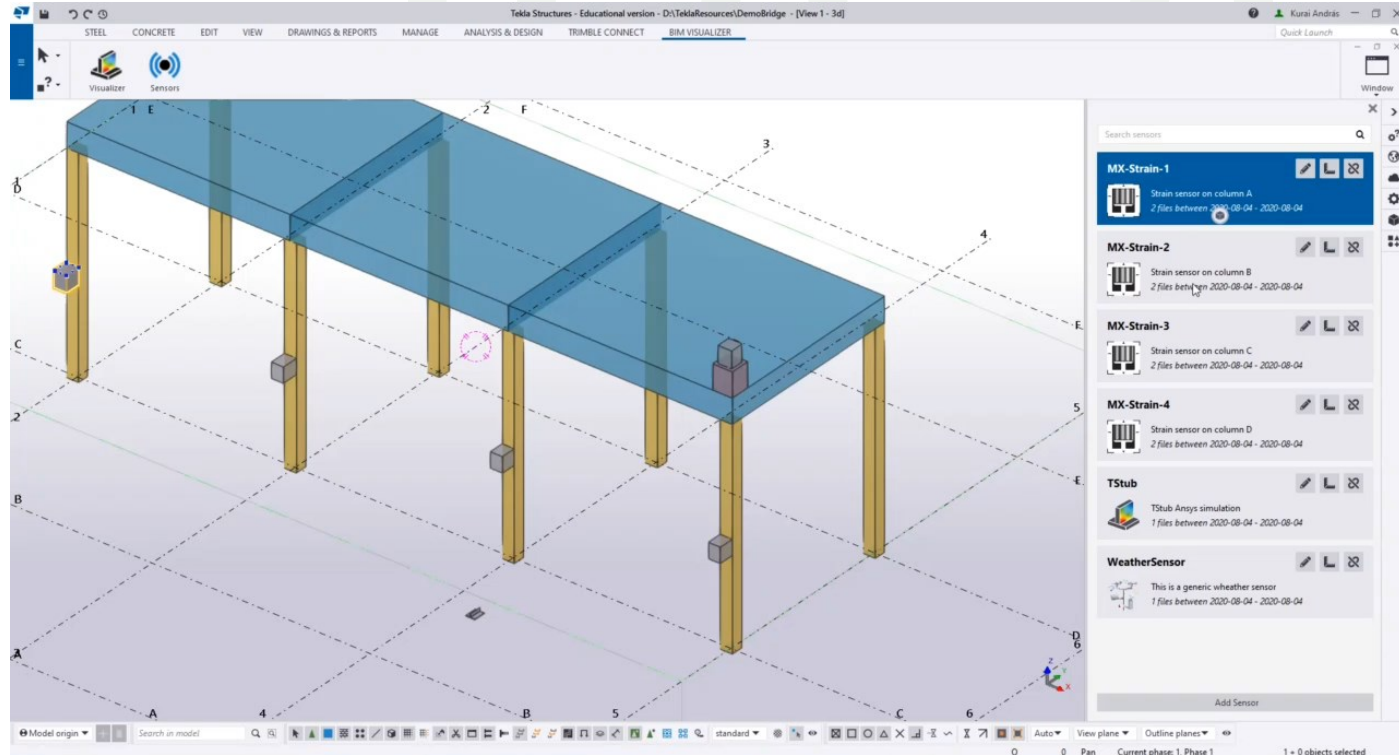
3D TEKLA BIM MODEL

Tekla Structures app

- Sensor elements/data
- Upload measured data
- Cloud storage
- Python interface

3D data visualization:

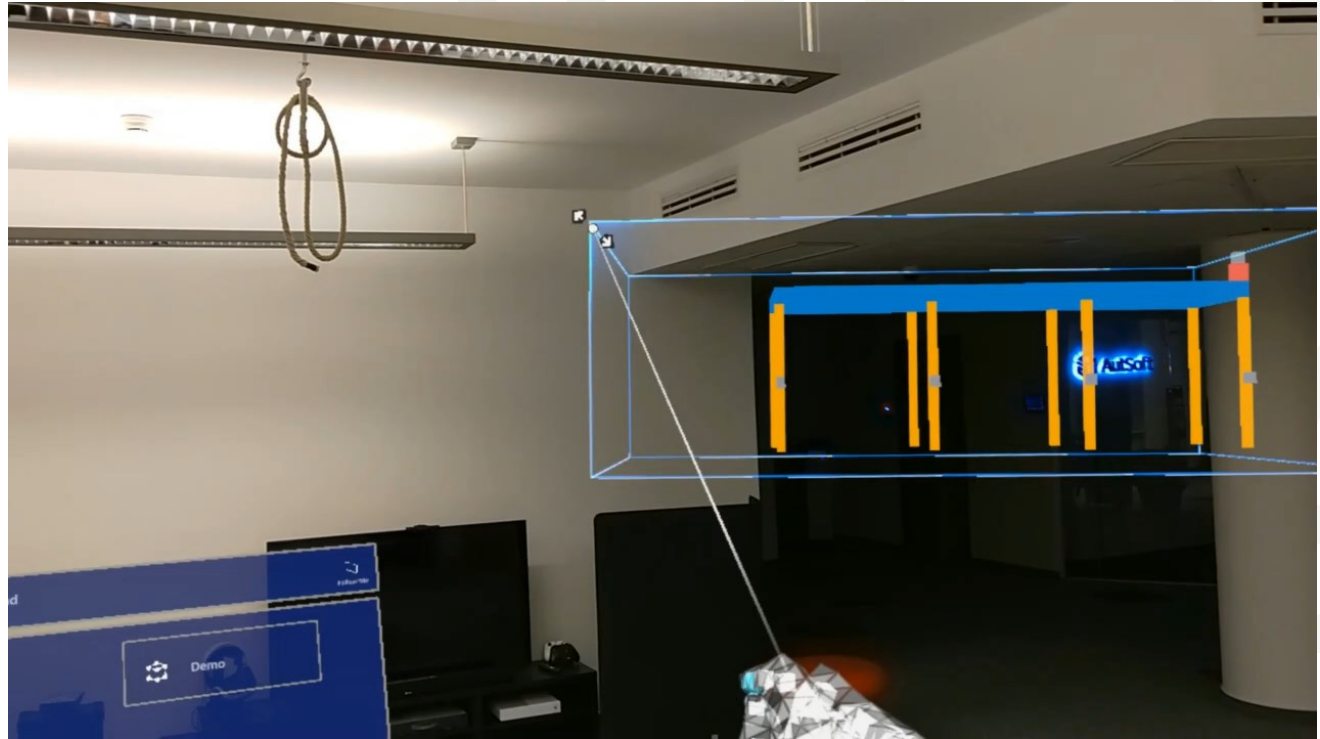
- Measured data in time
- Data limits
- Easy to use control panel
- HoloLens

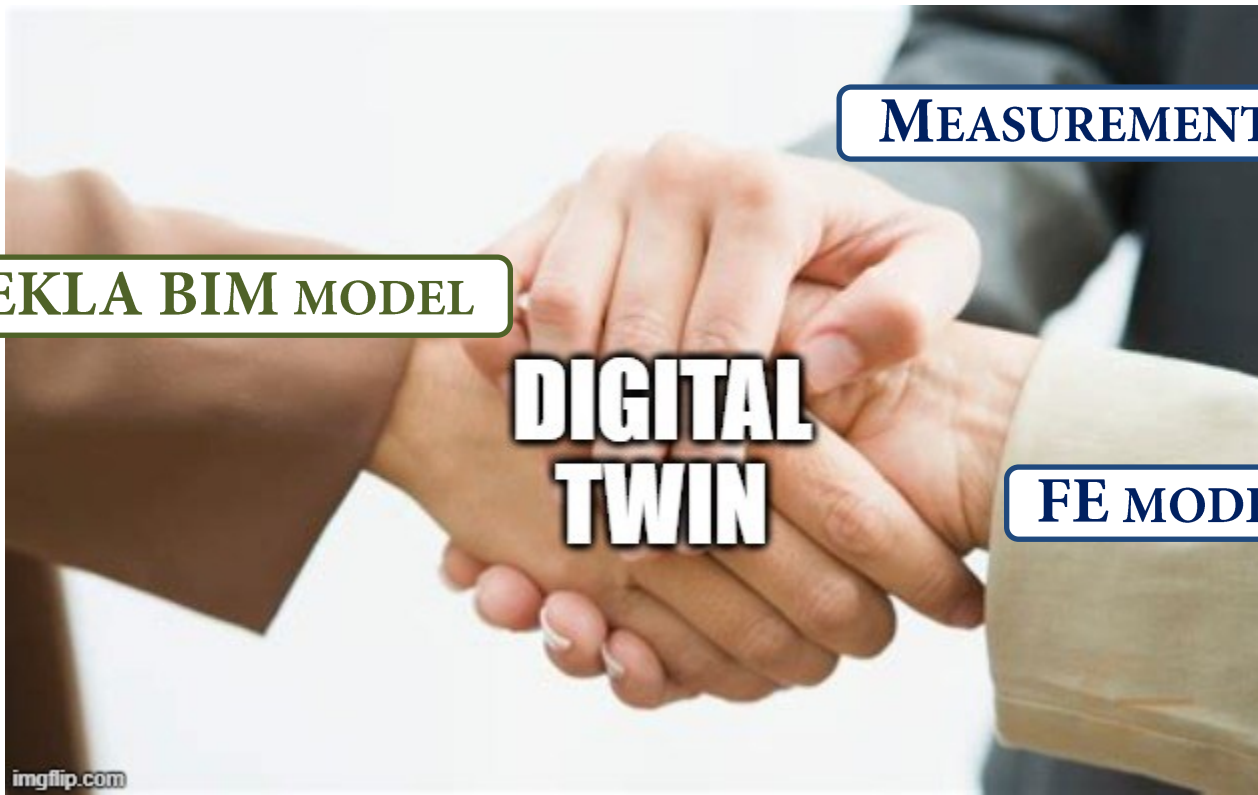


BIM APPLICATION – HOLOLENS

Service

3D TEKLA BIM MODEL





MEASUREMENTS

3D TEKLA BIM MODEL

**DIGITAL
TWIN**

FE MODEL

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Thank you for your attention!