Verification of the performance of tunnels assisted by innovative monitoring and digital twins

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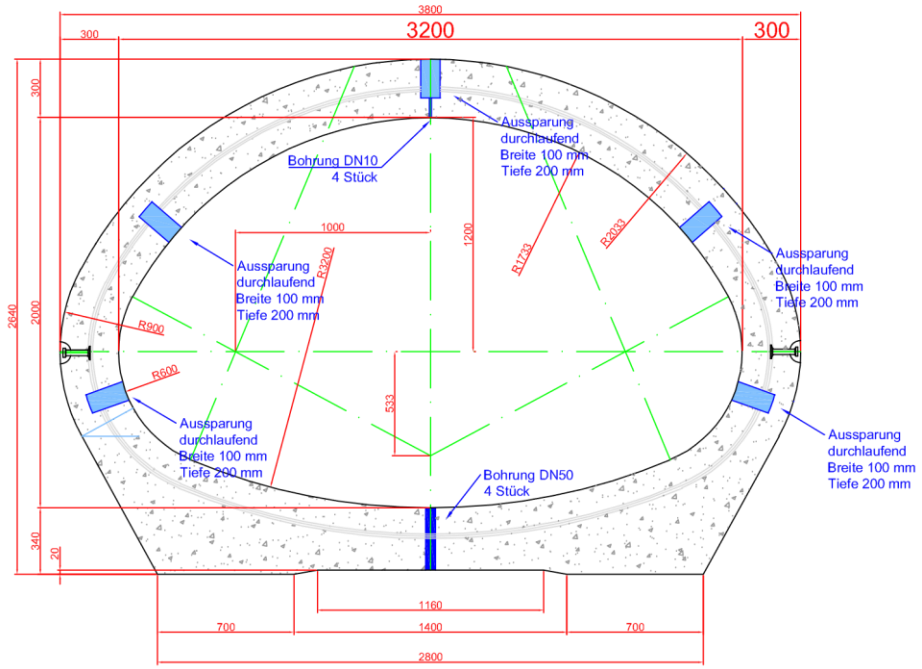
Objectives

Evaluation of suitable monitoring systems for the observation of critical deformation conditions in tunnel rehabilitation procedures

Accelerometer Arrays (AA), Fibre Optic Sensors (FOS), Laser Distance Sensors (LDS), Digital Image Correlation system (DIC),…

Evaluation of monitoring systems in respect to digital twins created by means of NLFEA modelling - allows an evaluation of the complex redistribution and cracking processes in tunnel structures

Tunnel demonstrator & analysed monitoring systems

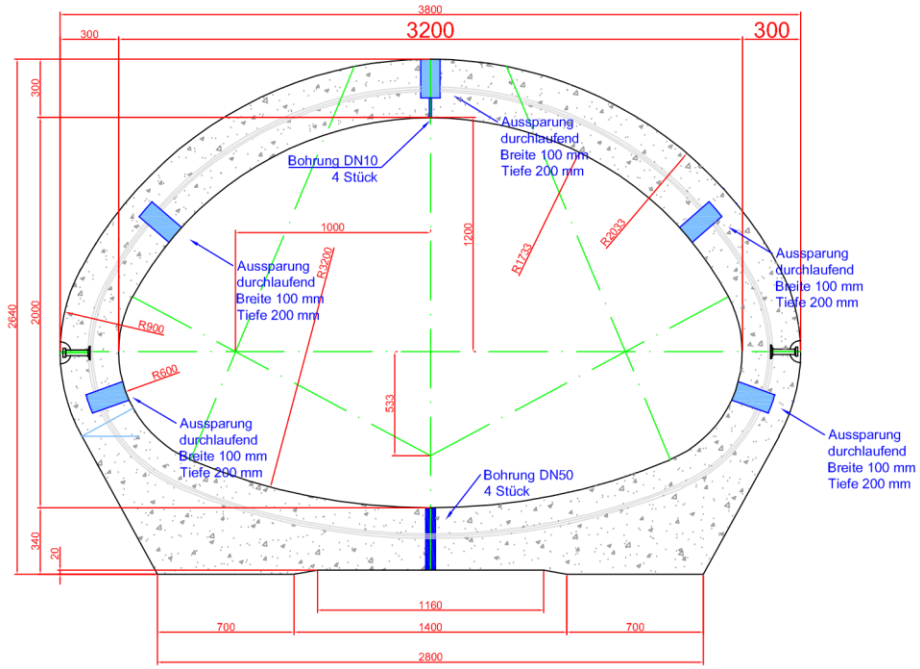


Measuring system	Data
Lasertracker (ref values)	Displacement
Tachymeter (ref values)	Displacement
Inclinometer (SAA)	Displacement
Laser distance sensor	Delta-Distance
Fibre optic system (FOS)	Strain
Longitudinal inclinometer	Inclinations and displacement
Digital Image Correlation DIC	Strain & Displacement in x & z
Temperature sensors	Temperature at depths 0, 5, 15, 22 cm

Tunnel mouth profile – field test

Selected installed monitoring systems

2-3D NLFEA Digital Twins of tunnel demonstrator



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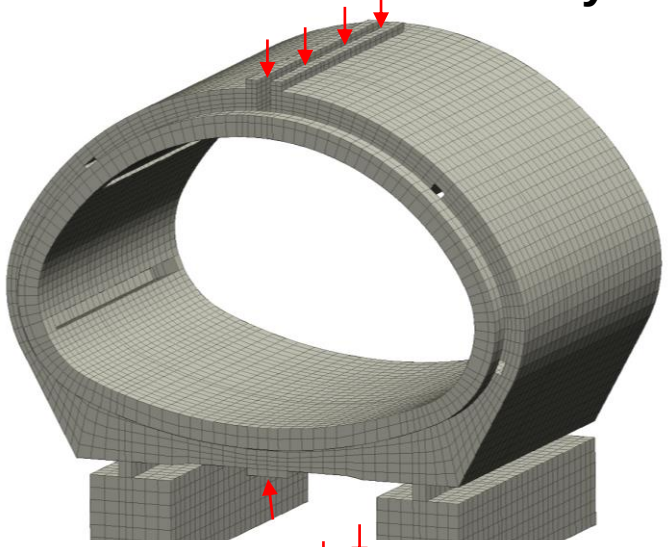
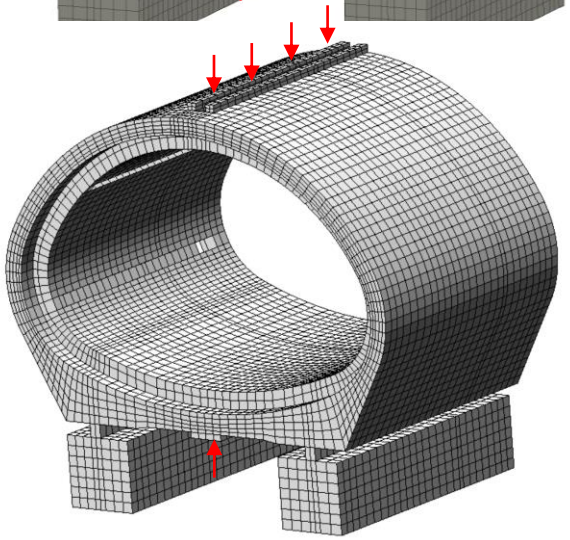
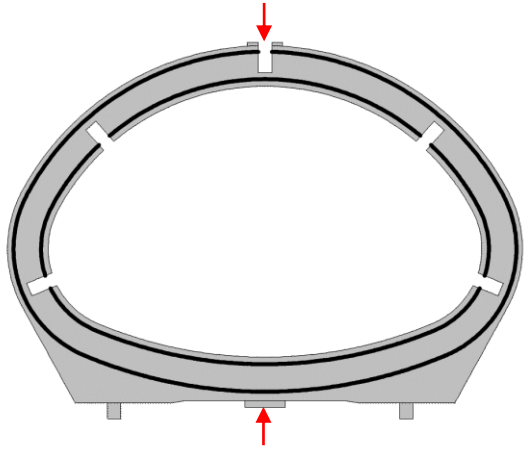
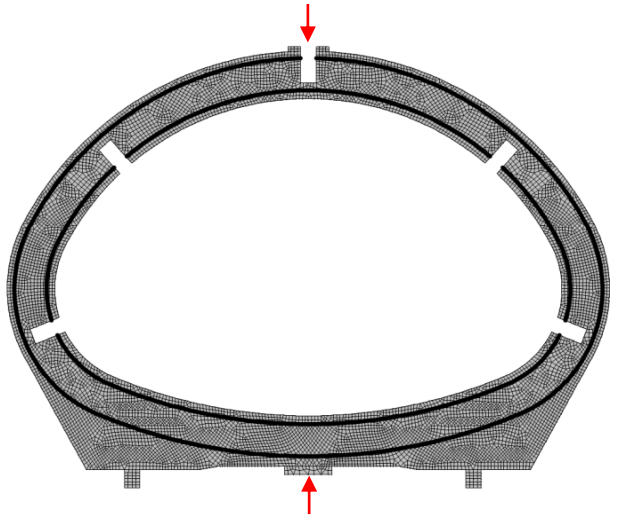
Non Linear 3D & 2D Analyses



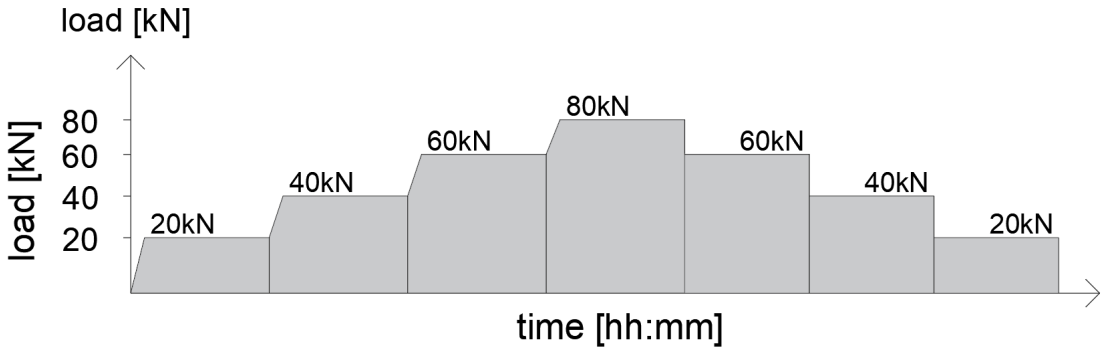






Proof loading processes on tunnel demonstrator

07.02.2022



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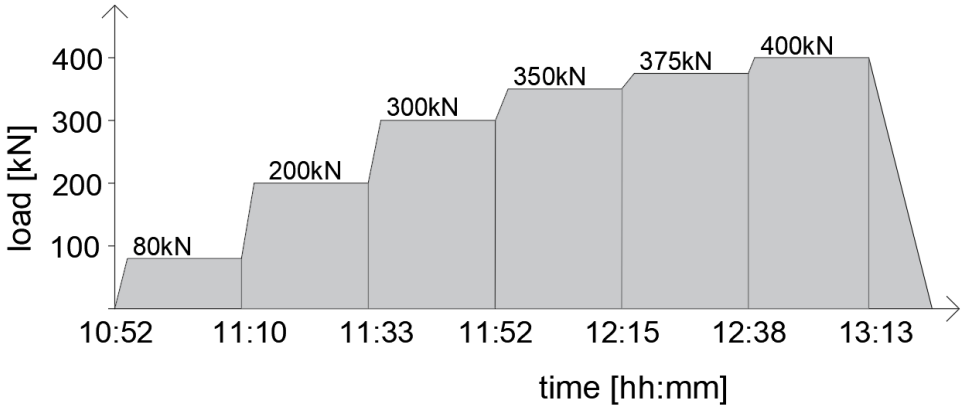

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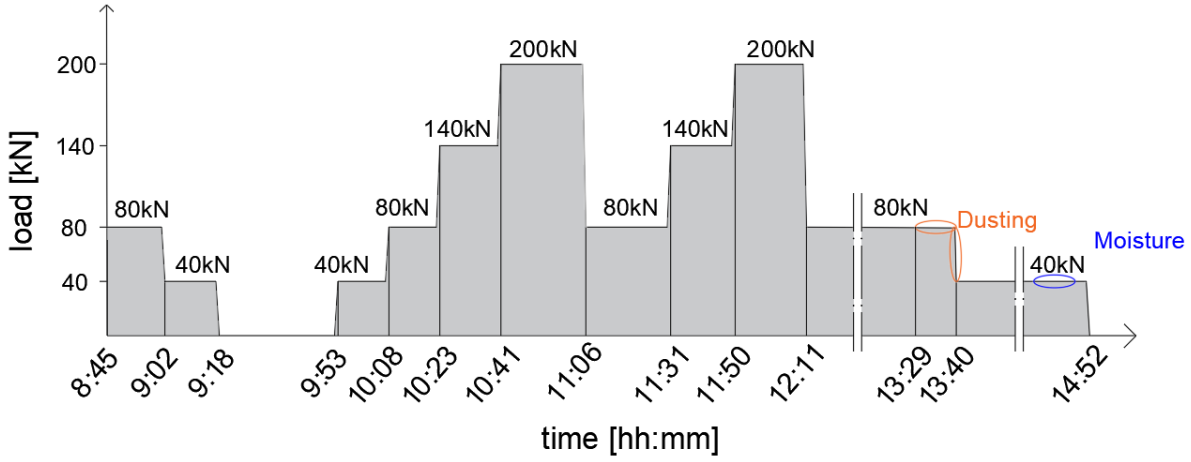
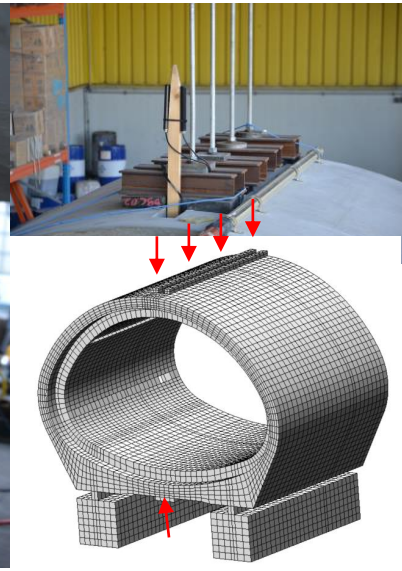
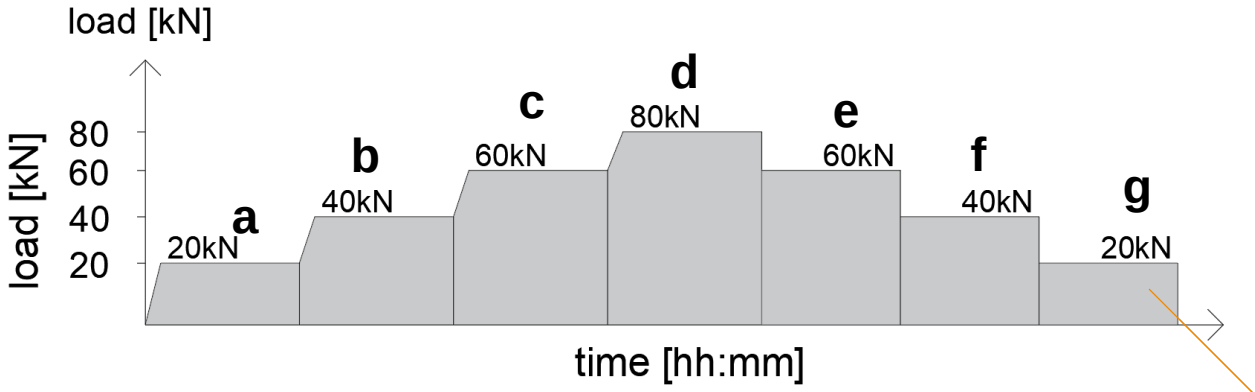


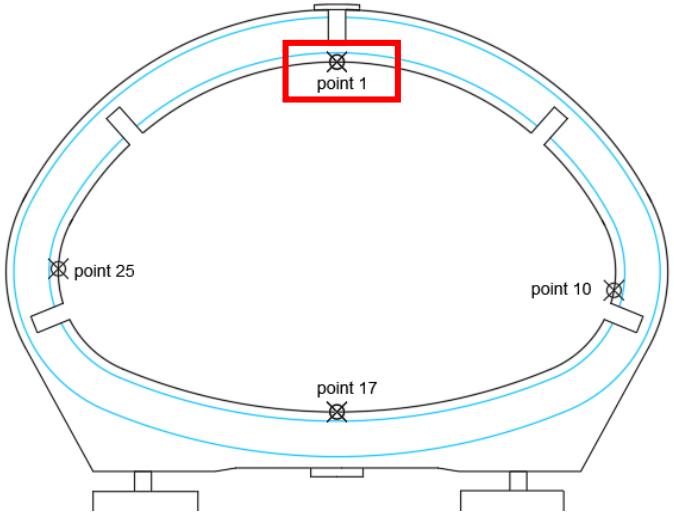


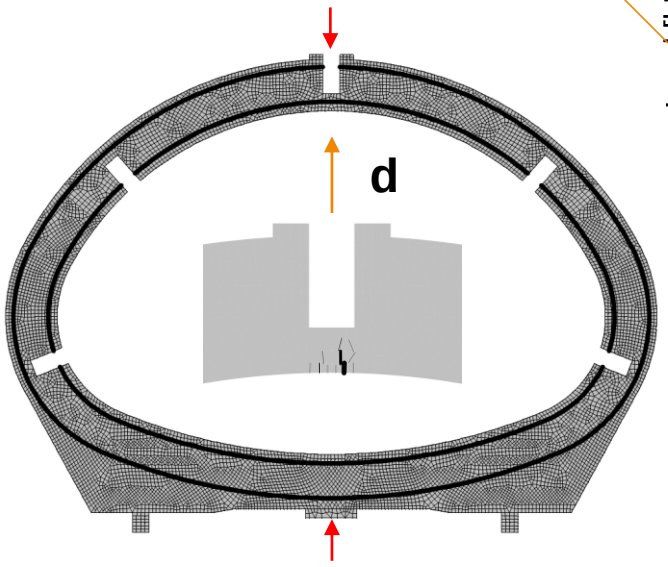
Calibration digital twin demonstrator vs. laser tracker

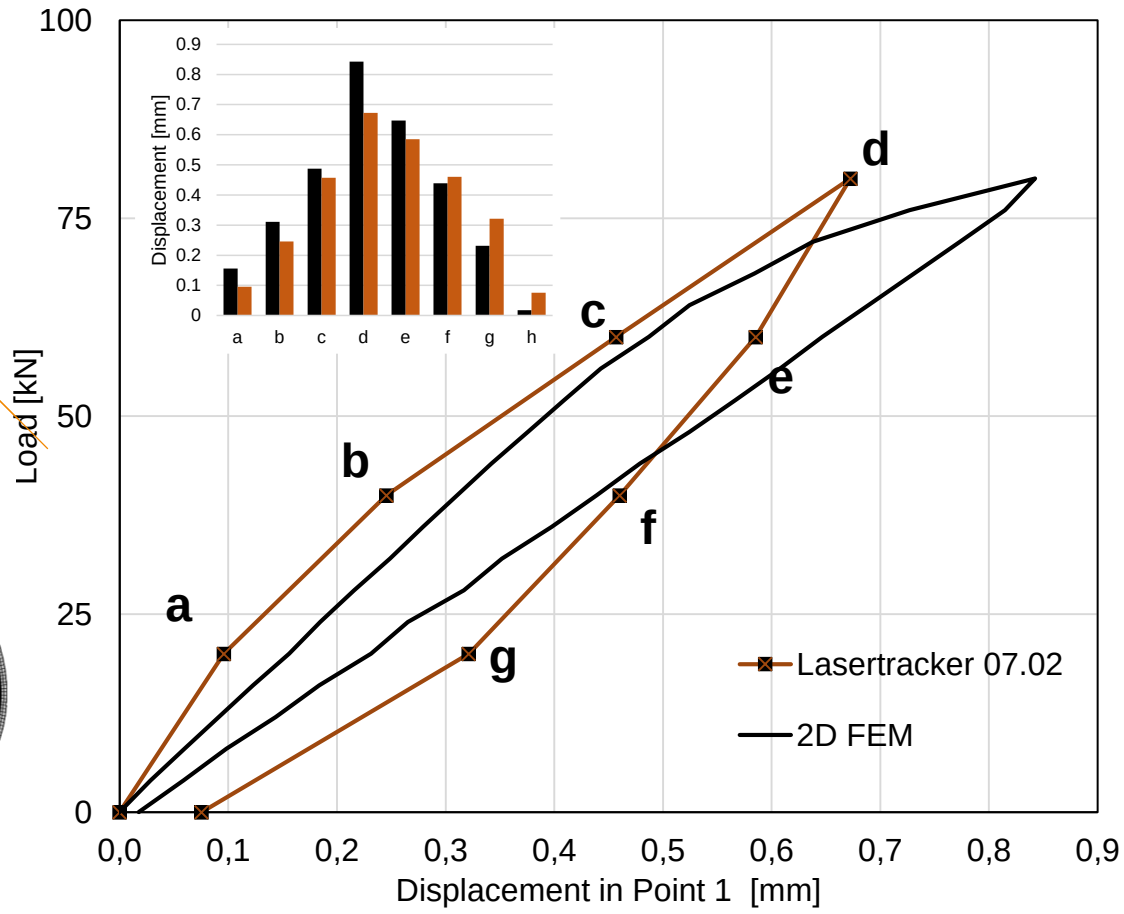
07.02.2022

Vertical deformation analyses









Digital image correlation (DIC) vs. digital twin analyses

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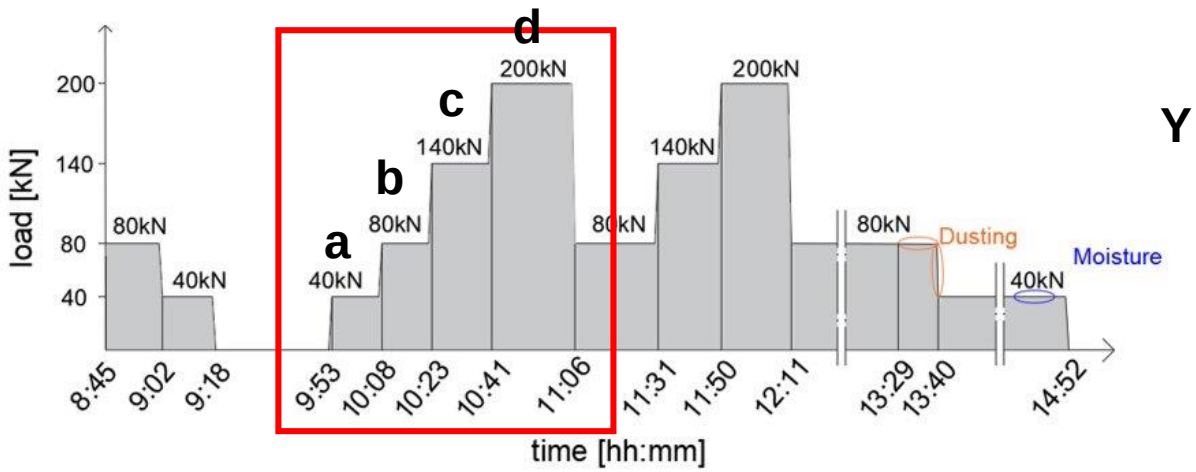
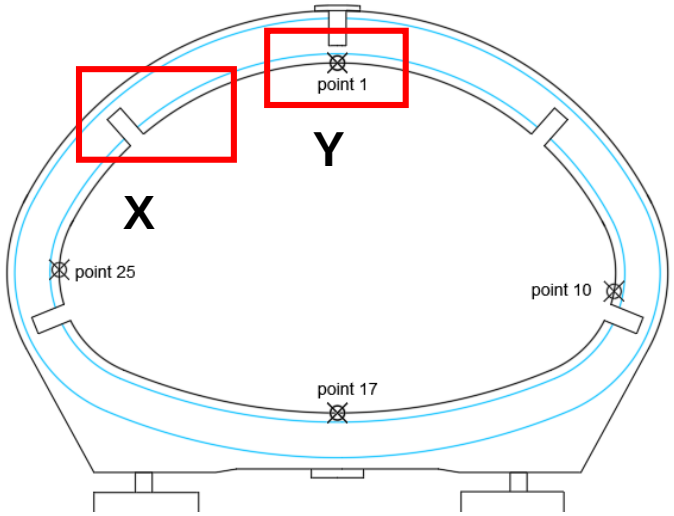
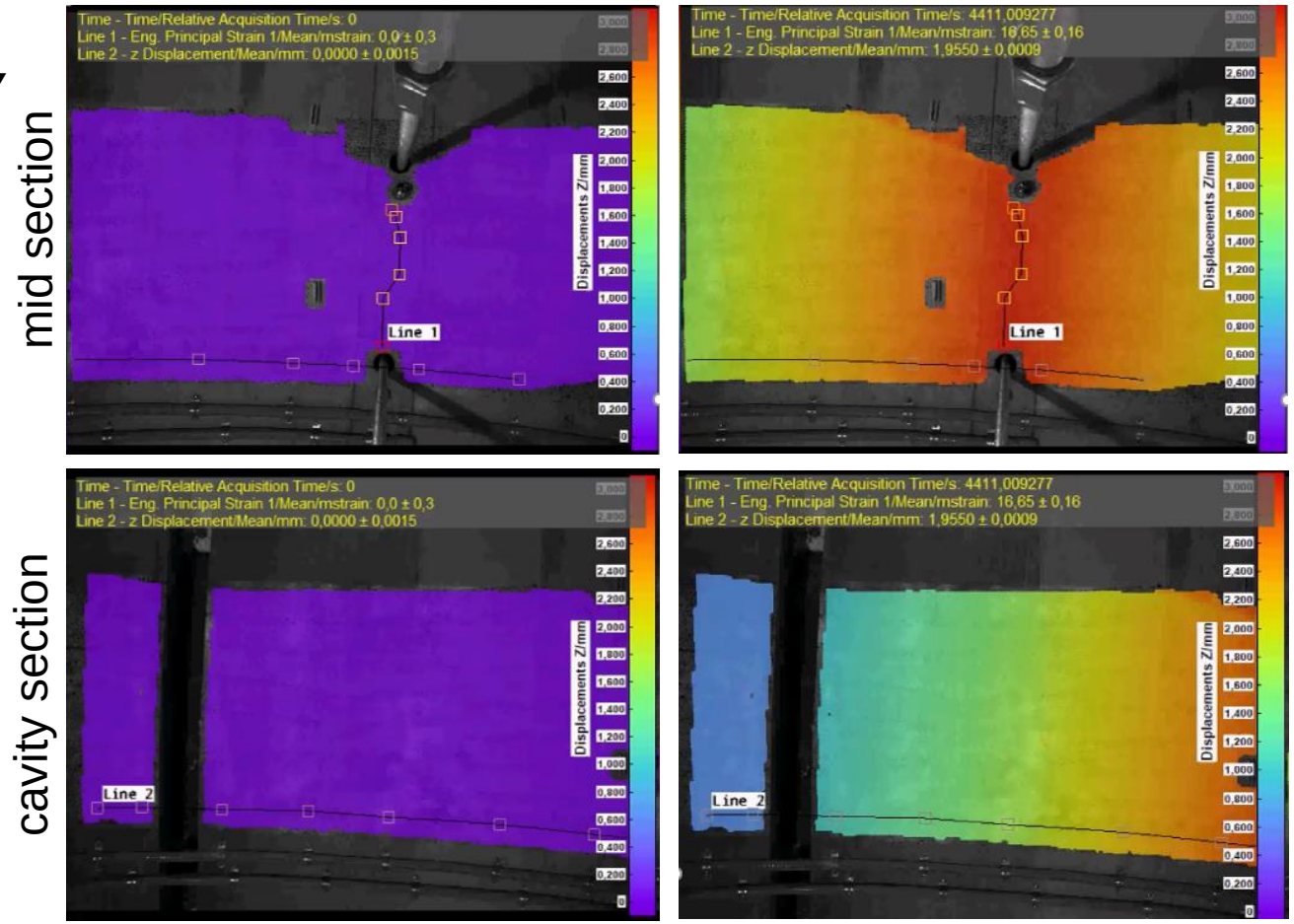


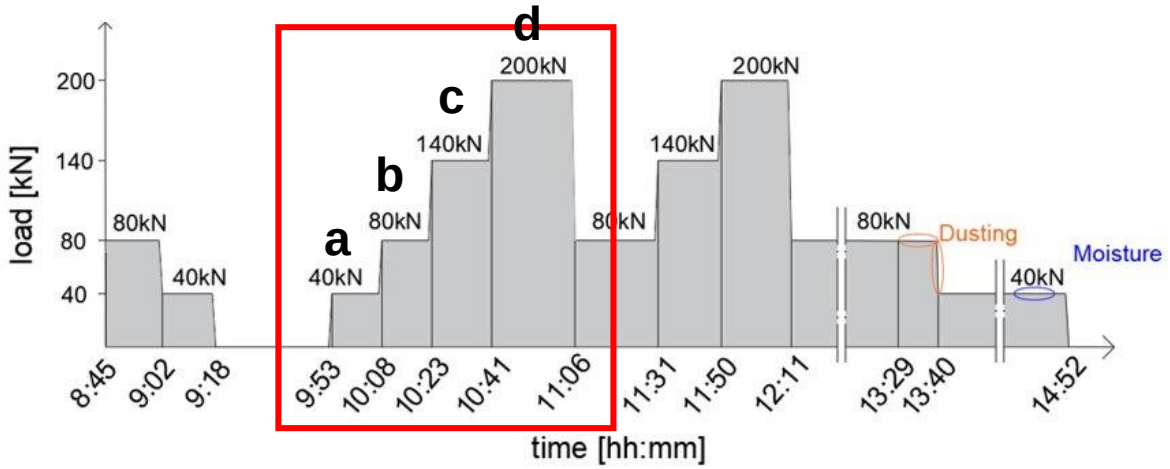


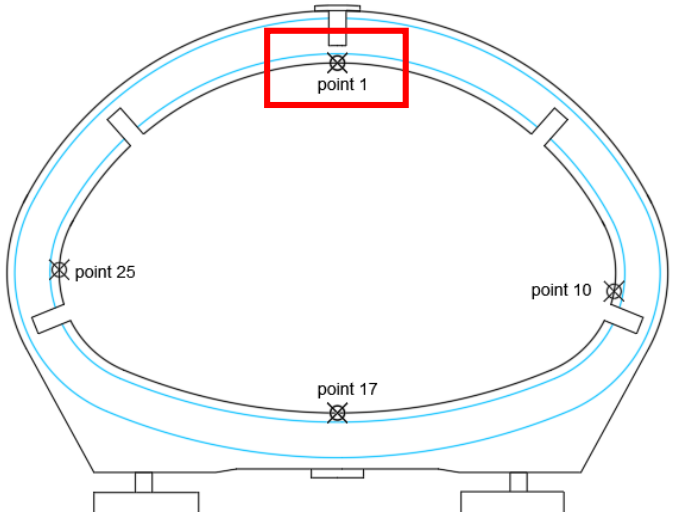
Strain tensor & crack pattern analyses



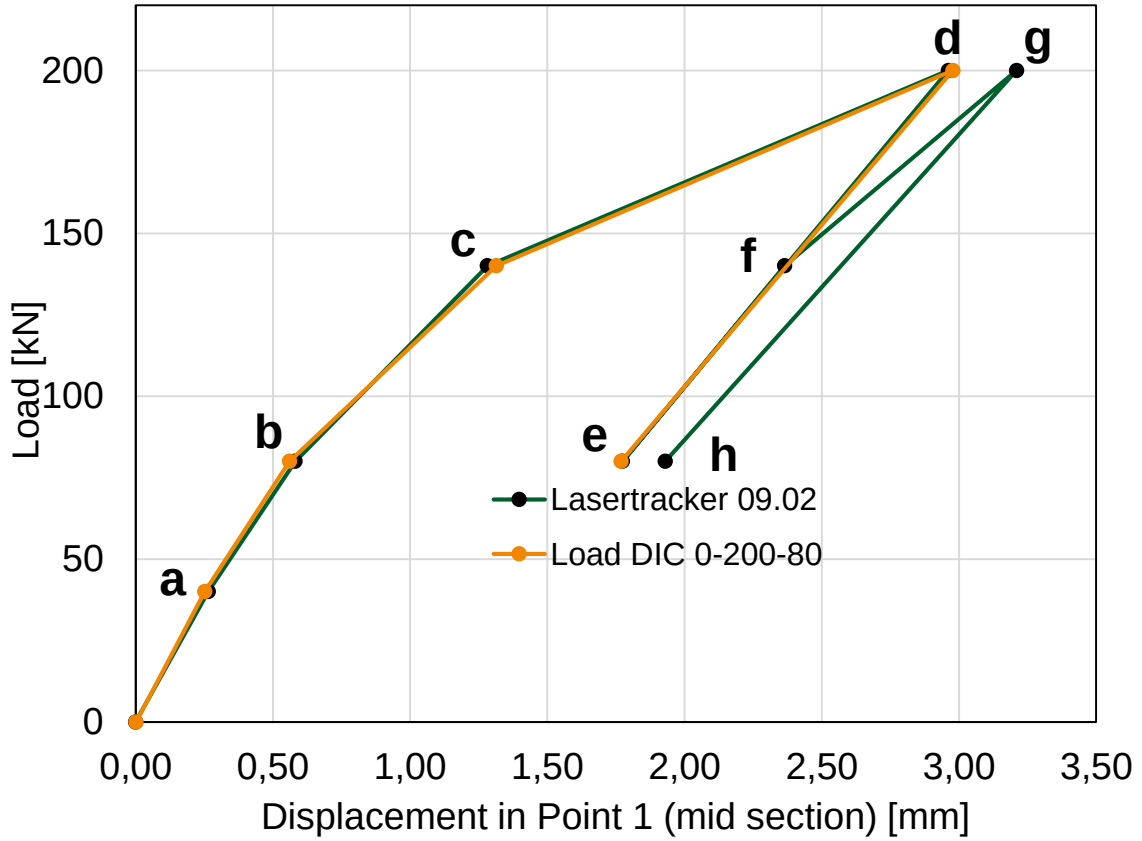
Digital image correlation (DIC) vs. laser tracker

09.02.2022





Vertical deformation analyses



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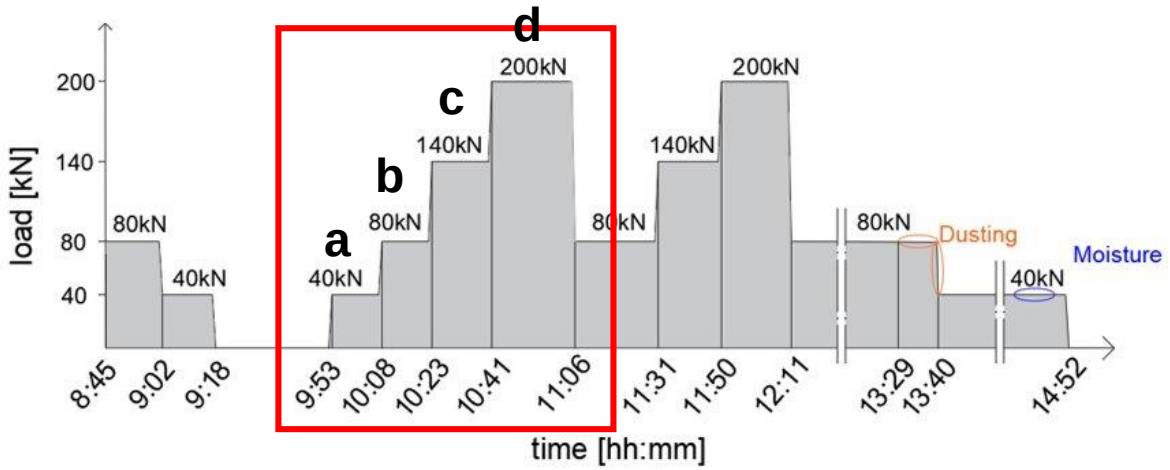
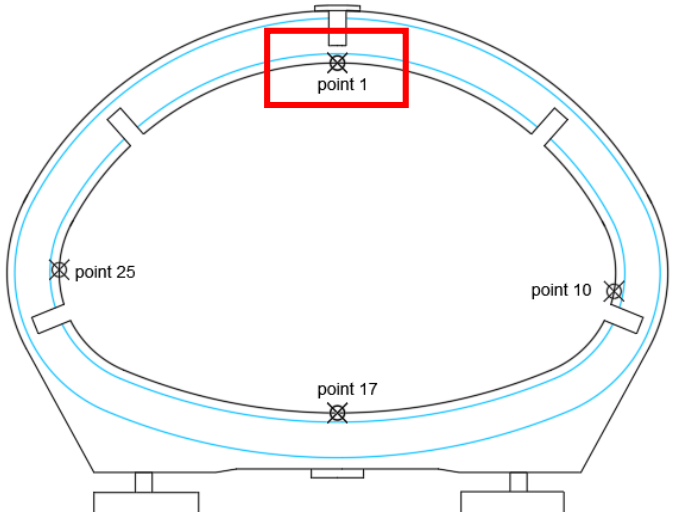
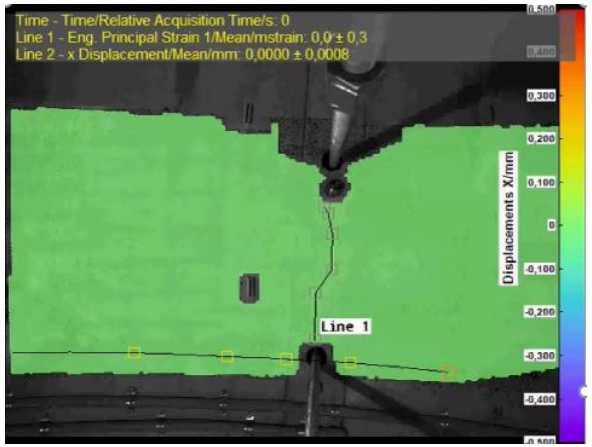




Horizontal Deformation Analyses

a



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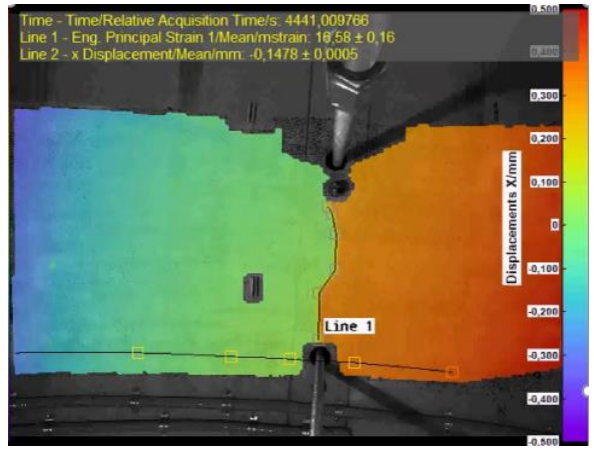

Calibration 3D digital twin demonstrator vs. laser tracker

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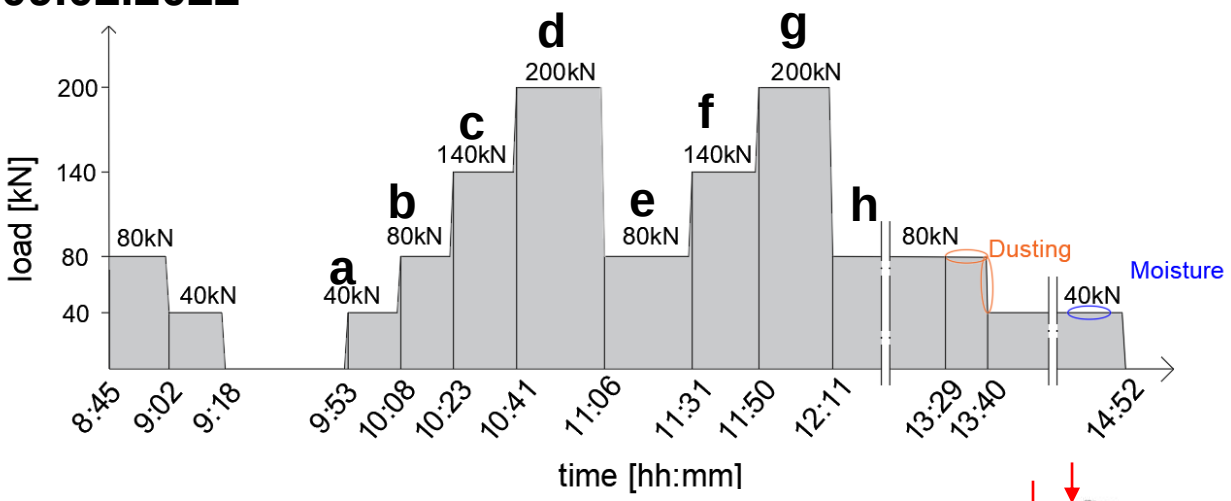
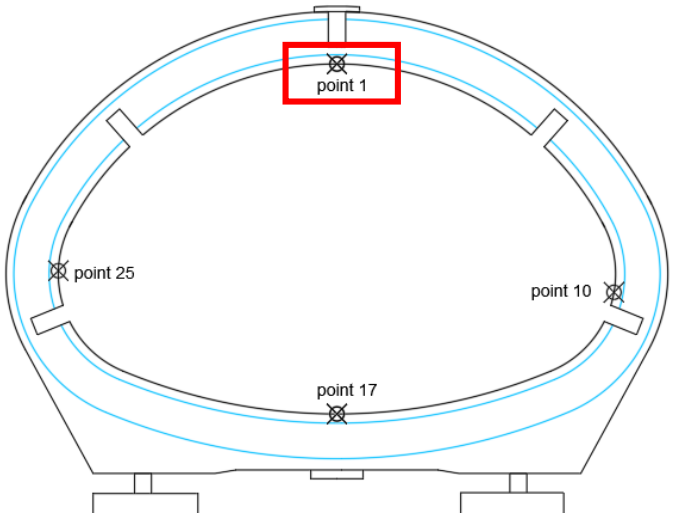
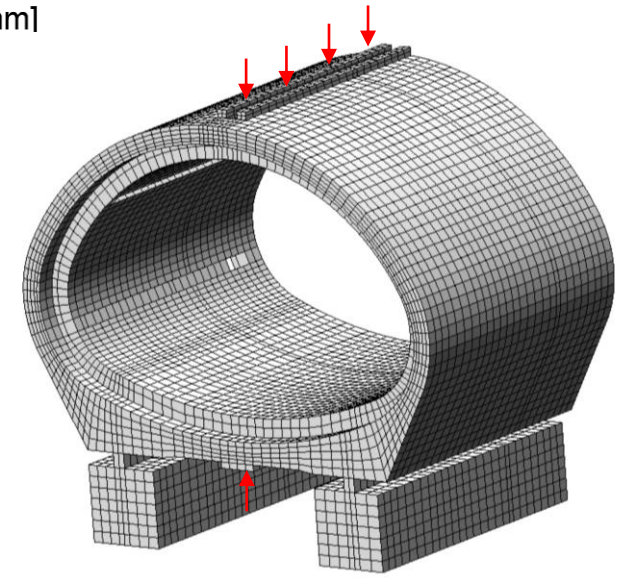
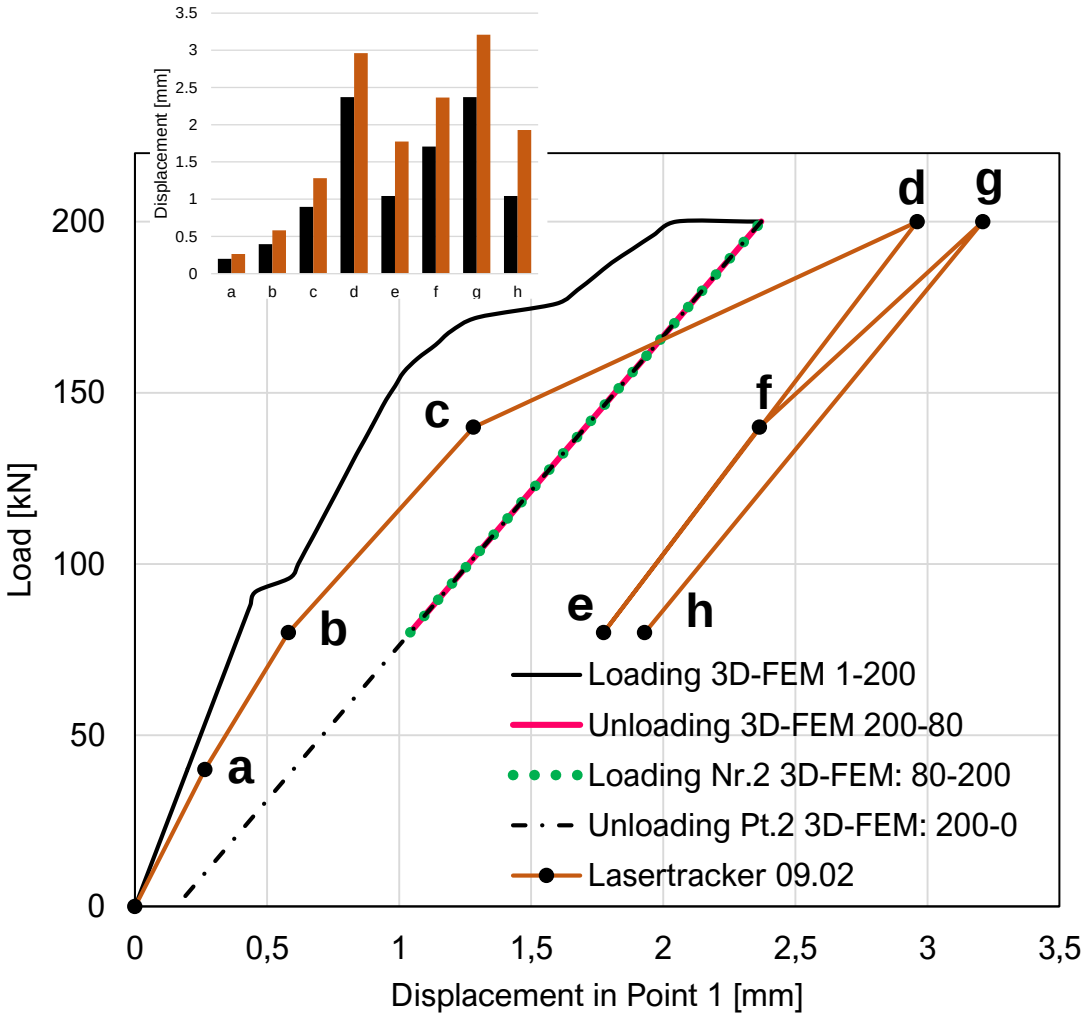






Vertical deformation analyses



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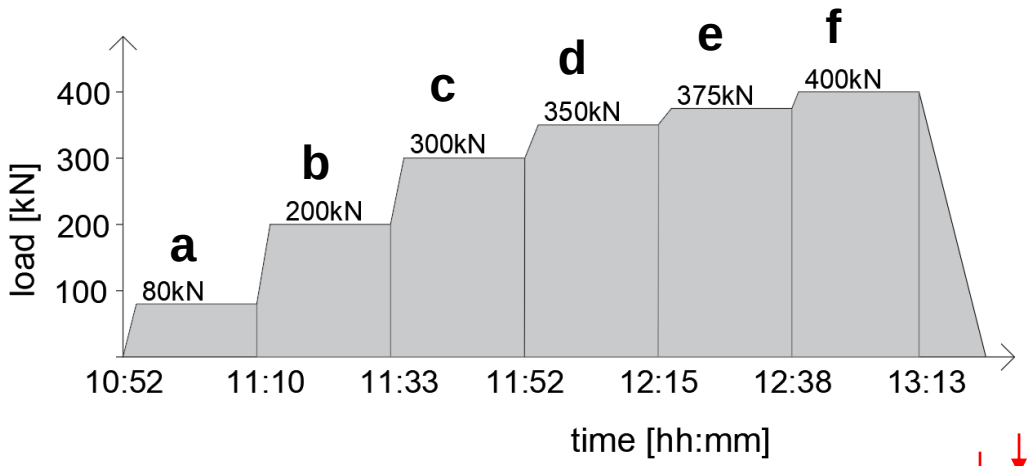

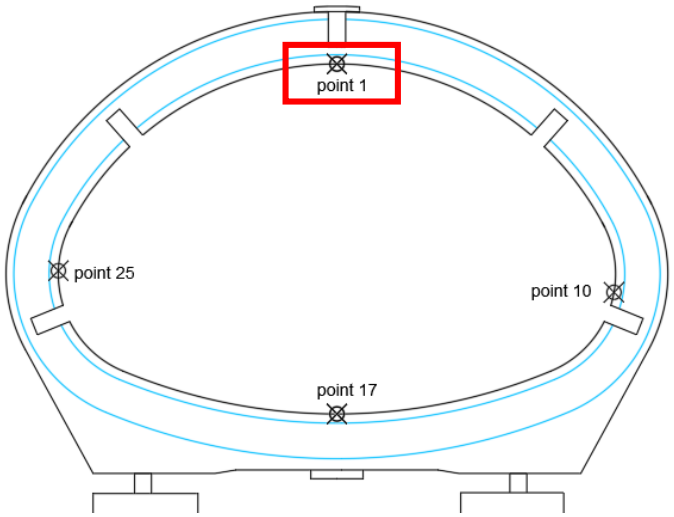

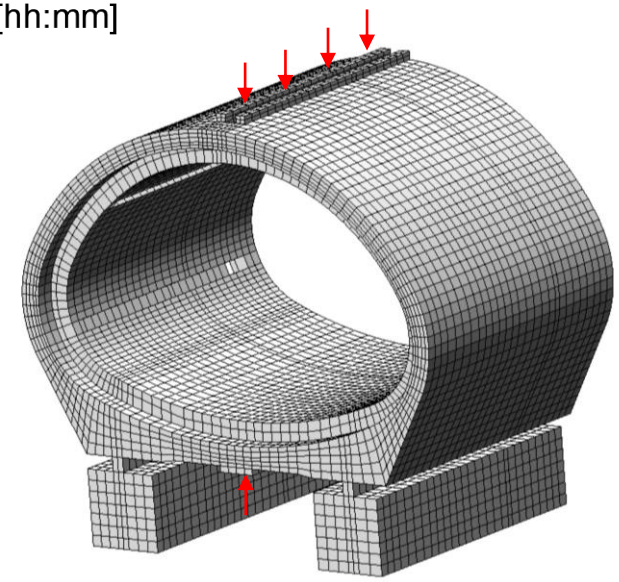

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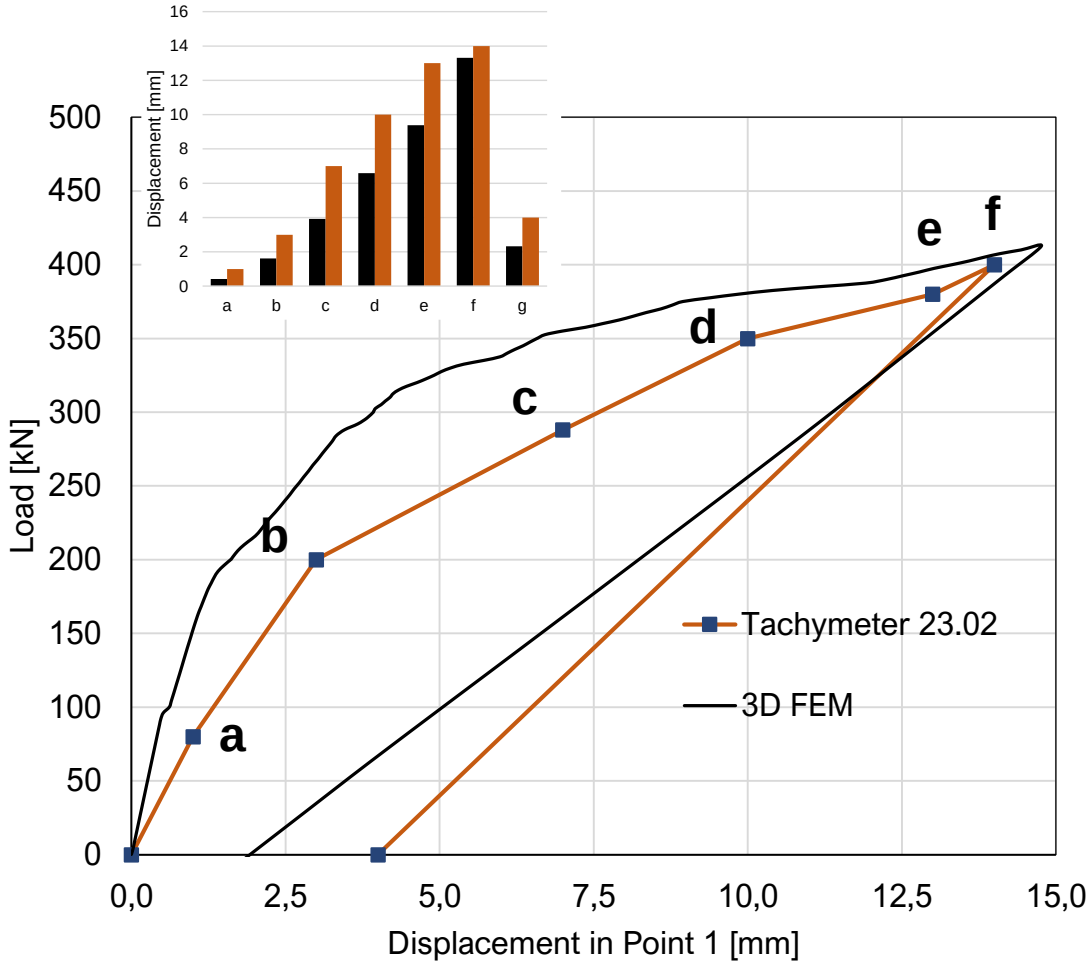

Findings

- The monitoring data from the laser tracker enabled excellent development of digital twins.
- Digital twins are an excellent basis for the evaluation of monitoring systems (strains, small and large displacements, inclinations,...).
- Calibrated digital twins are used in this project to evaluate the following:

  Digital correlation system
  SIA inclinometer system
  HBM fibre optic system
  Laser distance system

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and environment safer & resilience
thank you for your kind attention