NMA lunch seminar, January 14, 2020

Support of wooden shipwrecks

Experiences from the 17 the century warship “Vasa”

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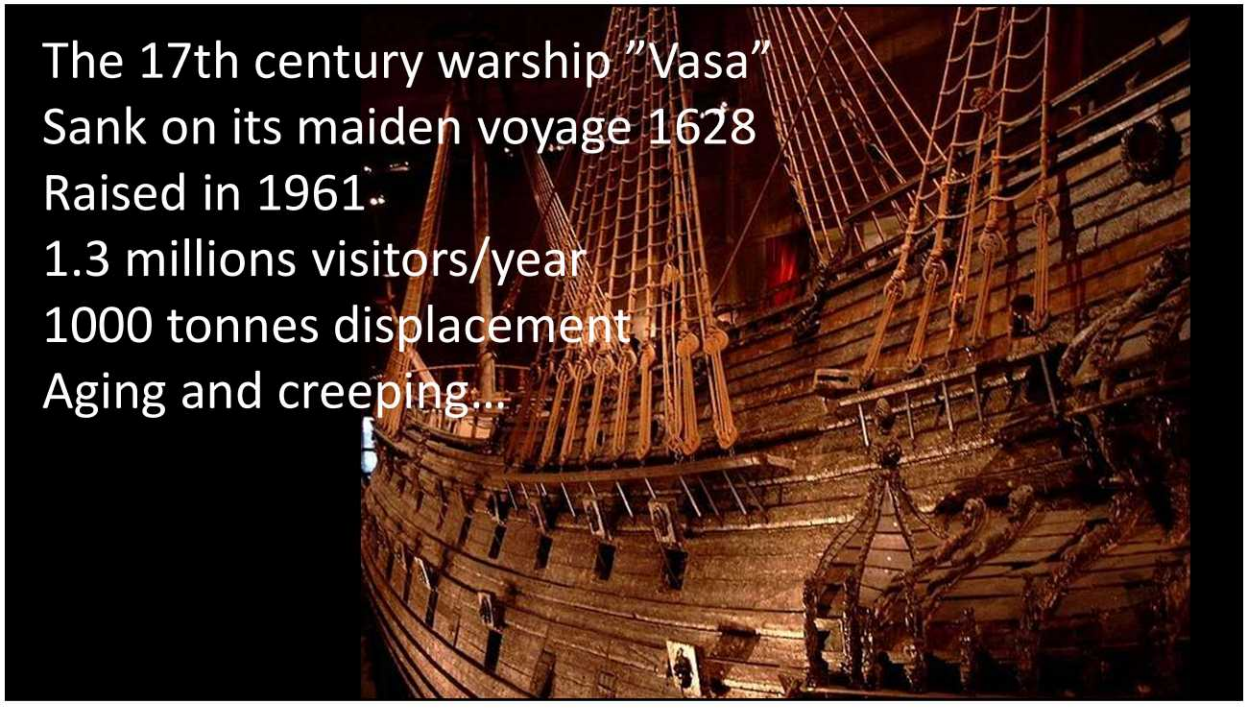
UPPSALA UNIVERSITET

VASA MUSEET

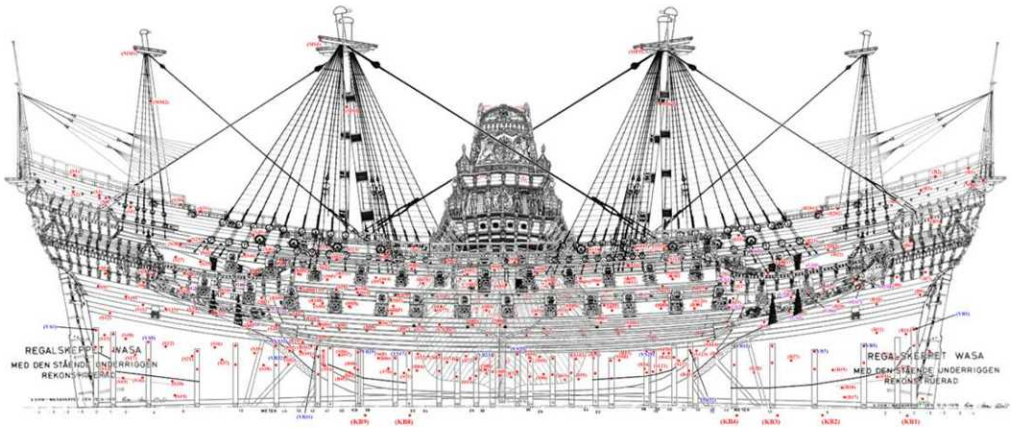


Background

- 1964: Simple cradle with 8 supports
- 1990: Increasing deformations → more supports
- 2000-: Geodetic measurements: increasing deformation

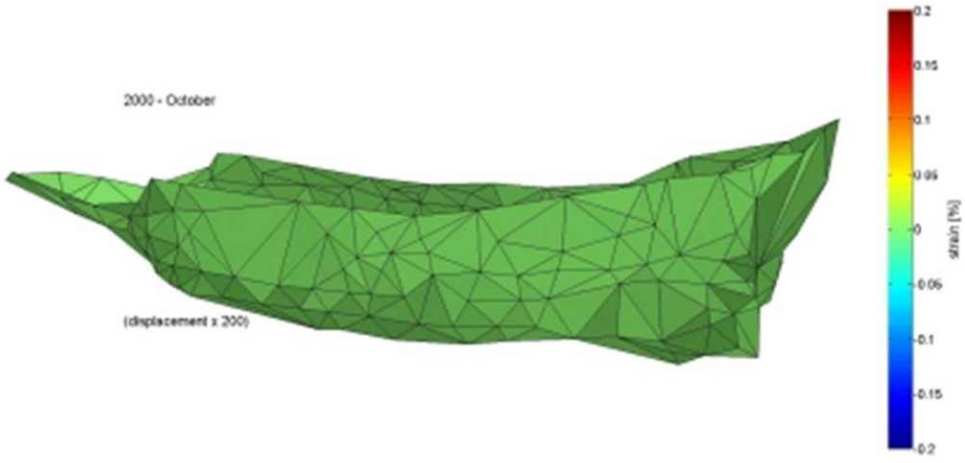
Need to design an improved support system:
Minimize the risk for collapse and achieve dimensional stability

Geodetic measurements

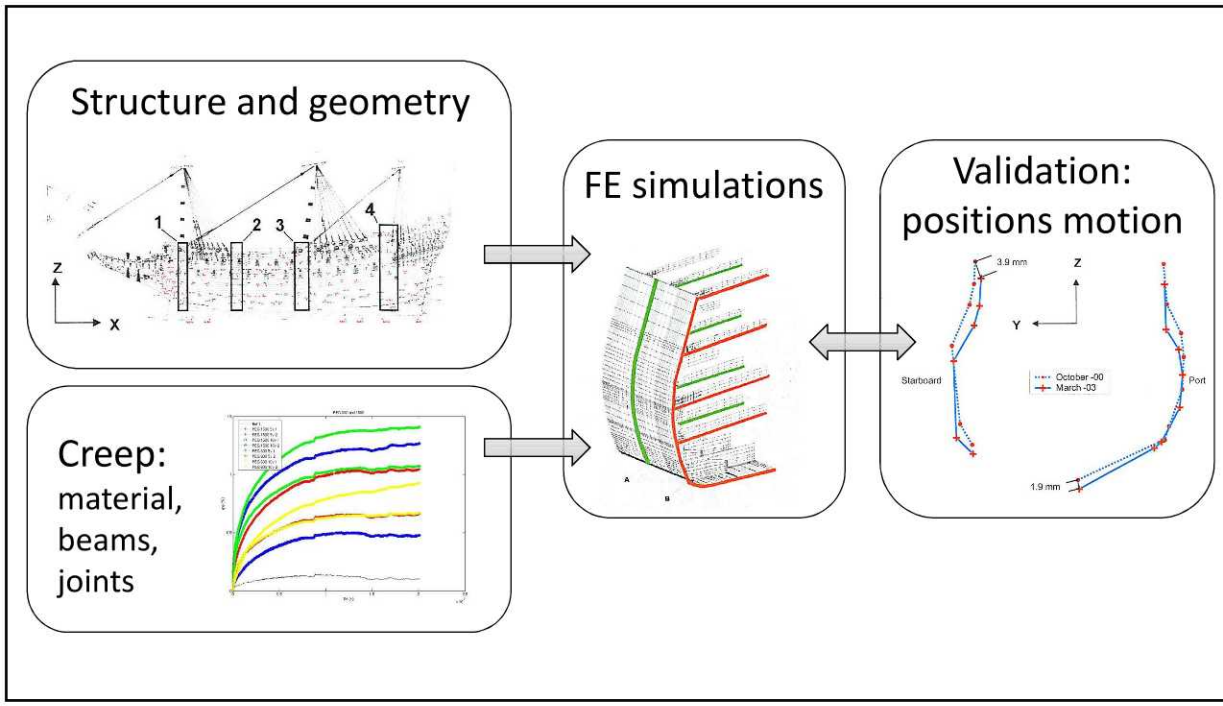


Measurements at 400 locations

Maximum principal strain, portside

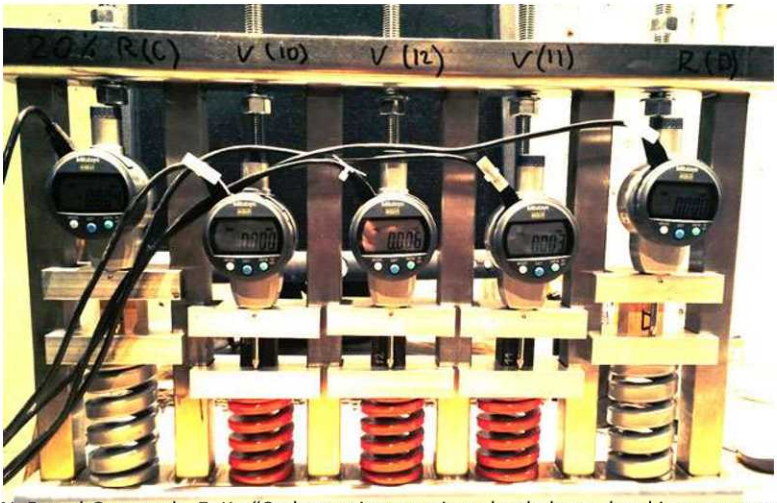


(van Dijk et al., 2016)



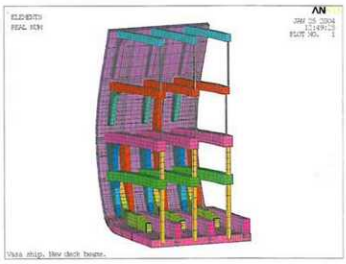
Destructive mechanical characterization of Vasa oak

Limited amounts of (in)valuable material



Vorobyev, A., van Dijk, N. P. and Gamstedt, E. K., "Orthotropic creep in polyethylene glycol impregnated archaeological oak from the Vasa ship", *Mechanics of Time-Dependent Materials*, in press, 2018. DOI: 10.1007/s11043-018-9382-3.

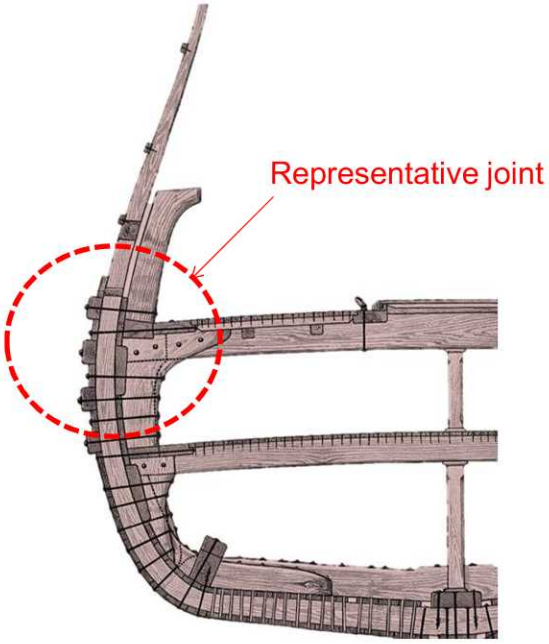
Effects of the joints on the global deformation



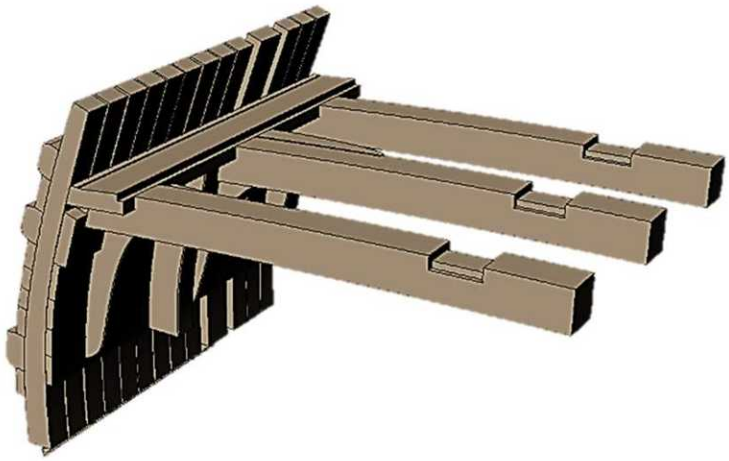
FE model of the ship

(1) Global FE – Whole ship

(2) Detailed FE model – Joint

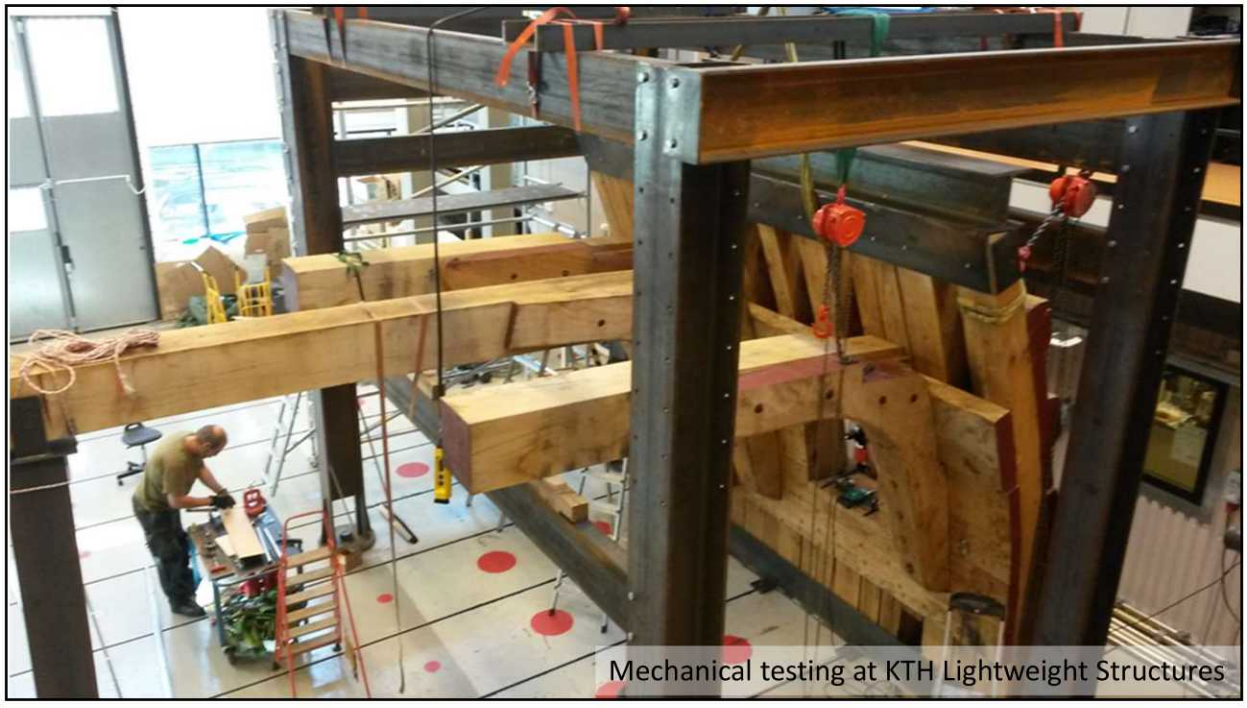


Mechanical testing of joints in a wall-section replica



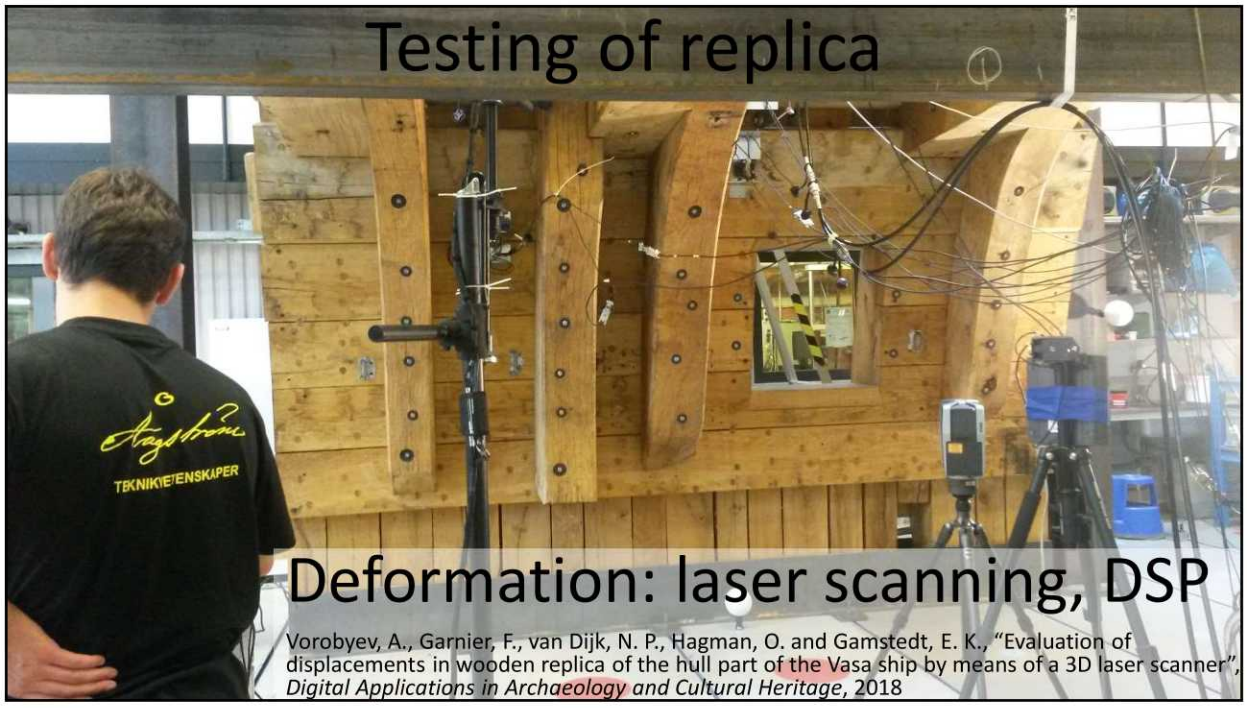
Afshar, R., van Dijk, N.P., Bjurhager, I. and Gamstedt, E.K., "Comparison of experimental testing and finite element modelling of a replica of a section of the Vasa warship to identify the behaviour of structural joints", *Engineering Structures*, **147** (2017), 62-76.

A big test sample…
Construction of 10 tonnes replica



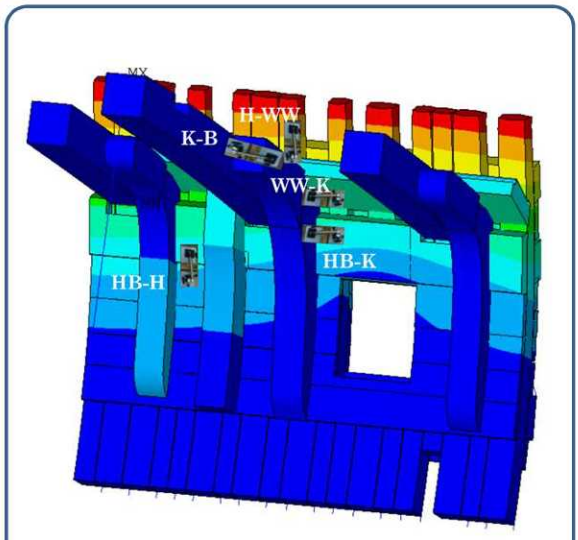
Mechanical testing at KTH Lightweight Structures

Testing of replica



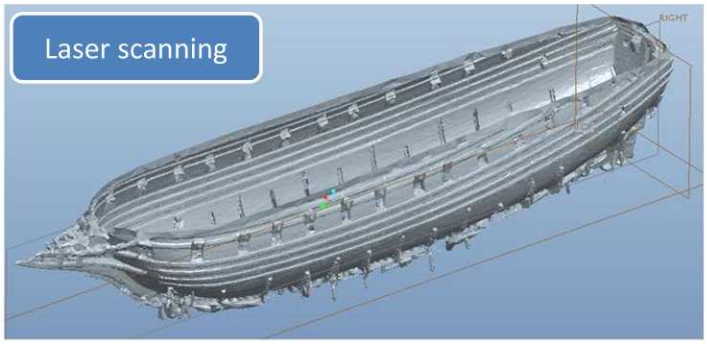
Deformation: laser scanning, DSP

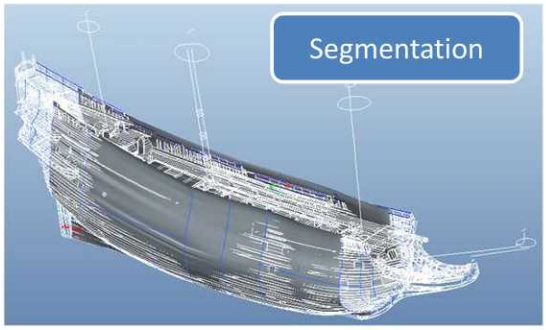
Vorobyev, A., Garnier, F., van Dijk, N. P., Hagman, O. and Gamstedt, E. K., "Evaluation of displacements in wooden replica of the hull part of the Vasa ship by means of a 3D laser scanner", *Digital Applications in Archaeology and Cultural Heritage*, 2018

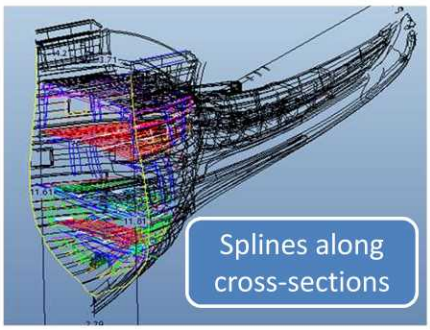


Comparisons FEM-Experiments → Spring constants

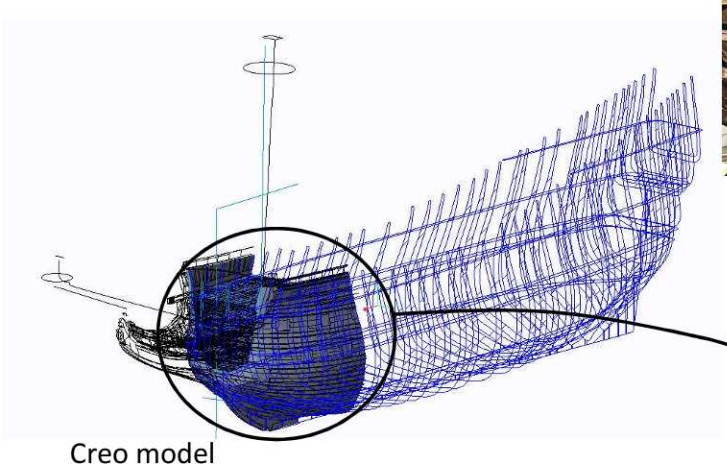
Ship geometry



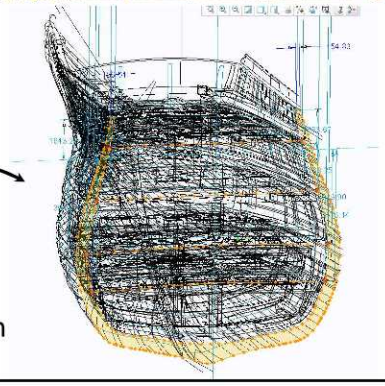




Division into cross-section and spline interpolation from frame model



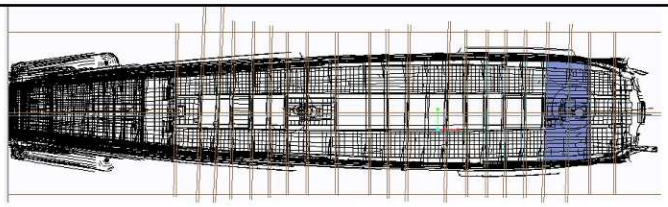
Creo model

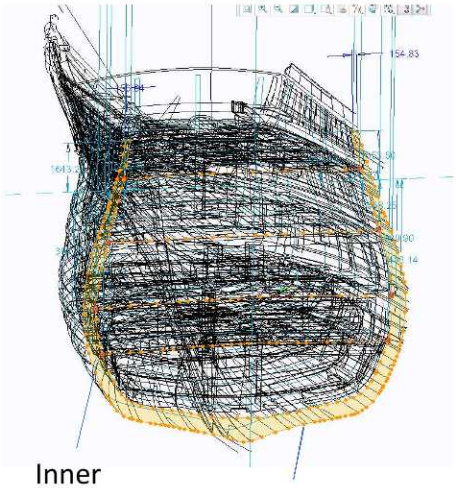


Schematic of a cross-section

Division into zones

Top view

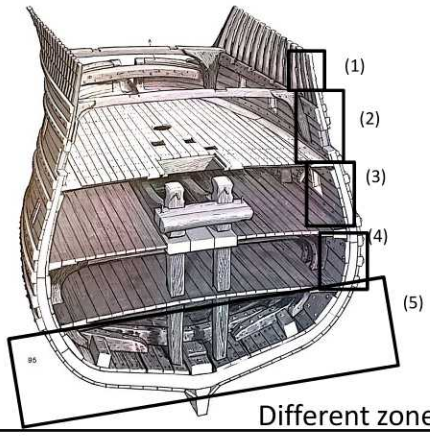




Inner

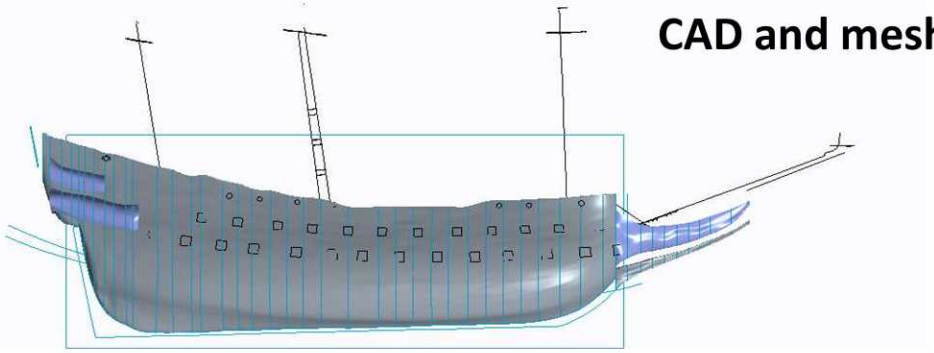
Outer

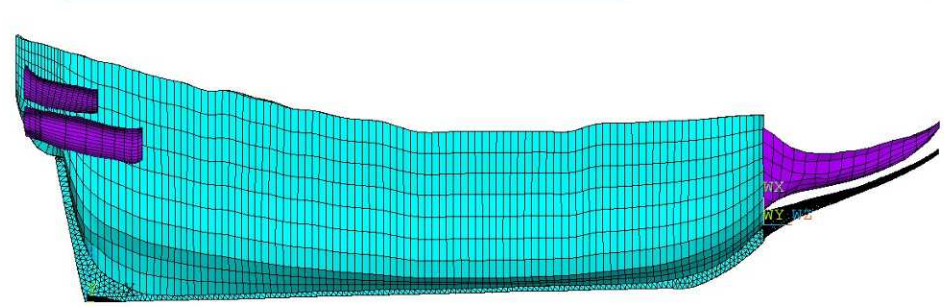
A cross-section: inner and outer planks



Different zone of the hull

CAD and meshed FE model

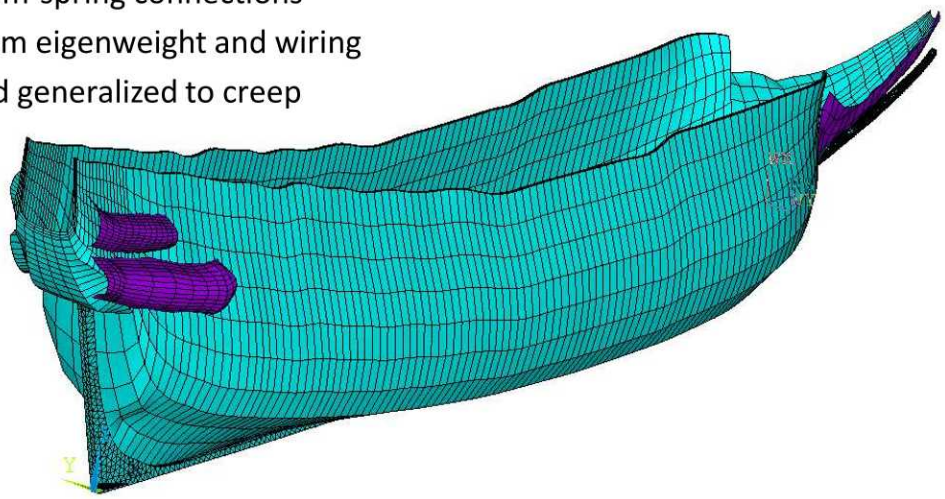




- **Solid shell**: hull
- **Shell**: decks, aft side (gallery), beck
- **Beam**: decks, cloumns, masts, stiffeners
- **Solid**: keel
- **Spring**: joint stiffness

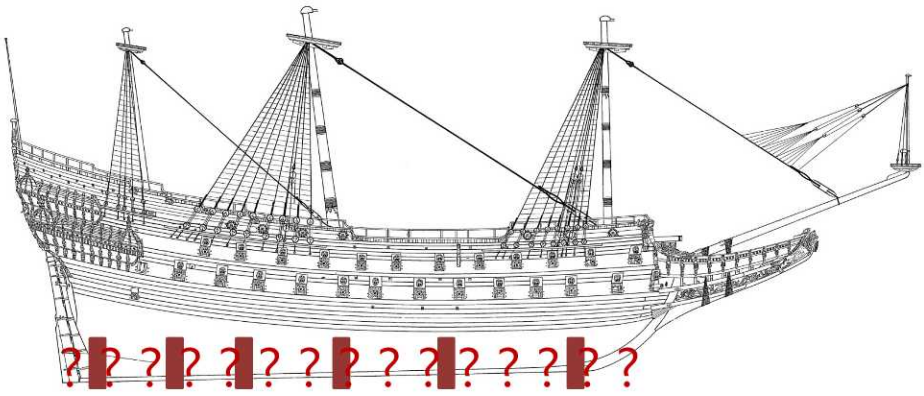
Meshed model (ANSYS)

- Orthotropic solid shell elements
- Shell-beam-spring connections
- Loads from eigenweight and wiring
- Static and generalized to creep

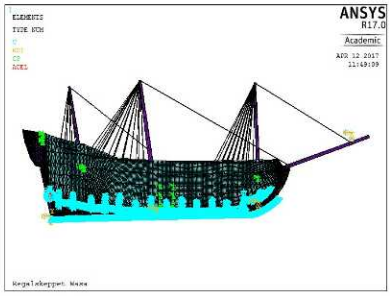


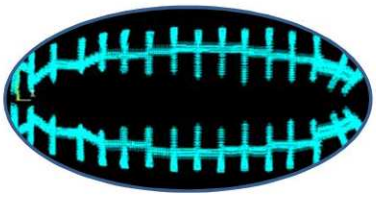
From a validated global **FE model**, provide a tool to bring forth an **optimized support structure**

Target: Relieve highly stressed regions, limit creep deformation

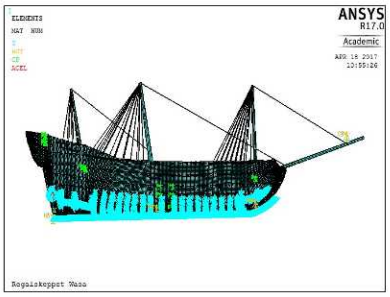


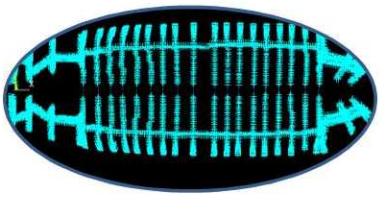
Current support



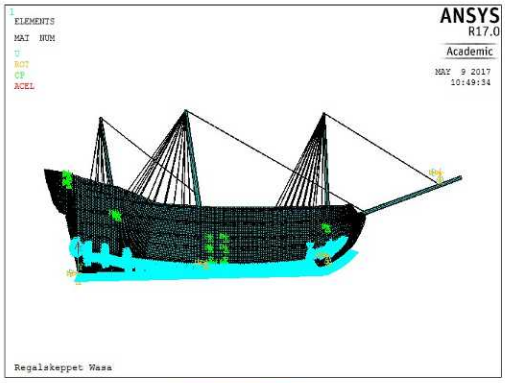


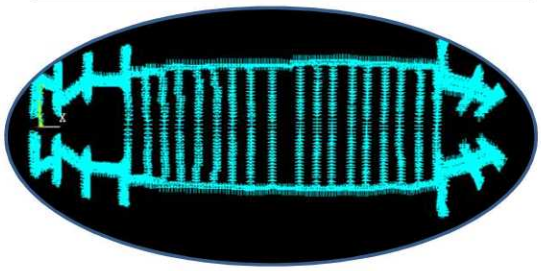
Concept #1





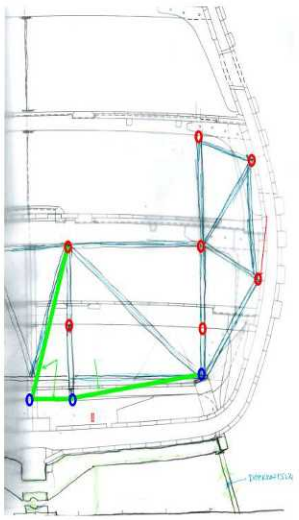
Concept #2





Comparison of designs:

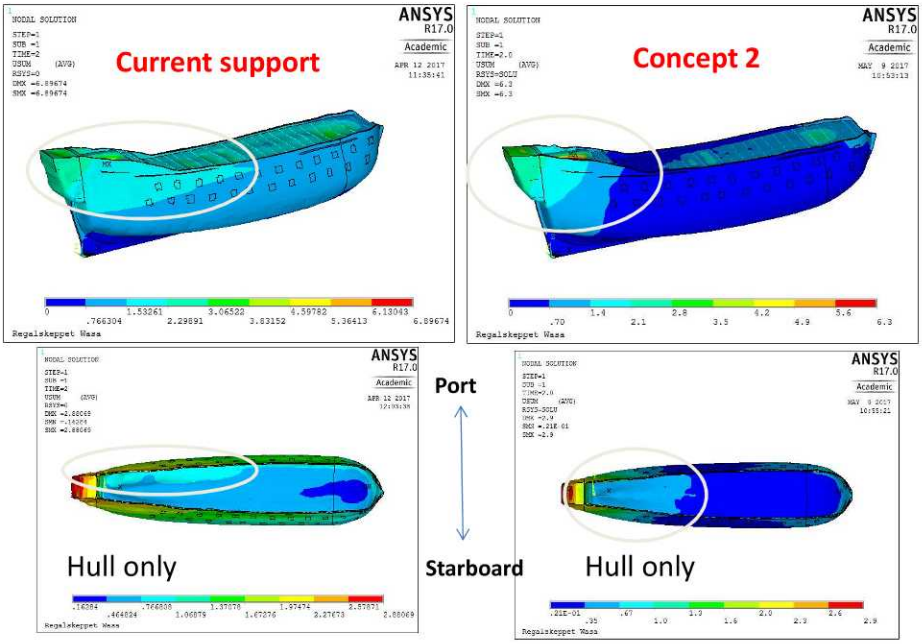
- displacement
- stress distribution
- reaction forces at the support locations



Internal support structure

Concept 2 better than current support

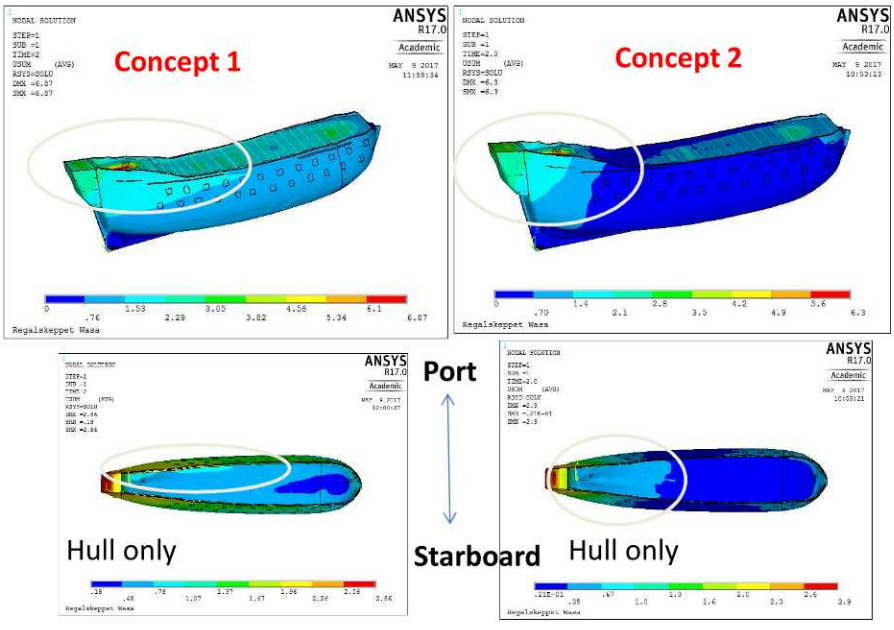
Less displacement
More symmetric



Concept 2 better than concept 1

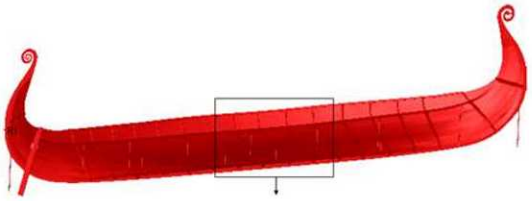
Less displacement!

Same trends for maximum stress and reaction loads



Not only Vasa…

- Oseberg and Gokstad viking ships
- Mary Rose
- HMS Victory
- Cutty Sark
- SS Great Britain
- Fregatten Jylland
- Bremer Cog
- Roman ships of Pisa
- Wooden buildings…?



(Craig A. Shutt, 2009)

Experiences from concrete bridges

Final thoughts

- Preservation of large wooden objects in cultural heritage necessitates a cross-disciplinary approach
- Structural mechanics, materials characterization, wood materials science, conservation science, climate control, monitoring…

References can be provided (e-mail me…)

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10. Afshar, R., Cheylan, M., Almkvist, G., Ahlgren, A. and Gamstedt, E.K., "Creep in oak material from the Vasa ship: Verification of linear viscoelasticity and identification of stress thresholds", *European Journal of Wood and Wood Products*, **78**, 2020, 1095-1103. https://doi.org/10.1007/s00107-020-01566-1
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