Finite Element Analysis (FEA) and its importance within Certification

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For over 50 years, we've been helping the construction and manufacturing industries **build confidence** in the solutions designed, created and implemented **throughout the entire supply chain**.

The BBA develops **long-term partnerships** with clients and associations to enable **continued growth in both the UK and Global marketplaces**, while remaining reassuringly impartial.

As a for-profit organisation Limited by Guarantee, the BBA looks **to reinvest in the industry as a whole** for the benefit of all stakeholders.

What we do

- **Product Approval Certification**
  - BBA Agrément Certification
  - Reproduction Certification
  - HAPAS
- **Testing**
- **Audit and Inspection**
- **Management Systems**
- **UKCA Marking**

To date

6,000+
CERTIFICATES ISSUED

72+
COUNTRIES REPRESENTED
by CLIENT BASE

130+
BBA PEOPLE

50+
YEARS IN BUSINESS

400+
TESTING METHODOLOGIES

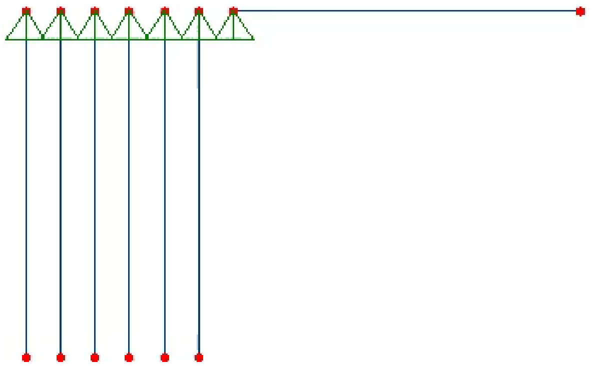
1000+
ANNUAL INSPECTIONS

What we'll cover;

- What is Finite Element Analysis (FEA)?
- Applying FEA
- Physical testing vs Mathematical modelling
- Approximate vs Exact
- FEA for Agrément Certification
- Q&A

Contents:

- Physical testing vs mathematical modelling
- Approximate vs exact solutions to mathematical models
- An introduction to Finite Element Analysis (FEA)
- Applications of FEA - A snapshot of developing trends in the Finite Element Method in product testing and development
- How FEA is used in the BBA testing and certification

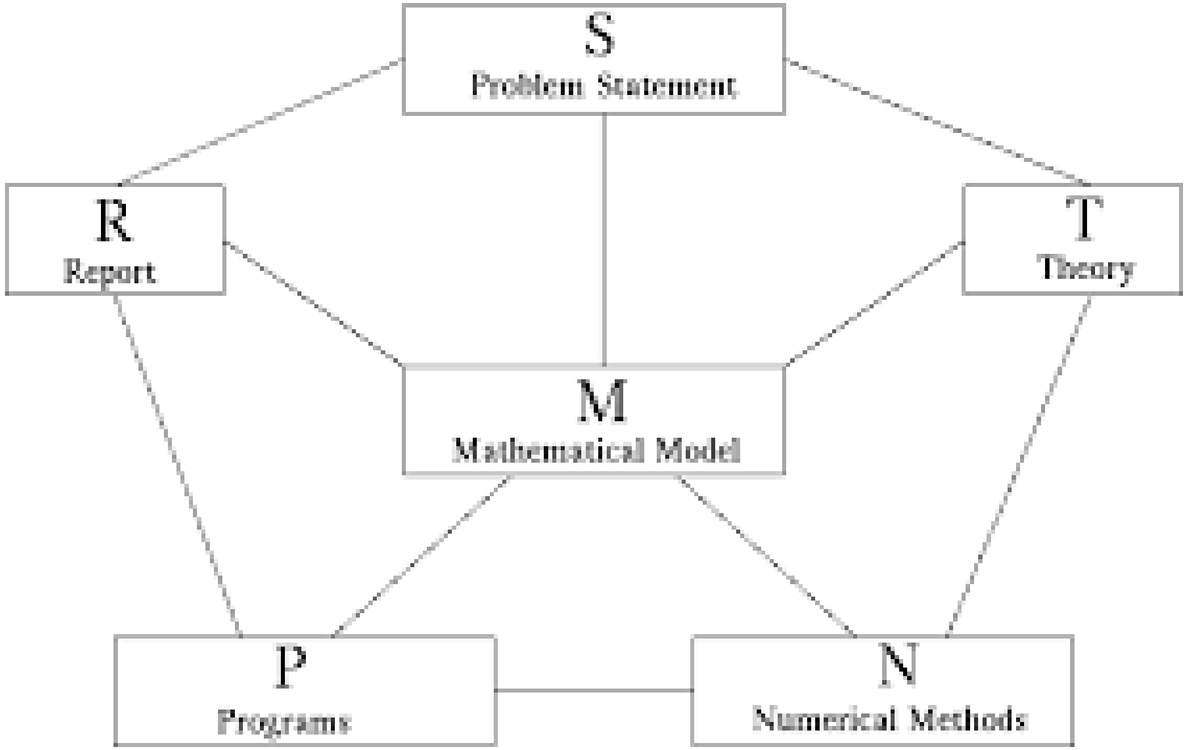


Physical testing vs mathematical modelling

A **mathematical model** is a description of a system using mathematical concepts and language.

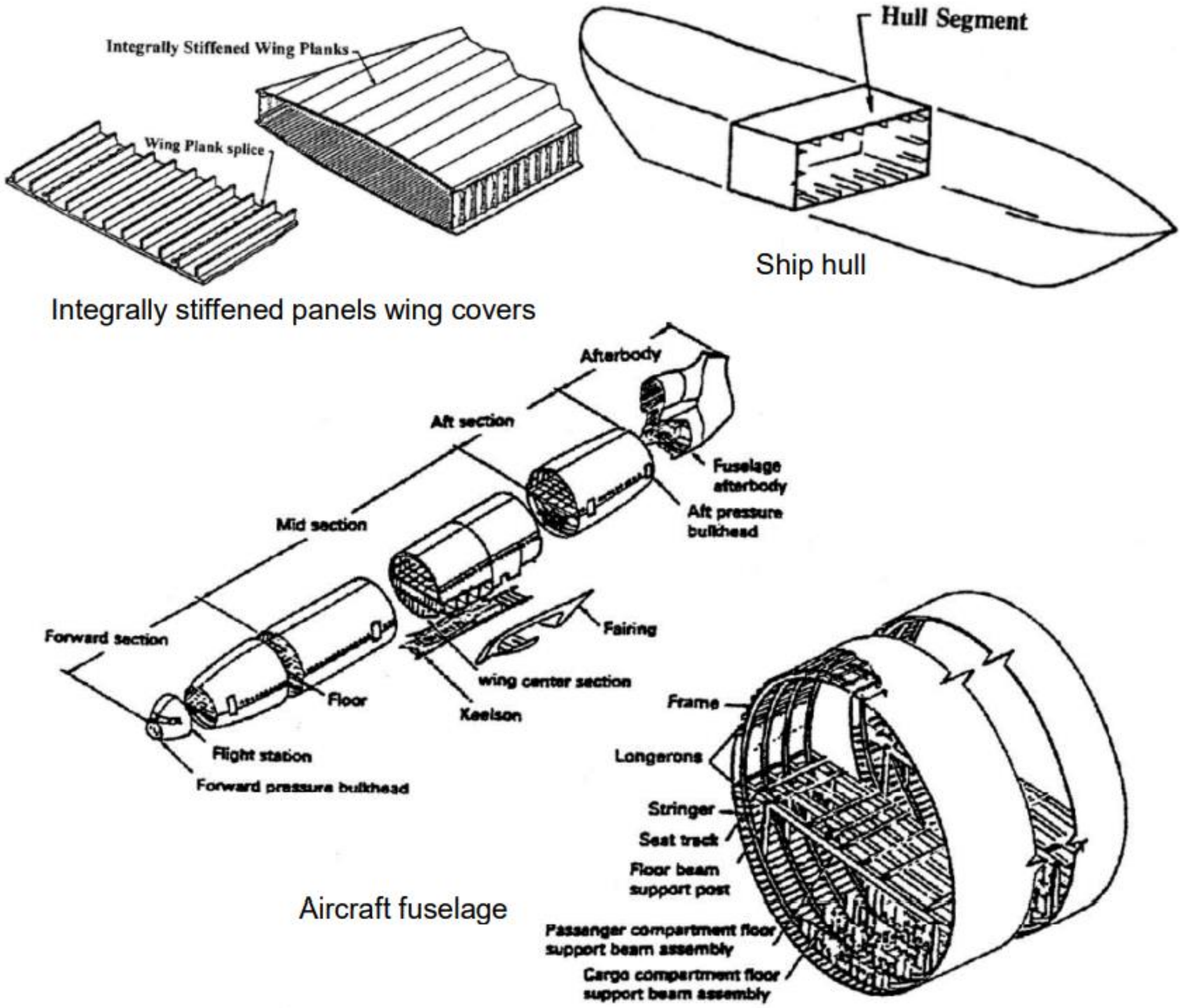
- Natural sciences (such as physics, biology, earth science, chemistry)
- Engineering disciplines (such as computer science, civil engineering)
- Non-physical systems such as the social sciences (such as economics, psychology, sociology, political science)
- music, linguistics, philosophy (for example, intensively in analytic philosophy), and religion (for example, the recurring uses of the numbers 7, 12 & 40 in the Bible)

Physical testing vs mathematical modelling



Pros: Less time, energy and cost
Cons: Simplification, approximate solution, not possible for all problems

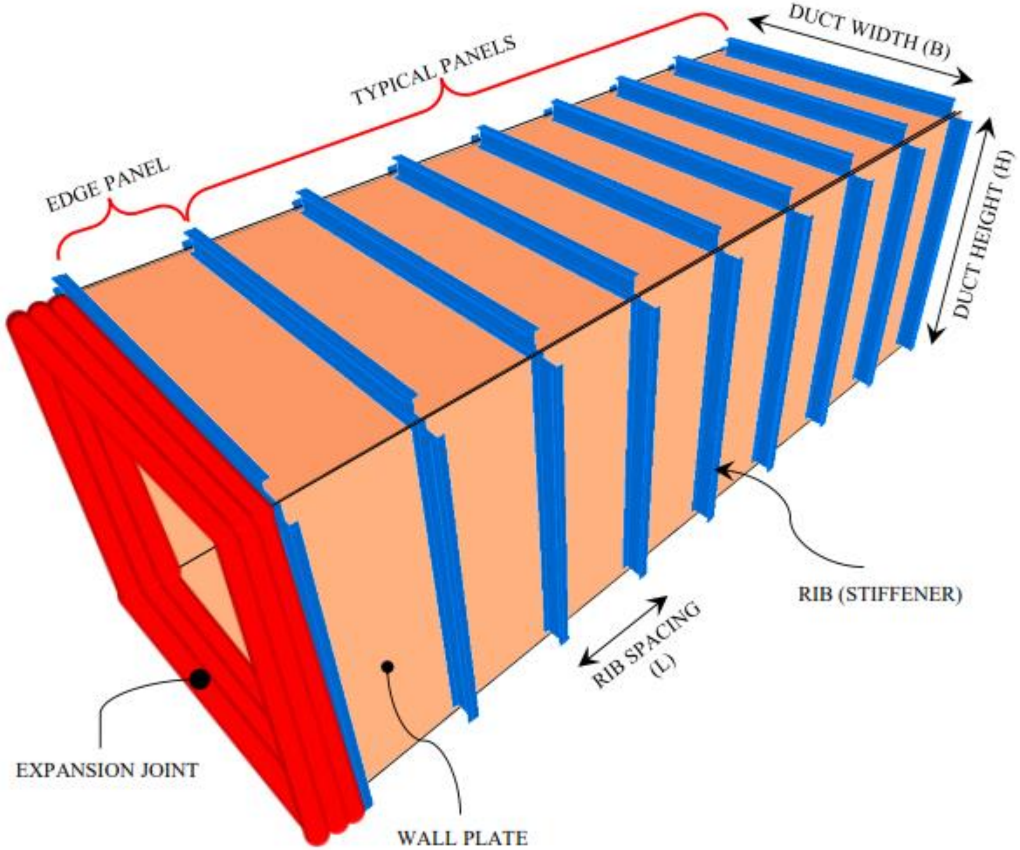
Physical testing vs mathematical modelling



Examples of stiffened plates and shells applications (Bedair, 2009)

Physical testing vs mathematical modelling

(a)



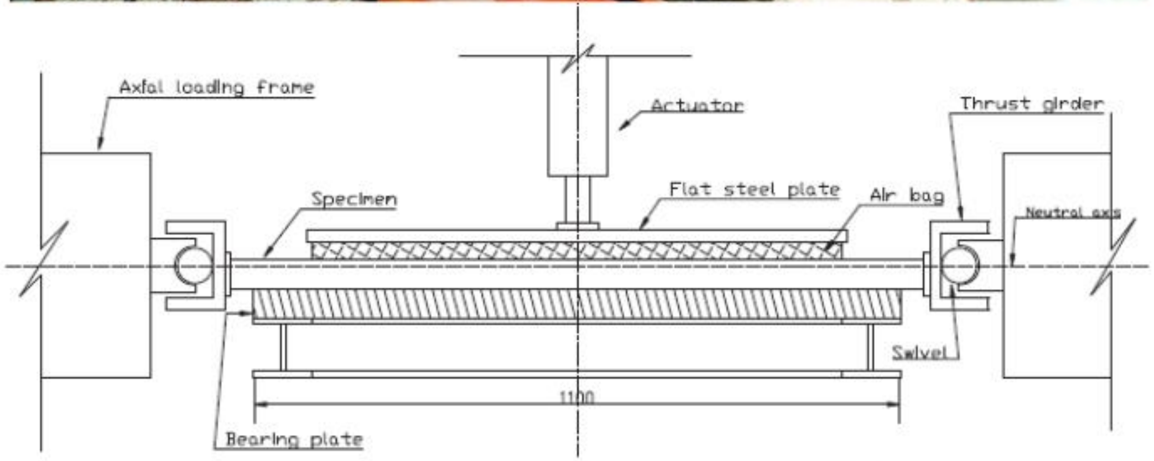
(b)

(a) Large industrial rectangular duct segments under construction (courtesy of fives-solios Inc.). (b) Schematic view of a typical rectangular duct segment

Physical testing vs mathematical modelling

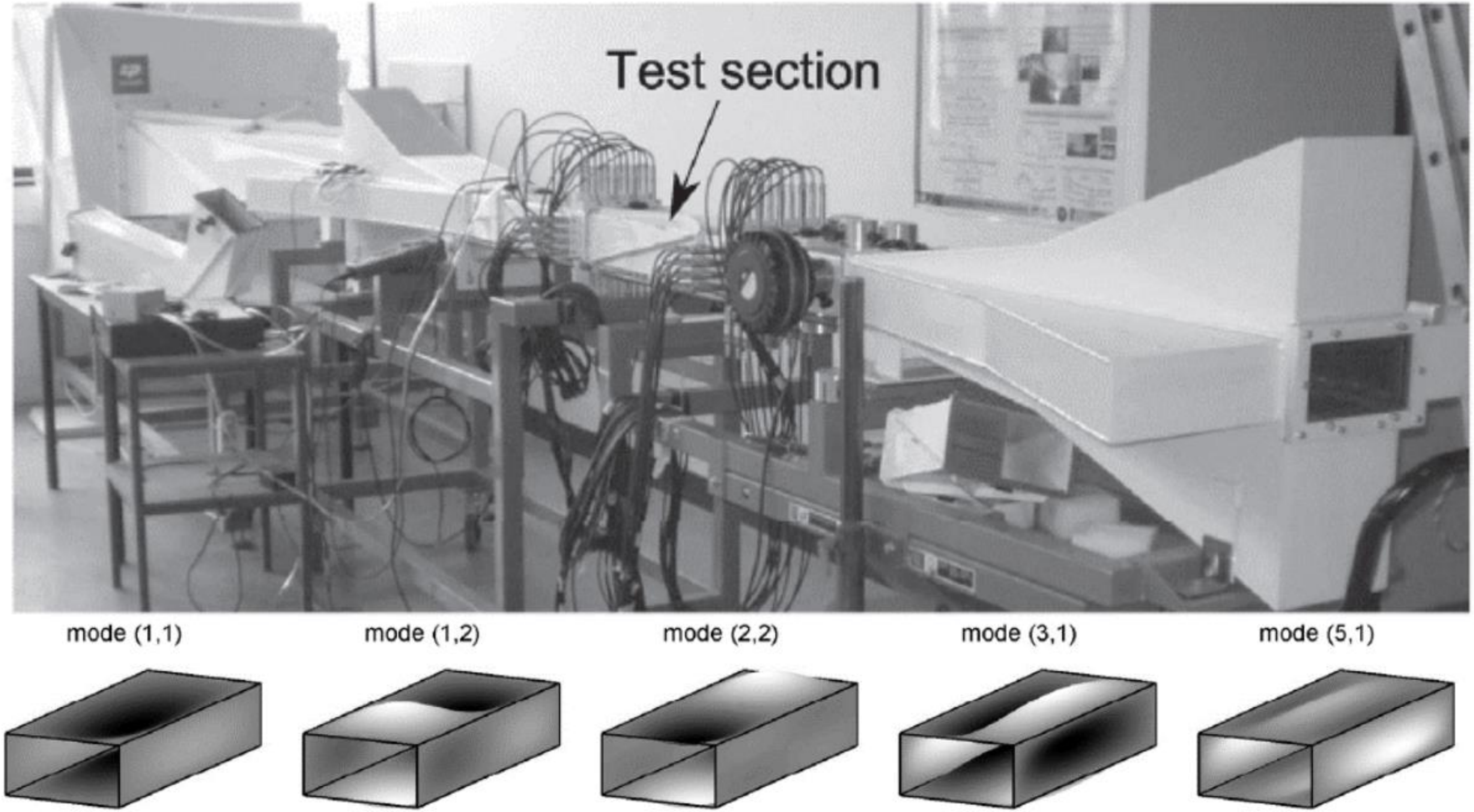
Test setup and deformed shape of the stiffened plate specimen (Kwon, 2014)

Physical testing vs mathematical modelling



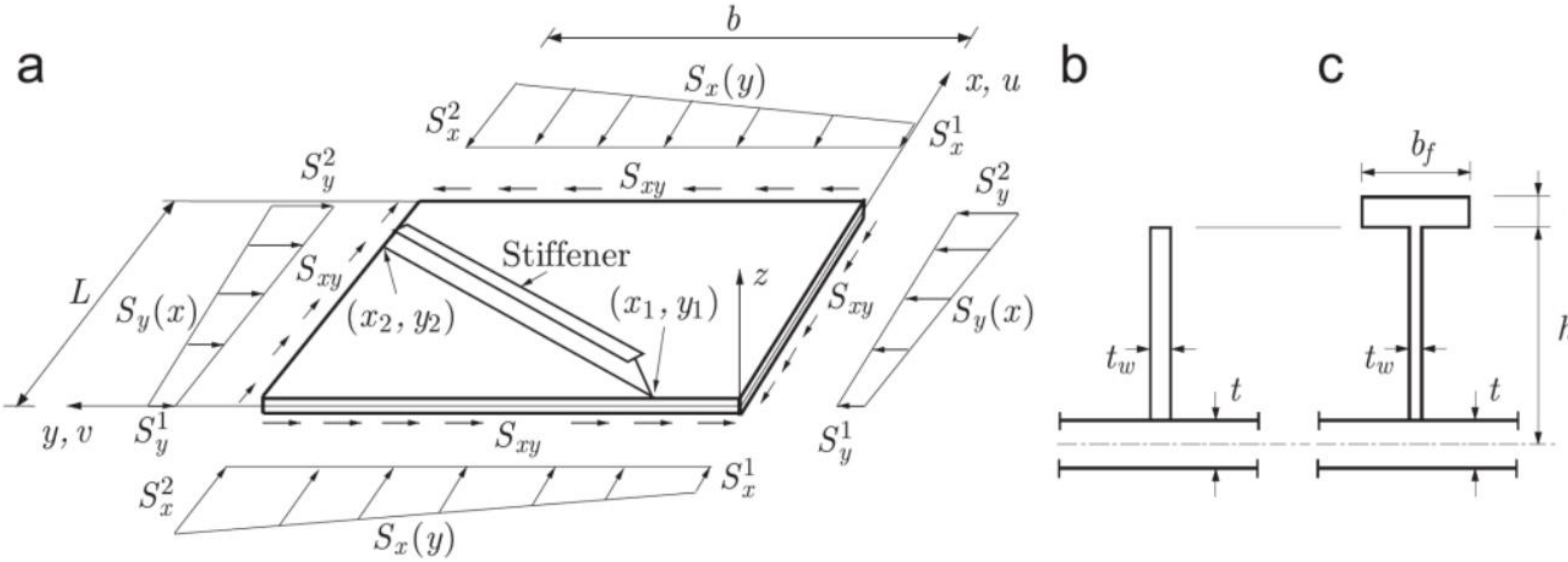
Test setup (up), and the sectional view of the test setup (down) by Shanmugam et al. (2014)

Physical testing vs mathematical modelling



The experimental test setup (up), and the expected modal shapes for the duct segment (down) by David et al. (2018)

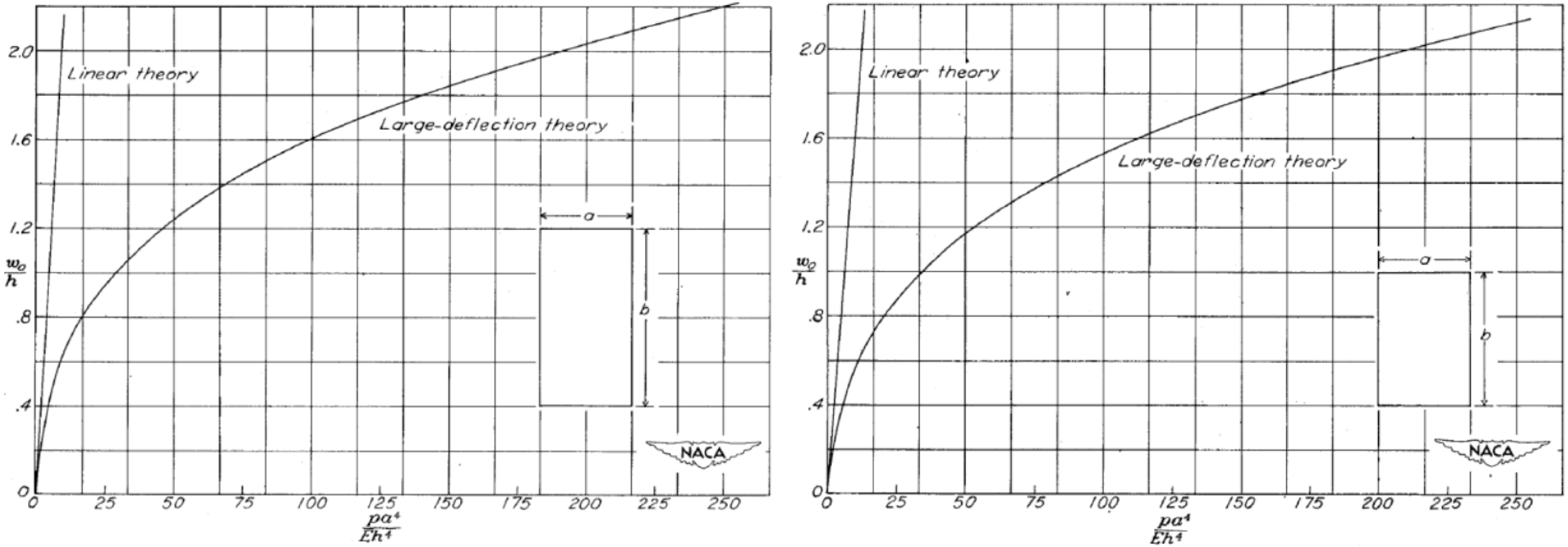
Physical testing vs mathematical modelling



Schematic display of the stiffened plate; (a) Stiffened plate subjected to applied in-plane shear stress (S_{xy}) and in-plane, linear varying compression or tension stress (S_x, S_y), and cross section of an eccentric, (b) flat bar and (c) T-stiffener. (Brubak and Hellesland, 2007-a, 2007-b, 2007-c, 2008)

Physical testing vs mathematical modelling

$$D\left[\left(\frac{\partial^2 w}{\partial x^2}\right)^2+\left(\frac{\partial^2 w}{\partial y^2}\right)^2\right]^2+ch\dot{w}+\rho h\ddot{w}=f+q+N_x\frac{\partial^2 w}{\partial x^2}+N_y\frac{\partial^2 w}{\partial y^2}+2N_{xy}\frac{\partial^2 w}{\partial x\partial y}$$

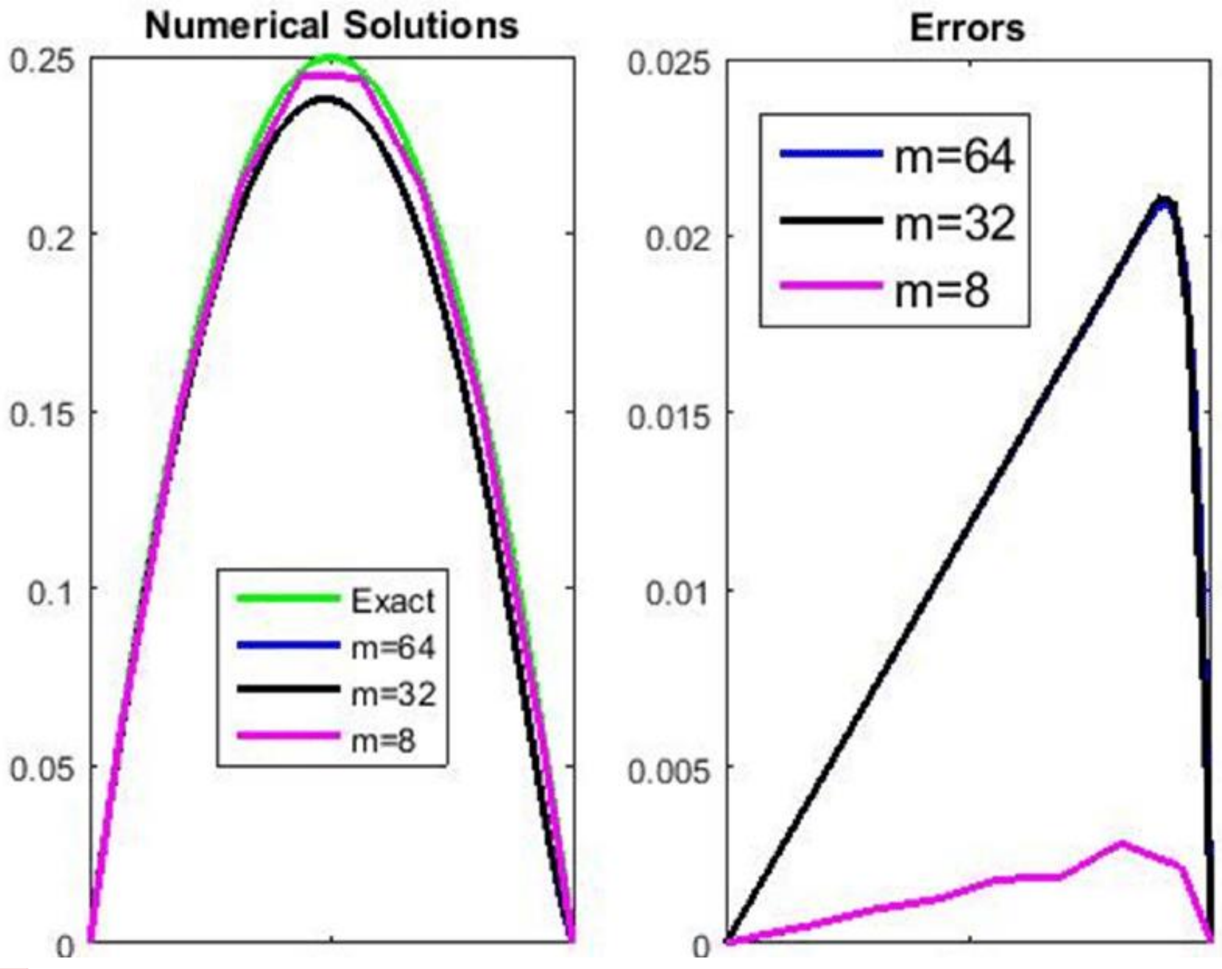


Load-displacement charts for rectangular plates with aspect ratio of 1.5 (right), and 2.0 (left) by Wang (1948)

Approximate vs exact solutions to mathematical models

$$D\left[\left(\frac{\partial^2 w}{\partial x^2}\right)^2+\left(\frac{\partial^2 w}{\partial y^2}\right)^2\right]^2+ch\dot{w}+\rho h\ddot{w}=f+q+N_x\frac{\partial^2 w}{\partial x^2}+N_y\frac{\partial^2 w}{\partial y^2}+2N_{xy}\frac{\partial^2 w}{\partial x\partial y}$$

Taken from: The Great Soviet Encyclopedia (1979).



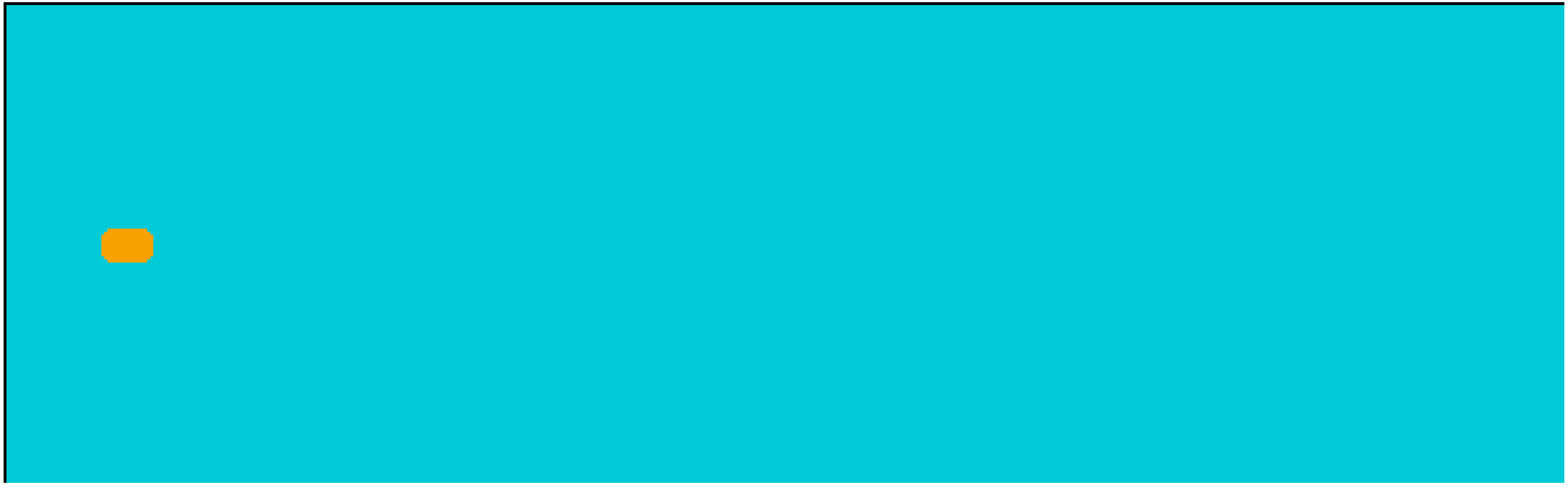
An **approximate solution** to a differential equation in the form of an analytic expression can be found by the method of series (power series, trigonometric series, and so on), the method of small parameters, the method of successive approximations, the Ritz and Galerkin methods, and the Chaplygin method. Each of these methods defines one or more infinite processes that under certain conditions can be used to obtain an exact solution to a problem. Termination of the process after a finite number of steps yields an approximate solution.

Memory Effects Due to Fractional Time Derivative and Integral Space in Diffusion Like Equation Via Haar Wavelets; January 2016Applied and Computational Mathematics 5(4):177; DOI:10.11648/j.acm.20160504.12

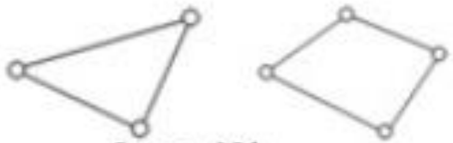
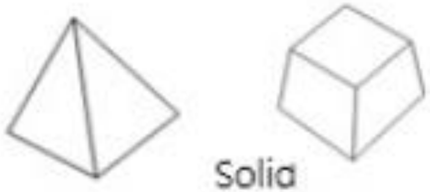
An introduction to Finite Element Analysis (FEA)

Taken from: Wikipedia

The **finite element method (FEM)** is a numerical solution method for differential equations.
FEM divides the system into smaller, simpler parts called finite elements.
The process for creation of the finite elements is called meshing.
The FEM formulation of a boundary value problem finally results in a system of algebraic equations. The method approximates the unknown function over the domain. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. The FEM then approximates a solution by minimizing an associated error function via the calculus of variations.



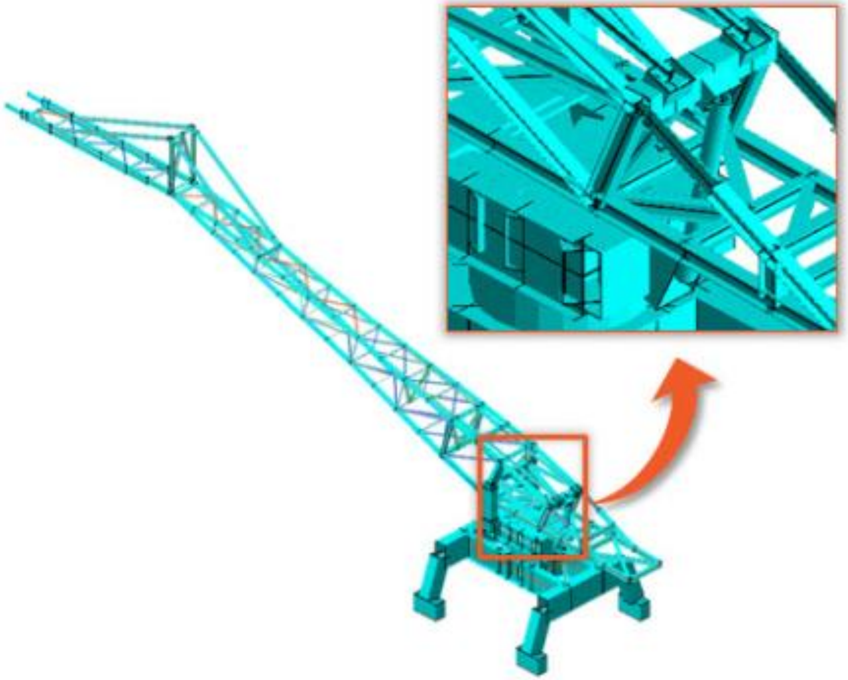
Taken from: feaforall.com

Type	Actual Models	Finite Element Expressions (Geometric Properties Defined by Nodes)
1D	 Rod (Truss) Beam	 Length (L)
2D	 Shell, Plane Stress, Plane Strain, Axisymmetric, etc	 Area (A)
3D	 Solid	 Volume (V)
Misc.	Spring, Mass, Rigid Link, etc.	-

1D Elements

Taken from: feaforall.com

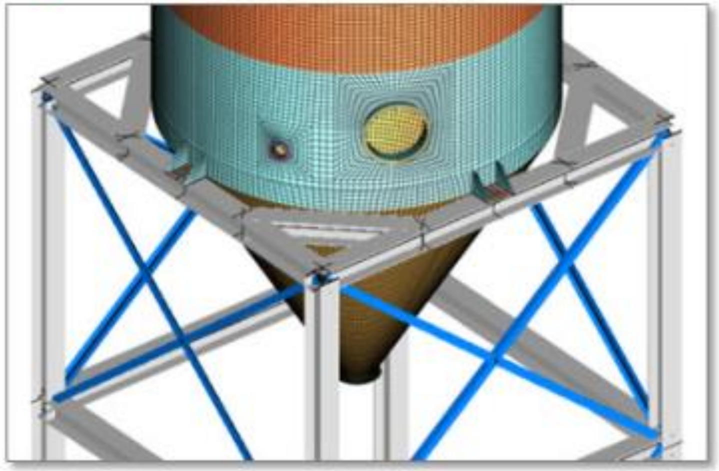
- ✓ Also referred to as line elements.
- ✓ Often used to represent members, which are too long compared to the measurement of the cross-section (L/r >20).
- ✓ Useful when bending is the root cause of failure.
- ✓ Fundamental assumption: Changes in material properties along the cross-section are negligible.



Taken from: feaforall.com

2D Elements

- ✓ Also referred to as shell elements.
- ✓ Often used when thin, sheet structures are under bending deformation
- ✓ Can consider 2D stress conditions and bending and shear deformations
- ✓ Fundamental assumption: Changes in material properties along the thickness of the structure are negligible.

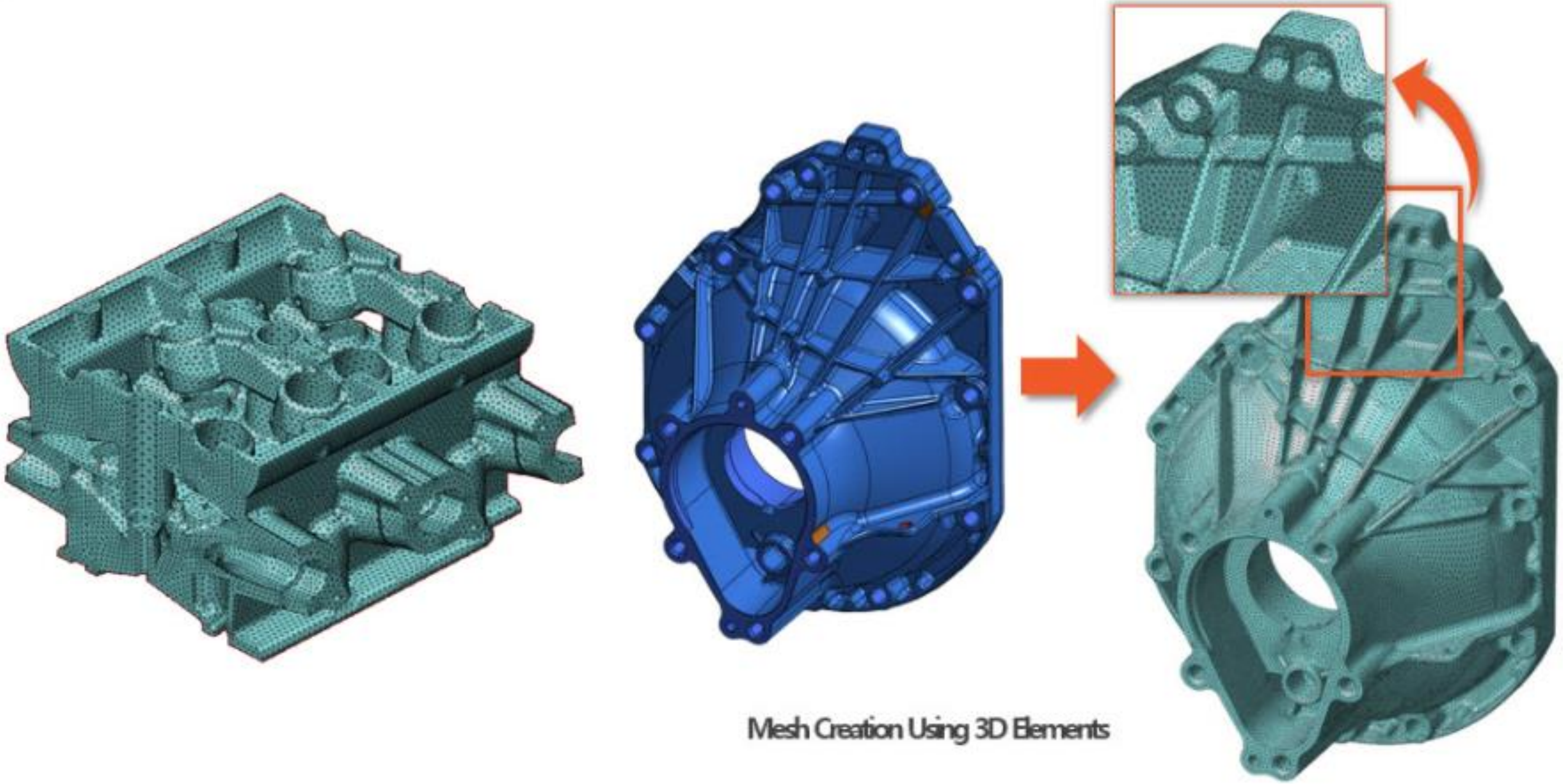


Mesh Creation Using 2D Elements

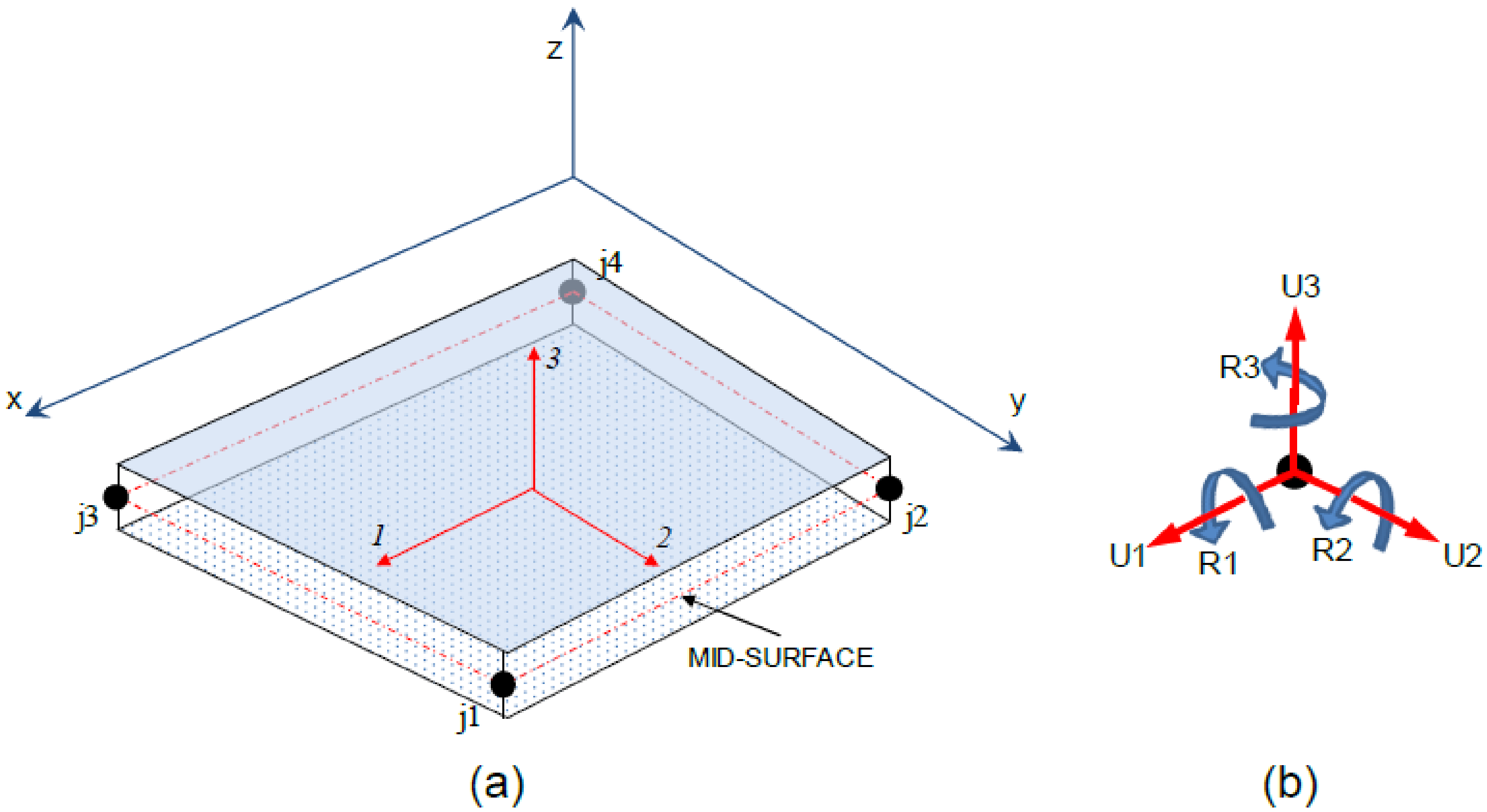
An introduction to Finite Element Analysis (FEA)

Taken from: feaforall.com

- ✓ Also referred to as solid elements
- ✓ Since actual tasks deal with 3D model using CAD, they are used in analyses the most.

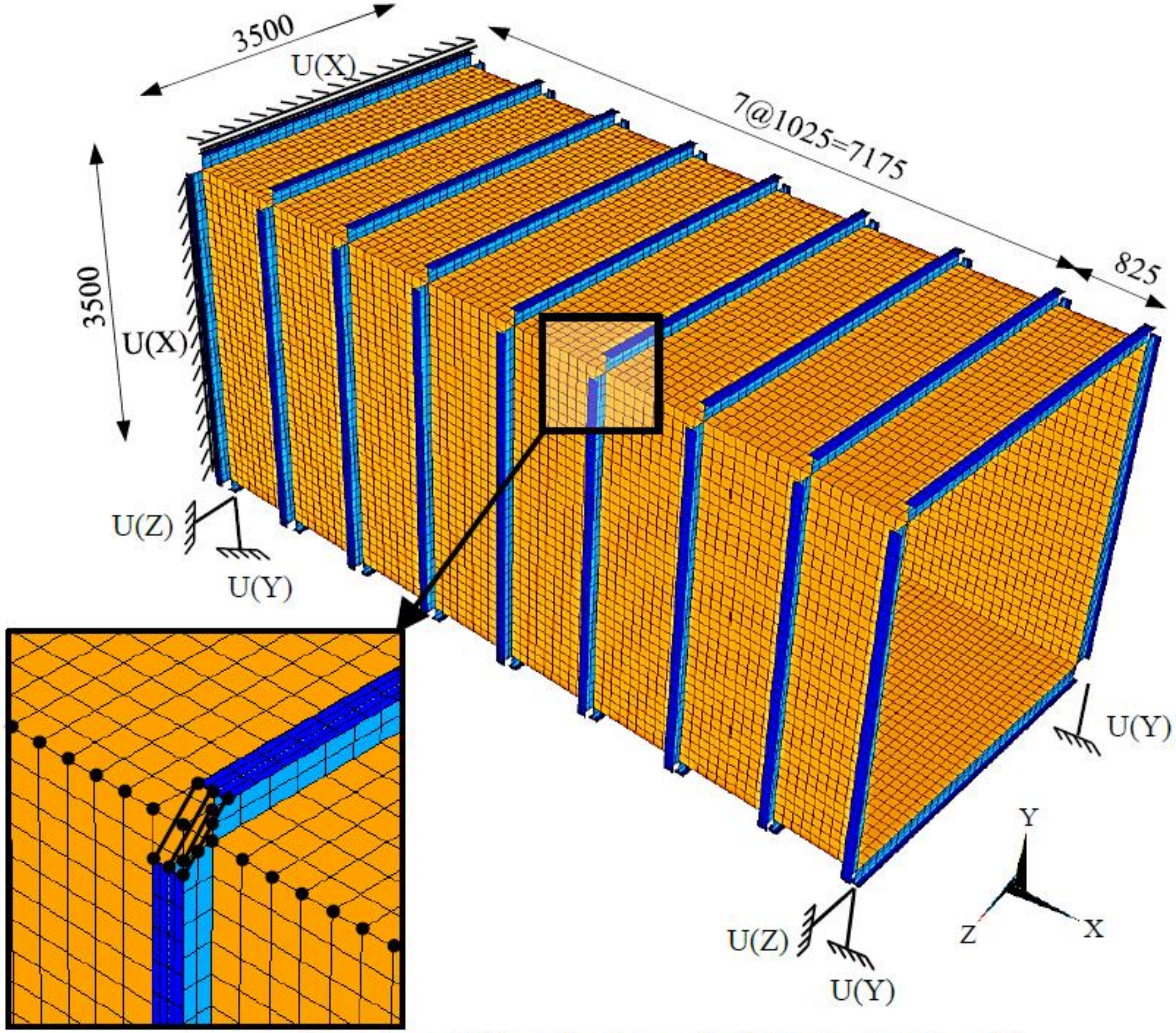


Mesh Creation Using 3D Elements



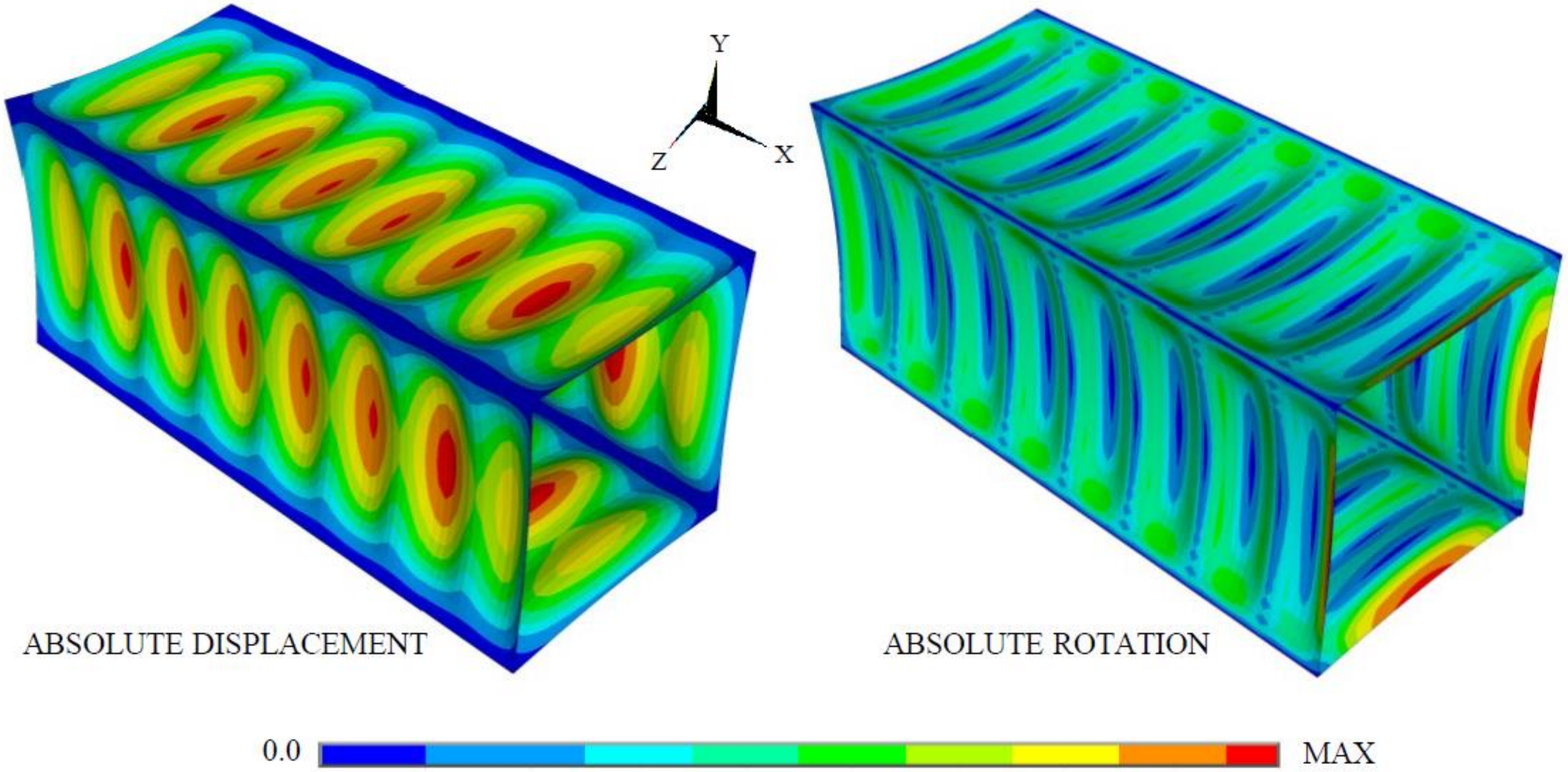
(a) General view of the nodes, surfaces, global and local coordinates of the shell element (b) Local degrees of freedom at a given joint

An introduction to Finite Element Analysis (FEA)



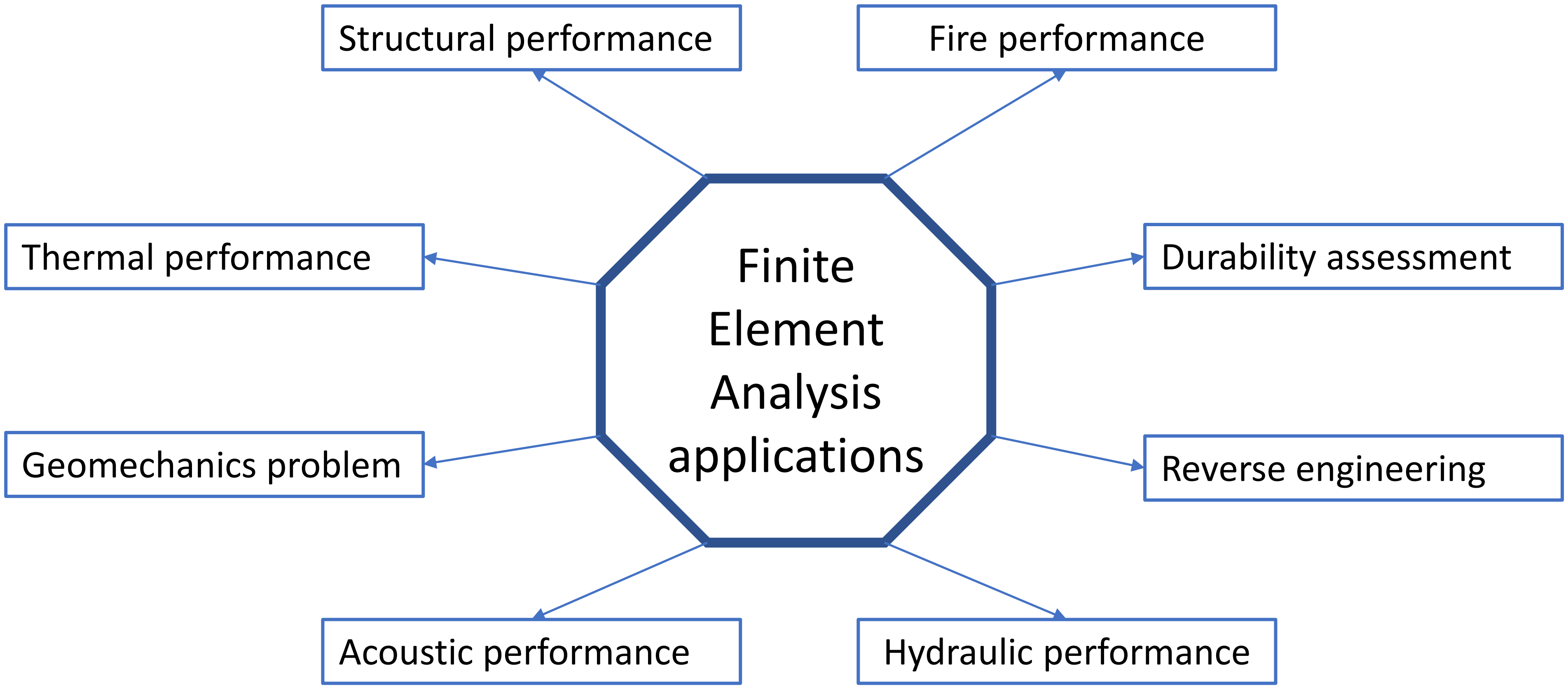
Geometry and FE mesh of a sample 3D duct segment model

An introduction to Finite Element Analysis (FEA)



Absolute deformation and rotation of the duct segment model under the applied internal pressure (rib elements removed from the view for clarity)

Applications of FEA (in construction industry)



How FEA is used in the BBA testing and certification

Finite Element Analysis applications

- Structural performance
- Fire performance
- Thermal performance
- Durability assessment
- Geomechanics problem
- Reverse engineering
- Acoustic performance
- Hydraulic performance

Questions?

Engineering is the art of being approximately right rather than exactly wrong!!!
(Prof. Rod Smith)