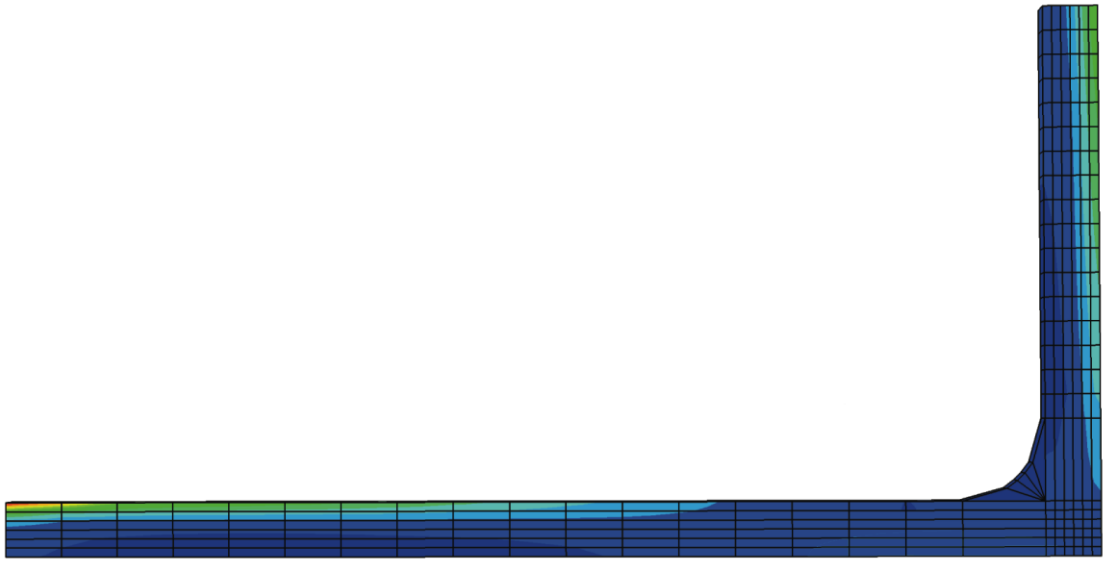
Practical application of the MFE

Part 1 : Modelling

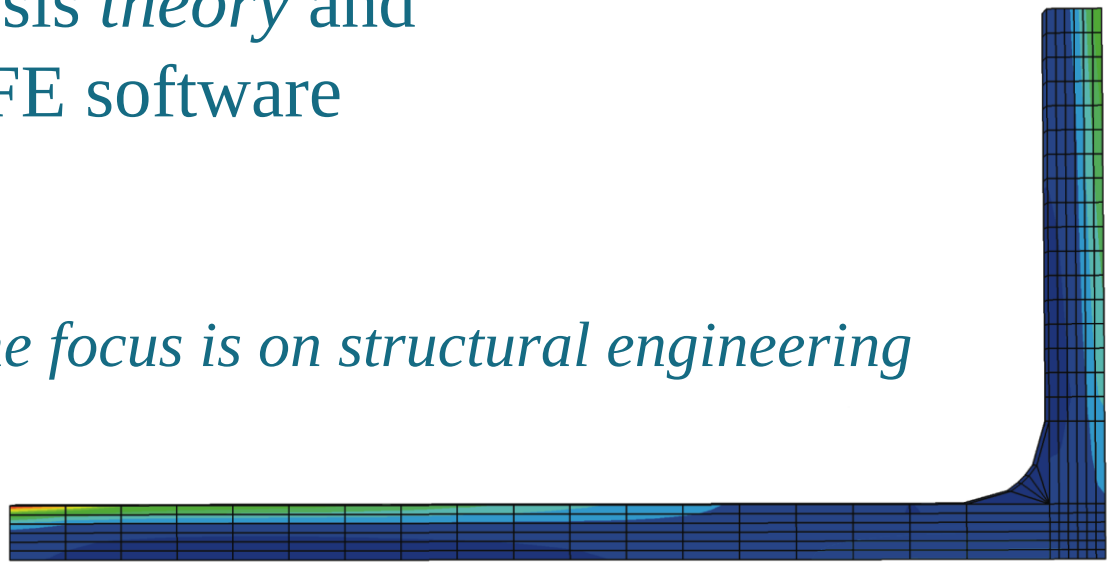


Goals of this Lecture

- Demonstrating the importance of modelling when applying the MFE

- Closing the gap between
  structural analysis *theory* and
  application of FE software

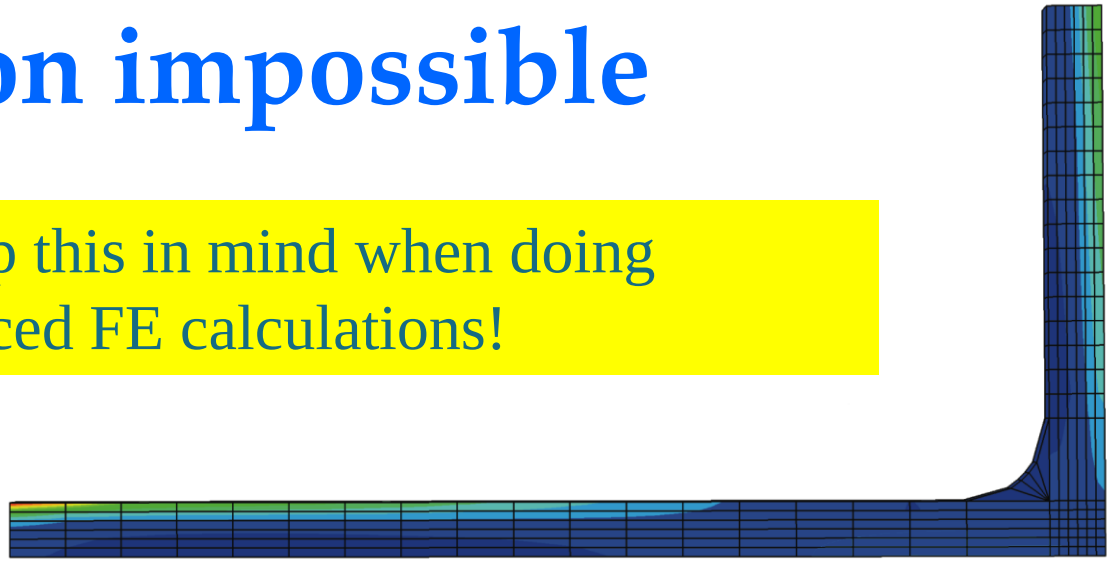
Note: In this lecture the focus is on structural engineering



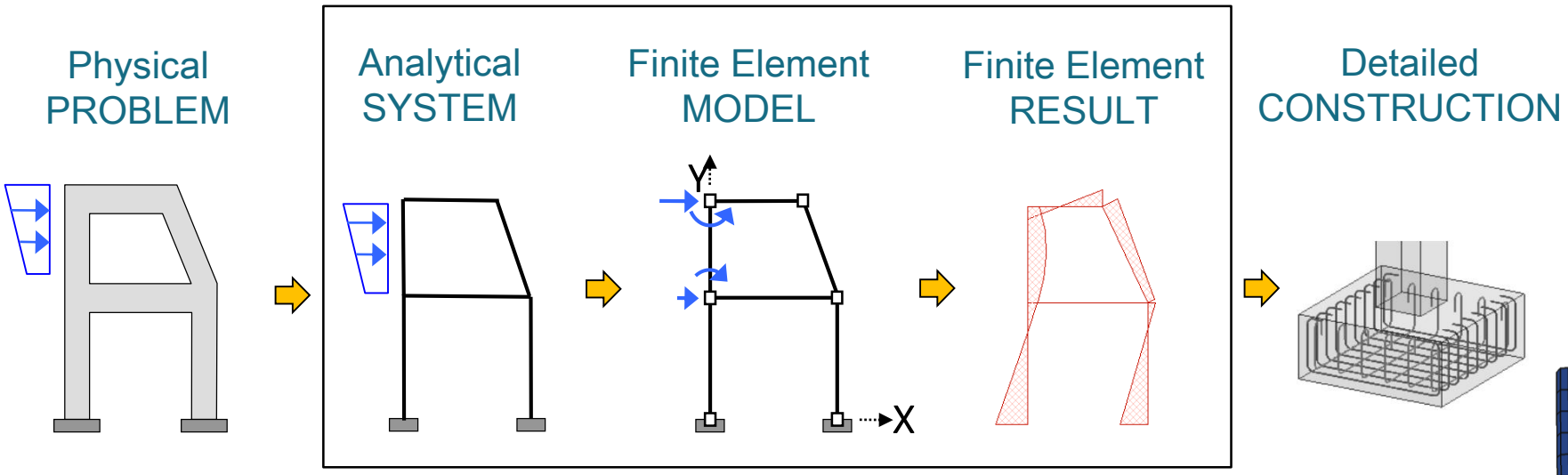
*"**Structural engineering** is the art of molding materials we don't wholly understand, into shapes we can't fully analyze, so as to withstand forces we can't really assess, in such a way that the community at large has no reason to suspect the extent of our ignorance."*

Structural Engineering
=
Mission impossible

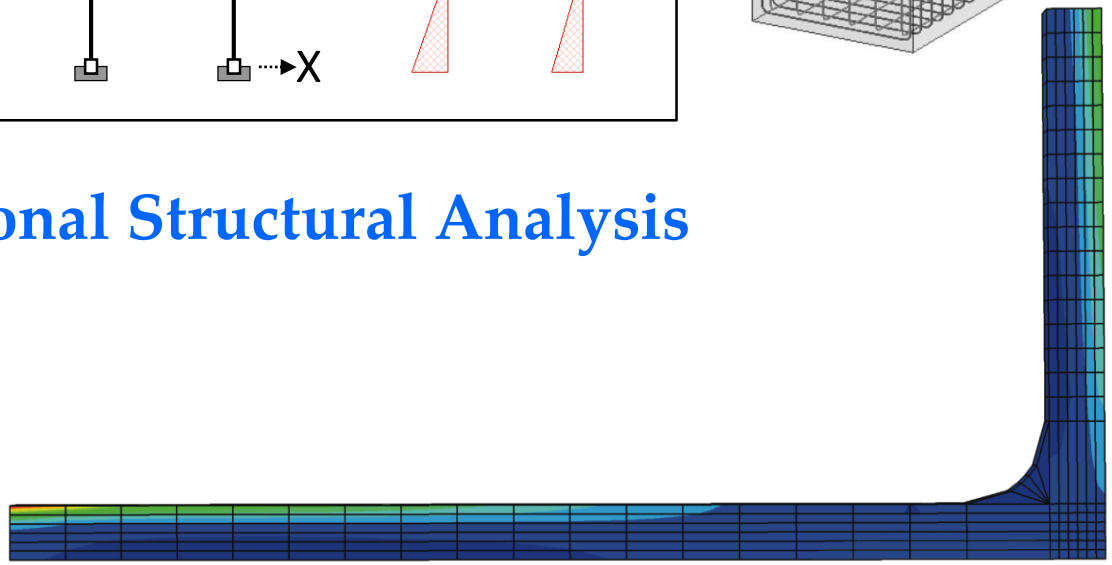
Always keep this in mind when doing advanced FE calculations!



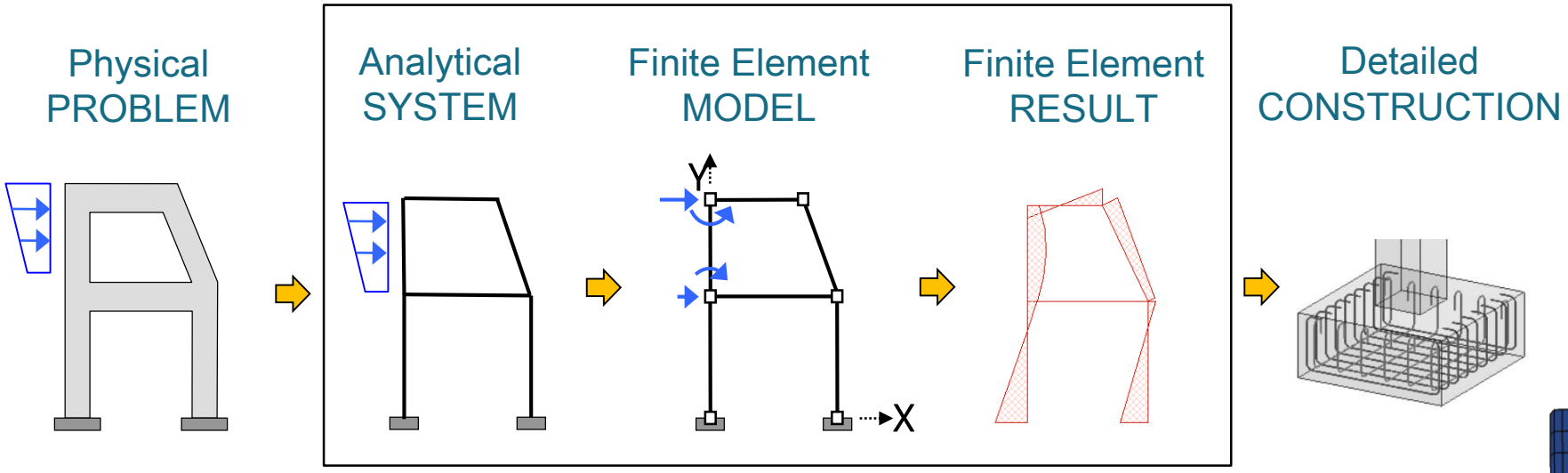
Structural Engineering



Computational Structural Analysis

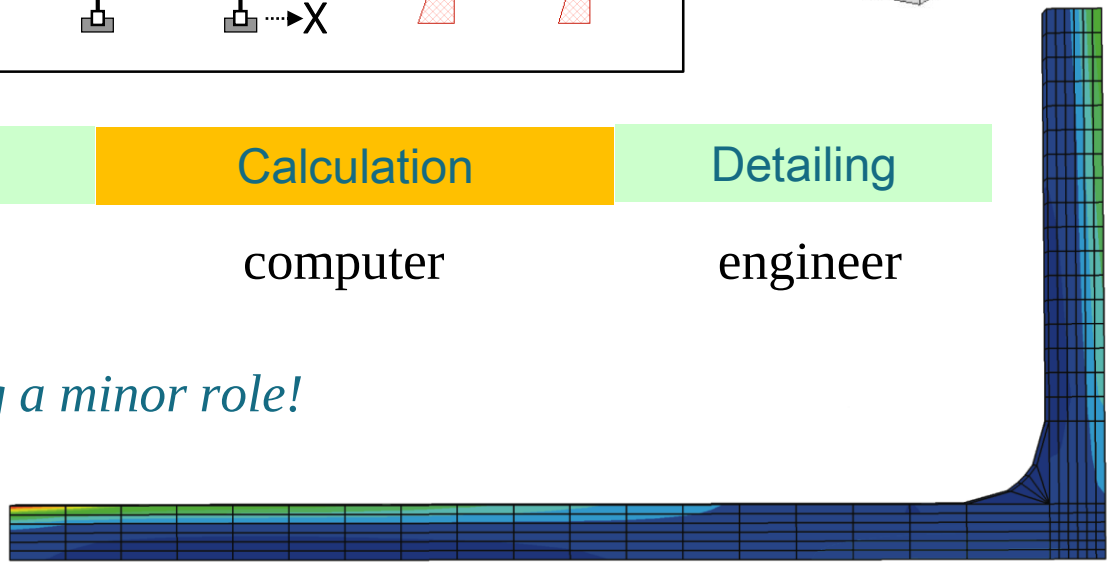


Structural Engineering

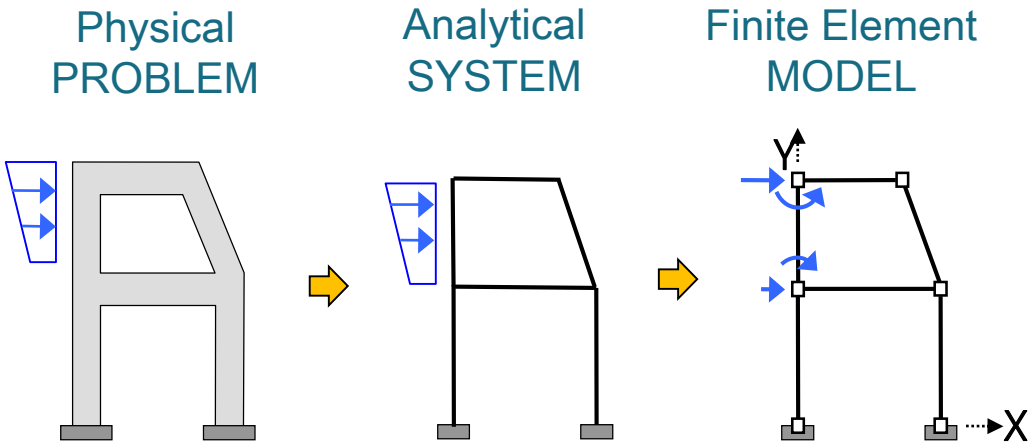


Modelling	Calculation	Detailing
engineer	computer	engineer

Note: The computer is playing a minor role!

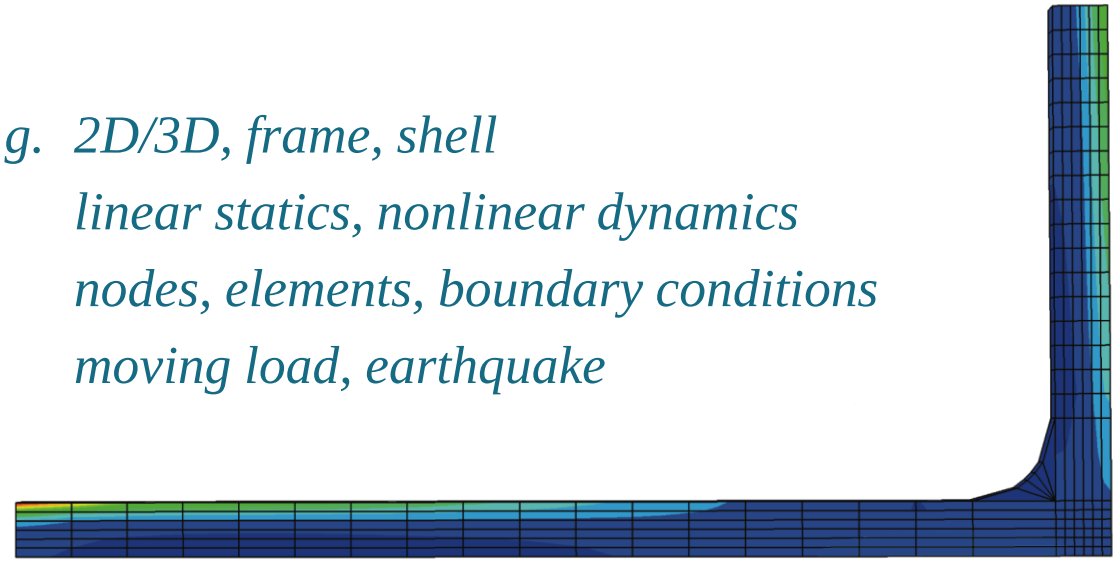


FE Modelling



Modelling = defining…

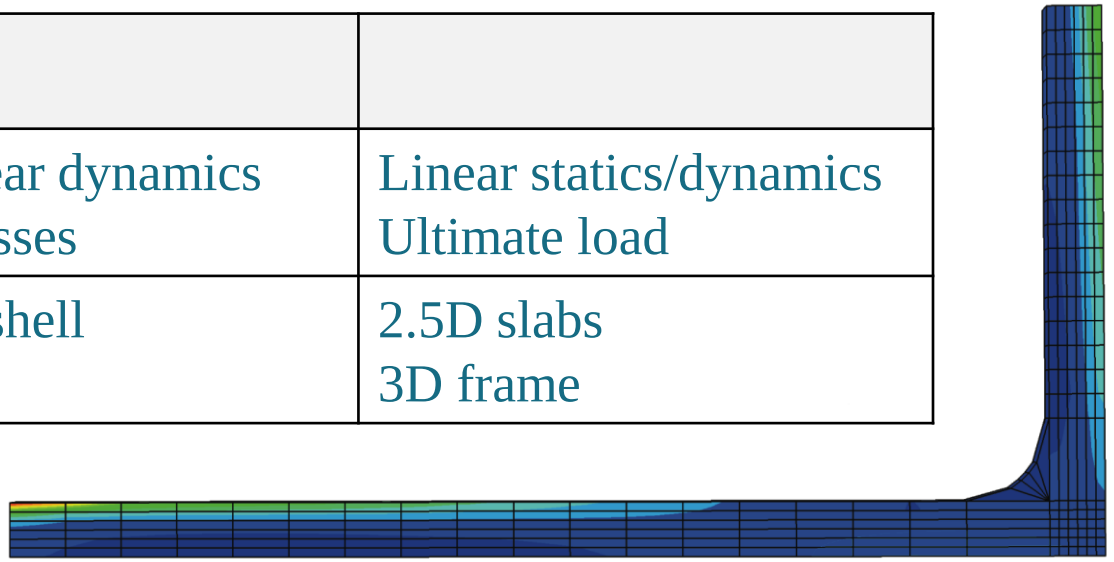
- Structure type *e.g. 2D/3D, frame, shell*
- Analysis type *linear statics, nonlinear dynamics*
- Analytical system *nodes, elements, boundary conditions*
- Actions *moving load, earthquake*



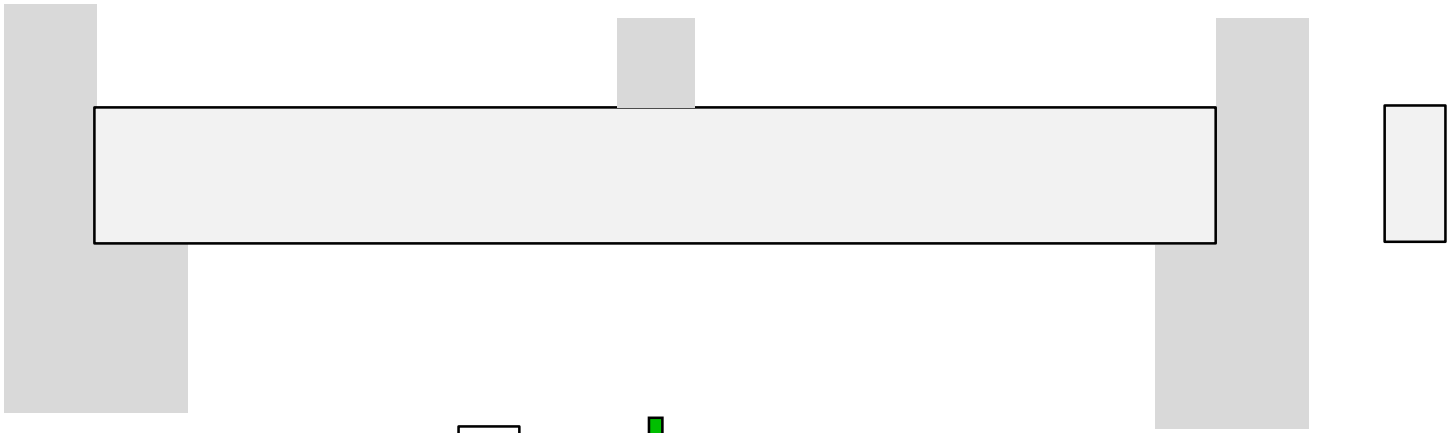
FE Modelling

	Mechanical Eng	*Civil Eng*
World		
Object	Airplane	Building
Problem	Vibrations Cracking	Deformations Collapse

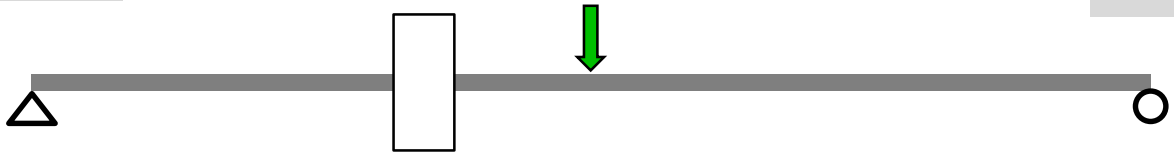
(FE) Model		
Analysis	Linear dynamics Stresses	Linear statics/dynamics Ultimate load
Structure	3D shell	2.5D slabs 3D frame



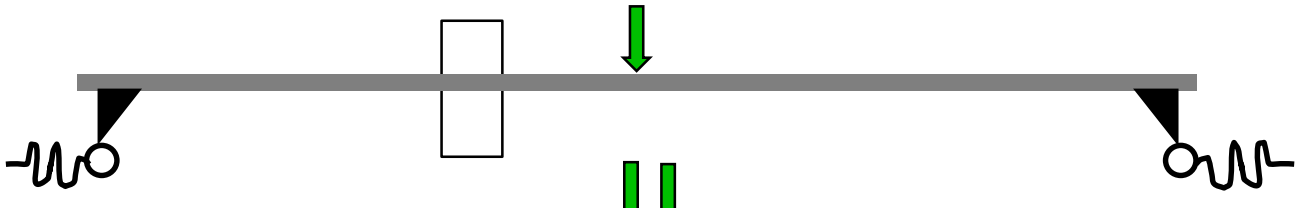
Example: Modelling a Girder



Model A



Model B



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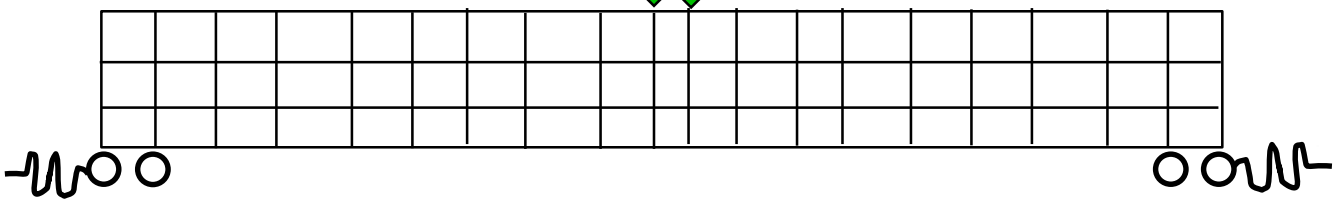
Model C



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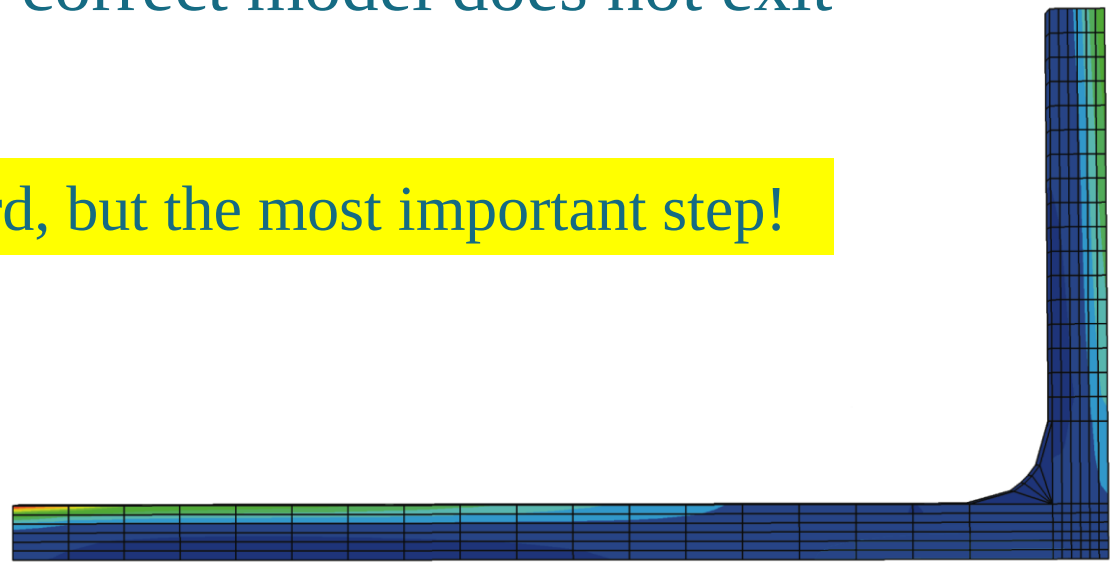
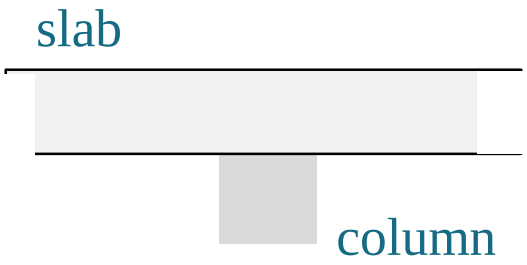
Modelling

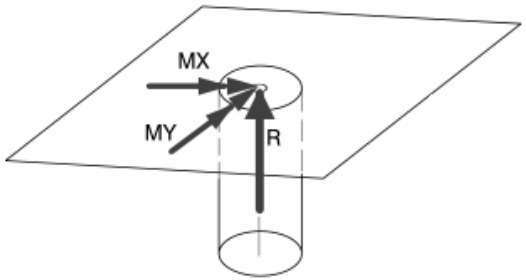
- Making assumptions based on engineering judgement
- Building an appropriate, consistent analytical system
- The (one and only) correct model does not exit

Modelling is hard, but the most important step!



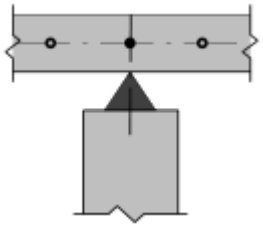
Example: Slab on Columns
FE Model

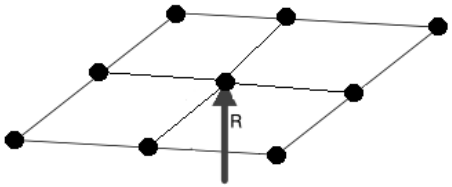




Best FE model = ?

FE Model A





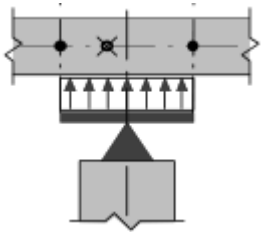
2D slab
3 dof/node, bending element
linear elastic analysis
point support

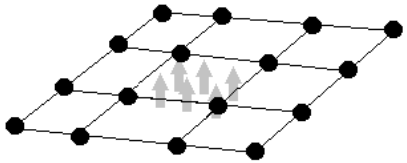
=> Stress concentrations at support node !

Example: Slab on Columns

FE Model B

elastic element support



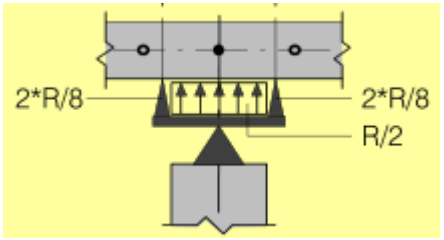


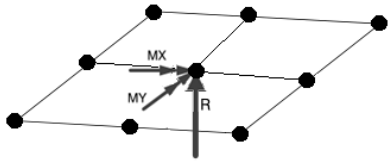
=> No clamped support possible !

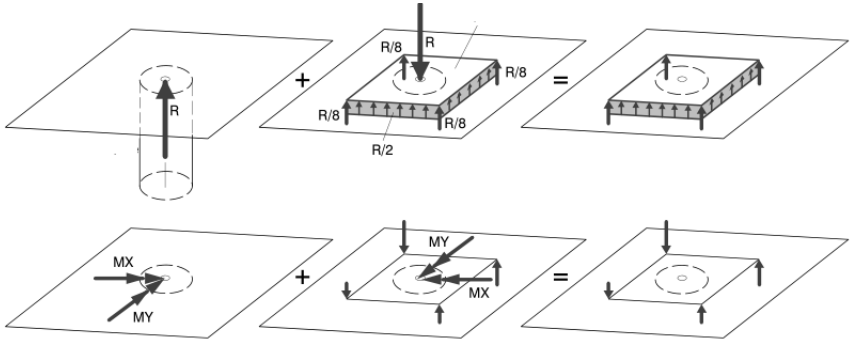
FE Model C

1. Find reactions from point support

2. Add correcting loads:



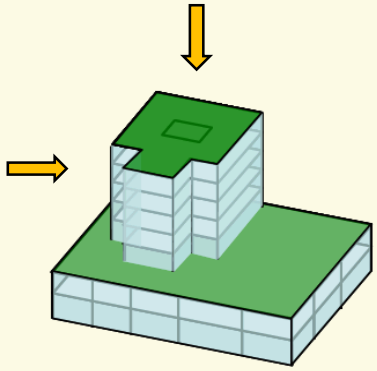




=> Best results !

Example: Modelling a Building

Physical Problem



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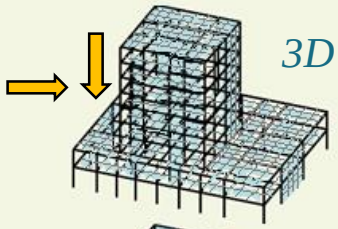
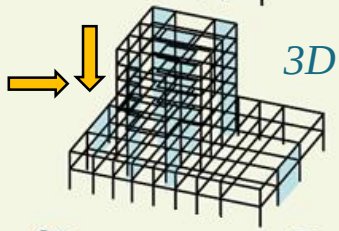
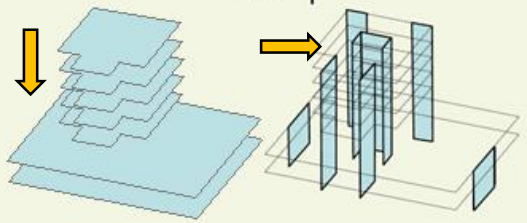
FE Models







2.5D slabs + 3D frame / system of beams

Increased complexity

Example: Modelling a Building

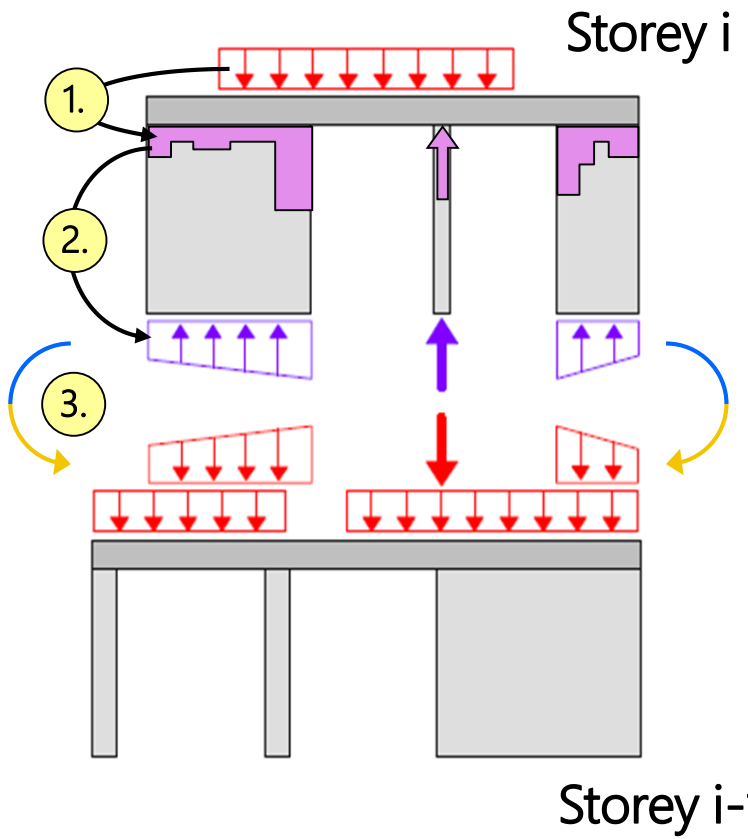
2.5 D Model for vertical loads: "Stack of slabs"

Start with top story:

1. Upper story: 2D slab analysis => reactions
2. Walls/columns: reaction transfer + dead load => foot reactions
3. Lower story: import reactions as slab loads

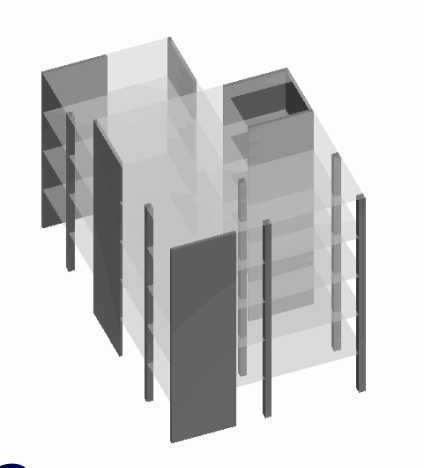
Continue to next story and repeat the 3 steps

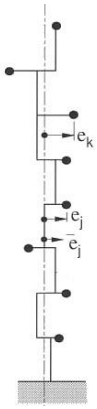
all the way to the foundation.



Example: Modelling a Building

Earthquake Analysis





Equivalent cantilever beam

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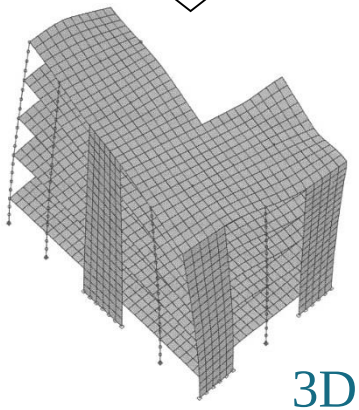
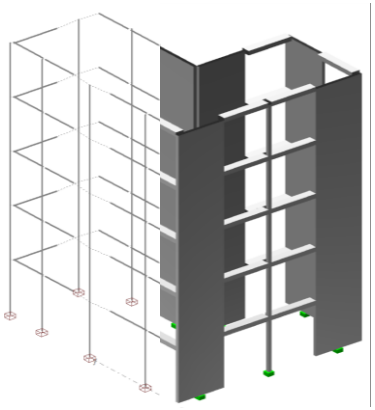
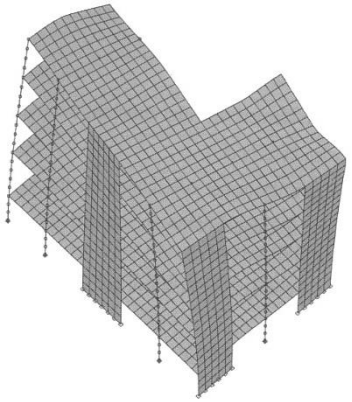


3D shell

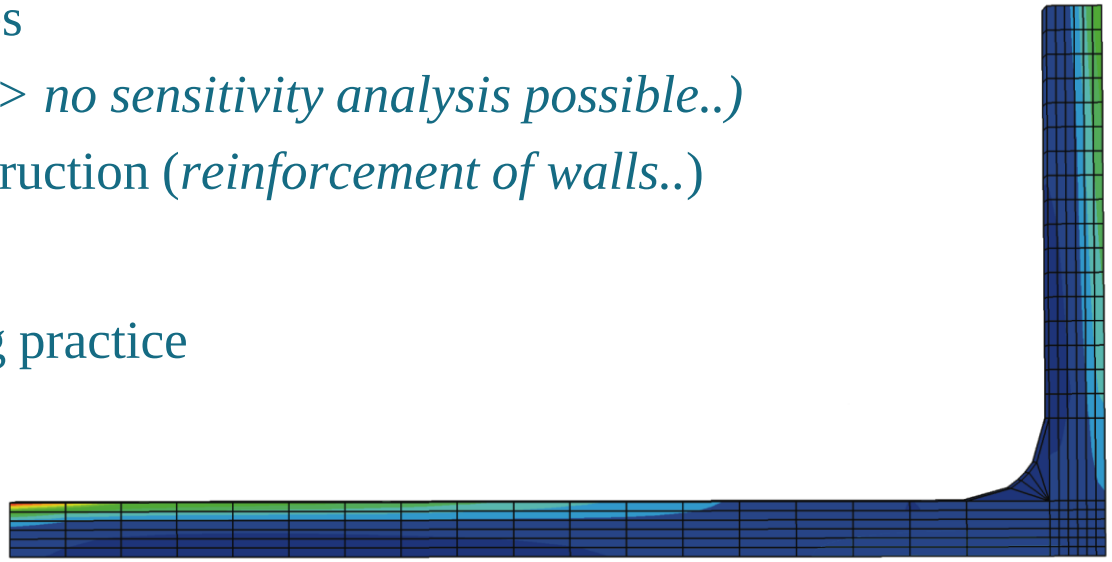


3D frame / system of beams

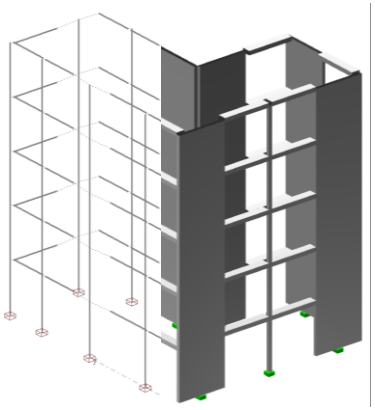
Model: 3D Shell



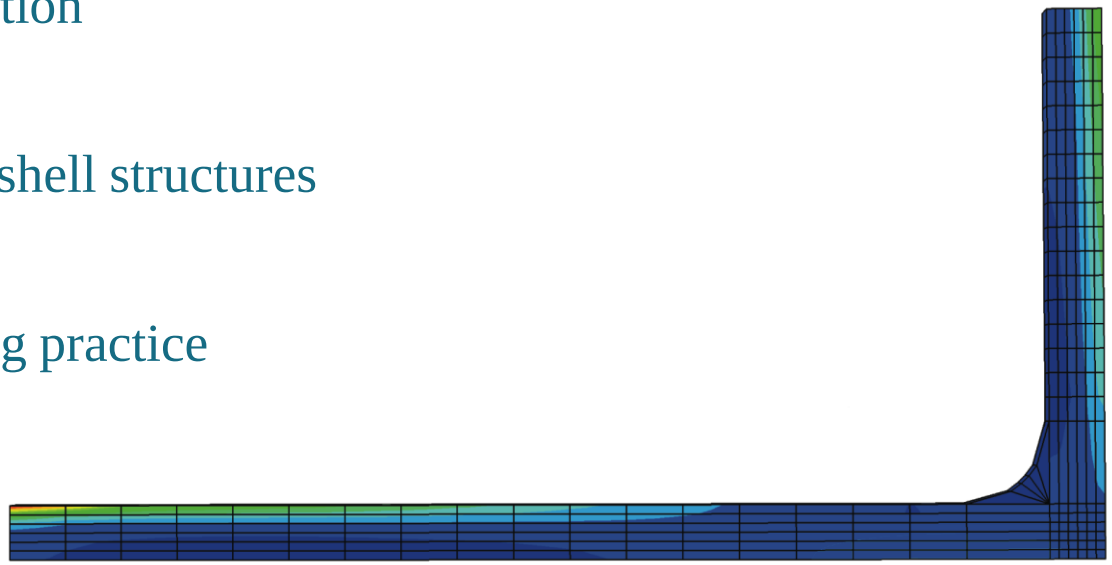
- **Good**
  - Suitable for any geometry (*curved shells..*)
  - Nicest result pictures (*marketing..*)
- **Bad**
  - Most detailed model (*big input => big output*)
  - Verifying the results is extremely demanding
  - Not fully covered by codes
  - Long computing times *(=> no sensitivity analysis possible..)*
  - No direct results for construction (*reinforcement of walls..*)
- **Verdict**
  - Not suited for engineering practice



Model: 3D Frame



- **Good**
  - Based on beam theory *(=> result interpretation..)*
  - Directly supported by codes
  - Very well covered by literature
  - Suitable for all types of analysis
  - Short computing times *(=> sensitivity analysis..)*
  - Direct results for construction
- **Bad**
  - Cannot model 3D curved shell structures
- **Verdict**
  - Best model for engineering practice



The 4 Golden Rules of FE-Modelling

1. Understand the problem before starting the FE software
2. Model the (structural) system not the geometry
3. Unverifiable FE results are generally false
4. Follow the basic system assumptions all the way to the construction