

The „save side“

- or -

What means Quality Assurance in FE-Analyses in Civil Engineering

Dipl.-Ing. Marc Quint VDI

Reutlingen

marc.quint@xperteez.de

• Civil Engineering

Differences to Mechanical / Automotive / Aerospace Engineering

- Large structures
- Large deviation of properties (95% fractiles)
- natural materials used (timber, stone, cement,)
- Loads and their combinations are uncertain
- Time history is not known and uncertain
- created in „the open“ - difficult to control
- no design rules based on *von Mises* stresses e.g. for concrete
-

and above all

NO PROTOTYPES !!!

• Model Idealization

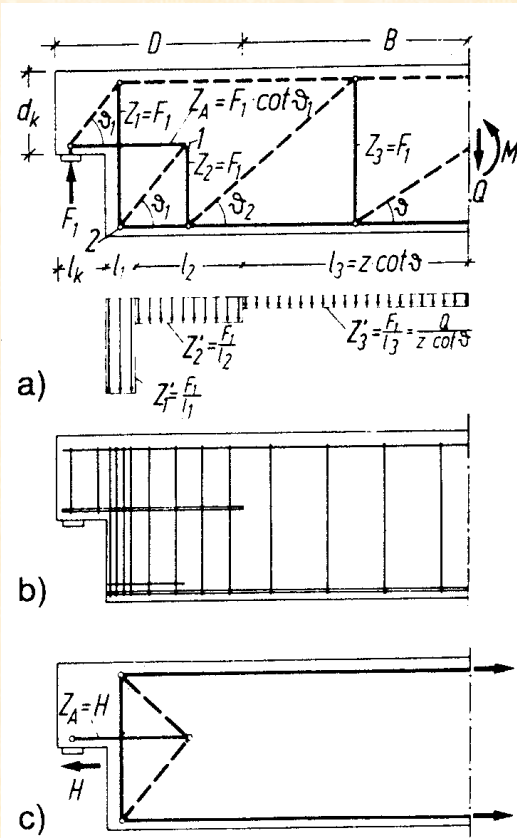


Bild 4.2-10. Balken mit abgesetztem/hochgezogenem Auflager.

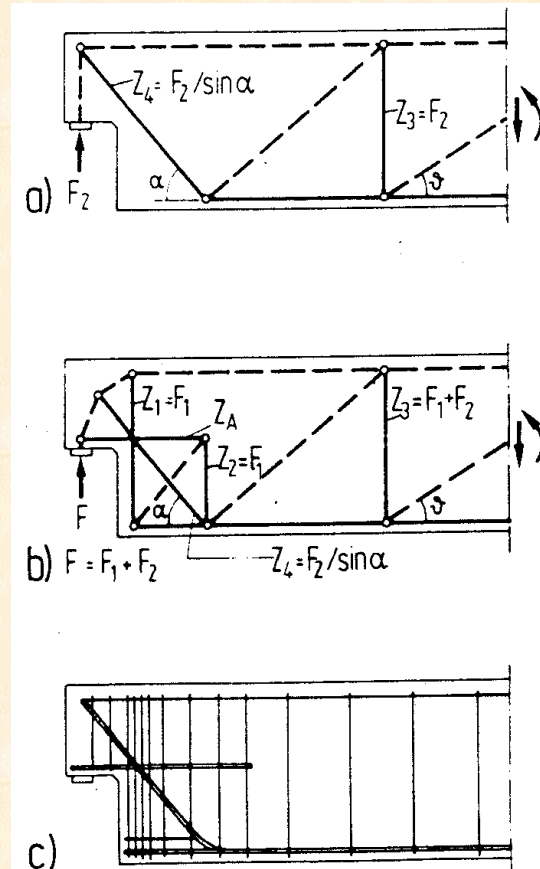
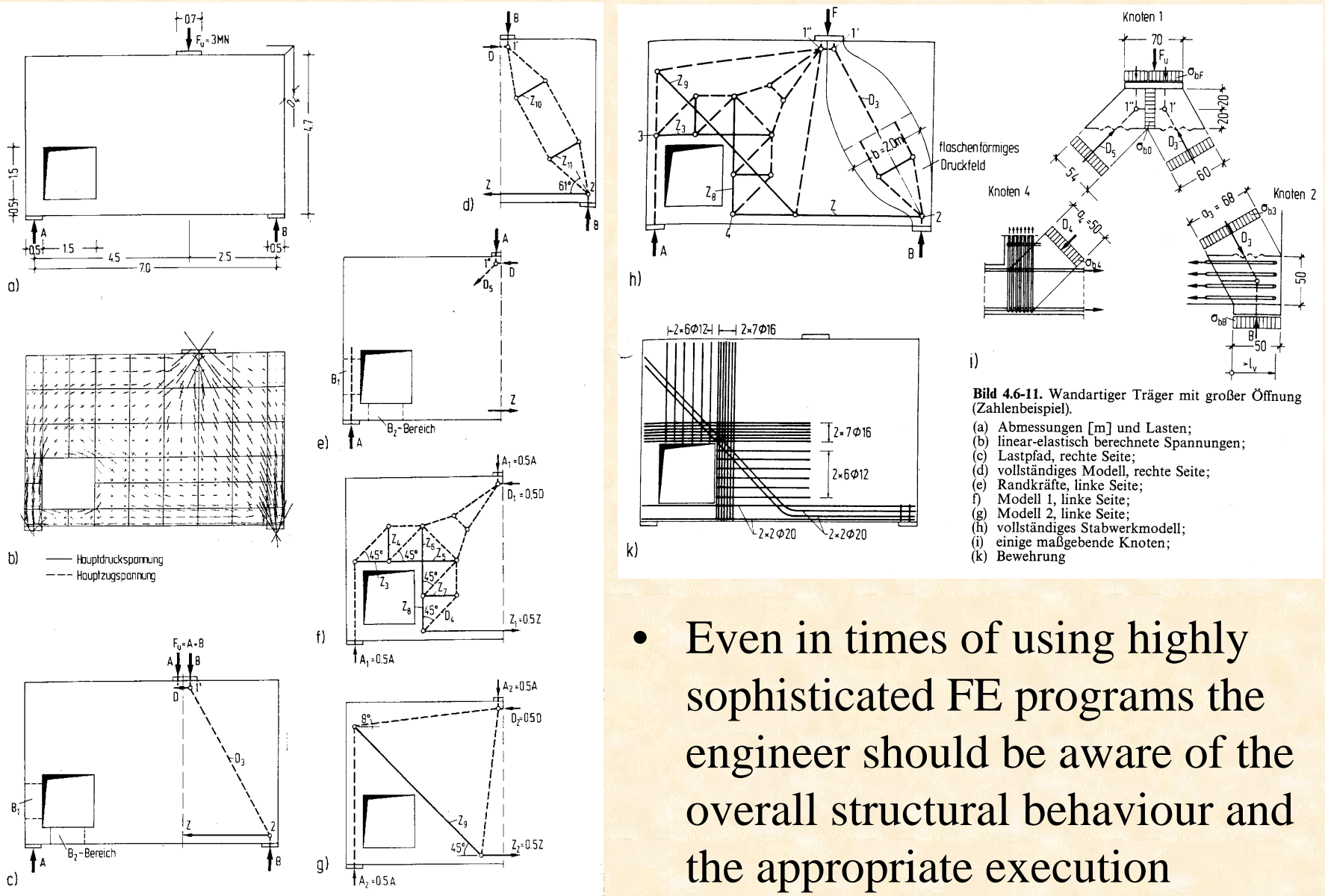


Bild 4.2-11. Auflagerbereich eines Trägers

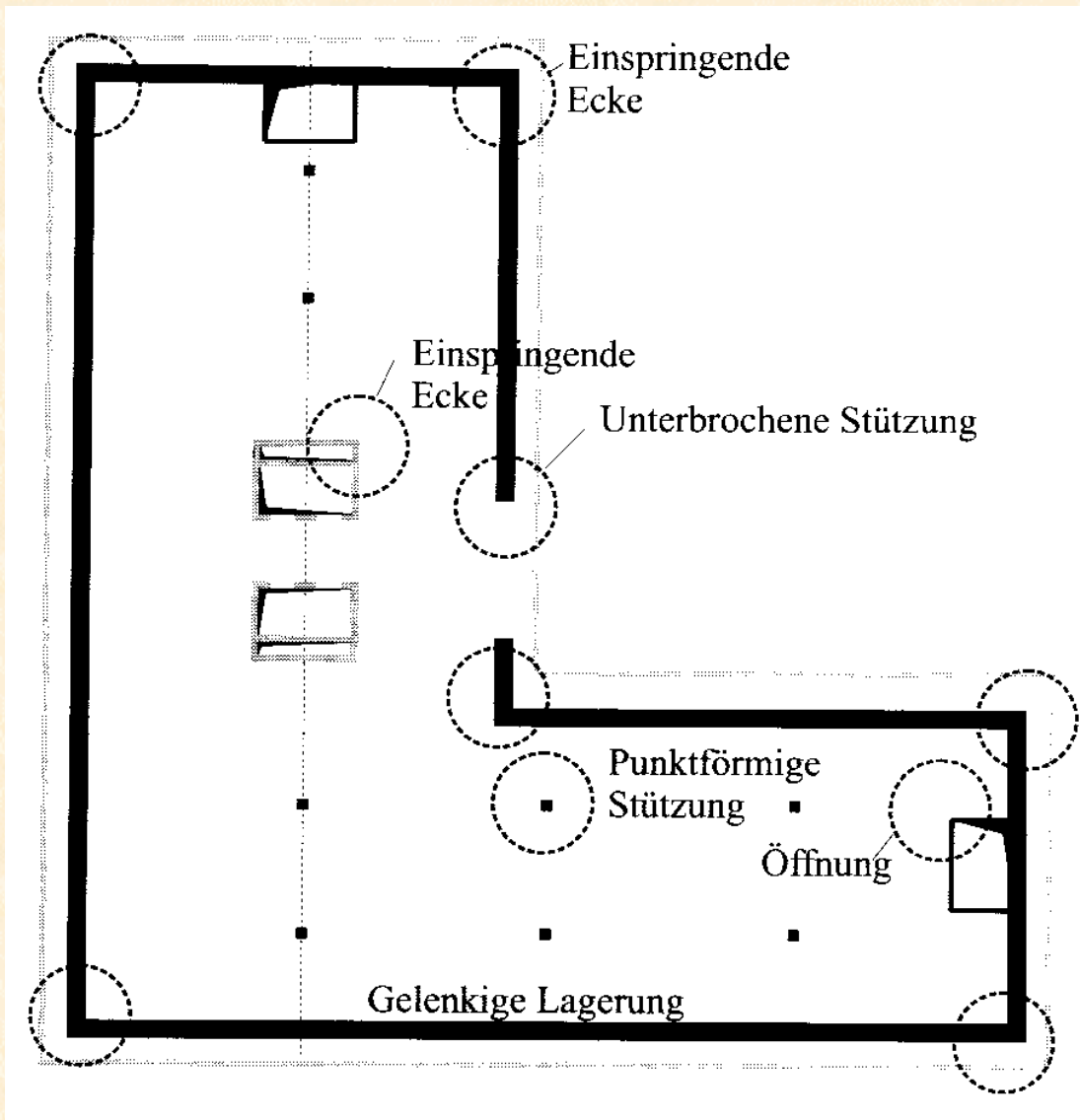
- There might exist more than one possible structural solution
- Important is to idealize in a ,complete‘ fashion and to accomplish the chosen model in the realized structure

• Model Idealization



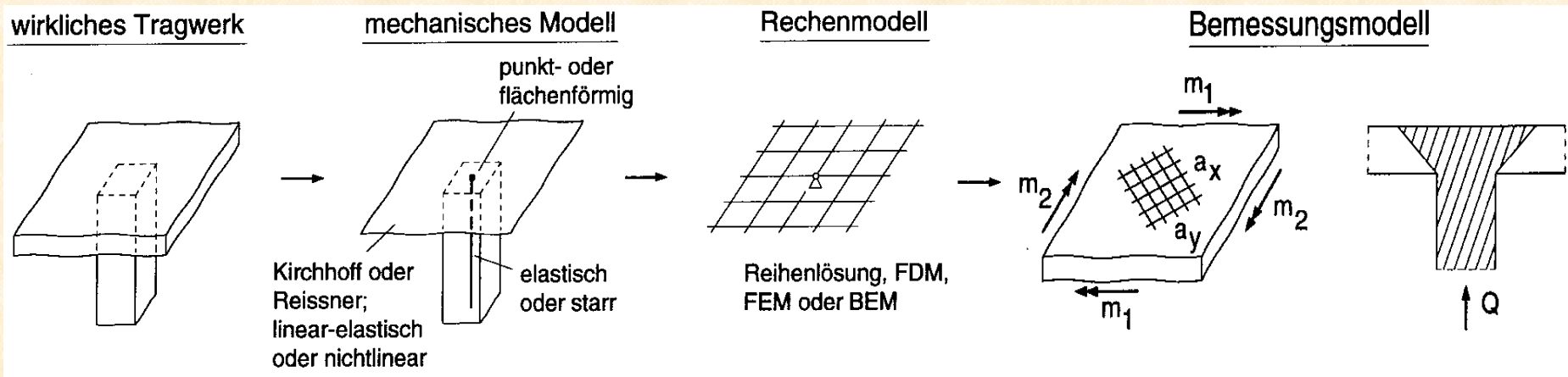
- Even in times of using highly sophisticated FE programs the engineer should be aware of the overall structural behaviour and the appropriate execution

• Singularities / Discontinuities



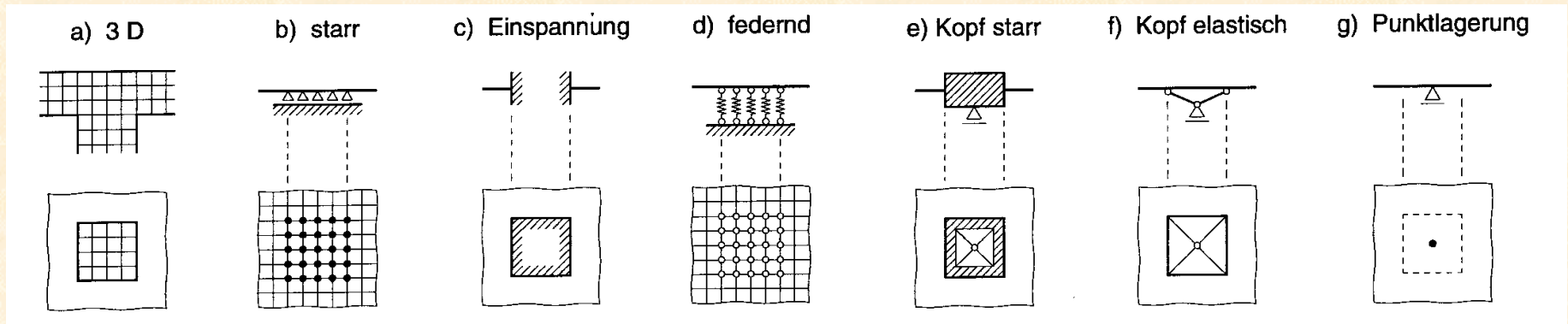
- There are various places in a structure where singularities occur
- Any of these needs a particular treatment that is only partially accomplished by standard FE analysis and design programs

• Singularities / Discontinuities



- Using midsurface idealizations is adequate to represent the overall structural behaviour (global action e.g. equilibrium)
- For the precise description of local actions the real measures and many other influences should be considered
- The user of FE programs should be aware that the program only approximates the deformations of a discrete mathematical and mechanical model. This solution comprises the homogenous differential equation and multiple particular integrals !

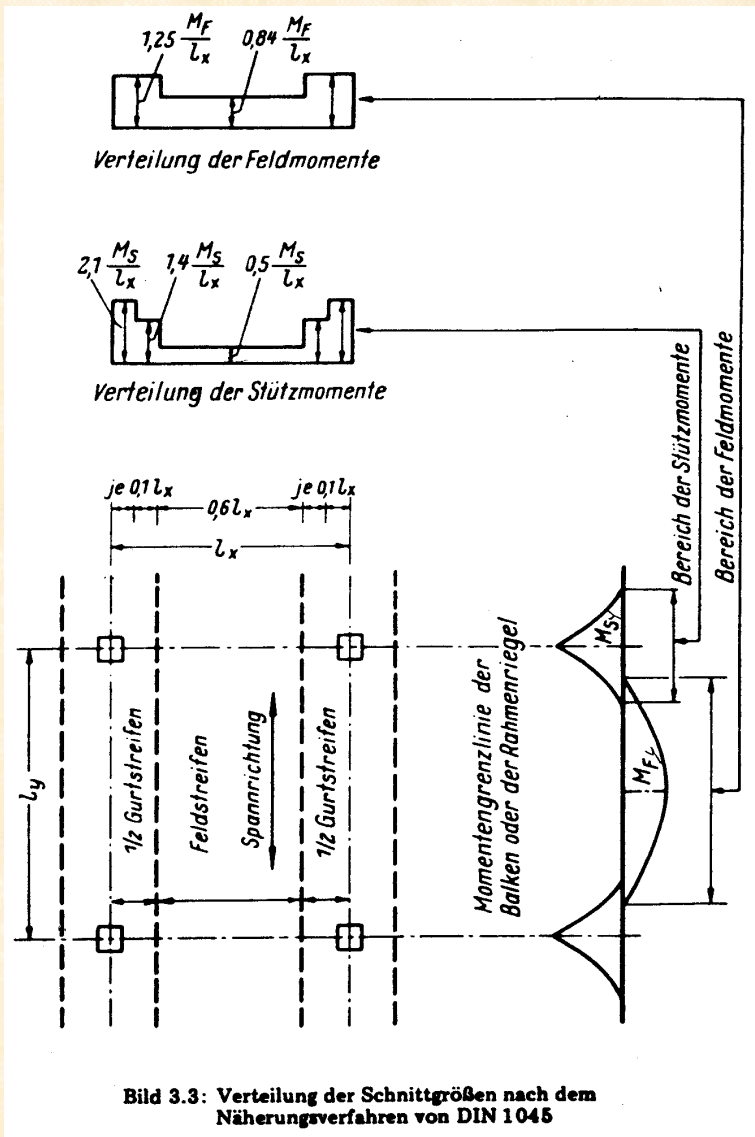
• Singularities / Discontinuities



- Again there exist more than one way to idealize the „real world“ structures
- Depending on the effort you spend in terms of FE and man power you can get closer and closer to the correct solution
- Between type a) and g) are great differences not only in the exactness but also to the usefulness of the model

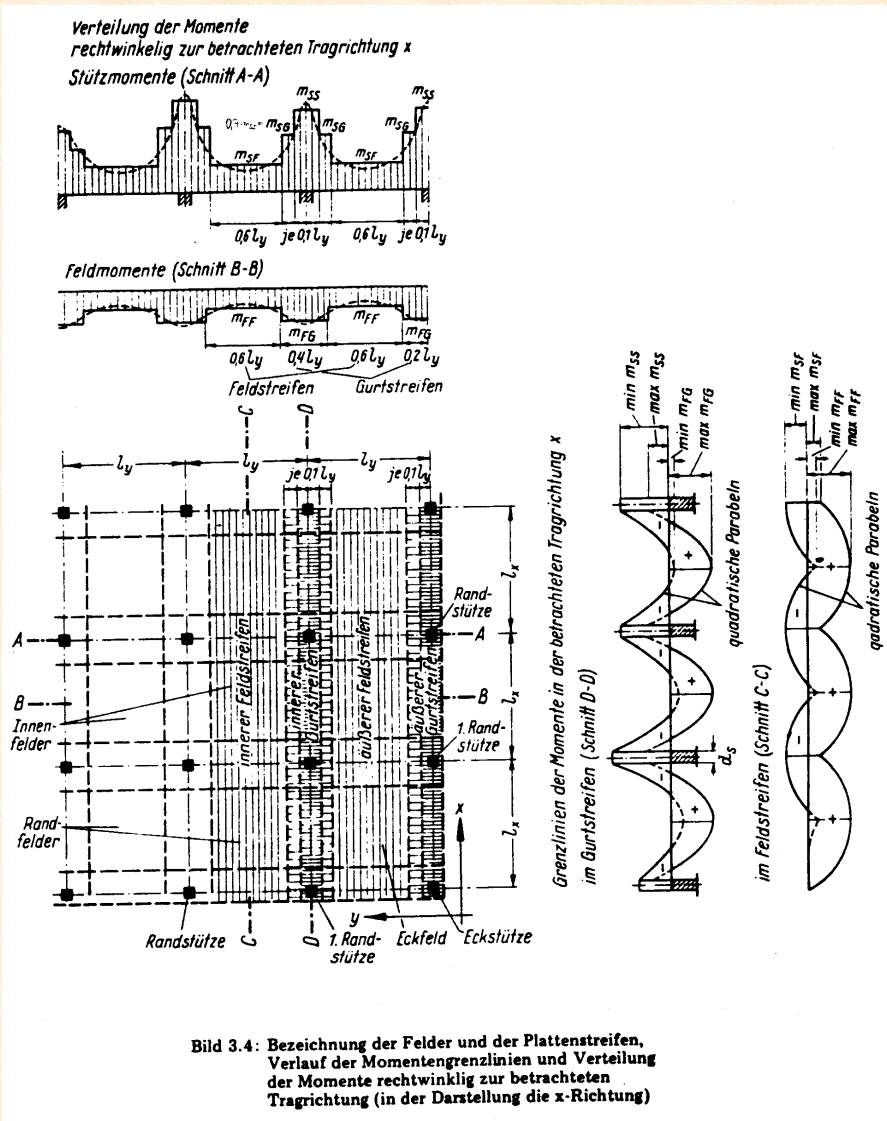
You can not practically use a) but perfectly the system g) !!

• Singularities / Discontinuities



- There is nothing wrong with the way analysis and design were done for decades
- FE programs do not change reality - you might only get a better hint at what is „going on“ in a structure
- The experienced engineers „think“ in deformations or actions. If a crack happens in a concrete slab a redistribution will take place. The rebar will eventually plastify and the adjacent rebar will get a greater „part“ of the overall force. **Most important is that the redistribution can happen !**

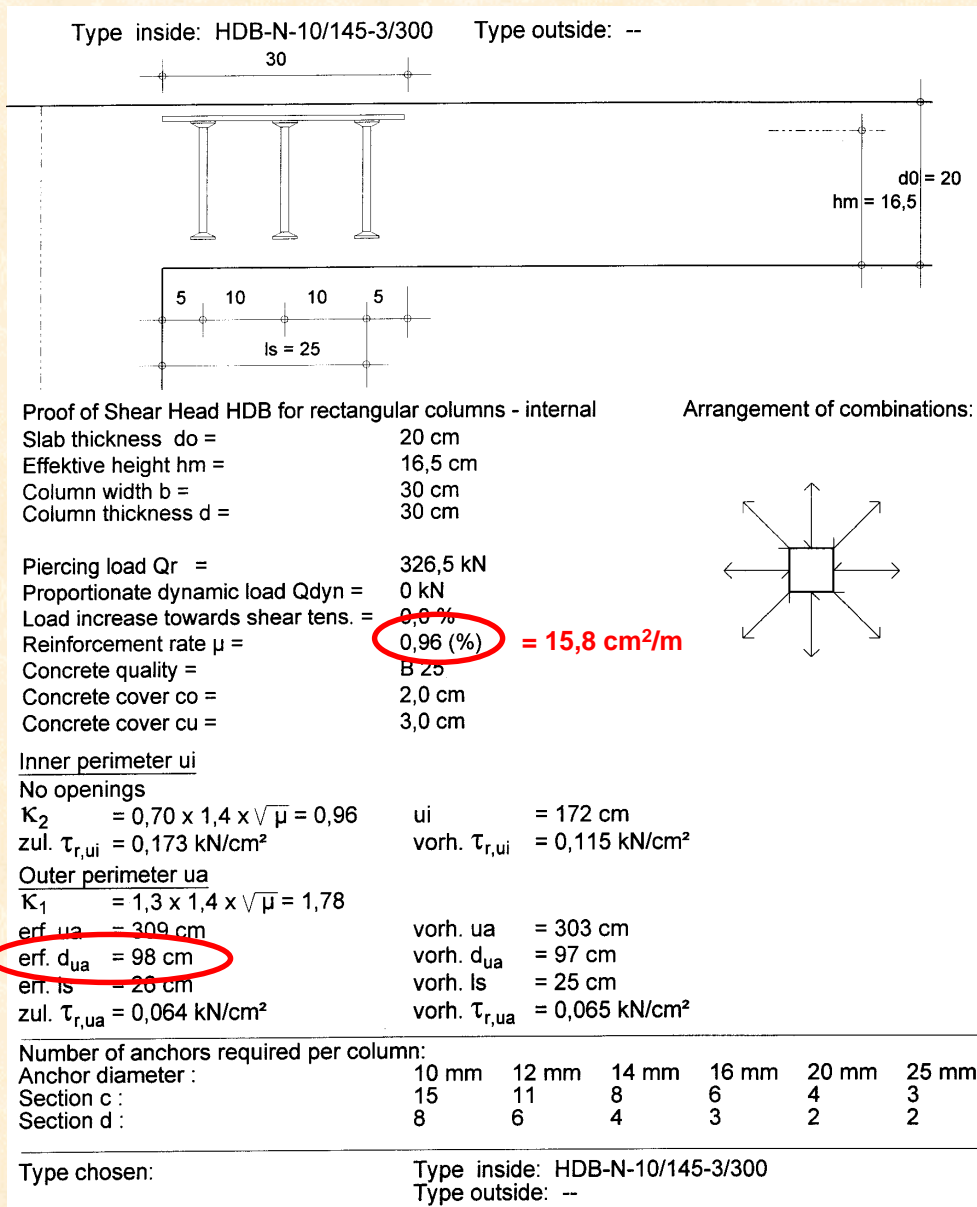
• Singularities / Discontinuities



- Useful simplifications were made in the past to offer practical design schemes to the engineer
- FE Analysis results should also lead to rules for the design
- Integrating actions over a certain area is adequate as long as the error is within a certain range. This range is more based on empirical data than exact science.

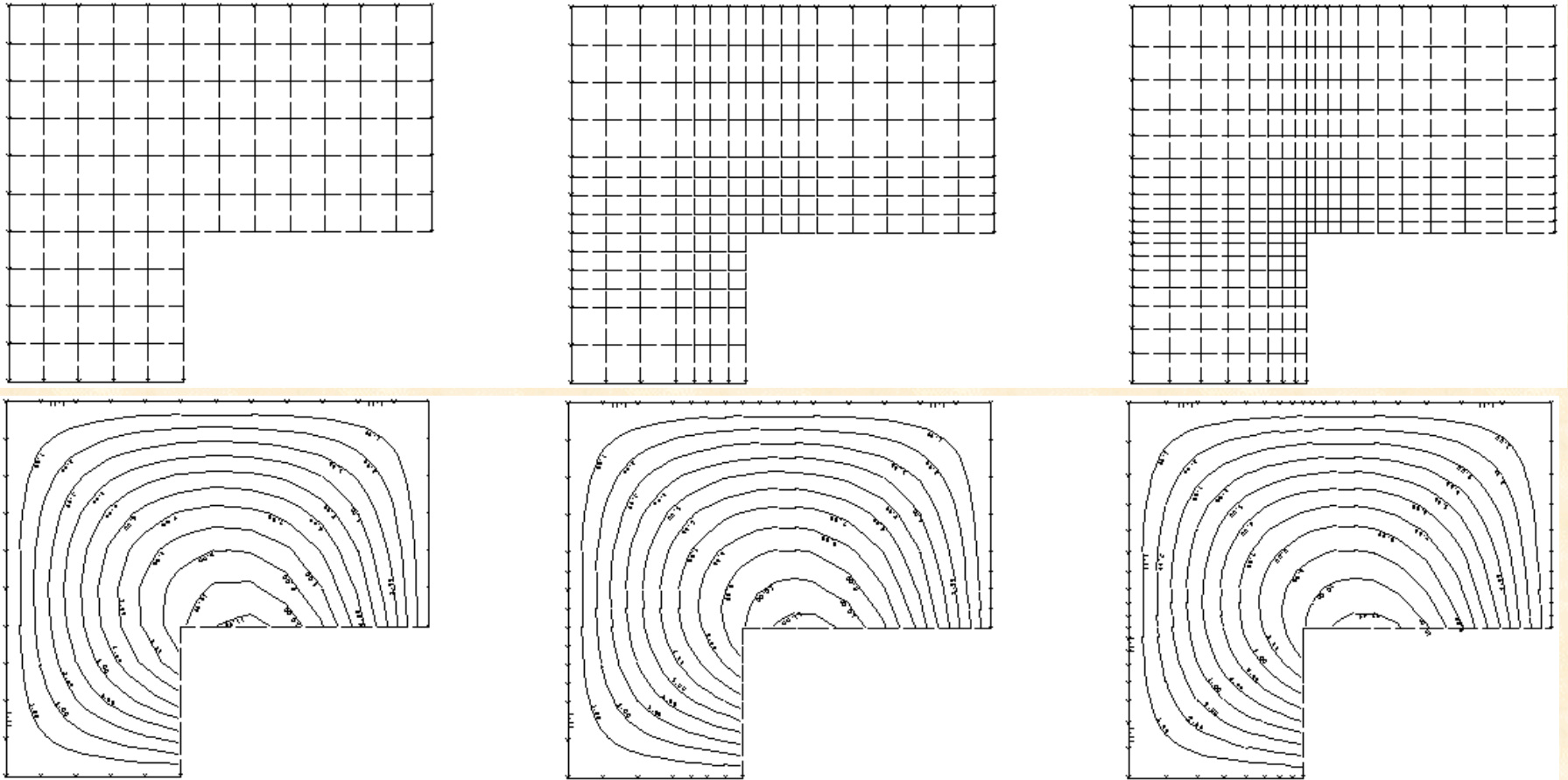
Do you know where the worker puts the rebar exactly *in situ* ?

• Singularities / Discontinuities



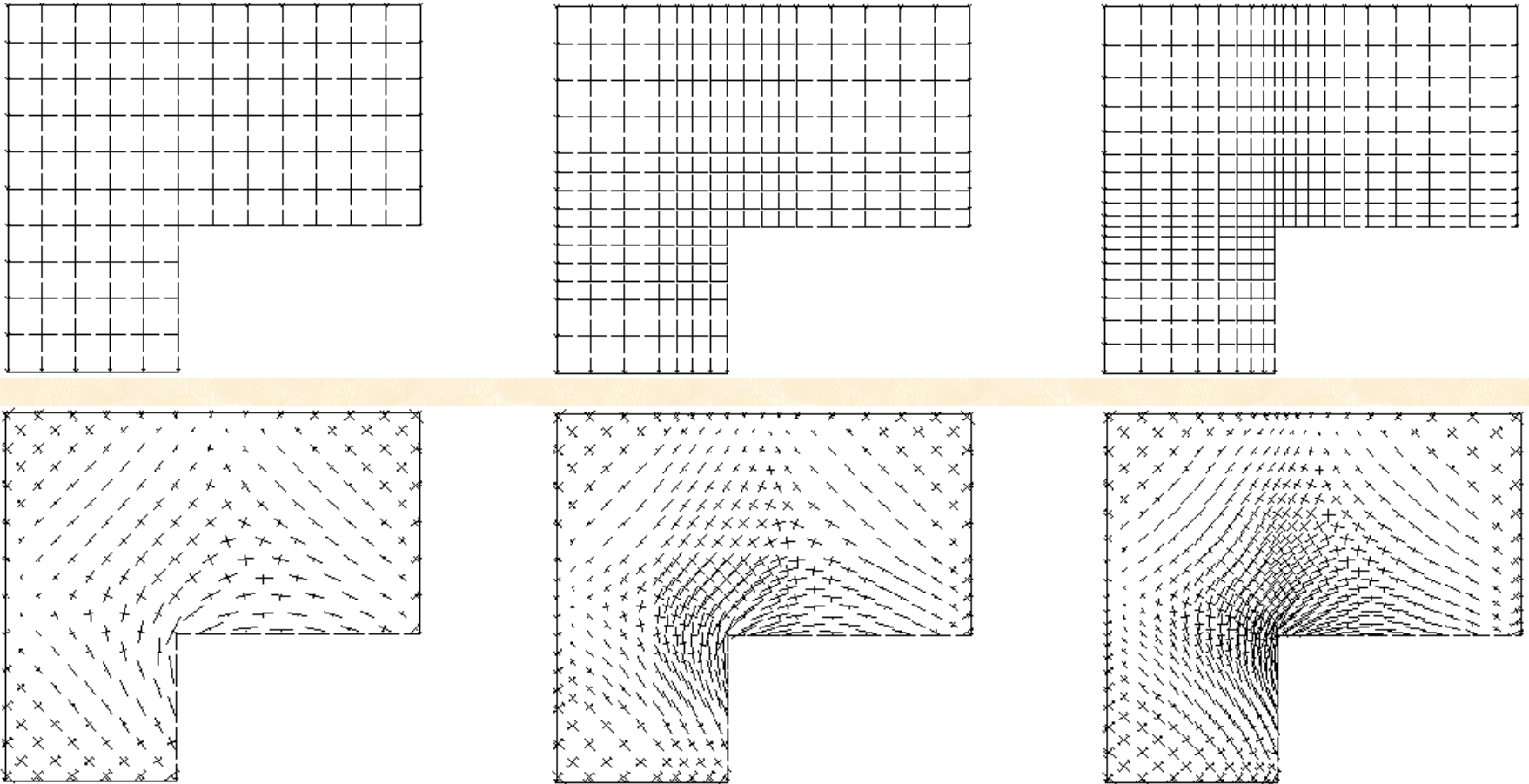
- This shear stud design uses a slightly higher averaged reinforcement ($\mu=0.96\%$) in a more compact area of $d_{ua}=0,98 \text{ m}$
- This user input resulted in the selection of only 8 shear studs which are far easier to handle
- The overall amount of rebars in this new perimeter sums up to $0,98 \times 15,8 = 15,5 \text{ cm}^2$

• Discontinuities



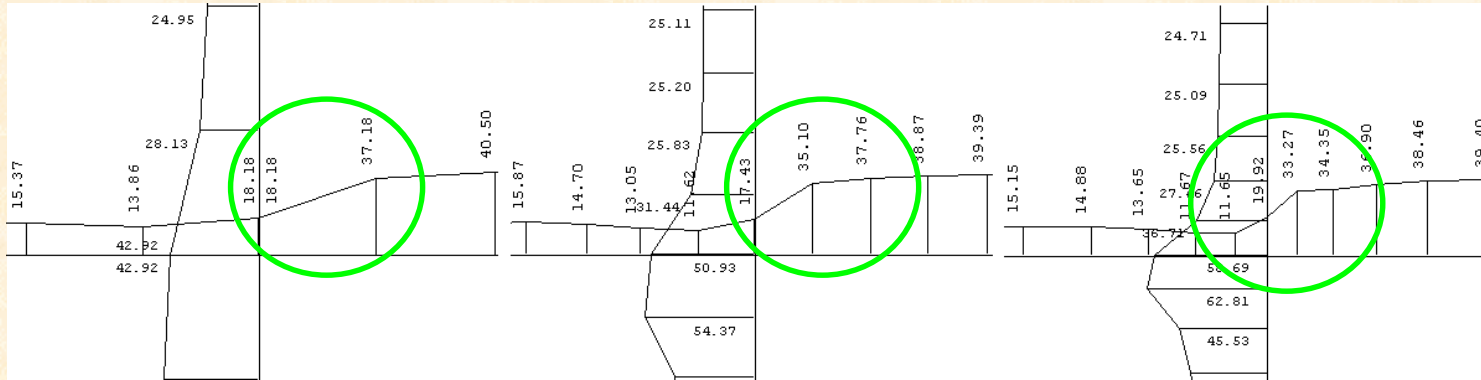
- Using finer meshes in the vicinity of discontinuities will not necessarily result in more information for the design engineer
- The ,global‘ behaviour will be described even with the coarse mesh

- Discontinuities

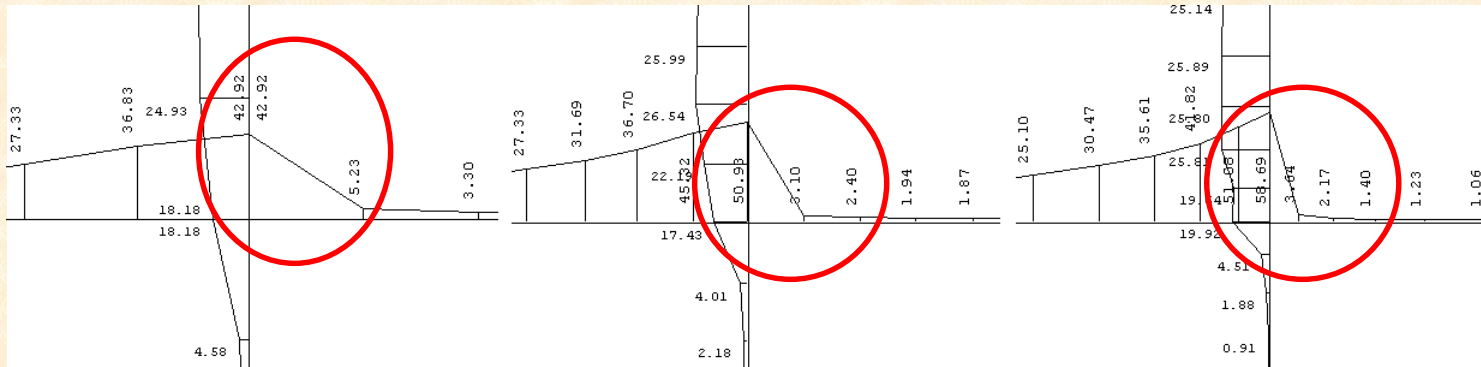


- Obviously the amount of data increases - not only for the better.
But what happens really at the inner corner ?

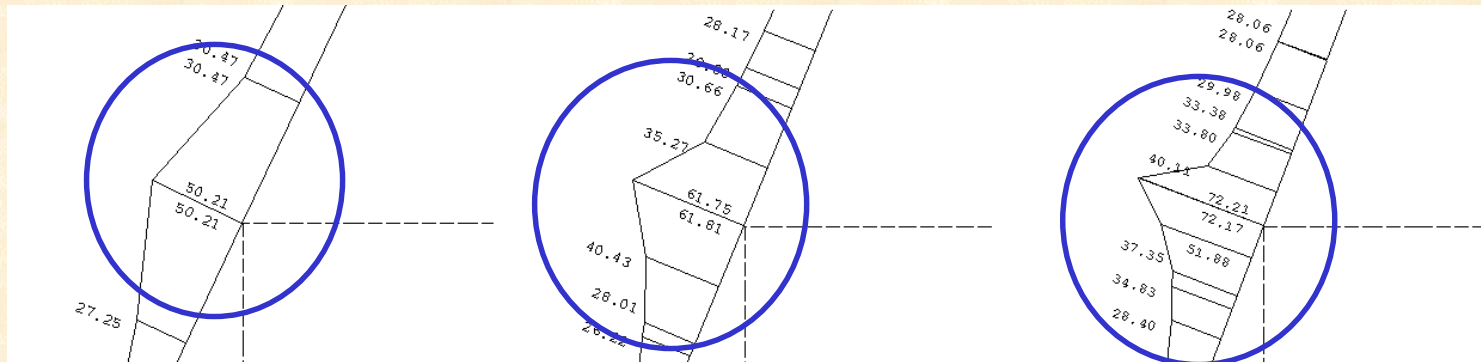
• Discontinuities



- m_n
(Moment along the cutting line)



- m_t
(Moment perpendicular to the cutting line)



- $m_I = m_n$
(Moment along the cutting line in direction of the main momentum)

• Discontinuities

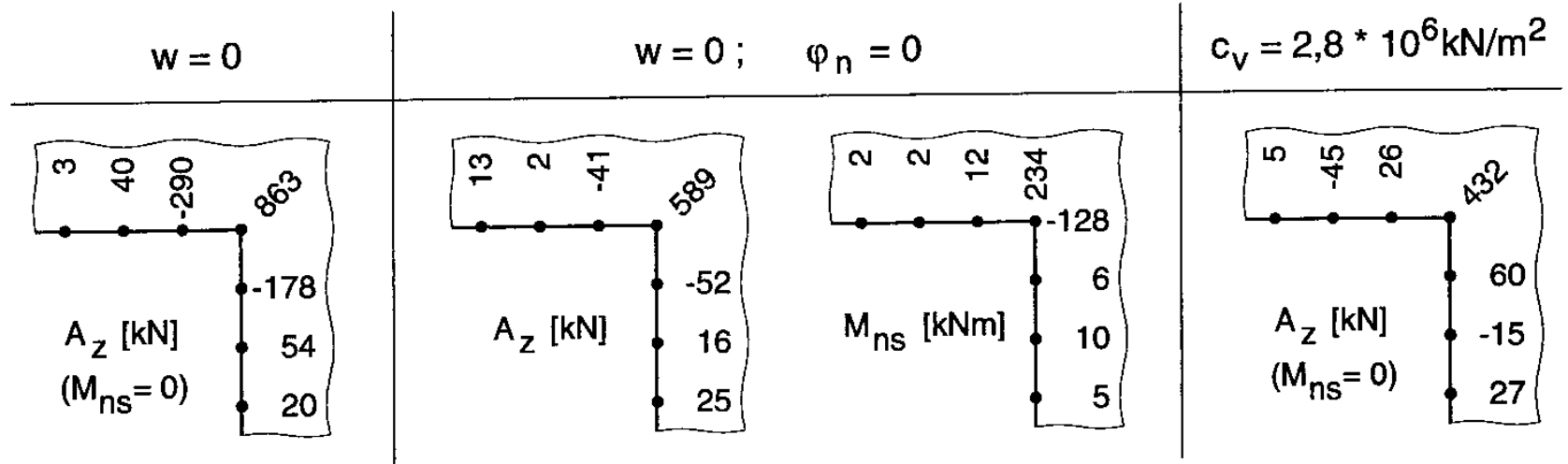
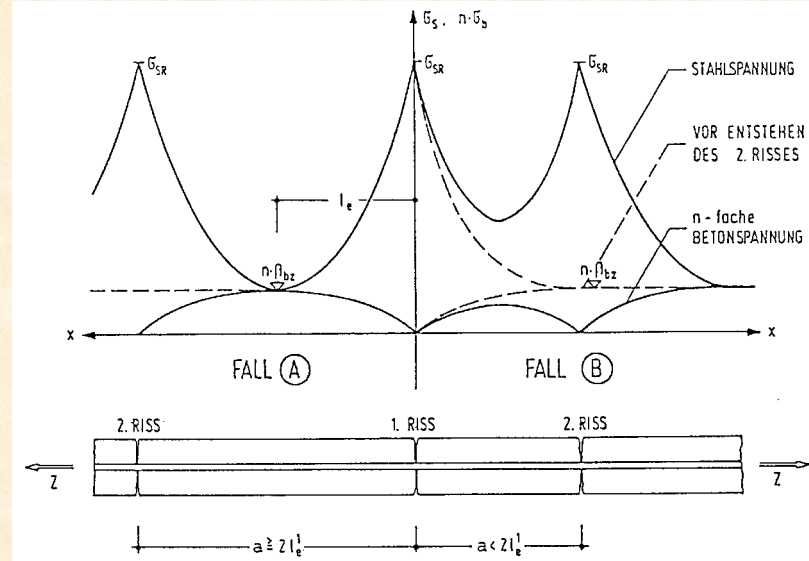


Bild 3: Einspringende Ecke B2 - Auflagerreaktionen

- Change in e.g. boundary conditions using the same discretization can result in major differences for the output values.
- The use of simple $u_z=0$ constraints results in a fixation about the momentums because the deflected midsurface is forced to run through all fixed nodes. But integrating the actions will result in fairly small differences (440 kN - 514 kN - 458 kN using 5 nodes)

• Redistribution



- The redistribution of forces and actions is one of the most important principles in civil engineering design.
- In concrete design the aspects of discontinuous cross sections, tension stiffening and even the change from a predominantly bending system to arch or membrane systems is of great importance.
- In steel design the capability of plastification in certain regions with no loss of resistance and activating adjacent sections up to a limit state can provide substantial gain in performance.

If a conclusive model and analysis is chosen the main remaining aspect is the serviceability !!

• Conclusions

There are numerous particularities in the analysis and design in the field of civil engineering structures.

The use of FE analysis programs takes away much of the tedious work but still leaves many tasks to the design engineer.

It is not - and hopefully will never be - possible to automatically design complete buildings. The individual structure always asks for an **attentive engineer** who is able to convert the ideas of architects to a mathematical-mechanical model and after analysis to a „real world“ structure which is then build with the least possible efforts.

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In the attempt to support NAFEMS' efforts in
„Creating Awareness - Delivering Education & Training - Stimulating Standards“
free Web-Space is offered for the discussion on „How to ...“ and „How not to ...“
not only for Civil Engineering but for all aspects of the use of FE Analyses at
www.xperteetz.de

Any contribution - preferrably in PDF or PS format - shall be submitted to :

marc.quint@xperteetz.de

Dipl.-Ing. Marc Quint VDI

Ingenieurbüro für Tragwerksplanung / STRUCTURAL DESIGN

Kaiserstraße 85 in 72764 Reutlingen