

V Praze

18.5.2022

Návrh pomocí MKP

Martin VILD

České vysoké učení technické v Praze

FAILNOMORE

Mitigation of the risk of progressive collapse
in steel and composite building frames
under exceptional events



Research Fund for Coal & Steel

FAIL **NO**
MORE



Prezentuje

Ing. Martin Vild, Ph.D.

Zkušenosti:

IDEA StatiCa[®]

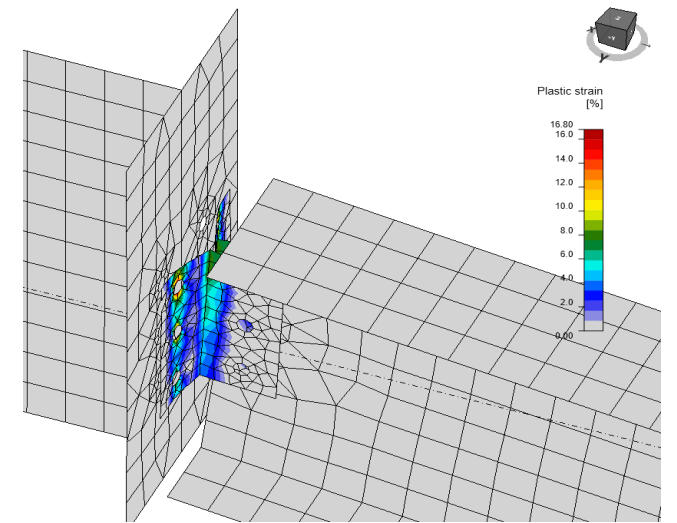
Product Owner for Steel



Výzkumný pracovník

Obsah

- Přehled norem
- Duktilita
- Metoda konečných prvků
- Validace a verifikace
- CBFEM – Vazné síly
- Demo – styčník
- Validace – Member
- Závěr



Přehled norem a literatury

- Normy:
 - EN 1991-1-7 – Annex A
 - EN 1993, prEN 1993-1-14
- Literatura:
 - SCI P391: Structural robustness of steel framed buildings
 - SCI P358 – Appendix A



Normy – Praktická doporučení

- Posudek plechů

- $\frac{f_u}{\gamma_{Mu}}$ místo $\frac{f_y}{\gamma_{M0}}$

$$\gamma_{Mu} = 1,1$$

- Posudek svarů

- γ_{Mu} místo γ_{M2}

$$\gamma_{M0} = 1,0$$

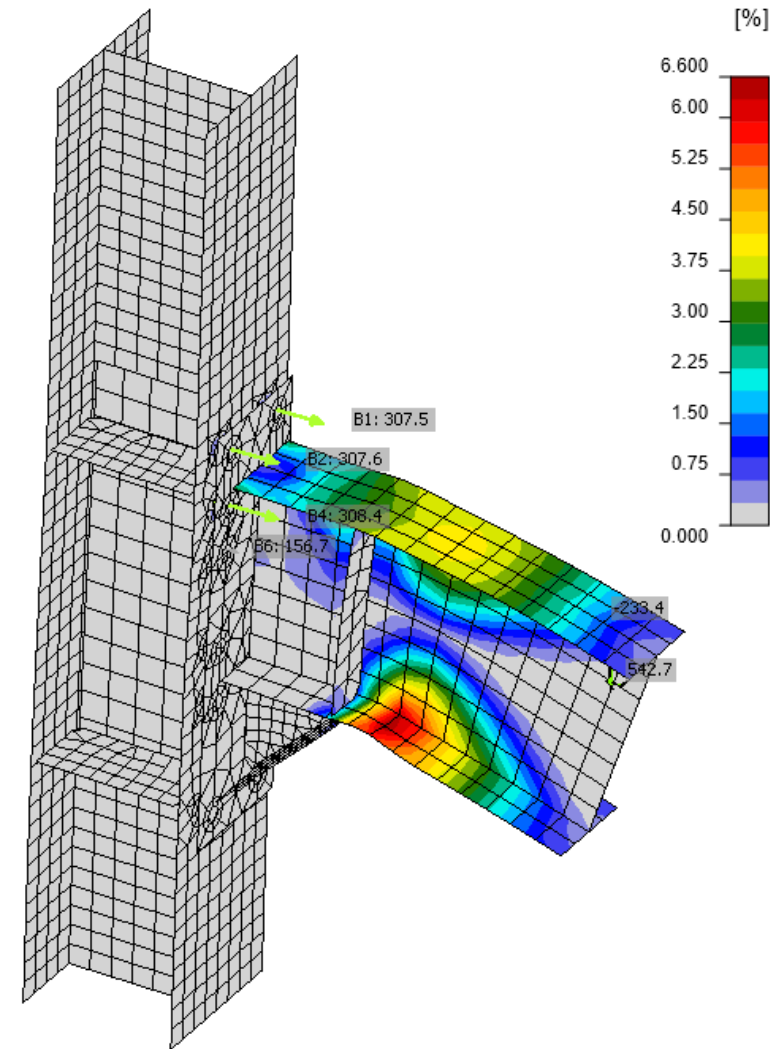
- Posudek šroubů

- γ_{Mu} místo γ_{M2}

$$\gamma_{M2} = 1,25$$

Duktilita

- Tažné jsou:
 - Plechy
- Křehké jsou:
 - Svary
 - Šrouby
 - Kotvy
 - Beton

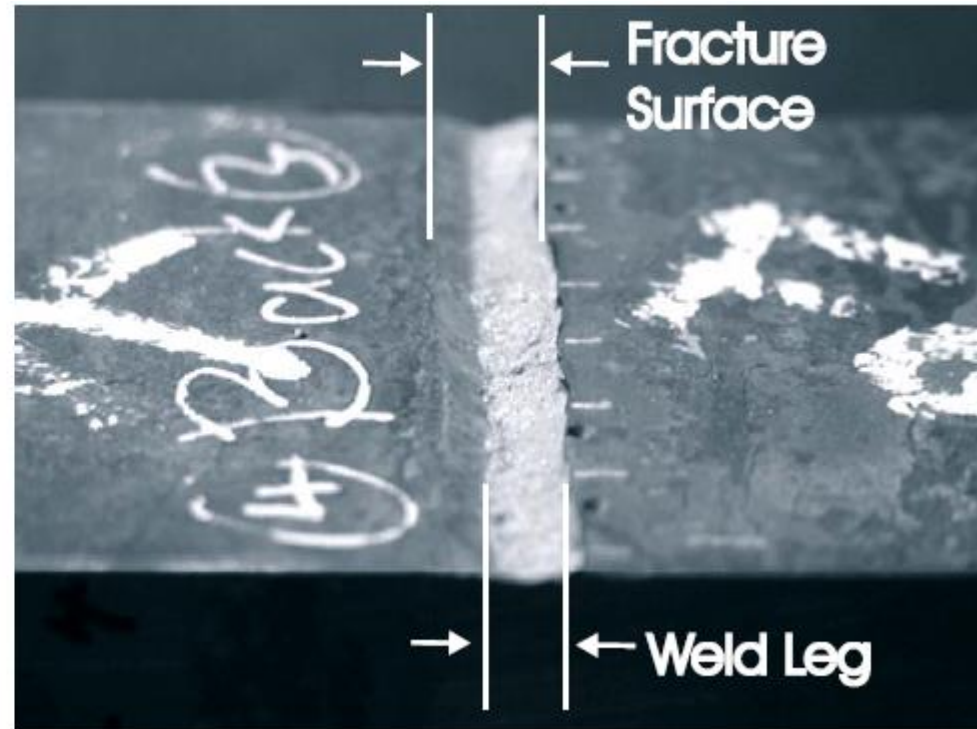
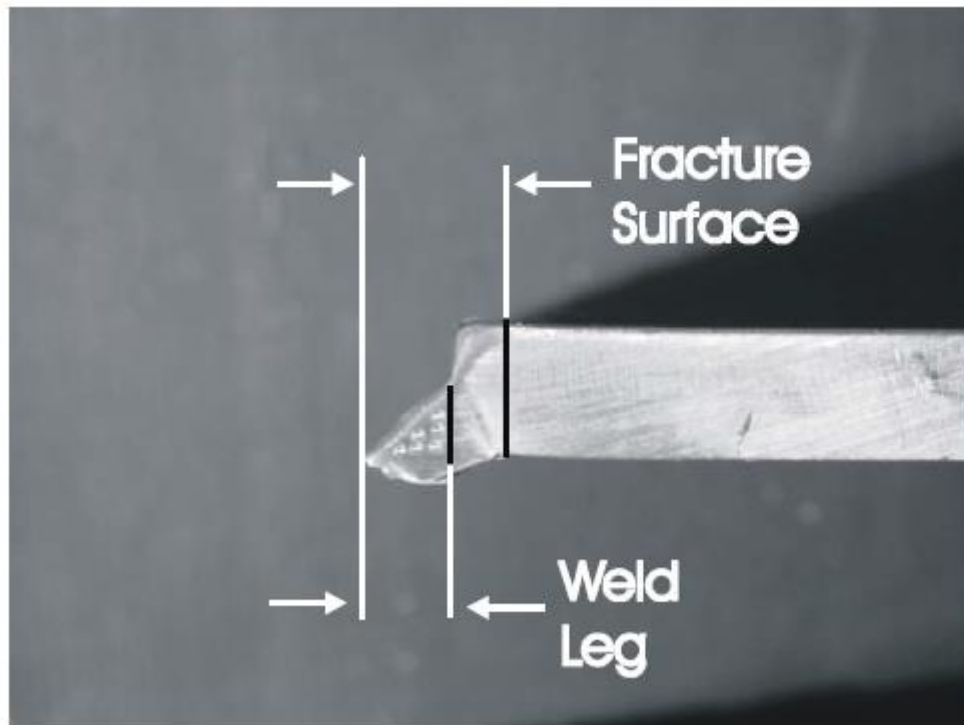


Duktilita



Duktilita – Svary

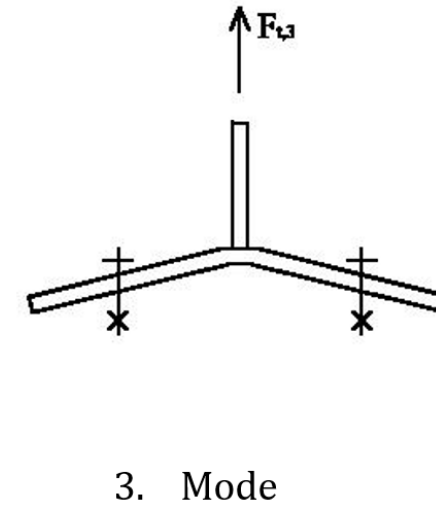
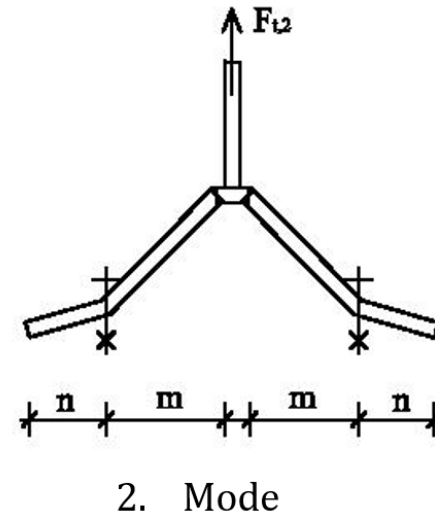
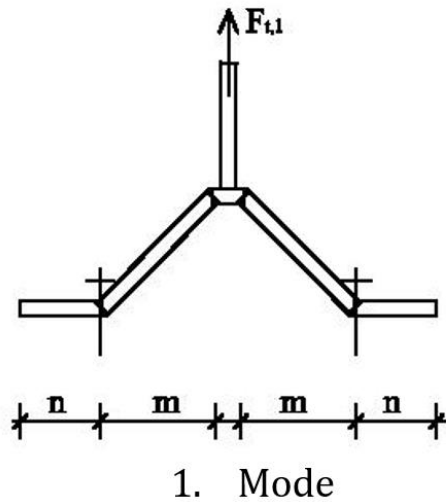
- Svary navrhovat na plnou únosnost



Ng, Driver, Grondin – Behaviour of transverse fillet welds, University of Alberta, 2002

Duktilita – Šrouby

- Šrouby v tahu
 - Preferujeme 1. a 2. mód



Duktilita – Šrouby

- Šrouby ve smyku
- Preferujeme otláčení

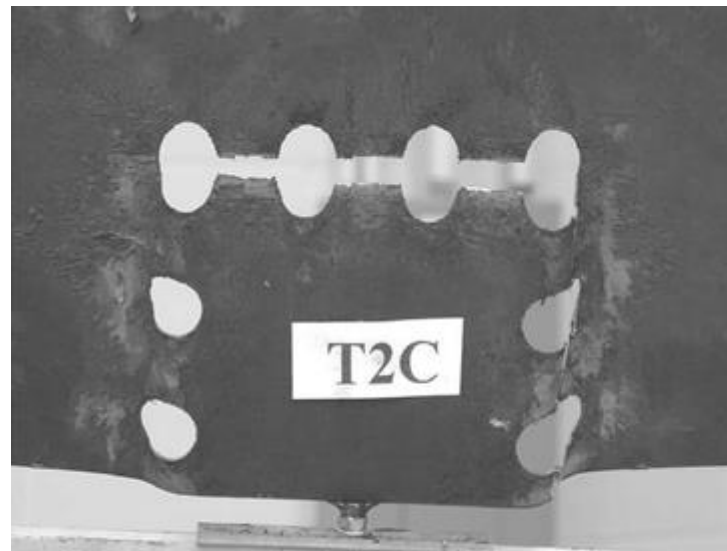
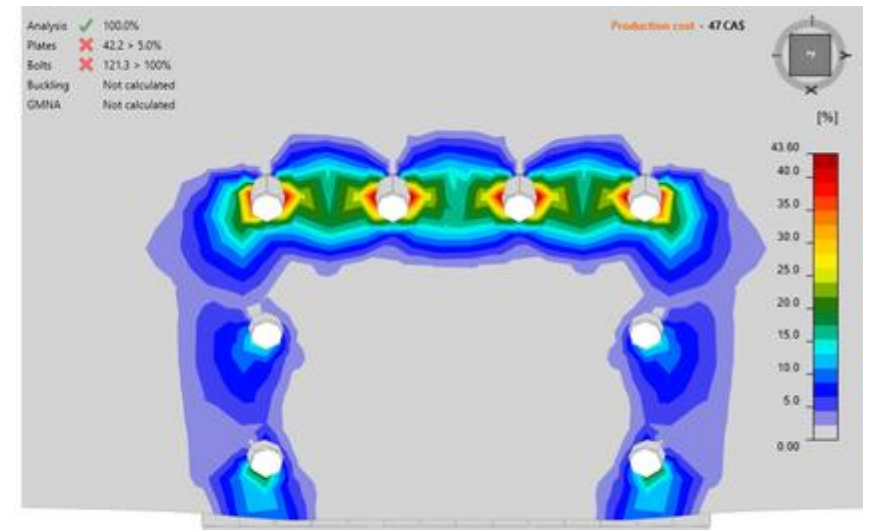


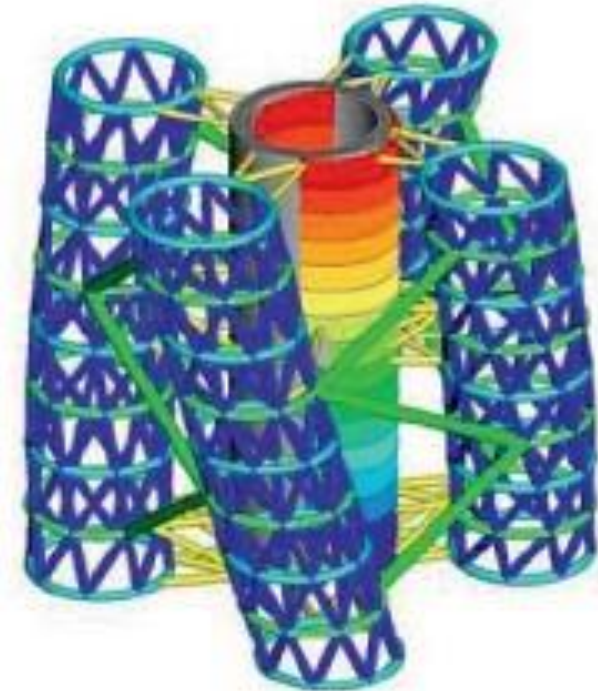
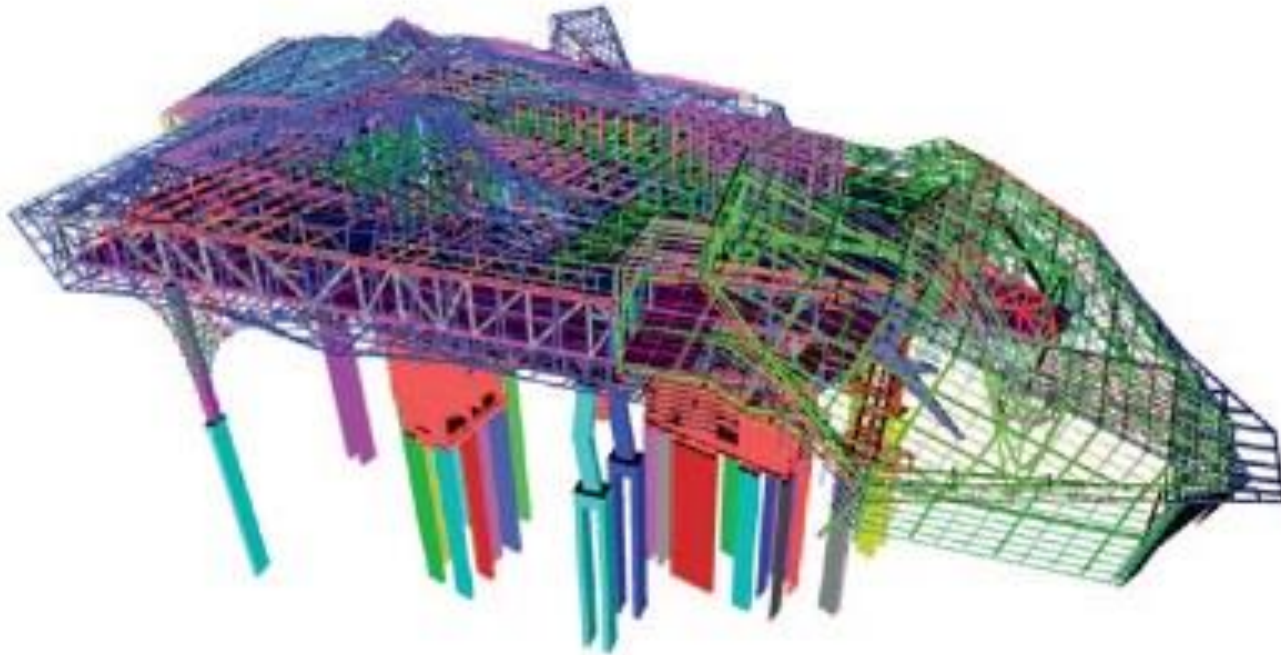
Figure 3-36 Specimen T2C at end of testing



Praktická doporučení

- Svary na plnou únosnost
- Šrouby dostatečně velké –
mód 1 nebo mód 2
- Poruchy v plechách

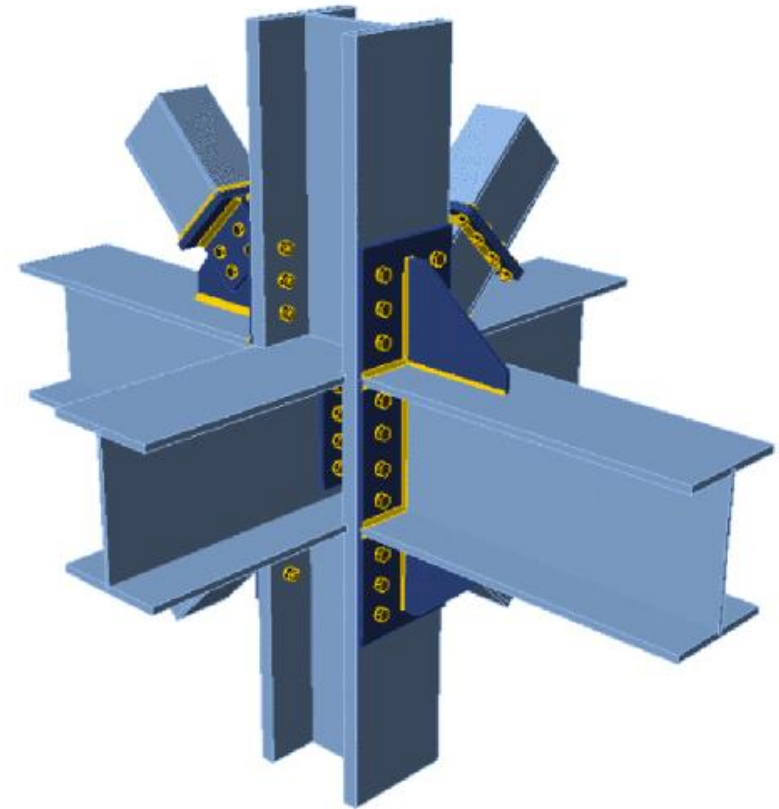
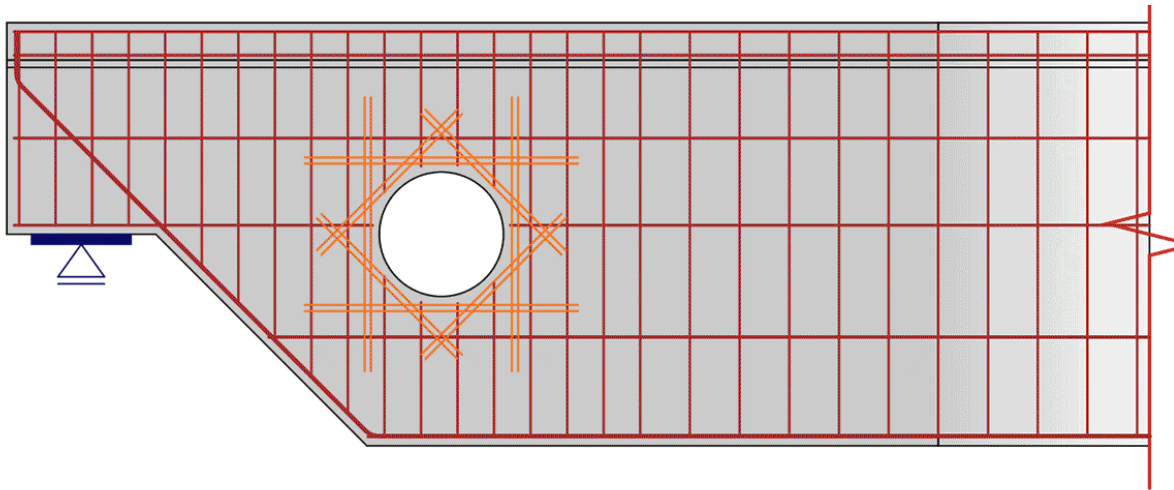
Metoda konečných prvků



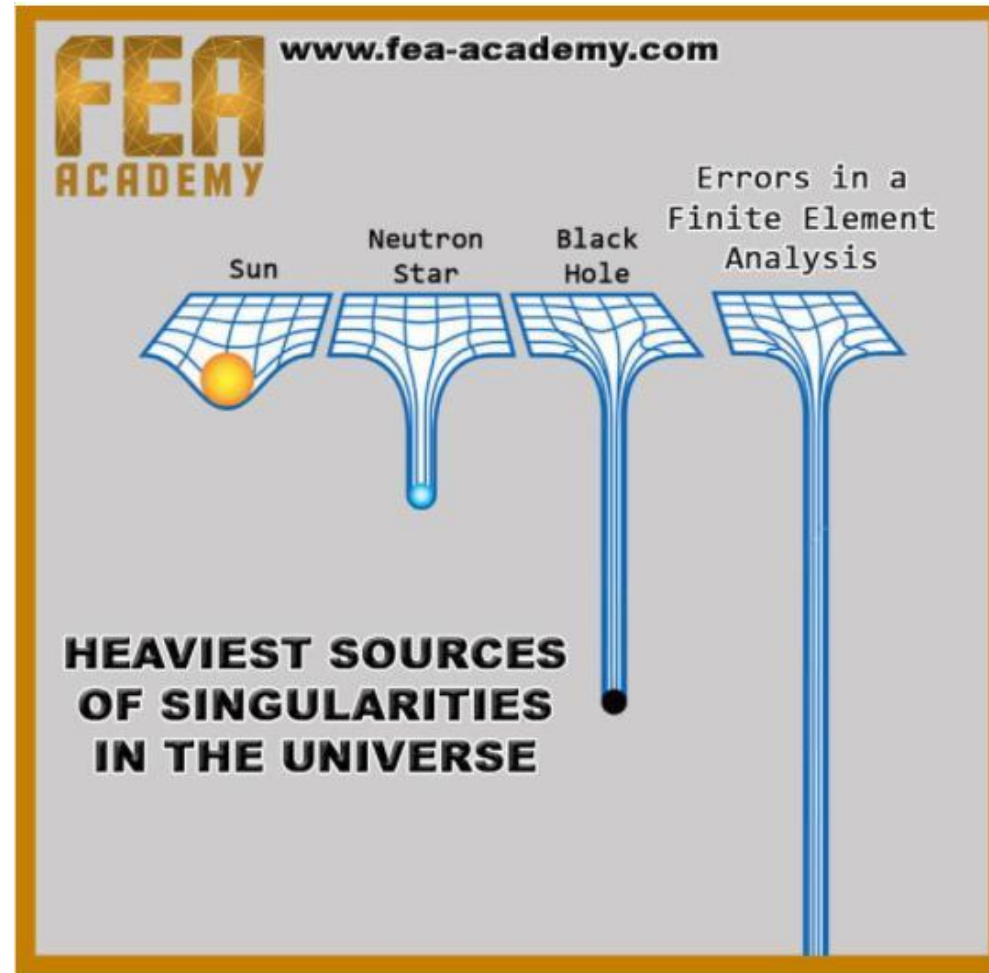
Josef Trubáček:
Scia Engineer, Frilo Statika a Scia Design Forms. Z webu CAD.cz

Metoda konečných prvků

- Gabrage in, garbage out?
- Black box?



Metoda konečných prvků

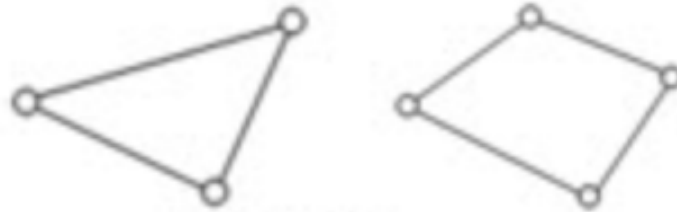


Metoda konečných prvků

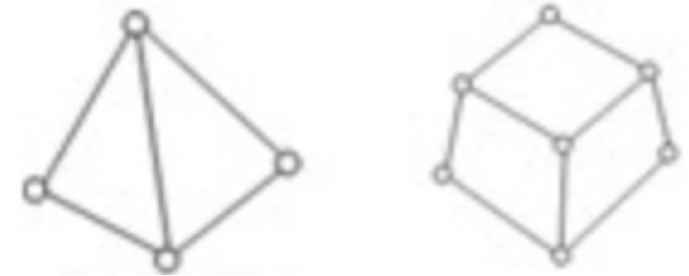
1D (Beam)



2D (Shell)



3D (Solid)

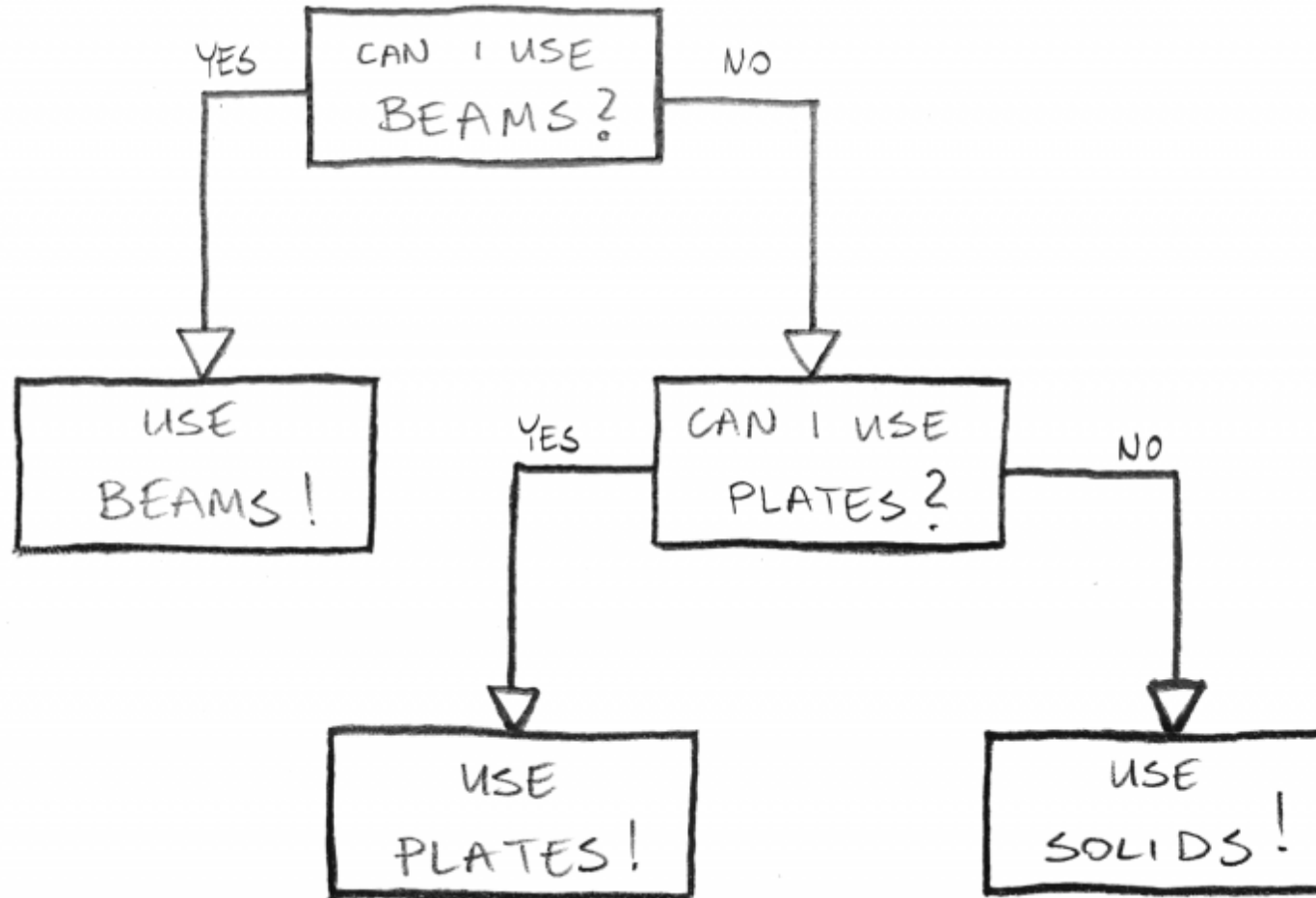


- + Rychlá analýza
- + Rychlá úprava modelu
- Vhodné pro dlouhé prvky

- + Lépe vystihují ohyb
- Vhodné pro desky a stěny

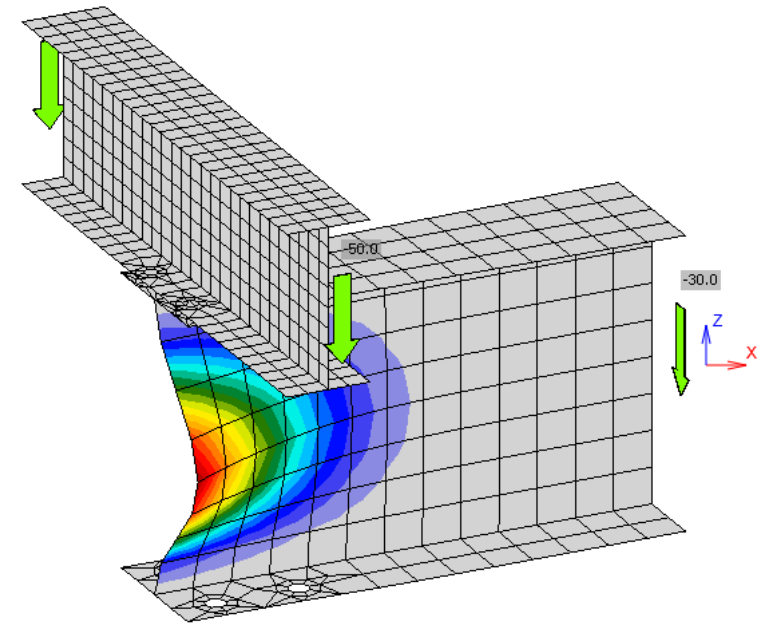
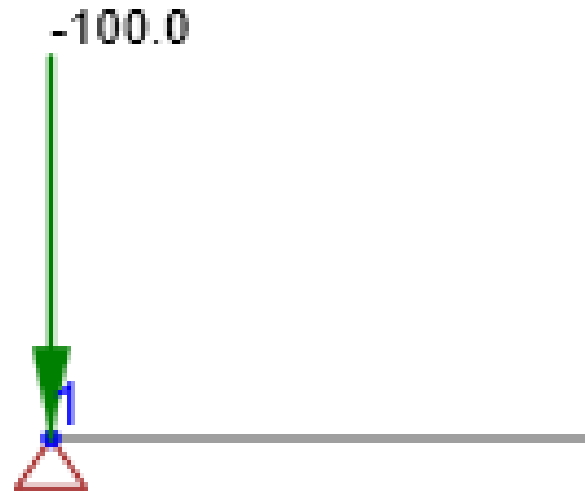
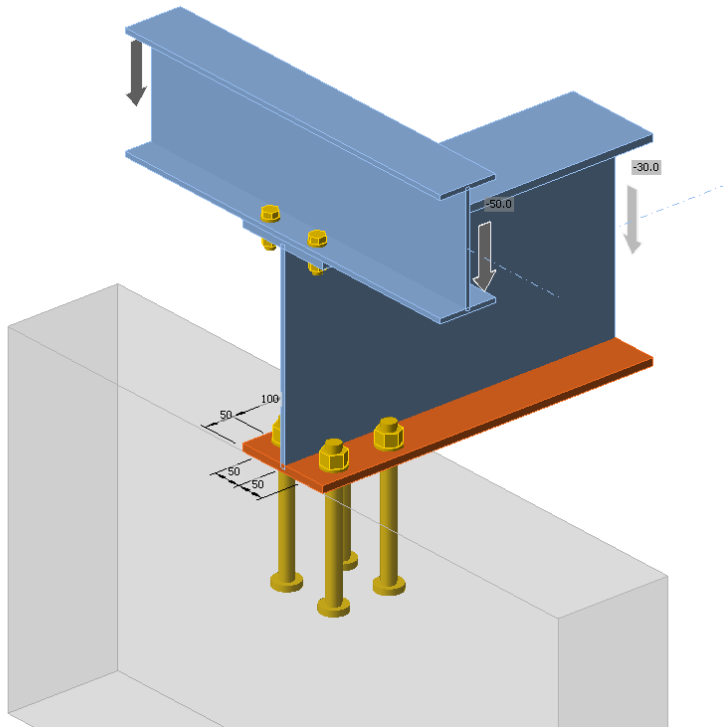
- + Univerzální
- Pomalá analýza

Metoda konečných prvků



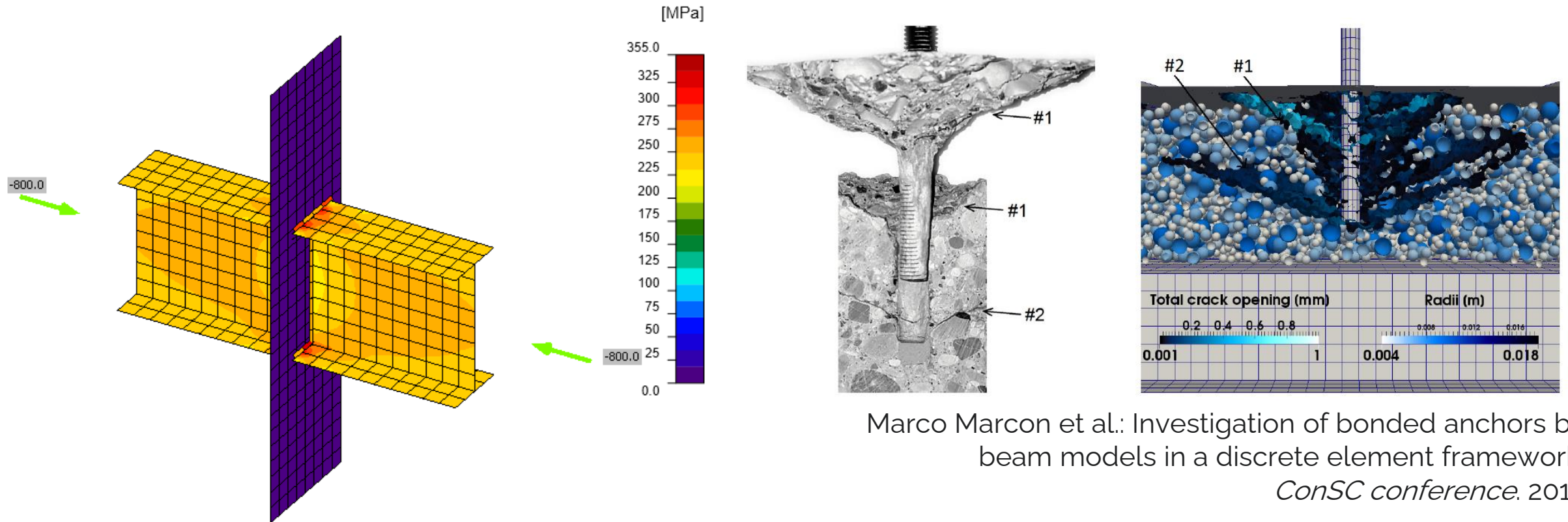
Metoda konečných prvků

- Limity prutového modelu



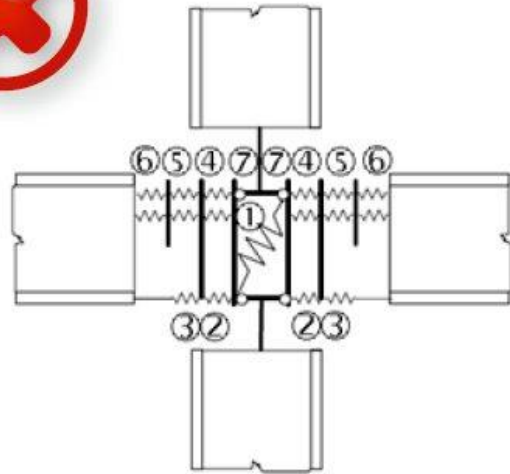
Metoda konečných prvků

- Limity deskostěnového modelu

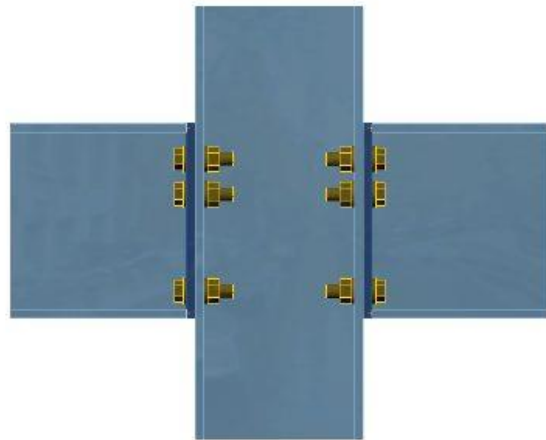


Marco Marcon et al.: Investigation of bonded anchors by beam models in a discrete element framework.
ConSC conference. 2017

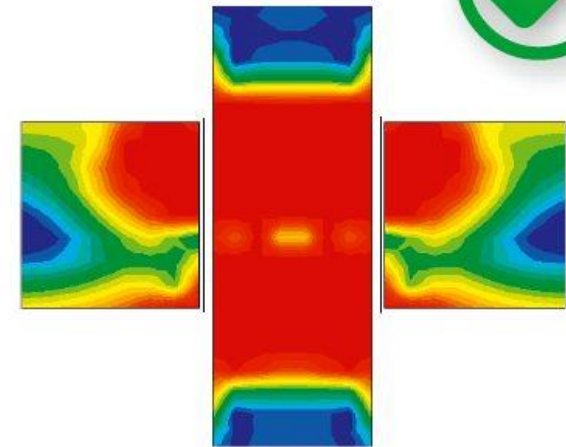
CBFEM



Component model



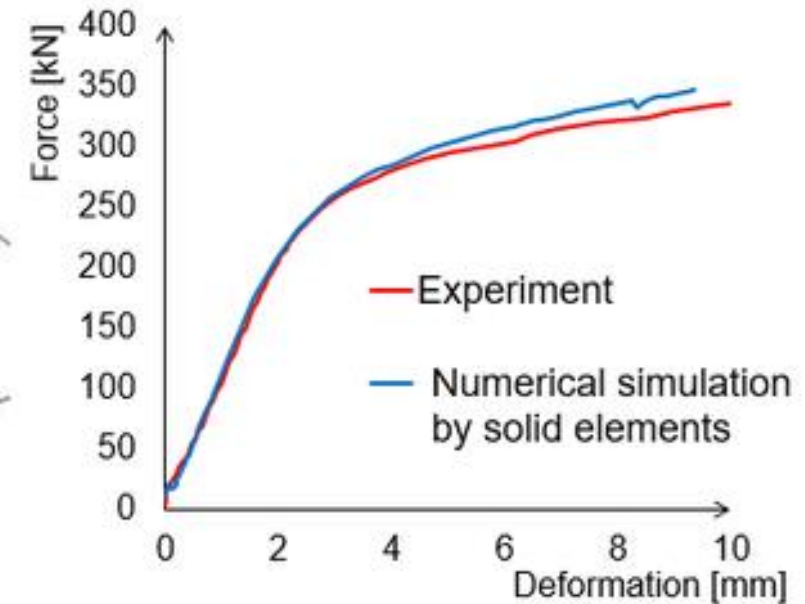
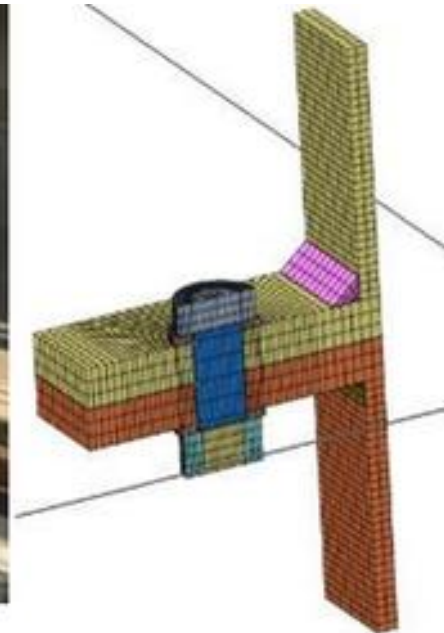
Bolted joint



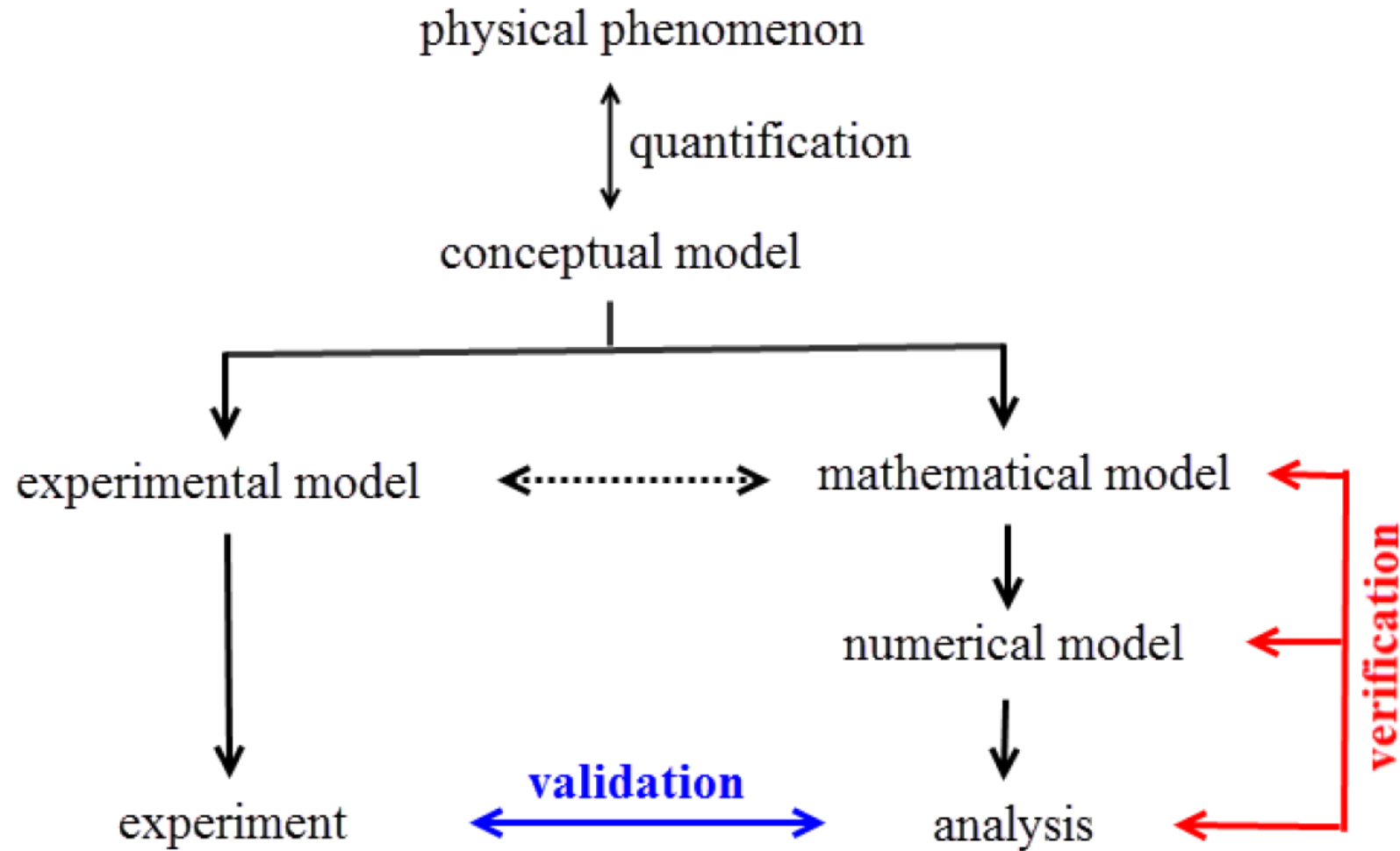
CBFEM model

CBFEM – Verifikace a validace

- Potřeba pro všechny numerické modely
- Kapitola 7 v prEN 1993-1-14

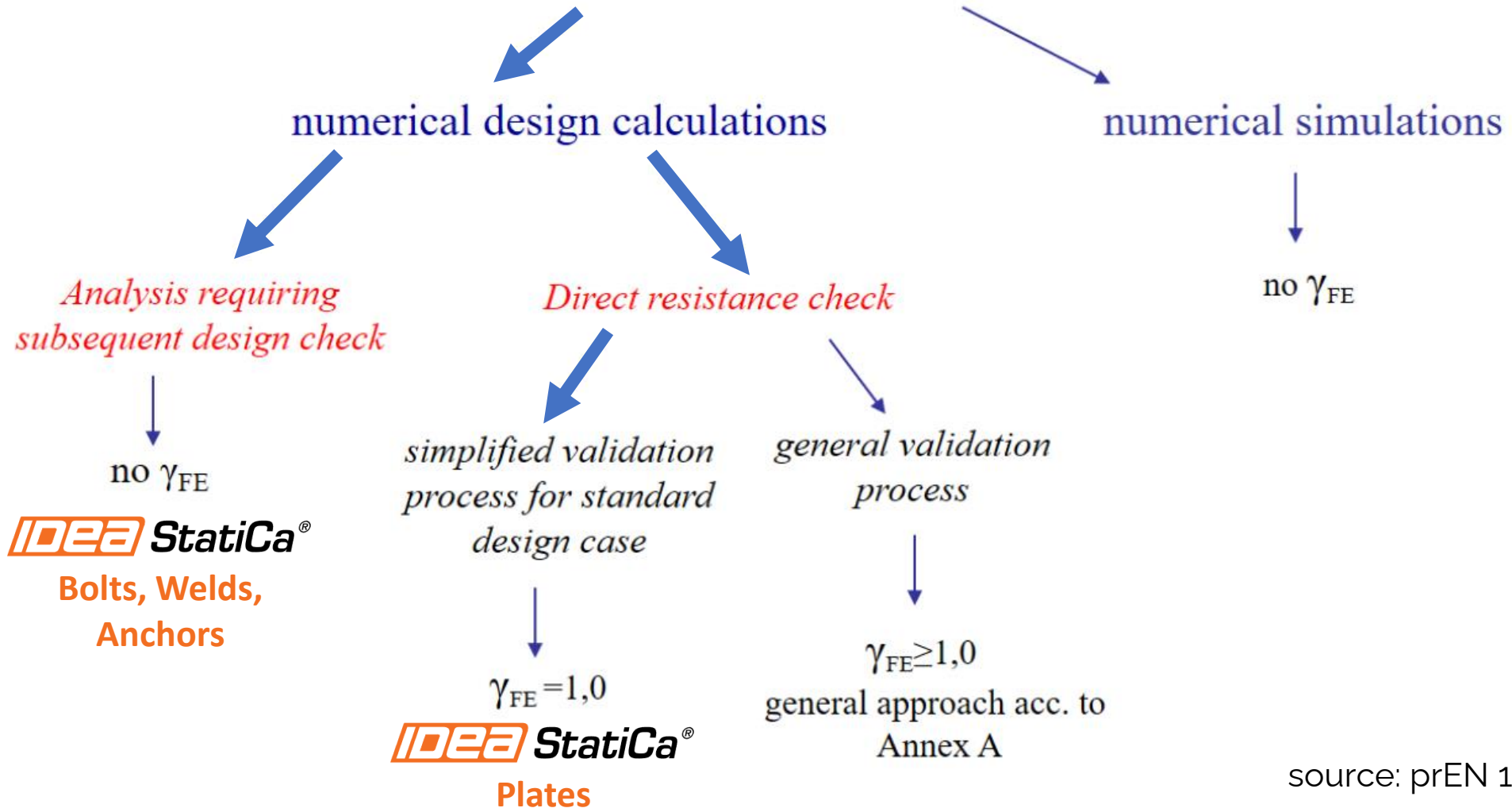


CBFEM – Verifikace a validace



CBFEM – Verifikace a validace

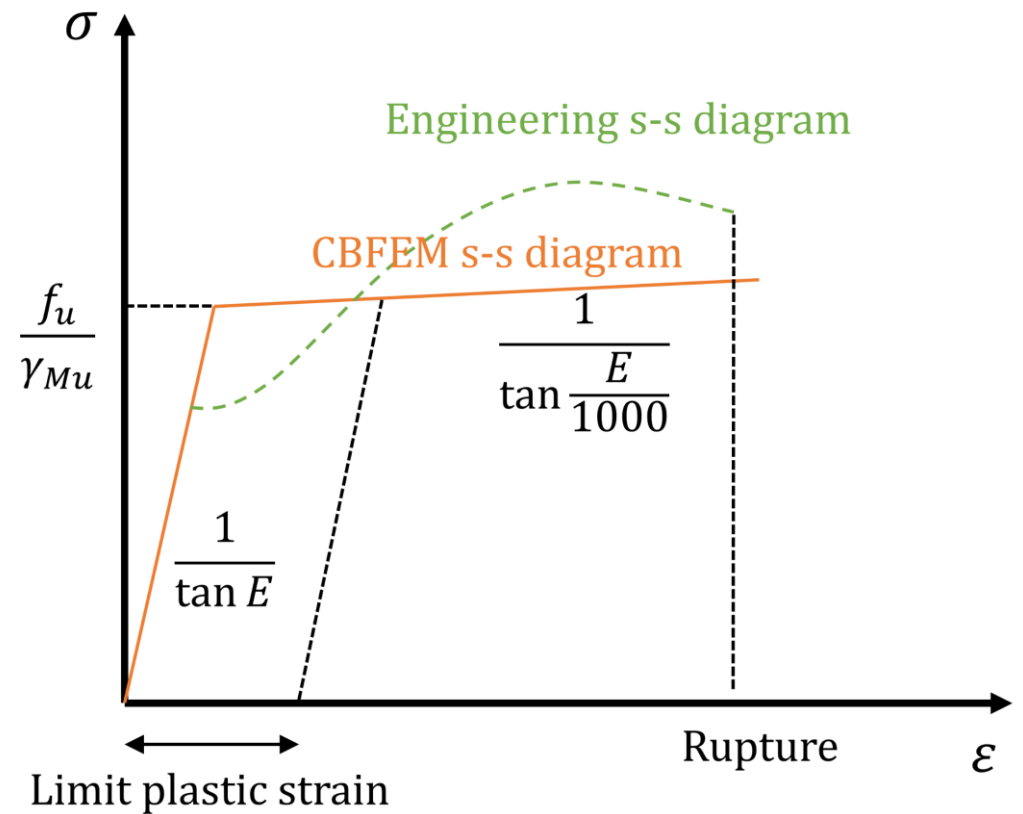
FE based design methods



source: prEN 1993-1-14:2021

CBFEM – Vazné síly

- Zatížení pouze tahovou silou
- $\gamma_{Mu} = 1,1$
 - přepsat γ_{M2}
- Přepsat f_y na $\frac{f_u}{\gamma_{Mu}}$
- Předpjaté šrouby
 - změnit na standardní



CBFEM – Vazné síly

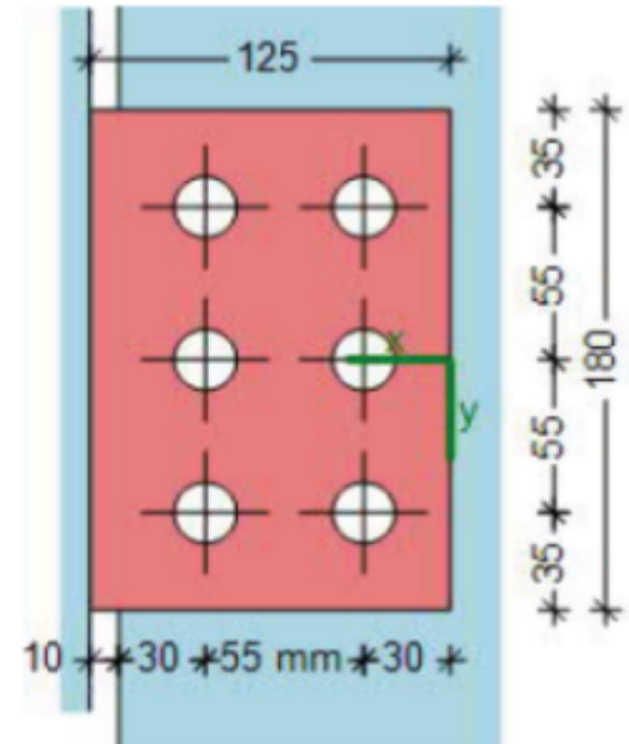
- Demo



CBFEM - verifikace

Component	μ
1) Bolts in shear	0,76
2) Fin plate in bearing	1,16
3) Fin plate in tension (gross section)	0,62
4) Fin plate in tension (net section)	1,09
5) Beam web in bearing	1,04
6) Beam in tension (gross section)	0,22
7) Beam in tension (net section)	0,28
8) Supporting member in bending	0,00

2) Fin plate in bearing	1,16
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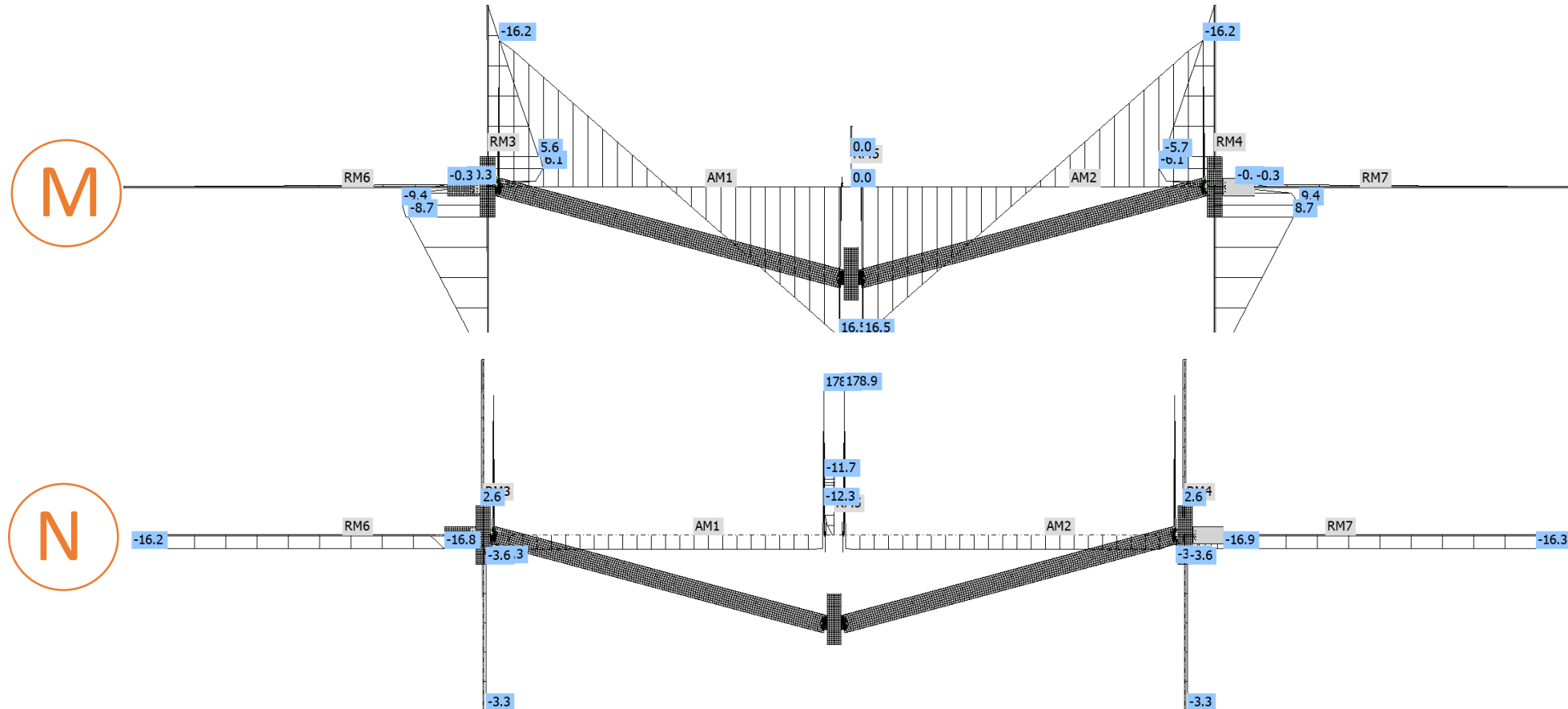


CBFEM - verifikace

Position s = strong axis w = weak axis	Tying force (kN)	Failure mode	UF
A1s / A2	268.8	Fin plate in bearing	0.63
A1w	268.8	Column web in bending	0.73
B1 / B3	499.2	Fin plate in bearing	1.16
C2w	499.2	Column web in bending	1.15
C3w	499.2	Fin plate in bearing	0.67
D3s/D3w	499.2	Beam web in bearing	2.02
D3w	90	Beam web in bearing	0.88
1-1 / 2-2	400.5	End plate in bending	0.88
3-3	694.2	End plate in bending	1.31

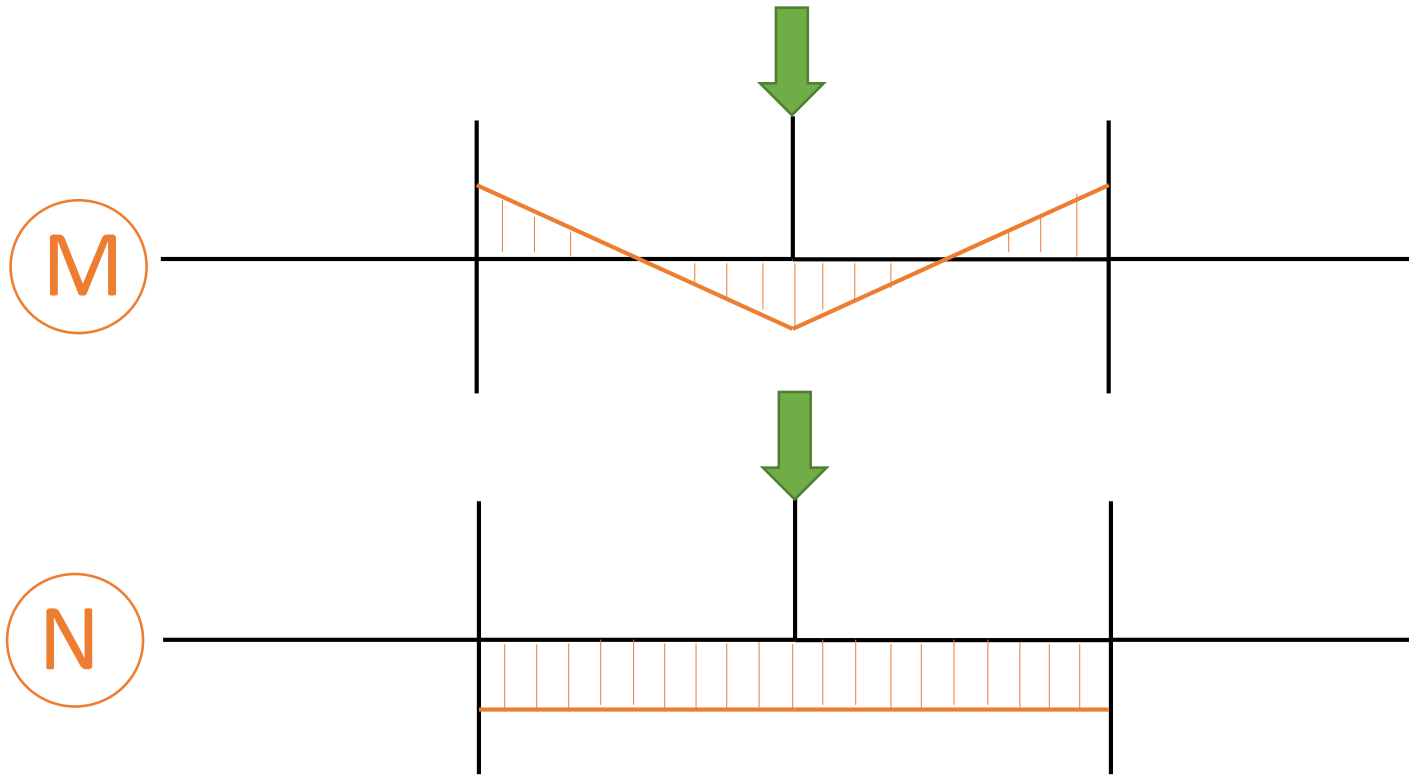
Metoda konečných prvků

- Geometrická nelinearita



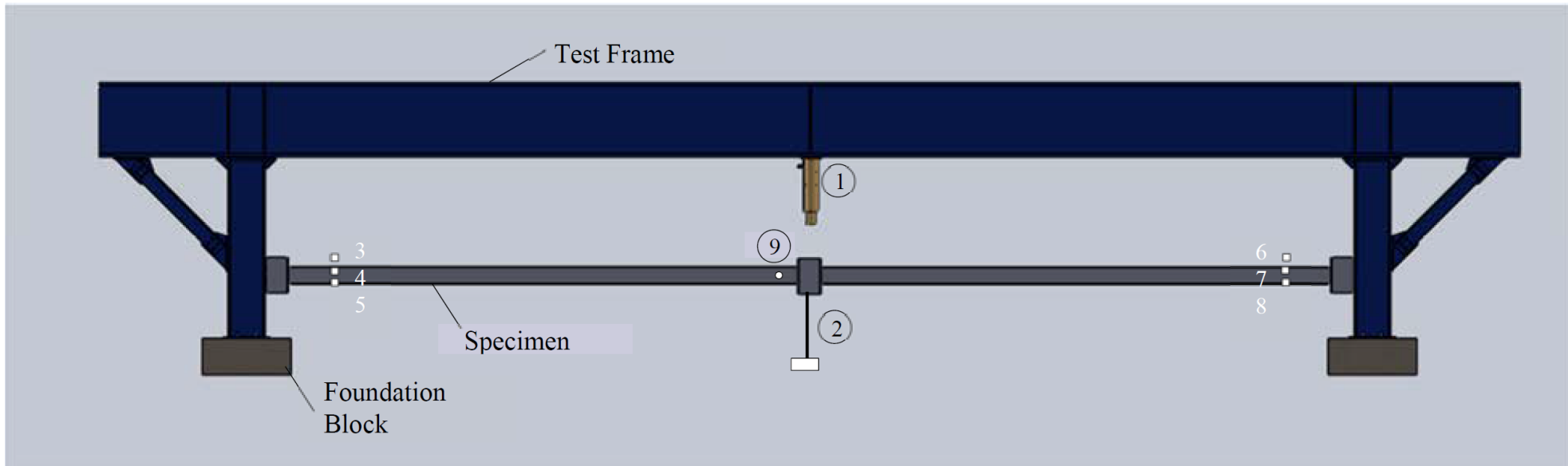
Metoda konečných prvků

- Geometrická nelinearita



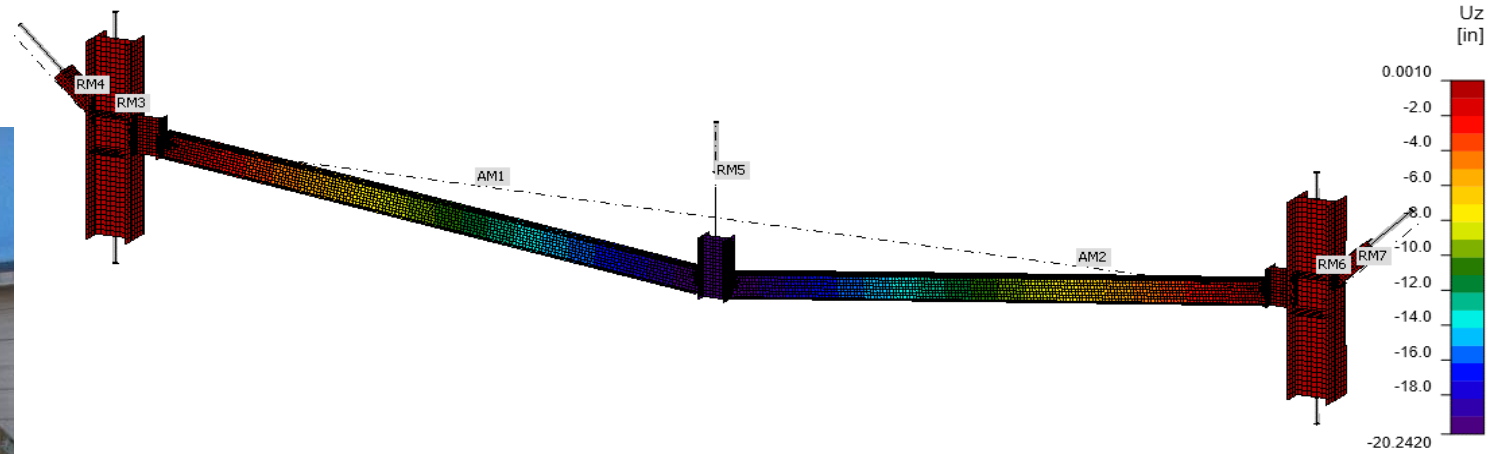
CBFEM – vazné síly

- Validace

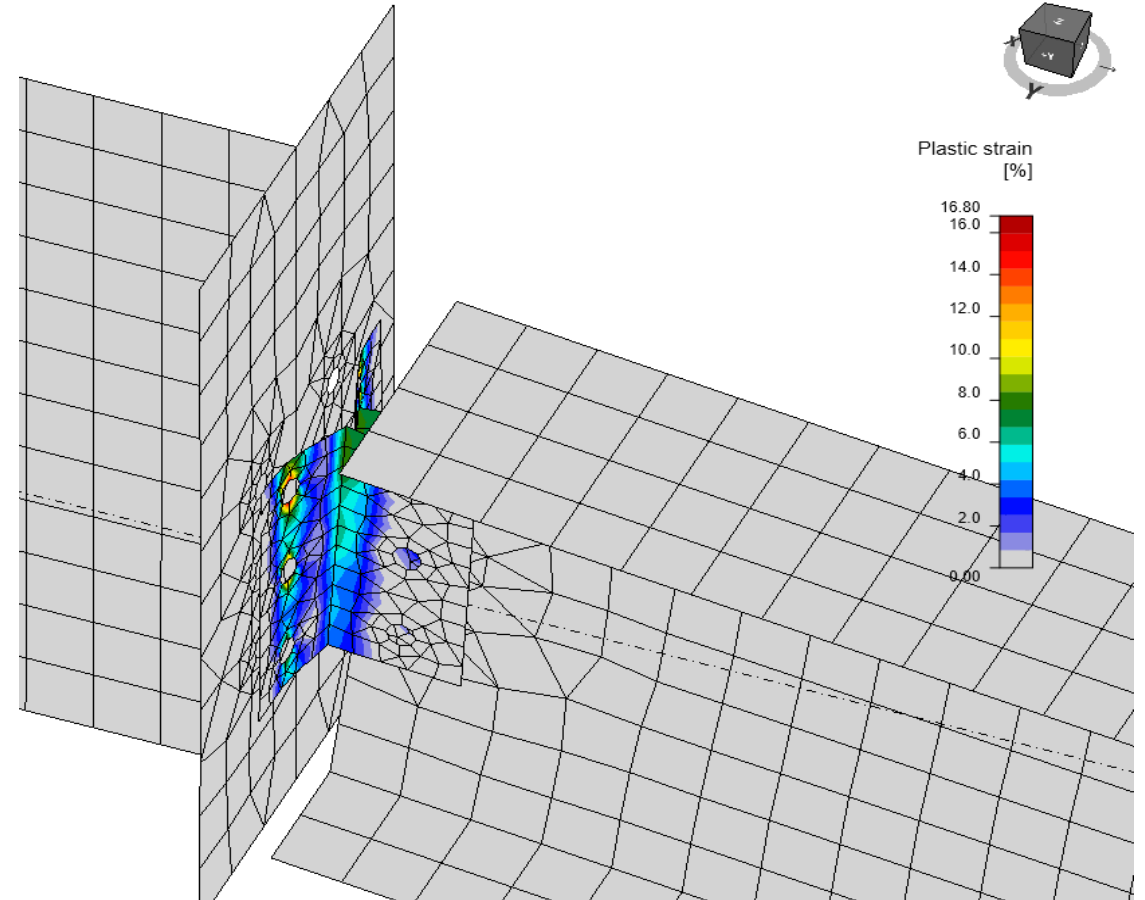


Cortes, Liu: Framing Strategies for Robustness in Steel Buildings, 2015

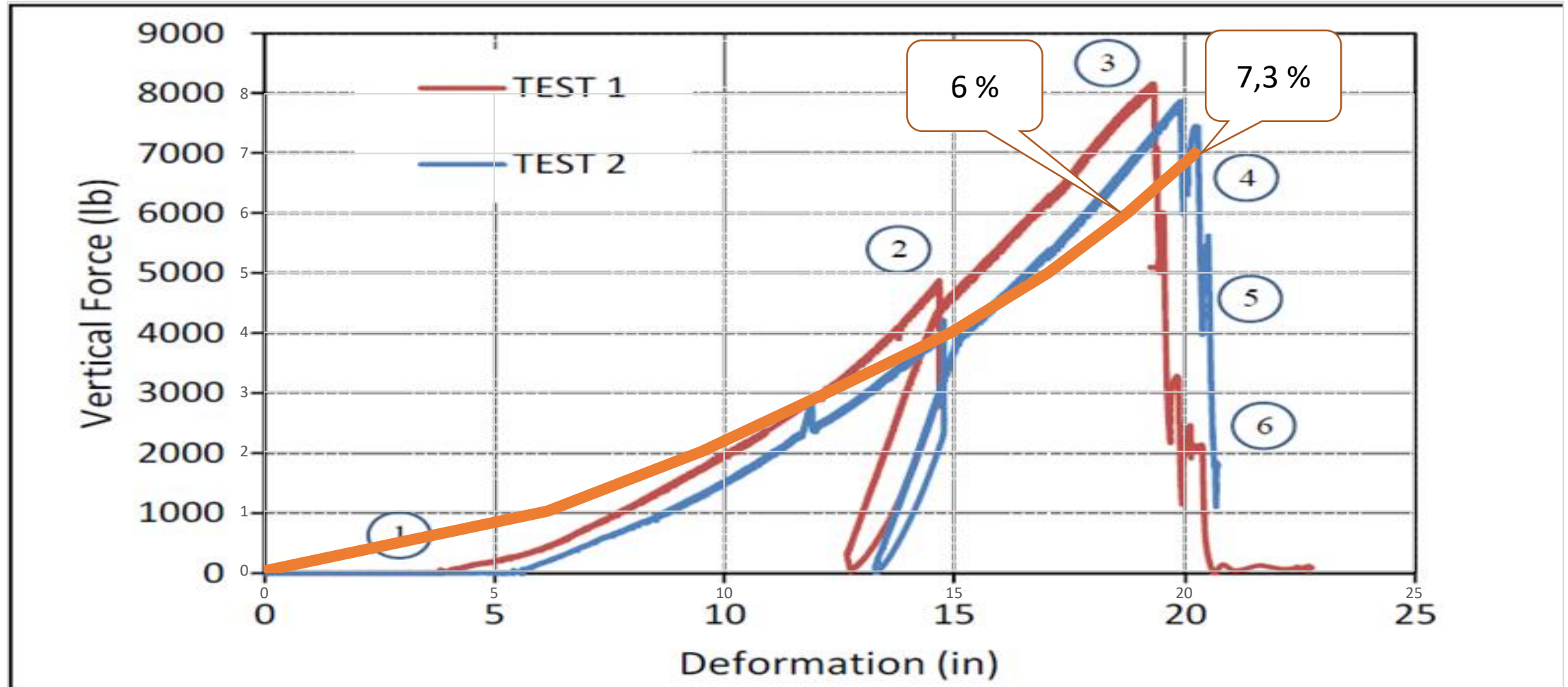
CBFEM – Validace



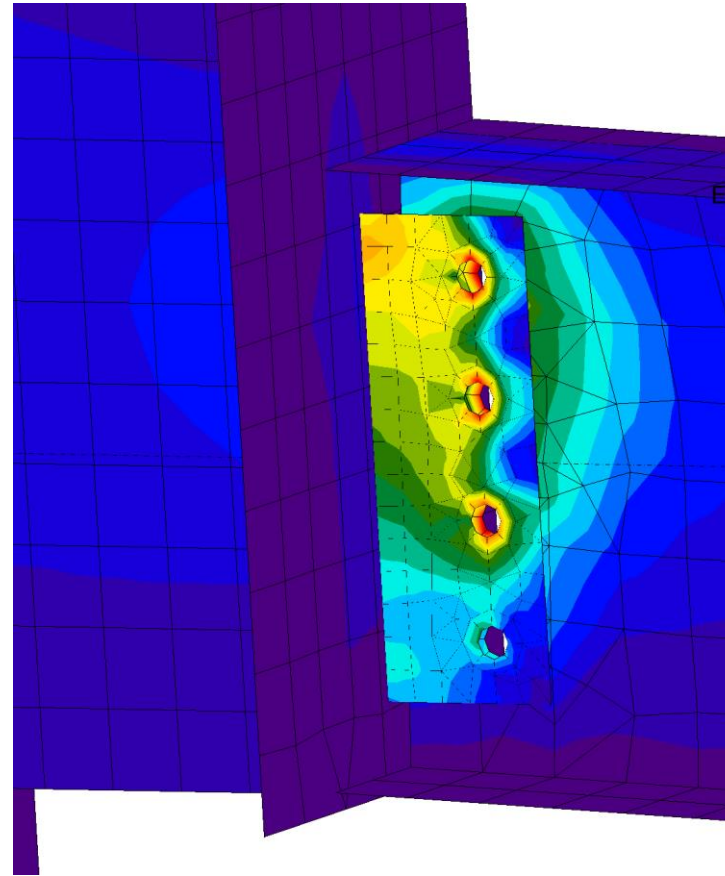
CBFEM – Validace – Úhelníky



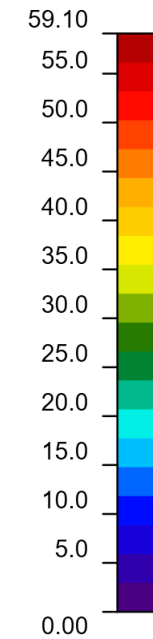
CBFEM – Validace – Úhelníky



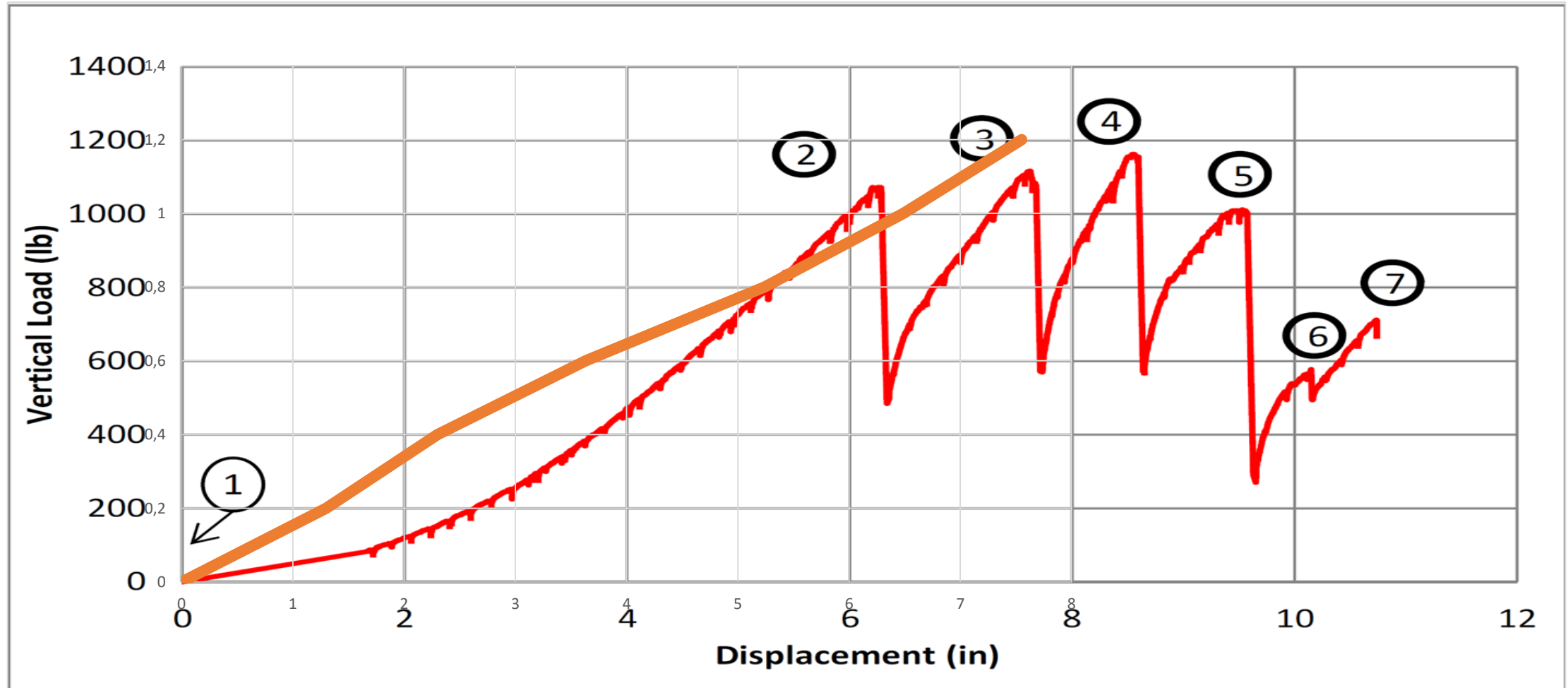
CBFEM – Validace – Žiletka



Equivalent stress
[ksi]



CBFEM – Validace – Žiletka



Závěr

- Duktilita
 - Svary na plnou únosnost
 - Šroubové spoje
 - mód 1 nebo 2
 - otláčení
- CBFEM model
 - f_u/γ_{Mu} místo f_y/γ_{M0}
 - γ_{Mu} místo γ_{M2}
 - Zatížení pouze osovou silou
 - N-Vy-Vz model type

WORKED EXAMPLES

V Praze

18.5.2022

Děkuji za pozornost!

Martin Vild

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<http://steel.fsv.cvut.cz/FAILNOMORE/index.htm>



steelconstruct.com/eu-projects/failnomore



Research Fund for Coal & Steel

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