Plastic failure mechanisms of eccentrically loaded thin-walled cold-formed steel members

Stefan Špirić, BSc
Mentor: Prof dr Daniel-Viorel Ungureanu

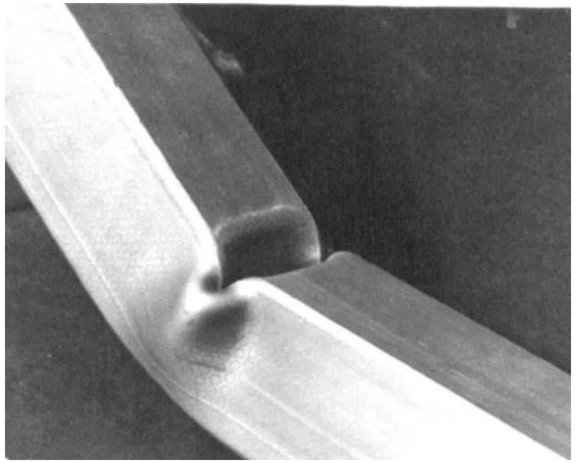
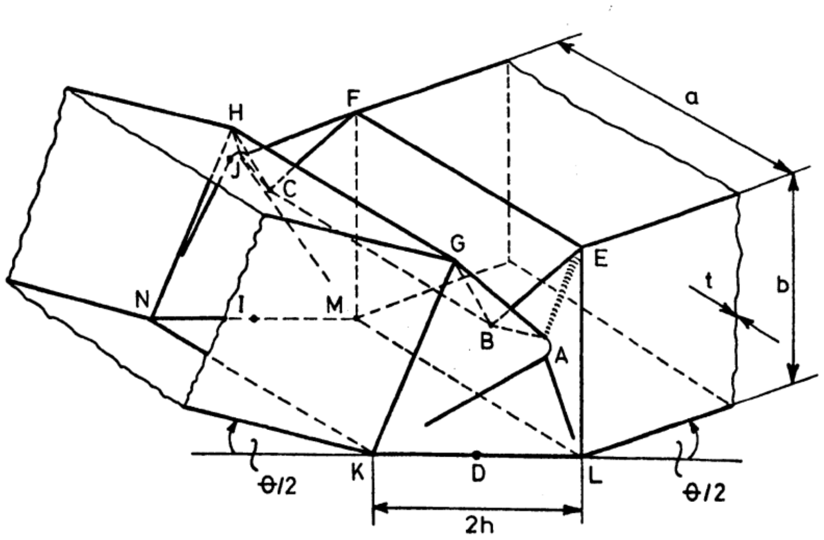
Contents

1. Introduction

1. Introduction

What is a plastic failure mechanism?



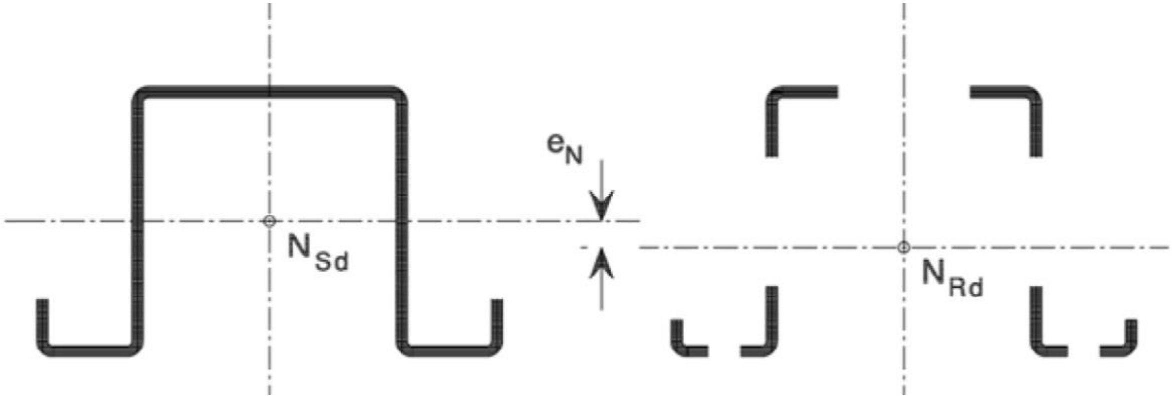
1. Introduction

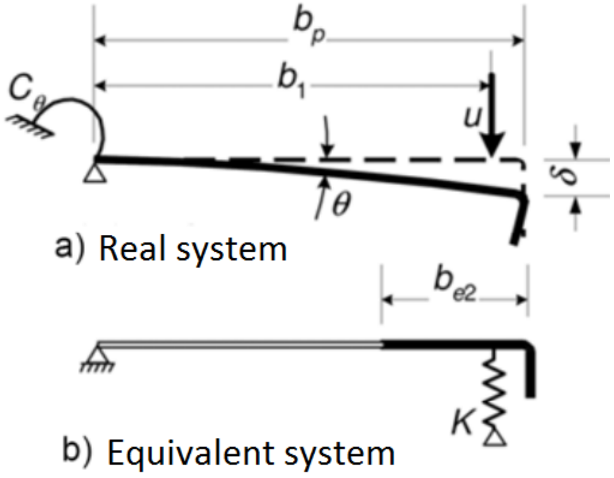
Why are we analysing it?

- To obtain the members' **load capacity**

What is wrong with the conventional "Effective width" method given in design codes worldwide?

- Requires numerous iterations
- Complicated for nonstandard cross-sections





1. Introduction

- Thin-walled cold-formed (TWCF) steel structures are usually made of **class 4** sections which are prematurely susceptible to local or distortional buckling in the elastic range
- Failure of these members in compression and bending is always initiated by local-global interactive buckling of plastic-elastic type
- This interaction manifests as a **plastic failure mechanism**
- Examination of the complete collapse response is needed, particularly for design under extreme loads

BREAKDOWN

- **Subject**: thin-walled cold-formed (TWCF) steel members - class 4 sections
- **Loading**: compression, bending and their interaction
- **Phenomenon**: plastic-elastic interaction of local/distortional and global buckling → *local plastic failure mechanism*
- **Analysis:**
  - FE simulation (Abaqus)
  - Analytical (yield line analysis)

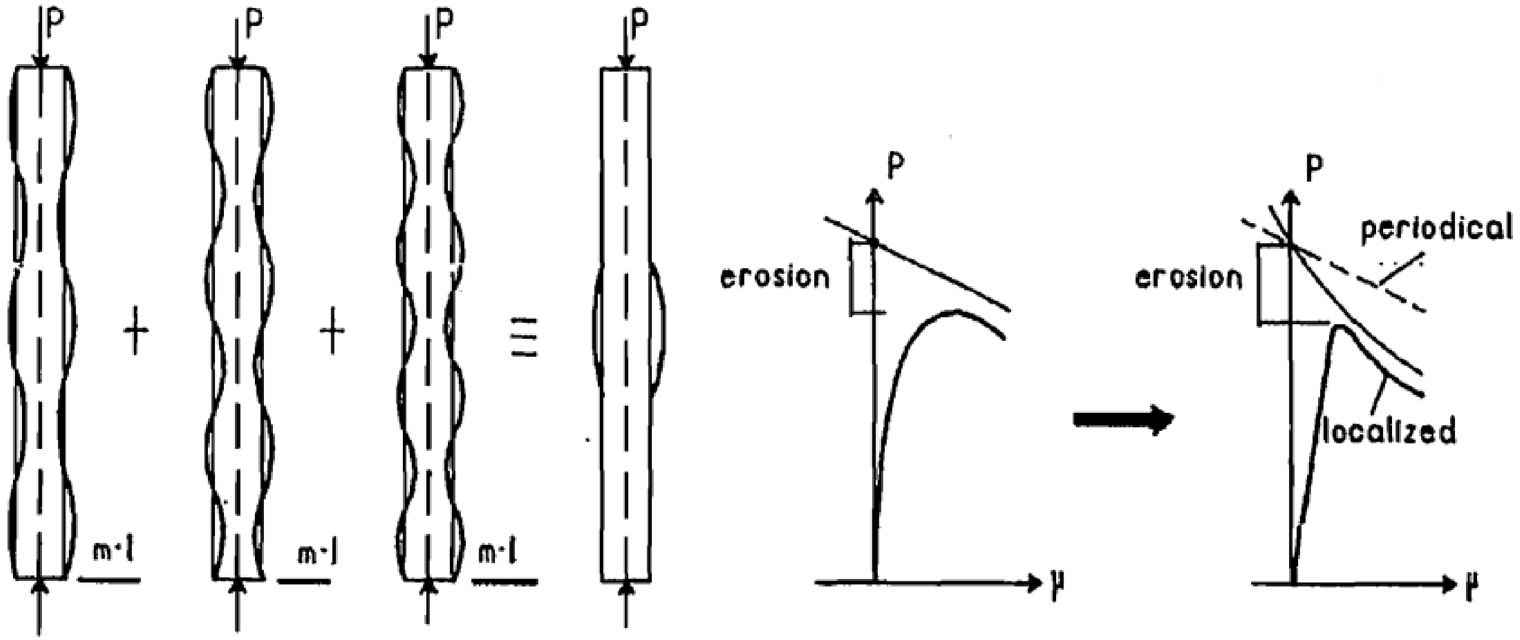
1. Introduction

Buckling interaction

Two forms of interaction occur:

1. Interaction of **local** buckling modes

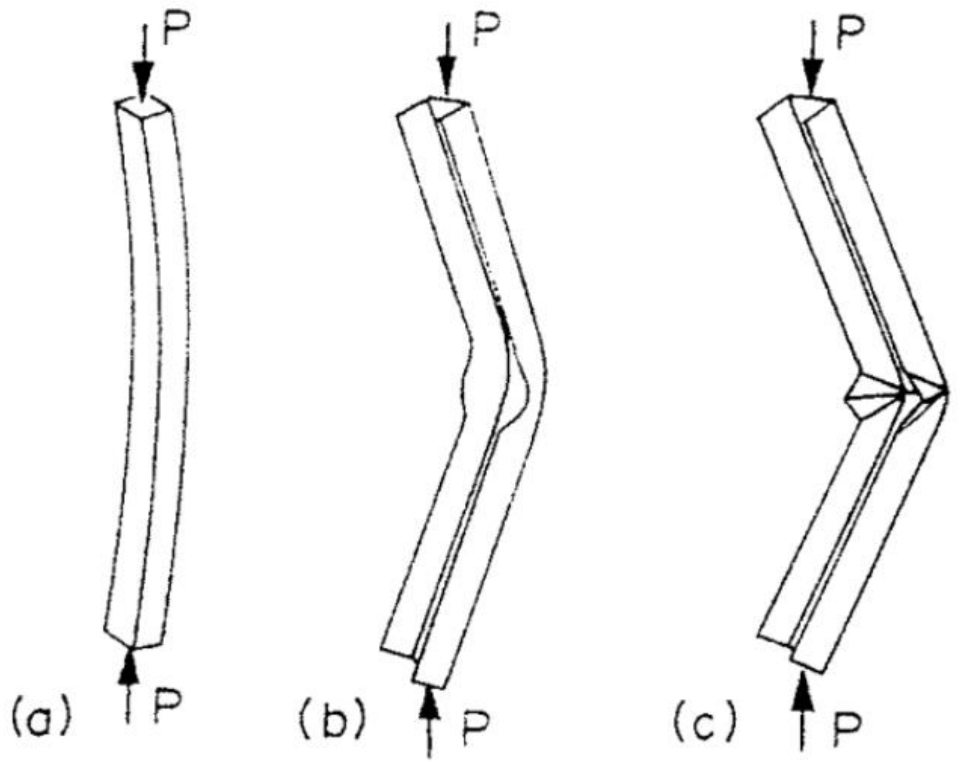
2. **Local-global** interactive buckling



Interaction of local buckling modes

1. Introduction

- Local-global interaction
- Factors that influence PFM
  1. f_y
  2. Type of cross-section
  3. b/t
  4. Geometrical imperfections
  5. Residual stresses

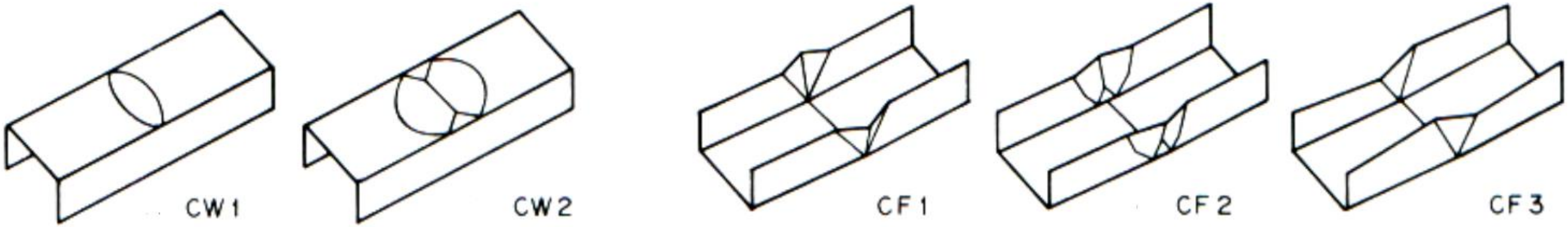


- **Not a linear superposition of M+N!!**
- **Hard to determine *a priori***

2. State of art review

2. State of art review

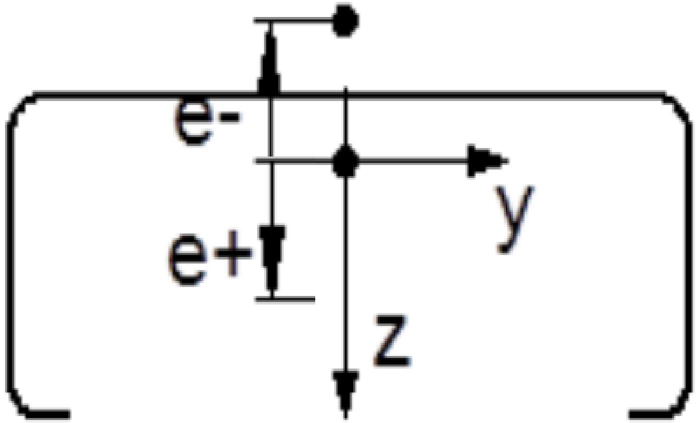
- Murray and Khoo (1981) observed 5 mechanisms that repeatedly manifested for plane channels in compression – **5 basic mechanisms**
- Various researchers performing experiments since the 1960s

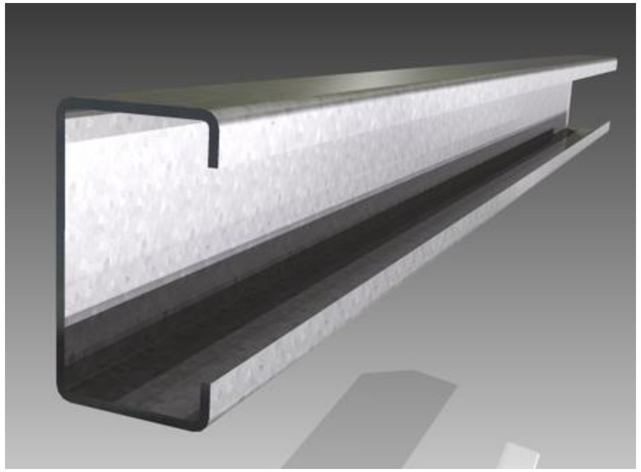


3. Numerical analysis

3. Numerical analysis

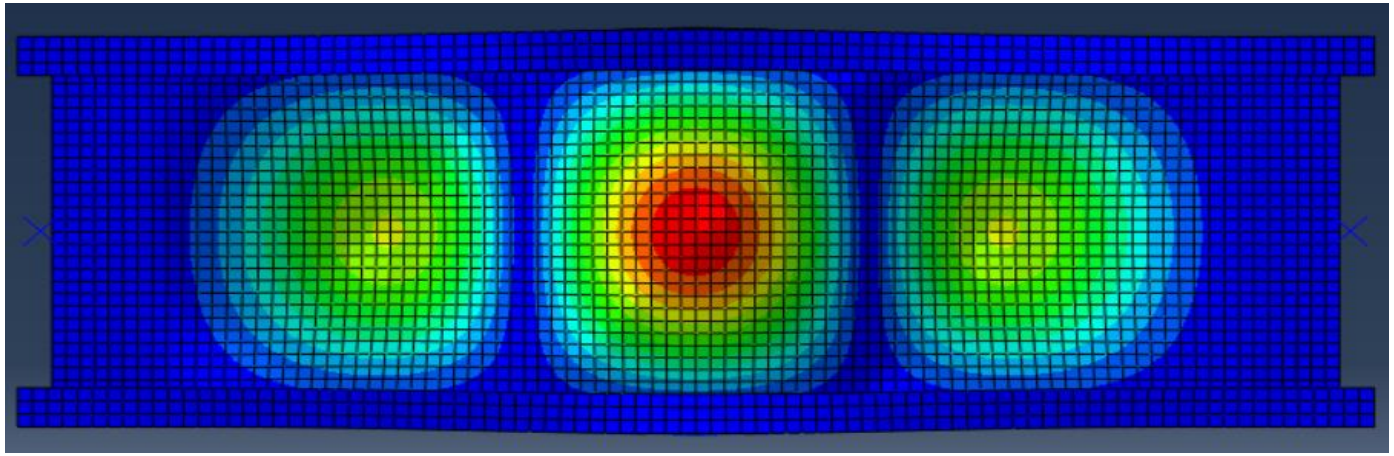
- Subject: lipped-channel (C-section)
- Loading: eccentric compression

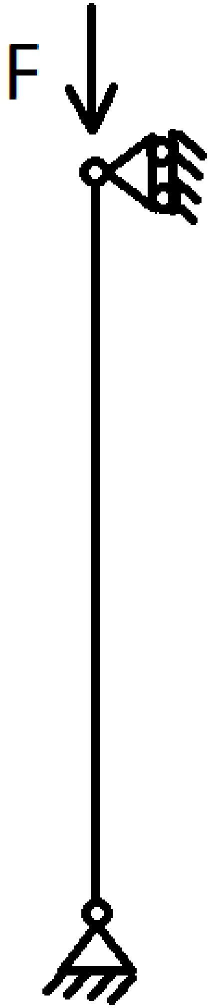




3. Numerical analysis

- Boundary conditions: pinned-pinned
- Imperfections: eigenmode

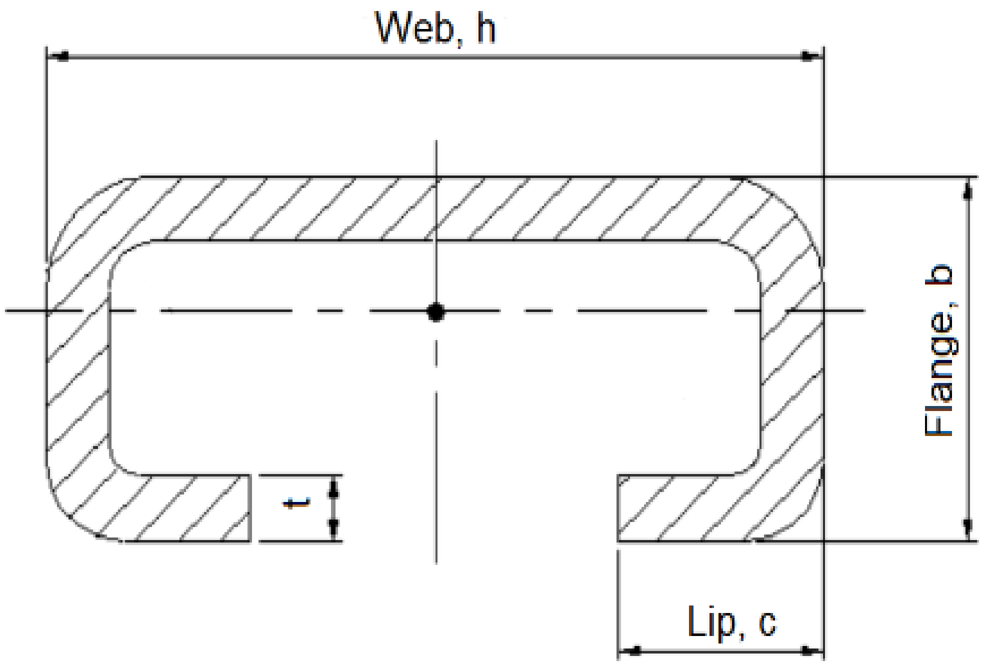




3. Numerical analysis

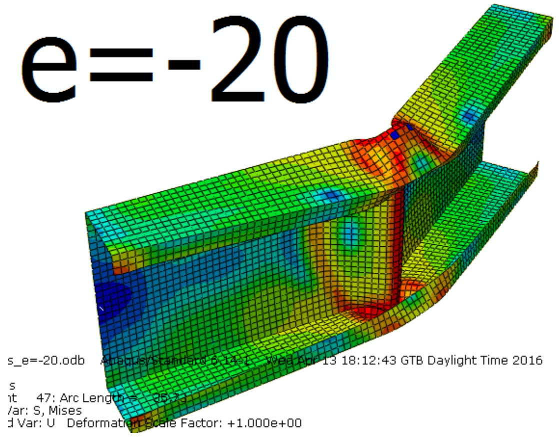
Input

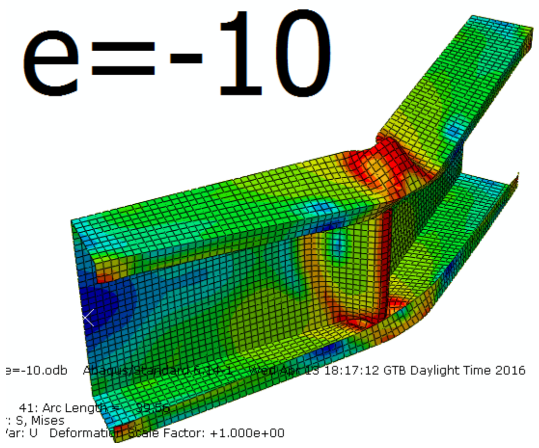
- $fy = 355 \frac{N}{mm^2}$; $E = 210\,000 \frac{N}{mm^2}$; $\nu = 0.3$
- $h = 150\, mm$
- $b = 50\, mm$
- $c = 15\, mm$
- $t = 1.5\, mm$
- $L = 450\, mm$

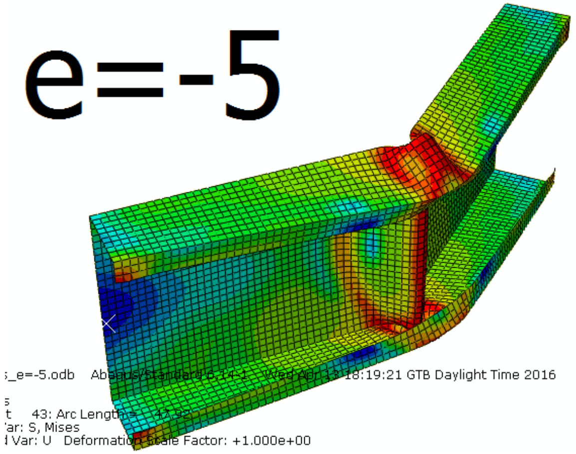


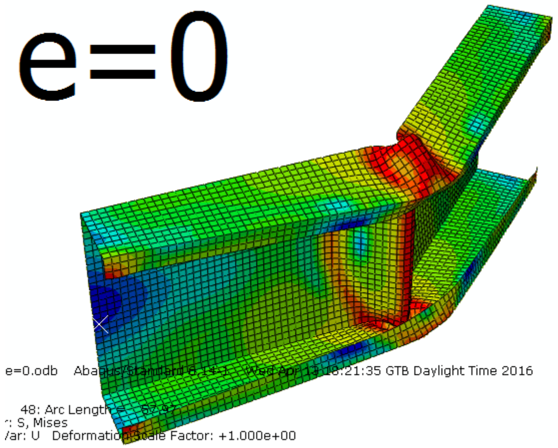
3. Numerical analysis

Negative eccentricities

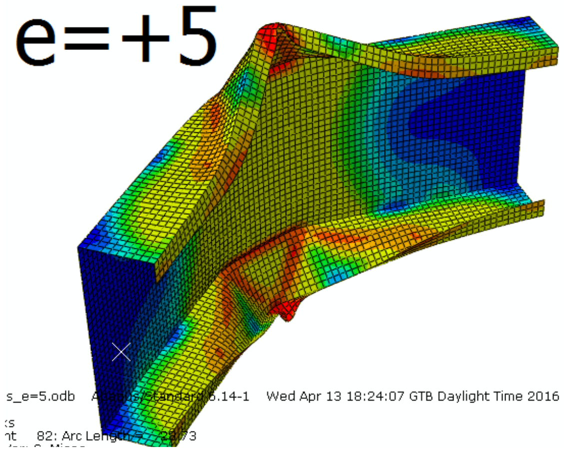


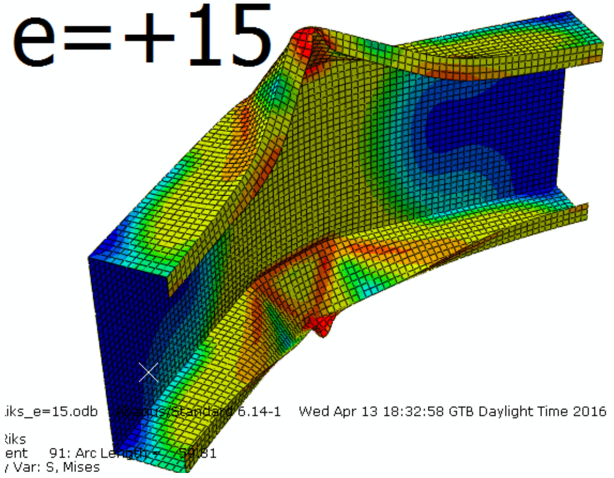


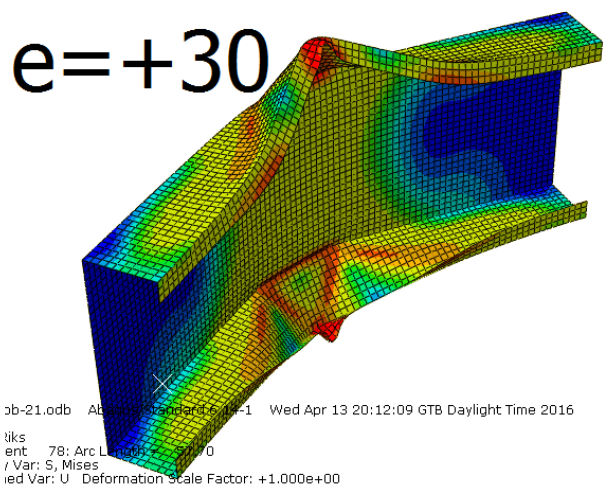


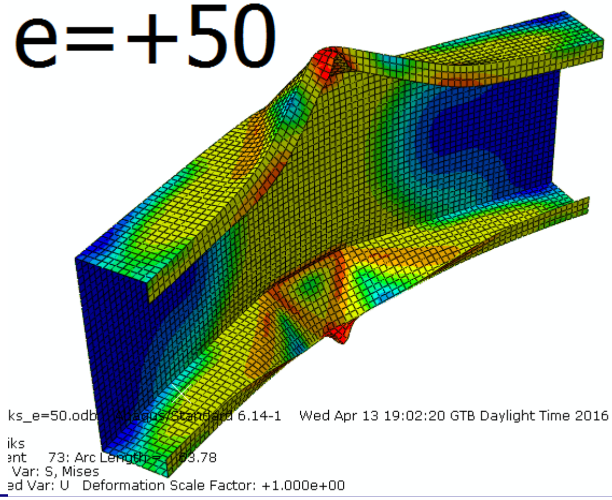


Positive eccentricities

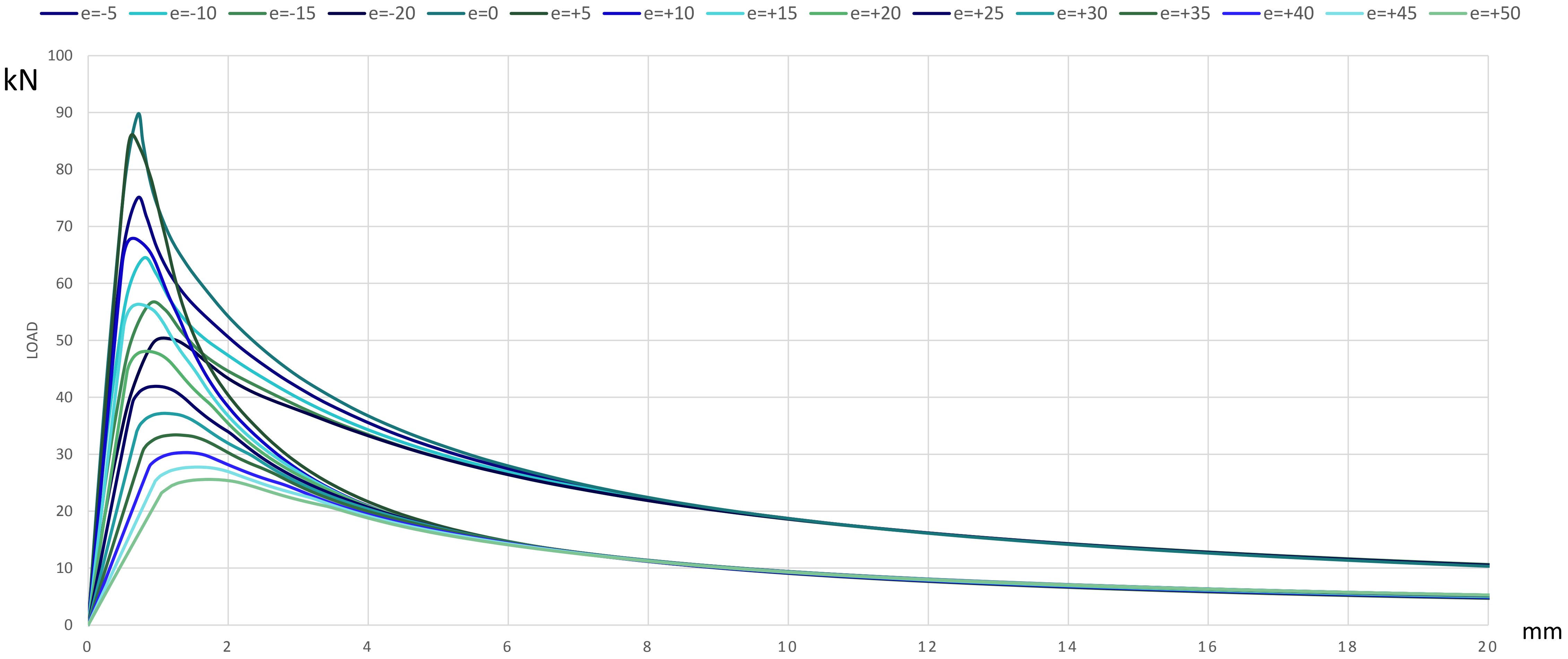








3. Numerical analysis

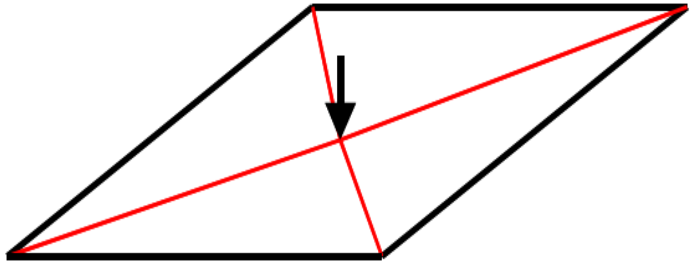


4. Analytical analysis

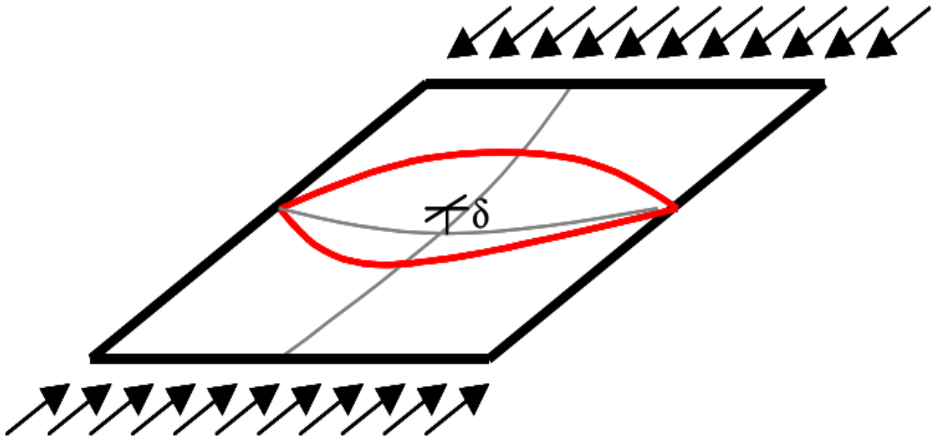
4. Analytical analysis

Yield line analysis

theoretically **zero-width** lines of yielded material



(a) classical yield-line analysis of a simply supported plate (slab) with out-of plane load, yield-lines and patterns develop from *first-order* forces and moments



(b) generalized yield-line analysis of a simply supported plate with in-plane load, yield-lines and patterns develop from consideration of *second-order* forces and moments

4. Analytical analysis

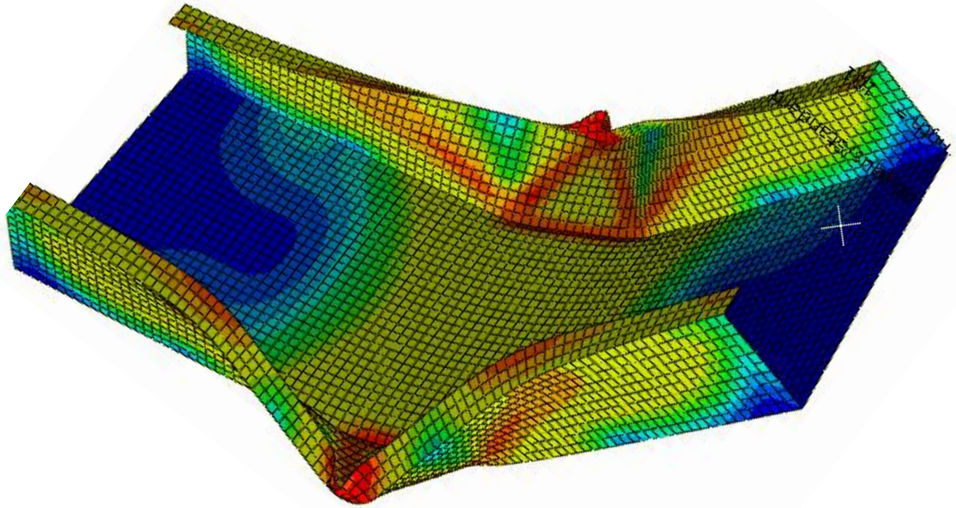
Slab VS Beam/column differences

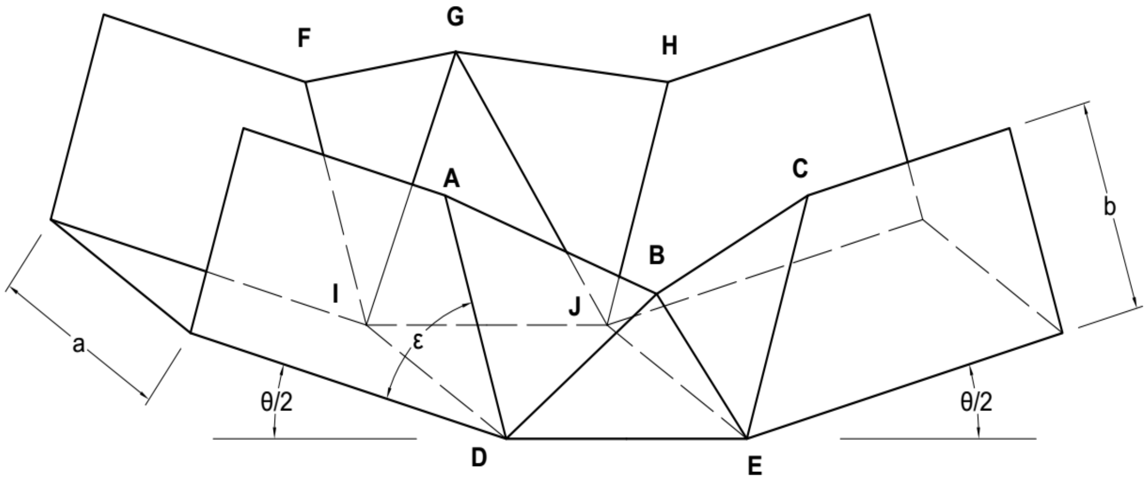
1. Out-of-plane vs in-plane loading
2. No way to predict the mechanism –
   not necessarily the one with the lowest loading capacity!

4. Analytical analysis

Proposed mechanism model

- Model for failure in positive eccentricity
- Based on observations of FE simulation

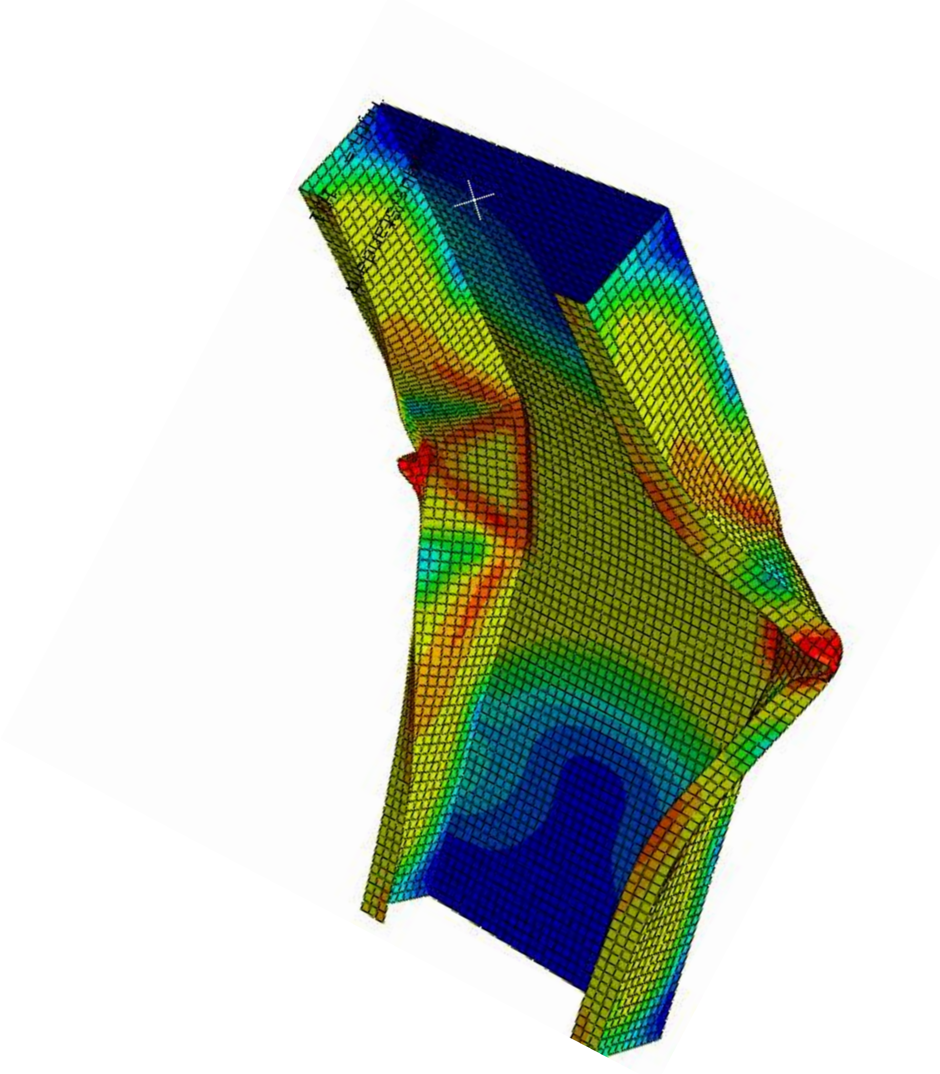




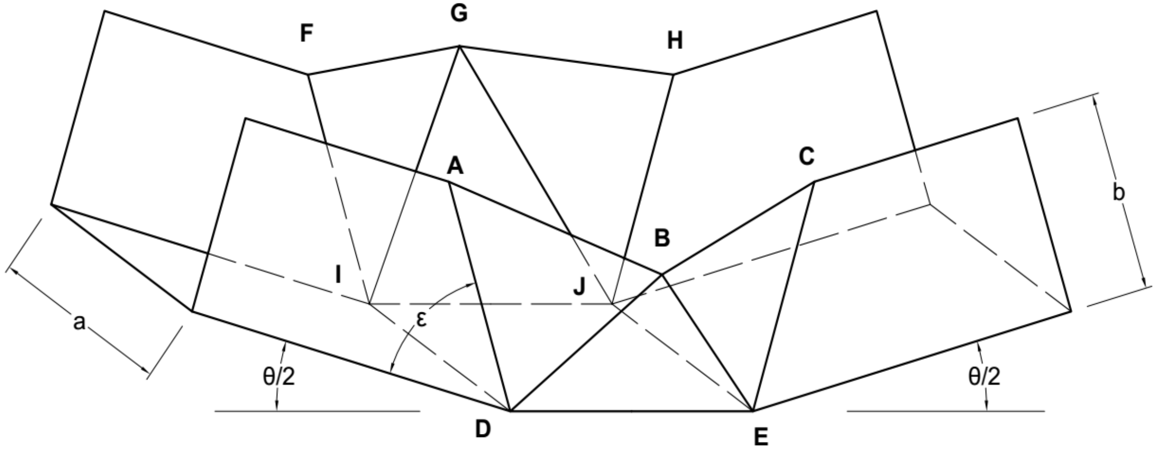
4. Analytical analysis

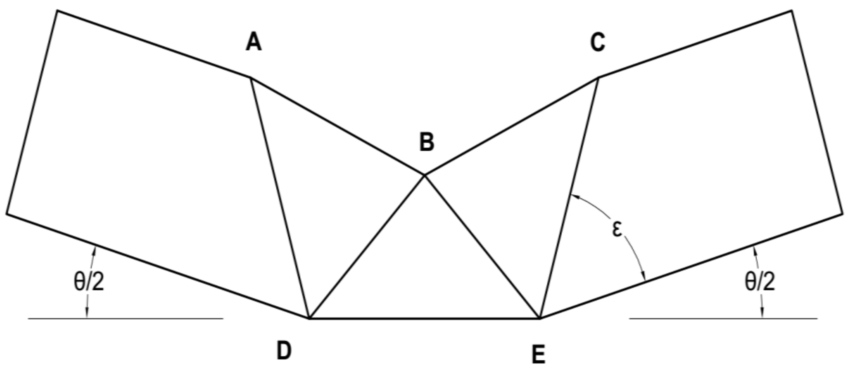
Proposed mechanism model

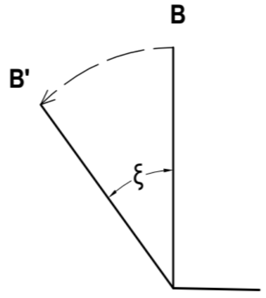
- Flanges and lips of the element are in compression
- Web in tension
- Yield lines in lips of the section were not accounted for
- All walls are considered inextensible and incompressible - all deformation happens along the yield lines only

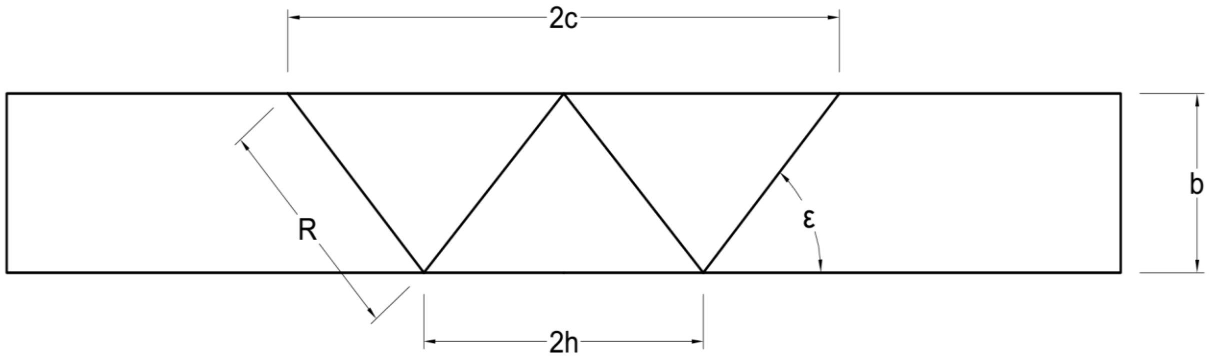


4. Analytical analysis

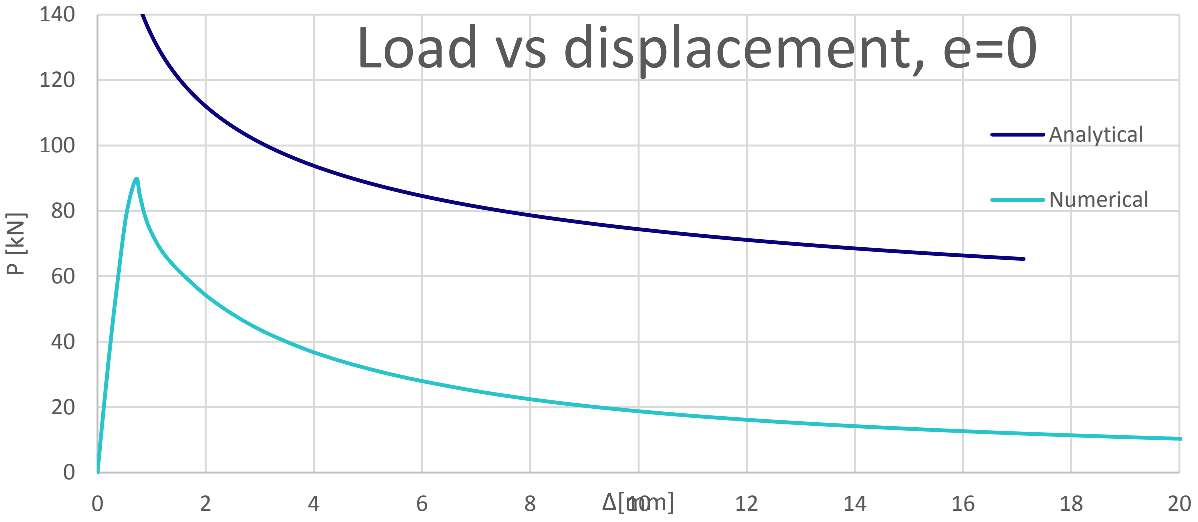


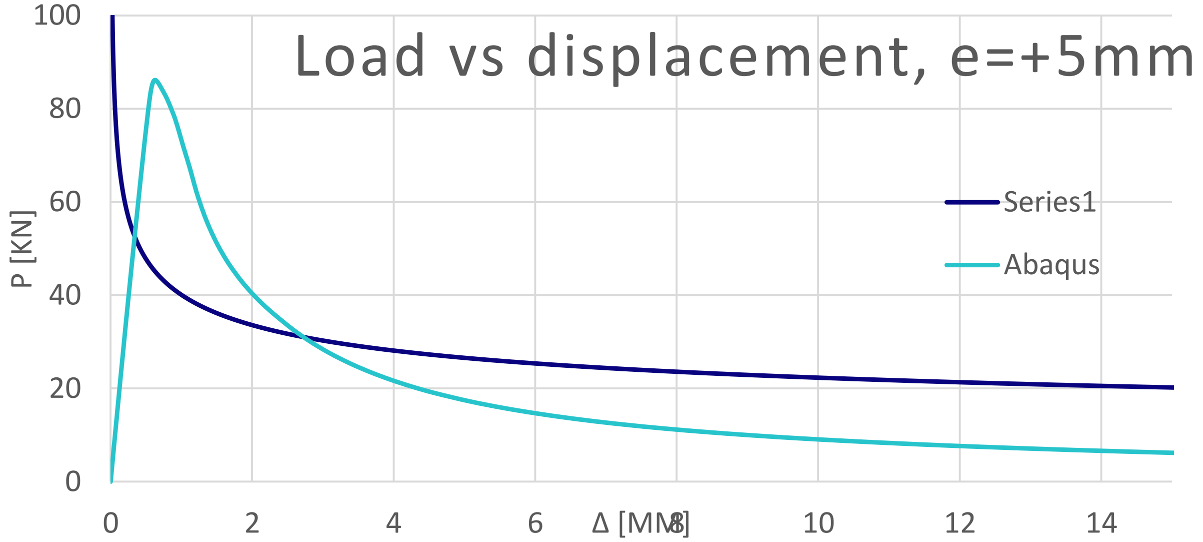


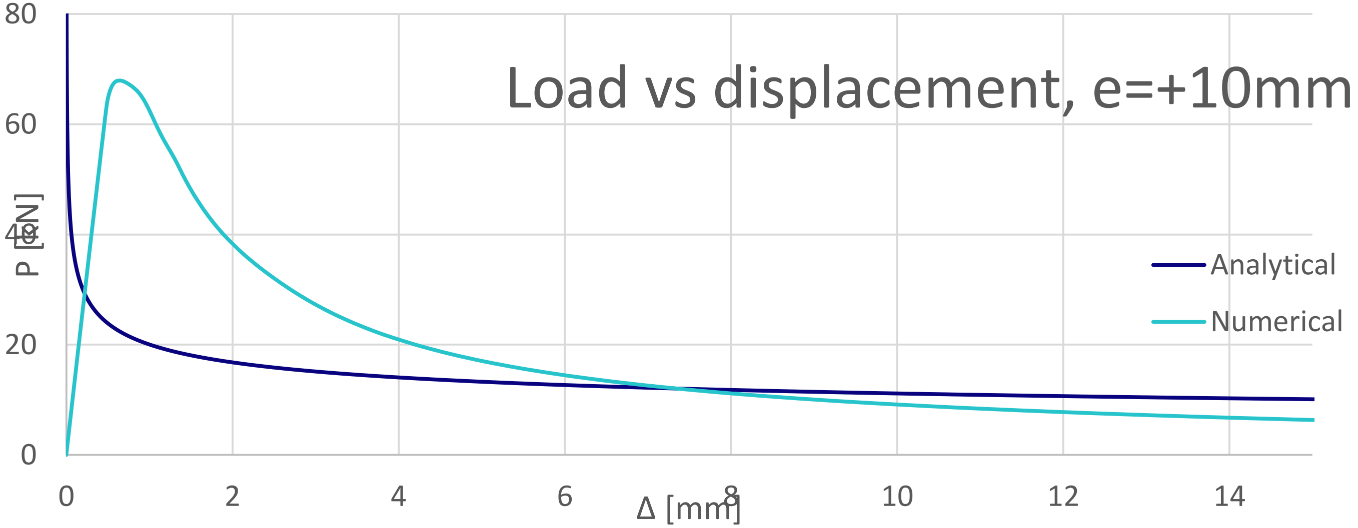




4. Analytical analysis







Erasmus+

Universitatea Politehnica Timişoara

5. Final remarks

5. Final remarks

- Short TWCF columns in eccentric compression fail by forming a plastic collapse mechanism – confirmed
- Agreement of the theoretical and numerical curve is not very good - the model needs more work
- Detailed derivation of the mechanism model and load capacity expressions will be presented in a MSc thesis of the same title

Thank You for your attention!