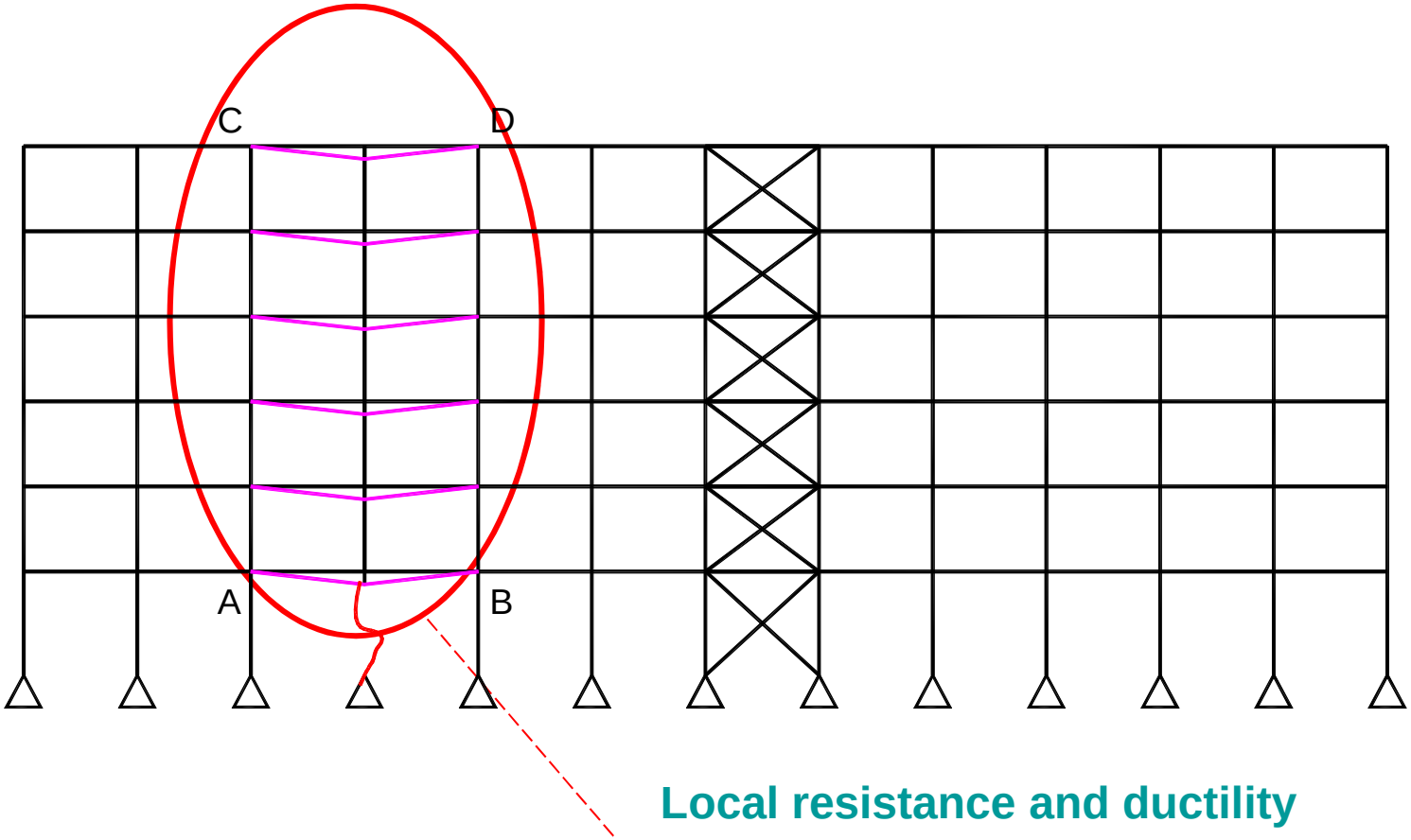
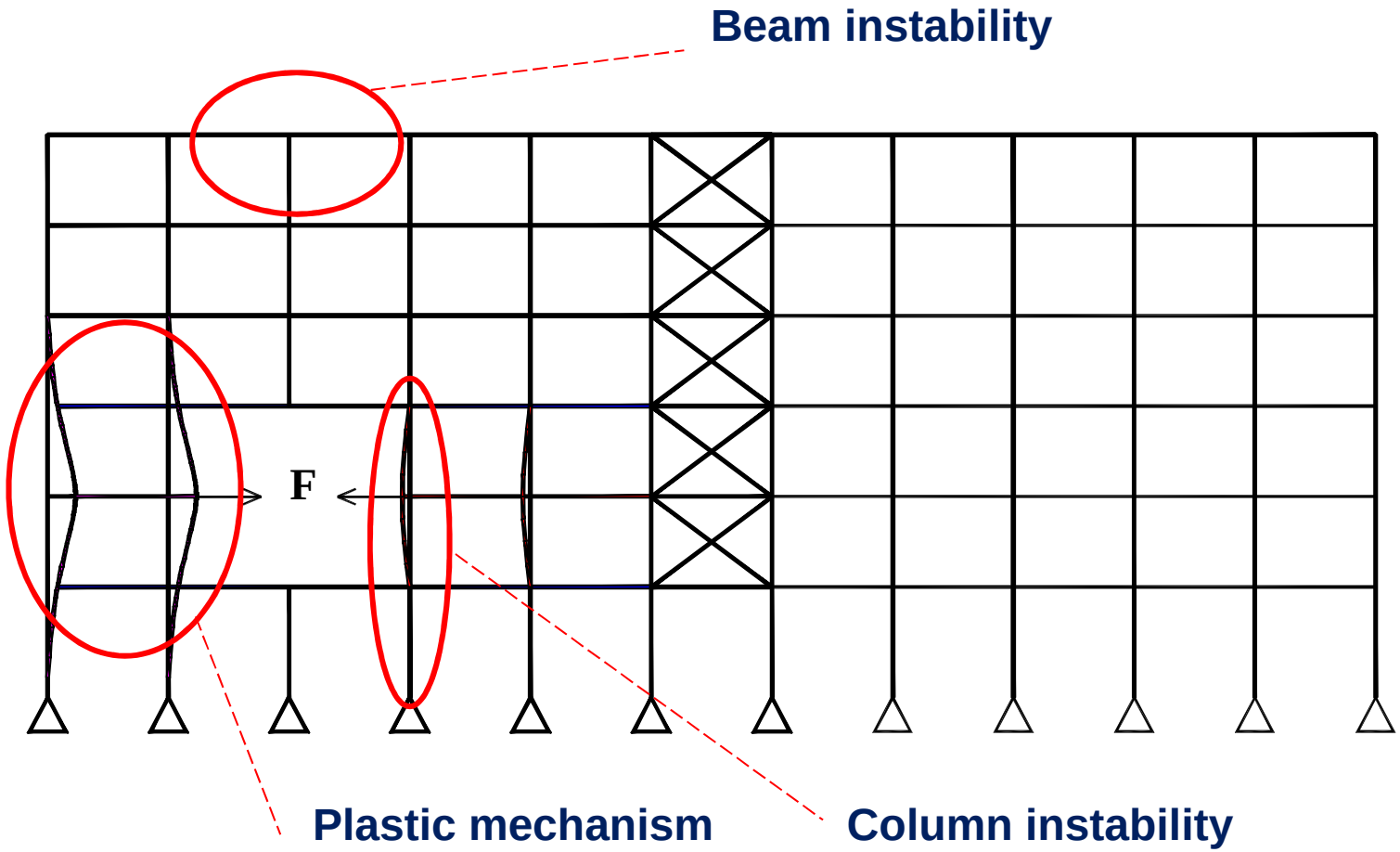
ALTERNATIVE LOAD PATH METHOD

Alternative load path

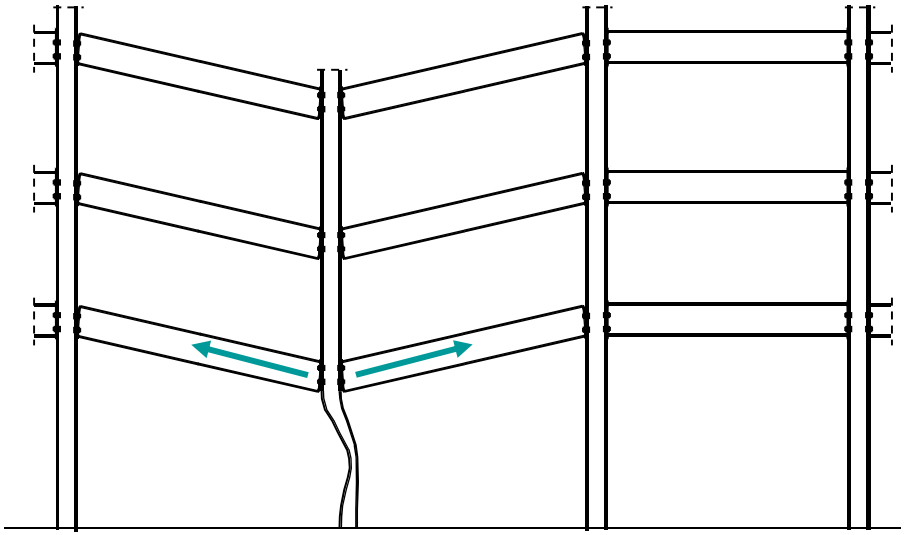


Alternative load path

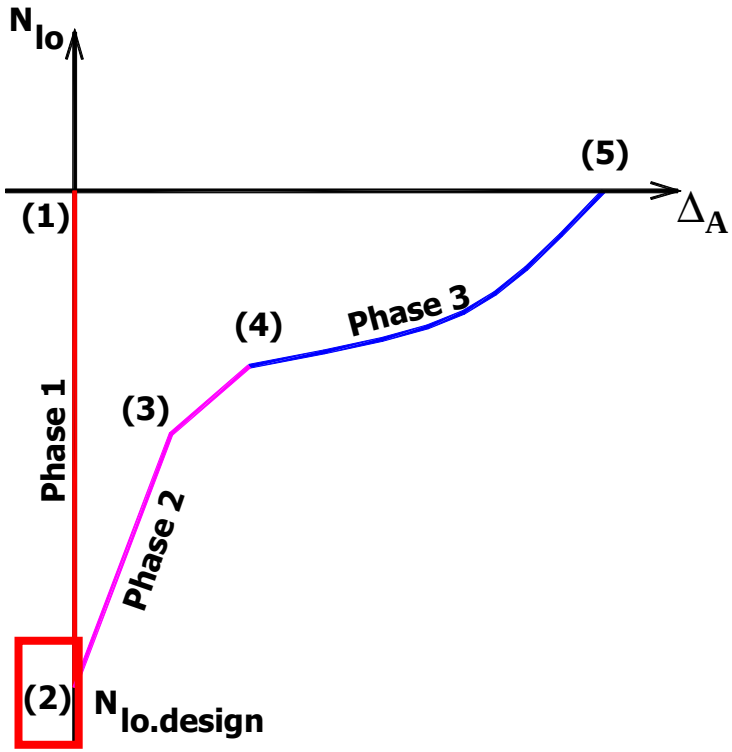


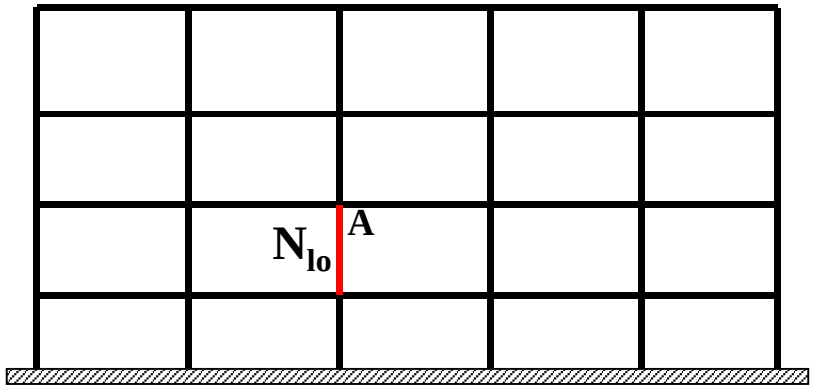
Alternative load path

- Economical approach
- Requirements:
  - tying resistance
  - ductility criteria
  - redundancy
  - …

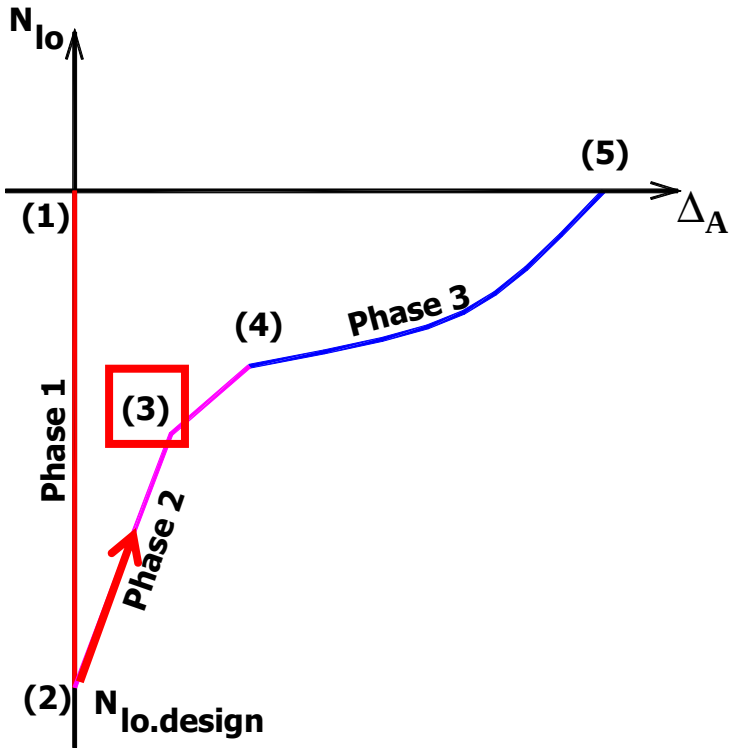


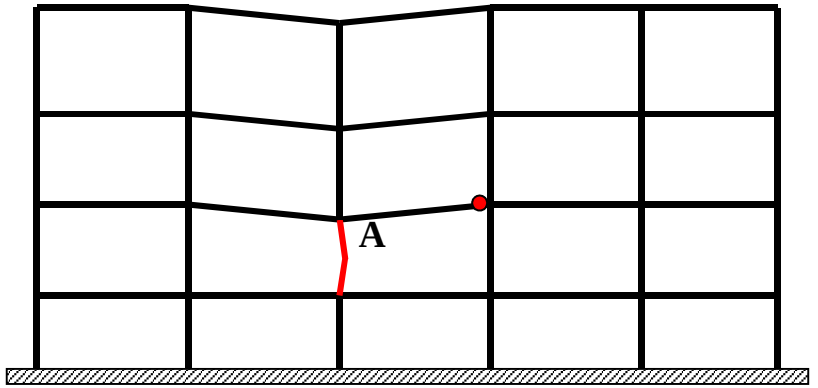
Frame response



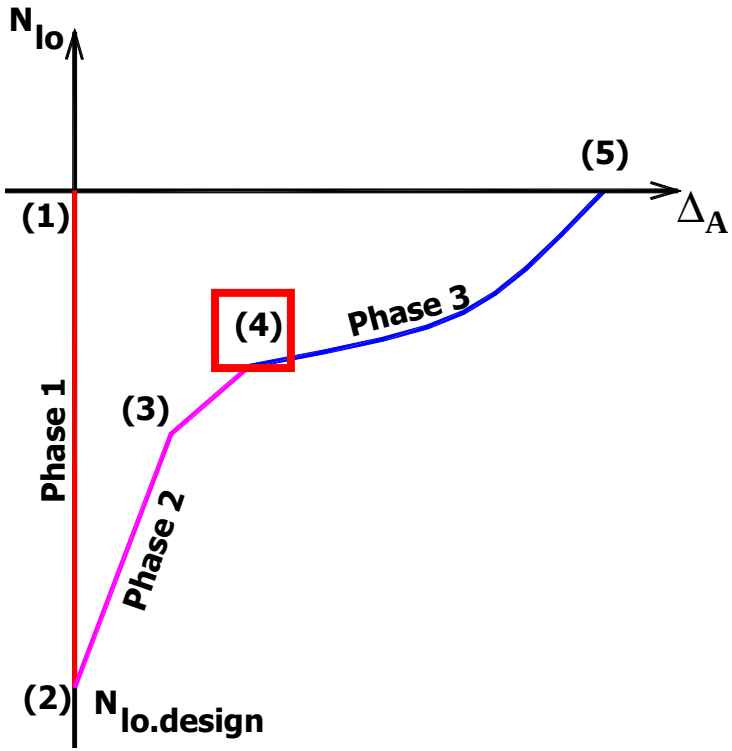


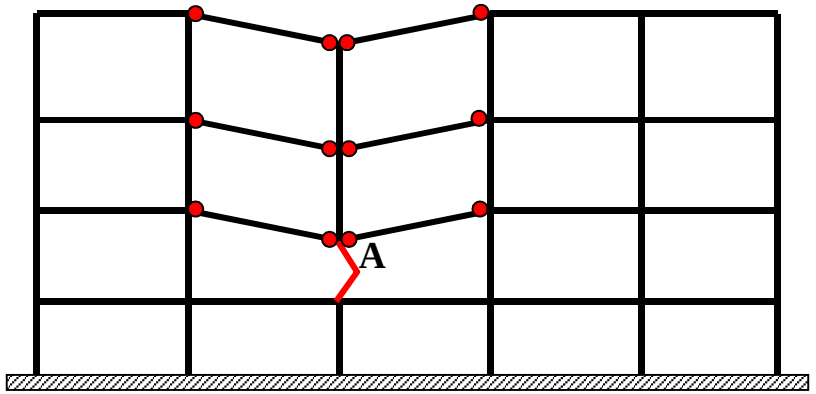
Frame response



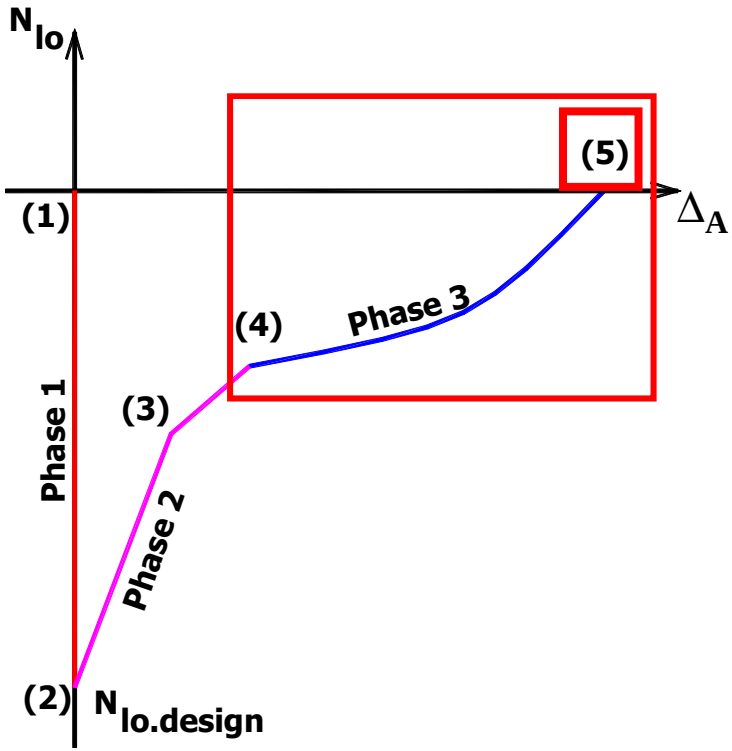


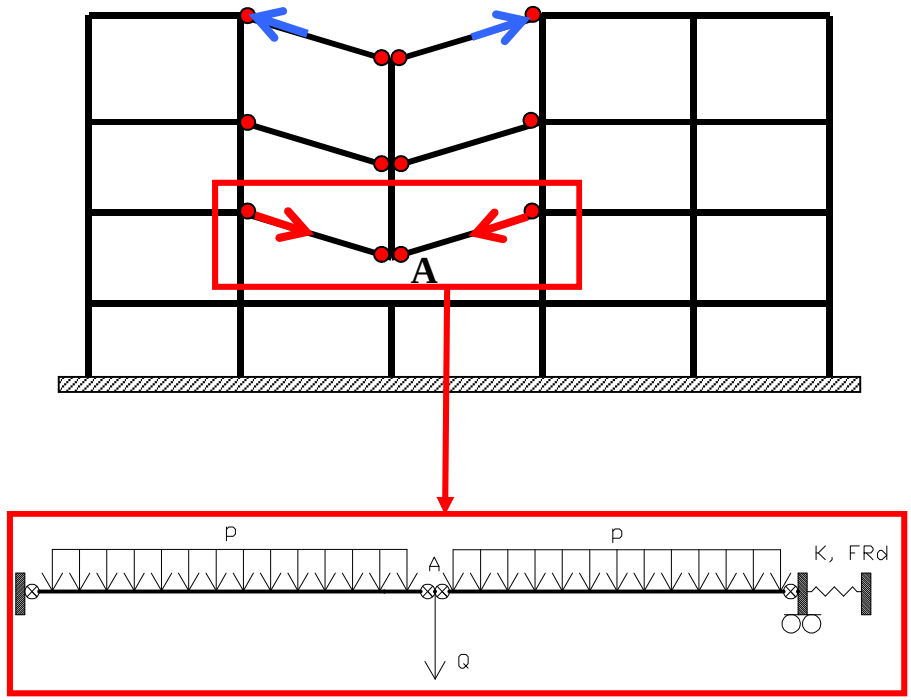
Frame response



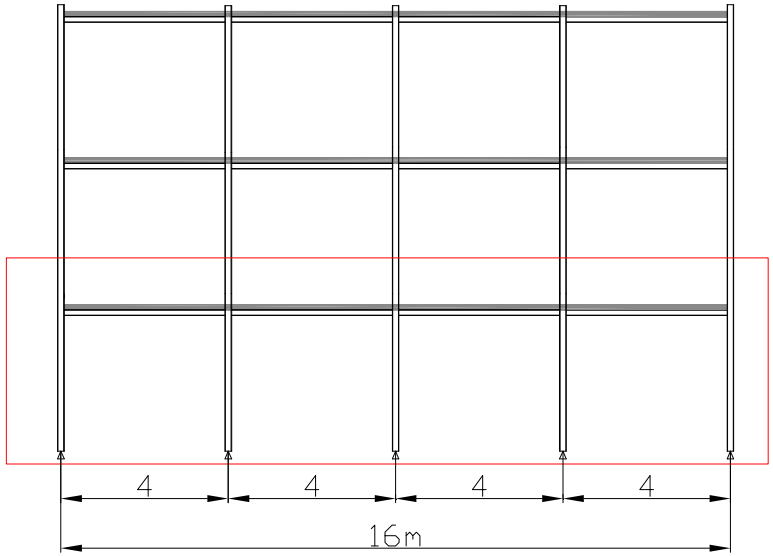


Frame response

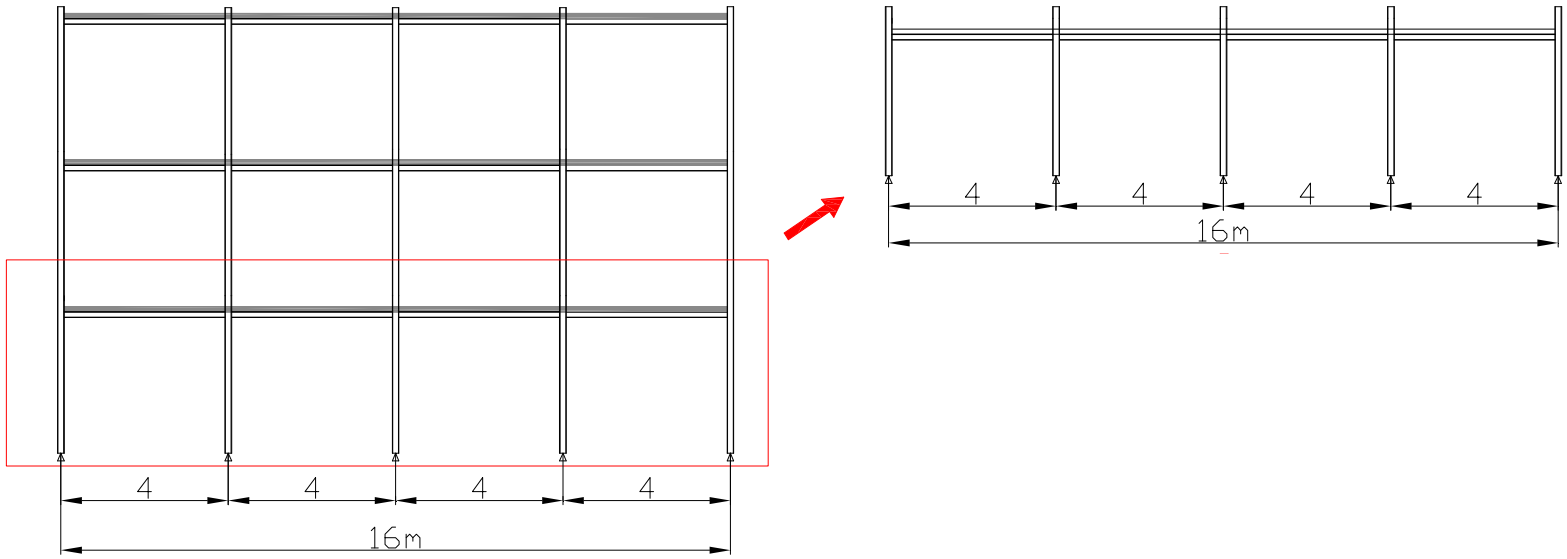




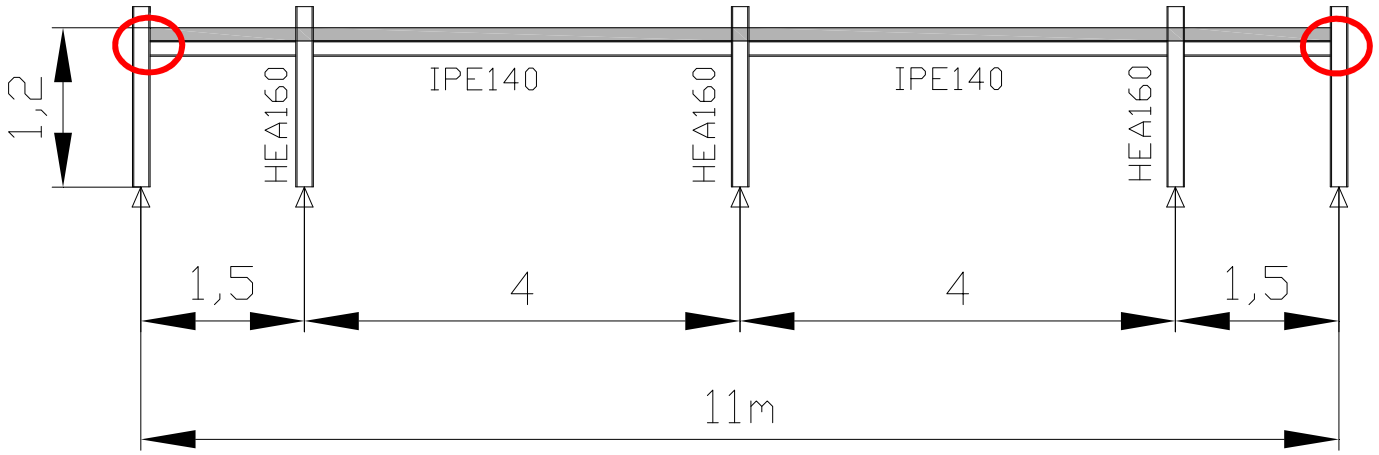
Sub-structure test

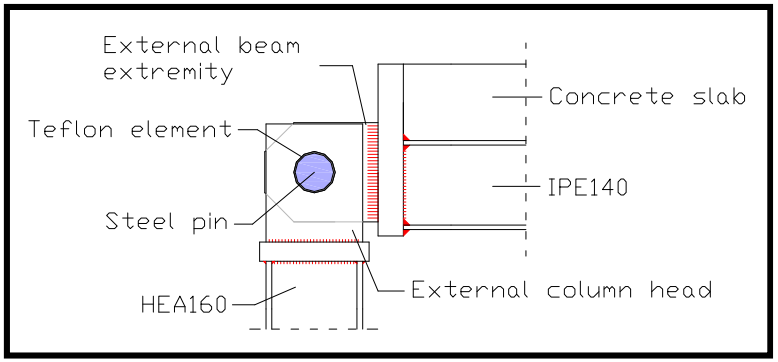


Sub-structure test

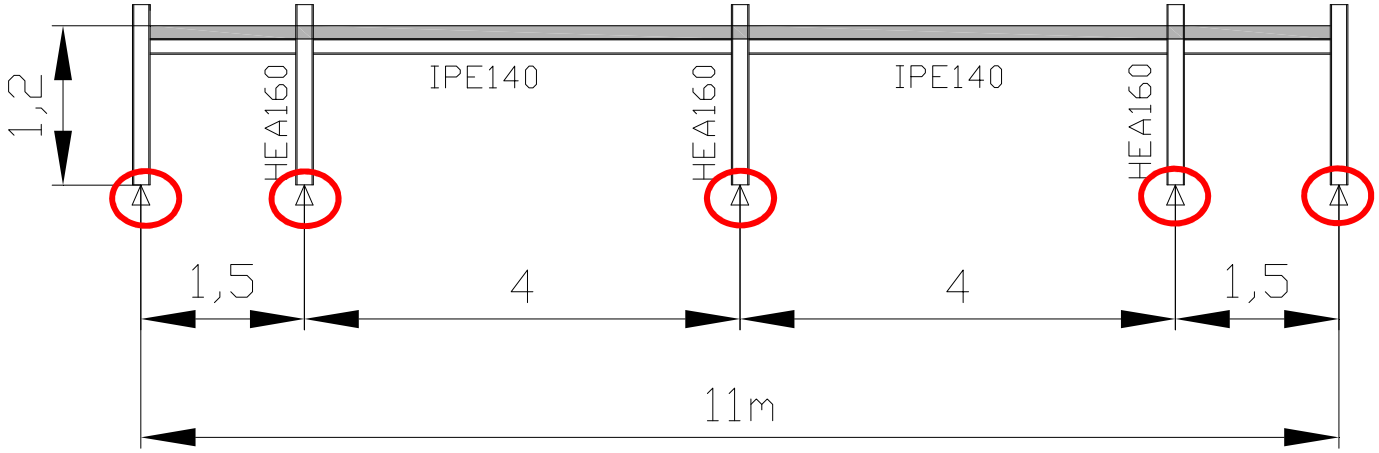


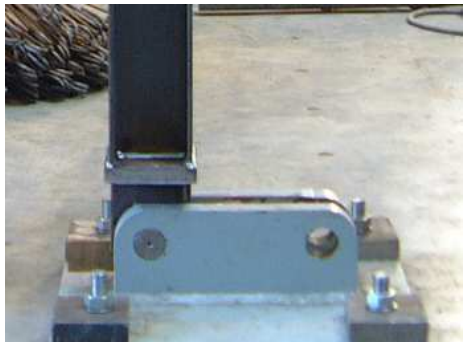
Sub-structure test

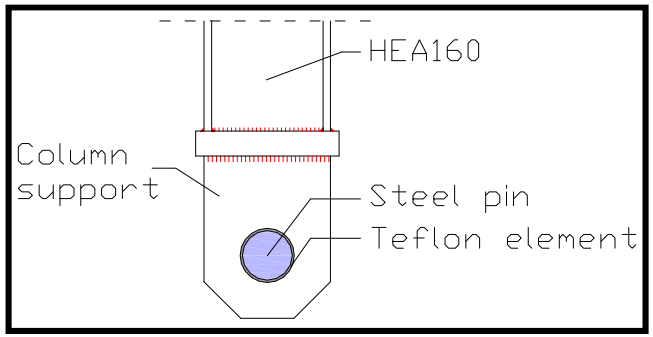




Sub-structure test

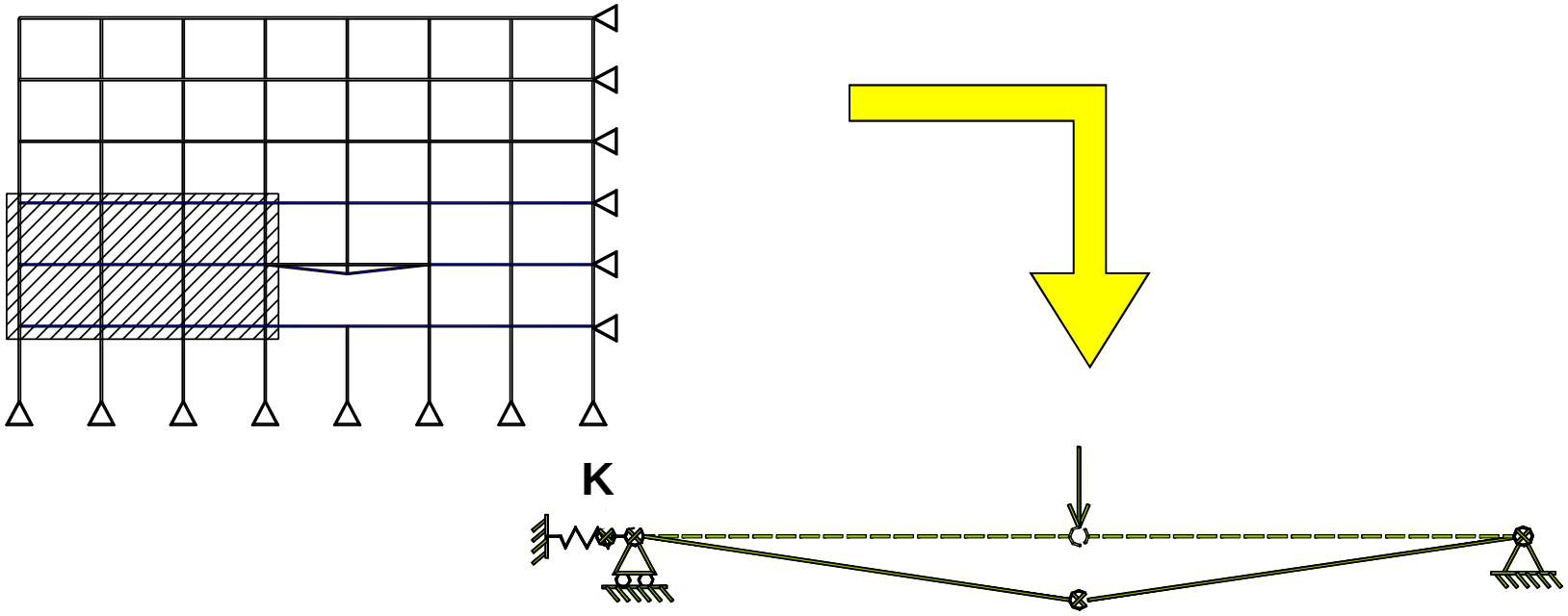






Sub-structure test

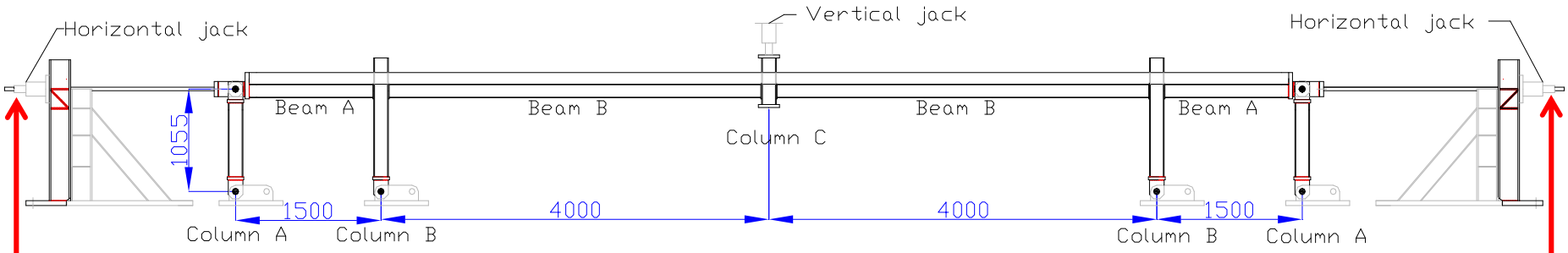
- Key parameter for the catenary action

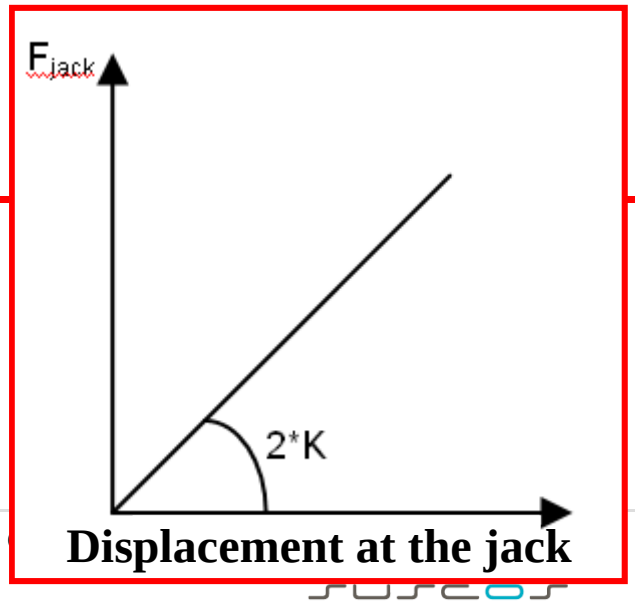


Structural restraint K ➔ catenary action

Sub-structure test

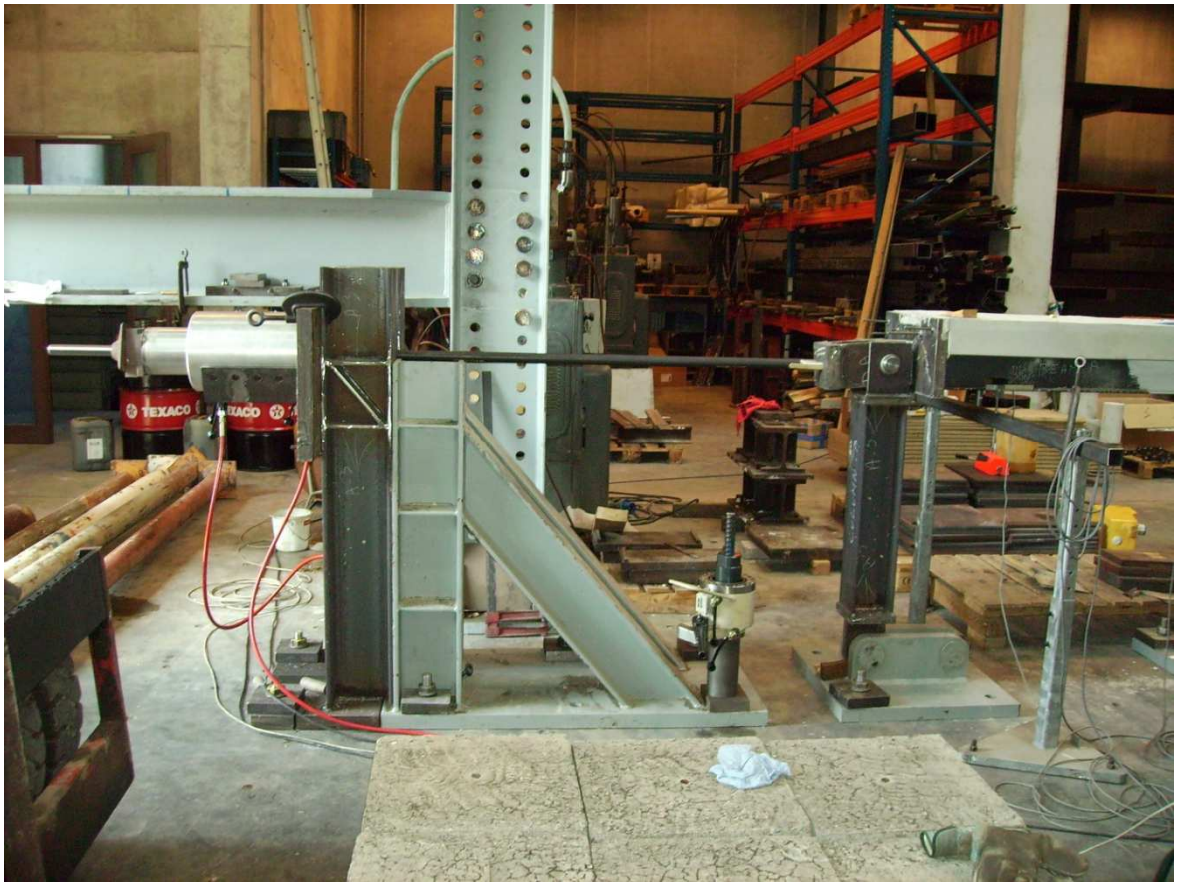
- Lateral restraint simulated by horizontal jacks



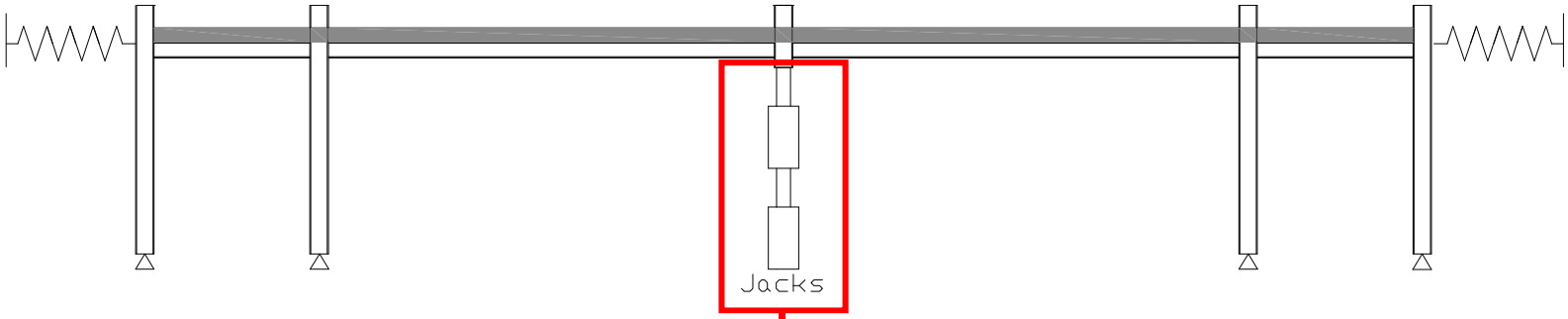


Calibration of the jacks

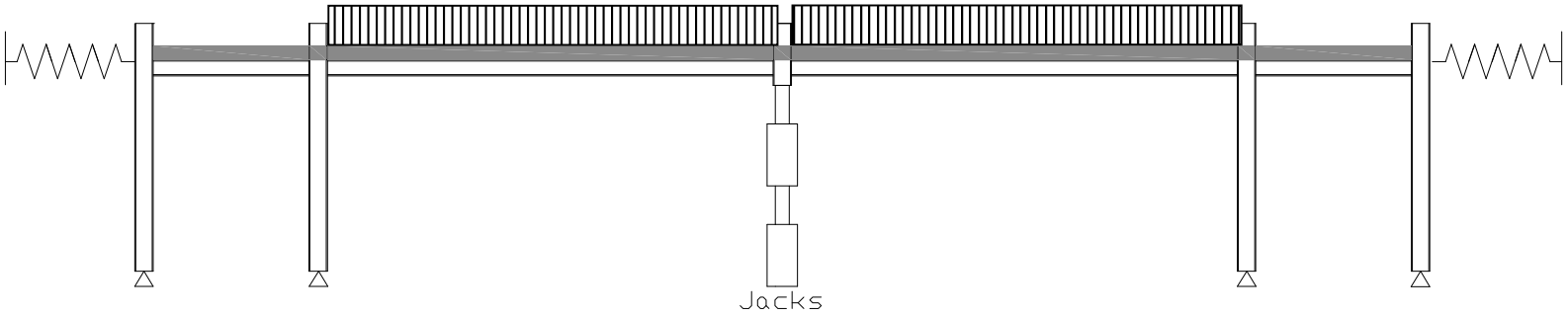
Sub-structure test

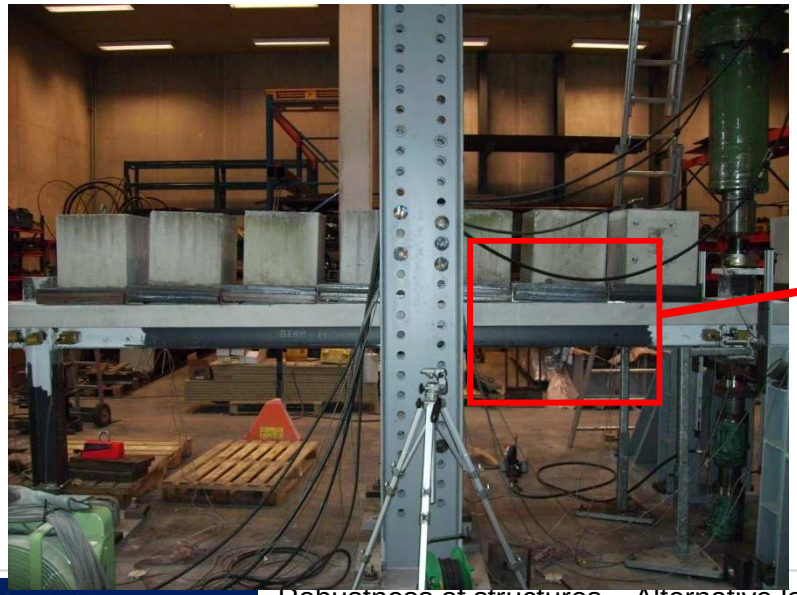


Sub-structure test

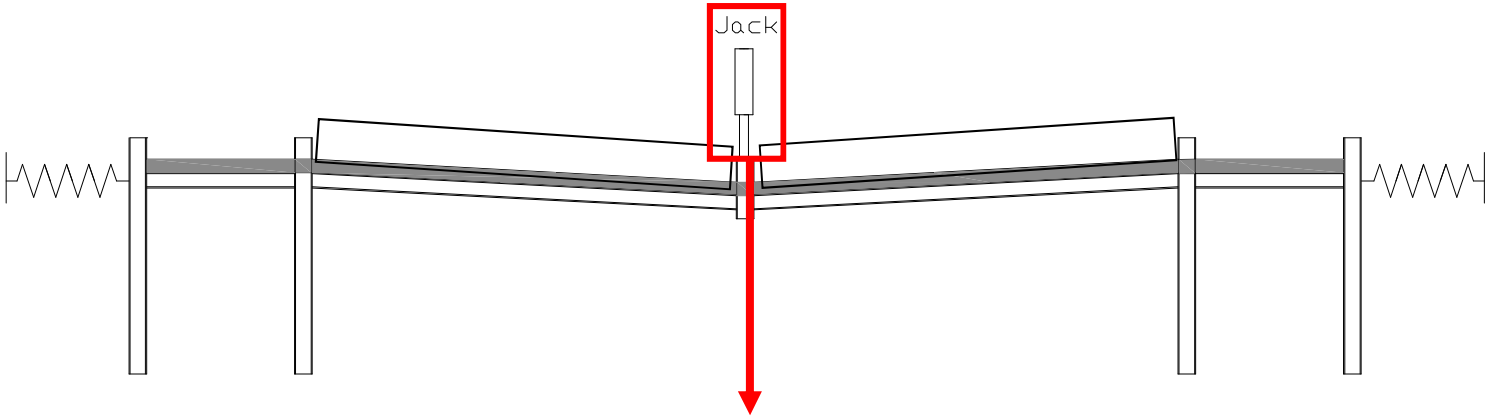


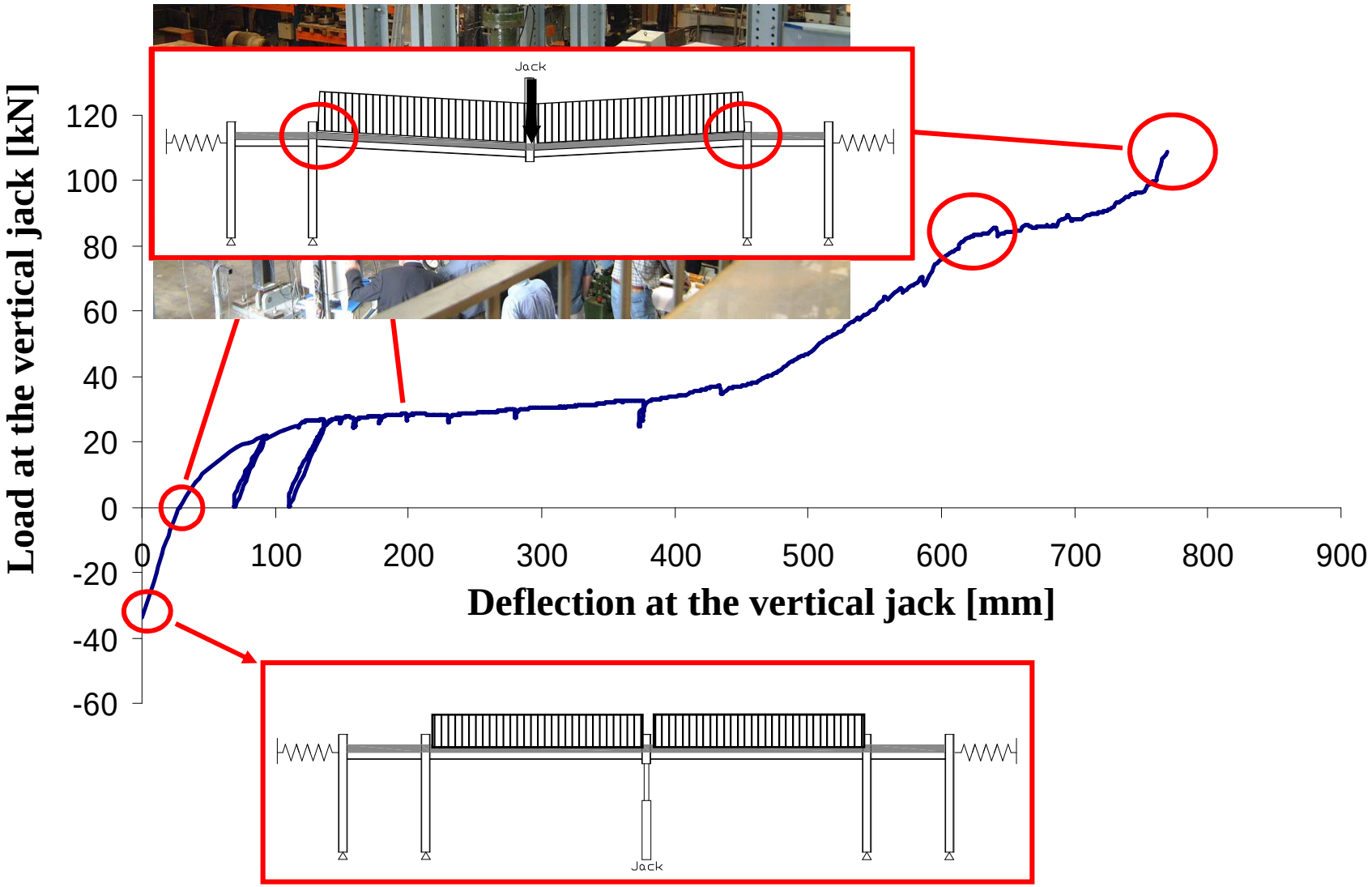
Sub-structure test



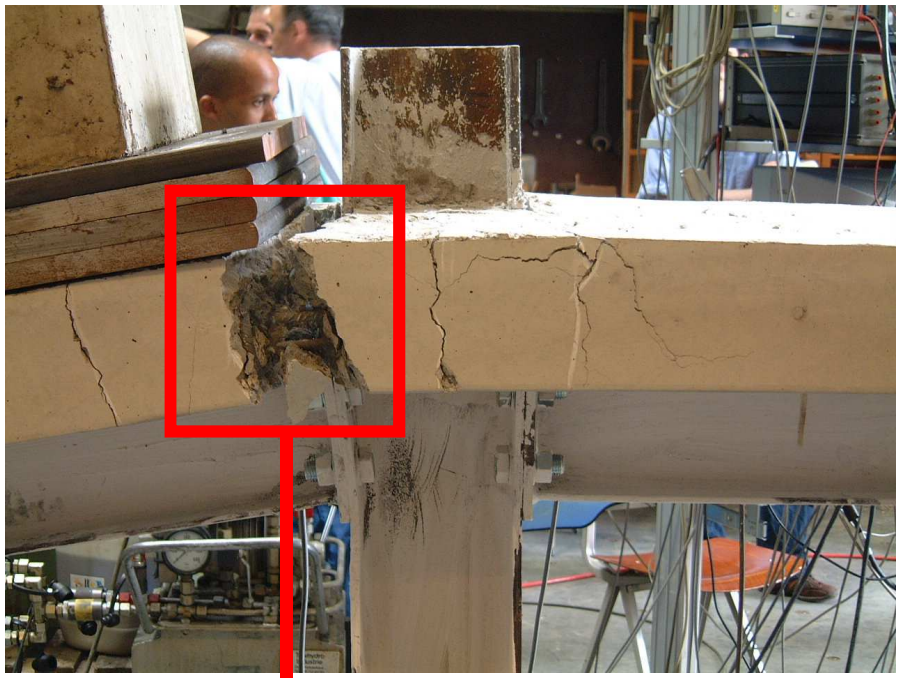


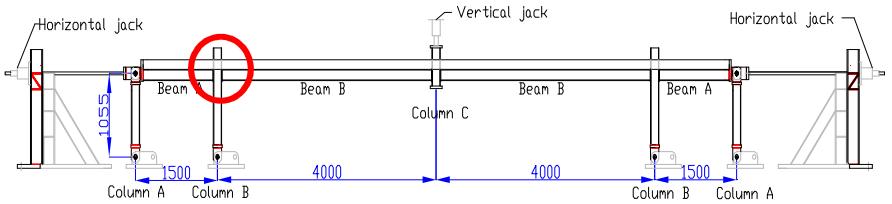
Sub-structure test



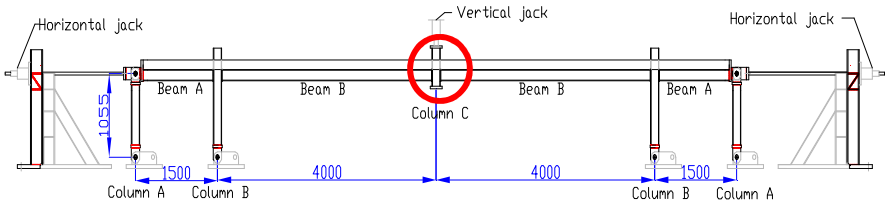

Jack
Load at the vertical jack [kN]
120
100
80
60
40
20
0
-20
-40
-60
0
100
200
300
400
500
600
700
800
900
Deflection at the vertical jack [mm]
Jack

Sub-structure test



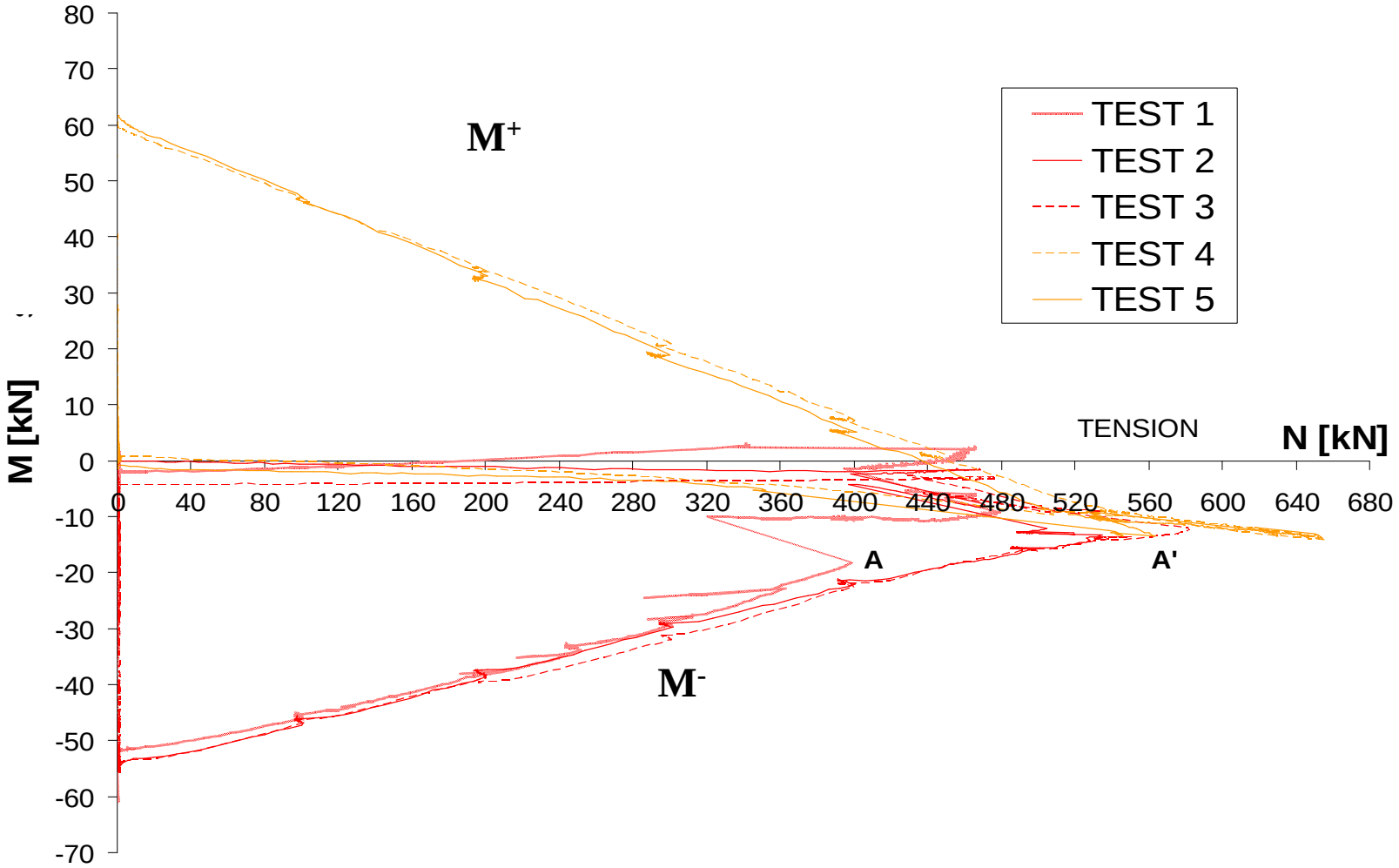


Sub-structure test

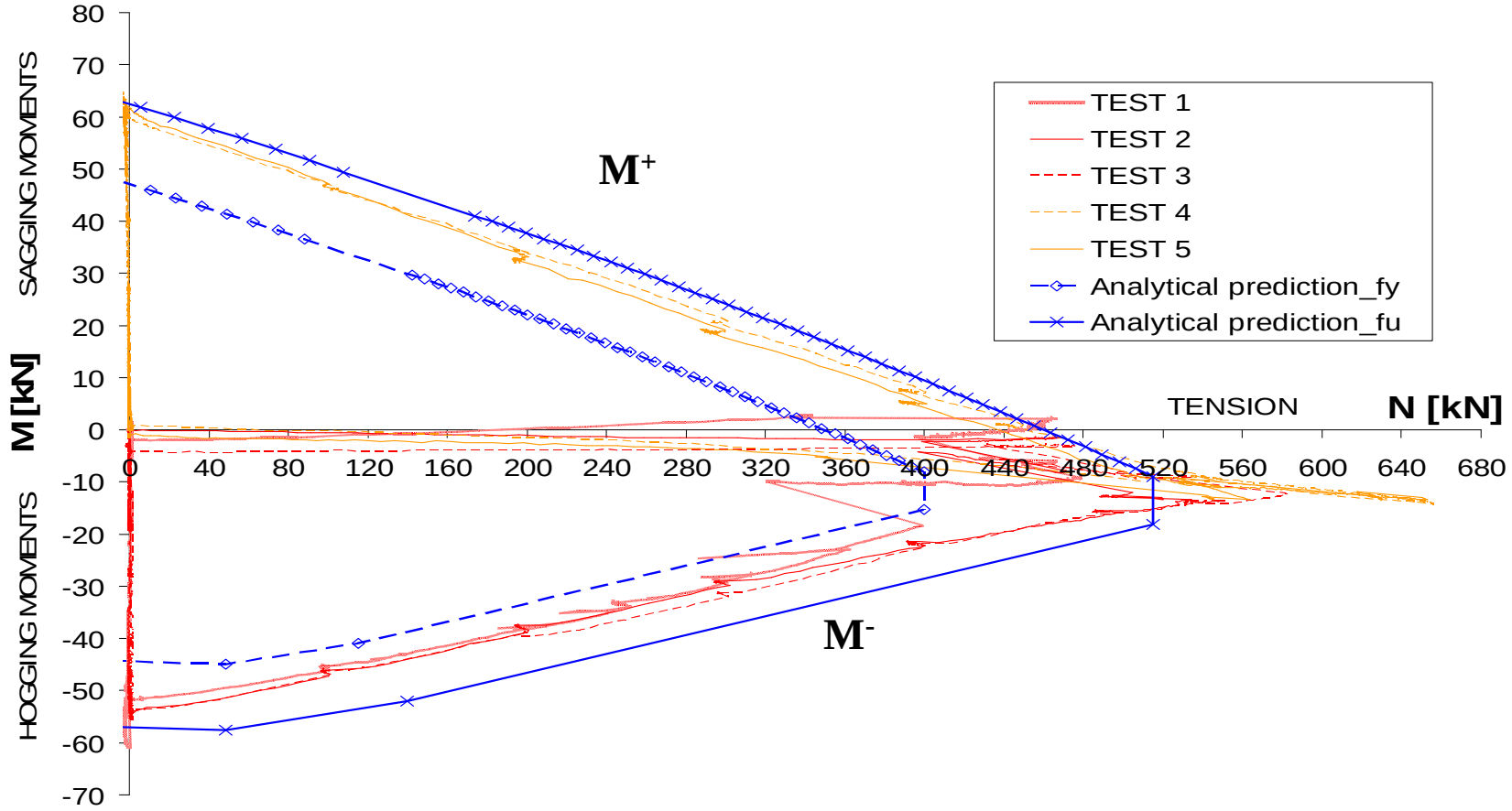


Sub-structure test

M-N response of connections



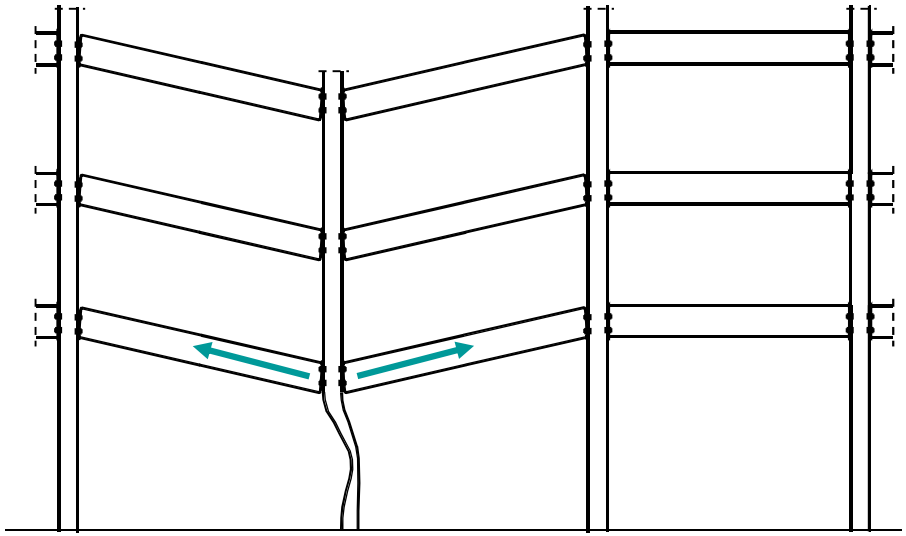
M-N response of connections



Lg

Alternative load path

- Economical approach
- Requirements:
  - tying resistance
  - Ductility criteria
  - Redundancy
  - …



Design of joints

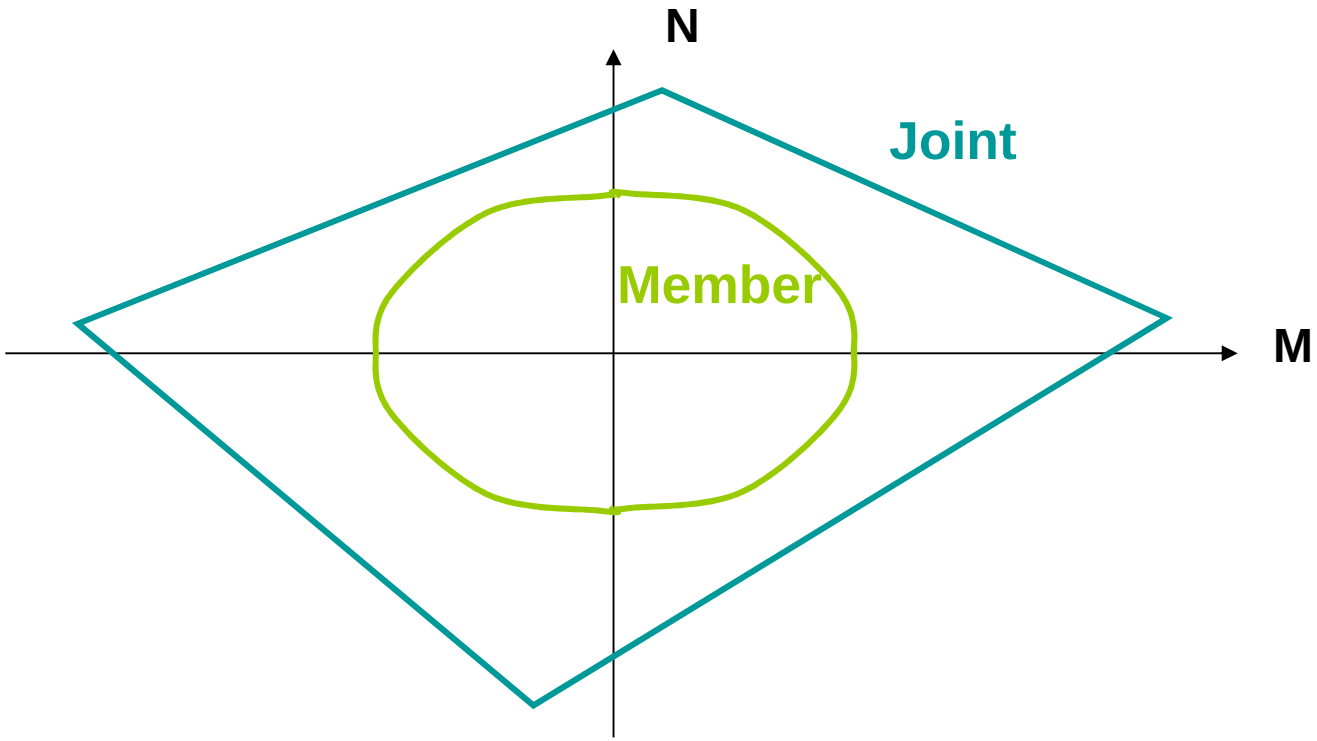
- First philosophy possibly to be followed:
  - Capacity design of joints

JOINTS ARE AT LEAST ENOUGH RESISTANT THAN THE WEAKER OT THE TWO CONNECTED MEMBERS

'overstrengthed' joints

$\Rightarrow$ robustness can only result from the frame itself

Design of joints



Design of joints

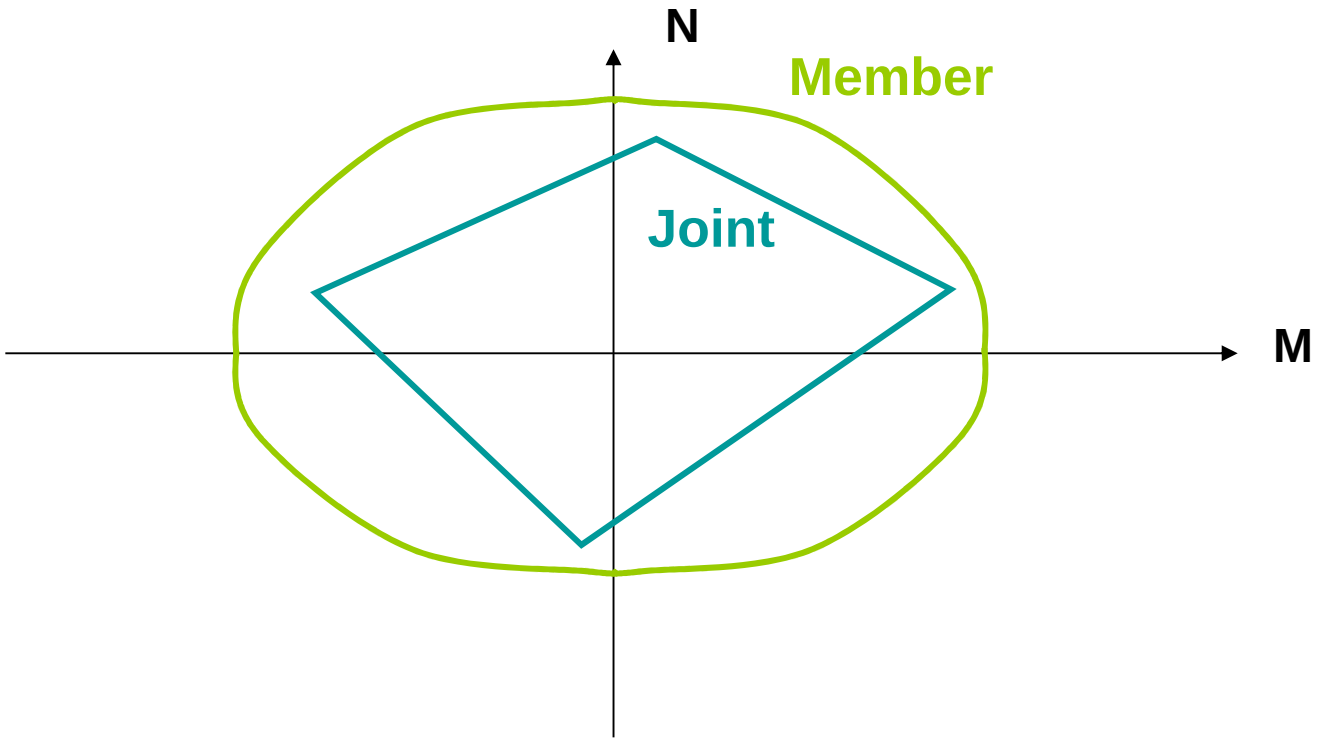
- Second philosophy possibly to be followed:
  - Structural redundancy and ductility of joints

JOINTS ARE POSSIBLY LESS RESISTANT THAN THE WEAKER OT THE TWO CONNECTED MEMBERS

'partial-strength' joints

$\Rightarrow$ redundancy and ductility required by the frame and by the joints

Design of joints



Design of joints

- Robustness requirements

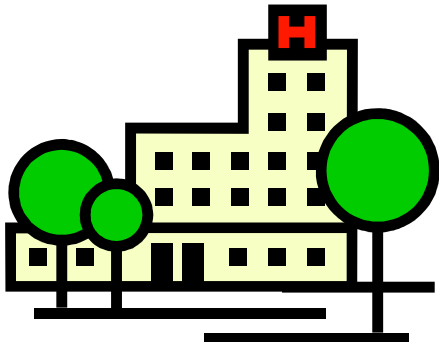
  - Redundancy
  - Ductility

in: the frame alone or

the frame and the constitutive joints

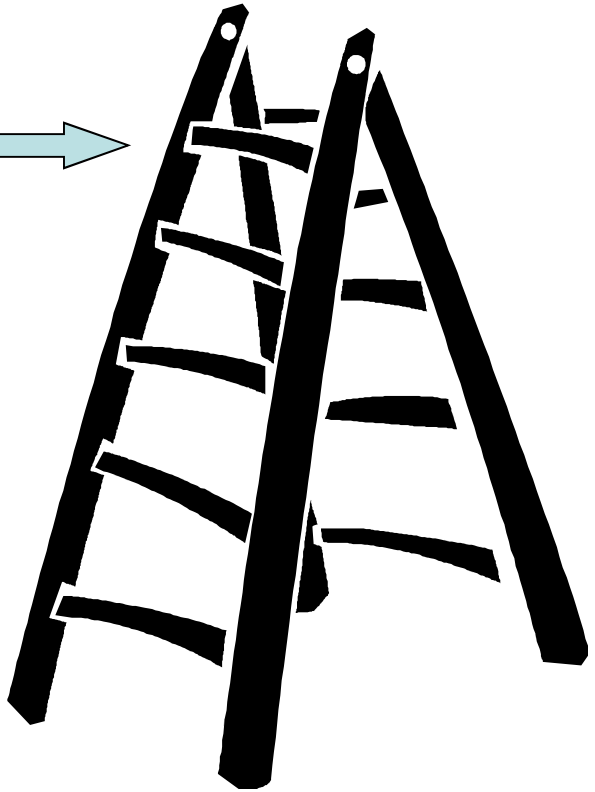
DERIVATION OF DESIGN REQUIREMENTS

Robustness index

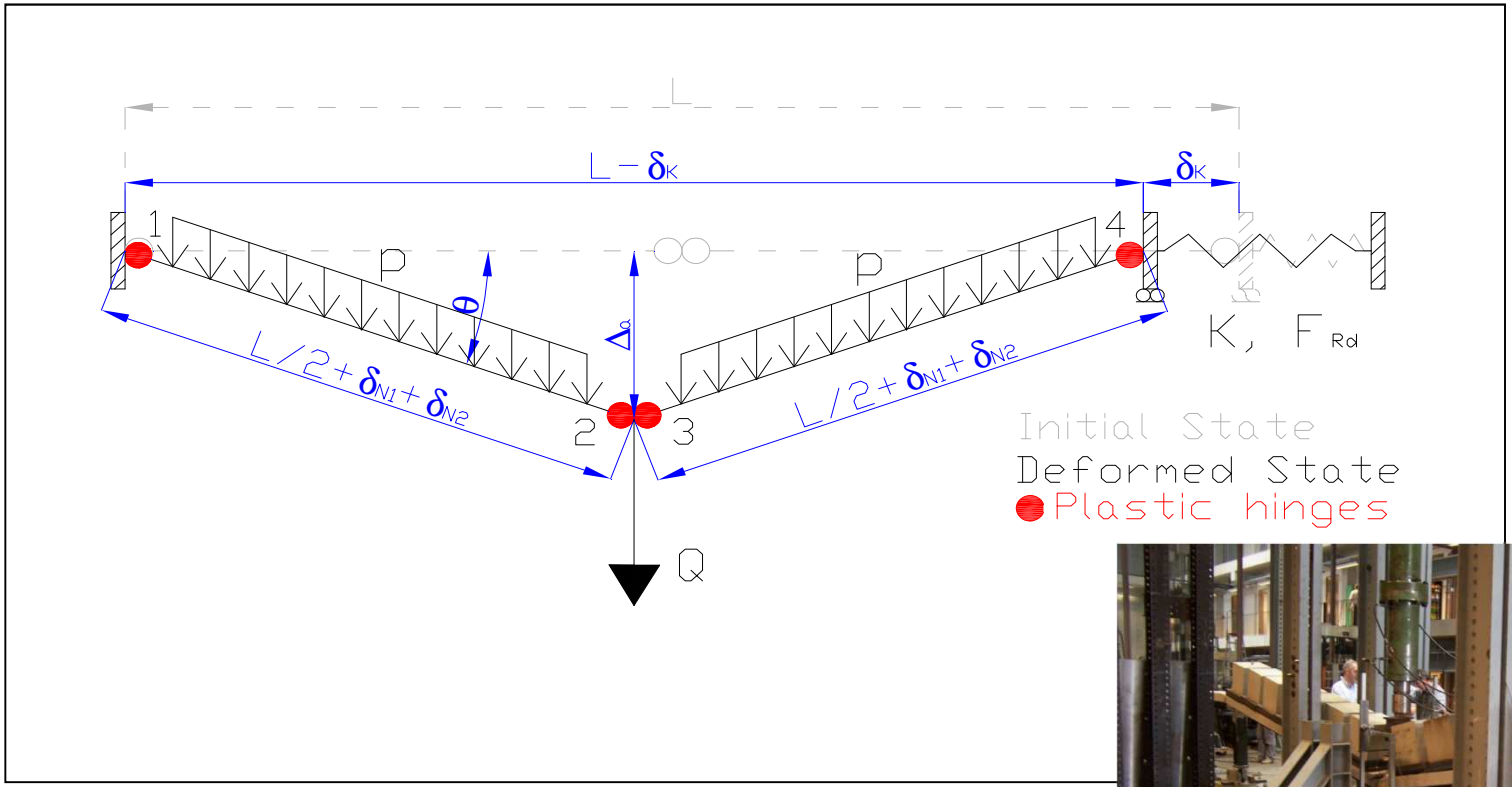


HIGH INDEX REQUIRED

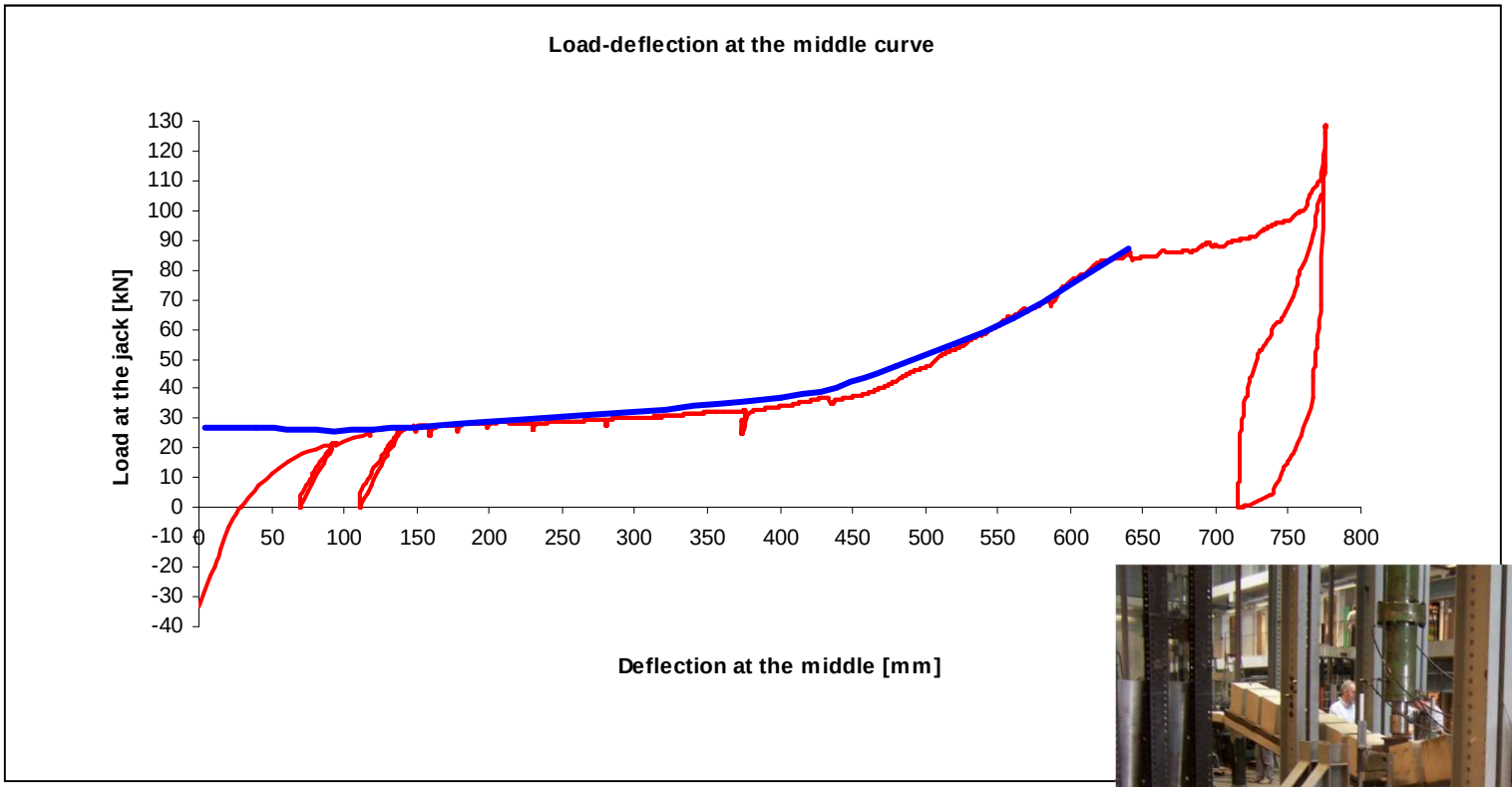
LOW INDEX REQUIRED



Development of analytical models



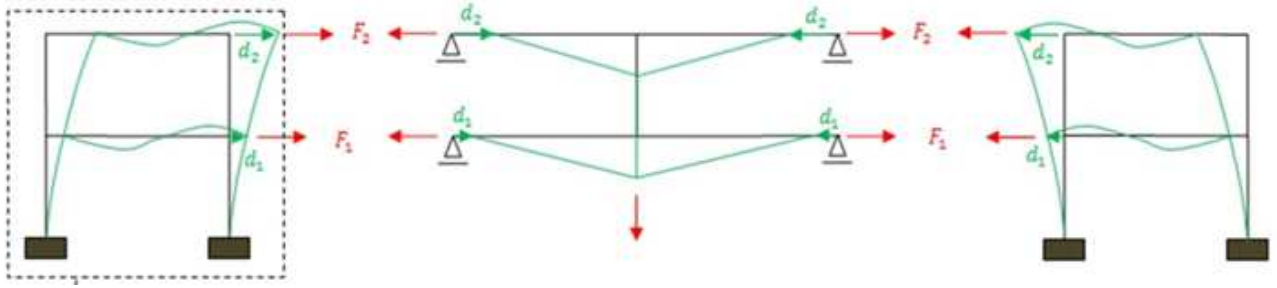
Development of analytical models



Development of analytical models

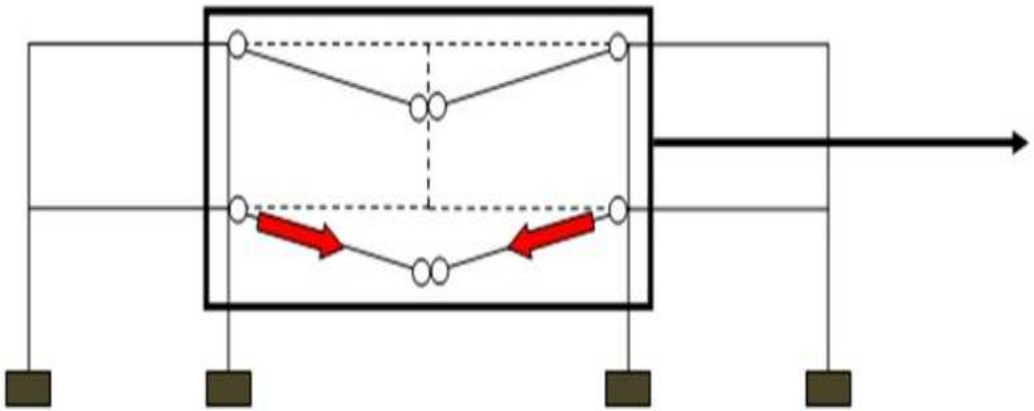
- **Limitation of the substructure** extracted by Demonceau :
  - Valid only if the normal force in the column above the column lost N_{up} is constant

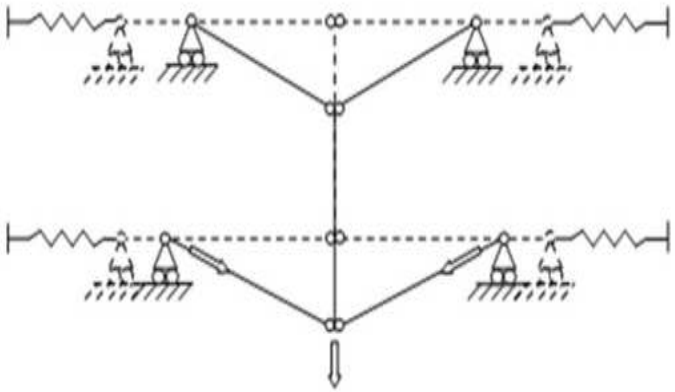
- Huvelle developments: **couplings** between the directly and indirectly affected parts of the structure and between the different storeys



Development of analytical models

- New substructure model:



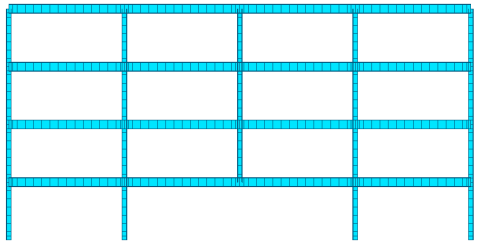


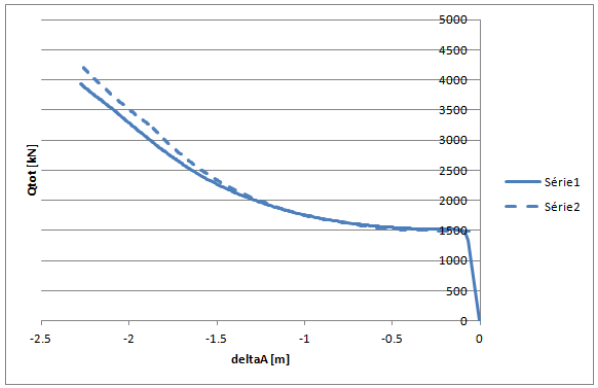
Development of analytical models

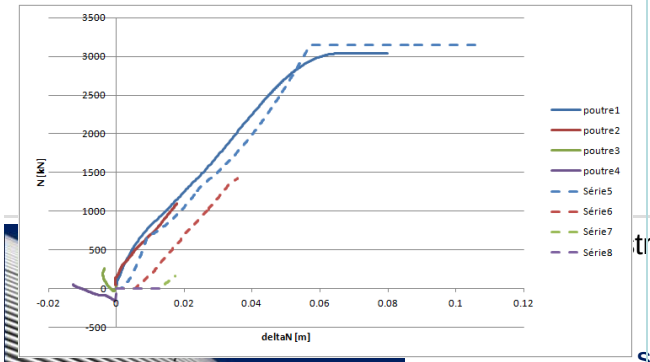
- Matlab program that allows the computation of the response of a frame submitted to a column loss
- Input data's
  - number of span, number of stories
  - length of the spans, height of the stories
  - beam and columns cross sections
  - E, fy
  - location of the lost column in the frame

Development of analytical models

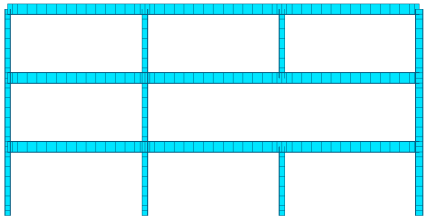
CAS 1

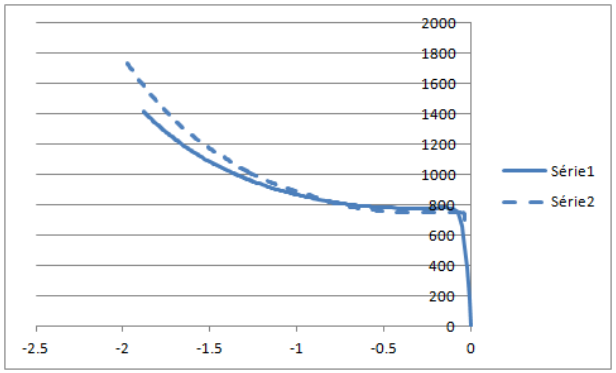


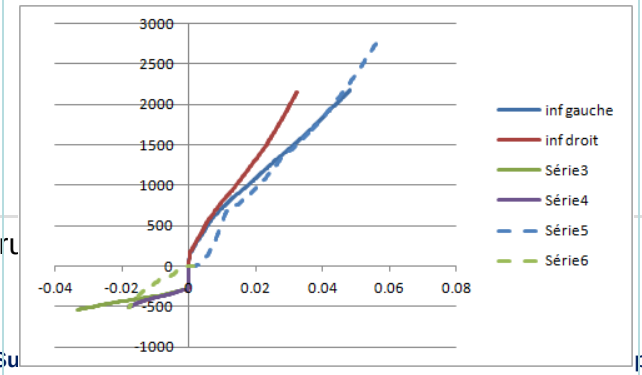




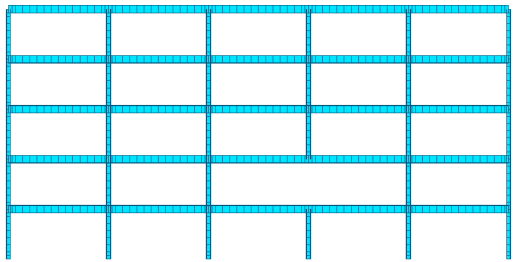
CAS 4

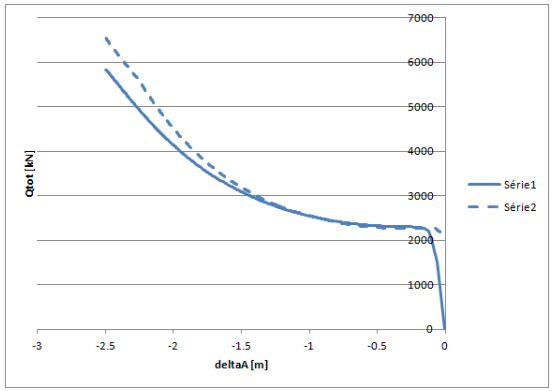


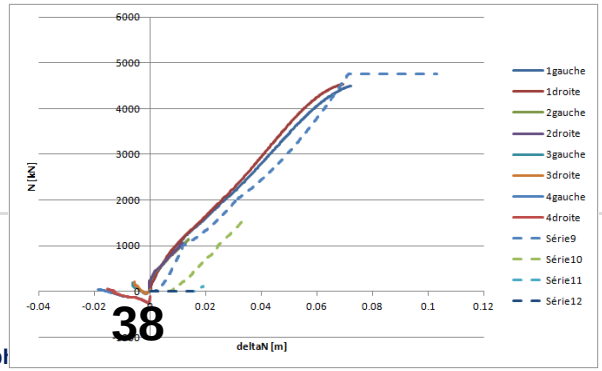




CAS 6

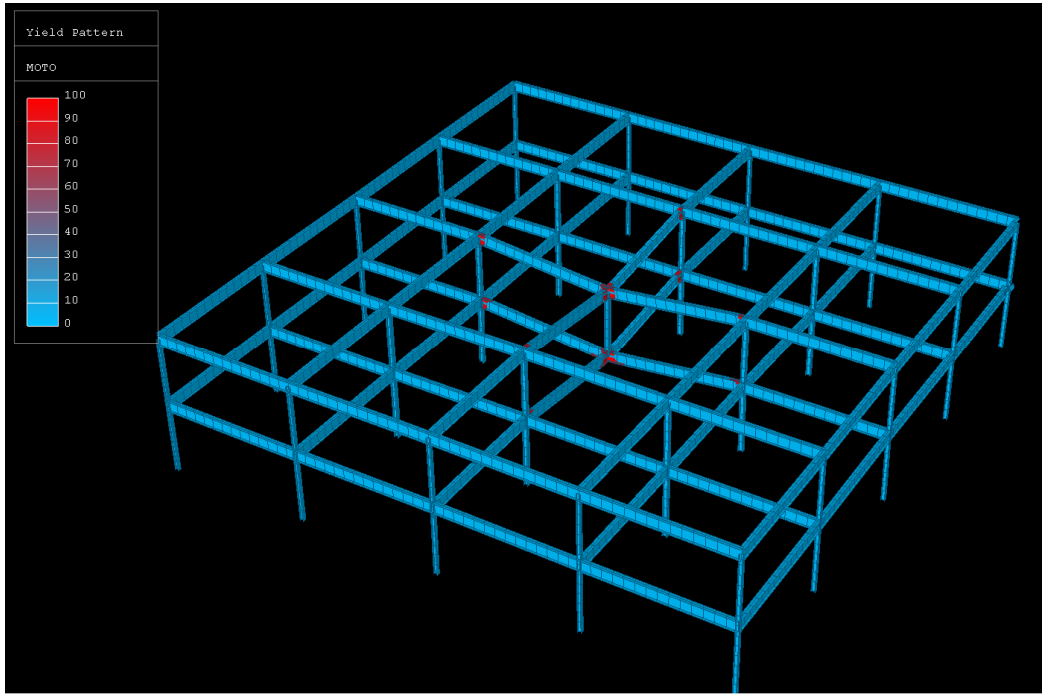






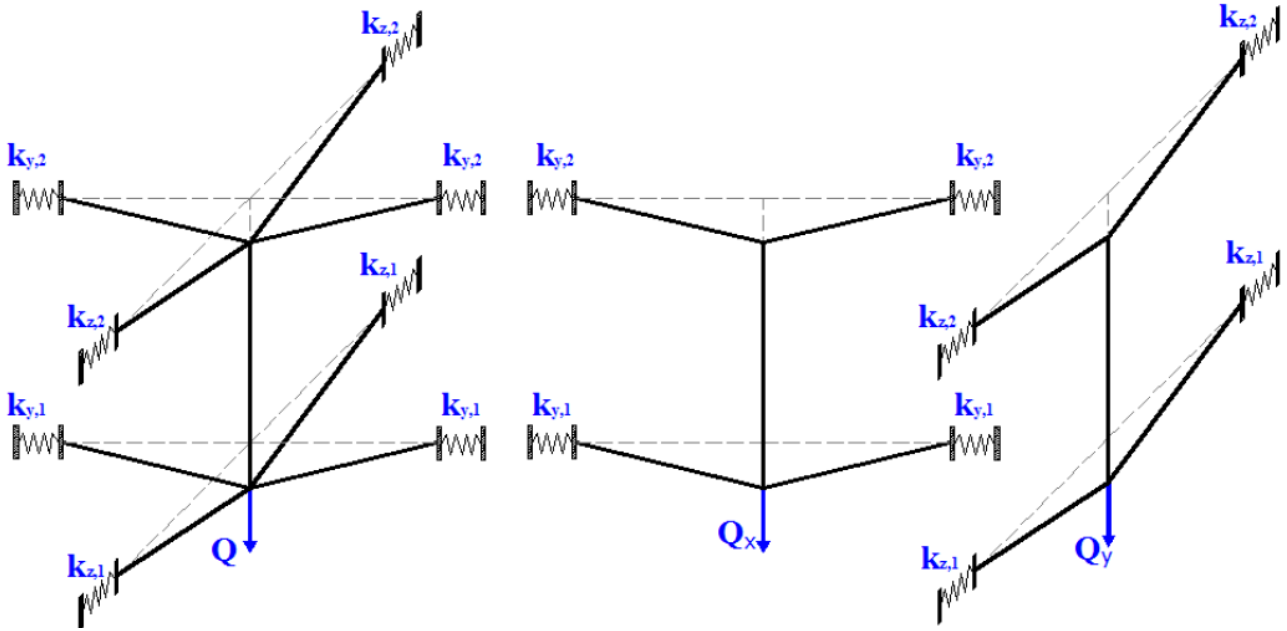
Development of analytical models

- Master dissertation on 3D aspects within SUSCOS program
- Use of the new analytical methods, generalization of the Matlab program



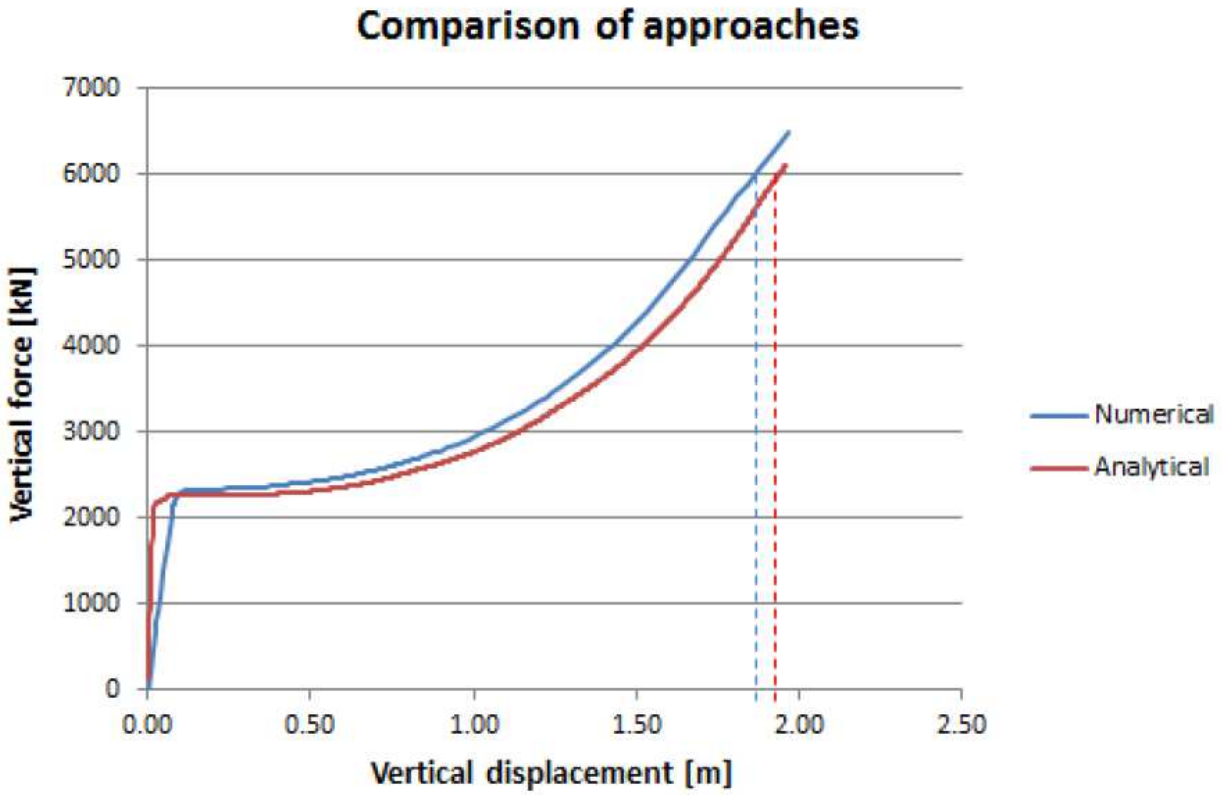
Development of analytical models

- Main conclusion:
  - The ULg model appears to be accurate for the prediction of a 3D structure



Development of analytical models

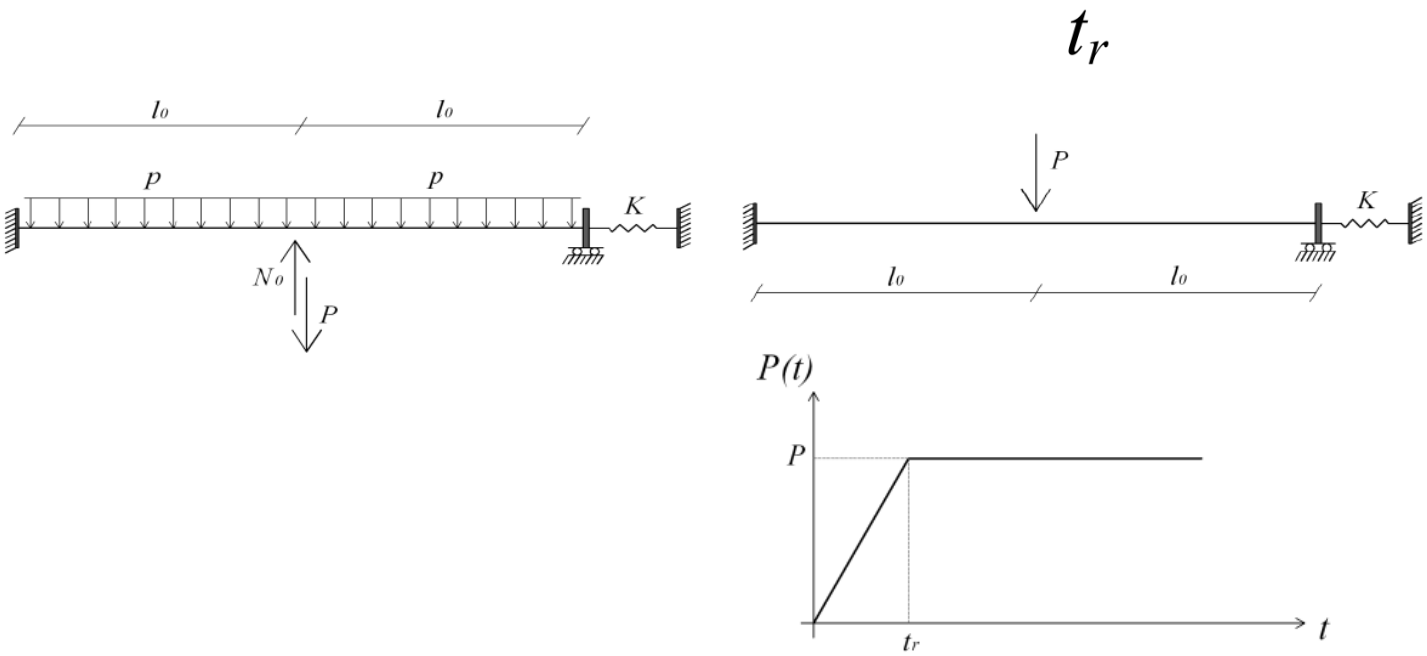
- Example of comparison:



P. Jaspart, ULg

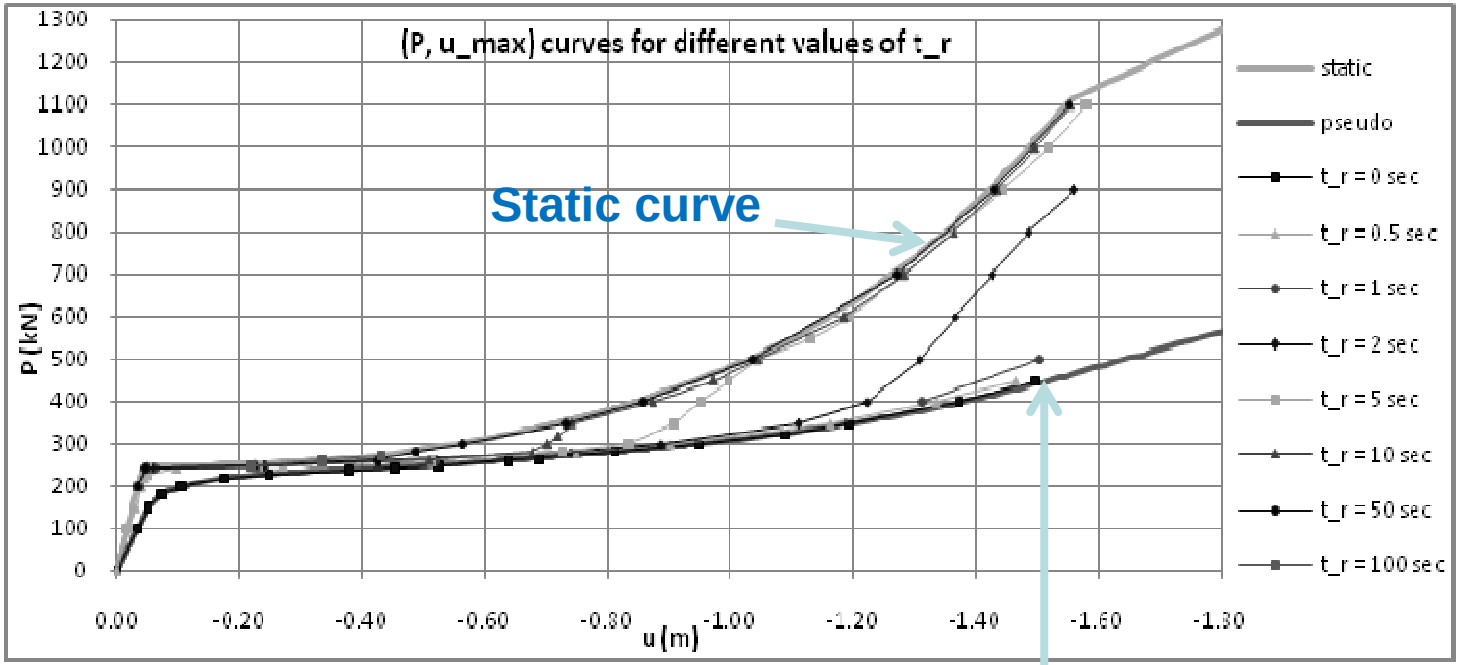
Development of analytical models

- Description of the considered substructure and loading



Development of analytical models

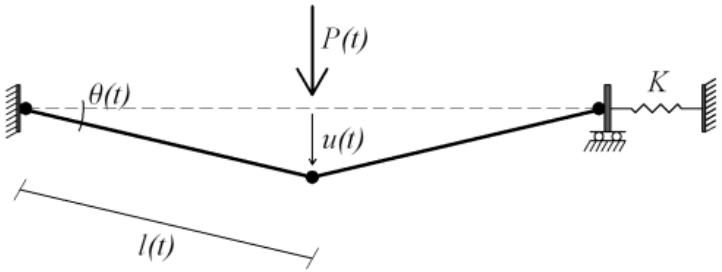
- Maximum dynamic displacement according to the value of the load P (or Q) and its rise time :



Pseudo-static curve gives the maximum displacement reached if P is applied instantaneously.

Development of analytical models

- Basic simplified model was developed under the following assumptions :
  - Rigid-plastic model ;
  - Beams are supposed to be infinitely rigid and thus keeping a constant length ,
  - Plastic hinges are submitted to a moment $M = M_{pl}$ assumed to be constant, interaction with the axial load being neglected ;
  - Moderate displacements :
    - $\theta \approx u/l \left(\approx \sin(\theta) \approx tg(\theta)\right)$
    - $\cos(\theta) = 1 - \frac{\theta^2}{2} = 1 - u^2/(2l^2)$



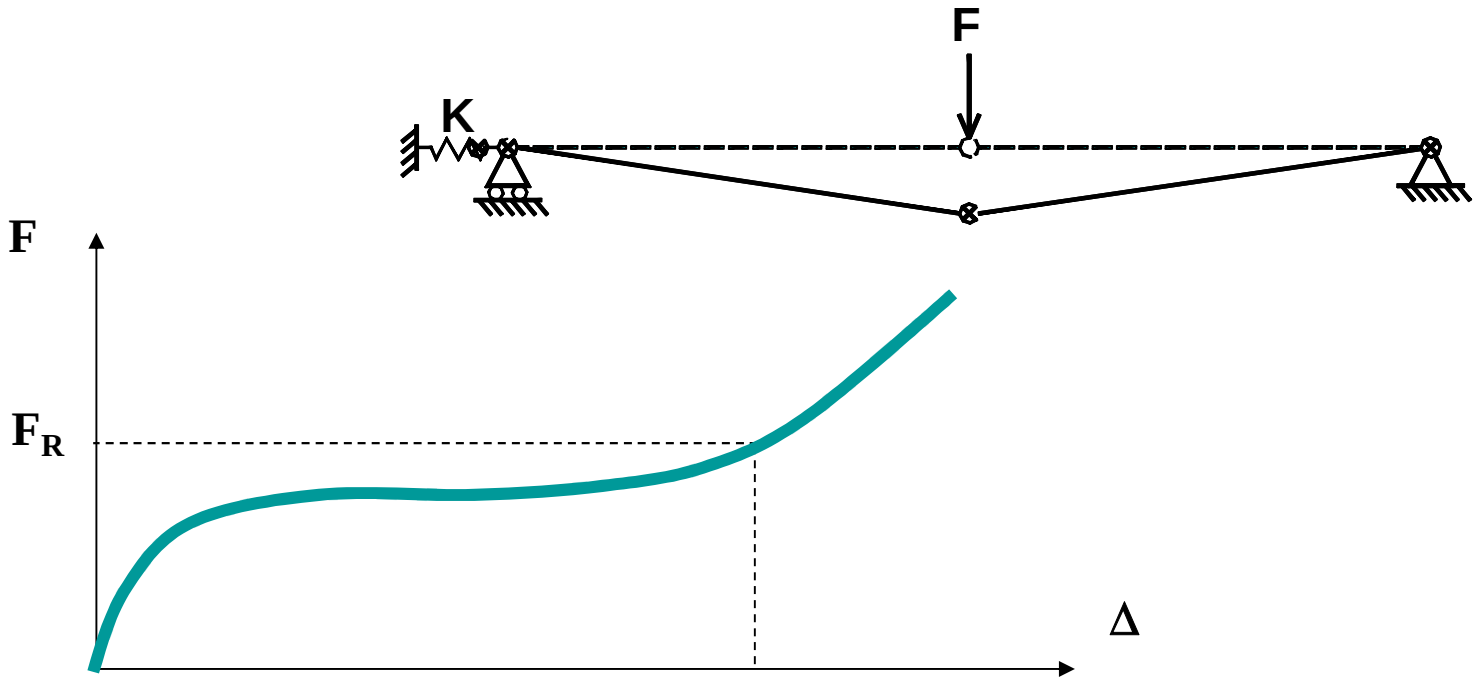
- Energy equation :

$$E_{kinetic} + E_{hinges} + E_{spring} = W_e \Leftrightarrow \frac{1}{2} M_g . \dot{u}^2 + 4. \int M(\theta) . d\theta + \int F_K(\delta_K) . d\delta_K = \int P(u) . du \qquad (1)$$

$$\Leftrightarrow M_g . \ddot{u}(t) + \frac{4. M_{pl}}{l} + \frac{2K}{l^2} \cdot u(t)^3 = P(t) = P. \frac{t}{t_r} \qquad (2)$$

Derivation of requirements

- Available resistance and ductility requirements

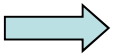


Derivation of requirements

- Design requirements transformed into design guidelines
- Example of such guidelines for joints

Design requirements

- F_u > …..
- Φ_u > ……
- failure modes
- …



Design guidelines for joints

- percentage of reinforcement
- provisions for t/d ratios
- favourable failure modes
- …

To be or not to be … robust

To be or not to be … robust