

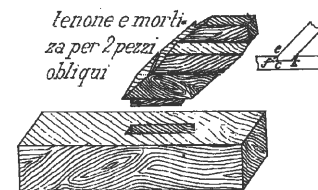


COST Action E55



LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

Mechanical behaviour of traditional carpentry joints in service conditions



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Timber Structures Division

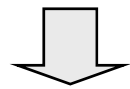
National Laboratory for Civil Engineering (**LNEC**)

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Background

> Assessment of ancient timber structures

- Necessary to know {
 - mechanical properties of elements and joints
 - influence of different strengthening techniques
- Building codes focus mainly modern industrialized joints



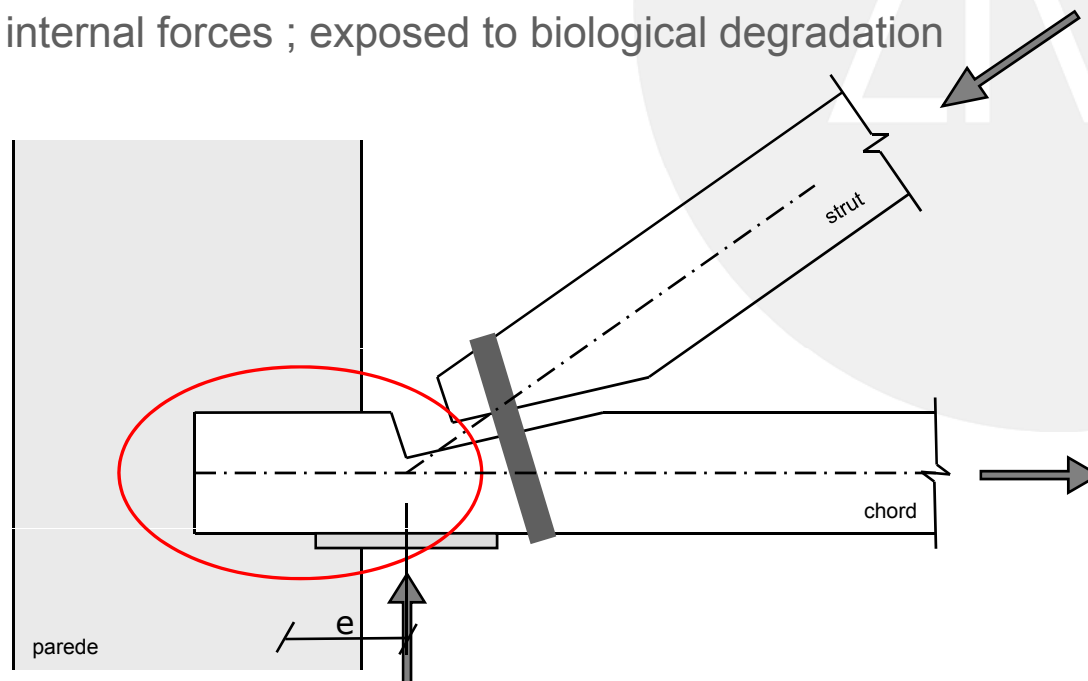
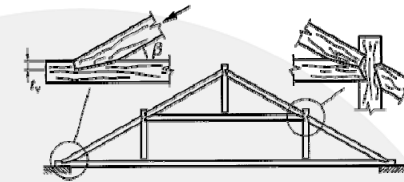
> Traditional timber carpentry joints

- Necessary to establish {
 - behaviour models
 - influence of several aspects (geometry, metal parts, moisture content, biological degradation, ...)
 - guidelines to future interventions in ancient timber structures

Background

> Connection between the strut and the chord

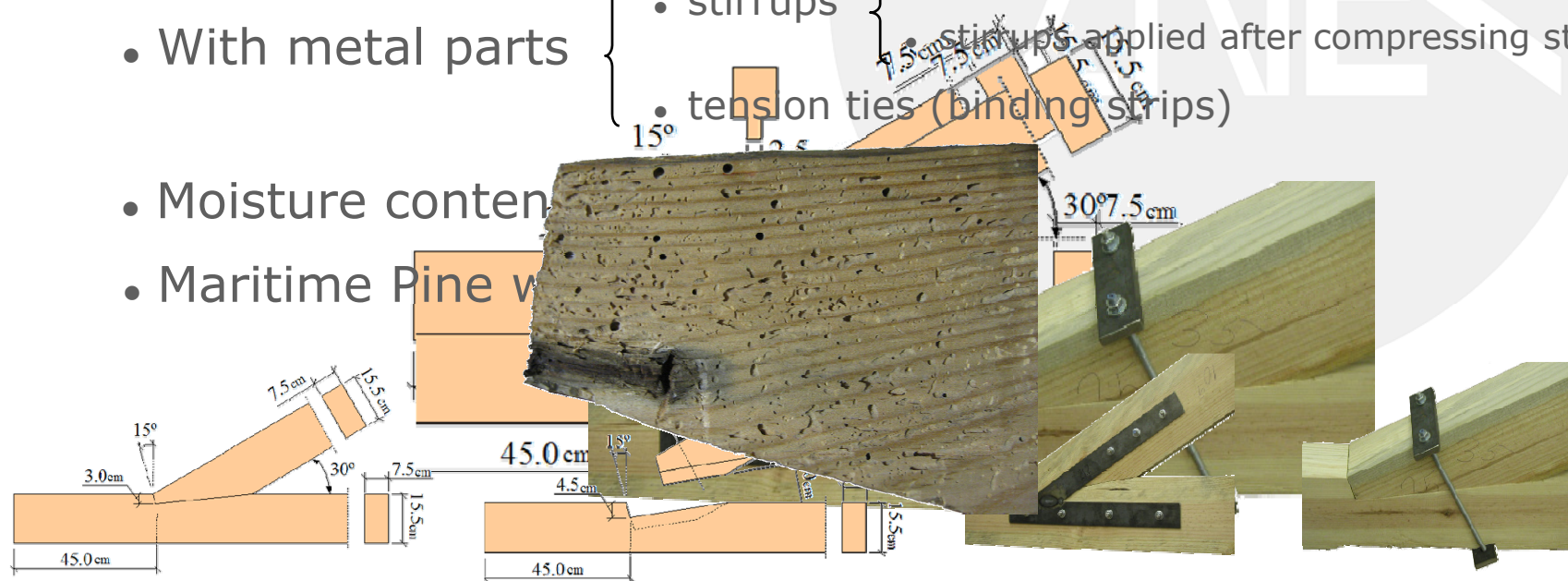
- Front notched joint
- Directs the horizontal component of the compression force to the chord
- Metal parts are often used
- High internal forces ; exposed to biological degradation



Test program

> Tested configurations, materials and geometry

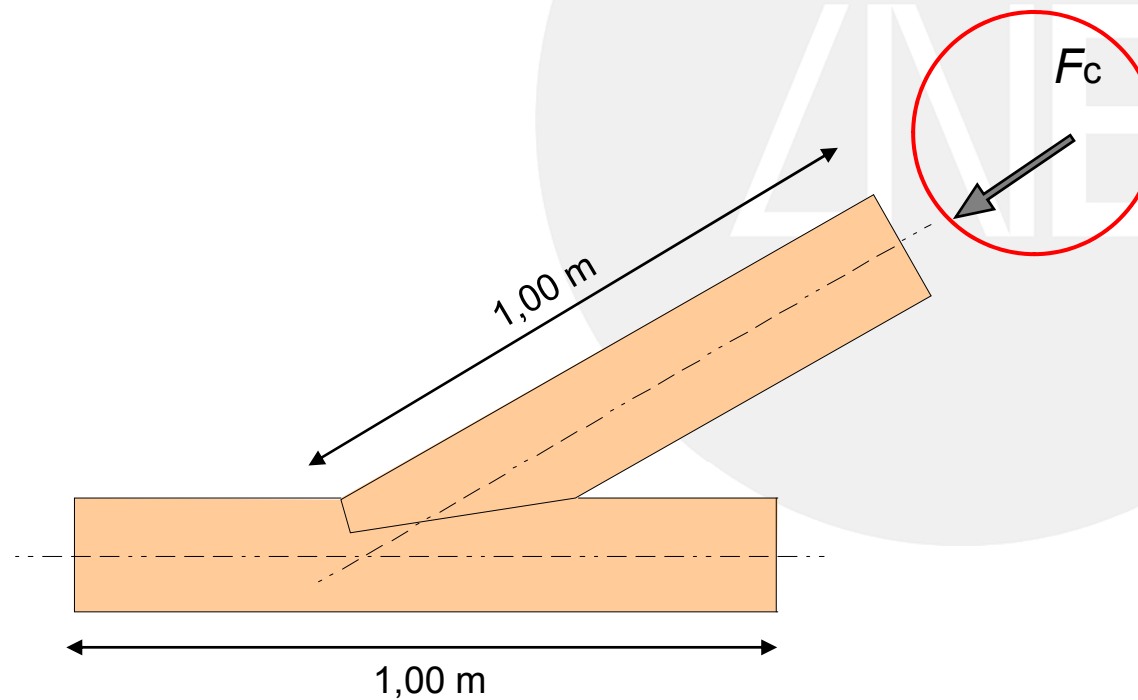
- Without metal parts
 - notch depth (t_v) of 4,5 cm
 - notch depth (t_v) of 3,0 cm
 - with mortise and tenon
 - with furniture beetle degradation
- With metal parts
 - stirrups
 - strut compressed before applying stirrups
 - stirrups applied after compressing strut
 - tension ties (binding strips)
- Moisture content
- Maritime Pine wood



Loading, procedure and equipment

> Loading

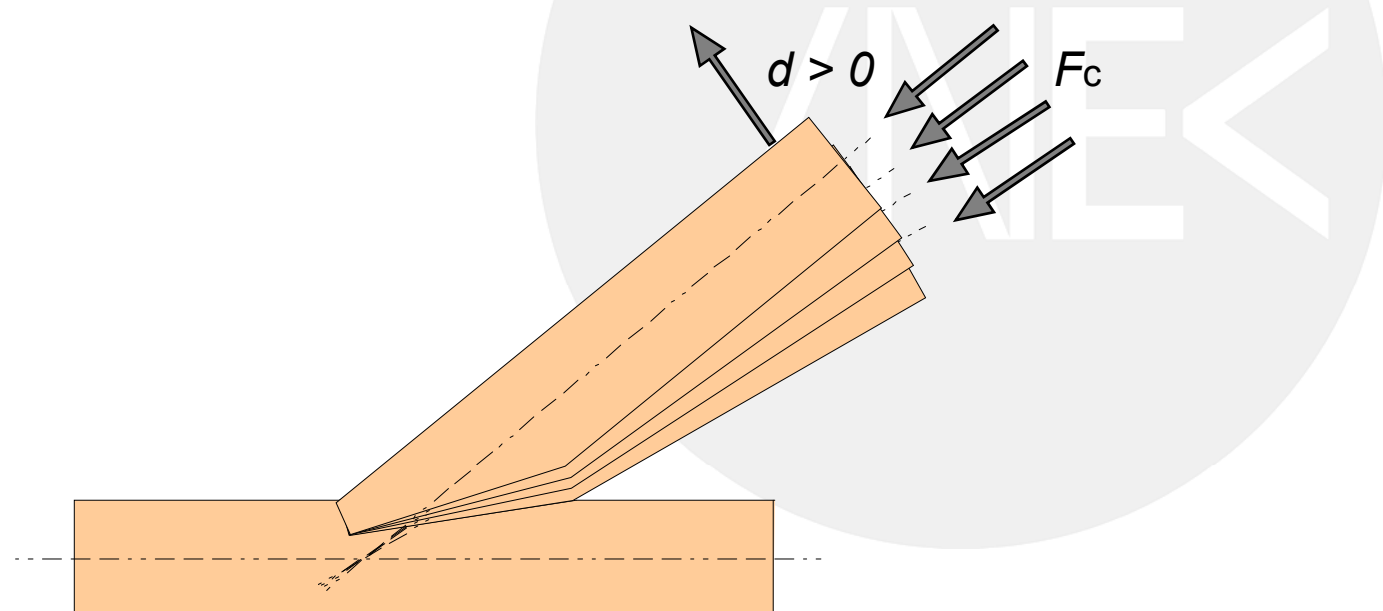
- compression in the strut, $F_c = 15 \text{ kN}$ ($\sigma_c \approx 1.3 \text{ MPa}$)



Loading, procedure and equipment

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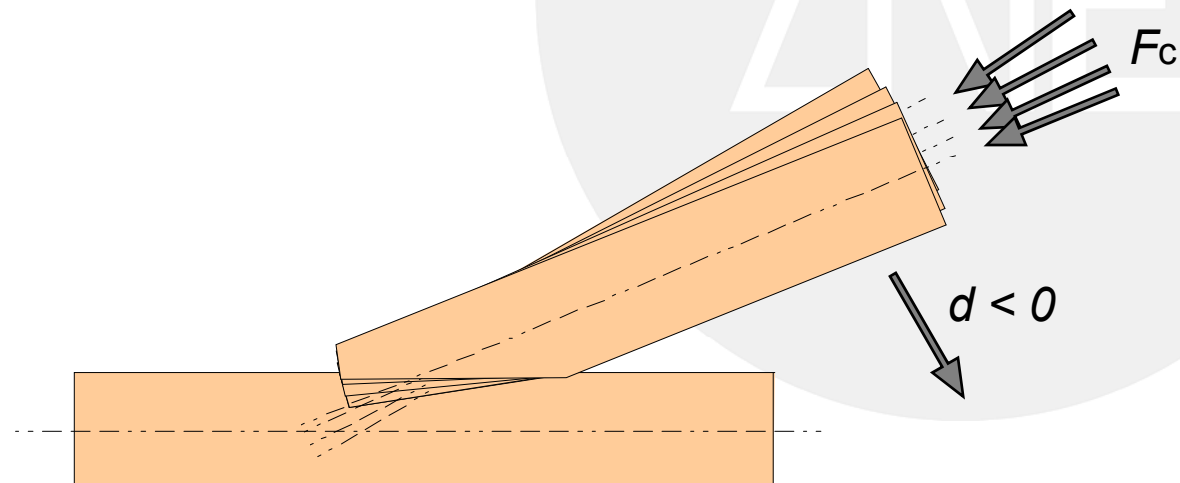
- compression in the strut, $F_c = 15 \text{ kN}$ ($\sigma_c \approx 1.3 \text{ MPa}$)
- transversal displacements $d = \pm 100 \text{ mm}$



Loading, procedure and equipment

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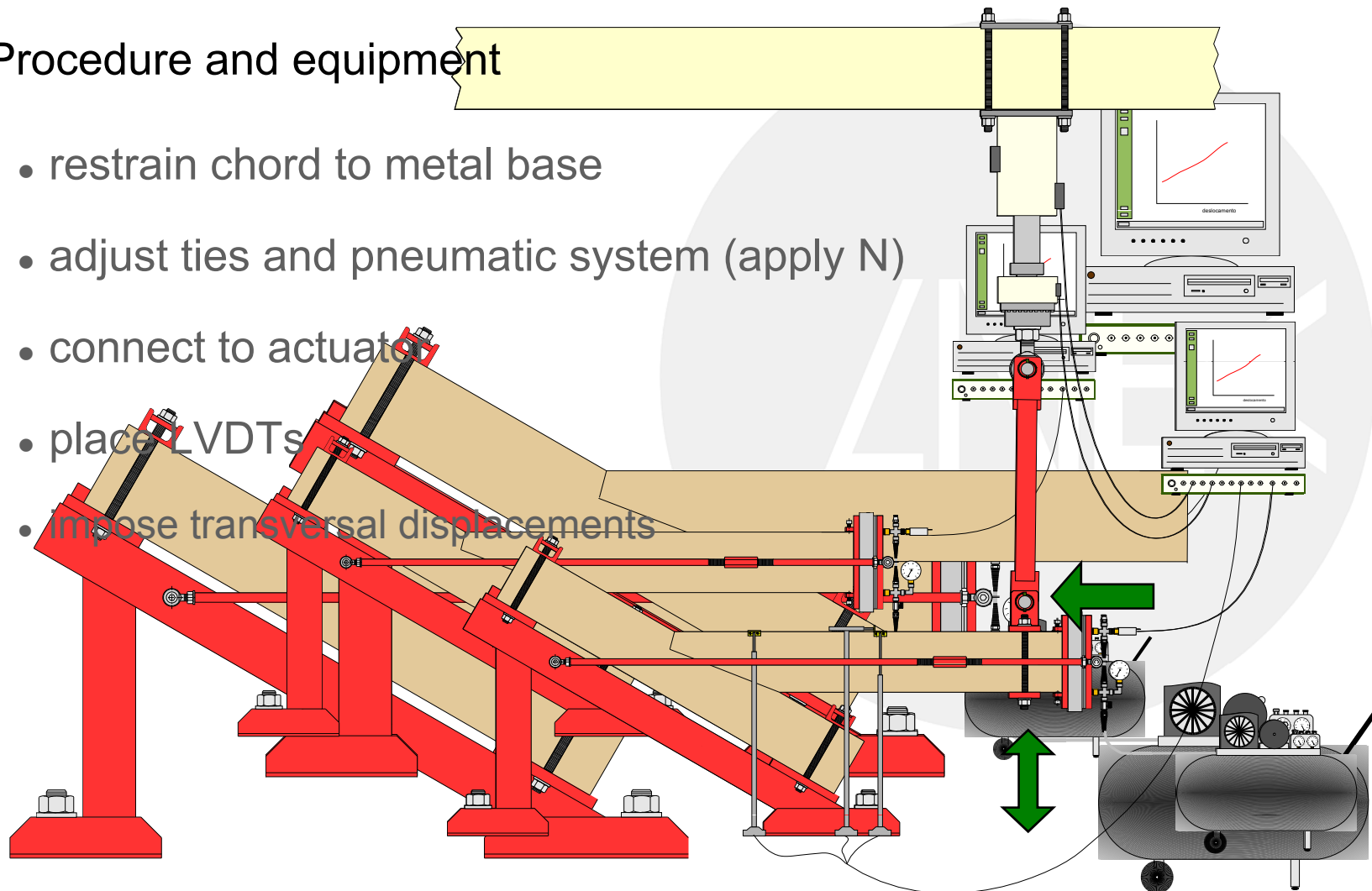
- compression in the strut, $F_c = 15 \text{ kN}$ ($\sigma_c \approx 1.3 \text{ MPa}$)
- transversal displacements $d = \pm 100 \text{ mm}$
- monotonic and cyclic tests



Loading, procedure and equipment

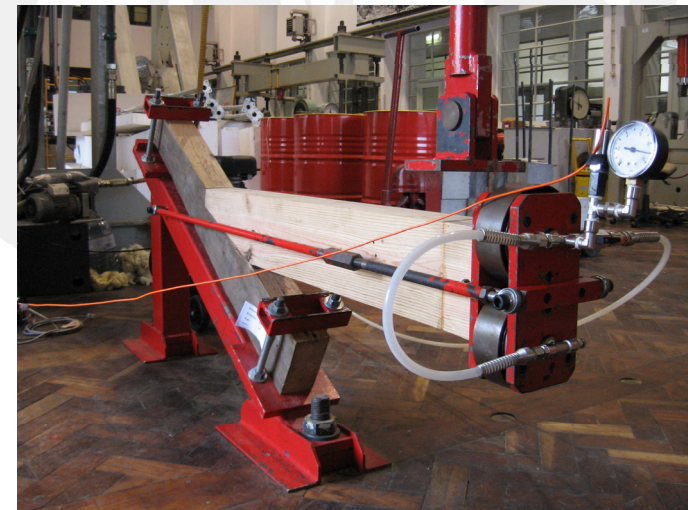
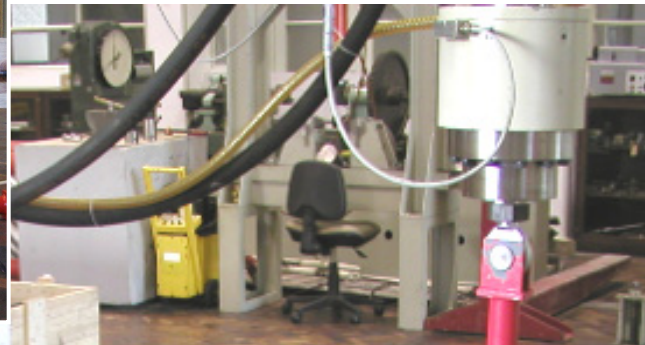
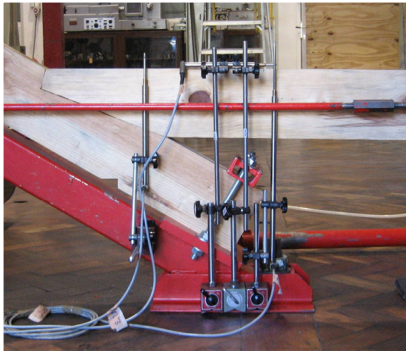
> Procedure and equipment

- restrain chord to metal base
- adjust ties and pneumatic system (apply N)
- connect to actuator
- place LVDTs
- impose transversal displacements





Loading, procedure and equipment



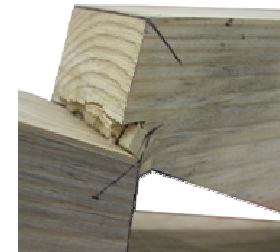
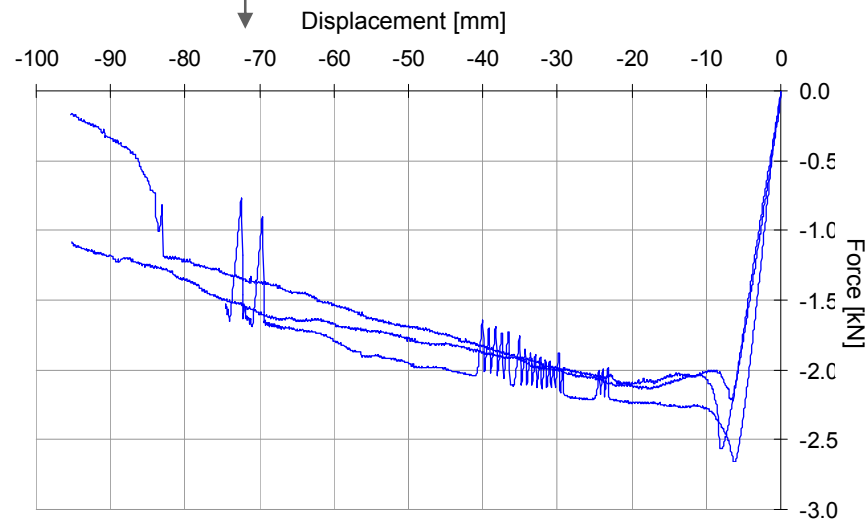
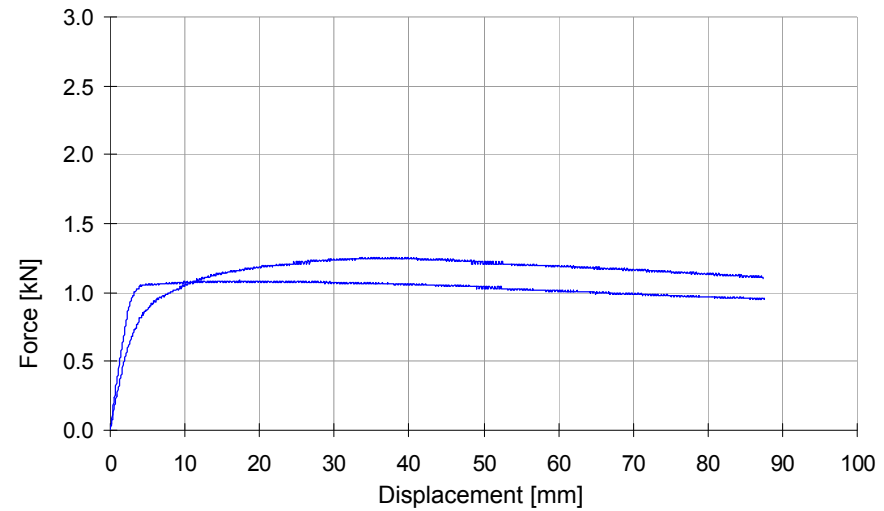
Monotonic tests - results

> Simple joints

- Notch depth of 4,5 cm, 12 % MC

- *opening skew angle*

- *closing skew angle*

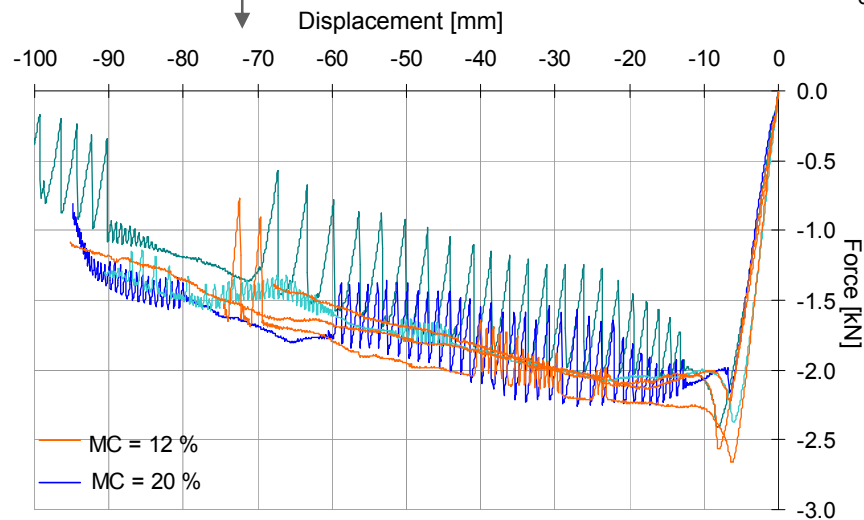
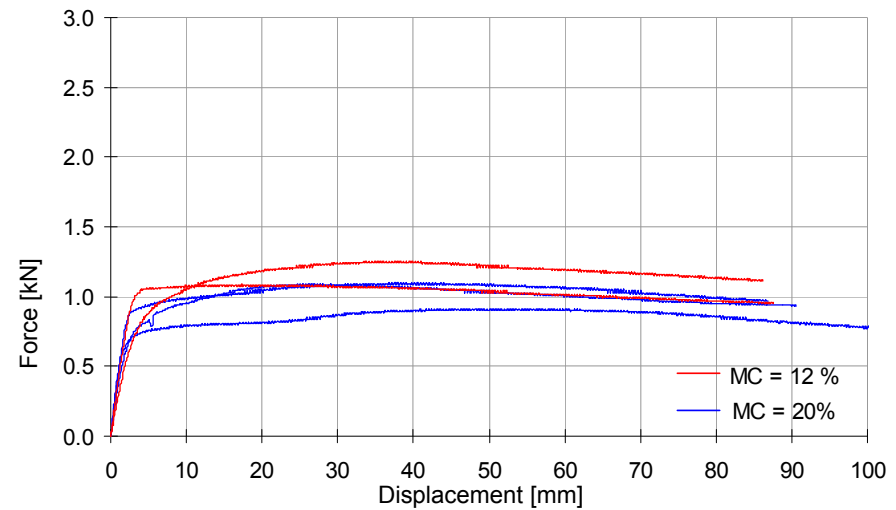


Monotonic tests - results

> Simple joints

- Notch depth of 4,5 cm, 20 % MC

- *opening skew angle*
- *closing skew angle*

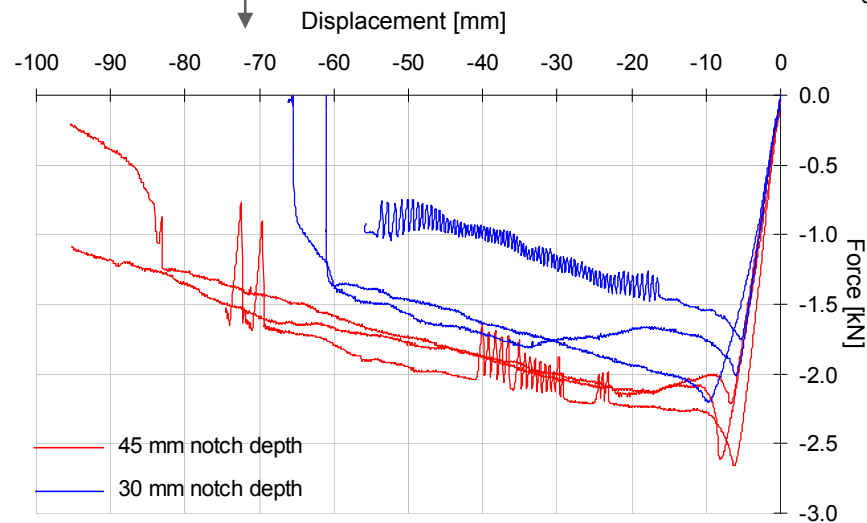
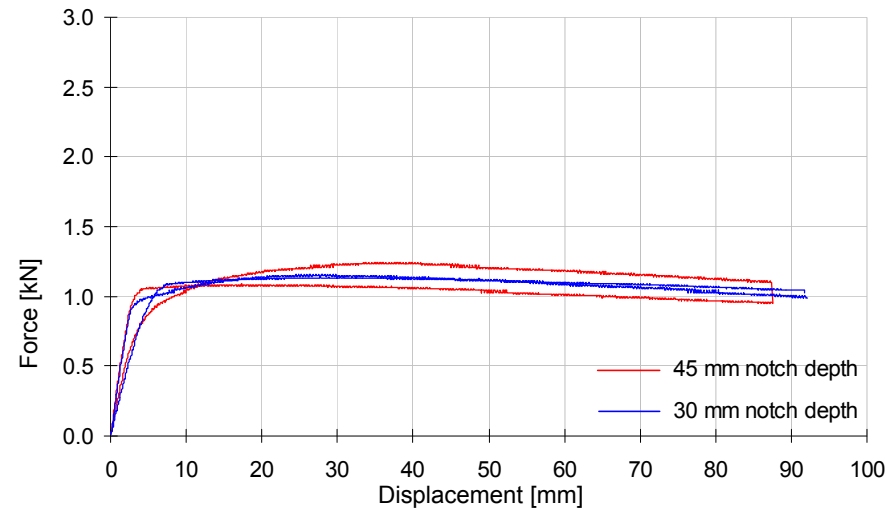


Monotonic tests - results

> Simple joints

- Effect of notch depth, 12 % MC

- *opening skew angle*
- *closing skew angle*



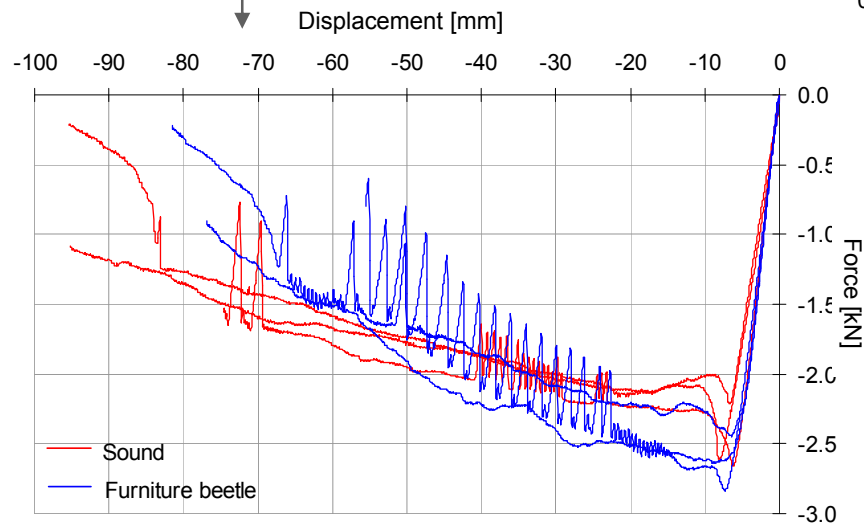
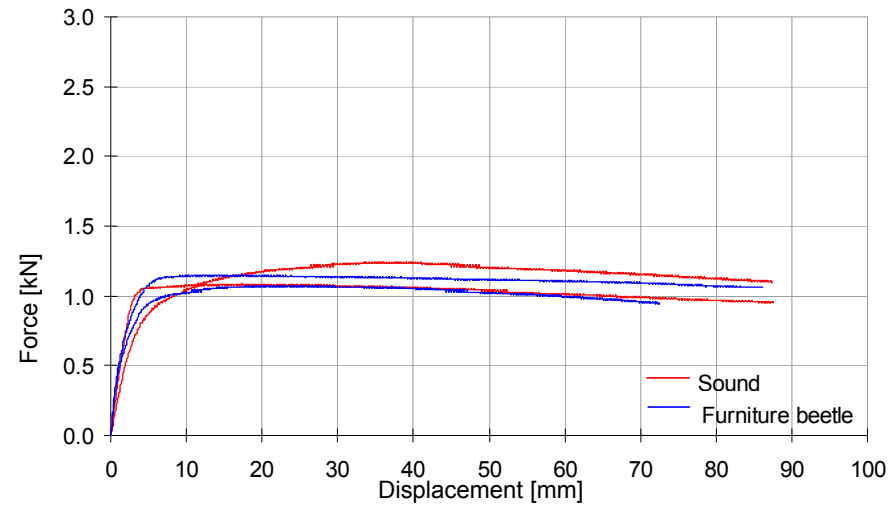
Monotonic tests - results

> Simple joints

- Furniture beetle damage, 12 % MC

- *opening skew angle*

- *closing skew angle*



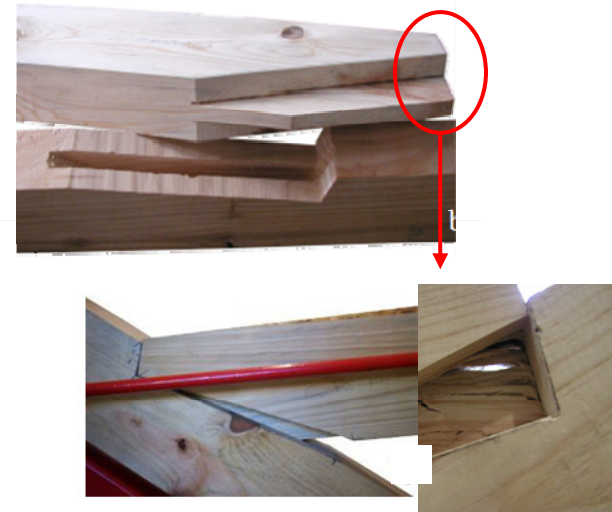
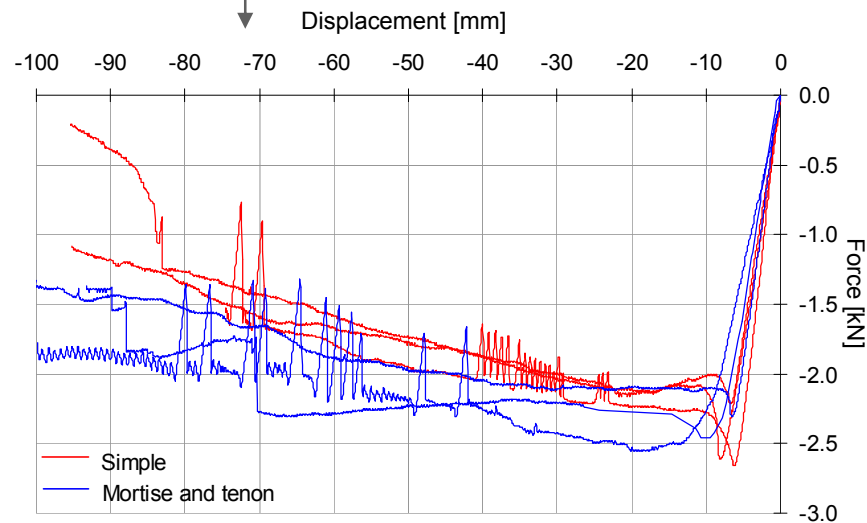
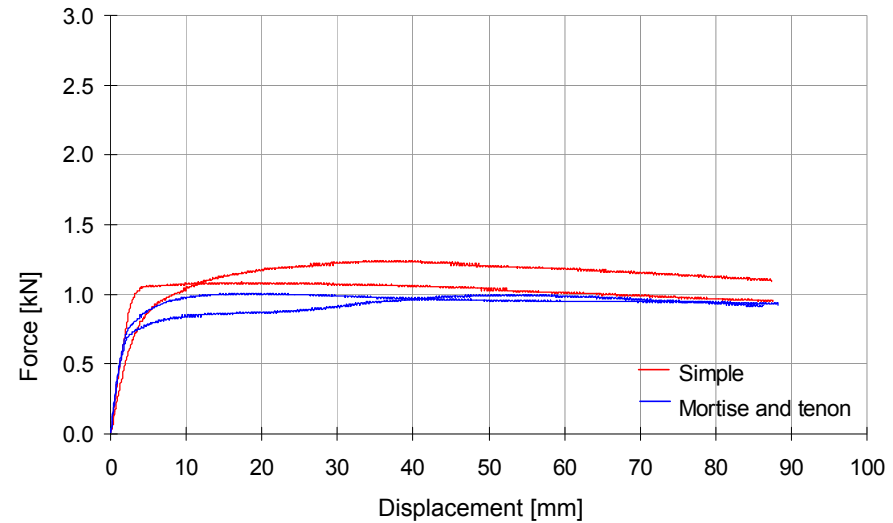
Monotonic tests - results

> Mortise and tenon joints

- Notch depth of 4,5 cm, 12 % MC

- *opening skew angle*

- *closing skew angle*



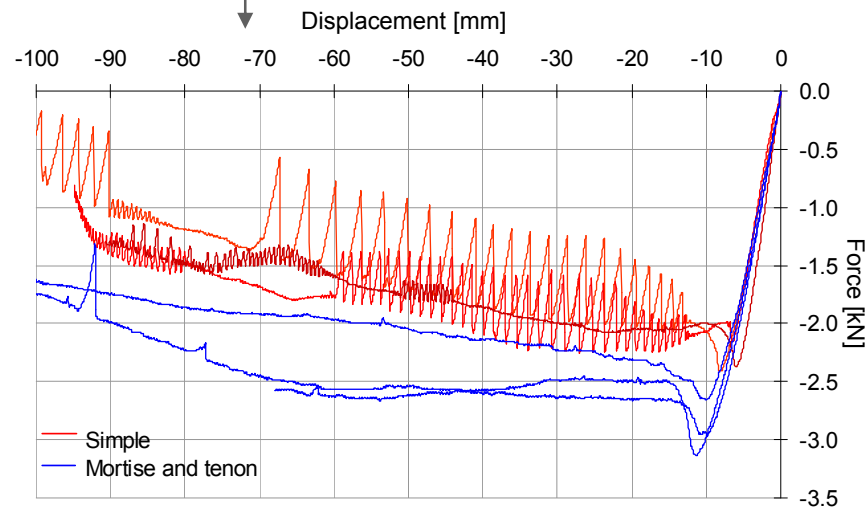
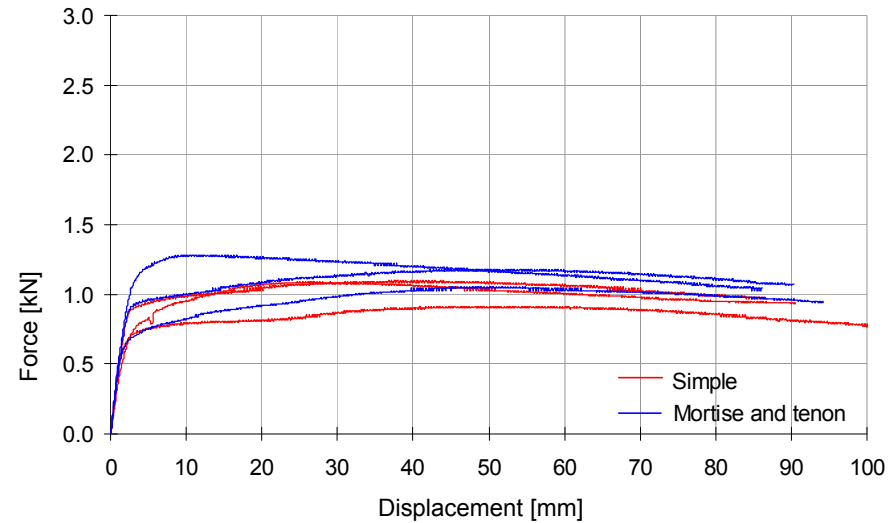
Monotonic tests - results

> Mortise and tenon joints

- Notch depth of 4,5 cm, 20 % MC

• *opening skew angle*

• *closing skew angle*

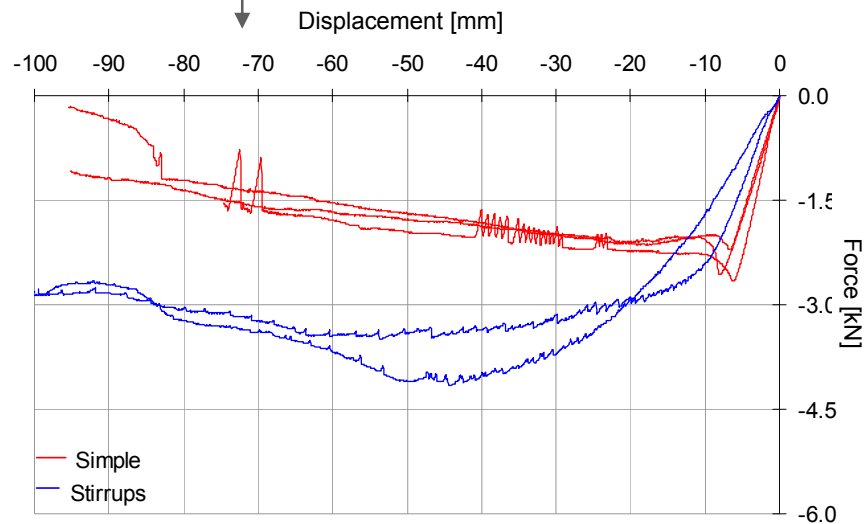
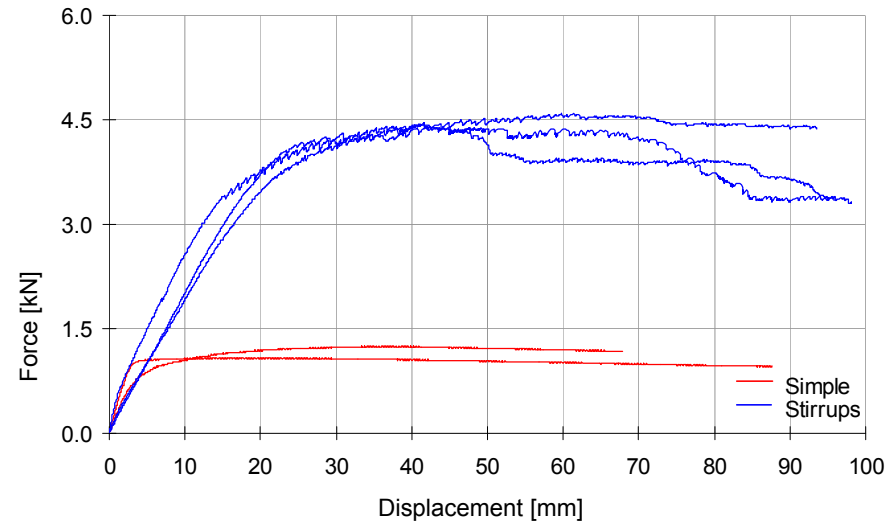


Monotonic tests - results

> Stirrups

- Notch depth of 4,5 cm, 12 % MC

- *opening skew angle*
- *closing skew angle*



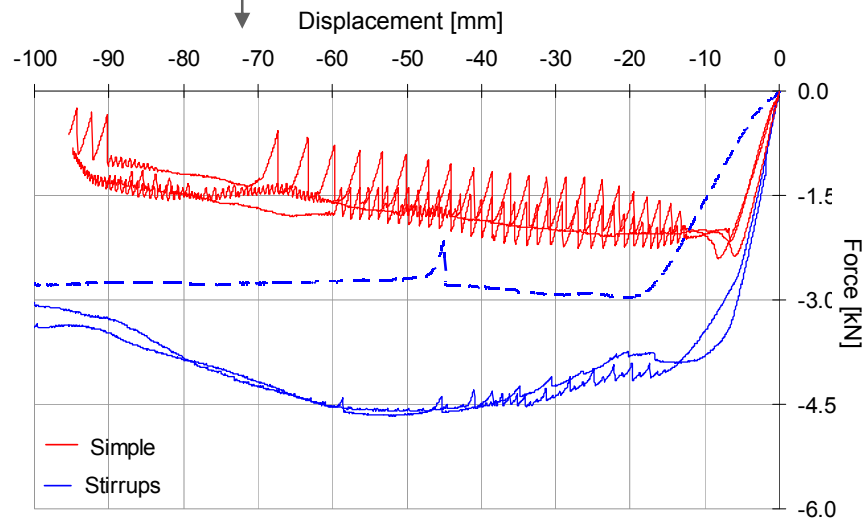
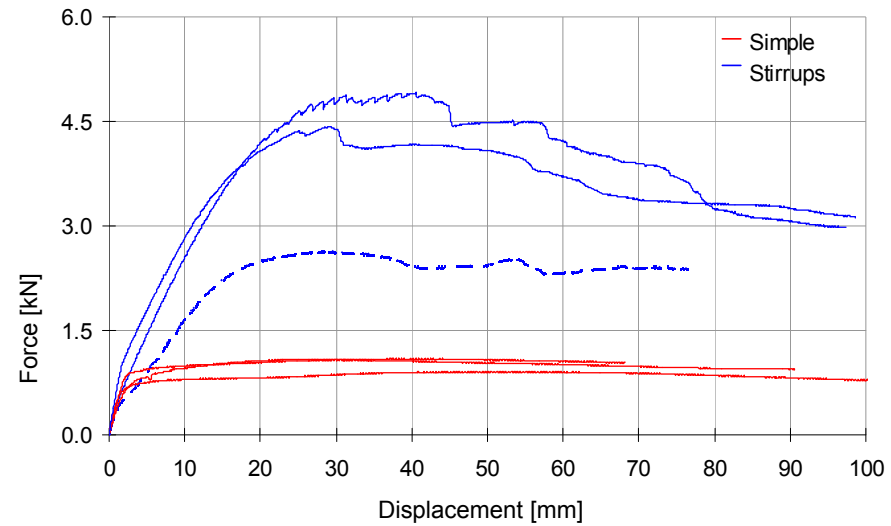
Monotonic tests - results

> Stirrups

- Notch depth of 4,5 cm, 20 % MC

- *opening skew angle* →

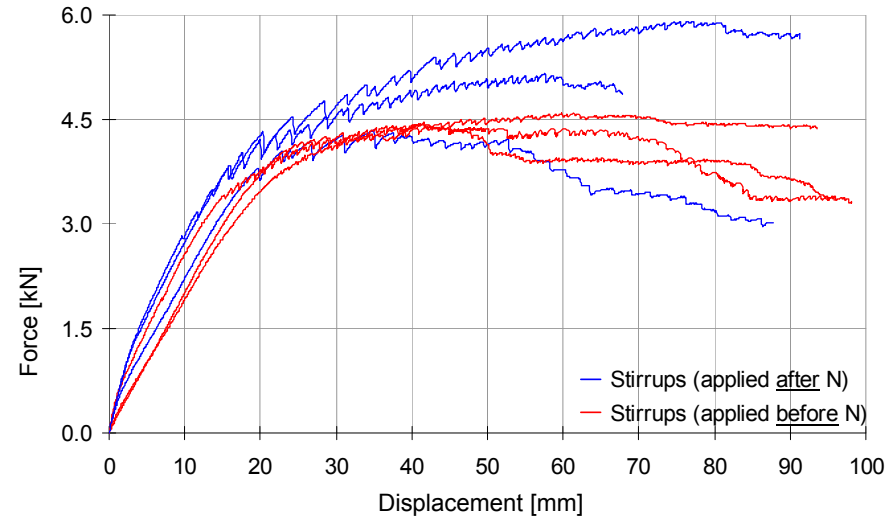
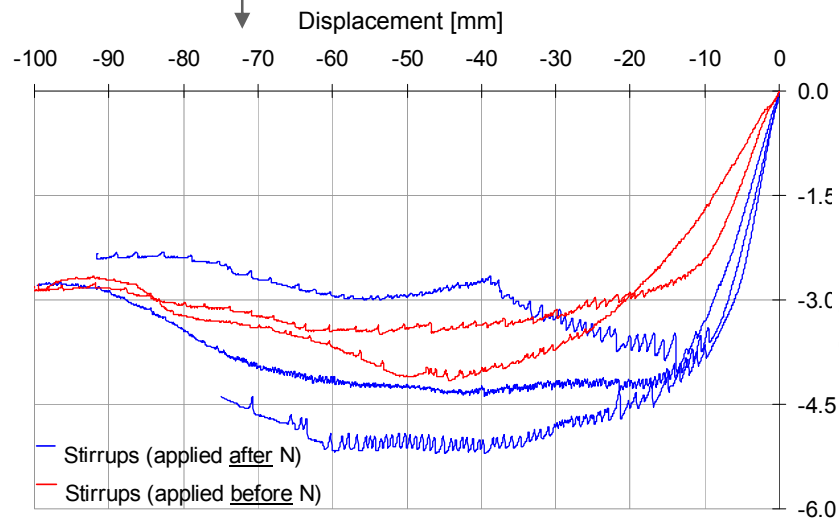
- *closing skew angle* ↓



Monotonic tests - results

> Stirrups

- Applied after compressing the strut
- *opening skew angle* →
- *closing skew angle* ↓

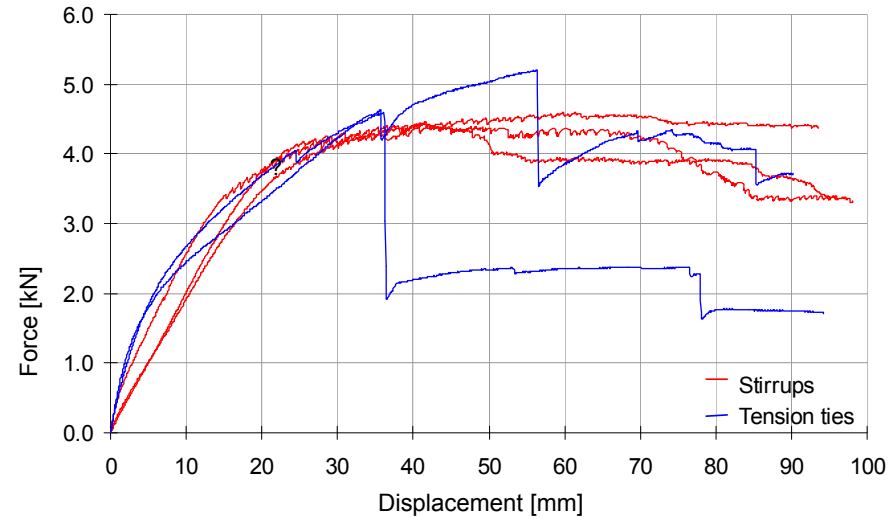
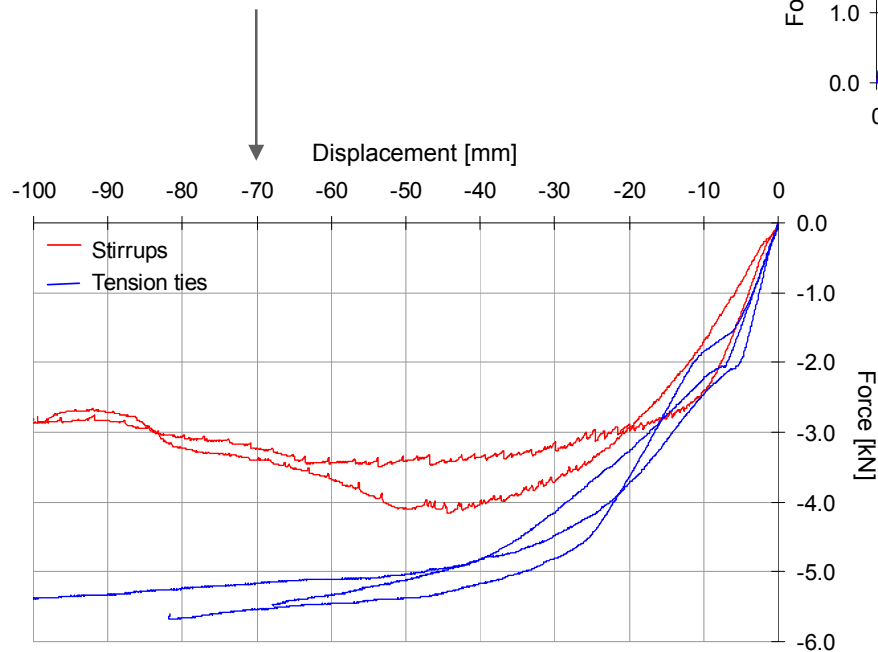


Monotonic tests - results

> Tension ties (binding strip)

- Notch depth of 4,5 cm, 12 % MC

- *opening skew angle*
- *closing skew angle*



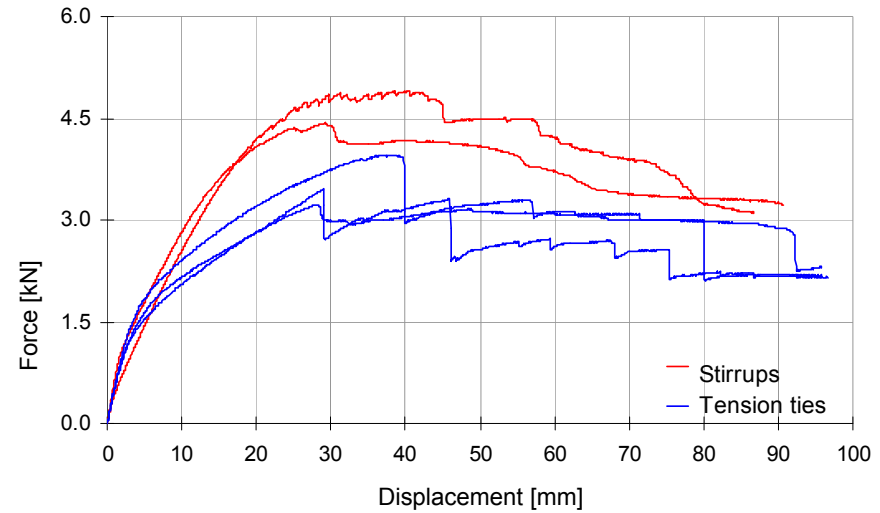
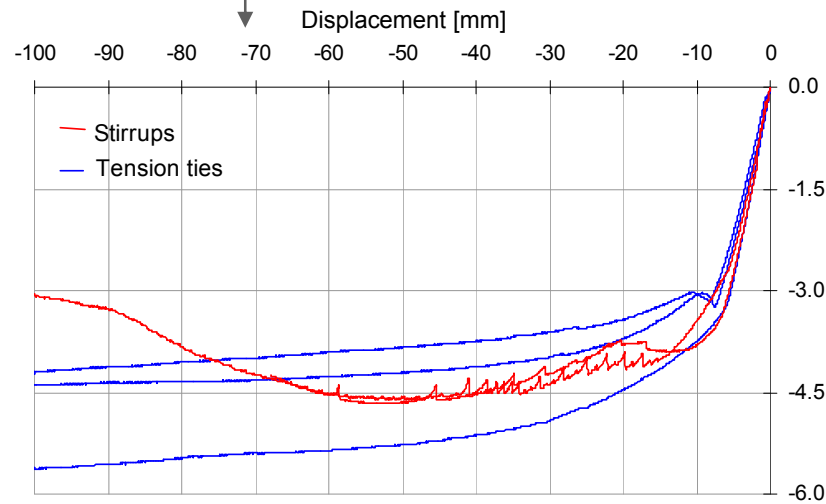
Monotonic tests - results

> Tension ties (binding strip)

- Notch depth of 4,5 cm, 20 % MC

- *opening skew angle*

- *closing skew angle*





Conclusions

> Joints without metal parts

- No influence of notch depth in the opening mode performance
- Mortise and tenon improve strength and ductility when closing the skew angle (higher increase for MC = 20%)

> Joints with metal parts

- Stirrups
 - increased strength and ductility (compared to simple joints); more symmetrical behaviour
 - importance of perfect match of the members in the notch surface
 - Increased strength and stiffness when tested at higher moisture content
 - Increased strength and stiffness when applied after compression of the strut
- Tension ties
 - increased strength and ductility (compared to simple joints)
 - fragile perpendicular to grain failures (opening skew angle)
 - loss of contact in front surface of the notch (closing skew angle)
- Stirrups vs Tension ties
 - Wood shrinkage in service → more penalizing for stirrups than for tension ties
 - Wood wetting and swelling in service → more beneficial for stirrups than for tension ties

Thank you for your attention!

