A dovetail joint – its behaviour and experimental tests

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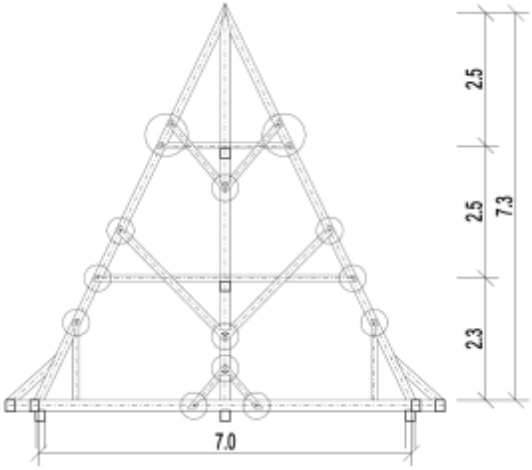
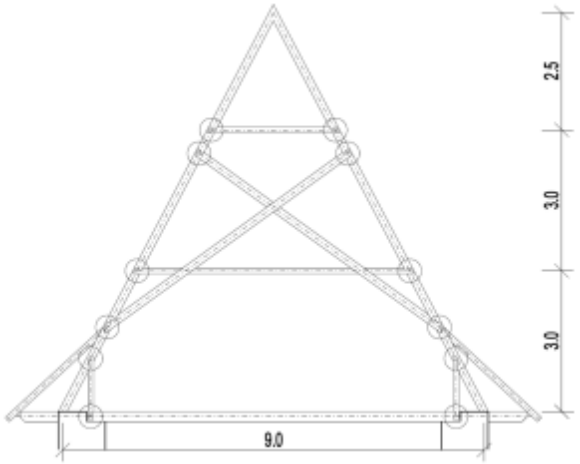
Motivation

- All-wooden carpentry joints which is mainly used in high roofs typical of the Gothic period, being very common in collar beam trusses.
- One of joints which were recommended for more careful study, since are commonly used in renovation of historical trusses, where preservation of originality of wood material and structural heritage is demanded.
- Advantages:
  - can transfer tensile normal force and bending moment
  - large applicability in the different parts of the structure.
- Besides load carrying function, it can acts as a design element.

Motivation



Chapel in Kozojedy
(Jičín, Czech Republic)



Church of Saint Anna in Prague
(Czech Republic)

Construction of a dovetail

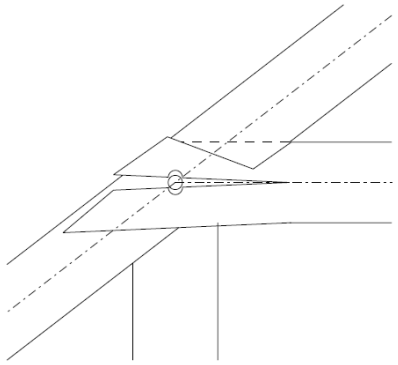
- Connects two elements:
  - two-sided dovetail – orthogonal connections
  - one sided dovetail – angled connections.
- The joint is held together by wooden dowel.
- Both members are narrowed by 1/x of the thinnest member (depending on type of overlapping; if overlap is full, both elements are narrowed by ½ of the width of the thinnest member).
- A typical chamfer, which creates a characteristic dovetail shape, is commonly made by 1/6 – 1/3 of the height of skew element.

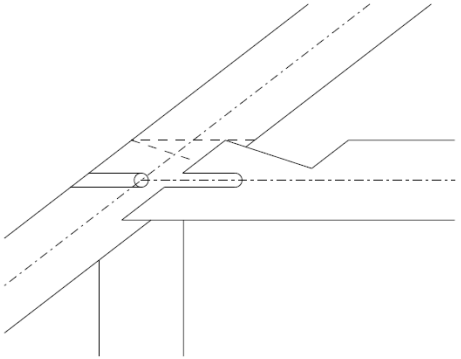
Structural behaviour and assessment

- The forces are transfered by direct contact of areas under compression.
- During the assessment the condition of compressive areas should be checked together with the condition of the key.
- The key is generally made of hardwood, it suffers from rotting.
- Problems can occur if the quality of the material in the part of the element in red cyrcles is poor due to the influence of wood rotting, insects, humidity …

Failure mechanisms

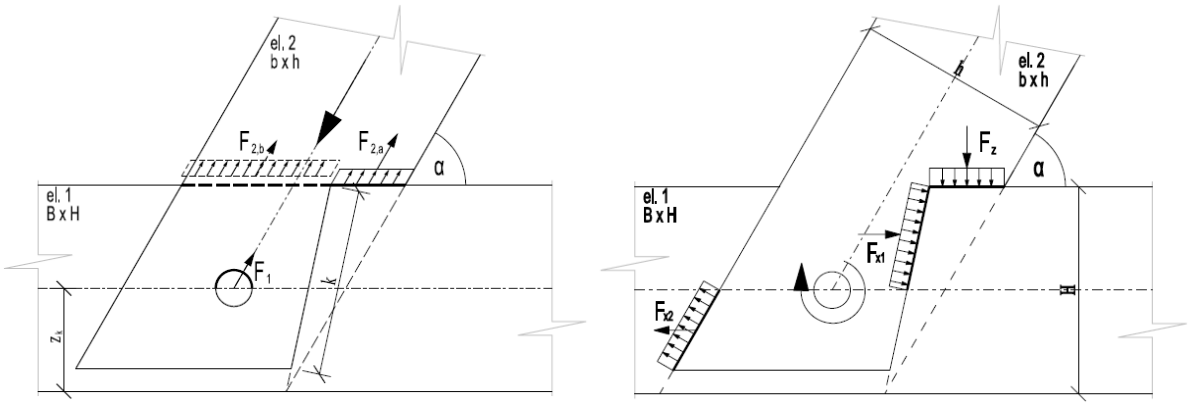
- Splitting of the dowel surroundings
  - Large bending moment (big ratation)
- Slipping of a part of the joint
  - Large tensile force and unsufficient possition of the dowel
- Failure of the dowel
  - Large tensile force
- Disintegration of the joint
  - Variable wind and snow loading
  - Seasonal variation of humidity
  - Long term cyclic loading





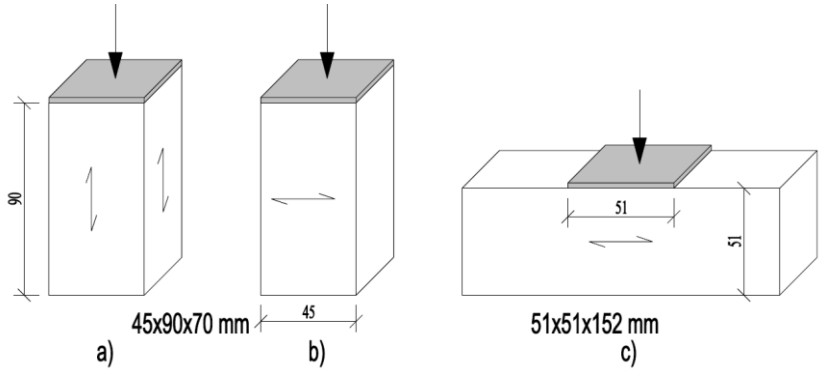
Analytical model – compressive areas deformation method

- The main assumption – forces transfered through compressive areas.
- The bearing capacity of the joint is compesed from bearing capacities of considered compressive areas, inspiration in component method.
- Compressive bearing capacity of a compressive area calculated using :
  - $F_{u,i} = A_i \cdot f_{c,\beta}$
- Deformation of compressive area calculated using:
  - $r_i = k_\beta^{-1} \cdot f_{c,\beta}$



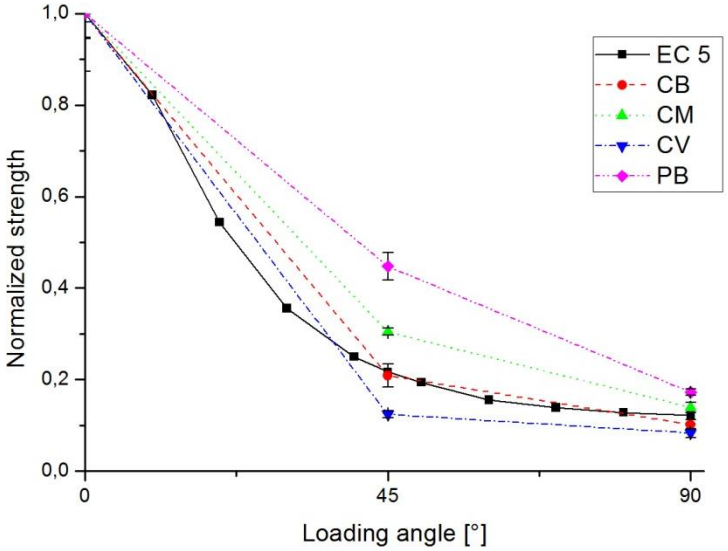
Experiments of wood specimens in compression

- Material characteristics of wood species evaluated from wood specimens made according to EN 12512 and ASTM D143-14 (spreading of loading) for their utilization in the analytical solution.
- Evaluated characteristics:
  - strength, modulus of elasticity, stifness of specimens – using bi-linear simplification of the force – displacement relationship (area of specimens similar to compressive areas), influence of loading angle on the value of the characteristics



Experiments of wood specimens in compression

- Evaluated characteristics from compression test of specimens used in the compressive areas deformation method.
- Evaluated values of the compressive strength higher than expected values according to visual survey (approx. C24 $f_{c,0}$ = 24 MPa; $f_{c,90}$ = 2,5 MPa).



$$f_{c,\beta,d} = \frac{f_{c,0,d}}{\frac{f_{c,0,d}}{f_{c,90,d}} \sin^2 \beta + \cos^2 \beta}$$

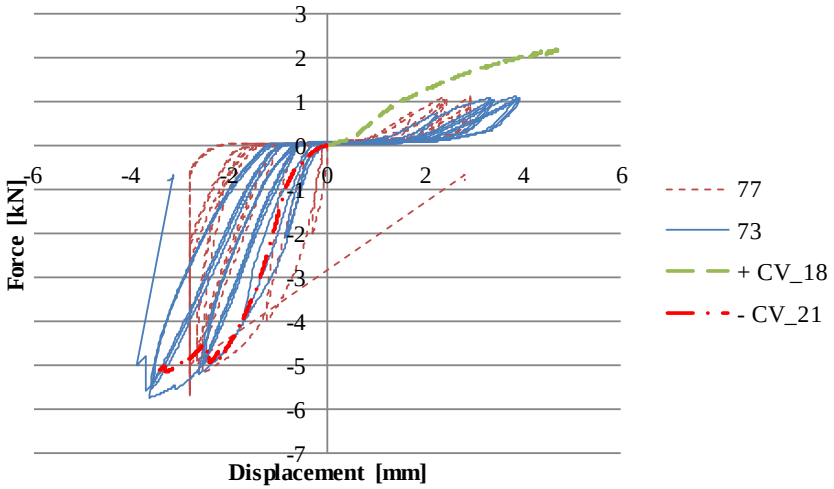
	C-90 [MPa]	VP-90 [MPa]	C-45 [MPa]	VP-45 [MPa]	C-0 [MPa]	Density [kg/m3]
Silver fir (CB)	3.29	5.43	6.76	11.1	32.36	422.61
Chestnut (CM)	6.6	16.98	14.43	22.15	47.42	647.75
Scots pine (CV)	4.08	7.25	6.07	12.03	48.9	545.36
Maritime pine (PB)	6.99	15.51	18.14	24.9	40.53	624.58

Experiments of scaled models in ration 1:2 with the dowel

- Behavior of the joint to different types of loading was examined both in the simple and cycling loading
  - Compression / tension
  - Negative / possitive bending moment
- During the tests efford to determine:
  - utilization of compressive areas
  - bearing capacity to different type of loading
  - typical failure modes for different types of loading
  - Safety of the joint

Experiments of scaled models with the dowel

- Utilization of compressive areas was verified.
- Determination of typical failure modes for different types of loading proved for some types of loading (compression and tension shown during TS) – not enouch amount of specimens to establish typpical failure modes.
- Sufficient behaviour in case of safety (cycling loading).



Experiments of scaled models without the dowel

- Important role of the dowel in the compressive areas deformation model.
- The role of the dowel in real behaviour of the joint can be discussed.
  - Just tides the joint together or has also load carrying role?
- Thus experiments of the joint in ratio 1:2 without the dowel established just for simple loading cases.
- Comparison of results from experiments should explain the role of the dowel in the behaviour of dovetail joints.
- Sum of results from previous STSM (experimental campaign of wood speciemens and scaled joint) can be found at http://www.costfp1101.eu

Thanks for your attention!

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