Fracture analysis of single-shear joint equipped with oak dowel loaded perpendicular to grain with eccentricity

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A common damage of tie beams and rafters is found in historical structures: decayed beam ends due to water leakage or insect-related issue. Lap joints for replacement of such parts could be a suitable solution. Since the combined loading is often found in the structural members, **the design of the lap joint is not an easy task**. The design of lap scarf joints for tensile and compressive loading in the direction along the grain is possible, because the existing codes partly cover the topic [1]. Unfortunately, combined loading induces a complex stress state on the coupling elements, which is not fully covered in standards [2], especially when concerning surrounding matrix failure. In the case of momentum (see Fig. 1) or combined loading, the task is more complicated. The requirement of cultural heritage institutes is often to preserve the maximum amount of the original material and aims at the use of historical traditional carpentry approaches which often deal with the all-wooden joints, meaning the ones equipped with coupling elements made of wood. English oak, as a widespread hardwood specie in Europe, is usually selected for the dowels. The bearing capacity of the oak dowels in the direction parallel-to-grain is significantly lower when compared to the steel coupling elements. However, oak dowels do not suffer the issues related to incompatibility of the materials, the fitting could be adjusted using pre-dried dowels compensating the wood shrinkage, and, finally, provide nearly invisible look suitable especially for exposed parts of the structure. Therefore, the task covered in the paper is clear: **assess the bearing capacity of oak dowel** connecting two softwood elements (Norway spruce) **loaded eccentrically perpendicular-to-grain** using LEFM approach and numerical modelling. The results are compared to the experimental outputs.

Numerical model is developed using ANSYS Mechanical APDL with geometry given in Fig. 1. A linear material model is considered (limited plasticity models available) with orthotropic material model for the dowel and surrounding matrix (English oak, Norway spruce, respectively) according to [4, 5]. The contact between the dowel and the matrix is defined and the friction coefficient of μ=0.4 is used. The same strain energy release rate as in [5] is adopted, i.e. G_c = 300 Nm^{-1} (opening mode I present). The mesh is made: 1) uniform, 2) densified around notch tip. Both mesh types are evaluated in the results. Unit load (F) is applied and following load steps were considered: a) loaded system, b) the same system with the first nodes at the crack propagation zone sequentially released using coupling equations from the inside to the outer edge on both members simulating the crack growth Δx. The change of system compliance is computed from the load steps. Based on the fracture mechanics relation between energy needed to create a new surface of length Δx and change of system compliance the critical force $P_{90,Rk} = \sqrt{2G_c b\Delta x/(\Delta u(\Delta x)/F)}$ of the onset of crack is computed. The force is compared to the results of parallel-to-grain values [1] and to the results of steel dowels [5]. The detailed results will be presented at the conference.

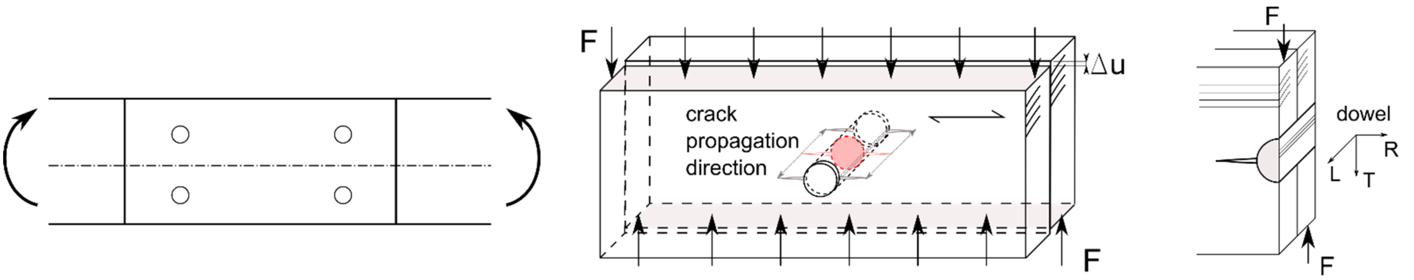

Figure 1: The configuration of the stress state (left), problem definition (rest)

References

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