Notches in wood at arbitrary beam location – numerical modelling and challenges

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In both historical and modern structures, the phenomena of notching are omnipresent and evident. Notching is either characterized by abrupt changes of cross section with respect to height or width, holes in beams or even loading – external or by internal forces or moments – not distributed over the whole cross section, but acting on subsections. At the location of the (therefore) created edge, the phenomenon of peak stress affects all involved stress components. The present design recommendations in EC5 [1] only handle the onset of crack formation induced by a coupled set of shear force and moment, as it is the case of e.g. single span beams without further cantilevers. In the meantime, strategies for the approval of reinforcements have been developed and implemented in national appendices of EC5, still referencing the initial ultimate load carrying capacities at onset of crack formation at the tensile bending side of the notched beam. Nevertheless, further research revealed, that the increased level of load carrying capacity for the case of reinforced notches is also limited by a factor of approximate two times the load carrying capacity at onset of crack formation. Because of this scientific finding, all timber structures designed in the past according to the traditional design concept for reinforced notches should be classified as insufficient with respect to the expected safety level and therefore eventually be upgraded. Besides this economic disaster, the most important consequence would be the loss of engineers trust in the reliability of traditional and future design concepts related to this topic.

The here presented research activities aim at a gentle solution of the above-mentioned problem by scanning all related background documents, reproduction of the referenced derivation of design equations from Gustafsson [2] and validation against a more flexible calculation made using numerical 2D formulations. First findings have revealed that the referenced **beam model is better adjusted to moments than to shear forces**. With the shift of the notching to the compressive bending side of a beam, a global **increase factor of about two due to the change of the corresponding fracture mode** (from I to II) and related smaller change of the compliance could be applied with reference to the basic design equations from EC5. When considering the original concept of Gustafsson [2], the validity of the design of the original formula has been checked especially in the context of **varying height of beams, also to account for high beams made of LVL or glulam**. A study **on possible decomposition of internal forces** was performed and results were compared to the original formula. The **fracture mode** (I or II), suitable to be applied to some specific problem, could **be chosen according to change in deflection respective slope** of the (newly created) crack. The early-stage research showed good applicability of simple numerical models to describe phenomena according to Fig. 1.

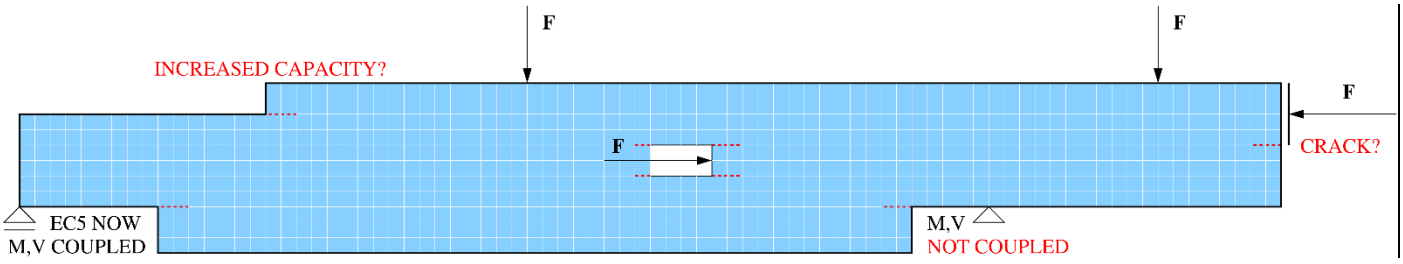

Figure 1: Problem sketch of some of the problems found in practice

Concluding, the issue of notching should principally be applicable for an arbitrary set of internal forces consisting of moments, shear forces and normal forces from global structural assessment. Since analytical formulae, only to be derived from simplified beam models, will never do this job, **reliable and more flexible numerical models (and submodels)** in the background of structural engineering software [4] could offer a reasonable solution for this urgent problem and frequent design situation in timber engineering. However, this topic requires high amount of experimental data not only from the past, but also new ones, since verification of the design procedure should be made using extensive additional experimental work. A project relating this topic should be considered in order to fulfil the ambitious goals.

References

[1] EN 1995-1-1:2004 + AC:2006 + A1:2008: Design of timber structures Part 1-1: General – Common rules and rules for buildings.
[2] P.J. Gustafsson, A Study of Strength of Notched Beams, *Proceedings of 21st Meeting of CIBW18*, Parksville, Canada, 1988, vol. 25, 1988.
[3] R. Jockwer, Structural behaviour of glued laminated timber beams with unreinforced and reinforced notches, *IBK Bericht Nr. 365*, November 2015, Institut für Baustatik und Konstruktion, ETH Zürich.
[4] RFEM 5.17, *www.dlubal.de*, Dlubal GmBH.

ISBN: 978-91-88898-64-7