Predicting delamination influence on the mechanical performance of straight glued laminated timber beams

Florindo Gaspar[1], Helena Cruz[2], Augusto Gomes[3]

EXTENDED ABSTRACT

Delamination at the glue lines is one key factor to take into account when assessing glued laminated timber members in service. In order to gain a more objective and wide knowledge about the importance of delamination relative to its type and extension, a numerical study was developed. This focused the case of straight beams previously tested by the authors (Gaspar, 2006), and therefore results are somehow limited to the chosen beam geometry.
Finite element modeling (FEM) was used to evaluate the delamination influence (near the surface, on the vertical faces and ends) on the mechanical performance of straight glued laminated timber beams.
The modeled beam was 0.10 m wide x 0.24 m high (h) (6 x 0.04 m thick lamellas) x 4.40 m long, simply supported over a 4.32 m span, with two symmetrical loads applied in the middle third of the beam (EN 408, 2003). Glued joints were numbered 1 to 5, starting from the lower face of the beam.
The following limit states were considered: deformation (DLS), bending strength (BLS) and shear strength (SLS), according to EN 1995 1-1 (2004). The maximum load applied for each limit state was determined assuming glulam class GL24h (EN 1194, 2002).
When checking deformation, two 5 kN loads were applied at 1.44 m (6 x h) from the beam ends (the test set up proposed by EN 408 (2003)). For bending strength, each load was 7.5 kN. For shear (SLS), maximum loads considered were of 18.4 kN applied at a distance of 2 x h from the supports.
It was found from preliminary simulations that the values adopted for the mechanical properties of glue line elements would not significantly affect the predicted stresses and deformations. Therefore the same mechanical properties of timber were also adopted for the glue lines.
Timber was modeled as linear elastic. However, in some computer simulations the characteristic strength values were exceeded, compromising safety. Therefore, Hill's criterion (Hill, 1950) was used, in order to compare the stress states obtained in the three limit states' verifications and to identify possible risk situations for the structural member.
The FEM was validated by comparing stresses and deformations obtained with the model and with the application of the beam theory, assuming that cross sections would remain plane, for the above referred limit states.
Results were satisfactory, with an expected better agreement between FEM and beam theory when timber isotropic behaviour was assumed in the FEM (rather than an orthotropic behaviour).

Delamination influence was checked as a function of its depth, considering both symmetric delamination (modes A,s to E,s) and non-symmetric delamination (modes B,ns to D,ns). In symmetric modes, delamination varied from 10 to 40 mm deep (each face) or up to (40 mm + 50 mm, in the case

---

[1] Florindo Gaspar, Department of Civil Engineering, Polytechnic Institute of Leiria, School of Technology and Management, Portugal, florindo.gaspar@ipleiria.com
[2] Helena Cruz, Timber Structures Division, Laboratório Nacional de Engenharia Civil - LNEC, Portugal, helenacruz@lnec.pt
[3] Augusto Gomes, Department of Civil Engineering, Technical University of Lisbon, IST, Portugal, augusto@civil.ist.utl.pt

of 90mm delamination). In non-symmetric modes, delamination was assumed on one face only, varying from 20 to 90 mm. The following delamination modes were considered:

Modes A and B – delamination along the whole beam length: either just on the middle glue line (mode A) or in all glue lines (mode B).

Modes C and D – delamination in all glue lines: either just in a central zone 3.44 m long (mode C) or near the beam ends in 0.48 m length (mode D).

Mode E – delamination on both ends of the beam and in all glue lines. Delamination length varied from 80 to 480 mm near each end, affecting the whole beam width.

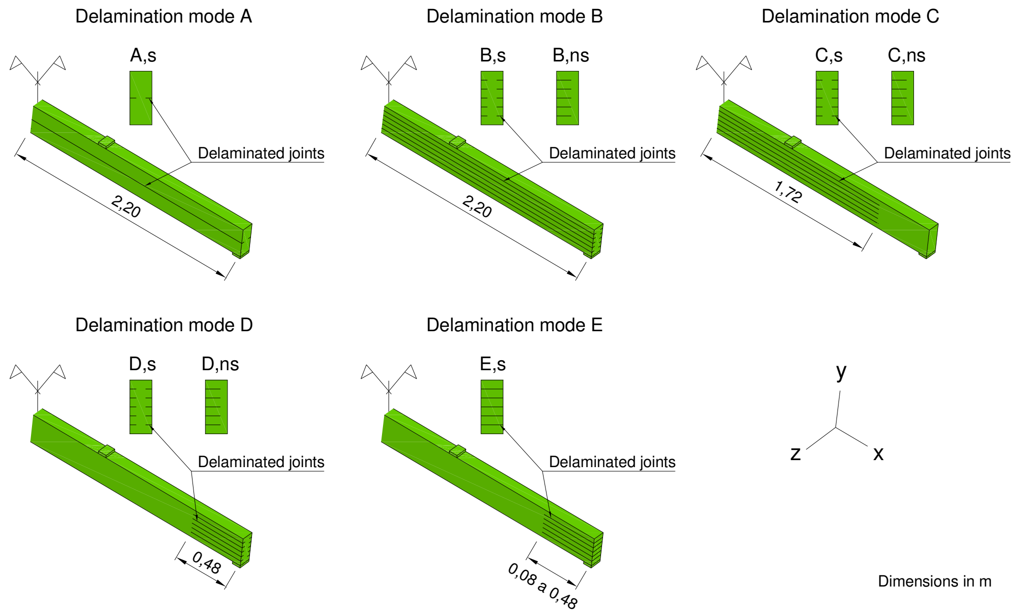

Figure 1 – Delamination modes taken into account in the model

The FEM results confirm that, when inspecting glued laminated timber structures in service, attention should be paid to the presence of fissures in the lower lamellas of bent members that may significantly decrease their bending strength.

When delamination is non-symmetric regarding the member's cross section, it can cause the member's lateral instability, thus increasing its stresses and deformation. Additionally, delamination around supports or under loading application points may rise highly unfavourable stress states in the structure, especially under high shear stresses where the glulam failure is more likely to occur.

Delamination is particularly critical when it goes from one face to the opposite face.

On the contrary, delamination is not a problem when it occurs in members or member areas with low shear stresses, particularly when it is symmetric and does not reach the whole width of the beam.

The stresses corresponding to the bending or deformation limit-state are close to the elastic limit only for very important delamination.

Nevertheless, delamination depth higher than 60% of the cross section width may be regarded as a turn point beyond which the structural integrity may be at risk.

REFERENCES

EN 408 (2003). Timber structures. Structural timber and glued laminated timber. Determination of some physical and mechanical properties, European Committee for Standardization.

EN 1194 (2002) Timber structures. Glued laminated timber. Strength classes and determination of characteristic values. , European Committee for Standardization, Brussels.

EN 1995-1-1 (2004). Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings, European Committee for Standardization.

Gaspar, F. (2006). Estruturas de madeira lamelada-colada – Viabilidade da utilização da madeira de pinho bravo tratada com produto preservador, MSc thesis, Instituto Superior Técnico, Lisbon, p. 359.

Hill, R. (1950). The Mathematical Theory of Plasticity Oxford, Clarendon Press.