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EXTENDED BEAM MODEL FOR SIMULATION OF HYGRO-MECHANICAL AND VISCO-ELASTIC DEFORMATIONS IN INHOMOGENEOUS TIMBER STRUCTURES

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Due to numbers of failures of large glue laminated (glulam) timber structures there seems to be a need for better design tools for wood applications. In EC5 and in many textbooks on timber design it is stated that the moisture sensitivity of the wood material needs to be taken into account in the design process. But the fact is that in stress calculations associated with ordinary timber design, these matters are not dealt with properly. The problem is that it is very difficult to predict the variation of moisture-related stresses during the service life of the timber structure as a whole. A proper prediction requires that material inhomogeneity, mechano-sorption effect and visco-elastic behaviour are taken into account.

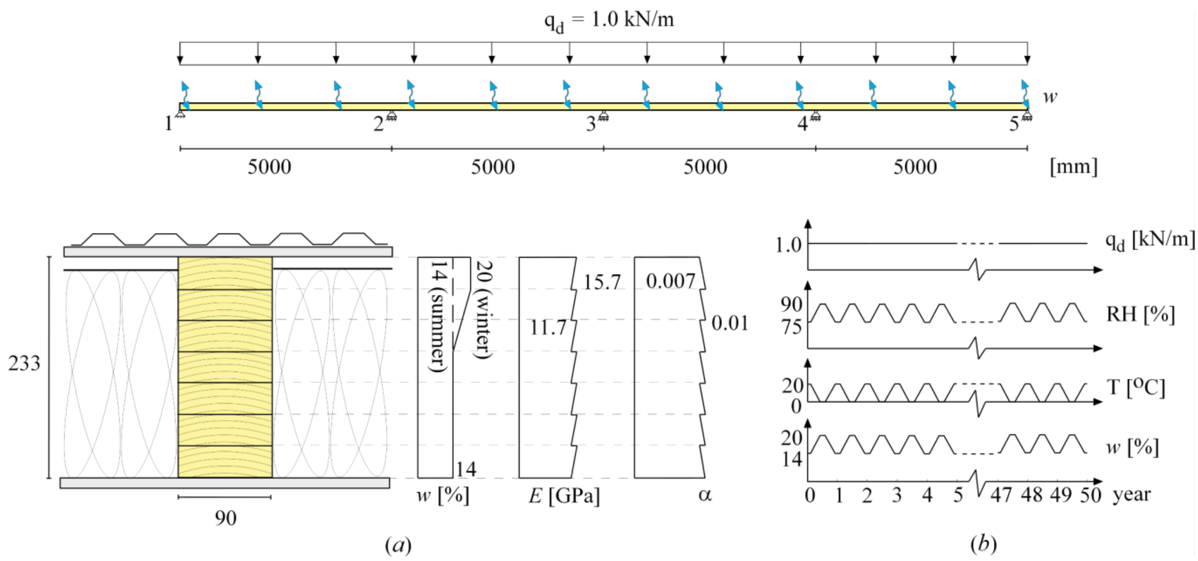

Figure 1: A glue laminated beam subjected to bending and cyclic moisture variation
(a) Cross section geometry and variation in the modulus of elasticity *E*, the shrinkage coefficient α and the moisture content *w* over the depth of the cross section
(b) History for the utility load and the cyclic climate variation that is acting only on the top surface of the beam during 50 years.

The paper presents a finite element implementation of a new beam element able to simulate hygro-mechanical and visco-elastic behaviours in inhomogeneous timber structures. The material model employed concerns the elastic, shrinkage, mechano-sorption and visco-elastic behaviour of the wood material. The cross section of the beam element is divided into a number of lamellas where the moisture content w and the material parameters, such as E and α, can vary in a continuous manner within each lamella, see Figure 1*(b)*. The model is an incremental model that can deliver historical output for displacements and rotations (v, ϕ), section forces (M, V, N), curvatures and strains (κ, ε) and stresses (σ, τ) during the whole service life of the structure. To illustrate some advantages this model can provide, Fig. 2 shows historical output for deflection, bending moment and stresses for the beam shown in Fig. 1 when it is simultaneously subjected to bending and cyclic climate loading.

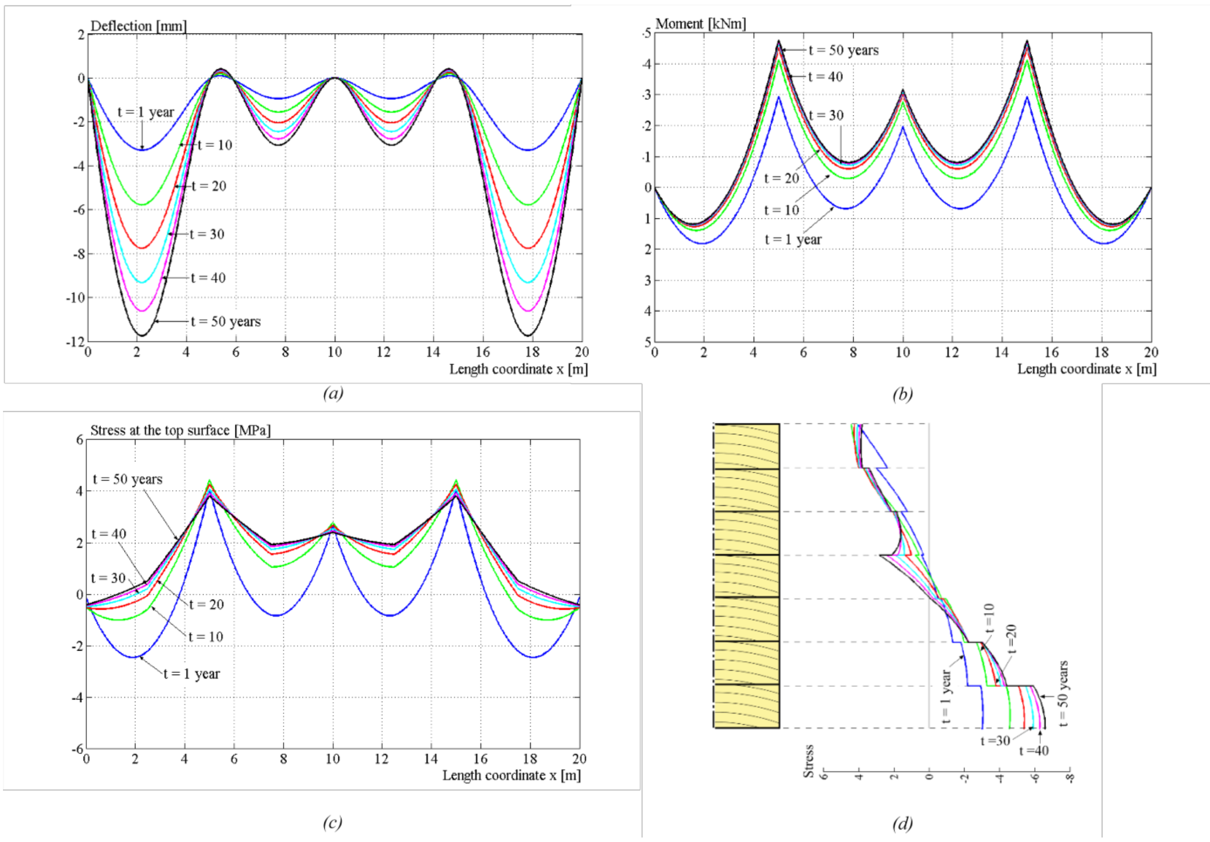

Figure 2: Numerical results at several (summer) times for the beam shown in Fig 1 *(a)* Deflection curves, *(b)* Moment curves, *(c)* Stress variation along the top surface, *(d)* Stress profile for the cross sections at supports 2 and 4.

The results in Fig. 2 clearly show how the deflection is increasing during the entire service life but with decreasing deflection rate. For the support cross sections, the negative moments and the compression stresses at the bottom surface are significantly increasing with time whereas the tensile stresses at the top surface are not changing very much. It may also be noted that the stress profile over the cross section in Fig. 2*(d)*) shows both nonlinear and discontinuous shape and it also changes significantly with time. It can be concluded that cyclic climate load action has a significant effect on both deformations and stress distribution in inhomogeneous and statically indeterminate timber structures subjected to bending.