Construction and Building Materials xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Assessing the integrity of glued-laminated timber elements

Philipp Dietsch [a],*, Thomas Tannert [b]

[a] Timber Structures and Building Construction, Technische Universität München, Germany
[b] Wood Building Design and Construction, The University of British Columbia Vancouver, Canada

HIGHLIGHTS

- Description of main properties of interest and corresponding assessment methods.
- Description of state-of-the-art in assessment methods.
- Extensive background information for all methods.
- Extensive section on how to evaluate on the results from an assessment.

ARTICLE INFO

Article history:
Received 4 May 2015
Received in revised form 25 June 2015
Accepted 29 June 2015
Available online xxxx

Keywords:
Timber structures
Glued-laminated timber
Assessment
Damages
Cracks
Glueline
Moisture
Environmental conditions

ABSTRACT

Glued-laminated timber (Glulam) – allowing for large span and curved elements to be produced – had revolutionized the way timber could be used in structural applications. As the importance of assessing large timber structures is growing, so is the interest of the professional community in assessment methods for existing timber structures. The performance of Glulam elements depends on the quality of the individual laminations, the quality of the finger joints, the quality of the glue-lines and the integrity of the cross-section. This paper presents and discusses feasible methods to: (i) create a general overview of the structural integrity of Glulam elements; (ii) assess the environmental conditions in which these are placed; (iii) determine their moisture content; (iv) map cracks; and (v) assess the integrity of glue-lines. There are multiple methods available; each method, however, only allows assessing a certain type of property or damage. Therefore the application of just one method might not be suitable to enable confident decisions, making it necessary to combine different methods to derive a full picture about the integrity of Glulam elements. As a consequence, expert's reports treating the safety of a structure featuring Glulam oftentimes are set up from a standpoint which can be summarized as "safe on the best knowledge we have".

1. Introduction

1.1. Glulam in structural applications

Historically, timber structures were characterized by elements which were limited both in their cross-sectional dimensions and length by the dimensions of the existing trees in the surrounding area. For the structural design community, the step from solid sawn timber elements to glued-laminated timber elements (Glulam), started by Hetzer [1], represented a significant technological progress and widened the range of application of timber in the building sector. Joining single boards to continuous lamellae and subsequently gluing and stacking them enabled to disengage from the size of the stem cross section and to reduce the effect of defects (e.g. knots) in the material. Amongst the other advantages of Glulam were the possibilities to prefabricate free construction shapes and timber cross sections with high load bearing capacity. The results were larger and more variable (e.g. curved) geometries and timber being increasingly used, e.g. for large-span structures [2–4].

The performance of Glulam elements depends on the quality of the individual laminations, the quality of the finger joints, the quality of the glue-lines and the integrity of the cross-section which is made up of single lamellae that are stacked and glued to cross-sections. As a non-proprietary product, the production of Glulam, including the procedures of grading, finger joining, gluing, and finishing processes, is regulated by standards, e.g. EN 14080:2013 [5] in Europe and CSA-O122-06 in Canada [6].

* Corresponding author.
E-mail addresses: dietsch@tum.de (P. Dietsch), thomas.tannert@ubc.ca (T. Tannert).

http://dx.doi.org/10.1016/j.conbuildmat.2015.06.064
0950-0618/

Please cite this article in press as: P. Dietsch, T. Tannert, Assessing the integrity of glued-laminated timber elements, Constr. Build. Mater. (2015), http://dx.doi.org/10.1016/j.conbuildmat.2015.06.064

1.2. Damage to Glulam structures

Timber structures, when appropriately designed, built, and maintained can last for centuries, as many examples around the world demonstrate [7–9]. But unfortunately, not every structure meets these design, construction, and maintenance requirements, as documented in several publications, e.g. [10–14]. The most frequent damage affecting the integrity of the cross-section is cracking, see Fig. 1 [14].

Cracks are a form of stress relief and should not be mistaken for checks [15]. The reason for the frequent occurrence of cracks in the grain direction of timber is the very low tensile strength perpendicular to the grain (the ratio of the strength perpendicular to parallel in Glulam varies between 1/30 and 1/50 c.f. [5]). Tensile stresses perpendicular to the grain in Glulam elements can be generated by several mechanisms: external loading, internal stresses due to deviation forces in e.g. curved members, uneven shrinkage of the cross-section due to changes, or gradient in moisture content (MC).

1.3. Necessity for the assessment of Glulam structures

The increased interest of the professional community in assessment methods is caused by the increasing importance of assessing large timber structures. The need for an assessment of an existing structure can be based upon a multitude of reasons, e.g. a change of the requirements to the use or to the structure (increased loading, etc.); or doubts whether the assumptions applied during the design are fulfilled, e.g. no inspection for longer period or negative results of an investigation, an unexpected degradation, accidental loads, new knowledge, or, unfortunately extreme incidents like the collapse of the ice rink in Bad Reichenhall in 2006 [10] and a series of other failures of timber structures in Europe over the course of few years [11–14]. These incidents prompted an international research focus on the assessment of timber structures, specifically the RILEM technical committee "AST" [16] and a task force within COST Action "E55" [17]. The findings from these two committees were published in two state of the art reports [18,19] and a series of recommendations on the assessment of timber structures using

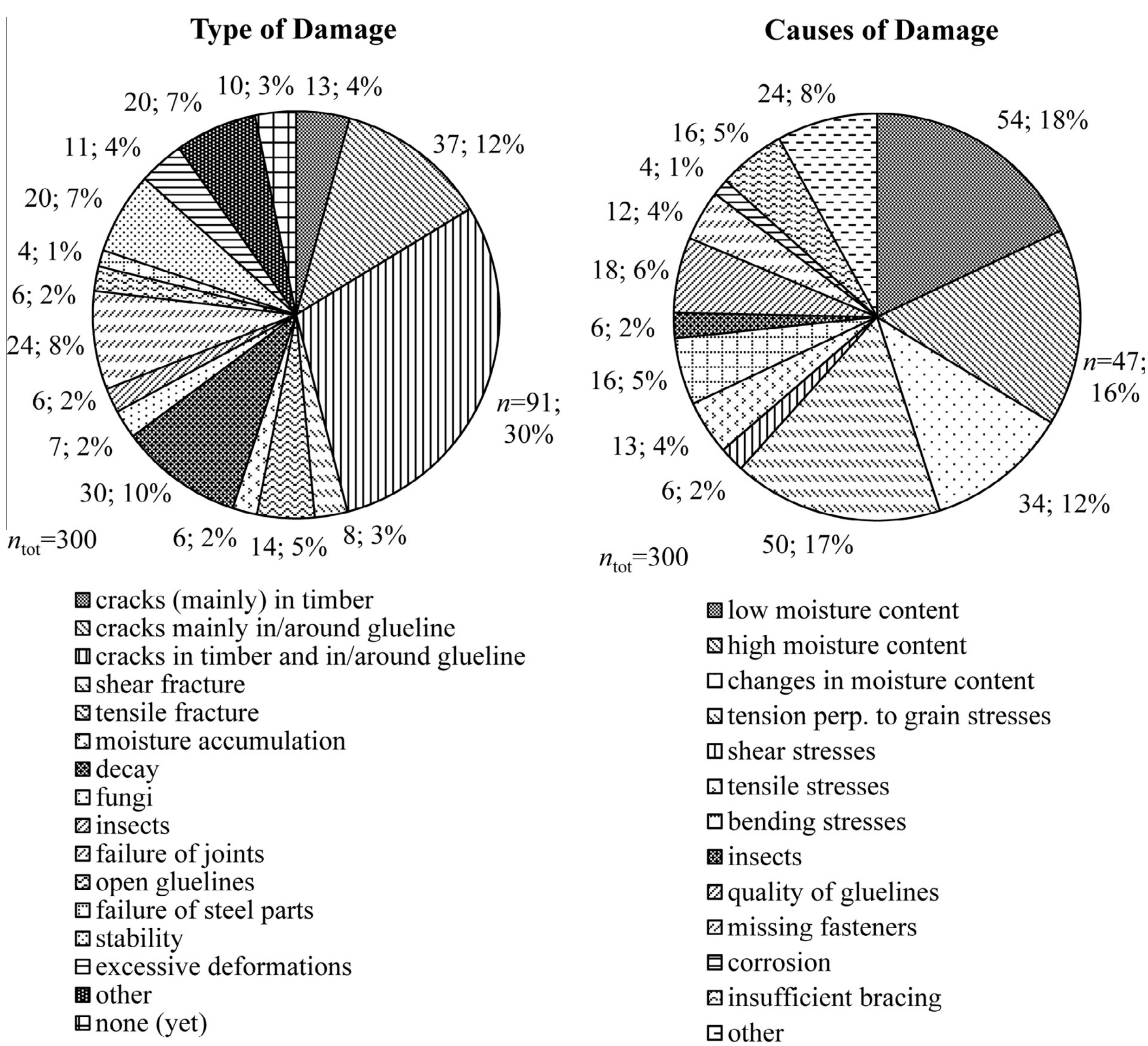

Fig. 1. Evaluation of 245 cases of damaged large-span timber structures [14]; type of damage (left) and causes of damage (right).

Please cite this article in press as: P. Dietsch, T. Tannert, Assessing the integrity of glued-laminated timber elements, Constr. Build. Mater. (2015), http://dx.doi.org/10.1016/j.conbuildmat.2015.06.064