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Robustness of large-span timber roof structures — Structural aspects

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ABSTRACT

Design rules for robustness require insensitivity to local failure and the prevention of progressive collapse. This is often verified by applying the load case "removal of a limited part of the structure". This paper will evaluate typical structural systems for large-span timber roof structures against these requirements, comparing the results against typical reasons for damages and failures. Applying the finding that most failures of timber structures are not caused by random occurrences or local defects, but by global (repetitive) defects (e.g. from systematic mistakes), it is shown that the objective of load transfer – often mentioned as preferable – should be critically analysed for such structures. Based on these findings, proposals for structural systems and details towards a robust design of large-span timber roof structures are given.

1. Introduction

1.1. Robustness requirements for timber structures

The requirement for a robust structure is often defined as a structure being "designed in such a way that it will not be damaged by events like fire, explosions, impact or consequences of human errors, to an extent disproportionate to the original cause" [1]. A structure shall be insensitive to local failure (disproportionate collapse), thereby including the design against progressive collapse. This is a property of the structure itself, independent of possible causes of initial local failure. There are several approaches to demonstrate a robust design, e.g. given in [2]. One of these approaches is to demonstrate that a load case "removal of a limited part of the structure" will not lead to extensive failure.

1.2. Structural systems for large-span timber roof structures

Although there is a multitude of possibilities for structural systems (see e.g. [3]), most large-span timber structures as roof structures of arenas or halls are often composed of a determinate primary structure carrying a secondary structure in the form of purlins; see Figs. 1 and 2.

The primary structure often consists of single-span members, e.g. pitched cambered glulam beams, trussed beams or three hinged frames. The purlins can be realized as simply supported beams (a), continuous beams (b), gerber beams (c) and lap-jointed purlins (d); see Fig. 3.

Evaluating purlin systems from a structural perspective will highlight continuous systems due to their lowered maximum bending moments, enabling the realization of larger spans e at given spacings e_p and cross-sections. Due to this and due to the acceleration of the construction process, purlin systems today are often realized by continuous systems like lap-jointed purlins.

Design rules for robustness require insensitivity to local failure and the prevention of progressive collapse. This is often verified by applying the load case "removal of a limited part of the structure". In the following, typical purlin systems for timber roof structures will be evaluated against these robustness requirements.

2. Robustness evaluation of typical purlin systems in large-span timber roof structures

2.1. Evaluated system

The evaluation of typical purlin systems utilized for timber roof structures (as shown in Fig. 3) with respect to their influence on the robustness of the whole structural system is realized by a comparison of how the removal of a limited part of the structure will affect the remaining structure. This is supported by comparative deterministic calculations on the exemplary roof geometry given in Fig. 1. Since the detailed description of the evaluated system as well as the full presentation of the results would lead to an excess size of this publication, only the key results will be given. The reader is therefore kindly referred to the detailed description given in [5]. Typically, two cases are evaluated (see Table 1).

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