Analysis of structural failures in timber structures: Typical causes for failure and failure modes

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Abstract

Collapses of timber structures are negative for the competitiveness of timber on the construction market. The question is what can be done to reduce the risk for failure in timber structures in the future. For this purpose a comprehensive survey and analysis of failures in 127 timber structures have been made. The present paper summarises the results from this survey with an analysis of the underlying causes and associated conclusions and recommendations. The most common cause of failure is related to weaknesses in or lack of strength design (41.5%), followed by poor principles during erection (14.1%), on-site alterations (12.5%) and insufficient or lack of design with respect to environmental actions (11.4%). In total, about half of the failures are caused by the designer and about one fourth of the failures are caused by the personnel working at the building site. Wood quality, production methods and production principles only cause a small part (together about 11%) of the failures.

1. Introduction

When implementing Eurocode 5 the level of safety for timber structures is re-evaluated in many European countries in national application rules. This has raised the question whether the current level of safety for timber structures is appropriate in relation to e.g. steel and concrete structures. A similar debate has also been initiated as a consequence of several spectacular failures in timber buildings e.g. in the Nordic countries and Germany, during recent years.

During the winter 2005/2006, many structures collapsed under high snow loads in Southern Germany and Austria [1], and in early spring 2010, the same happened in Sweden [2].

Several surveys for building structures in general and for all structural materials can be found in the literature. A general conclusion from such studies is that failure almost without exception occurs due to human errors. Kaminetzky [3] suggested that human errors can be divided into three categories: errors of knowledge (ignorance), errors of performance (carelessness and negligence) and errors of intent (greed). Other comprehensive studies of structural failures found errors in the design/planning phase and construction phase [4,5]. A majority of mistakes is related to conceptual errors and structural analysis: incorrect assumptions or insufficient consideration of loads and actions was found to be a common type of error [5]: see Table 1. Failures due to material deficiencies or maintenance are relatively uncommon [4].

Rather few cases related specifically to timber structures are found among the published failure investigations. The conclusion from this is not necessarily that timber structures are “safer” than structures from other materials. A more probable explanation is that failure cases related to timber structures have been included only to limited extent in the data material collected in the previous investigations. However, special investigations of failures in timber structures are found in Refs. [6–8], but these are rather limited and usually do not allow general conclusions to be drawn. The available newer publications describe the collapses that happened during the last decade in Europe [1,9,10]. Dröge and Dröge [6] describe 31 cases in a rather detailed manner. From their investigation, the following technical causes of damage which occur in timber structures can be identified: inadequate behaviour of joints, effects of moisture exposure (imposed strains, shrinkage), poor durability performance, inadequate bracing of structural system, inadequate performance of material and products, and inadequate appreciation of loads. Dietsch and Winter [1] described and analysed damages in 214 long-span timber structures from Southern Germany during winter 2005/2006. 550 damages were included in the study reported by Blaß and Frese [9].

During early spring 2010, almost 160 large-span structures collapsed in Sweden under snow load [2]. About half of the structures were made of steel, others were timber and glulam structures. About 32% of the buildings were agricultural buildings, 26% storages/warehouses, 17% sports halls (sports, ice arena, equestrian centre etc.). Most buildings had large spans (most frequently between 10 and 30 m) and low roof inclination (below 15°). More than 65% of the buildings were built from 1980 and so on. However, this may be due to the fact that the same regions in Sweden that...