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Introduction, Failure Assessment Publication

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1. Current status of the publication

This report covers summaries of studies on structural failures on timber structures around Europe. Additionally guidelines on implementing inspections on structures and on the building process concepts to obtain quality and avoid failures are given. These assessment studies and guidelines were drafted by the Cost members (or member institutions).

The main purpose of this publication is to discuss the various failure assessment methods used in the different studies and to conclude with an agreement on a common procedure to be used for future assessments. This mainly applies on how the assessments should be carried out and on how to classify the failures, which may be done in different ways.

The provisional table of contents and its current stage is as below. The publication is open for further presentations during the course of this action.

Table of content

1. Introduction, TT **(ready)**

2. Terminology used in the failure assessment **(not ready)**
(Nordic &German), EF, MF

3. Failure assessments
3.I Analysis of failures on timber structures in Germany, Frese & Blass **(ready)**
3.II Design of timber structures, learning from failures, Frühwald & al. **(ready)**
- Open for further presentations....

4. Guidelines
4.I Guidelines for a first evaluation of large span timber structures, HK **(ready)**
4.II Guidelines for quality in the timber building process, TT, **(ready)**

5. Failure classification procedures
5.I German study, Frese & Blass **(not ready)**
5.II Nordic study, Frühwald & al. **(ready)**
5.III Dutch example, Leijten **(not ready)**
5.IV Drafting of European wide failure classification, **(future brainstorming)**

6. Discussion

2. Survey of failures in buildings and other built facilities with timber as the main structural material - Nordic study

Below is a short description on how the failures were defined and classified in the Nordic study. The main reference is: Design of safe timber structures – How can we learn from structural failures in concrete, steel and timber: Fruhwald, Serrano, Toratti, Emilsson and Thelandersson, Report TVBK-3053 Lund 2007.

2.1 General background

In the Nordic project, which ended in 2006, with the objective to develop procedures for Quality Assurance of design and construction of buildings with wood as a structural material, one subtask is to make a survey of building failures to find out e.g.

- the underlying reasons for observed failures
- which type of components are most prone to failure
- which failure modes are most frequent
- what can be done to avoid or reduce failures

The background for the investigation is that some spectacular collapses of timber roof structures have occurred recently in the Nordic countries, fortunately without personal injuries. Such events can however be quite negative for the competitiveness of timber on the construction market.

2.2 Definition of "failures"

The concept of failure considered in the survey was mainly related to the ultimate limit state and not to loss of serviceability. Thus, failures are defined as events which directly or indirectly have or could have implied risk for human lives. Examples are direct collapses of structures, local cracking, crushing or degradation which can be expected or suspected to have negative effects on the safety of the structure.

Events which are outside the scope of the survey are e.g. vibrating floors, excessive deformations or moisture movements and building physical effects such as growth of mould and fungi which clearly do not have any consequence for the safety of the structure.

2.3 Format of the requested information

a) Copies of investigation reports

The best alternative is to obtain copies of investigations reports from individual cases. To be able to assess the reliability and impartialness of the investigation
we need to know

- Who did the investigation?
- Which part commissioned and paid for the investigation?
- Why was it made?

if such information is not already included in the report. Note that names of companies and persons involved in the cases are not revealed, but only their role (building owner, contractor, consultant, material supplier etc.) The final reporting of this project is on a generic level without mentioning names of involved parties from individual cases, unless this is cleared with those involved or if the information is already public.

b) Brief summary of information from the failure case

2.4 Free format description of "failure" case - Example

Case X – Cracking in glulam arch structure

Description of structure

The structure was built in 1934 and consists of six parallel arches, which act as statically indeterminate load-bearing frames. The arches have I-shaped cross sections and web stiffeners at every 4 m. The flanges are held together with bolts going through the beam at the stiffeners. The structure was originally used as an outdoor theatre arena. In 1983 the building was subject to renovation and insulation was placed in the roof, in order to make the theatre an indoor facility. The insulation was placed in between the arches, not on top of the existing roof.

Description of failure

When additional restoration work was conducted in 1988, a large crack was found in one of the arches. No data on when the crack had developed was available. SP was commissioned to perform an investigation of the structure.

Original investigation performed and conclusions

An on-site inspection was performed. The crack that had led to the call for an inspection was measured, and is schematically shown in Figure 1.

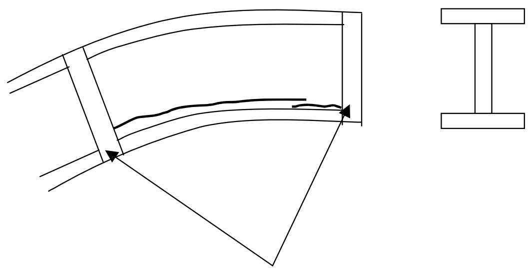

Figure 1. Schematic of arch apex with cracks. The crack length was about 4 m.

In addition to the cracks it was also noticed that the bolts holding the flanges together had loose fittings. Distances of about 5 mm were measured between the nuts and washers.

The original investigation concluded that the failure was due to the changing climate conditions after insulation was added to the roof. By placing the insulation in between the arches instead of on top of the existing roof, a temperature and thus a moisture gradient was created. The drying of the wood induced the perpendicular to grain failure. Calculations showed that the loading by self weight resulted in approximately 0.2 MPa perpendicular to grain stresses, which is about the allowable stress. The moisture gradient induced stresses were estimated to be also about 0.2 MPa, and thus the strength of the material was reached. The moisture variation was assumed to be linear over the beam depth, with a difference of 6% MC between the inner and outer parts of the arch.

Additional conclusions and comments

The conclusions from the original investigation seem adequate. The failure can be classified as being due to poor knowledge about moisture induced stresses in wood. This failure shows the importance of accounting for other loads than mechanical ones when designing load-bearing structures.

2.5 Questionnaire about failure cases in timber structures

Please complete one questionnaire for each individual failure case. Give the case a title which is neutral as to the identity of the case, e.g. one storey industrial building or glulam purlins failure.

Case	
My name	

1. Type of building

☐ Residential

☐ Office

☐ Public

☐ Sports Hall

☐ Industrial

☐ Other type, specify:

____

Number of storeys = ______________________________

2. Structural system

☐ Timber frame system

☐ Post and beam structure

☐ Large scale glulam structure

☐ Large scale LVL structure

☐ Massive wood elements

☐ Other type, specify :

____

3. Structural element or connection involved in the failure case

☐ Beam, span _____ m

☐ Truss, span _____ m.

Specify type (e.g. timber, glulam, tension rod type, trussed rafter etc.)

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☐ Arch, span _____m

☐ Column, length ____ m

☐ Shear wall

Dowel type joints (shear or withdrawal)

☐ Nailed

☐ Screwed

- ☐ Steel dowels
- ☐ Bolted
- ☐ Slotted-in steel plate
- ☐ Other dowel type joint, specify

- ☐ Punched metal plate fastener joint
- ☐ Glued joint
- ☐ Other type, specify:

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4. Special Characteristics

E.g. notches, holes, reinforcement etc. in member,
toothed metal plate strengthening, reinforcement etc. of joints

5. Description of failure event and failure mode (free text)

6. Cause(s) of failure according to investigations performed

Give one or more reason for the failure by writing one or several numbers as follows
1= primary reason
2= secondary reason
3 = tertiary reason.
(The same figure e.g. 2 can be used for more than one reason)

- ☐ Poor design/lack of strength design
- ☐ Poor design/lack of design related to environmental actions
- ☐ Poor principles during construction
- ☐ Alterations on-site of intended design or products
- ☐ Deficiency of code rules for prediction of capacity
- ☐ Extreme loading exceeding code values
- ☐ Inadequate quality of wood material
- ☐ Poor manufacturing principles for wood products
- ☐ Manufacturing errors in factory
- ☐ Misuse or lack of maintenance of the structure
- ☐ Other, specify below

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6. Additional conclusions and comments