A Proposal A Proposal for a failure template

Cost E55

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Background

- Failure studies on timber structures have recently been carried out in various countries in Europe.
- These failure assessments have not been done in a uniform manner, which makes comparisons between the studies and the development of common procedures a difficult task.
- The purpose of this paper is to propose a common format on gathering information from failure cases of timber structures.
- This is a discussion paper for working group 1 of Cost E55.

Objectives of a Failure template

To help the expert carrying out the assessment to find the relevant questions that need answers.

Uniform quality and uniform level of detail of assessments

Produce material for further analysis to pinpoint weaknesses in the material/design/construction/use processes:

- design procedures perhaps need improvement,
- if our construction material is getting weaker
- if there are not enough human resources allocated for specific tasks such as for the structural design,
- lack of communication in the construction site or misunderstandings
- or other similar deficiency

Factors to keep in mind (1)

Durability cases

- It is clear that not all structural failures can be reached with these assessments.
- It is suspected that in many cases failures are simply not assessed and/or that very few persons know about them.
- It may be assumed that one such group of cases on timber structures could be the cases related to durability.
- This suspicion comes from the fact that there are not very many durability cases in at least the Nordic cases.
- It is here suspected that such cases are not always assessed and that these are often not even regarded as failures, but as normal end of service-life situations.

Factors to keep in mind (2)

Serviceability cases

- An aspect which has not been addressed in these failure studies (in at least the Nordic study), is the serviceability failure cases.
- There are many such failure cases related to excessive vibration of floors.
- Most often these cases are not public.
- Another problem with many of these cases are that floor vibration design procedures in the current codes are very liberal.
- Recent vibration studies in VTT on the subjective assessment of floors and measurements of floor vibrations due to walking have revealed that the Eurocode 5 design is not always satisfactory.
- In such cases neither the designer nor the constructor have done errors, but the floors clearly vibrates and the users are not satisfied.
- This brings up the question: if vibration failures are failures at all or is it simply due to that the human requirements on floors have raised.

Factors to keep in mind (3)

Publicity

- The template may be used in both public and confidential assessment situations.
- It is clear however, that further analysis of the data for 'public use', essentially require publicity on the assessment data or at least partial publicity .
- Whether the data is public, partially public or confidential is not at all addressed in the failure template procedures.
- This of course applies on how the information is utilized in further processing.

Failure cause classification

Related to structural design

- Poor design or lack of design related to strength or environmental actions
- Deficiency of code rules for prediction of capacity
- Extreme loading exceeding code values

Related to construction on-site

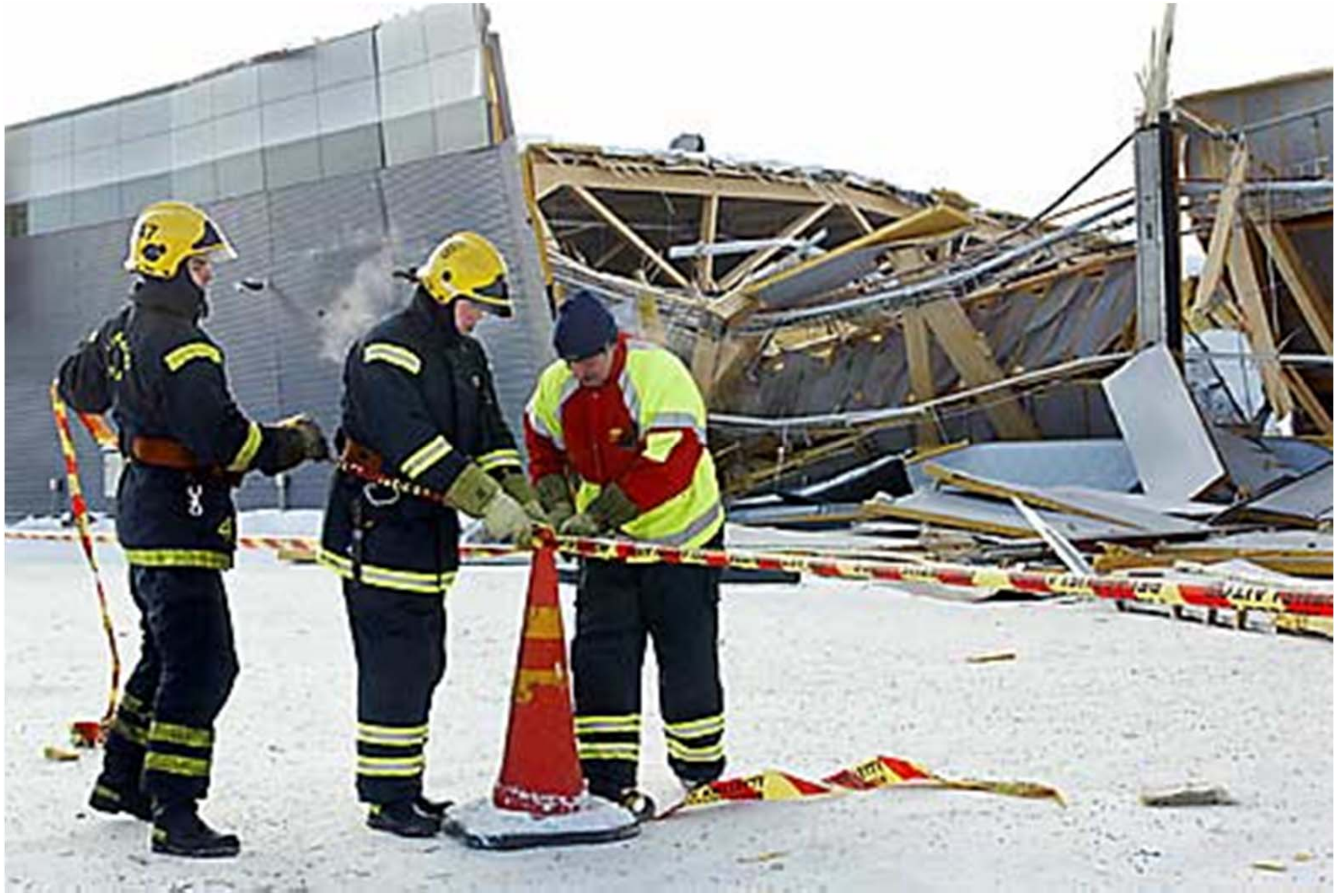
- Poor principles during construction on site
- Alterations on-site compared to design

Related to building materials

- Inadequate quality of (wood) material used in construction
- Poor manufacturing principles for wood products (glulam, finger-joints etc.)
- Manufacturing errors in factory on prefabricated products (elements)

Related to building use

- Was the building used as intended
- Was there lack of maintenance of the structure



Case name *Jyväskylä fair centre*

Case *Jyväskylä, Finland*

location

My name *Mr.X*

1. Type of building

Residential
Office
X Public
Sports Hall, which kind (e.g. swimming, ice-skating, etc.)
Industrial
Agriculture.
Shopping
Other type, specify:
Number of storeys = *1*

2. Structural system

Primary structure:

Timber frame system
X Truss roof system, span: 55 m
Post and beam structure
Straight beam, number of support: ____ span(s): ____
Single pitch beam, number of support: ____ span(s): ___
Double tapered beam, span: ___
Arch structure, span: ___
Massive wood elements
Other type, specify :

Structural material of primary structure:
X Glulam, Grade: GL32h
LVL
Strength graded timber, Grade:____ visual or machine grade:______
Non graded solid timber
Other type, specify :

Description and material of secondary structures:

3. Occurrence of failure

At which phase did the failure occur

Construction phase
X Building use phase, give age of building at failure in years: _0
Time of the year of failure

- Describe loads at failure (snow or other loads)
- Describe humidity and temperature conditions at failure (and in the near past if information available)

Snow load was 25% (0.5kN/m²) of the design snow load. The building was in use, so the interior humidity and temperature conditions were normal. Exterior conditions nearly calm, clear sky and temperature of -26ºC.

4. Structural element or connection involved in the failure case

Beam, span _____ m
X Truss, span _55_ m.

Specify type (e.g. timber, glulam, tension rod type, trussed rafter etc.): *glulam truss-roof on concrete columns*

Arch, span _____m
X Column, length _≈6.5_ m
Shear wall

Connections involved in the failure:

Nailed
Screwed
X Steel dowels
Bolted
……

5. Description of failure

a) triggering failure event and failure mode

b) secondary failure events

(free text and pictures)

The primary (triggering) failure was caused by a dowel connection of the roof-truss in the vicinity of the support. The failure of the connection caused the failure of the truss and the 2 trusses in the vicinity. Some concrete columns, and part of the wall were also destroyed

6. Assessment of the progressive nature of the failure and robustness

(this is based on ref. [3])

A. Was there a Collapse

X Yes
No
Not known

Explanation: Collapse is defined as one or more structural elements falling down as a result of the failure.

B. Progressive nature of collapse

Classification levels:

X Large secondary damage
Medium secondary damage
Damage limited to the element where failure was initiated

Explanation: Large secondary damage could e.g. be seen as damaged area which is more than about three times larger than the area related to the element where failure was initiated. The lowest level corresponds to damaged area which only to a small extent (<50%) goes beyond the zone where failure starts. A subjective assessment may also be made if quantification of damaged area is not relevant. Obviously, all cases where collapse did not occur belong to the lowest level.

C. Consequences

X High
Medium
Low

Explanation: Consequences are related to risk for humans as well as to economical losses. The scenario when substantial parts of the building collapsed and humans might have been killed or injured is typical high consequence failure.

D. Nature of warning

No warning before collapse (order of seconds)
X Warning allowing evacuation of a limited number of people (order of minutes)
Warning giving time for temporary strengthening (order of hours or more, includes cases where collapse did not occur)

E. Degree of proportionality between consequences and cause

X Very disproportionate consequences
Moderately disproportionate consequences
Consequences in proportion to the triggering event

Explanation: This is included because it is how robustness is often interpreted. The difficulty here is to assess the denominator, i.e. to define "magnitude or extent" of the cause.

F. Subjective assessment of the robustness of the structural system

High robustness
Medium robustness
X Low robustness

Further descriptions:

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

Give one or more reasons 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 case)

Additional questions might apply under the failure cause as noted below:

Related to structural design

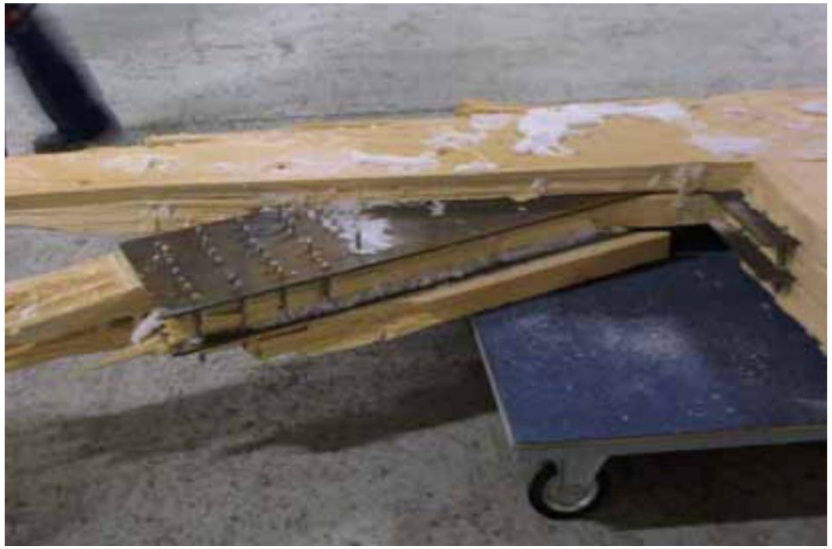
Poor design/lack of design related to strength or environmental actions

- Quality control measures performed on the design (eg. external design check), describe

2 Deficiency of code rules for prediction of capacity

- Identify the code design equation and the building codes (and national annex) used

The European pre-standard (Eurocode 5, ENV 1995-1-1) used as design guideline at this time in the structural design of the trusses, failed to consider the block shear type of fracture in connections. The result was that the true strength of the a critical joint was only about 50 % of the designed value. According to the investigation commission, the errors discovered in the guidelines imply deficiencies in the drafting of the standard.



Related to building materials

Inadequate quality of wood material used in construction
- Describe origin of material and quality control procedure applied on the material

Poor manufacturing principles for wood products (glulam, finger-joints etc.)
- In this case best practice is not good, suggest improvements for best practice

1 Manufacturing errors in factory on prefabricated products (elements)
- Quality control measures performed on manufacturing (eg. internal or external production control), describe:

A critical joint close to the support of the truss of the roof truss pair having first collapsed, only had 7 dowels while according to the structural design their number should have been 33. The collapse was initiated by this control negligence by the truss manufacturer. Only on one truss of a truss pair revealed missing dowels. The collapse progressed how ever also to neighbouring trusses due the block shear failures in connections (second failure cause)

Summary

- The present paper describes a failure assessment template, which is intended for use by experts carrying out failure assessments on failed timber structures.
- The template has at least three major benefits:
  a) information is gathered in a uniform manner and the build-up of failure databases is simplified,
  b) the expert will be more aware on the relevant questions that need answers when carrying out an assessment,
  c) major weaknesses in construction processes or in material performance or standard design procedures are identified.
- It is evident that this template will need further developments in future studies.
- The template has been used by some experts in different European countries and positive feedback has been received so far.