WG1
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Proposal for a Failure template

1. Background

Failure studies on timber structures have recently been carried out in various countries in Europe. However, 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.

2. Objectives of a Failure template

The objectives of a failure template are:

- To help the person carrying out the assessment to find the relevant questions that need answers. This is mainly when new cases are assessed, but it may be used also for a re-evaluation of past failure cases.

- To produce a failure assessment that is more uniform and which is less dependant on the expertise, professional involvement or personal characteristics of the person carrying out the assessment. Clearly the human factor cannot be fully ruled out.

- Produce material for further analysis to pinpoint weaknesses in the construction process, which need attention or further research. This may be to identify if
  - design procedures need improvement,
  - if our construction material is getting weaker
  - if there are not enough human resources allocated for specific tasks as structural design,
  - lack of communication in the construction site or misunderstandings
  - or other similar deficiency

3. Some points to remember when using the failure data

<u>Durability cases</u>

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.

<u>Serviceability cases</u>

Another 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. These are troublesome in many ways: most often these are not public cases, and the assessment is carried out as a private commission and such material may not be used, except in a

disguised way not revealing the building and sometimes not even the floor structure. 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 vibrate and the users are not satisfied. A possibility is to compare the vibration levels to ISO recommendations on transient vibrations, but the procedures are not totally clear and the criteria are broad. VTT has produced criteria of its own, but these do not stand any legal status *(ref. Toratti T., Talja A.: Classification of human induced floor vibrations. Building acoustics. Journal of Building Acoustics 2006 vol 13 no 3.)*
In any case this brings up the questions if vibration failures are failures at all or is it simply due to that the human requirements on floors have raised. This seems to be partly so, as similar floors are more accepted in small houses than in multi-storey apartments.

4. 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.

5. Benefit of the failure template

When an expert is called for a failure assessment, he/she may use the template in gathering the relevant information. It is not always important that the template is fully completed and certain information can be missing. This could possibly be due to that the information is simply not there or that a certain part is restricted from public for whatever reason.

The real benefit from a common template comes when a number of failures cases are investigated. This should reveal if there are deficiencies in the material, design, construction process etc.
This provides the information needed to pinpoint where alerts and/or remedy actions are needed.

The failure causes are in this draft classified based on a slightly developed version of the classification used in the Nordic study. An additional question is posed under each failure cause class, in order to bring up further light on the backgrounds of the cause.

Additionally, questions related to progressive failure and robustness are added from another study running in parallel *(Cost Action TU0601 paper: Robustness evaluation of failed timber structures, Frühwald E., Thelandersson S., Fülöp L., Toratti T.)*.

6. Failure Cause classification used

Related to structural design

a) Poor design/lack of design related to strength or environmental actions
   - Quality control measures performed on the design (eg. external design check), describe

b) Deficiency of code rules for prediction of capacity
   - Identify the code design equation and the building codes (and national annex) used

c) Extreme loading exceeding code values
   - Identify the building codes (and national annex) used

Related to construction on-site

d) Poor principles during construction on site
   - Describe quality control measures performed in construction
   - Is the construction method known as best practice

e) Alterations on-site of intended structural or detailing design
   - Describe quality control measures performed during the construction works (eg. construction inspections)

Related to building materials

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

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

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

Related to building use

i) Is the building used as intended (as designed)
   - Describe

j) Is there lack of maintenance of the structure
   - Was sufficient information on use or maintenance procedures given ?

7. Draft Failure Template

This proposed questionnaire on failure cases in for timber structures is based the one used in the Nordic study, it is here used with an example failure case from Finland.

Besides the description of the failure itself, the most important information relate to the cause of failure. In this way section 7. is very important. It is felt that the degree of detail in this proposal is a minimum in order to achieve the benefits described above.

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 name	*Jyväskylä fair centre*
Case location	*Jyväskylä, Finland*
My name	*FÜLÖP Ludovic*

1. Type of building

[ ] Residential
[ ] Office
[X] Public
[ ] Sports Hall, which kind (eg. swimming, ice-skating, etc.)
[ ] Industrial
[ ] Agriculture.
[ ] Shoping
[ ] Other type, specify:
Number of storeys = 1

2. Structural system

[ ] Timber frame system
[X] Truss roof system
[ ] Post and beam structure
[X] Large scale glulam structure
[ ] Large scale LVL structure
[ ] Massive wood elements
[ ] Other type, specify :

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/m^2) 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
[ ] Slotted-in steel plate
[ ] Other dowel type joint, specify
dowel connection acting in shear
[ ] Punched metal plate fastener joint
[ ] Glued joint
[ ] Other type, specify:

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

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 vecinity of the support. The failure of the connection caused the failure of the truss and the 2 trusses in the vecinity. Some concrete columns, and part of the wall was also destroyed

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

(this is based on the Cost Action TU0601 paper: Robustness evaluation of failed timber structures, Frühwald E., Thelandersson S., Fülöp L., Toratti T.)

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. Cases where collapse does not occur are e.g. excessive deflection, cracks or other visible damage (included in the database due to a potential risk with respect to safety).

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. Cracking and minor damages which did not cause collapse just local failure of the element are typical low consequence events, as the building could be repaired at limited costs. Consequences depend on the use of a building so that a collapse is regarded as more severe in a building where many people may be present such as a sports arena, than in e.g. a storage building.

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)

☐ Not known (NA)

E. Degree of proportionality between consequences and cause

☒ 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. Take as an example a case where the whole building falls down because bracing has not been provided at all in the building. Then the consequences are quite reasonable in view of the mistake by the designer. In the present investigation the assessment must be related to seriousness of the errors performed, since most of the cases are related to errors in design or construction.

F. Subjective assessment of the robustness of the structural system

☐ High robustness
☐ Medium robustness
☒ Low robustness

Further descriptions:

7. 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)

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

[3] Deficiency of code rules for prediction of capacity
- Identify the code design equation and the building codes (and national annex) used

☐ Extreme loading exceeding code values
- Identify the building codes (and national annex) used

Related to construction on-site

☐ Poor principles during construction on site
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<u>Related to building materials</u>

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- 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

<u>Related to building use</u>

☐ Is the building used as intended (designed)
- Describe

☐ Is there lack of maintenance of the structure
- Was sufficient information on use or maintenance procedures given:

[2] Other, specify below
Lack/deficiency of quality control during the manufacturing process.

8. Additional conclusions and comments