FAILURES OF TIMBER STRUCTURES IN SLOVENIA

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TYPICAL FAILURES OF TIMBER STRUCTURES

- In last 30 years just few failed structures
- Two types of failures:
  - contemporary structures
    - glued laminated beams (curved and tapered beams, straight beams, arches...)
    - roof trusses - nailed plates connections
  - hystorical structures
    - roof structures
    - floor beams

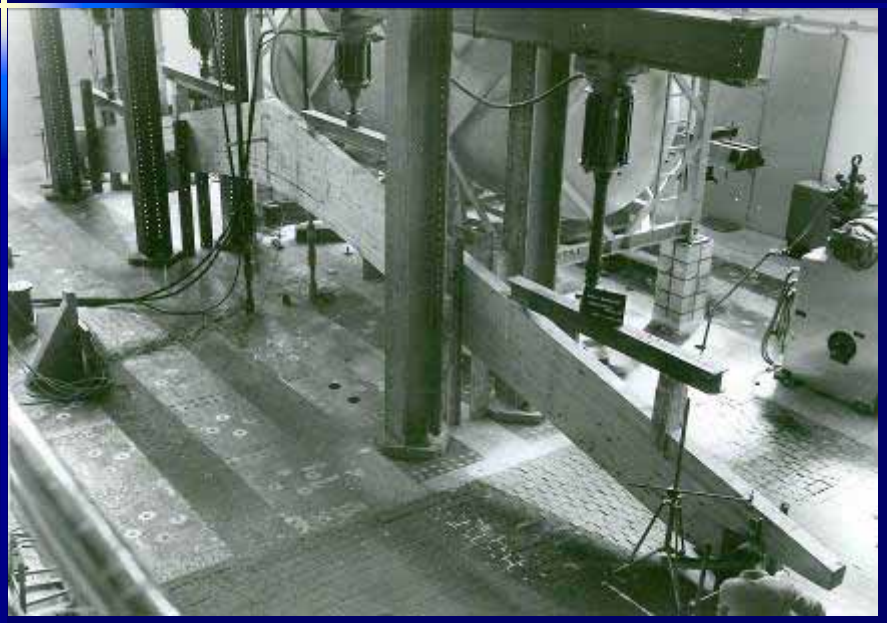
BASIC ORIGINS OF FAILURES

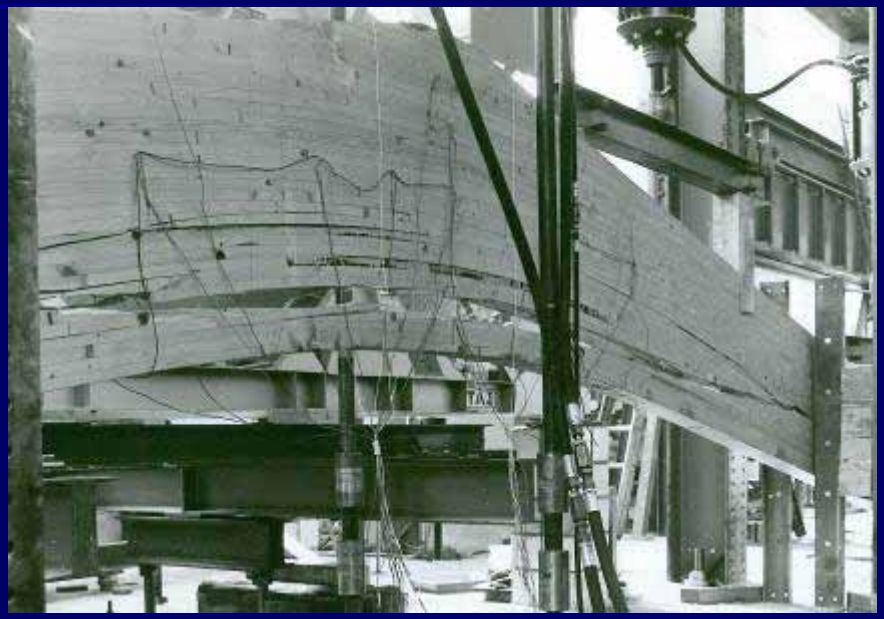
- Contemporary structures
  - design mistakes or omittances
  - improper use of materials (e.g. glue...)
  - problems in production (gluing...)
- Hystorical structures
  - bad details - constant wetting
  - improper restauration measures
  - lack of maintenance!

Markovec near Cerknica, November 1979

- 3 buildings for chichen stables, in each 15 curved and tapered glulam roof beams, span 13,65 m, height 0,58 - 1,04 m, depth 0,145 m
- all 15 elements in one building failed
- in other buildings cracked elements
- estimated snow load 0,8 kN/m^2
- radial stresses not controlled - failure due to exceeded perpendicular to grain tensile strength

Laboratory tests of the same type of beams





- load bearing capacity ca 3-times higher then estimated load at on-site failure
- different position of origin of failure
- failure in the wood, no failed glue lines
- difference in load bearing capacities caused also by hindered movement of supports (friction)
- beams of the collapsed building were (according to users) exposed to weathering

On-site loading test, Sport hall Ig, February 1980

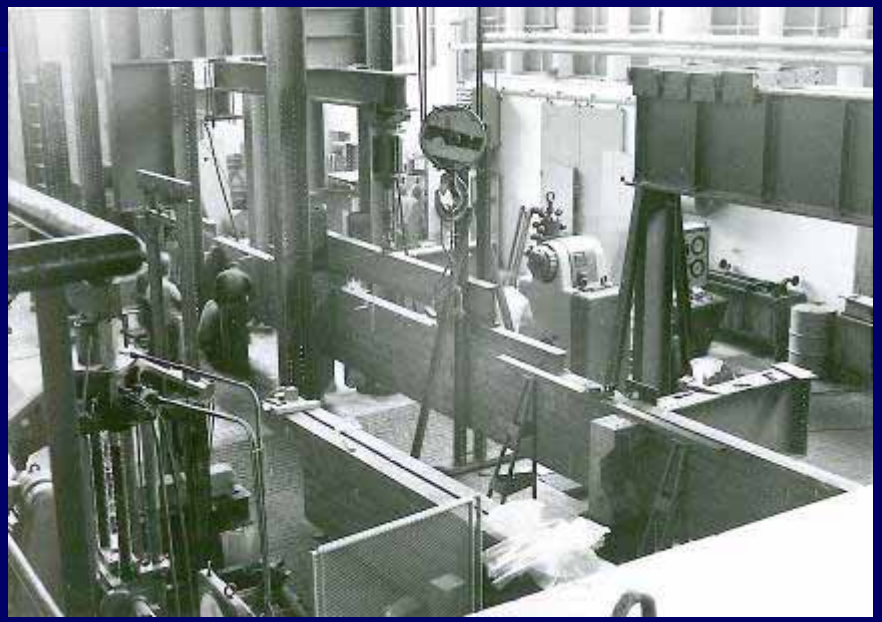
- failure during the test at 1.16-times design load
- brittle failure without increasing deflections
- failure in the wood and partially in glue lines
- beam was removed and brought to laboratory to study strengthening methods (ties in radial direction, tensile tie between supports)

Three hinged arch, laboratory test 1982

- non-symmetrical load
- brittle failure due to exceeded perpendicular to grain tensile strength below the middle hinge (detail with two dowels)
- redesigned hinge detail: three fixing dowels, additional transverse dowel
- increased load bearing capacity for ca 100%
- failure due to bending stresses in the element - increasing deflections noticed

Gerber hinged beam, 1983

nondestructive testing for assessing fitness for use (measuring deflections by lifting)



- in straight roof beams (span: 17,5 +3m, 15m, 3+17,5 m) visible cracks
- cause: improper use of glue (casein glue in the industrial premise)
- laboratory tests to the failure of three beams
- big differences in load bearing capacities proved on-site measurements

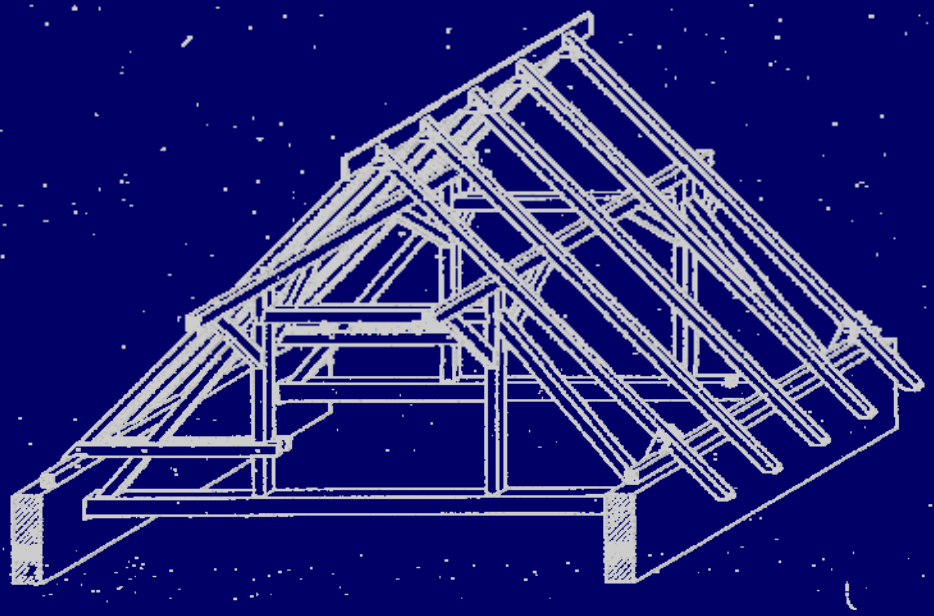
Trusses with nail plate connections, Črnomelj, 1987

- roof trusses in school building
- failure observed on the deformed roof plates
- failure due to improper location of nail plates - out of centre line
- exceeded perpendicular to grain tensile strength

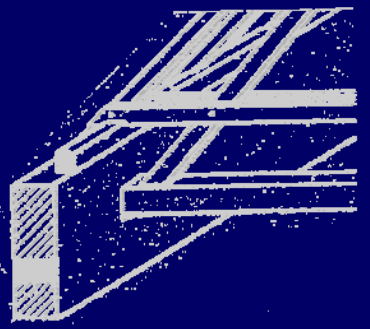
MOST FAILURES HAPPENED DUE TO TENSION PERPENDICULAR TO GRAIN!

Historical structures

- Roof structures
- classical roof structures from solid wood - strutted and suspension frames
- problematic details: supports on outer walls



timber elements closed in walls



Damaged roof structures - examples

- constant moisture in wall - ideal for fungi attack
- usually wood attacked by rottening fungi (brown rottening, loos of integrity and load bearing capacity)

Damaged roof structures - examples

Problematic roof details - examples

Historical structures

- Floor structures
- two types of floor structures from solid wood - hollow and massive floors

Problematic floor details - examples

Failed massive wooden floor, Ljubljana, 2007

Roofs: problematic construction measures during use

The most common (and problematic) measure at classical roof structure is cutting lower chords to make passages

- central posts near the cutting points are elongated to the attic floor level, lower chord is supported by temporary short studs,
- on other spot the height difference of about 10 centimetres between cut parts occurred

WHAT TO DO TO AVOID FAILURES?

Controls:

- contemporary structures
  - design (obligatory for important structures: public buildings, schools, sports facilities , especially with larger spans...)
    - ➢problematic details, real service class, condensation danger
  - materials, components (for all structures)

On-site inspections

- contemporary structures
  - regular inspections for important structures (similar as for bridges: basic on 2 years period, detailed 6 years period)
- historical structures
  - when damage in wood or improper construction measures are suspected
  - checking design only if a higher load is predicted

CONCLUSIONS

- In Slovenia the majority of failures of contemporary structures happened ca 20 - 30 years ago
- Better design using Eurocode 5
- Some of historical structures in very bad shape - due to constant wetting failures still occur
- To avoid failures controls of design of important buildings with large spans (public buildings...) should be obligatory
- Regular controls of installed structures in the above mentioned buildings are recommended
- Special attention should be paid to the structures in the severe climatic conditions (e.g. roofs in ice halls...)

THANK YOU FOR YOUR ATTENTION!