Historic roof trusses and their preservation - A qualitative approach to structural analysis

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Abstract This paper has two purposes: One is to describe the structural behaviour of a large group of Swedish historical timber roof structures. The other is to show the usefulness of qualitative structural analyses as a tool in safety assessment of timber structures.

Keywords roof truss, structural analysis, structural behaviour

1. INTRODUCTION

In Swedish churches, roof trusses constitute a rich cultural heritage representing timber building expertise from the 12th century until today. In modern times, the preservation of these historically important structures has been unsatisfactory. Measures have been extensive and radical and modern materials and methods have been used. A research project has been carried out, with the aim of exploring the reasons for and adequacy of these restoration measures. A need for a general understanding of roof structures was identified, as well as a need for methods to communicate structural behaviour between professionals. The following research questions were formulated: How do old roof trusses in Swedish churches carry their load? How is this load bearing influenced by the design? Which designs are most rational? How can comparative qualitative results in analyzing these trusses best be achieved?

2. METHOD

In order to answer these questions, a qualitative approach was adopted.

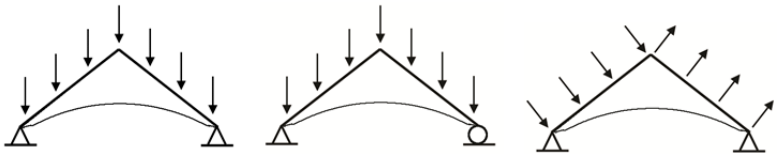

Figure 1 – Pictures symbolizing three important tasks for roof trusses.
1) To carry vertical load when horizontal support movement is restricted. 2) To carry vertical load when horizontal support movement is permitted. 3) To carry anti-symmetric uniform load perpendicular to the roof surface when horizontal support movement is restricted.

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Three important ”tasks” for roof trusses were identified − the task of carrying vertical load when horizontal support movement is restricted, the task of carrying vertical load when horizontal support movement is permitted and the task of carrying anti-symmetric load when horizontal support movement is restricted (fig.1). For each task a structural model of a roof truss was studied and the design (with respect to position of the different members in the truss) was varied systematically.

3. CONCLUSIONS

The qualitative approach made it possible to distinguish general phenomena and patterns such as:
- Historic Swedish roof trusses without tie beams can (curiously) be interpreted as *arches*. As such, they exert horizontal as well as vertical forces to their supports and their members act largely in compression.
- The size of the horizontal force from the truss to the wall depends on the pattern that the compression forces describe. Horizontal forces are smaller from a truss where the load path describes a high and narrow form.
- These structures comprise in their form, the form of polygonal arches (the upside-down V-form being an arch for one point load, the trapezoidal form being an arch for two point loads etc.). The larger the number of such arch forms that are inscribed in the form, the stiffer and stronger the roof truss will be.
- Like arches, these trusses are not rational structures if they lose their horizontal support. Large tensile forces and bending moments in members are unavoidable for stability.

The roof trusses studied are not equally sensitive to changes in the parameters geometry, joints, supports, material and load. Support properties are by far the most important factor. For vertical load, the difference between having two fixed supports and having one fixed and one roller support leads to differences in stresses of several hundred percentage units. Providing proper support for these trusses is often enough as a repair measure. Thorough studies of material properties and extensive geometry studies can frequently be omitted.

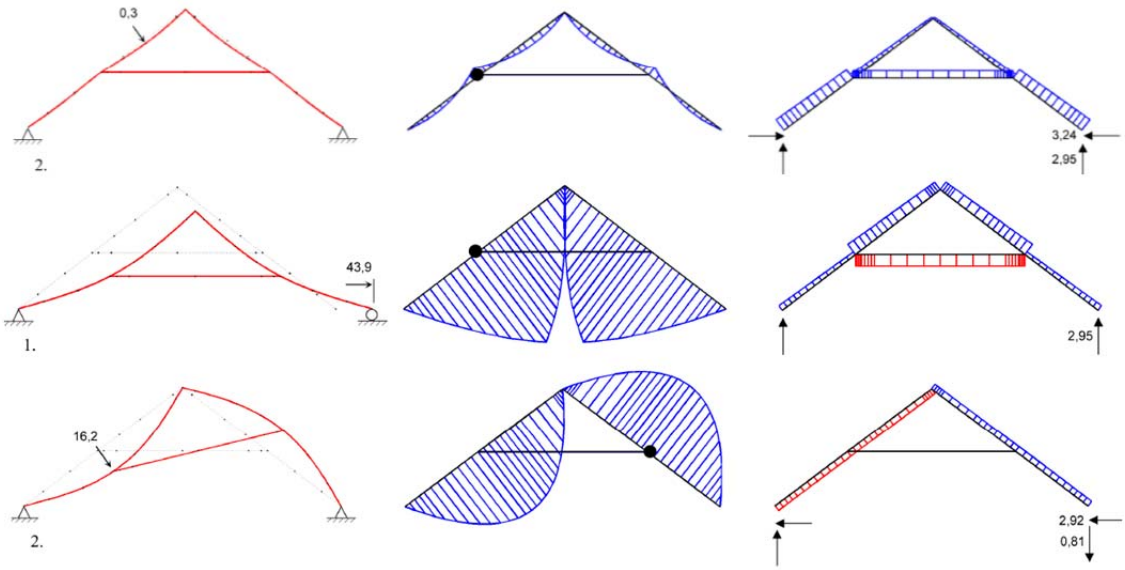

Figure 2 – The structural behaviour for one of the studied truss designs for each of three defined “tasks”. Old Swedish roof trusses are normally rational for “task 1” (row 1), but not for “task 2” (row 2). In the latter case, large bending stresses occur and carpenter joints are subjected to excessive tensile forces. Roof trusses without scissor braces are weak for “task 3” (row 3).

REFERENCES

Sandin, Y. (2005). *Träbärverk i äldre svenska kyrkor* (in Swedish). Diss., Chalmers University of Technology, Gothenburg.