Shear failure in glulam frames

An actual case

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Summary

In March 2005, three of a total of 14 parallel glulam frames, covering the main court of a sports center in northern Norway, experienced severe shear cracking resulting in noticeable deformations. The hall was evacuated, but the structure remained intact, and the three damaged frames were considered repairable.

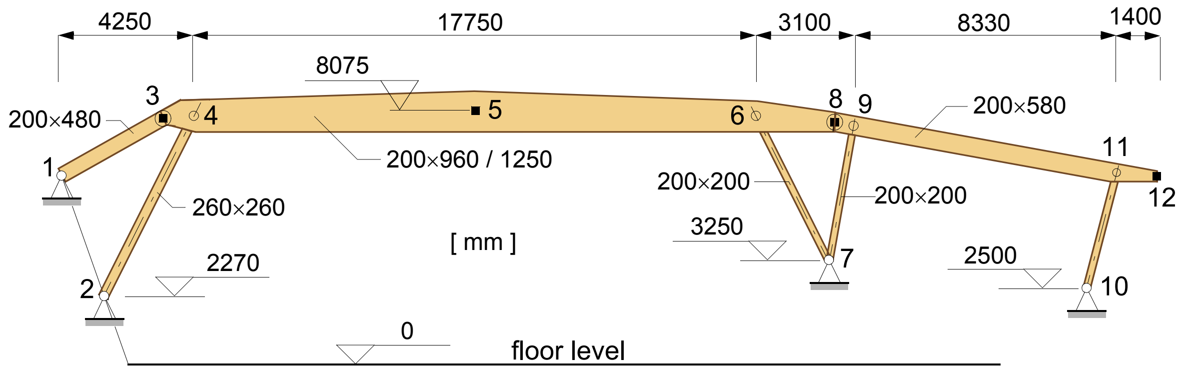

Figure 1 A typical frame

Figure 1 shows one of the identical 14 frames supporting the roof of the sports center. The frames are spaced 3 m apart and they support purlins which in turn support a wooden ceiling on which are placed insulation, tar paper, plastic, gravel and turf.

When design started the characteristic snow load on the ground, at the location of the building, was 3,5 kN/m^2 (based on a 5 year return period). However, the winter 1999/2000 saw a lot of snow in this area, and it was decided to increase the characteristic snow load to 5,5 kN/m^2. The current characteristic snow load for the location, which is based on a 50 year return period (introduced by a new code in 2001), is 6,5 kN/m^2. The dead load of the roof, excluding the frames, was estimated to be 2,5 kN/m^2.

The day after the incident measurements were made of both loading (snow) and vertical displacements of the frames. The actual snow load on the roof varied from 2,3 to 3,5 kN/m^2. Assuming the dead load to be 2,5 kN/m^2 and a uniform snow load of 3,0 kN/m^2 at failure, the "failure load" on the frames was only about 50 per cent of the design load (which includes form and load factors).
The maximum vertical displacement of the two most damaged frames (numbers 1 and 2 from the east end of the building) was about 200 mm (L/90) or twice that of the (visibly) undamaged frames.

The original design was checked (reanalyzed), and apart from a slightly overstressed column, it seemed to comply with the code. The design shear stresses in the beam were high, but they did not exceed the strength values (as specified by the Norwegian code - NS 3470)[1].

The largest computed shear stresses at failure were only about 50 per cent of the shear strength, as specified by NS 3470.

The presentation is concerned with:

- *The structure* - a description of the structural arrangement of the hall.
- *The problem* - a description of the failure, with pictures of the most serious cracks and results from displacement measurements.
- *The cause* - we are not entirely satisfied that we have been able to fully explain what triggered the failure, but we are fairly confident that substandard glulam quality must take the brunt of the blame. There is some obvious proof of poor glulam quality, and some of the cracks follow the glue lines. Another observation that seems to support this explanation is the fact that no visible cracks are detected in the areas where the highest computed shear stresses are found.
  A most likely failure scenario is offered.
- *The repair* - a brief description of the repair works, consisting of some extra column supports for one frame and reinforcement by Kerto plates on all frames, is included.

Even if the failure is (most likely) due to substandard glulam quality, this case seems to support the concern about shear failure in large glulam components reported by other investigations - a concern that has led to changes being proposed for the shear design in Eurocode 5. The glulam used in the sports center was provided by a well reputed manufacturer.

1. It should be noted that the original design, based on NS 3470, would not have passed the requirements of the current version of Eurocode 5 (EC 5), and it would have been even more “in the red” if the proposed changes to EC 5 concerning shear design had been in effect.