Acoustics and vibrations at Limnologen, an eight storey wooden house

Kirsi Jarnerö

The prefabricated floor elements are generally 2.4 m wide and consist, in the load carrying part, of a 73 mm thick three-layer cross-laminated timber board and glulam beams. The beams consist of C40 glulam webs and flanges, with dimensions $42 \times 220 \text{ mm}^2$ and $56 \times 180 \text{ mm}^2$ respectively. The space between the beams is filled with mineral wool. The ceiling is separated from the load carrying part and is self-supporting on the walls in the underlying room. Half of the secondary spaced boarding in the ceiling is pre-assembled at the factory and the rest is nailed up in situ. Water and sewage installations are placed in the top load carrying part of the floor. Ventilation, sprinklers and electricity are placed in the lower part, in the ceiling. The ends of the floor elements are placed on the walls below, on which Sylodyn strips are mounted to reduce the flanking transmission. The floor rests here only on the cross-laminated timber board, but on intermediate supports it rests on the flanges.

To investigate the vibration properties with as little influence as possible from surrounding structural parts laboratory tests with well defined support conditions were performed. A single floor element, 1.5 m wide and 5.4 m long that is a duplicate of a floor element in a bedroom floor, was tested with free-free support conditions on sprung mattresses and simply supported on rigid supports. To get comparable results with this the first series of measurement in situ was made after the floor element had been laid up on the supporting walls, but not been coupled to the adjacent floor elements. The subsequent measurements were then made after coupling the elements and after mounting wall and floor elements on upper storeys and at last when the partitions in the measurement room had been built. To investigate the influence of a flexible support on the vibration properties tests were performed in an apartment where the floor has an intermediate support, a glulam beam with dimensions $215 \times 270 \text{ mm}^2$. The total length of this floor is 11.7 m, with the beam placed 6.3 m respectively 5.4 m from the ends. The width of the room is 3.8 m. The room with largest risk of annoying vibrations is a living room with the length 7.9 m and the width 3.7 m. In a short part of the width the span reaches 9.7 m. The floor element is here reinforced by means of beams 45 mm higher than in the regular floor elements. In the same room tests were made to investigate the influence of parquet flooring on measurement results.

Measurements of deflection due to a point load at the centre of the floor in the different rooms were performed and compared with calculations of deflection due to a 1 kN point load at the middle of the span of a simply supported one metre wide strip of floor. The first natural frequency was also calculated and compared with the in situ measured ones. In the calculations it has been taken into account that the three layers in the cross-laminated timber board have different directions and consequently different stiffness values. The same consideration has been made for the glulam beams. The stiffness in transverse direction has not been considered in the calculations. The results presented here should be regarded as preliminary ones since they are not derived by performing a complete modal analysis. The results are presented in tables in the appended power point slides.

From the tests on the bedroom floor it can be seen that the damping is rather high in situ and also that it to a large extent is influenced by the degree of integration to the surrounding structural parts, especially by the addition of partitions. The in situ measurements indicate that calculation of the first natural frequency and deflection due to a point load on a one metre wide strip seems to be accurate considering a floor with support conditions corresponding to a simply supported beam on rigid supports. Floors with flexible supports or floors where the length-to-width ratio is special the supports and the transverse stiffness of the floor should be taken into account. Excitation of the floor with or without parquet flooring with impulse hammer showed only small differences in the first natural frequencies.
Kirsi Jarnerö, Outlines

- Floor structure
- Vibration measurements
  - Test setup
  - In situ and in laboratory
- Calculations and numerical analysis
- Results
- Discussion and conclusions

Floor structure

- Floor components of cross laminated solid wood board and glulam beams
- Type of Sylodyn® strip is dependent on static load
Vibration measurements: Test setup

- Electromagnetic shaker excitation
- 15 accelerometers relocated to measure a grid of 36, 81 or 90 points
- Deflection of a 1 kN point load in centre of floor

Vibration measurements: In situ

- Bedroom
  - change in vibration properties during construction
- Kitchen-living room
  - flexible support
- Living room
  - long span width
Kitchen – living room

• Study the effect of an intermediate flexible support

Living room

• Study the effect of a long span width and special support condition
Living room

• Study the effect of parquet on vibration measurements
• Impulse hammer excitation on bare floor and after parquet floor was laid

Bedroom

• Study the change in natural frequencies and damping during construction
Laboratory

• Free-free support conditions – on spring mattresses
• Simply supported on rigid supports

Calculations and numerical analysis

• Calculation of *deflection* due to a 1 kN point load and first *natural frequency* of a simply supported 1 m wide floor strip
• Eigenvalue analysis with a FE-model
• Comparison of results from modal analysis in laboratory and in situ
Results

- Deflection
- Natural frequencies

<table>
<thead>
<tr>
<th>Room</th>
<th>Span width</th>
<th>Deflection</th>
<th>First natural frequency</th>
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<tr>
<td></td>
<td>(m)</td>
<td>(mm)</td>
<td>(Hz)</td>
</tr>
<tr>
<td></td>
<td>Calculated</td>
<td>Measured</td>
<td>Calculated</td>
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<tr>
<td>Bedroom</td>
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<td>Kitchen – Living room</td>
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<tr>
<td>Living room</td>
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<td></td>
<td>Calculated</td>
<td>Measured</td>
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<tr>
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<tr>
<td>Kitchen – Living room</td>
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<td>5.5</td>
<td>26.8</td>
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<tr>
<td>Living room</td>
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<tr>
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<th>Un-supported elements</th>
<th>Coupled elements</th>
<th>Walls</th>
<th>Floor+ walls</th>
<th>Floor+ walls</th>
<th>Floor+ walls</th>
<th>Floor+ Walls+ Partitions</th>
<th>Free-supported (Lab</th>
<th>Simply supported (Lab)</th>
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<td>25.9</td>
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Results

• Parquet floor

Discussion and conclusions

• The calculated first natural frequency and deflection due to a 1 kN point load of a one metre wide floor strip seems to be accurate considering a floor with support conditions corresponding to a simply supported beam on rigid supports

• More complicated support conditions must be considered more accurately

• Damping to a large extent is affected by the degree of integration of the floor to the surrounding structural parts, especially by the addition of partitions
Thanks for listening
any questions?