The strength of weakness; the architectural potential of non-hierarchical load bearing

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Summary

This paper presents architecturally based structural design in the case of a pavilion built in Rjukan, Norway. The architectural idea for the pavilion was a three-dimensional timber grid. According to structural analyses, the proposed grid would not be sufficient for the actual spans. After discussing the architectural consequences of various structural principles, the load bearing was finally solved by simply introducing skylights above the largest spans. With their side walls, these skylights transfer the loads from the middle of the spans to the surrounding and stiffer parts of the grid. Thus, we avoided adding structural elements that would make the original grid secondary. Instead, the structural potential of the weak but numerous equal elements of the original grid is exploited to achieve a load bearing in accordance with the architectural intentions for the building, ensuring the three-dimensional timber grid being the architectural character also of the pavilion as built.

Keywords: Non-hierarchical load bearing, timber grid structure

Fig.1: Exterior (photo: B.Manum)

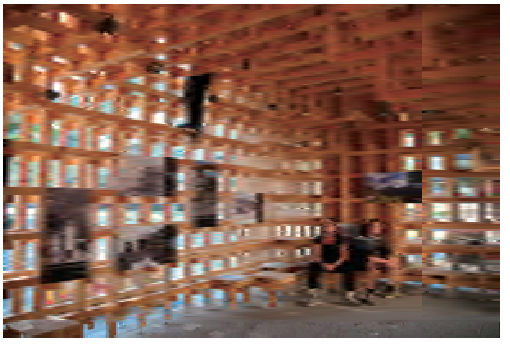

Fig.2: Interior (photo: B.Manum)

The architectural intention for this pavilion was to create a free-form interior space within a three-dimensional non-hierarchical grid structure of timber. In accordance with this concept, the timber grid ought to cater for as much of the building's architectural and functional program as possible, reducing the need for additional elements. According to structural analyses, the proposed grid was not sufficient for the actual spans. From shells and vaults, we know that insightful combinations of forms and materials may result in exceptionally thin and elegant structures. Besides the form itself, a condition for the seemingly simple elegance of shells is the fact that a large share of the building is load bearing, which is notably different from buildings where the structural elements carry heavy weights of structurally unnecessary building components. Somewhat similarly to this logic of shells, the structural design concept for this pavilion has been to include the entire building in the load bearing, instead of carrying by particular structural elements.

The structural system is a three-dimensional grid of 3x3" timber c-c 400 mm that is hinged at all connections, with a roof providing bracing on top. Due to the spans, timber dimension and the lack of walls, rigid corners or diagonals, this structure would not be sufficient for the actual spans. After discussing architectural consequences of various structural principles, the load bearing was finally solved by adding stiffness only in the softest parts of the structure, i.e. at the middle of the largest spans. More precisely, the solution consisted in introducing skylights with side walls of plywood providing stiffness transferring the loads from the middle of the spans to the surrounding parts of the grid. Thus, it was not necessary to add structural elements that would have made the original grid secondary. Instead, the structural potential of the weak but numerous equal elements of the original grid was exploited; achieving load bearing in accordance with the architectural intentions of the building, making the three-dimensional non-hierarchical timber grid an astonishing architectural character also of the pavilion as built.

By this paper, we hope to inspire engineers to examine the load bearing potentials of architectural ideas also when the ideas initially appear structurally insufficient.

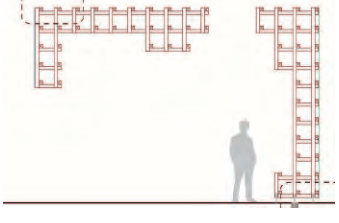

Fig.3: Cross section (of proposal)

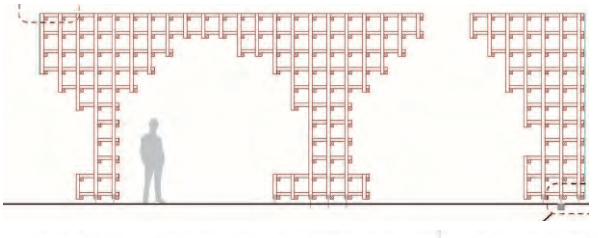

Fig.4: Longitudinal section (of proposal)

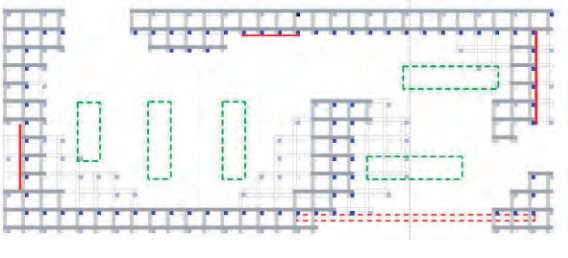

Fig.5: Plan, structural system (as built)

Legend

Blue:	*columns (to ground)*
Red dotted line:	*beam over entrance*
Red lines:	*shear walls*
Green lines:	*skylights*

Acknowledgements

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