MULTI-STOREY RESIDENTIAL BUILDINGS IN CLT – INTERDISCIPLINARY PRINCIPLES OF DESIGN AND CONSTRUCTION

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ABSTRACT: Cross-laminated timber (CLT) is a very efficient and powerful building material and thus recently discovered for the erection of multi-storey timber towers. In our paper, we focus on building science and services related topics regarding these constructions. Thereby, we firstly identify moisture ingress as main problem worsening their durability and thus discuss possible detail solutions for both external and internal critical building zones such as flat roof, balcony system and wet rooms. The second main topic we are concentrating in this paper are simple measures to increase the efficiency of CLT constructions by simplifying and improving their structural systems (floors, walls and connections). Both topics are connected by the major importance of interdisciplinary thinking and acting when building with CLT.

KEYWORDS: Cross-laminated timber; moisture ingress; building science and services; efficient detail solutions

1 INTRODUCTION

Due to its huge potential in terms of two-dimensional load-bearing in-plane and out-of-plane as well as its high grade of prefabrication, CLT is nowadays seen and also applied “as the new concrete”. In fact, wood is a natural product and, consequently, does not share the same physical properties with concrete. To avoid expensive rehabilitation works caused by hidden and uncontrollable moisture ingress, external and internal constructive wood protection has to be seen as one of the major tasks when planning a multi-storey timber building in CLT. Critical building parts such as flat roofs, balcony constructions or wet rooms, which are situated in contact with external surface water or internal water lines, should be designed and realised by thinking and acting interdisciplinary to guarantee the durability of the building as basic requirement given in EN 1990. Consequently, in the following sections we especially concentrate on these interdisciplinary issues, subdivided in external and internal critical building zones, and discuss their possible solutions. The increasing worldwide sales figures of CLT elements (and also of wood based products in general) in combination with a rapidly increasing energetic utilisation of wood (especially in Central Europe), will lead to conflict situations regarding the distribution of resources in the next few years. Efficient structural systems as result of an intelligent interdisciplinary planning process are seen as contribution to a more resource-friendly and economical way of using CLT and thus also discussed in this paper.

2 EXTERNAL CRITICAL ZONES

2.1 FLAT ROOF

Figure 1 shows a possible solution for a durable timber roof system with a special regard to moisture protection. The main difference to common assemblies for mineral solid constructions is the back ventilation. Due to the permanent air change in this zone, it not only provides a certain degree of protection against overheating in summertime but also serves as second protective coat in case of unexpected moisture ingress of the wooden under roof where construction can dry out. Therefore, it makes sense to construct the back-ventilation zone inclined.

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Figure 1: Proposal for a flat roof construction in CLT
2.2 BALCONY CONSTRUCTION
As shown in Figure 2, one solution of this detail situation may be a balcony system as steel secondary construction. If compared to a commonly used CLT cantilever system, the following advantages are worth to be mentioned: (a) There’s no necessity of any height compensation due to the additional floor lay-up and (b) the construction is easily to replace in case of damage or when its lifetime is over. Optical disadvantages or restrictions of the architectural design due to additional supporting can be solved by hidden anchoring in the level of the handrail.

![Figure 2: Balcony system as steel secondary structure](image)

3 INTERNAL CRITICAL ZONES
In addition to the aim of guaranteeing a reliable and durable building envelope for multi-storey residential buildings in solid timber construction with CLT, also vulnerable internal zones are worth to be focused in detail. One possible water line run solution of a solid timber construction is as follows:

- The water supply and delivery system is mainly situated in a transition zone between the flats in STC and a central staircase in RFC (or a protected and observed centre well). All wet rooms directly adjoin this inner core.
- All additional rooms with a need of water supply (kitchens, etc.) or radiators of the central heating are reached by a pipe system arranged in the suspended ceiling.

4 EFFICIENT STRUCTURAL SYSTEMS
4.1 FLOORS
Due to its typical lay-up (uneven number of boards/layers with crosswise orientation), CLT has a significantly lower shear stiffness if compared to a unidirectional oriented timber product. Consequently, CLT elements are predomately decisive regarding serviceability limit state leading to maximum span lengths of 5 to 5.5 m for systems commonly used in practise. To avoid uneconomic dimensions, this fact should be considered when thinking about the room layouts of a residential project. In addition to the proposed use of optimised span lengths, the chosen structural floor system should not strongly vary in its type and dimensions in the frame of one project. In contrast to more flexible in-situ RFC solutions, CLT always is a prefabricated product and significantly benefits from uniform conditions (lay-up and thickness).

4.2 WALLS
Two essential principles have to be pointed out with regard to the arrangement of CLT bearing walls:

- To avoid waste of resources as consequence of large offcuts, all elements have a full storey height and no openings. Windows and balcony doors are also room high or partially combined with secondary components. With regard to maximum dimensions producible ($l_{\text{max}} \approx 16$ m), another alternative would be the arrangement of continuous CLT wall elements over the whole building height.
- The positioning of the walls on top of each not only simplifies their design and decreases their stress rate but also ensures that horizontal loads are directly transmitted to the foundations. Thus, the loads the connections have to bear are also significantly reduced.

5 CONCLUSIONS
Based on both topics discussed in our paper, we summarise and conclude:

- For multi-storey residential buildings, erected as solid timber constructions with CLT, the flat roof, the balcony construction and the wall assembly itself are identified as the critical parts of the building envelope influencing the durability of the construction.
- As discussed in section 2, CLT flat roof assemblies should provide an inclined back ventilation zone accessibly for maintenance and serving as second protection against moisture ingress.
- To enable the possibility for replacement due to different lifetimes as well as to avoid uncontrolled air and moisture transfer into the bearing structure, the balcony system should always be installed as renewable secondary construction in steel or timber.
- Details concerning building services, especially ones, which include pipe systems containing water, have to be solved for a bearing structure losing its performance in case of moisture ingress. The proposals made in this paper are only seen as begin of a development in that direction.
- CLT is a prefabricated product. Thus, uniform and material-optimised structural systems (vertical and horizontal) maximize its efficiency and avoid waste of resources.