URBAN DENSIFICATION - CASE STUDY OF A SCHOOL EXTENSION USING TS3 TECHNOLOGY

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ABSTRACT: Many school buildings need extension for capacity. So does the school building in Richterswil, CH, which needed an extension of 1'500 square meters during the five weeks of summer holidays. This could only be realized by two additional timber structure storeys with the TS3 technology. A biaxial load-bearing flat ceilings with spans of 8×10 metres could be installed on the same load-bearing structure of the existing concrete building. The floor-wall system allowed the façade to be designed independently of the supporting structure. The timber construction and closing of the building was realized during the summer break, while the less noisy interior work was done during the school operation with no negative influence. All advantages of timber construction in addition with the specialized TS3 technology were convincing for the extension.

KEYWORDS: timber, school building, building top-up/extension, end grain bonding, new technology

1 URBAN DENSIFICATION THROUGH SUSTAINABLE TIMBER EXTENSIONS

Urban densification is a key challenge for future urban development. One particularly sustainable and climate-friendly solution is the vertical extension of existing buildings using timber. As a lightweight yet high-performance building material, timber is ideal for this approach as it places less stress on existing structures than conventional building materials, [1] and [2]. In addition, timber acts as a long-term carbon sink, storing CO_2 throughout its lifecycle and actively contribute to the climate protection.

In Switzerland, the demand for additional school space is expected to grow significantly in the coming years. The population continue to grow all over the world and the need for expanding school facilities becomes increasingly critical. The rising number of students necessitates additional classrooms, modernized infrastructures, and enhanced educational resources to ensure that every child receives a quality education.

This extension is not merely about accommodating more students but also about providing an environment conducive to effective learning and development, [3], [4] and [5].

A highly efficient and resource-conscious way to meet this demand is by extending existing school buildings with timber construction. Timber offers numerous benefits, including reduced weight, lower noise levels, minimal environmental impact, and CO_2 storage. Moreover, it showcases the possibilities and ecological advantages of sustainable building to future generations.

Thanks to a high degree of prefabrication, new floors can be added in a very short time. Beyond its efficiency and sustainability, timber enhances indoor comfort and creates an optimal learning environment. As a renewable, natural material, it fosters a pleasant atmosphere and serves as an example of responsible construction. By integrating wood into school buildings, children gain early awareness of its potential not only for climate-friendly construction but also for creating healthy and inspiring spaces.

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2 PROJECT SCHOOL RICHTERSWIL

2.1 BACKGROUND

In response to the significant increase in pupil numbers in the municipality of Richterswil, it made the decision to expand the space available in the “Feld 1” school building by approximately 1500 square metres. But how do you extend a reinforced concrete school building with a supporting structure with spans of 7×10 metres and a roof with insufficient load-bearing capacity while the building is still in use? The question was posed in a public architectural competition concerning the extension of the school building. Moreover, it was imperative that the construction of the new two-storey building extension must be undertaken during the summer recess, which spans a duration of five weeks and is a period during which educational operations are not in session. Previous solutions proposed a hybrid construction of steel and timber. Due to the insufficient load-bearing capacity of the existing structure, a steel interception grid was designed to be installed on the existing roof. This grid distributed the additional loads from the extension to the existing load-bearing walls and columns of the building. In this approach, the required floor slabs were planned as timber hollow-box decks, ensuring both structural efficiency and material sustainability.

The project team, led by the general contractor Allreal, realised that such a solution would require a significant increase in the height of the interception grid and would significantly extend the shell construction time - an approach that was not feasible given the limited timeframe of just five weeks for the complete shell structure. The TS3 technology, with its biaxial, point-supported slab system, offered significant advantages in meeting these requirements. Co-developed by Timbatec, the TS3 timber construction technology offered an innovative alternative. Instead of a steel interception grid, a load-distributing slab made of cross laminated timber (CLT) was designed on the existing roof. This allowed the new floor slabs to be designed within the existing reinforced concrete grid using TS3 technology. TS3 enables the construction of timber ceilings as biaxial load-bearing flat ceilings with wide grids of supporting structures, similar to concrete construction.

With spans of up to 7 × 10 meters, the structure was realised without additional beams, resulting in significant material and weight savings throughout the structure. This approach also provided greater flexibility in the design of both the interior spaces and the façade of the building. In the end, the TS3's rapid construction method proved highly effective. Within just a few days, the floor slabs had reached their full load-bearing capacity, allowing the next floor to be constructed without delay. As a result, completing the building shell within the required five-week schedule was no longer a challenge.

2.2 GENERAL

The “Feld 1” school building in Richterswil was originally commissioned in 1971 and has now reached its capacity limits. To meet the growing demand for educational space, the existing three-storey structure was extended by two additional storeys. The TS3 technology allowed for a beamless construction, providing maximum spatial flexibility. As a result, the interior spaces could be adapted to meet evolving needs and different educational requirements. A light-filled atrium was integrated into the top floor, enhancing the quality of the space and creating an open and inviting learning environment. The panels are supported by interior walls and exterior supports, allowing for an independent façade design. This flexibility is reflected in the varied window arrangements across the building's sections. Table 1 provides a summary of the key stakeholders involved in the project, as well as the key construction details.

Table 1: Project overview with key information

Project overview – School Richterswil, Switzerland	
Building owner	Gemeinde Richterswil
Architect	Batimo AG, Zofingen
General entrepreneur	Allreal Generalunternehmung AG
Timber Engineering	Timbatec Holzbauingenieure Schweiz AG
Timber system construction	Saxer Holzbau GmbH, Zürich Timber Structures 3.0 AG
Building type	School
Building year	2021
Number of floors	2
Gross floor area	1'757 m²
Cross laminated timber	549 m³
TS3 technology	540 linear meters

Figure 1. School building in Richterswil after completion of the extension, the two new storeys are designed with the dark façade, note the extremely mixed arrangement of windows compared to the classic arrangement on the lower floors, Photo: DUCO, HOME OF OXYGEN, Veurne

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Figure 2. View into the atrium of the school. Photo DUCO, HOME OF OXYGEN, Veurne

3 STRUCTURAL SYSTEM

The structural system of the extension is designed as a timber frame structure, adding two storeys to the existing building. The primary structural elements are of reinforced concrete skeleton. The floor slabs are constructed using TS3 technology, which enables a beamless design by fully activating the biaxial load-bearing capacity of the slab system. This approach eliminates the need for additional beams and allows efficient use of materials while maintaining high spatial flexibility.

The floor system spans up to 8 × 10 metres, providing large column-free areas that support adaptable interior layouts. The vertical loads, such as dead and live loads, are transferred to the permeable load-bearing structures via timber columns and load-bearing walls. The vertical loads are transferred directly through the existing reinforced concrete column grid of the lower floors. By aligning the new structural elements with the existing load-bearing system, the additional weight of the new floors is efficiently distributed without exceeding the capacity of the existing foundation. No reinforcement or extensions to the primary structure were required.

Horizontal stabilisation is provided by a reinforced concrete core that is structurally connected to the timber frame and also acts as a staircase. This core effectively absorbs and transfers lateral loads such as wind and seismic forces, ensuring the overall stability of the building.

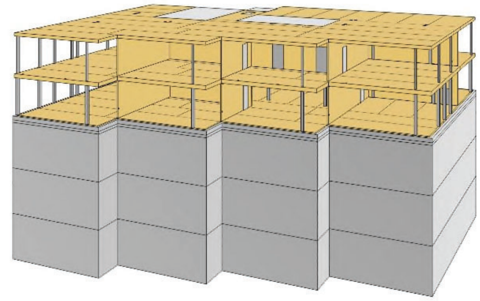

Figure 3. Two storey extension of the school building: Visualisation of column and panel construction with TS3, Source: Timbatec Holzbauingenieure Schweiz AG

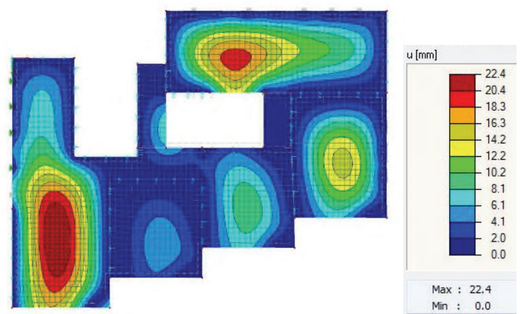

Figure 4. Floor plane with the TS3 segmenten and deformation for the load combination strucutral safety, Soruce Timbatec Holzbauingenieure Schweiz AG

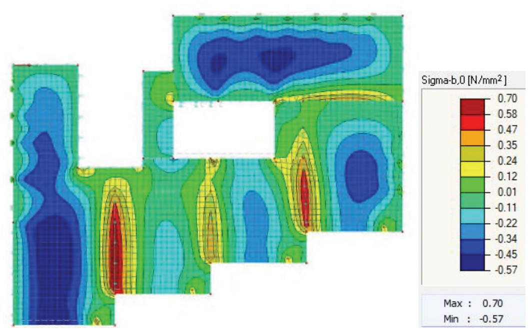

Figure 5. Stress distirbution for load combination structual safety, Source: Timbatec Holzbauingenieure Schweiz AG

4 DETAILS

The use of TS3 technology did not require the development of custom details. Instead, the project utilised standard timber construction details for connections between floor slabs, walls, façades, and the stairwell concrete core. This approach, which was both efficient in terms of planning and execution, also ensured that the finished structure would be highly structurally integrity, fire resistance, and acoustics.

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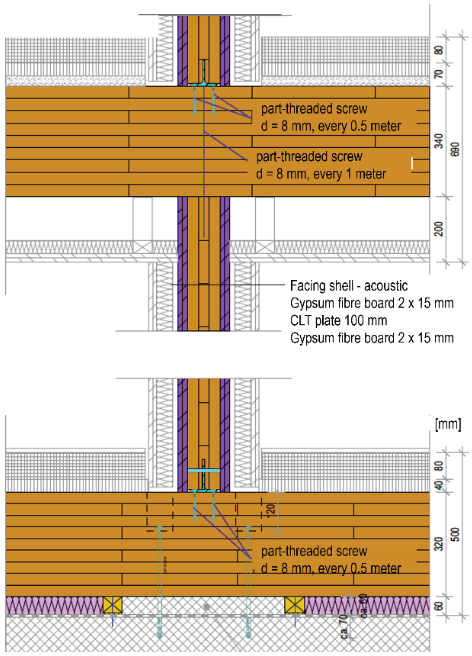

Figure 6. Details of the connection of the load-bearing wall to the ceiling, the wall fulfils R60 fire resistance, Source: Timbatec Holzbauingenieure Schweiz AG

As illustrated in Figure 6, the connection between the floor slab and the load-bearing wall adheres to established timber construction principles. The wall assembly complies with R60 fire resistance requirements and incorporates an additional facing shell to enhance sound insulation.

5 TS3 TECHNOLOGY

5.1 GENERAL

Pioneering the future of sustainable timber construction, TS3 is a new technology to reach infinite biaxial load bearing CLT plates. As the leading solution for large-scale timber construction, TS3 allows for column spacings in grids of up to eight-by-eight meters, making it possible to use wood for building expansions and bold architectural designs. This was the key technology that enabled the transition of the school Richterswil within 5 weeks of construction time.

Representing the next generation of timber construction, TS3 is the result of over a decade of intensive research in collaboration with the Federal Institute of Technology in Zurich and the Bern University of Applied Sciences. The breakthrough lies in a rigid, bend-resistant jointing technique for cross-laminated timber slabs, achieved through a specialized pouring-to-solid process. After more than 2,000 tensile and bending tests, the technology is ready to use, [2]-[7]. Now, the TS3 innovation enables the creation of joist-free, timber-frame structures with slender, point-supported slabs, paving the way for more sustainable and aesthetically striking architectural solutions.

5.2 THE TS3 JOINING

The fundamental technology of TS3 is the TS3 connection by edge joint grouting at a distance, without pressure and any other connecting means. This facilitates the production of panels of any size, enabling the construction of beamless timber structures with slender, point-supported slabs. Figure 4 illustrates the construction process in a simplified manner, delineating the following stages: (a) the initial arrangement of CLT plates on temporary supports and beams. A 4 mm gap is maintained between the plates. The end faces are prepared with a pre-priming process, which is undertaken to protect the opaque surfaces and to secure the bonding process. (b) the casting resin is then filled into the joints, section by section. (c) after a period of sever-al days, the casting resin has hardened, and the temporary support

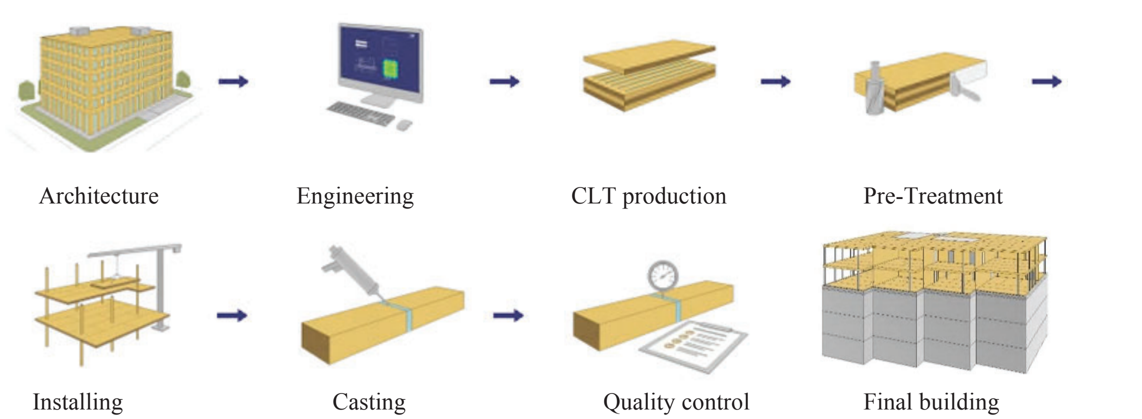

Figure 7. TS3 technology: stepwised illustrated, beginning with the architecure over the engineering, porduction, installing up to the final building. Source: Timber Structures 3.0 AG

can be removed. (d) the building is completed. This innovation has enabled the transition from hybrid to fully timber constructions.

5.3 ADVANTAGES OF TS3-TECHNOLOGY

Historically, concrete construction maintained a distinct advantage due to its ability to create structural elements capable of bearing loads in multiple directions, such as floor slabs. Second-generation timber construction lacked this capability, limiting its application in large-scale projects. However, this constraint has now been overcome. With TS3 technology, timber construction has reached structural parity with reinforced concrete, even for extensive load-bearing surfaces.

TS3 enables wood to replace reinforced concrete in most structural applications, offering a significant environmental advantage. The production of steel and cement - essential components of reinforced concrete - is highly energy-intensive and a major source of CO_2 emissions. Globally, reinforced concrete accounts for approximately nine percent of human-induced CO_2 emissions. In contrast, wood acts as a carbon sink, continuing to store CO_2 even after installation. By replacing steel and concrete with wood, TS3 facilitates sustainable construction solutions across various building types, directly contributing to climate protection.

Figure 8. View on the construction site, Source: TS3 AG

Figure 9. Sealed 4 mm gap as TS3 joint at the construction site (left) and injection of the glue into the joint (right), Source: TS3 AG

6 EFFICIENT CONSTRUCTION PROCESS

The construction of two additional storeys was completed during the summer holidays, in a period of time, that was significantly shorter than would typically be expected. This was made possible by the high degree of prefabrication in timber construction and the use of TS3 technology. This facilitated the completion of the entire shell construction of the two-storey extension within a span of just a few weeks, thereby ensuring minimal disruption to the school's operations. The interior finishing work, which generates significantly less noise in timber construction compared to conventional methods, was carried out while the school remained in operation.

A significant benefit of contemporary timber construction is the precision prefabrication of components in manufacturing facilities. The CLT panels were pre-cut to exact dimensions, treated with primer for optimised bonding, and transported to the site under controlled conditions. This process minimised on-site adjustments, reduced waste, and enabled an efficient assembly process. The installation of the prefabricated elements was completed expeditiously due to the seamless integration of the floor slabs using TS3 technology, see Figure 8 and Figure 9. Following the pouring of the slabs, the joints hardened within a few days, reaching full load-bearing capacity shortly thereafter. The project team confronted the five-week construction timeline with a high level of motivation. A notable logistical challenge during the project was the timely delivery of the CLT panels from the factory. However, through the implementation of efficient coordination and supply chain management strategies, this issue was successfully resolved, ensuring an uninterrupted workflow. The precisely prefabricated CLT panels, measuring up to 3 metres in width, 280 to 340 millimetres in thickness, and 13.5 metres in length, were placed on temporary supports and seamlessly connected using TS3 technology to form a large-scale, multi-axial load-bearing slab. The Richterswil school extension has been identified as a model project for timber construction in urban environments, illustrating the potential for the efficient expansion of existing concrete structures using sustainable materials. The new building follows the same load-bearing structure as the original, but utilizes timber instead of concrete, significantly reducing weight and environmental impact.

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7 ADAVANTAGES AND CONCLUSIONS

In Switzerland, it is anticipated that the demand for additional school space will experience substantial growth in the forthcoming years. A highly efficient and resource-conscious approach to meeting this demand is to extend existing school buildings. A particularly efficacious solution to this problem is the vertical extension of existing buildings using timber. The high degree of prefabrication in timber construction facilitates the expeditious addition of new floors. The school extension in Richterswil serves as a prime illustration of the efficacy of timber in expediting the extension process.The integration of timber construction's inherent advantages [1] with the advanced TS3 technology [2] has yielded economically viable solutions, underscoring the viability of timber as a construction material. In this particular case study, a vertical extension was constructed using timber, and it was found that the existing load-bearing structure did not require reinforcement. The loads can be transferred via the existing structure. The implementation of biaxial load-bearing timber ceilings with TS3 technology was instrumental in achieving this objective. The execution of this project did not necessitate the introduction of any unique details. The project's timely completion during the summer recess can be attributed to the effective prefabrication and the streamlined execution of the TS3 technology.

In the context of this approach, timber is a lightweight yet high-performance building material that is ideal for use due to the fact that it exerts less stress on the existing structure than conventional building materials. Additionally, timber functions as a long-term carbon sink, accumulating CO_2 throughout its lifecycle and thereby actively contributing to climate change mitigation. In addition to the benefits of speed and sustainability, timber also improves indoor comfort and creates an optimal learning environment. As a renewable, natural material, it has the capacity to foster a pleasant atmosphere and serve as a model for future generations. The incorporation of wood into school buildings has the potential to instil in children an early awareness of its benefits, not only in terms of climate-friendly construction, but also in the creation of healthy and inspiring spaces.

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