Växjö train station and city hall, a timber-concrete hybrid

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1. Introduction

It is well known that increased use of timber products in construction is environmentally beneficial [1], [2]. A study showed that using load-bearing structures in timber instead of concrete for residential buildings would reduce the CO_2 footprint by 33% in the Swedish market [3]. However, timber use is very low compared to concrete in building projects in Sweden today [4]. Implementing new materials within the construction industry is slow compared to other industries [5]. Timber as an organic material differs from other traditional materials in building design. There are negative concerns regarding timber as a material, such as insecure wood supply, insufficient knowledge in the area, durability, and poor form stability, for example [6]. A solution to introduce more timber in construction is to use timber elements along with concrete elements in building projects, so-called timber-concrete hybrid buildings.

Växjö, a town in the southeast of Sweden and a population of 71,000, is a city with the slogan of being the greenest city in Europe [7]. The city has a long tradition in the timber industry; for example, the international forest industry group Södra has its headquarters in Växjö [8]. The city was awarded the European Green Leaf in 2018 by the European Commission for its work in improving the environment and working for a more sustainable industry [9]. As part of this work, the municipality of Växjö has developed a strategy to increase timber use in buildings [10]. As part of this strategy, a specific share of communal buildings needs to be built in timber, and dedicated areas are to be developed by the private sector with buildings in timber. Växjö, together with Skellefteå [11], was one of the first municipalities with such strategic work, adapted in other municipalities in the later years.

In 2014, investigations started on what to do with the aging city hall of Växjö. In 2015, a second investigation started on the future of the train station, which became too small for the city. The idea was created to build a new building, combining the station building with the city hall. Since the area was already under development since 2010, the location of the old train station building was chosen. The area is planned to include residential buildings, offices, and a hotel and is expected to be finished in 2025.

Following this strategy of Växjö, the *Växjö Stations- och Kommunhus* (Växjö train station and city hall) [12] was planned to focus on *Miljöbyggnad Guld* [13], the highest environmental rating in Sweden, with timber as the preferred building material for the load-bearing structure.

2. Växjö Train Station and City Hall

An architect competition was announced for the Växjö train station and city hall in 2016. White Architects won the award under the slogan "Under a Roof" where the building was divided into three parts: the station building of 1,850 m2; the city hall of 13,770 m2; and the living space room of Växjö with an area of 780m^2 [14]. To fit with the surrounding low-rise buildings to the north, the façade is slanted, giving the building a certain characteristic look, seen in Figure 1.

Figure 1: The award-winning proposal from White Architects for the Växjö train station and city hall.
Illustration: White Architects and Växjö Kommun

Vöfab, the real estate company within the municipality of Växjö, started the construction of the building in 2018, with Skanska as the main contractor. The agreement was done in a partnership where Vöfab and Skanska worked together to produce a more cost-effective building without challenging the overall goal of a building that realizes the highest environmental ratings.

2.1. Structural system and management

The structural solution for the building is a timber-concrete hybrid shown in Figure 2. The foundations and the walls below the surrounding surfaces were constructed in cast-in-situ concrete. This is due to the high surrounding groundwater level adding extra demands on a waterproof substructure. On this floor, additional precast concrete columns were used along with delta steel beams and hollow core slabs on top of the floor.

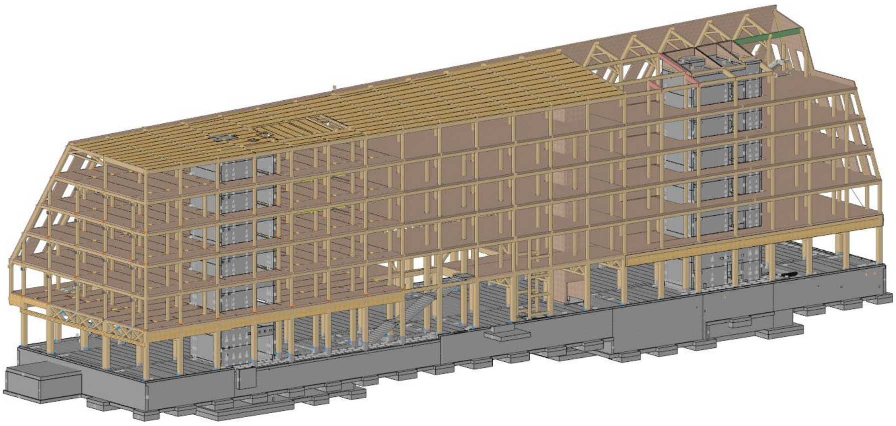

Figure 2: Visualization of the structural system from IFC-models by Binderholz (timber elements), Skanska (cast-in-situ concrete), Starka (precast concrete slabs), and Torps Byggelement (precast concrete walls).

Above this, a 6-story structure in the form of a post-beam system in glulam timber (GLT) along with cross-laminated timber (CLT) slabs from Binderholz was chosen. Due to large openings in the slabs and the limited number of available shear walls, the shear walls were made from precast concrete. The slanted façade walls were made in CLT along with vertical light-frame timber walls assembled on site. The façade was reworked during this process resulting in a heavy dual-layered glass façade. The supporting roof structure, twisted in two directions, was made in CLT and glulam trusses.

Five structural designers were involved with different responsibilities for the project, such as foundation and cast-in-situ concrete design, steel element design, timber element design, precast wall design, and precast slab design. To handle a large number of structural designers, an additional designer was working at Skanska full time during the project as a structural design leader to ensure that the overall requirements of the building were fulfilled.

2.2. Construction Site Cover

Due to building regulations in Sweden, mold in building elements is strictly prohibited [15]. Timber is an organic material known for increased risk of mold growth or decay with increased moisture content in the material. Due to these risks, the use of unprotected timber during construction is heavily debated in Sweden. Recent studies have identified a significant risk of mold growth during construction without a construction site cover in simulations [16] and in-situ measurements [17].

At an early stage in the project, the problem of potential mold growth was identified and became a top priority within the partnership between Skanska and Vöfab. Late in the design- and planning process, a supplier of a construction site cover was found that had the capability of covering the entire construction site. The solution provided by SiteCover, was a construction site cover with a length of 130m, a width of 43m, and a height of 40m, shown mounted over the construction site in Figure 3. Two internal overhead cranes, handling up to 25t, provided the lifting capabilities on site. The size of the cover made it possible to drive in with trucks, allowing it to load and unload all materials fully weather-protected.

Figure 3: Photo during mounting the construction site cover provided by SiteCover of the Växjö train station and city hall. Photo: Michael Dorn

Figure 4: Photo during construction inside the construction site cover. Photo: Skanska

Several other factors were also beneficial by the cover regarding construction management. Weather protective tasks became unnecessary, and the controlled climate without wind or rain made the work for the professional workers inside easier and safer. Especially the workload regarding the advanced façade was heavily reduced due to the cover.

The investment in the site cover solution was initially deemed too high for the project. However, due to the partnership agreement, both Skanska and Vöfab saw the potential and agreed to split the investment, though the initial return was unknown. This decision made it possible for the project to increase the tempo on the construction site. The interior work started without an entirely constructed building envelope.

3. Timber-concrete hybrid buildings in Sweden

Växjö train station and city hall is an excellent example of a timber-concrete hybrid building, defined as a building using structural elements in both timber and concrete above the foundation level. This is not to be mixed with composite members in timber and concrete, defined as sharing load-bearing capabilities within the same member. Such composite members may be included in a timber-concrete hybrid building.

In a recent interview study regarding ten mid-to-large size timber-concrete hybrid building projects in Sweden, three main structural themes were identified: a timber structure in CLT/GLT on top of a concrete structure; a post beam system in GLT with CLT slabs and walls in concrete; a post beam system in GLT with concrete hollow core slabs, as shown in Figure 5 [18]. None of the investigated buildings used timber-concrete composite elements.

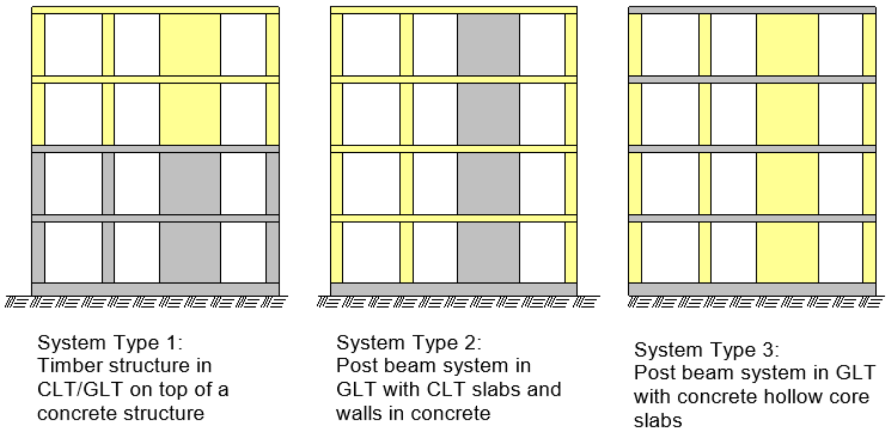

Figure 5: Example of structural system types of timber-concrete hybrids identified

A common factor in these projects was that the property developer or a municipality initiated the project with a clear vision of a timber building. Due to different reasons, a pure timber structure includes concrete elements, such as lack of self-weight, span issues, shear wall capacity, lack of timber design experience, or a timber solution that was too costly.

The studied buildings had different purposes for the finished buildings, mostly office use, schools, or residential buildings. Of the three identified structural system types in Figure 5, System Type 1 is most common for residential buildings. Concrete stories in the bottom add extra weight to the building and raise the possibility of having a different function on these floors when a lightweight CLT structure is put on top. System Type 3 was mainly used for school buildings, whereby concrete hollow core slabs significantly increased the span compared to solutions with CLT slabs.

System Type 2 was the most common solution for office buildings and the structural solution chosen for the Växjö train station and city hall. Concrete walls are used as the core of the building due to increased weight and shear capacity compared to CLT walls. The reason for the limited number of available structural walls for office buildings. Architects often aim for a flexible interior, limiting the number of available load-bearing or stabilizing walls. A post-beam system in GLT and the use of CLT slabs make this flexible interior possible with structural timber elements.

Architects, structural designers, and contractors must work together to find an optimal solution for timber-concrete hybrids. As for the structural designers, the study identified that the number of involved structural designers increased compared to normal projects. This is because each designer specializes in their type of structural elements and material. Usually, the main designer that includes all structural elements in a single calculational model is not found. The numbers of designers in the studied projects were in the range of 2-5, highlighting the importance of good management of structural design in these projects.

Figure 6: Photo showing structural members in timber and concrete for the first floor of the building. Photo: Skanska

With an increased number of structural designers involved in timber-concrete hybrids, the project management of the structural designers is vital. Previous studies regarding the solutions provided by structural designers show significant variance in result/response [19] [20]. Many of these results can be derived from different assumptions made by the designers implying the need for extra good collaboration and project management within these projects.

This topic is covered in a research project funded by SBUF [21] and Skanska in collaboration with Linnaeus University [22]. The project uses a dynamic measurement system to observe global dynamic parameters in full-scaled buildings. The project includes long-term dynamic monitoring of a building using System Type 2. In addition, the project follows the construction of a building using System Type 1 with short-term dynamic measurement following each phase during construction. The results from the dynamic measurements work as an input for calculational models, investigating how to model timber-concrete hybrids accurately during design.

4. Conclusions

The solution for increasing the amount of timber in construction, timber-concrete hybrids have been proven to be working in several projects in Sweden. Växjö train station and city hall is a good example of a successful timber-concrete hybrid project, recognized by the client Vöfab and the contractor Skanska.

Initially, costs for the project were estimated to be 710 MSek. At the end of the project, the cost was reduced to 640 MSek. Most of the reduced cost is related to the partnership agreement between Vöfab and Skanska and joint decisions during the design, planning, and production. The construction site cover played a significant role in completing the project on time, especially during planning and production. The investment of the construction site cover was 18 MSek, however, Skanska initially had an economic post of 15 MSek for lifting operations and weather protective measures. Therefore, the extra investment in the construction site cover was 3 MSek.

During production, no stops occurred due to bad weather. Lifting operations could be done every day as work conditions were always favorable. The work environment improved significantly compared to regular projects, and no serious accidents were reported. The construction site cover protected the construction from 645mm of rain during construction time, protecting the timber structure from 3,600 tons of water.

Figure 7: Photo of the exterior in the finished project in 2021. Photo: Skanska

Figure 8: Photo of the finished interior of the project in 2021. Photo: Skanska

In numbers, the initial extra investment for the construction site cover was for 3 MSek. At the project's end, the additional cost of the construction site cover was concluded to be 1.7 MSek. However, the construction site cover was introduced late in the design and planning phase. In an internal evaluation by Skanska, the conclusion is that if the construction site cover was known in the early-stage process, the cost-saving was estimated to be 12 MSek.

4.1. Acknowledgments

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5. List of references

[1] H. Guo, Y. Liu, Y. Meng, H. Huang, C. Sun, and Y. Shao, «A Comparison of the energy saving and carbon reduction performance between reinforced concrete and cross-laminated timber structures in residential buildings in the severe cold region of China,» *Sustain.*, vol. 9, no. 8, 2017, doi: 10.3390/su9081426.

[2] S. H. Teh, T. Wiedmann, J. Schinabeck, and S. Moore, «Replacement Scenarios for Construction Materials Based on Economy-wide Hybrid LCA,» *Procedia Eng.*, vol. 180, pp. 179–189, 2017, doi: 10.1016/j.proeng.2017.04.177.

[3] T. Malmqvist, M. Erlandsson, N. Francart, and J. Kellner, «Minskad klimatpåverkan från flerbostadshus [Reduced climate impact from residentual buildings],» 2018. [Online]. Available: https://vpp.sbuf.se/Public/Documents/ProjectDocuments/d2e167ce-42ae-4250-8249-a8d7c9d93eb1/FinalReport/SBUF 13355 Slutrapport Minskad klimatpåverkan från flerbostadshus.pdf.

[4] TMF, «Trähusbranschen; Bostadsbestånd, Nybyggande [Timber House Industry; Housing Stock new buildings],» 2019. [Online]. Available: https://www.tmf.se/statistik/statistiska-publikationer/trahusbranschen/.

[5] T. Reichstein, A. J. Salter, and D. M. Gann, «Last among equals: A comparison of innovation in construction, services and manufacturing in the UK,» *Constr. Manag. Econ.*, vol. 23, no. 6, pp. 631–644, 2005, doi: 10.1080/01446190500126940.

[6] A. Roos, L. Woxblom, and D. Mccluskey, «The influence of architects and structural engineers on timber in construction – perceptions and roles,» *Silva Fenn.*, vol. 44, no. 5, pp. 871–884, 2010, doi: 10.14214/sf.126.

[7] Växjö Kommun, «Europas grönaste stad,» 2021. https://vaxjo.se/sidor/hallbar-utveckling/kommunens-hallbarhetsarbete/europas-gronaste-stad.html.

[8] Södra Skogsägarna AB, «Södra,» 2021. https://www.sodra.com/en/global/.

[9] Växjö Kommun, «European Green Leaf 2018,» 2018. https://vaxjo.se/sidor/hallbar-utveckling/kommunens-hallbarhetsarbete/european-green-leaf-2018.html.

[10] Växjö Kommun, «Växjö Träbyggnadsstrategi,» 2018. https://vaxjo.se/download/18.cfac4d716951d944dd1a4cb/1551961221853/Växjö kommuns träbyggnadsstrategi – layout version.pdf.

[11] Skellefteå Kommun, «Träbyggnadsstrategi [Timber Building Strategy],» 2014. [Online]. Available: https://www.skelleftea.se/Bygg och miljokontoret/Innehallssidor/Bifogat/Träbyggnaddstrategin skärm.pdf.

[12] Växjö Kommun, «Växjö stations- och kommunhus,» 2021. https://www.vaxjo.se/sidor/trafik-och-stadsplanering/vaxjo-vaxer/handel-och-kontor/vaxjo-stations--och-kommunhus.html.

[13] Sweden Green Building Council, «Miljöbyggnad,» 2021. https://www.sgbc.se/certifiering/miljobyggnad/vad-ar-miljobyggnad/.

[14] White Architects, «Växjö City Hall & Train Station,» 2021. https://whitearkitekter.com/project/vaxjo-city-hall-central-station/.

[15] Boverket, «BBR29,» 2020.

[16] C. S. Tengberg and C. E. Hagentoft, «Risk assessment framework to avoid serial failure for new technical solutions applied to the construction of a clt structure resilient to climate,» *Buildings*, vol. 11, no. 6, 2021, doi: 10.3390/buildings11060247.

[17] L. Olsson, «Fuktsäkerhet vid KL-träbyggande utan väderskydd,» 2019. [Online]. Available: https://vpp.sbuf.se/Public/Documents/ProjectDocuments/812fba34-2bc8-4f0d-bc3c-9e5e8e62e7ae/FinalReport/SBUF 13548 slutrapport_Fuktsäkerhet vid kl-träbyggnade utan väderskydd 2019-12-20.pdf.

[18] C. Larsson and M. Dorn, «A survey of the design of hybrid load-bearing structures in timber and concrete in Sweden,» [Working Paper].

[19] M. Fröderberg and S. Thelandersson, «Uncertainty caused variability in preliminary structural design of buildings,» *Struct. Saf.*, vol. 52, no. PB, pp. 183–193, 2015, doi: 10.1016/j.strusafe.2014.02.001.

[20] A. Klasson, I. Björnsson, R. Crocetti, and E. F. Hansson, «Slender Roof Structures – Failure Reviews and a Qualitative Survey of Experienced Structural Engineers,» *Structures*, vol. 15, no. June, pp. 174–183, 2018, doi: 10.1016/j.istruc.2018.06.009.

[21] SBUF, «Svenska Byggbranschens Utvecklingsfond [Development Fund of the Swedish Construction Industry],» 2020.

[22] C. Larsson, «Byggnadssystem av KL-trä och betong i samverkan – modellering och kravställning vid dimensionering.» https://lnu.se/forskning/sok-forskning/forskningsprojekt/doktorandprojekt-byggnadssystem-av-kl-tra-och-betong-i-samverkan--modellering-och-kravstallning-vid-dimensionering/.