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Architects and engineers need to move beyond thinking about wood and tall timber buildings in terms of steel and concrete precedents, construction and carbon sequestration.

Measuring-up in timber: a critical perspective on mid- and high-rise timber building design

Patrick Fleming, Simon Smith and Michael Ramage

Architects, engineers and researchers alike often cite practical reasons for building with wood. Since the development of curved glulam beams and columns over a century ago, the widespread use of massive structural timber elements has allowed architects and engineers to design and build in wood with unprecedented speed and scale. Moreover, rising concerns of climate change and the carbon-dioxide emissions associated with construction encourage the use of wood as a viable alternative to steel and concrete, due to CO_2 sequestration in trees.

In mid- and high-rise buildings, the current shift from steel and concrete towards massive structural timber elements like glulam, laminated-veneer lumber (LVL) and cross-laminated timber (CLT) is evident in a number of recently completed timber buildings in Europe, ranging from seven to nine storeys. Several speculative design proposals have also been made for 'timber towers' of thirty, forty-two and even sixty-five storeys, recognising that designing with massive structural timber elements in high-rise buildings is still in its infancy. This paper offers a new perspective on building with wood at this scale, beyond carbon sequestration and construction. Criticism of existing projects and proposals, including the authors' own previous design work, is used to highlight the shortcomings of thinking about wood purely as a substitute material for steel and concrete in tall buildings. Two positive case studies are used to further show how wood offers new opportunities for architects and engineers to engage with the materiality, tectonics and structure of mid- and high-rise without neglecting wider urban, cultural and social issues. This discussion seeks to begin a debate on the future role and wider use of structural timber in contemporary architecture.

Murray Grove Stadthaus and super-tall timber

Designers interested in using wood in mid- and high-rise buildings often meet with scepticism over fire performance and other technical issues. The Murray Grove Stadthaus *[1]*, selected for an RIBA President's Award for Research in 2010, was one of the pioneering UK projects to show how massive structural timber is technically and financially competitive with steel and concrete. This residential building is formed of eight storeys of CLT walls and

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1 The Murray Grove Stadthaus by Waugh Thistleton Architects

2 A speculative sixty-five-storey timber tower design proposal by Fleming, Ramage and Smith

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floors on top of a concrete podium. The building was erected at a rate of one storey per week in 2009 with a crew of only four carpenters.[1] Due to the client's insistence,[2] all of the building's wooden structure is completely concealed both on the facade and interior. The Stadthaus project was also the basis for a speculative proposal for a 65-storey residential tower in CLT by Fleming, Ramage and Smith[3] to examine how the CLT panels would fail under the extreme loadings of skyscrapers *[2]*.

Although both these projects challenge the perceptions of, and scepticism about, what can be accomplished with wood, these buildings are conceived of as tower blocks using concrete slabs but built using CLT panels. Both projects repress the materiality and tectonics of their structure, and have no special material presence in an urban context which is dominated by brick, steel, glass and concrete. For mid- and high-rise timber buildings to gain wider acceptance and overcome scepticism among the general public, they have not only to stand up and perform in accordance with building regulations, they also need to engage strongly with non-technical issues in their design and establish themselves as wood buildings, instead of mimicking the design of ordinary concrete buildings.

Historical introduction of new structural materials

Current design trends in multi-storey CLT buildings are best understood in the context of the development of other structural materials throughout history and how, initially, a new structural material is imagined to bear a close relationship to its predecessors. In the case of cast iron, the world's first cast-iron bridge was constructed near Coalbrookdale, England, in 1779. With only precedents of wood and iron truss connections available to reference, the bridge was joined using half-blind dovetail joints borrowed from traditional carpentry.[4] Gradually, through experimentation with the material, its production, and especially new joining techniques, cast-iron construction diversified with bolted and riveted connections and developed into wrought iron and steel construction for bridges, towers and buildings. Towards the end of the nineteenth century, a similar situation is seen with the introduction of reinforced concrete, where reinforced-concrete frame buildings initially mirrored the form of steel beam and column construction. Robert Maillart was the first to show that the reinforcement from slabs could be linked directly into the reinforcement within mushroom-shaped columns, without the need for supporting beams under the slabs.[5] Now designers are beginning to return to wood and massive structural timber elements like glulam and CLT, yet pioneering projects such as the Stadthaus still closely resemble their concrete precedents and lack a meaningful tectonic strategy to relate structure to material and space.

Perhaps one of the main reasons why new structural materials tend to first mimic the form of their predecessors is the conservative nature of the construction industry, and especially building codes. For example, even in traditional medieval timber buildings, it took almost three centuries of cautious use before carpenters trusted flat iron connectors and nails exclusively, without being applied on top of, or alongside, typical wooden-pegged mortise and tenon joints. Initially, it is easier to promote a new and perhaps untrusted structural material or technique in reference to the status quo, showing that it can simply replace the old material while keeping the same form, rather than proposing new material, design and construction methods simultaneously. However, with the gradual acceptance of structural timber as a suitable alternative in many instances for steel and concrete, architects and engineers will have more opportunities to discover new benefits, cultural meanings, properties, and modes of design and construction for wood. Exploration and even playful experimentation with structural timber, as in some work of the London-based architecture firm dRMM, are needed in order to move past this initial stage of simply translating the design of concrete buildings into massive structural timber elements.

LCT 1 and FFTT

Other recent high-rise timber buildings – such as the glulam-concrete hybrid LCT 1 by Hermann Kaufmann, Michael Green's 'Finding the Forest Through the Trees' (FFTT) proposal, and SOM's 'Timber Tower Research Project' – continue to raise awareness of the technical abilities of wood, but offer little in terms of new spatial design. As opposed to the Stadthaus, these buildings could actually allow people to see their timber structure, or in the case of the LCT 1, at least in the interior. The uniform and flat recycled metal facade of the LCT 1 building *[3]* highlights the ambiguous and limited thinking about how large-scale wood buildings might respond to existing topography and urban context, either in a direct articulated way, or in a representational (symbolic) manner.[6] The LCT 1 building is a marked departure from Kaufmann's earlier projects that show a genuine engagement with space, structure, topography and traditional wood architecture.

The most unsettling aspect of these more recent high-rise wood buildings is that they are fundamentally designed as technical systems (or machines for their own construction), rather than as a work of architecture that responds to an existing cultural or social context. In the case of the LCT 1 building, its details and design are driven not by the need to engage with the architectural context, but by a desire to build faster, cheaper and in a more 'sustainable' fashion; the resultant system allowed the building's structure to be erected at a rate of one storey per day. Similar emphasis on construction and assembly technique is also

3 **The universal facade of the LCT 1 by CREE Rhomberg and Hermann Kaufmann Architekten**

4 **The generic thirty-storey FFTT proposal by Michael Green and Eric Karsh**

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seen in Michael Green's work,[7] at the expense of engaging with architectural and urban issues. The same criticisms can be easily applied to SOM's more recent 2013 study on the structural design of a forty-two-storey timber building, where the design of their 'prototypical' timber building is based on the design of a 1966 concrete tower in Chicago.[8] These studies may play an important role in exploring the technical aspects of modern wood construction, but their limited scope ignores the most basic architectural ideas associated with high-rise buildings such as typology, monumentality, connection with the ground, spatial programming and changing concepts of flexibility. These projects, with their preoccupation to demonstrate only the technical possibilities of wood construction and its speed, treat wood as a 'new' commodity that can be exploited by the construction industry, rather than as a material with a long history closely related to human culture and tradition. Lacking architectural purpose, these recent projects represent a new kind of universal system of building, to be replicated like the generic suburban house, but at the scale of high-rise structures *[4]*.

The rhetoric of carbon sequestration

When discussing the choice of wood for a building project, architects and engineers commonly cite the practical or construction-based reasons previously discussed, along with a superficial aesthetic appreciation of timber by the general public. A rationale based on the carbon sequestration effect is also frequently observed and, in the future, may become one of the main driving forces behind a renewed interest in building with wood. While the practical benefits of building with wood cannot be denied, along with using other structural materials with low embodied energies and carbon emissions, these limited rationales demonstrate the uncritical position that architects and engineers are willing to adopt with regard to wood as an architectural or even cultural material. Architects and engineers rarely speak of the impacts of forestry in either creating or destroying natural ecosystems, or the social and economic benefits and possibly detrimental effects on local communities.

A rare example where these issues are considered in the design process is in the small Canadian practice of architect Richard Kroeker, whose structural use of wood is closely related to culture, history and innovative technical and construction considerations.[9] More importantly, however, although sustainably managed forests in Europe are currently expanding,[10] carbon sequestration in wood materials for buildings and furniture only amounts to roughly 3% of the total carbon emissions associated with fossil fuel combustion.[11] The rhetoric of reducing carbon emissions by designing and building with wood instead of concrete and steel may hold some truth, but a widespread change to simply building with wood will most likely play a relatively small role in the complex social, economic and political issue of climate change.

Measuring up

Rather than use massive structural timber elements to simply copy the forms of steel and concrete construction in mid- and high-rise buildings, wood offers far more potential than current design ambitions based on superficial aesthetics, carbon sequestration and cost-saving construction. Although smaller in scale, the stone and timber bridges and buildings of Conzett, Bronzini, Gartmann AG provide relevant examples in this regard, and are described by Mostafavi as navigating a critical line between the dominating and enabling aspects of technology.[12] Wood needs to be regarded first and foremost as a fibrous material that is grown in nature and then adapted, in contrast to steel, concrete and glass, which are all produced industrially and formed from a liquid state. New techniques for adapting wood for buildings, and designs incorporating such ideas, can serve a purpose other than their own construction, and should engage with other architectural and urban issues beyond aesthetics and carbon sequestration.

Through the engagement with materiality, topography and monumentality, the exploration of new techniques for using structural timber in tall buildings does not need to be restricted by structural rationalism, where each structural material is thought to have one definitive form of construction. On the contrary, many new ways of building with massive structural timber elements can be developed while responding to human issues. As Adrian Forty shows in his recent work on concrete,[13] the principles of structural rationalism from nineteenth-century architectural debates could not apply to concrete due to its uncertain character and to our relationship with it both as designers and people. The same can certainly be said of wood with its paradoxical use as both a permanent and long-lasting material, or as a short-lived and temporary material, in a wide range of buildings and structures, from basic trusses to elaborate gridshells. Rather than arguing for a narrow form of structural rationalism, our argument reminds architects and engineers that the design of mid- and high-rise timber buildings does not need to be limited to focusing on carbon and construction or forms already established in steel and concrete.

So far we have offered only criticism of the efforts of architects and engineers trying to champion the use of wood as a replacement to the near exclusive use of steel and concrete in mid- and high-rise buildings. To encourage further debate and discussion, two different examples are now considered in a different light: the first example is the seven-storey Tamedia Office Building by Shigeru Ban Architects and Hermann Blumer, and the second is a design proposal by the authors for a six-storey office building in Mayfair, London. The projects show two very different ways of working with structural timber to respond to a brief for a multi-storey office building. The two projects also reveal and conceal their timber structures in different ways and to different degrees. Despite these differences, neither project uses wood to conform to generic steel and concrete office buildings. Instead, they explore ideas beyond construction and carbon sequestration to illustrate how a deeper engagement with the materiality and structure of wood can be beneficial in mid- and high-rise building design. Although the site of each project is connected with existing buildings and therefore does not provide a direct comparison with the freestanding towers of Michael Green's FFTT proposal or Hermann Kaufmann's LCT 1, the more general response to a brief for an open-plan office building using glulam and CLT gives a reasonable point of comparison.

Tamedia Office Building

The Tamedia Office Building *[5]* serves as a guiding example of how structural timber might lead to a radically different tectonic form than those already established by steel and concrete. The building's unique longitudinal oval-shaped glulam beams fit through massive solid glulam columns and the hoop-like connections of larger 20-metre transverse beams. The portions of the oval beams that fit through the columns are made of LVL and form a rotation-resistant connection without the use of metal connectors or screws. This simple connection detail *[6]* and tectonic strategy is not derived from steel or concrete construction, but is much more closely related to traditional all-wood joints. The relatively simple structural design of using continuous beams in the transverse direction (instead of simply supported spans) also provides additional small social meeting and circulation spaces at the exterior of the building, apart from the main open-plan working space spanning 14 metres. The multi-layered facade of the building lets these social spaces open completely up to the outdoors *[7]*, allowing these shared social spaces to mediate between the building's main interior and the surrounding exterior environment and urban context. Here, the materiality and tectonics of the structure is not hidden, and together with the facade plays an important role in the spatial experience throughout the building.

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5 The Tamedia Office Building by Shigeru Ban Architects

6 Social space and typical all-wood beam and column connection in the Tamedia Office Building

7 Facade of the Tamedia Office Building with social spaces and structure opened up to the surrounding outdoor environment

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Grosvenor Office Building

A new design proposal for a six-storey office building in Mayfair, London provides a more detailed example of how wood could be used as an alternative to steel and concrete in broader terms than just construction. At present, an existing steel and concrete design developed by Ramboll and Flanagan Lawrence (BFLS) has been proposed for a site on Grosvenor Street [8, 9]. The project client, developers Grosvenor, has called for an exemplary office and retail building with well-lit, open-plan offices with high levels of specification, design and amenity.[14] Underlying these requirements is the client's stated concern for sustainability by 'minimising carbon emissions, the use of energy, conserving resources and reducing waste'. Instead of analysing and criticising the existing proposal, the brief and site [10] are used to provide a context for developing an alternative design in wood. Although the environmental, structural and urban issues of this six-storey office design proposal were negotiated simultaneously, they are presented hereafter in a sequential manner for clarity.

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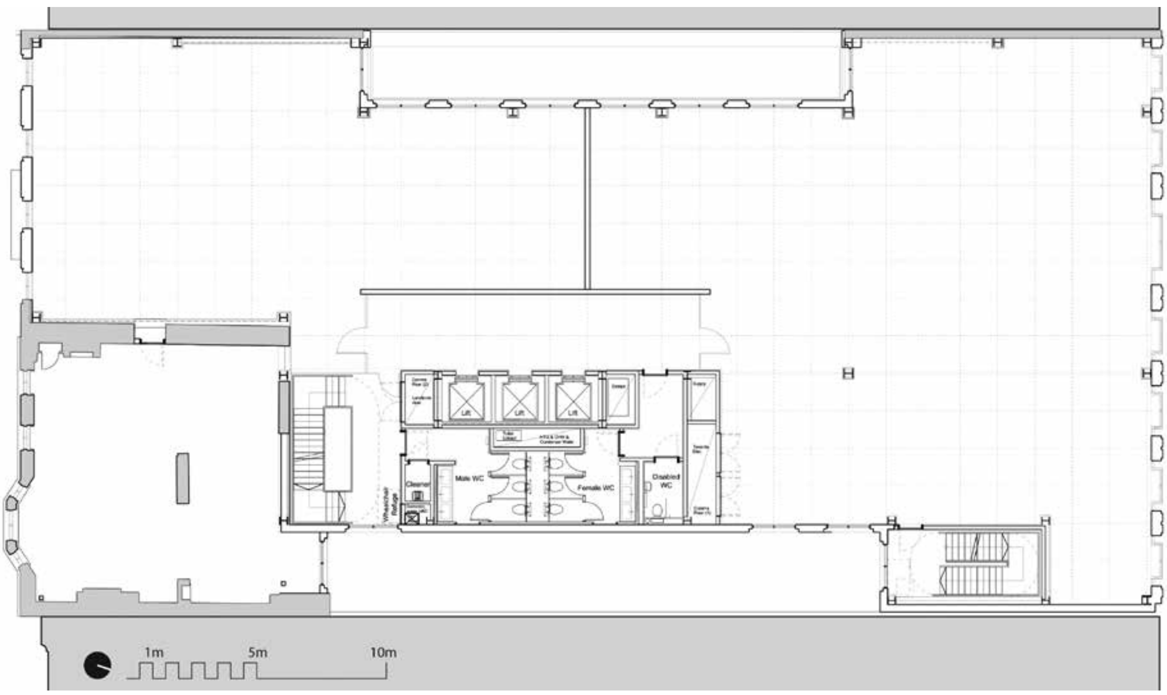
8 Proposed facade by BFLS and Ramboll for a six-storey office building in Mayfair, London

9 Typical plan for the proposed steel and concrete office building by BFLS and Ramboll

10 The site location for an alternative design proposal by Fleming, Smith and Ramage in massive structural timber for a six-storey office building in Mayfair, London



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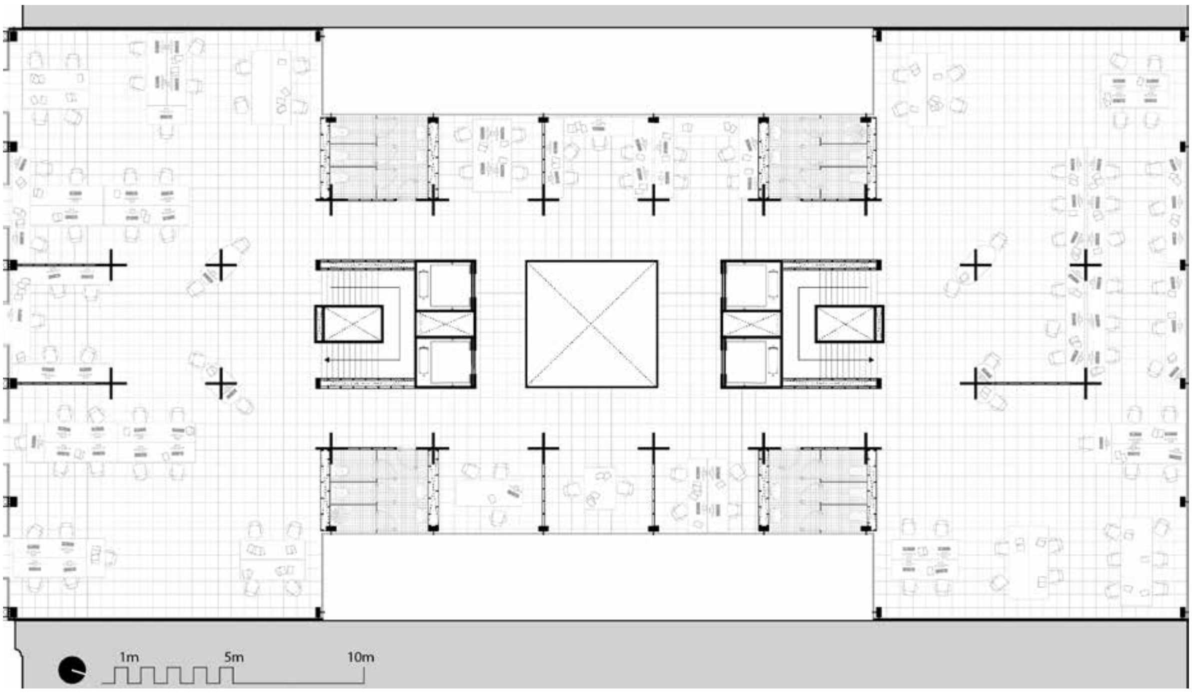
Environment

Open-plan office buildings are designed with flexibility in mind, so that spaces can be reconfigured to meet the future needs of corporate tenants. Yet at any given time, a typical open-plan office space results in a homogeneous internal environment or atmosphere, with little potential for diversity in temperature, lighting or acoustics. More importantly, the social environment also becomes homogeneous and fixed as workers are either confined as individuals within private cubicles or, more often, forced into team-based units in shared work-hubs and tables with little privacy. Underneath this typical office situation is a tension between working as an individual and working within larger teams of co-workers, or a company at large. The proposed timber office design *[11]* suggests a variation of the generic open-plan that still allows for some flexibility with similar numbers of workers per square metre as standard UK offices.[15] The timber proposal offers spaces for private individual offices or team-based work hubs of varying sizes, all clustered around the perimeter of the building for its natural daylight. Intermittent and open individual workspaces underneath individual light wells are also organised around the building's vertical structure. Although current open-plan offices tend to incorporate basic individual and team-based 'break-out' spaces, these different kinds of spaces are accomplished at the scale of interior design or furniture set in an open plan. A timber office building's massive structure, which fundamentally arises from the material's lower load capacities compared with steel or concrete, can also serve to provide a diversity of workspaces and internal environments *[12]*.

11 Typical floor plan for a timber office building showing similar occupancy density as common steel and concrete offices

12 CLT jointing and glulam connections and structure of the proposed alternative timber office building design



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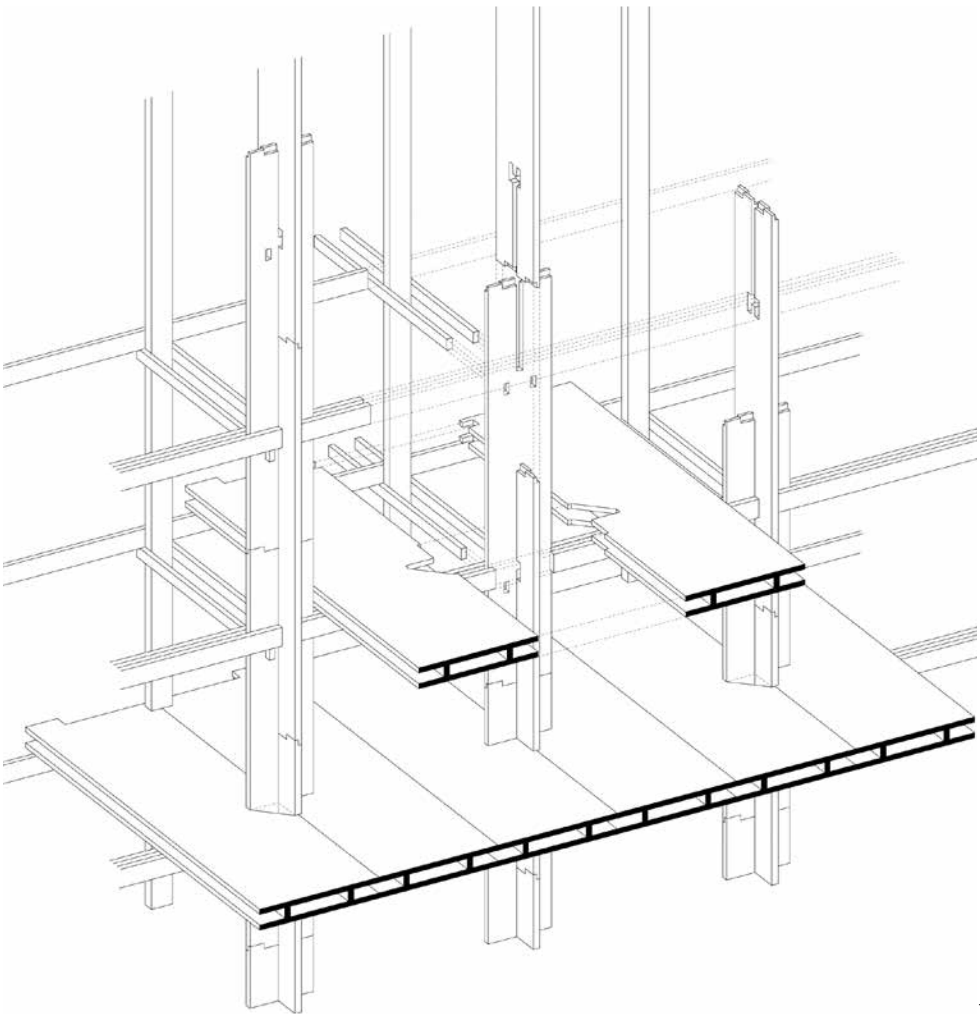
Structure

In section, office floor plates of stressed-skin panels or timber cassettes, made up of glulam beams and CLT panels, provide a means for spanning distances of up to 12 metres. These timber cassettes are comparable in depth to a steel and concrete floor plate, and also allow overhead and under-floor space for services. In plan, concrete and steel buildings commonly use solid columns to support beams and floor plates. A similar structural design can be followed in wood using massive glulam columns. However, breaking apart columns into thin-walled sections of CLT panels provides a different strategy and yields the open, individual, workspaces previously described along with the potential for small vertical light wells that bring daylight down throughout the different levels of the building. These cruciform columns also have structural benefits by increasing the column's second moment of area and buckling resistance, much in the same way as steel I-beams, but only at a larger scale. By providing individual workspaces and light wells, the columns' design and construction *[13]* closely relates to the internal environment, as well as other structural components such as the secondary beam structure. Like the beams in the Tamedia Office Building, these timber columns do not mimic steel or concrete precedents, but instead take full advantage of the long fibrous nature of wood, and the automated cutting and relatively slender maximum proportions (2.4 x 16 metres) of CLT panel production. The proposed column construction and jointing is also closely related to the massive wood columns found in traditional wood buildings.[16]

Urban context

The urban context of Mayfair provides a challenging site for proposing a convincing timber facade. The proposed facade uses charred timber *[14]*, partly for its durability but also as a positive expression and reminder of the ability of massive timber to lightly burn and protect itself, from either weather or further combustion, by forming a protective layer of charring. Simple strip windows ensure ample daylight for the internal environment, while horizontal shading devices outside the windows reduce glare and overheating due to the facade's southern orientation. The rhythm and proportions of the existing building facades are reflected in deliberate breaks in the horizontal shading. The proposed timber facade aims to enrich the existing urban context by offering a material presence other than brick or stone. This facade demonstrates how large-scale timber buildings can be more successfully integrated into an existing urban context on their own terms, rather than as concrete or steel buildings constructed in wood.



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13 **Interior view of the proposed timber office building design showing vertical skylights over individual workspaces around the vertical timber structure**

14 **Charred wood facade of an alternative timber office building design in the urban context of Mayfair, London**

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Conclusion

As noted above, pioneering examples of mid- and high-rise timber buildings closely resemble the designs and forms already established by ordinary steel and concrete structures. In reference to the historical development of structural materials such as cast iron and reinforced concrete, this mimicking is perhaps expected, and confirms that current methods and ideas for designing and building tall structures with wood are still immature and far from developed. The way forward for building in wood at this scale, we argue, is not to continue to simply copy the form of steel and concrete buildings, or to design timber buildings to respond primarily to construction methods and speed. Rather, architects and engineers need to explore and experiment with new ways of adapting and using wood for mid- and high-rise buildings while engaging with architectural and urban issues. The Tamedia Office Building in Zurich and a design proposal for a six-storey office building in central London show that even for rather generic office design briefs, engaging with the materiality and tectonics of wood offers architects and engineers new design opportunities for mid- and high-rise buildings. Dialogue and architectural debate is needed to support and guide future developments for using wood to respond to existing situations, beyond the limited technical aspects of carbon sequestration and construction.

Notes

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