In this article we review the characteristics and key considerations for utilising CLT in structural frames, how it compares to traditional steel and concrete frames and why it has become a more popular choice in commercial buildings in recent years.

We are focusing on the cost and programme impacts that specifying CLT has on a typical project, based on our own experiences.

**WHAT IS CLT?**

Cross laminated timber (CLT) is a form of engineered timber made from gluing layers of dried spruce board together, in a similar process to plywood, but with much thicker layers. It offers high strength, comparable to steel or concrete despite it being a lightweight option.

Once fabricated, the CLT panels are hoisted into position and bolted together to build the structure floor by floor. It has traditionally been used on low rise buildings, however we are now seeing this being specified on buildings of six storeys and above.

**CLT is a hot topic in the construction industry. It is commonly becoming an alternative to traditional steel or concrete frame construction.**

We are seeing that the number of projects being specified with a CLT frame or a hybrid CLT/steel frame has increased over the last few years.
WHY CLT?

MATERIAL COSTS
The raw material cost for CLT itself tends to be higher than concrete and steel, however, the cost needs to be considered on a wider level to take into account reduced requirements on foundations / substructure and eliminating the need for reinforcement, formwork, etc.

A hybrid variation of CLT (usually CLT slabs with a steel frame) is pretty much commonplace on major refurbishment / cut and carve schemes with significant added mass. This is thanks to the lack of pressure its usage puts on the building’s existing substructure. In some instances, adding mass has lessened the overall load.

The supply chain for CLT products is currently solely from the European Union (EU) and this represents a potential supply risk after the transition period ends, depending on the future UK/EU trade deal. Whilst this is relevant to a number of products in construction, it is particularly acute for this product with no current UK alternative.

LABOUR CONSIDERATION
The demands for onsite labour are significantly less on a CLT frame. In a market where there is a long-standing labour shortage, this is an advantage over other frame types. The pre-fabricated panels require less labour to install them, although it’s important to consider that a CLT frame requires more skilled labour for installation.

Due to the specialised nature of the labour required, installing a CLT frame means a reduction in the number of trades required on site. For example, an exposed CLT soffit will mean a reduced requirement for a dry lining contractor on site.

Less people on site is also a big benefit when considering the new requirements for social distancing.

PROGRAMME BENEFITS
Based on our experience of current projects, CLT construction is approximately 15-20% quicker than a composite slab for the frame construction.

The main reasons for this are:
- Prefabricated nature.
- Large panel sizes.
- Ease of subsequent fixings for follow on trades.
- Limited wet trades means less drying time.
- Reduced waste, therefore minimal waiting times.

The crane hook time associated with a steel and composite deck solution versus a steel and CLT solution is very similar, however, with the steel and composite solution there is a period of time on site for the concrete pour and drying time which extends the programme.

A reduced programme on site obviously brings with it a cost benefit which must be considered as part of any frame study during the feasibility of a project (i.e. impact on main contractor preliminaries).

Appointing a CLT contractor early on a project under a pre-construction services agreement (PCSA) has clear advantages, such as allowing the design to develop in a more coordinated fashion earlier on in the design programme and ironing out any specific details / interfaces which may be bespoke to a particular project. The design needs to be completed ahead of starting on site to give time for the offsite manufacture and requires full coordination.
ON SITE BENEFITS

Given the lightweight nature of CLT (approximately a fifth of concrete), there will be a reduced substructure scope which can save both time and money on a project.

Handling, wet trades and dust are reduced when compared to a concrete frame, making CLT a preferred option in terms of health and safety. All of this saves time, and subsequently money.

The installation of CLT is also much quieter, which is a big benefit, particularly in the central London market with restrictions on noisy working times, and sometimes sensitive neighbours.

It is, however, important not to overlook the fact that when CLT is delivered to site it requires a dry space on which to be laid. On a constrained site in central London this will impact the progression of work and may lead to a requirement for consolidation centres to store other materials off site.

Reduced deliveries to site, particularly in a constrained central London site, are a major benefit when it comes to programme, cost and sustainability.

The large panel construction speeds up the process which allows work on site to continue during the installation. As the CLT panels do not require time to cure it means as soon as they are installed, they are working in a structural manner.

Given the prefabricated nature, this allows coordination with other trades at an earlier point in time, such as façade interfacing and MEP installations.

Images: Heyne Tillett Steel
TECHNICAL CONSIDERATIONS

DESIGN

In our experience, it is important to bring the detailed design forwards on a project and consider a PCSA with a CLT frame contractor to minimise any surprises when a project is tendered.

This knowledge and experience will save both time and money and will provide comfort going into contract that the frame has been fully designed and de-risked.

How CLT looks is a key driver for the increase in specification of CLT frames, where the timber soffits can be left exposed. The cost for CLT however, can vary depending on the grade of the wood and visual requirements. Where it is intended for the soffit to be exposed, careful consideration needs to be paid to service distribution on floor, which can become costly should service channels within the CLT be required.

Additional costs should be considered for large scale mockups, particularly where the CLT is being exposed. These mockups can then be used to better understand the coordination with the services and lighting.

The impacts of the CLT design on any future Category B fit out need to be well thought out. Tenant requirements for services may require penetrations to be made into the CLT which impacts the durability and the aesthetics. The acoustic requirements of a tenant will be important when specifying CLT, the likelihood is that acoustic screed or board will be required as a minimum. It should also be considered that an exposed CLT soffit is not to every tenant’s taste. Design life also needs to be considered when specifying CLT.

From our experience on a project in central London, hybrid structures such as concrete and CLT offer the best value and versatility.

INSURANCES

A common first thought is that insurance premiums will significantly increase, not only for the works during construction, but also of the asset itself post construction.

What we are finding is that works insurance during construction does increase, as expected, however post construction we are seeing building insurance premiums be commensurate with the premiums of the existing asset, i.e. non-CLT construction.

In terms of insurances, key considerations would therefore be with regards to on site management and safety procedures put in place by the main contractor, e.g. protection of the CLT itself and keeping any apertures / openings boarded up to prevent the spread of any fire. This ultimately has impact on time and cost which should be also taken into consideration during the pre contract, planning stage.

Image: Piercy&Company ©Millerhare

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London's independent construction cost advisors
Encapsulation is in essence boarding over CLT elements with a fire-resistant system. This may address any carbon drives a client may have, but may be a difficult and expensive pill to swallow from a design perspective.

FIRE
As expected, fire is one of the utmost concerns / considerations when trying to design elements of CLT into a scheme, whether that be a new build or refurbishment.

As with all consultants, early engagement is paramount, particularly with Building Control who can advise on the best steps to mitigate fire issues, especially with local fire brigades.

There appears to be two avenues of approaching this:

• Extensive testing prior to construction.
• Encapsulation of the exposed timber elements.

Although a robust testing regime may help protect the client’s aspirations of having exposed CLT soffits for example, this comes with a significant capital cost and may result in bad news - encapsulation.

Encapsulation can be embraced from earlier in the design process but eradicates any celebration of CLT features.

PROTECTION, WATERPROOFING AND MOISTURE

During construction, one of the main focus areas is ensuring the protection of the CLT materials and mitigating the risk of moisture through a project specific moisture control plan (MCP).

This is typically developed by both the CLT contractor and the main contractor to ensure robustness.

The MCP will be operated by the CLT subcontractor during the works and by the main contractor once the works are handed over. The main areas of site activities are listed below, however the document will be quite detailed and include many more valid factors:

• CLT materials are package wrapped during delivery. On site the packaging is opened to enable ventilation around the CLT. End grain sealer is applied to the exposed end grain of the CLT.
• Moisture control readings taken at regular intervals to measure the moisture content in the CLT. This is important to measure prior to the final finishes, if any, being applied.
• Removing standing water from the CLT surfaces via water vacuums or temporary outlets.
• High risk areas can receive a factory applied temporary waterproof membrane bonded to the CLT.
• The preference is to ensure the best practice measures as described above are implemented rather than installing a number of temporary measures that ultimately provide no additional guarantees.
Of late, it is likely we have all seen a spike in interest in net zero carbon and how our new buildings and prospective projects can be designed to achieve this outcome and meet these targets.

There are generally two bodies of guidance helping us better understand the key requirements for new buildings, such as performance targets developed by the London Energy Transformation Initiative (LETI) and the Royal Institute of British Architects (RIBA). There is currently a limited understanding of the practical implications for designing and delivering these buildings including, critically, an evaluation of the wider project impacts and costs.

The below graph compares the embodied carbon of a typical steel and composite deck framed commercial office building against the aspired embodied carbon target in the brief of a current project. The frame and substructure, in the typical project, equate to circa 40% of the overall embodied carbon and offer the biggest opportunity, as a single element, to improve on any given project. The utilisation of a steel and CLT hybrid frame is currently estimated to improve the embodied carbon of this element by circa 40% and is the single biggest contributor to achieving the target brief.

Whole life embodied carbon is measured in kgCO2/sq m/GIA.

Broken down into constituent elements.

‘Standard construction’ (assumed concrete frame) usually hits around 1,000 kgCO2/sq m/GIA.

This metric is as defined by whole lifecycle carbon assessments guidance - Mayor of London April 2020.

Clients are now targeting much reduced whole life, embodied carbon targets.

RIBA 2020 calls for 800 kgCO2/sq m/GIA.

RIBA 2030 calls for 500 kgCO2/sq m/GIA.
The chart to the right is based on Stage 3 market testing received from B&K Structures for a hybrid CLT and steel frame in central London.

Although the CLT and steel in this example are the highest proportion of the costs, there are other factors that need to be considered, such as surface spread of flame and acoustic screed.

These ‘other considerations’ will have a big impact on the costs and need to be carefully considered early on in a project.

The below is an extract from a detailed, structural frame comparison study we undertook on a central London scheme considering different frame types:

### STAGE 2 STRUCTURAL FRAME COMPARISON

<table>
<thead>
<tr>
<th>CAT A FLOOR TO CEILING HEIGHT (DISPLACEMENT)</th>
<th>REINFORCED CONCRETE SLAB AND FRAME</th>
<th>CLT PANELS WITH STEEL FRAME</th>
<th>STEEL FRAME AND COMPOSITE SLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substructure</td>
<td>Substructure generally incl. 1000mm thick reinforced concrete raft slab (assumed thickness TBC)</td>
<td>Substructure generally incl. 500mm thick reinforced concrete raft slab (assumed thickness TBC)</td>
<td>Substructure generally incl. 750mm thick reinforced concrete raft slab (assumed thickness TBC)</td>
</tr>
<tr>
<td>Frame</td>
<td>£42.2/sq ft</td>
<td>£39.9/sq ft</td>
<td>£41.0/sq ft</td>
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<tr>
<td>600mm reinforced concrete columns and 300mm reinforced concrete core walls</td>
<td>£9.2/sq ft</td>
<td>£22.6/sq ft</td>
<td>£23.2/sq ft</td>
</tr>
<tr>
<td>Upper floor and roof slab</td>
<td>Reinforced concrete floor slab 275mm thick</td>
<td>CLT planks c/w cellecta screed board, insulation and acoustic layer</td>
<td>Reinforced concrete slab on 150mm metal deck</td>
</tr>
<tr>
<td></td>
<td>£19.2/sq ft</td>
<td>£18.2/sq ft</td>
<td>£8.8/sq ft</td>
</tr>
<tr>
<td>Subtotal</td>
<td>£70.6/sq ft</td>
<td>£80.7/sq ft</td>
<td>£73.1/sq ft</td>
</tr>
<tr>
<td>Programme</td>
<td>No benefit</td>
<td>To be confirmed</td>
<td>To be confirmed</td>
</tr>
<tr>
<td>MC preliminaries</td>
<td>OH&amp;P, contingency, etc.</td>
<td>OH&amp;P, contingency, etc.</td>
<td>OH&amp;P, contingency, etc.</td>
</tr>
<tr>
<td>£5.1/sq ft</td>
<td>£7.3/sq ft</td>
<td>£7.3/sq ft</td>
<td>£5.7/sq ft</td>
</tr>
<tr>
<td>Total (3Q 2020 prices)</td>
<td>£75.7/sq ft</td>
<td>£88.0/sq ft</td>
<td>£78.8/sq ft</td>
</tr>
<tr>
<td>Variance to reinforced concrete slab and frame (+/-)</td>
<td>-</td>
<td>£12.3/sq ft</td>
<td>£3.1/sq ft</td>
</tr>
</tbody>
</table>
SUMMARY

Whilst on a like for like basis the cost of CLT can sometimes be higher than other frame options, other factors need to be considered holistically, such as impact on existing substructures, new foundations, structural strengthening (if a refurbishment project) and time on site.

ADVANTAGES

- Speed of construction.
- Reduced site labour force.
- Reduced site noise.
- Reduced substructure interventions / works.
- Reduced levels of structural intervention on refurbishment projects.
- Reduced embodied carbon.

DISADVANTAGES

- On site weatherproofing / protection.
- Acoustic considerations.
- Potential encapsulation - impact of fire regulations / strategy.
- Impact on insurances, both during and post construction.