SUSTAINABILITY BUILDING STRUCTURES

In-use energy consumption is well regulated, so should we now consider embodied carbon? **Isabel McAllister** and **Anthony Mitchell** of **Cyril Sweett**, **Steve Webb** and **Anna Beckett** of **Webb Yates** report

01 / INTRODUCTION

In recent years UK Building Regulations have reduced building operational energy consumption (and associated carbon emissions) significantly. An office building built today to Part L 2010 standards consumes about half the energy of one built 20 years ago. Further Part L iterations are proposed so that new buildings will be "zero carbon" in operation by 2019.

However, Part L does not take account of embodied energy, and as operational carbon emissions reduce, the energy used to extract and manufacture building materials has become increasingly significant. For example, British Land stated last month on its website that "16% of the total carbon footprint results from the extraction, fabrication and erection of steel and concrete, making these priority materials for us to focus on in future developments."

This article looks at a common form of office floor construction and explores how capital costs and embodied carbon are affected by changes in design load, the use of lighter-weight materials, and switching from concrete to timber deck components.

02 / INDUSTRY STANDARD BASELINE SPECIFICATIONS

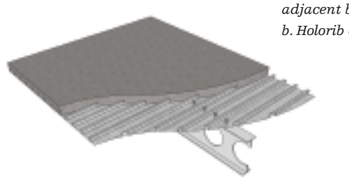
It is common practice in office building design today to take a design load of 4+1kN/m² (400kg/m² for the office occupancy and 100kg/m² for partition loading) despite the fact that the British Standard and now the Eurocode for imposed loading only require 2.5+1kN/m² as a minimum requirement. Normal office distributions allocate one person, their desk, chair, computer and their partitioning to 8m² of floor space. These are unlikely to weigh anywhere near the 4 tonnes that the 4+1 loading allows for. In the past this enhanced loading requirement gave office occupiers the ability to put dense file storage anywhere in the building, but as offices become less "paperful" the likelihood of anyone actually using this ability is slim.

It is unclear why the 4.0kN/m² load is still used today, but may be partly because of inertia in the industry and development specifications and partly because agents advise that given a choice a potential client may opt for a building with a higher spec even though they may not intend to use it. An additional value of 1kN/m² is included to allow for demountable partitions, but a study of typical distributions of lightweight partitioning in modern offices gives loads of less than 0.5kN/m².

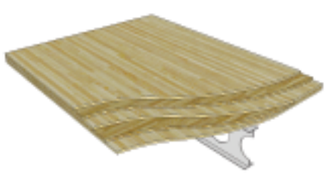
03 / CASE STUDY BUILDING

This study looks at a typical six floor office building, with a gross floor area of 3240m². It has a common column grid spacing of 9m x 7.5m and the analysis focuses on a standard internal bay and includes a piled foundation as shown opposite. Five options have been considered (see opposite page). In each the floor comprises cell beams supporting a thin floor deck. If the floor deck is concrete these types of floor constructions are either constructed with the floors and the steel beams acting together compositely (where the deck is attached to the steel beams with shear studs) or non compositely (the slab makes no contribution to beam strength). Each possibility is explored with heavy and light design loads with an option for a lightweight cross laminated (solid) timber floor deck of similar depth.

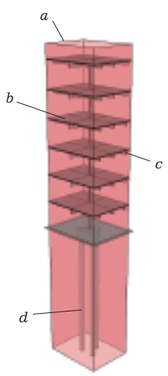
a. Area considered (in colour) includes one column and a quarter of each adjacent bay
b. Holorib concrete slab or cross laminated timber panels
c. Internal cellular beams
d. Piled foundations in London Clay
e. 4m storey height



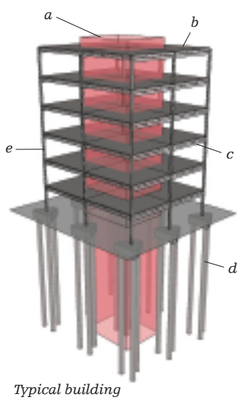
Section through composite floor deck



Section through cross-laminated timber deck



Section considered in calculations



Typical building layout

OPTION		MEMBER SIZE (LONGITUDINAL)		MEMBER SIZE (TRANSVERSE)			PILES		
		Top Bottom	Mass (kg/m)	Depth (mm)	Top Bottom	Mass (kg/m)	Depth (mm)	Diameter (mm)	Depth (m)
1	A 4 + 1 load requirement with non composite floor deck	406 x 140 x 46UB 356 x 171 x 57UB	51.5	481.2	610 x 229 x 101UB 610 x 229 x 101UB	101.2	689.4	750	27
2	A 4 + 1 load requirement with a composite floor beam/deck	356 x 171 x 51UB 356 x 127 x 39UB	45	475.2	457 x 152 x 67UB 610 x 229 x 125UB	96.1	708.3	750	27
3	A 2.5 + 0.5 load with a non composite floor deck	406 x 140 x 46UB 305 x 165 x 54UB	50	477.8	533 x 210 x 82UB 610 x 229 x 101UB	91.7	695.4	600	27
4	A 2.5 + 0.5 load with a composite floor beam/deck	254 x 146 x 37UB 406 x 140 x 39UB	38	473.2	457 x 152 x 60UB 533 x 210 x 92UB	76	667.1	600	27
5	A 2.5 + 0.5 load with a lighter solid timber deck.	305 x 102 x 33UB 356 x 127 x 33UB	33	472.3	533 x 210 x 82UB 457 x 191 x 74UB	78.2	665.9	600	25

04 / CAPITAL COST SAVINGS

	Frame and upper floors £/m² GFA	Foundations £/m² GFA	Total frame and upper floors and foundations £/m² GFA	Comparison with Option 1 %
Option 1	163.11	59.78	222.89	-
Option 2	157.24	59.78	217.02	-2.63%
Option 3	152.16	54.22	206.38	-7.41%
Option 4	130.64	54.22	184.86	-17.06%
Option 5	152.93	52.83	205.76	-7.69%

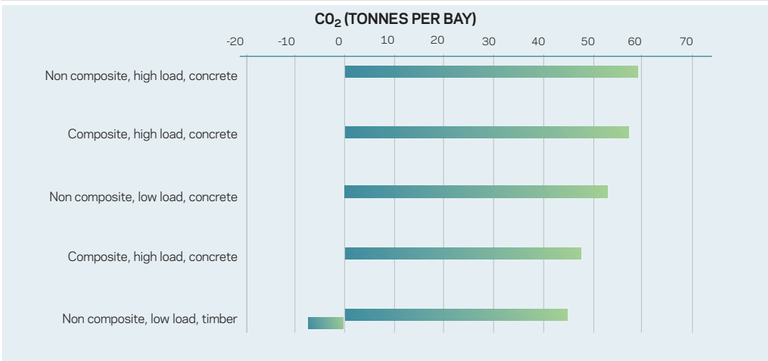
As would be expected, each of the lighter-weight options is cheaper than Option 1.

Option 5 (the timber solution) has advantages over the concrete solutions as the installation is quicker and involves fewer operations. The normal construction process for this type of building entails erecting the steel, laying out the steel deck, fixing shear studs (which for safety reasons stops work on the floor below), fixing reinforcement and finally pouring the concrete. The timber solution involves simply laying prefabricated timber panels onto the steels and bolting them down.

It would be reasonable to assume a 12 month typical build programme and the timber floor solution should reduce the programme by at least two weeks and potentially four weeks as a large area of floor can be craned into place relatively quickly. A two weeks off the programme could save £20,000 on prelims bringing the total for Option 5 down to about £200/m² – a saving of 10% on Option 1. (The cost savings attributable to a shorter programme are not denoted above.)

It should be noted that timber floors are rarely used in commercial buildings in the UK, consequently, the number of suppliers is limited. If timber were used more regularly in this way, capital costs could be expected to reduce notably. The UK timber industry would be well placed to adapt and deliver these products if they were more regularly specified.

05 / EMBODIED CARBON IN NUMBERS



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06 / EMBODIED CARBON

In addition to notably reducing capital cost, each of the lighter-weight options also has lower embodied carbon than Option 1.

The chart above shows the embodied carbon content for one whole six-storey bay (including foundations) for each option. The reduction in embodied carbon between the heavy floor load and lighter floor load is significant. Increasing the load from 2.5+0.5 to 4+1 increases carbon emissions by 21% or 10 tonnes of carbon for a six-storey bay.

Swapping the concrete deck for a timber deck makes a further reduction in the initial embodied carbon of 2.9 tonnes per bay.

When the carbon dioxide absorbed by the tree during its growth is subtracted from the total, the embodied carbon actually becomes negative at minus seven tonnes per bay which is a very significant reduction and means that the frame has become carbon negative (a carbon sink).

07 / CONCLUSION

Embodied carbon is not a commonplace consideration for many clients, however it is becoming increasingly relevant as Part L has reduced operational carbon emissions in recent years. So the relative importance of embodied carbon has increased, meaning embodied carbon makes up a bigger percentage of a building's whole life carbon footprint. As Part L gets tougher this ratio between embodied and operational carbon will become even larger. Design teams and contractors should start focusing on reducing embodied carbon in new buildings.

Current typical structural specifications for office buildings are onerous and support methods of working that are rarely relevant nowadays. This article shows that if design loads were more realistic, embodied carbon savings are available that also present modest capital cost savings. While there may be inherent resistance to the use of timber in commercial buildings based on preconceptions about the superior performance of concrete decks, it's use is very powerful in reducing the overall carbon footprint of a building at little additional cost compared with changes to building services strategy. In conjunction with an increase in sustainable forestry this could form a significant part of reducing CO_2 emissions from commercial construction.