The Sustainability Benefits of Pre-Cast Concrete Construction

Carbon dioxide is one of the main greenhouse gasses contributing to the increase in the earth's temperature. For this reason, the carbon footprint (total amount of carbon emissions) of a building is gaining increasing importance.

Total carbon emissions = operational carbon (generated from fuel, water electricity etc) + embodied carbon (the carbon generated from manufacture, transportation and other activities in the construction of the building).

The following article explains the advantages of using precast slabs in order to reduce the embodied carbon of a construction project.

The use of precast concrete elements, are considered as beneficial method of construction towards a more sustainable built environment. These provide several benefits which can collectively result in savings in material use, energy consumption and decrease in pollution.

As outlined below hollowcore prestressed concrete planks & prestressed predalles plates can obtain (tables below then outline the embodied carbon of the manufactured units together with a comparative analysis of varying structural systems):

1. Good thermal mass- when combined with good architectural design and allow air changes to the exposed concrete surface, the transfer of heat throughout the building would provide more stable temperatures during the day whilst preventing overheating. [1]

2. Aesthetics - Concrete planks can be left exposed and finished off neatly for industrialised looks, which in turn would create extensive savings in gypsum materials (Resulting in less material needed to be transported to the site, thus less CO_2 emissions during construction, and less material used) [1]

3. Hollow Core benefit- the hollow cores provide the benefit of serving as channels to pass services, preventing chasing, unnecessary lengthy cables, etc… [1]

4. Form work – concrete planks do not require formwork to be set-up. [1]

5. Reinforcement – prestressed planks & prestressed predalles work out at a reduced thickness & use much less steel as compared to the traditional cast in-situ ceiling. [1]

6. Speed of construction – A general benefit of precast elements, is that they expedite a projects time-frame. [1]

7. Re-usability – Hollow concrete planks can potentially be re-used once a building's life span expires. [1]

8. The role of the structural engineer, as part of a multi-disciplinary design team, is to develop structural solutions that contribute to reducing energy consumption, and to deliver buildings with a long life and a low embodied carbon footprint. The **embodied carbon** of the construction of the building (excluding fit out), spread over a 60 year design life, is between 6 to 15 $kgCO_2e/m^2$ on an *annual basis.* Taking a typical value of 5 $kgCO_2e/m^2$ for a typical office building and assuming the structure (primarily steel and concrete) represents 50% of this, then the structure accounts for an annual 2.5 $kgCO_2e/m^2$, with the other 50% approximating to the annual energy consumption of the building. If the structural engineer can, through clever design and material specification, reduce this by 30% then the saving is $0.8kgCO_2e/m^2$. [2]

9. Annual energy consumption – **operating carbon footprint.**

Real energy consumption is hugely variable and depends on:
Building type. Thermal performance of the fabric. Typical operational energy and carbon figures for buildings. Type and efficiency of heating, cooling, ventilation, lighting, domestic hot water and other systems. Equipment plugged in. Hours of operation. Average climate that year (warmer or colder). Control strategy. The expectations and behaviour of the building occupants. [2]

10. Embodied versus operating carbon

The embodied carbon for new construction of office buildings should typically tend to between 500 and 900 $kgCO_2e/m^2$ of GIA (Gross internal area). This is equivalent to five to ten years of the CO_2e emissions due to the energy consumption. The 10 years is for an office building with the 5 years for a lower grade building. [2]

11. Embodied versus renewables

The contribution that onsite renewables can make to reducing the whole carbon footprint of a building varies significantly depending on the building type and configuration, including the area of roof available for solar panels. But for example, a ten-storey $10,000m^2$ office building with a roof full of photovoltaics could reduce annual carbon emissions by around 2 $kgCO_2e/m^2$. [2]

12. Besides drinking water, concrete is the most used man-made material on earth, with 14 billion m^3 produced each year. As a result, the production of cement, the active binding agent in concrete, accounts for around 7% of global CO_2 emissions. While concrete production emissions arise from a range of sources, cement production is responsible for almost 60% of the embodied carbon in reinforced concrete. Thus, with 2050 rapidly approaching, action must be taken to reduce emissions and realise net-zero commitments. To address this, many companies are developing lower carbon concrete technologies. However, publicly available information about these technologies is often limited and inconsistent, making it difficult to draw comparisons with conventional concrete. [3]

13. The **3C's** of Innovation in Low-Carbon Concrete, examining decarbonising solutions across the **clinker, cement and concrete** production stages: It is not expected, or recommended, that engineers should try to provide detailed specification clauses to optimise concrete for carbon. Rather, this optimisation should be delivered by the supplier or an independent project concrete technologist if appropriate, to incorporate the construction requirements. Thus following collaboration and discussion with the engineer and contractor as early as possible, it will not be possible to achieve carbon savings in all concretes but discussions with concrete suppliers to optimise carbon of conventional concrete can lead to immediate savings of between 5 - 15%. [3]

14. The following tables 1-3 show the embodied carbon for each concrete plate predalles & hollowcore prestressed concrete plank produced by GMF. The embodied carbon is measured per square meter on plan. The values below only account for the production stage of the precast elements (A1-A3). These stages are identified as:

A1: Supply of raw material
A2: Transport of raw material to manufacturing facility
A3: Manufacturing of the product (predalles or hollow prestressed concrete planks)

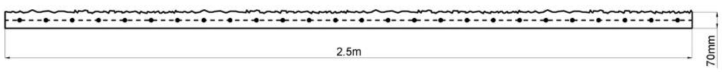
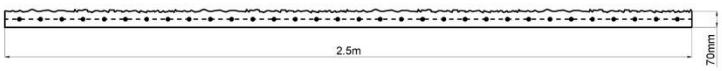
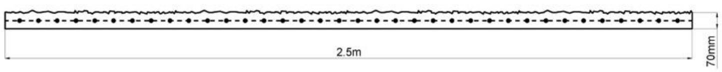
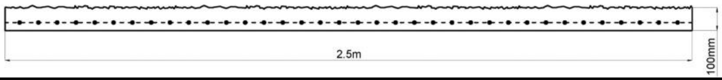
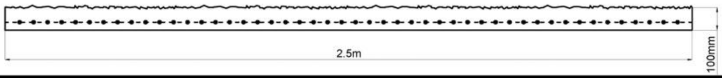
Section	Wires	Section Drawing	Embodied Carbon $kgCO_2e/m^2$
70mm	26		28
70mm	32		29
70mm	36		30
100mm	36		40
100mm	48		42

Table 1: GMF predalle planks embodied carbon

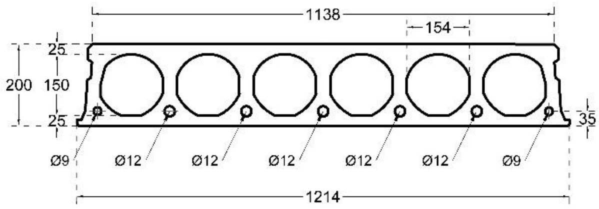
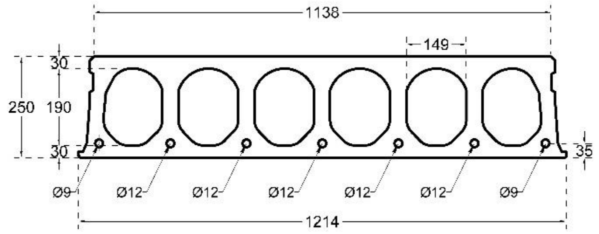
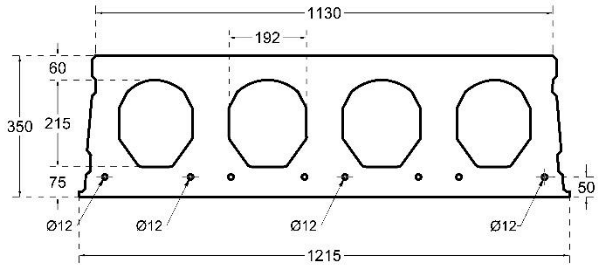
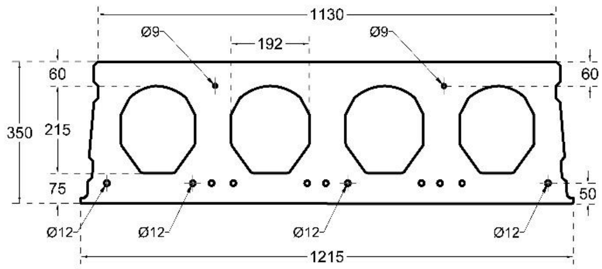
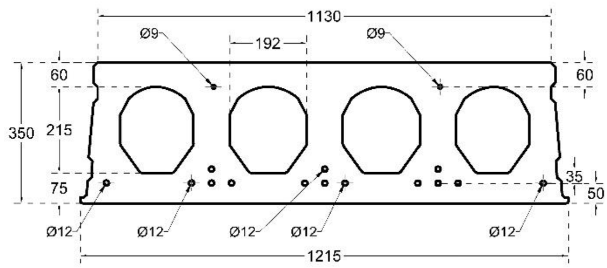
Section	Wires	Section Drawing	Embodied Carbon $kgCO_2e/m^2$
200	2 × 9Ø + 7 × 12Ø		57
250	2 × 9Ø + 7 × 12Ø		65
350 - 8w	8 × 12Ø		114
350 - 11w	2 × 9Ø + 11 × 12Ø		119
350 - 14w	2 × 9Ø + 14 × 12Ø		122

Table 2: GMF prestressed hollowcore planks embodied carbon

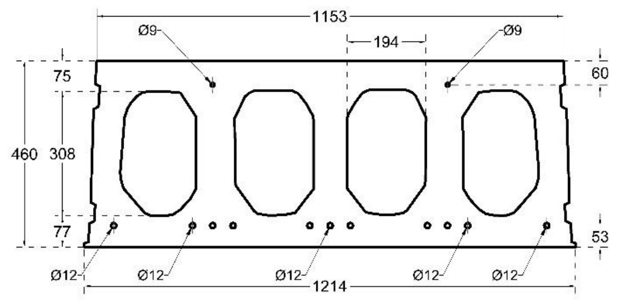
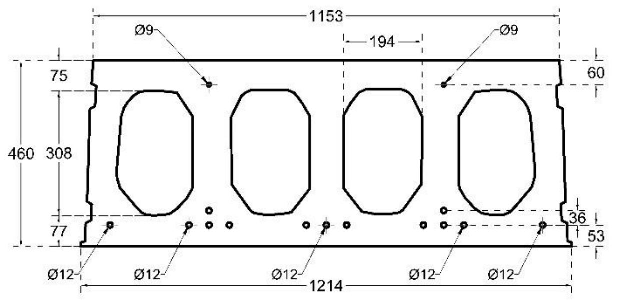
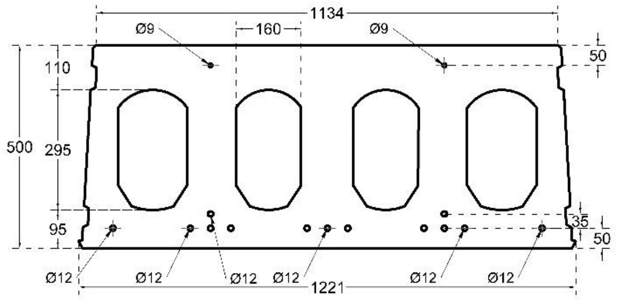
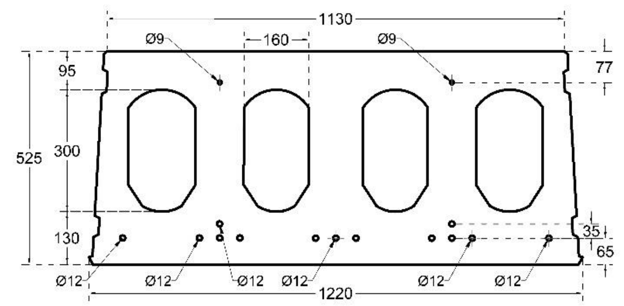
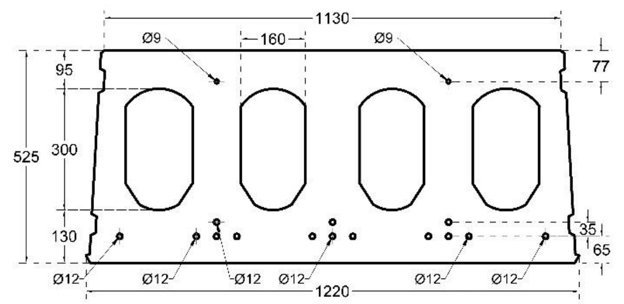
Section	Wires	Section Drawing	Embodied Carbon $kgCO_2e/m^2$
450 - 11w	2 × 9Ø + 11 × 12Ø		141
450 - 13w	2 × 9Ø + 13 × 12Ø		143
500	2 × 9Ø + 13 × 12Ø		173
525 - 13w	2 × 9Ø + 13 × 12Ø		185
525 - 14w	2 × 9Ø + 14 × 12Ø		186

Table 3: GMF prestressed hollowcore planks embodied carbon

15. The following table 4 is a comparison of the GMF products as compared to utilising solid reinforced concrete comparing the embodied carbon. The embodied carbon values shown in table below are calculated from the supply of raw material up till the construction on site (A1-A5).

A1: Supply of raw material
A2: Transport of raw material to manufacturing facility
A3: Manufacturing of the product (hollow prestressed concrete plank)
A4: Transport of the manufactured product to the construction site
A5: Construction and installation process including any wastage that might occur on site

		A1 - A5								
		Predalle			Prestressed hollow core slabs			Cast in-situ concrete		
Span m	Load kN/m²	Description	Embodied Carbon $kgCO_2e/m^2$ (on plan)	%	Description	Embodied Carbon $kgCO_2e/m^2$ (on plan)	%	Description	Embodied Carbon $kgCO_2e/m^2$ (on plan)	%
4.5	17.8	100/225/48	77	86%	200mm	79	87%	215mm & T12 @ 100mm	91	100%
6.5	11.5	100/275/48	92	78%	200mm	73	62%	285mm & T12 @ 75mm	118	100%
6.5	17.0				250mm	82	67%	300mm & T12 @ 75mm	122	100%
6.5	70.5				525mm - 14w	206	99%	400mm & T25 @ 100mm	207	100%
7.5	59.7				525mm - 14w	204	84%	425mm & T25 @ 75mm	241	100%

Table 4: Embodied carbon comparison between predalles, hollow prestressed concrete planks and cast in-situ concrete slabs

- Prestressed hollow core slabs are supported at each end with a reinforced C30 *sulletta* having a height of 1 course (*filata*) and a width of 9”, reinforced with 4 T16 steel bars. This is included in the embodied carbon.
- Embodied carbon for cast in-situ concrete slabs includes the formwork required.
- Waste factors included are:
    - Predalle: C25 concrete topping
    - Prestressed hollow core slabs: C30 concrete, T16 reinforcement and C30 grouting between the planks
    - Cast in-situ: C25 concrete, high yield reinforcement and formwork

An advantage of using precast elements over cast-in-situ concrete is that generally, precast elements have an embodied carbon varying between 13% - 35% of cast-in-situ concrete. On spans above 6m, precast elements can be circa 35% cheaper when compared to cast-in-situ concrete.

References

[1] Brooker, O. (2009) *Concrete Buildings Scheme Design Manual: A handbook for the istructe chartered membership examination, based on Eurocode 2*. Camberley: The Concrete Centre, part of the Mineral Products Association.

[2] Gibbons, O.P. *et al.* (2022) *How to calculate Embodied Carbon*. 2nd edn. London: The Institution of Structural Engineers.

[3] Concrete Technology Tracker (2024) The Institution of Structural Engineers. Available at: https://www.istructe.org/resources/guidance/concrete-technology-tracker/ (Accessed: 17 April 2024).