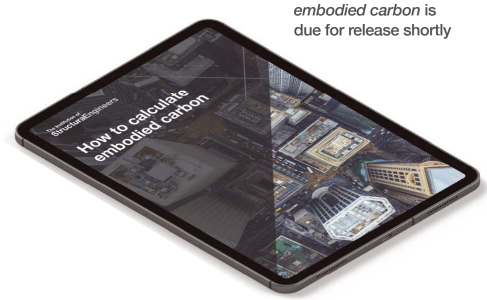
CO_2 2.Low carbon

A brief guide to calculating embodied carbon

John Orr, Orlando Gibbons and Will Arnold preview a forthcoming new guide from the Institution on calculating embodied carbon.



IStructE guide on *How to calculate embodied carbon* is due for release shortly

There is a pressing need to dramatically cut carbon emissions across the world. As discussed in the June issue of *The Structural Engineer*[1,2], structural engineers have a significant role in achieving this, mostly through minimising embodied carbon of structures and other building elements.

Consequently, there is a need to calculate the embodied carbon of our work at every design stage, giving engineers the ability to target carbon reductions through material selection, specification, efficiency and reuse. Firms that have signed the Structural Engineers' Declaration have already agreed to include 'whole-life carbon modelling as part of the basic scope of work' on their projects.

The Institution will shortly release a guidance document entitled *How to calculate embodied carbon* (referred to as *CEC* in this article). This forms part of its response to the climate emergency by enabling structural engineers to calculate embodied carbon in a consistent and robust way to make meaningful carbon comparisons between designs. (Note that carbon is shorthand here for carbon dioxide equivalent (CO_2e), encompassing all greenhouse gases.)

This article provides a very brief overview of *CEC*, and acts as a memo for some of the most important information within it, focusing on lifecycle modules A1–A5 (embodied carbon up to practical completion).

The full *CEC* guide should be used when undertaking embodied carbon calculations, as it gives a fuller understanding of the background, processes and all lifecycle stages. *CEC* also contains information on the main drivers for the carbon impact of each material, and so should be read when making material choices for a project.

CEC will be made available for free on the Institution's Climate Emergency webpage (www.istructe.org/climate-emergency). It also provides key references, all of which can be downloaded from https://carbon.tips/primer.

Calculating embodied carbon

The most important time to calculate embodied carbon is in the early design stages. It is crucial to have time and scope to make changes in light of your embodied carbon assessment.

The fundamental principle of an embodied carbon calculation is typically to multiply the quantity of each material or product by a carbon factor (normally measured in $kgCO_2e$ per kg of material) for each lifecycle module being considered:

Embodied carbon = quantity × carbon factor

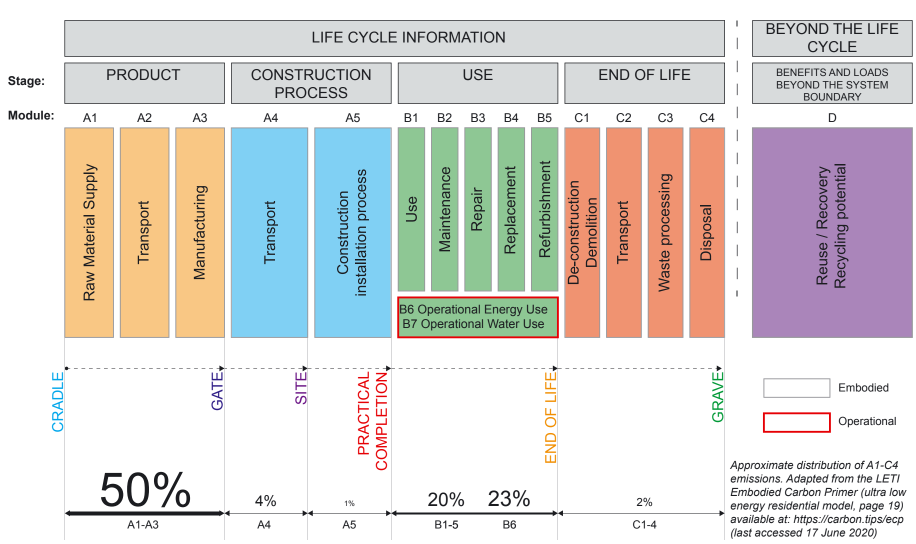
The **quantity** of each material or product is an estimate that improves in accuracy throughout the design process.

The **carbon factors** are split up by lifecycle module, and are estimates that improve in accuracy as more is known about the procurement process for the project.

Note that there are a few aspects of an embodied carbon calculation that follow a different procedure, such as quantifying site activity emissions (A5a) – these are outlined as required in *CEC* and this article.

As this is a straightforward calculation, the embodied carbon for an entire structure can be estimated quickly even at concept stage, allowing design options to be compared quantitatively alongside the other components of sustainable design.

FIGURE 1: Lifecycle stages and modules



Quantities

Material quantities can be calculated in a number of different ways, depending on the stage of design and the tools available to the engineer. At early design stages, it may be appropriate to estimate member sizes based on experience, quick calculations, or scheme design guides (e.g. the *Structural Engineer's Pocket Book*[3]). Later in the design process, material quantities may be exported from structural analysis or building information models.

Do not be deterred from calculating embodied carbon at early design stages because of uncertainty in material quantities, but recognise the limits of your calculations.

Lifecycle stages and modules

The user needs to be familiar with lifecycle stages (in accordance with BS EN 15978 (2011)[4] and BS EN 15804 (2019)[5]), which are used to define the amount of carbon released at the different stages of a material or product's life **(Figure 1).** Individual lifecycle modules make up each lifecycle stage (e.g.

TABLE 1: Lifecycle stages outlined in article

Lifecycle stage	Description
Production stage (A1–A3)	The extraction, processing, transportation and manufacture of materials and products up to the point where they leave the factory gate to be taken to site.
Transport (A4)	The transportation of materials and products from the factory gate to site.
Construction installation – material waste (A5w)	Extraction, processing, manufacture, transportation and end-of-life processing associated with materials wasted on site.
Construction installation – site activities (A5a)	Emissions due to energy usage on site in the construction process.

A1, A2 and A3 make up the product stage, A1–A3).

Calculating the A1–A5 emissions (cradle to practical completion) is the minimum scope for an embodied carbon calculation of sub- and superstructure, and thus is the scope of this article. Within this article, the stages are broken down as outlined in **Table 1**.

This article only contains information on calculating carbon for the most typical structural materials during the production (A1–A3) and construction (A4–A5) stages, as these are likely to make up the vast majority of the embodied carbon associated with our designs – and are therefore the emissions that must be addressed most urgently to respond to the climate emergency.

For other stages (B, C and D) and other materials, refer to *CEC*, which contains inputs for all lifecycle modules, along with important background information for Modules A1–A5 that should be read before undertaking carbon calculations.

Carbon factors

This article gives typical carbon factors for some structural materials at stages A1–A3. However, the range of each factor can be large, and so more accurate factors should be sought through the supply chain as you gain more certainty on product specification and source. Many manufacturers provide environmental product declarations (EPDs), which contain carbon factors for their products. *CEC* also includes a list of websites that contain EPDs.

Make sure you always ask the manufacturer for the EPDs of their products – creating demand for good environmental practices is a positive action.

A1–A3 Production stage carbon factors

Embodied carbon associated with modules A1–A3 is the largest contributor to the embodied carbon of a structure. The A1–A3 embodied carbon factor (ECF) depends on the material specification – varying with constituent materials, and how and where it is manufactured. For example, the A1–A3 factor for concrete varies by cement content and Portland cement (PC) replacement percentage, and the factor for steel sections varies by recycled content and production method.

The range can be large and an extreme example is rebar: the A1–A3 ECF for UK-produced rebar given below is 0.684kgCO_2e/kg, whereas a UAE-produced bar with no recycled content could be closer to 2.1kgCO_2e/kg.

The A1–A3 ECF is multiplied by the material quantity to give an estimate of the embodied carbon due to production of that material.

> **"THE MOST IMPORTANT TIME TO CALCULATE EMBODIED CARBON IS IN THE EARLY DESIGN STAGES**

Example UK ECFs are given in **Table 2** (these should be treated with care as per the reinforcement example above). A more accurate estimate should be taken as soon as possible by speaking to clients and the supply chain.

A more complete list of material ECFs is contained in *CEC* Table 3, including generic concrete, screeds, steel hollow sections, steel plate, galvanised steel decking, dense concrete blocks, brick wall build-ups (/m^2), stone, aluminium, and glass.

Carbon sequestration in timber

The timber values in **Table 2** exclude carbon sequestration – the removal of carbon dioxide from the atmosphere via photosynthesis, and the temporary storage of this carbon within the timber.

Inclusion of carbon sequestration in the reported embodied carbon value depends on the scope of calculation:

- Stages A1–A5: Report sequestration separately alongside the A1–A5 value reported.
- Stages A–C: Include sequestration within the total A–C value reported.

In the absence of product-specific data, carbon sequestered can be taken as **-1.64kgCO_2e/kg** (this factor is based on standard timber properties – refer to *CEC* to calculate this figure more accurately).

The sequestration factor is multiplied by the timber material quantity in the same way that the A1–A3 ECF is.

A4 Transport carbon factors

A4 emissions mainly concern the transport of materials and products from factory to site, and typically constitute in the order of <10% of the total embodied carbon of a structure. The A4 ECF depends on the mode of transport and distance travelled.

The A4 ECF is multiplied by the material quantity in the same way A1–A3 ECFs are.

Transport emission factors are given in **Table 3** for different modes of transport, and default ECFs for the UK are given in **Table 4**. A more accurate estimate can be made once the material or product source has been identified.

A5 Construction installation process carbon factors

A5 emissions are likely to account for a small but not insignificant percentage of structural embodied carbon over the lifecycle of a project. The emissions vary depending on construction methods, material choices, and site set-up, and are broken down into two parts. Emissions associated with materials wasted on site are identified as A5w emissions, while emissions due to site activities (construction machinery, site offices, etc.) are identified as A5a emissions.

A5w Material wastage

The A5w emissions factor accounts for the carbon emissions released during production, transportation, and disposal of wasted material. The factor itself represents the percentage estimate of how much of the material brought to site is wasted (using a waste factor, WF) so that *the A5w factor can be multiplied by the same material quantity used for the A1–A3 calculations.*

The A5w factor is derived by multiplying the WF by the sum of the relevant ECFs:

A5w = WF × (A13 + A4 + C2 + C34)

where:

- WF is the waste factor, based on expected % waste rate **(Table 5)**
- A13 is A1–A3 emissions for production of the wasted material, including sequestration factors for timber **(Table 2)**
- A4 for transporting the wasted material to site **(Table 4)**
- C2 for transporting the wasted material away from site (in the absence of better data, assume 50km by road to the nearest reuse/recycling location = **0.005kgCO_2e/kg**)
- C34 is C3–C4 emissions for processing and disposal of the waste material (in the absence of better data, assume **1.77kgCO_2e/kg** for timber products* and **0.013kgCO_2e/kg** for all other materials – see RICS, 2017[6], Section 3.5.3.4).

* This value is derived from default timber product end-of-life scenario assumptions (75% incineration, 25% landfill) in Section 3.5.4.4 of the RICS guide, assuming 1.64kgCO_2e/kg for incineration (equal to the amount of carbon sequestered) and 2.15kgCO_2e/kg for landfill (no gas recovery).

TABLE 2: A1–A3 ECFs for typical structural materials

Material	Type	Specification/details	A1–A3 ECF ($kgCO_2e/kg$)	Data source
Concrete	*In situ*: piling, substructure, superstructure	Unreinforced, C30/37, UK average ready-mixed concrete EPD[1] (35% cement replacement)	0.103	MPA, 2018[2]
		Unreinforced, C32/40, 25% GGBS cement replacement[3]	0.120	ICE V3[4]
		Unreinforced, C32/40, 50% GGBS cement replacement	0.089	ICE V3
		Unreinforced, C32/40, 75% GGBS cement replacement	0.063	ICE V3
		Unreinforced, C40/50, 25% GGBS cement replacement	0.138	ICE V3
		Unreinforced, C40/50, 50% GGBS cement replacement	0.102	ICE V3
		Unreinforced, C40/50, 75% GGBS cement replacement	0.072	ICE V3
	Precast	Unreinforced, C40/50 with average UK cement mix	0.178	ICE V3
		Reinforced, 150mm prestressed hollow core slab: British Precast Concrete Federation average EPD	50.2$kgCO_2e/m^2$	BPCF, 2017[5]
Steel	Reinforcement bars	UK: BRC EPD	0.684	BRC, 2019[6]
		Worldwide: Worldsteel LCI study data, 2018, world average	1.99	ICE V3
	PT strands	Assume the same as reinforcement bars		
	Structural sections	UK open sections: British Steel EPD	2.45	BS, 2020[7]
		Europe (excl. UK): Bauforumstahl[8] average EPD	1.13	Bauforumstahl, 2018
		Worldwide: Worldsteel LCI study data, 2018, world average	1.55	ICE V3
	Galvanised profiled sheet (for decking)	UK: TATA Comflor EPD	2.74	TATA, 2018
Blockwork	Precast concrete blocks	Lightweight blocks	0.28	ICE V3
Brick	Single engineering clay brick	Generic, UK	0.213	ICE V3
Timber, excl. carbon sequestration[9], [10]	Manufactured structural timber	CLT, 100% FSC/PEFC	0.437	ICE V3
		Glulam, 100% FSC/PEFC	0.512	ICE V3
	Studwork/framing/flooring	Softwood, 100% FSC/PEFC	0.263	ICE V3
	Formwork	Plywood, 100% FSC/PEFC	0.681	ICE V3
Plasterboard	Partitioning/ceilings	Minimum 60% recycled content	0.39	ICE V2
Intumescent paint	For steelwork	Specific EPD: Amotherm steel WB, Amonn	2.31	AMONN, 2019[11]

Data taken from *CEC* Table 2, and correct at time of publication. Check data sources to verify that data presented here are valid at time of your calculation.

[1] Covers 93% of production from member companies of the British Ready-Mixed Concrete Association.
[2] MPA, 2018. *UK manufactured generic ready-mixed concrete*. Produced by members of the British Ready-Mixed Concrete Association (BRMCA), part of the Mineral Products Association (MPA). published by Institut Bauen und Umwelt e.V. (IBU). Available online at https://carbon.tips/mpa1 (last accessed 07/04/2020)
[3] Note that the ICE V3 database has a wide range of concrete mixes, including PFA (pulverised fuel ash) cements. Additionally, see CEC §2.2.2.1.3 for more information.
[4] Jones and Hammond, 2019.
[5] British Precast Concrete Federation, 2017. *Environmental Product Declaration (EPD) report of 1m2 of 150mm precast concrete prestressed hollow core flooring slab.* Published by Institut Bauen und Umwelt e.V. (IBU). Available online at: https://carbon.tips/hollow
[6] BRC, 2019. *Environmental product declaration (EPD) report of fabricated steel products produced in the UK by Eco-Reinforcement members.* Gwent, BRC Limited. Available at https://carbon.tips/brcepd (last accessed 23/02/20)
[7] BS, 2020. *Environmental product declaration (EPD) report of Steel Rails and Sections (including semi-finished long products)*. Gwent, BRC Limited. Available online at https://carbon.tips/rails (last accessed 30/04/20)
[8] bauforumstahl e.V., 2018. *Environmental Product Declaration (EPD) report of Structural Steel: Sections and Plates*. Published by Institut Bauen und Umwelt e.V. (IBU). Available online at https://carbon.tips/ed6cd (last accessed 13/05/2020)
[9] The ICE V3 database also includes timber A1–A3 embodied carbon factors including sequestration.
[10] See CEC §2.2.2.1.5.
[11] AMONN, 2019. *Environmental Product Declaration, Intumescent Coating, Amotherm Brick WB - Amotherm Concrete WB - Amotherm Gyps WB Amotherm Steel WB - Amotherm Steel WB HI - Amotherm Wood WB.* Ponte nelle Alpi, J.F. Amonn Srl. Available online at https://carbon.tips/amonn (last accessed 12/06/20)

A5a Site activities

Site activity emissions can be estimated from on-site electricity consumption and fuel use, and should be monitored during construction to contribute to an accurate as-built embodied carbon calculation. Any site activity emissions data collected can also be used to inform estimates of A5a emissions in future projects.

For a whole building prior to construction starting, *A5a emissions can be estimated based on industry studies or previous project data.*

In the UK, the RICS guide provides a rate of A5a = 1400kgCO_2e per £100 000 construction cost to be used in the absence of site-specific data when calculating embodied carbon for the whole building (see Section 3.5.2.2). However, for superstructure and substructure only, a factor of this figure can be assumed based on predictions of the proportion of site activity emissions due to its construction (based on construction effort, required machinery and time).

As a preliminary estimate, this may be in the order of 50% for the construction of the super- and substructure only. This means that a rate of **A5a = 700kgCO_2e per £100 000** could be used for preliminary calculations in the absence of better data. More information on this topic is expected be included in future editions of *CEC* as site activities emissions are better tracked and understood.

John Orr
MEng, PhD, CEng, MIStructE, FHEA

Dr John Orr is University Lecturer in Concrete Structures and EPSRC Early Career Fellow at the University of Cambridge. His teaching and research are closely linked to sustainable construction, and improving construction sector productivity.

Orlando Gibbons
MEng

Orlando Gibbons is a Structural Engineer at Arup and member of the Institution of Structural Engineers Sustainability Panel.

Will Arnold
MEng, CEng, MIStructE

Will Arnold is a Senior Structural Engineer at Arup and member of the Institution of Structural Engineers Climate Emergency Task Group.

TABLE 3: Transport emissions factors for different modes of transport

Mode	TEF_{mode} (gCO_2e/kg/km)	Source
Road transport emissions	0.10650	(BEIS, 2020)[1]
Sea transport emissions	0.01614	(BEIS, 2020)[2]
Freight flight emissions	0.59943	(BEIS, 2020)[3]
Rail transport emissions	0.02556	(BEIS, 2020)[4]

Data taken from *CEC* Table 4, and correct at time of publication. Check data sources to verify that data presented here are valid at time of your calculation.

[1] For HGV (all diesel), all HGVs, average laden.
[2] For cargo ship, container ship, average.
[3] International, to/from non-UK, without RF.
[4] Freight train.
BEIS, 2020. *Greenhouse gas reporting: conversion factors 2020.* London, BEIS. Available online at https://carbon.tips/cf2020 (last accessed 23/02/20)

TABLE 4: A4 ECFs for typical transport scenarios (UK)

A4 Transport scenario	km travelled by road	A4 ECF (kgCO_2e/kg)
Locally manufactured	50	0.005
Nationally manufactured	300	0.032
European manufactured	1500	0.160

Data taken from *CEC* Table 5, and correct at time of publication. Check data sources to verify that data presented here are valid at time of your calculation.

TABLE 5: Waste factors for typical structural materials)

Material/product	Waste rate (WR)	Waste factor (WF)[1]	WRAP Net Waste Tool reference
Concrete *in situ*	5%	0.053	Table 2, concrete *in situ*
Concrete precast (beams and frames)	1%	0.010	Table 2, concrete precast (large precast elements)
Steel reinforcement	5%	0.053	Appendix 1, frame: *in situ* concrete frame generic; Table 2, ferrous metals
Steel frame	1%	0.010	Appendix 1, frame: steel frame generic
Blockwork	20%	0.250	Table 2, bricks & blocks
Brick	20%	0.250	Table 2, bricks & blocks
Timber frames (beams, columns, braces)	1%	0.010	Appendix 1, frame: timber frame
Timber floors (joists, boards)	10%	0.111	Appendix 1, floor: wooden floor
Plasterboard	22.5%	0.290	Table 2, plasterboard; Table 3: boarding
Sprayed cementitious fire protection	10%	0.111	Table 3: cementitious sprays

Data calculated using data from *CEC* Table 5, and correct at time of publication. Check data sources to verify that data presented here are valid at time of your calculation.

[1] WF = (1 / (1 – WR)) – 1
where WR is the % waste rate shown in *CEC* Table 6.

REFERENCES

1) Cook M. and Arnold W. (2020) 'A framework for change', *The Structural Engineer*, 98 (6), pp. 8–9

2) Arnold W. (2020) 'The structural engineer's responsibility in this climate emergency', *The Structural Engineer,* 98 (6), pp. 10–11

3) Cobb F. (2014) *Structural Engineer's Pocket Book: Eurocodes* (3rd ed.), Boca Raton, FL: CRC Press

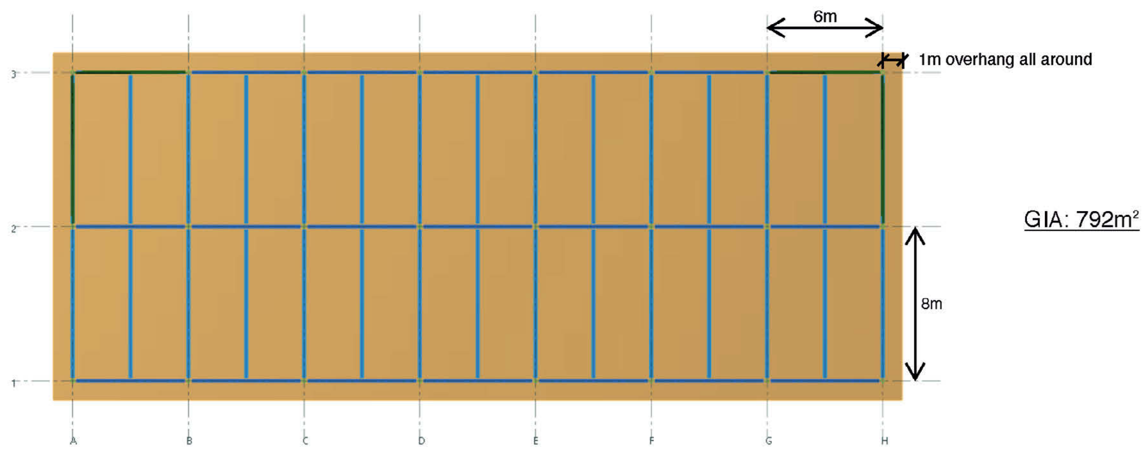
4) British Standard Institution (2011) *BS EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*, London: BSI

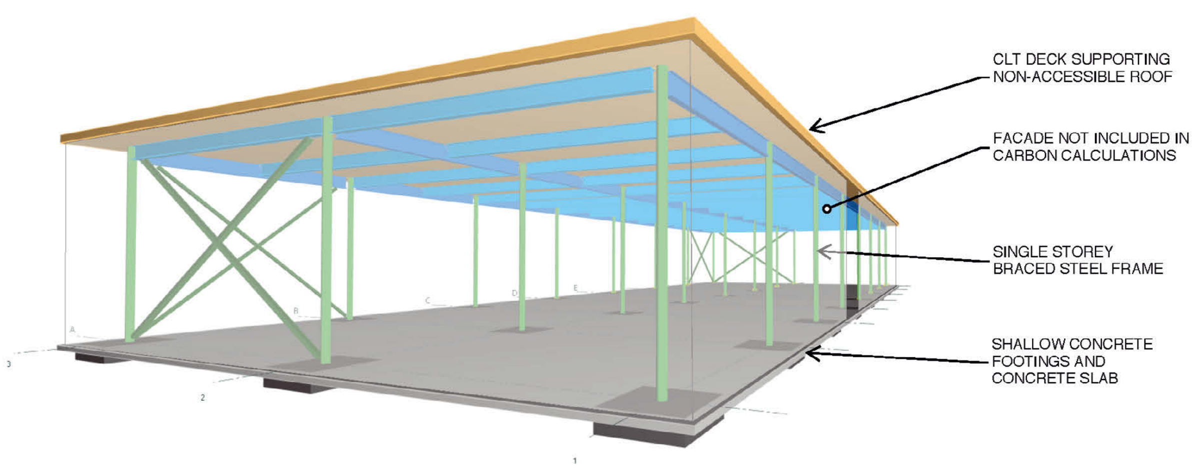
5) British Standards Institution (2012) *BS EN 15804:2012+A2:2019 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products,* London: BSI

6) Royal Institution of Chartered Surveyors (2017) *Whole life carbon assessment for the built environment* [Online] Available at: www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf (Accessed: June 2020)

Worked example: Quick embodied carbon calculation

A single-storey structure at concept design has a gross internal area (GIA) of 792m² and a total construction value of £800 000. How much embodied carbon does the design contain?





	A	B	C	E	F	G	I	J	K	M	N
1			Quantity (t)	ECF ($kgCO_2e/kg$)			Embodied Carbon (tCO_2e)				Total EC (tCO_2e)
2				A1-A3	A4	A5w	A1-A3	A4	A5w		A1-A5w
3	Reinforced concrete	Concrete	279.8	0.12	0.005	0.008	40.8	1.7	2.5	Reinforced concrete:	45.0
4		Rebar	10.5	0.684	0.032	0.039					
5	Steel frame		23.8	2.45	0.032	0.025	58.3	0.8	0.6	Steel frame:	59.7
6	CLT roof slab		59.4	0.437	0.16	0.007	26.0	9.5	0.4	CLT roof slab:	35.9
7										Total A1-A5w:	140.6
8										A5a:	5.6
9										**Total A1-A5:**	**146.2**
10										Sequestration:	-97.4

1. Inputs

1.1. Quantities

Reinforced concrete foundations and ground-bearing slab

Concrete
Ground-bearing slab: assume 120mm slab, across a GIA of 792m^2 = 95.0m^3

Footings: 24 No. pads, assume 1.5 × 1.5m, 400mm thick = 21.6m^3

Mass of concrete = 2400kg/m^3 × (95.0 + 21.6) = 279.8t

Rebar
Assume 90kg per m^3 of concrete (incl. laps) throughout

Mass of rebar = 90kg/m^3 × (95.0 + 21.6) = 10.5t

Steel frame
For whole frame, assume 30kg/m^2, including connections, at a GIA of 792m^2

Mass of steelwork = 30kg/m^2 × 792 = 23.8t

CLT roof slab
CLT panels: assuming 150mm thick, across a GIA of 792m^2 = 118.8m^3
Mass of CLT = 500kg/m^2 × 118.8 = 59.4t

1.2. Carbon factors

Reinforced concrete
Concrete
A1–A3 (production) = 0.12kgCO_2e/kg
(from Table 2, RC32/40 with 25% GGBS as cement replacement)

A4 (transport) = 0.005kgCO_2e/kg
(from Table 4, assume locally manufactured)

A5w (waste)
= WF × (A1–A3 + A4 + C2 + C3–C4)
= 0.053 × (0.12 + 0.005 + 0.005 + 0.013)
= 0.008kgCO_2e/kg
(WF from Table 5, concrete *in situ*, and default C2 and C3–C4 values)

Rebar
A1–A3 (production) = 0.684kgCO_2e/kg
(from Table 2, typical UK Specific Rebar EPD)

A4 (transport) = 0.032kgCO_2e/kg
(from Table 4, assume manufactured in UK)

A5w (waste) = 0.053 × (0.684 + 0.032 + 0.005 + 0.013) = 0.039kgCO_2e/kg
(WF from Table 5, steel reinforcement, and default C2 and C3–C4 values)

Steel
A1–A3 (production) = 2.45kgCO_2e/kg
(from Table 2, British Steel EPD)

A4 (transport) = 0.032kgCO_2e/kg
(from Table 4, assume manufactured in UK)

A5w (waste) = 0.010 × (2.45 + 0.032 + 0.005 + 0.013) = 0.025kgCO_2e/kg
(WF from Table 5, steel frame, and default C2 and C3–C4 values)

CLT
A1–A3 (production) = 0.437kgCO_2e/kg
(from Table 2, 100% FSC certified CLT)

A4 (transport) = 0.160kgCO_2e/kg
(from Table 4, assume produced in Europe)

A5w (waste) = 0.01 × ((0.437-1.64) + 0.160 + 0.005 + 1.77) = 0.007kgCO_2e/kg
(WF from Table 5, timber frames, assuming CLT is prefabricated to fit, and default C2 and C3–C4 values)

Other
Sequestration due to use of timber = -1.640kgCO_2e/kg (default value)

A5a (site activities) = 700kgCO_2e per £100 000 (default value)

2. Calculations

Reinforced concrete: foundations and ground-bearing slab

Concrete
A1–A3 (production) = 279.8t × 0.12 = 33.6tCO_2e

A4 (transport) = 279.8t × 0.005 = 1.4tCO_2e

A5w (waste) = 279.8t × 0.008 = 2.2tCO_2e

Rebar
A1–A3 (production) = 10.5t × 0.684 = 7.2tCO_2e

A4 (transport) = 10.5t × 0.032 = 0.3tCO_2e

A5w (waste) = 10.5t × 0.039 = 0.4tCO_2e

Steel frame
A1–A3 (production) = 23.8t × 2.45 = 58.3tCO_2e

A4 (transport) = 23.8t × 0.032 = 0.8tCO_2e

A5w (waste) = 23.8t × 0.025 = 0.6tCO_2e

CLT roof slab
A1–A3 (production) = 59.4t × 0.437 = 26.0tCO_2e

A4 (transport) = 59.4t × 0.160 = 9.5tCO_2e

A5w (waste) = 59.4t × 0.007 = 0.4tCO_2e

Other
A5a (site activities) = 700 × (£800 000 / £100 000) = 5.6tCO_2e

Sequestration due to use of timber = 59.4t × -1.640 = -97.4tCO_2e

3. Results

Embodied carbon per material
Reinforced concrete (A1–A5w) = 45.1tCO_2e

Steel frame (A1–A5w) = 59.7tCO_2e

CLT roof slab (A1–A5w) = 35.9tCO_2e

Other
Site activities (A5a) = 5.6tCO_2e

Sequestered carbon (stored temporarily until end of life) = -97.4tCO_2e

Estimate of overall carbon footprint for pavilion, cradle–completion (A1–A5), based on GIA of 792m^2:

Embodied carbon (A1–A5) = 45.1 + 59.7 + 35.9 + 5.6 = 146.3tCO_2e = 185kgCO_2e/m^2

Sequestered carbon (stored temporarily until end of life) = -123kgCO_2e/m^2

4. Tabulated calculation

You may choose to undertake a calculation like this in spreadsheet format, to allow easy analysis of where the carbon is concentrated within the design. For the example given here, this might look as shown opposite.

NB This table can be downloaded from https://doi.org/10.17863/CAM.53699