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CobBauge
European Regional Development Fund

WPT4.3 Report:

Data concerning the lifecycle of the CobBauge material providing the basis of an Environmental Product Declaration (EPD)

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ESITC CAEN Ecole Supérieure d'Ingénieurs des Travaux de la Construction
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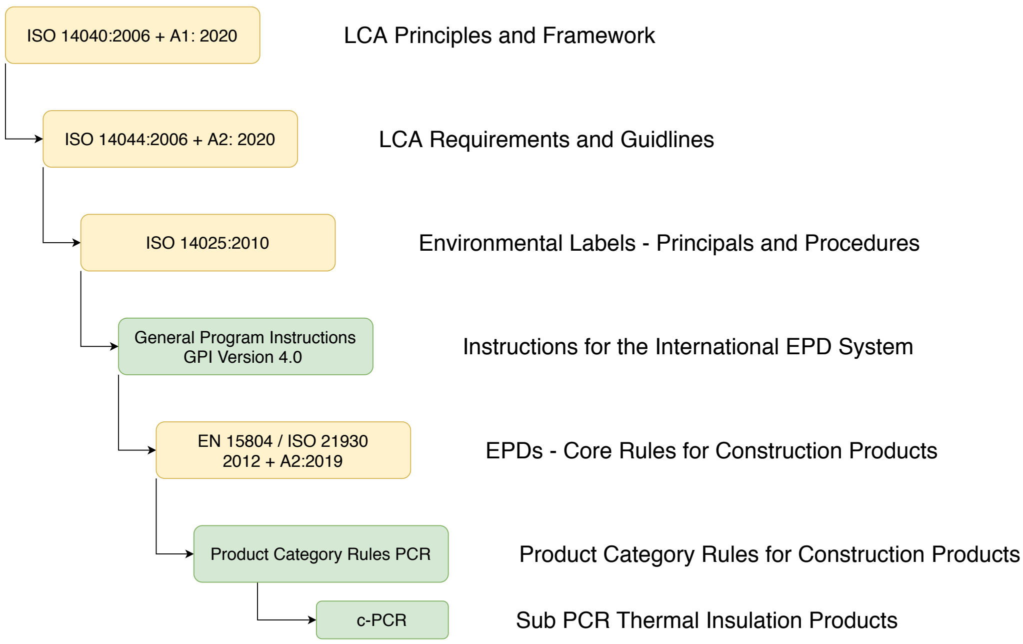
Introduction

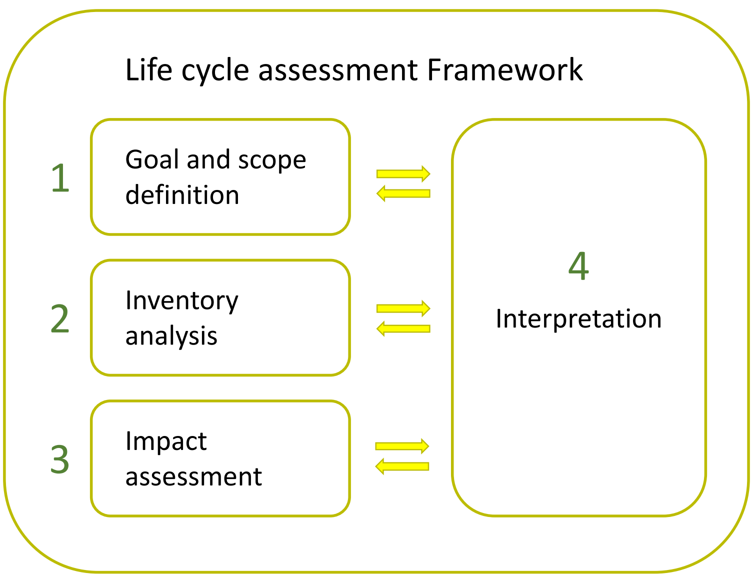
This report summarises and explains the data recorded during the Life Cycle Assessment (LCA) of the walls of the CobBauge building in Plymouth.
The raw data has been collated in a form that matches the LCA software used, 'SimaPro', and it therefore can be initially difficult to understand. This report will attempt to make sense of the data.

Methodology

The data has been collected within a hierarchy of the appropriate standards:

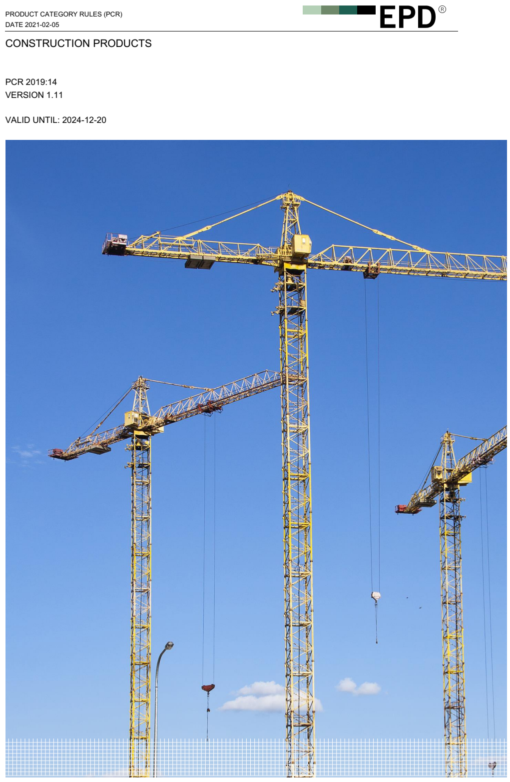


A simple model shows the flow of information in collating the LCA.



The goal and scope of the data for an EPD is largely dictated by the appropriate 'Product Category Rules' (PCR)
PCRs are specific guidelines for the calculation of the environmental impact of products within the same product category.

PCRs contain strict requirements that leave less room for interpretation than a general LCA. A PCR can specify, for example, the functional unit that should be used, or the databases that should be used, or the impact categories that should be included in the study.
There are also complimentary and sub-PCRs to further refine the criteria.



Once a PCR is found, the LCA is performed according to the specification in the EPD. The rules are usually quite straightforward and allow for rather simple procedures. Also, the impact assessment method is relatively simple. In general, the impact categories are limited to:
• Non-renewable resources (with and without energy content)
• Renewable resources (with and without energy content)
• Global warming (CO2 equivalents)
• Acidification (kmol H+)
• Ozone layer depletion (kg CFC11 equivalents)
• Photochemical oxidant formation (kg ethane-equivalents)
• Eutrophication (kg O2)

From: BS EN 15804:2012+A2:2019
'The declared unit in the EPD shall be declared applying one of the unit types listed below. A different unit may be declared for reasons that shall be explained. In such case, information shall be provided on how to convert this unit to one or more of the required unit types.

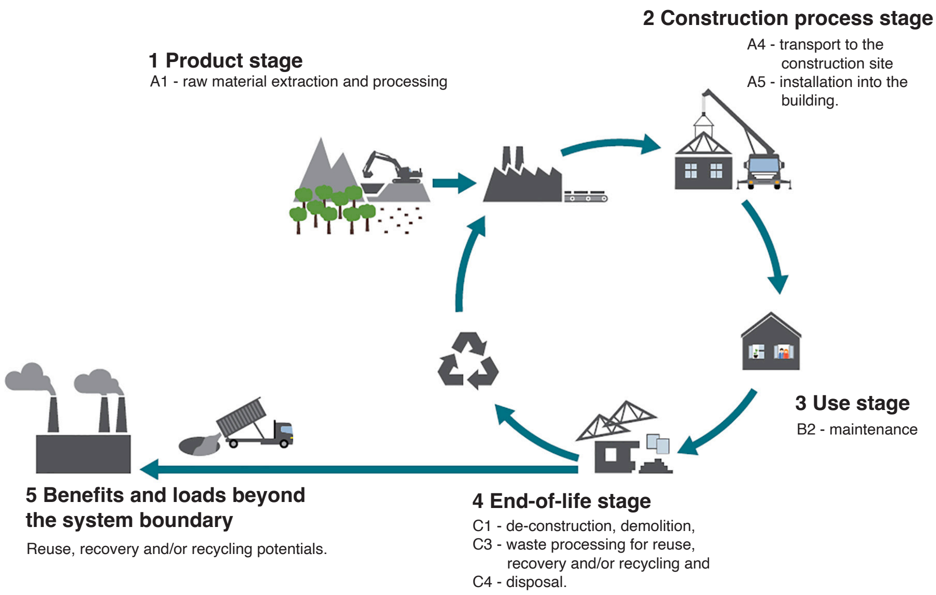
— An item (piece), an assemblage of items, e.g. 1 brick, 1 window (dimensions shall be specified);
— Mass (kg), e.g. 1 kg of cement;
— Length (m), e.g. 1 m of pipe, 1 m of a beam;
— Area (m2), e.g. 1 m2 of wall elements, 1 m2 of roof elements;
— Volume (m3), e.g. 1 m3 of timber, 1 m3 of ready-mixed concrete.

For the CobBauge wall system the obvious choice is to use area (m2)

System Boundaries

The PCR also defines the system boundaries used in the EPD:
According to EN 15804 Section 5.2 the following type of EPDs are possible for construction products:
a) Cradle to gate with modules C1–C4 and module D (A1–A3 + C + D);
b) Cradle to gate with options, modules C1–C4, module D and with optional modules (A1–A3 + C + D and additional modules). The additional modules may be one or more selected from A4–A5 and/or B1–B7;
c) Cradle to grave and module D (A + B + C + D);
d) Cradle to gate (A1–A3);
e) Cradle to gate with options (A1–A3 and additional modules). The additional modules may be A4 and A5.
(from PCR: 2.2.2 TYPE OF EPD AND INFORMATION MODULES INCLUDED)

This diagram illustrates the system boundaries of the CobBauge LCA



The life cycle of a product according to the system boundary (see diagram, above). In this case the EPD covers the product stage, installation into the building, use and maintenance, replacements, demolition, waste processing for re-use, recovery, recycling and disposal, and disposal. Includes all information in modules A1 to C4. In this EPD the information module D may be included.

At this stage in the development of the CobBauge walling system, the focus is on the Product stage and the Construction process phase, as we don't have enough data yet on the Use and End-of-life stages.

The raw data:

1 Product stage

A1 - raw material extraction and processing

Structural mix

481.25kg clay subsoil (12%) extracted with Yanmar B95W wheeled excavator	
7.5l diesel per hour for 01:15 minutes	= 0.13litre
Fibres: Wheat straw	= 0.00925t
Water	= 39litre
Mixing done at extraction site:	
7.5l per hour for 05:53 minutes	= 0.69l

Thermal mix

88.05kg clay rich subsoil (36%) extracted by JCB Backhoe digger	
5.4l diesel per hour for 0:15 minutes	= 0.0225litre
Hemp shiv	= 0.01904t
Water	= 50.2litre
Mixing at construction site:	
1.6kwh for 1:02:30	= 1.62kwh

2 Construction process stage

A4 - transport to the construction site

Structural mix to site, three axle rigid lorry 15 ton	
0.489t over 83.85k	= 40.83ktm
Thermal mix to site, three axle rigid lorry 15 ton	
0.088t over 87.2k	= 7.67ktm
Hemp shiv to site, delivery van 2.4t	
0.01904t over 534.3k	= 10.17ktm
Formwork: timber	= 0.082ktm
Formwork: Steel mesh + M12 bar, fixings	= 0.675ktm
Timber: Tamping tool + placement tool	= 0.0046ktm

A5 - installation into the building.

Formwork (Reused 25 times)

Timber, local larch	= -1.027kgCO2e
Steel mesh	= 8.172kgCO2e
M12 threaded bar plus washers and nuts	= 5.97kgCO2e
Electric tools on site:	
Battery drills	= 0.18kwh
Chop saw	= 0.95kwh

The data above is the headline data for the calculation of the LCA and EPD, formatted for SimaPro.
The following sections look at how the data was recorded, and what the significance of each process was in terms of embodied carbon.

The structural cob mix

The first stage is A1 - raw material extraction and processing.
Pictured above is the Yanmar wheeled excavator digging out the clay sub-soil ready for mixing.

After the soil was extracted, the same excavator was used to mix the soil. First with water to create a slurry, then with the straw added at a ratio of 2.5% to dry weight of the soil.
The process was recorded in detail, as shown in this annotated sheet:

Data and quantities from Cob mixing 19th of August 2021.

Venue; Cutwell Combe Farm, Avonwick. South Brent, TQ10 9HA, distance to University of Plymouth site 18 miles via A38 route.

Measurements of mass and volumes of materials.

One bale of barley straw equals 11 kg

mix with water first to activate clay – Ivo says don't add soil at the straw

One bucket for distributing water 10 L.

One excavator bucket empty 225 kg.

One bucket full of red subsoil minus the bucket 384 kg.

3 big buckets

First mix was 3 1/2 bucket falls of soil to 11 buckets of water mixed with 2 bales of straw.

1344kg soil

110 litres of water

22kg straw

Pa mix add water 3 mins plus straw = 5:30 move cob =

Original splat test 26 to 29 cm was concluded to be too wet and this is when an extra half bucket which is included into the 3 1/2 buckets stated of excavator soil.

2nd mix Load soil 1:13 move cob =

Second splat test 24 to 20 cm. ~~Mix~~ water 2:45

add straw man 1:10 mix straw 6:13

Once straw was mixed in two separate mixing processes two ball test two undertaken one showing slightly to dry at around 16 cm and after taking a second sample came through at 20 cm so under the 21 cm diameter for the 1 m drop ball test that was normally required by Francois.

Measurements for LCA analysis for mixing structural cob with Crediton Red soil as advised by Barry.

For continuous running with small breaks the digger used 75 L over a 10 hour day. Is therefore equates to 7.5 L per hour. The following times were approximately the amount of time needed for the 360 degree four wheeled rubber tyred back actor to mix a cob mix using a standard medium size skip.

Moving soil into skip to mix, two minutes.

Weighing bucket 1 minute

The pertinent information as far as LCA is concerned is the amount of fuel used by the excavator, and this was calculated, as were all the other processes, using a spreadsheet

Times	minutes	Taken from second mix session					
Move soil	00:01:13		00:00:26				
mix soil water	00:02:45						
Add straw	00:01:10						
Mix straw soil	00:06:15						
Move cob	00:05:00						
Total digger time	00:16:23			53 seconds as %			
Digger time m2	00:05:53			0.88			
Digger fuel	hour	Litres/hour			Digger fuel	hour	Litres/hour
Ratio to m2	01:00:00	7.00			Ratio to m2	01:00:00	7.00
10.20408163	00:05:53	0.69			52.173913	00:01:13	0.13

This gives us the amount of fuel used by the excavator to create the structural mix for our 'declared unit' of $1m^2$ of CobBauge wall. As part of the production process, the fuel has the highest impact, but the burning of 0.13 litres is not a significant amount of energy in the context of the production of cement for instance.

All the calculations for the raw data were done in a similar way, but are not shown in full here for reasons of clarity, including the emissions from the thermal mix (pictured above).

Transport

A4 - transport to the construction site

As the structural mix was created at the source of the soil, the next impact to consider is the transport of materials.
The transport process is expressed in ton-kilometres (tkm). One ton-kilometre means the transport of one ton over 1 kilometre, or 1 kg over 1000 km, or any other combination that has the same product of distance and weight. In this case 0.481.25tons are transported over 83..8 kilometers, so the result is 40.83 tkm. This will be the biggest impact for the structural mix.

The Construction process

The lightweight insulating layer was mixed on site using a vertical axis, forced action mixer.

The clay rich slip is added to the hemp shiv in the mixer in a volumetric ratio of three parts shiv to one part slip. This represents a proportion of hemp shiv by 50% weight of dry soil.

In this case the principal energy consumed was electricity, at 1.62kwh.

The Formwork

Another significant amount of carbon emissions for the CobBauge wall system comes from the construction of the formwork. The timber framing is not the issue as the carbon sequestered by the tree as it is growing normally makes up for the energy used to process it into usable pieces. Using data from the Inventory of Carbon and Energy (ICE) the calculated carbon emissions for the locally sourced larch are **minus 1.027kgCO2e (Carbon dioxide equivalent).**

The stainless steel used for the mesh that holds the CobBauge mixes in place, plus the M12 threaded bar and associated fixings are responsible for **14.142 kgCO2e of emissions per m2 of wall.**

The additional timber tools and smaller fixings do not contribute significantly to overall carbon emissions although they are included in the LCA calculations.

Comparisons

We can compare the 14.142 kgCO2e for the steel in the formwork with the transport emissions for the CobBauge material.
One litre of diesel fuel emits 2.68kgCO2e
The total for delivering the CobBauge mixes to site = 58.67ktm
A fifteen-ton truck carrying 0.481 ton of structural mix for 83,85km will use 3.46litres of diesel fuel. **This will release 9.27 kgCO2e.**

A calculated total shows that the emissions for transport are very similar to the embodied energy of the materials, but if you factor in the potential to re-use the formwork, then **the transport becomes the overarching factor.**

One reason for the higher than expected emissions from transport was the distance from the site of the Plymouth prototype to the source of the clay rich soils used for the walls.

Compared with a conventional masonry wall.

Another useful comparison can be done by using data from the Inventory of Carbon and Energy to compare the CobBauge system with traditional Cob and a standard developer wall using masonry construction, which is still the preferred method of the UK construction industry. For this calculation both walls have an equivalent U value that conforms to UK building regulations.

For typical wall	Density kg/m3	Thickness m	Weight per m2 kg	EE per m2 MJ/kg
Traditional Cob	1700	0.6	1020	114.57
Composite CobBauge				
Structural Mix	1700.000	0.300	510	65.18
Thermal mix	350.000	0.300	105	52.92
Total		0.600		118.10
Masonry Wall				
Dense Block	2000.000	0.115	230	154.10
Foam	40.000	0.050	2	216.00
Cavity		0.050		
Aerated Block	700.000	0.115	80.5	281.75
Total		0.330		651.85

Using this calculation, the CobBauge wall has 18.12% of the carbon emissions of the masonry wall.

Conclusion

CobBauge is an essential high mass walling material with a lower embodied energy than conventional masonry construction.

Traditionally, Cob walls were built from soils sourced from the same site as the building and therefore the transport emissions were minimal.
Ideally, the soil used for CobBauge walls would also be sourced nearer to the site of the potential building. This would have a significant impact on the overall emissions as it can be seen that these are the highest factor in the carbon footprint of CobBauge.

The materials used in the production of the formwork also have a significant impact, but the formwork is designed to be re-used up to twenty times, which greatly reduces this carbon dept.