ETH zürich

Communication Skills 2 – Assignment 2

Wood Concrete LCA

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Abstract

WooCon is a special lightweight concrete developed at Haute École d'Ingenierie et d'Architecture (HEIA) Fribourg. The aim is to establish an environmental friendly yet economically competitive product for construction. As the name indicates WooCon is not only composed of concrete but also contains wood, namely sawdust. Another specialty of the mix design are the bio-based materials: grape seeds, cherry pits and nutshell. Structural properties are currently tested at HEIA Fribourg. In this study, the focus lies on the environmental impact though. Therefore, a Life Cycle Assessment (LCA) is performed on material level using Ecoinvent database for Switzerland and SimaPro software. The results of the LCA present a decent potential for energy and emission savings in the construction industry. Currently the Global Warming Potential (GWP) of WooCon is comparable to an ordinary LC8/9.

1 Introduction

This year, climate awareness has reached a level never seen before. At the latest since climate strikes got popular on a global scale the topic is ubiquitous both in media and politics. One cannot just build a house without thinking about its environmental impact anymore. Which is good since the construction sector has a major impact on the environment as neatly stated in (Zingg, et al., 2017):

> *"Building sector consumes around 40% of the global energy use (UNEP, 2014). In building life cycle, operation phase usually represents the largest share in the energy consumption; about a quarter is consumed in the production of building materials (UNEP, 2014). However, continuous improvement in operation through the development of energy-efficient buildings has reduced the share of the operation energy compared to embodied energy. The current standard for sustainable building construction in Switzerland, the 2000W society, considers that new buildings will allocate 70% of their energy for the construction of the building and 30% for its operation, while retrofitted building will have a 50/50 share between operation and construction. These figures show the growing pressure that is put on construction building materials as they come into the spotlights."*[1]

The awareness described above also plays a role in the development of the WooCon material at HEIA Fribourg. The project aims to develop innovative lightweight concrete structures with low embodied energy. The idea of the concrete mix design is to replace ordinary aggregates like gravel and sand by a certain amount of renewable resources such as sawdust, grape seeds, cherry corn and nutshell. Thereby, the goal is not only to reduce the emissions but also counteract the resource scarcity of sand and gravel. This study presents the results of the wood concrete life cycle assessment.

2 Methodology

The environmental assessment is done through life cycle assessment (LCA) according to ISO standard (ISO, 2006). As described in (Hellweg & Llorenç, 2014) and shown in Figure 1 a LCA consists of four steps. The first step is the goal and scope definition. What is analysed and against what is it compared? The second step is to setup the life cycle inventory by quantifying the resources and their emissions. As a third step, the resources and emissions are grouped according to their impact, forming the life cycle impact assessment. Eventually the results of step two and three are interpreted in a forth step, bearing in mind the functional unit and system boundaries defined in step one.

[1] (Zingg, et al., 2017)

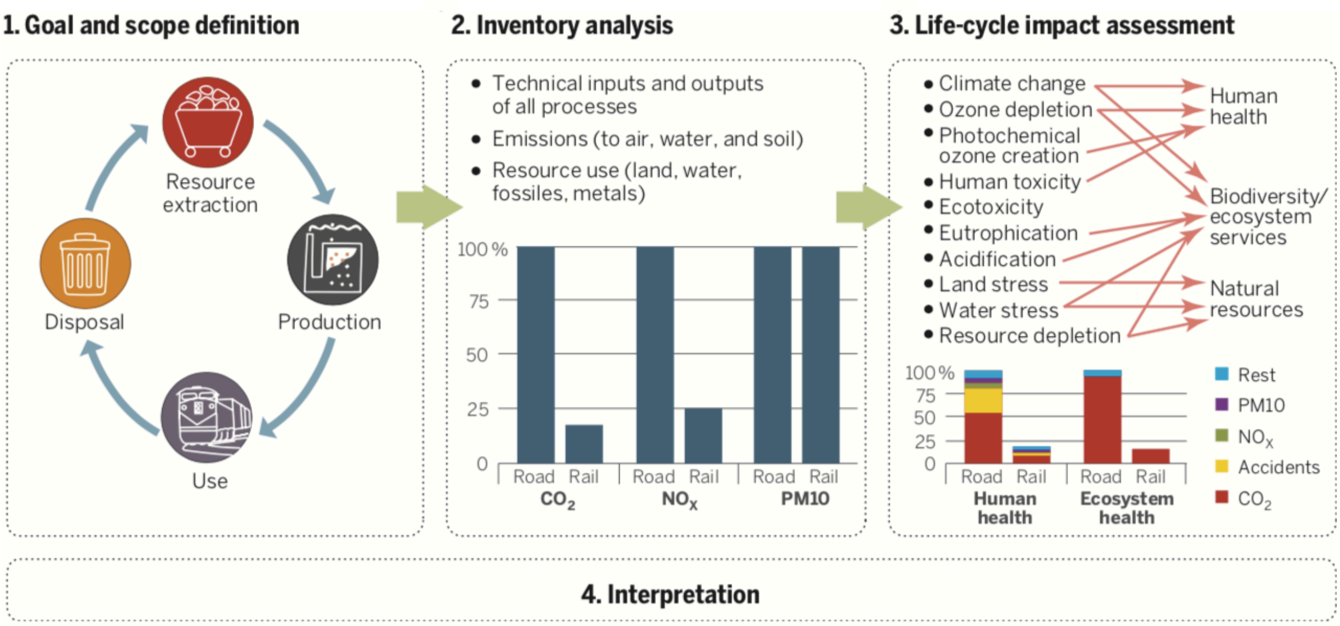

Figure 1: Four steps of a LCA (Hellweg & Llorenç, 2014).

The LCA method used in this study is the IPCC 2013 GWP 100a method for the calculation of the Global Warming Potential (GWP), i.e. greenhouse gas emissions measured (kg-CO_2-eq.). WooCon is compared against ordinary and lightweight concrete on material level. The easiest way to do this is by volume. Therefore, the functional unit (FU) to is 1 m^3 of material. A more complex way of comparison would be to take the structural properties of the materials, such as strength and stiffness, into consideration as well. Hence, the FU could also be 1 m^3MPa combining volume and strength or volume and stiffness.

Currently HEIA Fribourg is conducting research on structural properties of the 3rd generation of WooCon. Five different mix designs of this 3rd generation WooCon are analysed in this study: Nr. 6, 10, 12, 13 and 14. The first three samples are also tested on long-term behaviour. Due to confidentiality issues, not all quantities of the mix design can be published here. Nevertheless, Table 1 reveals information about the amount of cement, lime filler and sawdust used. Other materials used are expanded glass, water, superplasticizer, sand and expanded clay. A specialty of WooCon are its bio-based materials, namely grape seeds, cherry pits and nutshell. The mixes contain between 2 and 10% bio-based materials.

Table 1: WooCon mix design, structural performance and bio-based material content.

WooCon mix design		WooCon 06	WooCon 10	WooCon 12	WooCon 13	WooCon 14
Portland cement	[kg/m^3]	ca. 475	ca. 475	ca. 475	ca. 475	ca. 475
Lime filler	[kg/m^3]	ca. 400	ca. 400	ca. 400	ca. 400	ca. 400
Sawdust	[kg/m^3]	ca. 100	ca. 100	ca. 100	ca. 100	ca. 100
Expanded glass	[-]	x	x	x	x	x
Water	[-]	x	x	x	x	x
Superplasticizer	[-]	x	x	x	x	x
Sand	[-]	x	-	-	-	-
Expanded clay	[-]	x	x	-	-	x
Grape seeds	[-]	-	x	x	x	x
Cherry pits	[-]	x	-	x	x	x
Nutshell	[-]	-	-	x	-	-
Bio-based material	[M-%]	4.0	2.3	10.4	10.2	6.6

For all ingredients except for the bio-based materials the Ecoinvent database contained of equivalent materials. For the bio-based materials there was no data available though. Therefore, the data had to be established manually. The key assumption was to treat the bio-based materials as waste products from wine, juice, liquor and sieved walnut production. As a consequence, there is no environmental impact from the materials themselves. Only the processes were considered. After contacting the supplier of the cherry pits and the grape seeds it was discovered that the processes involved are sorting/sieving, crushing, washing, drying, conveyor belt and transport. The live cycle inventory was then established by taking similar processes from Ecoinvent and modifying them until they suited the required processes.

The life cycle inventory of ordinary C 30/37 used in this study was done in refference to Ecoinvent's "normal concrete" for Switzerland. The lightweight concrete mix design was established based on a mix design suggested by (Holcim & Partner, 2014). Depending on the density category, the quantities were interpolated to get the LC 8/9 and LC 12/13.

This study is limited on the embodied impact assessment. Neither operation efficiency nor end of life scenarios were considered.

3 Results and discussion

It is remarkable that 79 to 83% of CO_2-emissions are caused by the Portland cement used in the WooCon mix design. That is enormous. Figure 2 also exposes that 1 m^3 of WooCon causes around 430 kg-CO_2-eq., depending on the exact mix design. More than 350 kg-CO_2-eq are coming from the cement, mainly the clinker production.

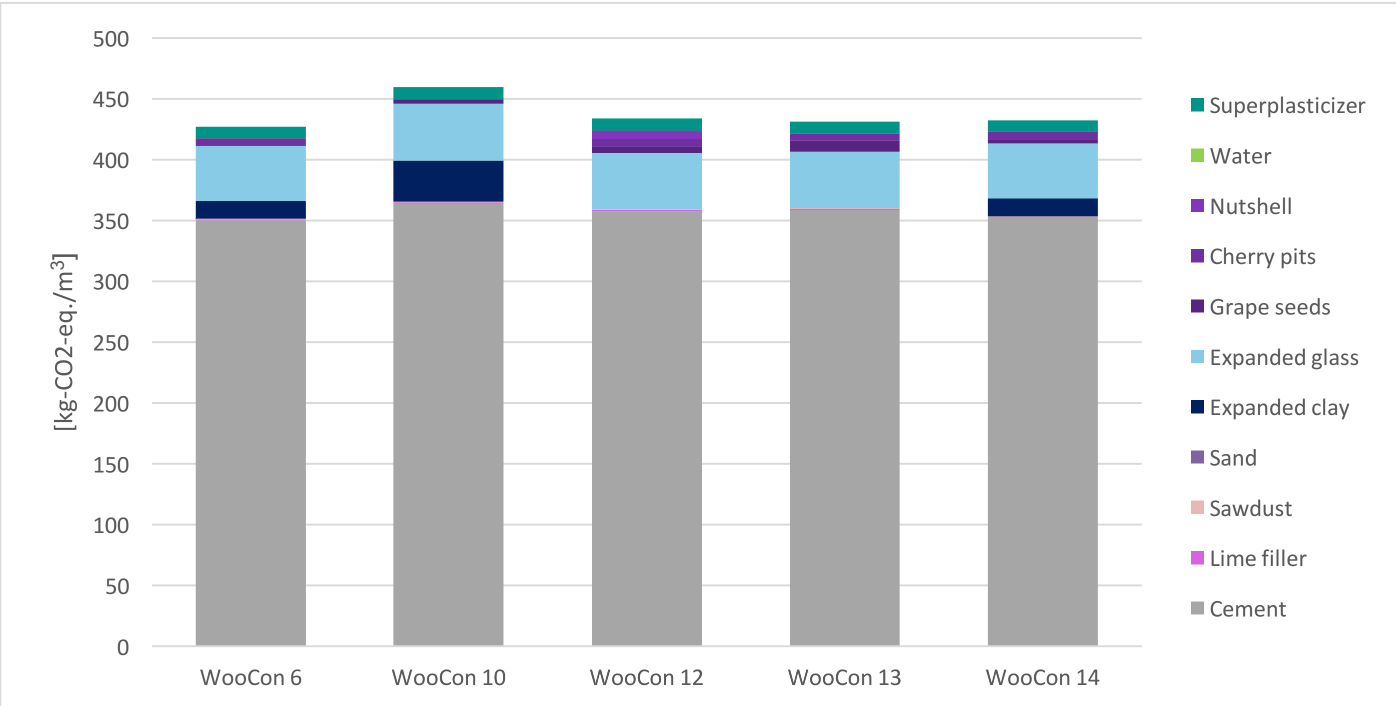

Figure 2: IPCC 2013 GWP 100a. GWP of WooCon mix designs.

Let us compare WooCon to ordinary and lightweight concrete now. Table 2 shows density, strength and stiffness (SIA, 2013) of all concretes considered in this study. C 30/37 has a much higher density, strength and stiffness than all the other materials, so it definitely does not have the same FU. Nevertheless, C 30/37 is used for the comparison as a reference value. Based on the structural properties it can be stated that WooCon has a similar FU to a low-strength lightweight concrete like LC 8/9 or 12/13. Generally speaking, there also seems to be a correlation between density and amount of cement. The lower the density, the higher the amount of cement. This is because for low density concrete there is only a very little amount of aggregates. However, it is mainly the aggregates like gravel which are carrying the loads and therefore providing strength. For ordinary concrete the cement simply functions as a binder. For lightweight concrete, on the other hand, cement is more than just a binder. It is required in larger amounts to guarantee a certain structural strength, compatibility and workability which are complex processes.

Table 2: Bulk density, amount of cement, average cylinder compressive strength and stiffness of WooCon, ordinary and lightweight concrete.

Material	Bulk density	Cement	Avg. cylinder compr. strength	E-Modulus
[-]	[kg/m^3]	[kg/m^3]	[MPa]	[GPa]
WooCon 06	1411	467 (CEM I)	18.0	9.1
WooCon 10	1343	485 (CEM I)	18.9	8.5
WooCon 12	1360	477 (CEM I)	13.6	6.1
WooCon 13	1360	478 (CEM I)	12.9	6.5
WooCon 14	1318	469 (CEM I)	14.0	6.2
C 30/37	2400	200 (CEM II)	38	33.6
LC 16/18	1200	351 (CEM II)	24	15
LC 12/13	1100	422 (CEM II)	20	12.5
LC 8/9	1000	493 (CEM II)	16	10

Figure 3 decomposes the GWP of the most promising WooCon mix (Nr. 6) into its components while being compared against the other concretes. It can be concluded that on material level WooCon is just about competitive compared to a LC 8/9. LC 12/13 has a 10% lower GWP than WooCon 6, whereas for a LC 16/18 it is 20%.

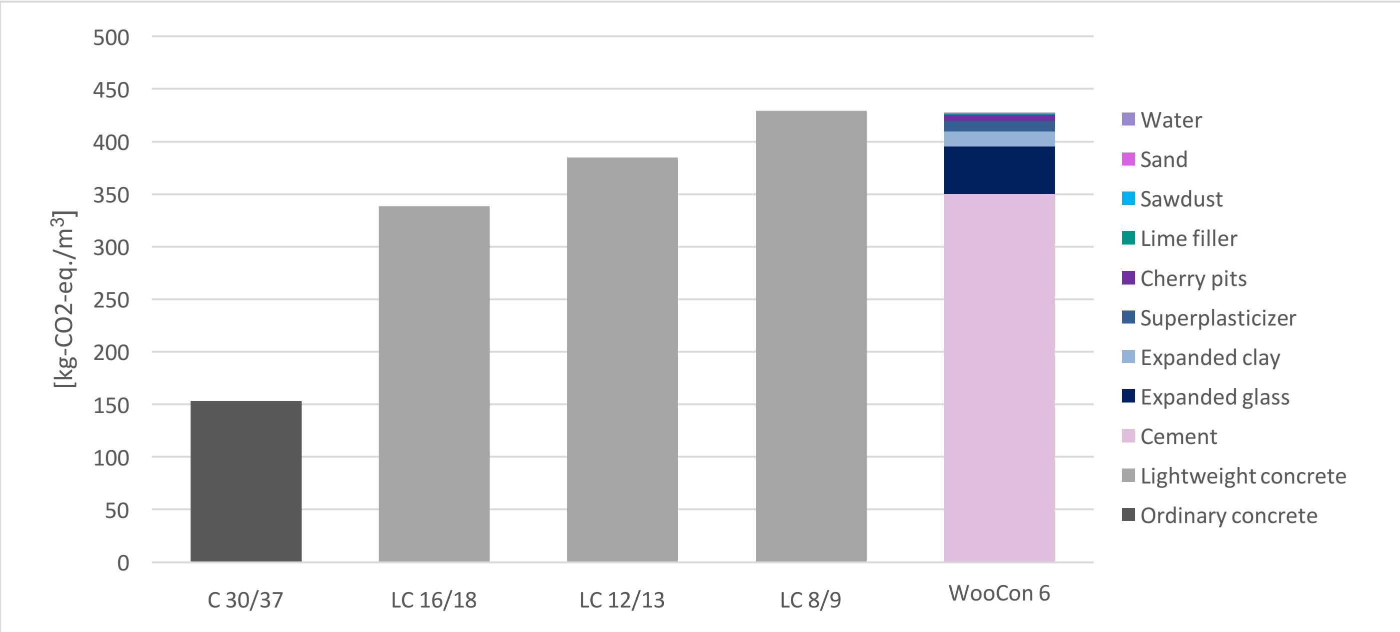

Figure 3: IPCC 2013 GWP 100a. GWP of 1 m^3 C 30/37, LC 16/18, LC 12/13, LC 8/9 and WooCon 6.

4 Conclusion

The environmental assessment of WooCon shows solid potential for emission savings in the construction sector. On material level, WooCon's GWP is virtually identical to the one of a LC 8/9. Note that this study was only focusing on GWP. However, the Ecoinvent database would also provide results about 17 other environmental impact categories, such as air and water pollutants, ozone depletion, radiation, resource scarcity (land use, copper, oil), toxicity (water, land, human health), acidification and biodiversity. Moreover, the comparison on material level is not enough. Further studies should also take the structural level into account, ideally an application for slabs. A comparison to ordinary slabs would then reveal a better understanding of the FU. Furthermore, a multifunctional comparison would be beneficial. For example, in addition to strength and density one could also consider thermal properties. Since cement has such a big influence on the GWP there lies also a great potential in cement optimisation. In the future HEIA Fribourg should investigate whether it would be possible to use a CEM II or CEM III instead of pure Portland cement. If those points are implemented in the future, WooCon might undercut the environmental impact of ordinary lightweight concrete.

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