Concrete as a Carbon Sink. Rethinking Carbon Sequestration in the Built Environment.

By William Larson & Frank Came

It's a mantra repeated so often that it is accepted on faith as being true: wood sequesters carbon, concrete production emits carbon. As in most things, the truth is often lost in translation.

It is true, living trees sequester carbon. And a long-lived, wood-based building product continues to sequester carbon; but only a small fraction of the carbon originally sequestered in a living tree. So too, the production of cement is a carbon intensive process that emits carbon into the atmosphere.

But the story of the carbon footprint of cement and concrete does not end there. Recent research has shown that in fact concrete reabsorbs much of the carbon previously emitted from cement production through a process called carbonation. Simply put, concrete might also serve as a carbon sink. So how do these two facts relate to the perennial debate of wood versus concrete as a building product? Here are some details that can shed light on this question.

A recent study reported in Nature Geoscience[1] notes there is a substantial global carbon uptake by cement carbonation. The study acknowledges that calcination of carbonate rocks during the manufacture of cement produced roughly 5% of global CO_2 emissions from all industrial process and fossil-fuel combustion in 2013.

However, the study notes, this does not represent the carbon intensity of cement; rather it is a function of the total volume of cement produced each year.[2] And while considerable attention has been paid to quantifying emissions from cement production, the natural reversal of the process—carbonation—has received little attention in carbon cycle studies.

Using new and existing data on cement materials during their service life, demolition, and secondary service lives for concrete waste, the researchers sought to estimate regional and global CO_2 uptake between 1930 and 2013 using an analytical model based on carbonation chemistry.

The research results suggest that carbonation of cement materials over their life cycle represents a large and growing net sink of CO_2, increasing from 0.10 GtC yr−1 (Gigatonnes of Carbon per year) in 1998 to 0.25 GtC yr−1 in 2013.

In total, it was estimated that a cumulative amount of 4.5 GtC of CO_2 has been sequestered in carbonating cement materials from 1930 to 2013, offsetting roughly 43% of the CO_2 emissions from production of cement over the same period.

While these estimates do not include emissions associated with fossil fuel use during cement production, 4.5 Gigatonnes is a lot of atmospheric carbon recaptured, roughly the same amount of carbon emitted from global industrial processes in 2013. In general, the researchers concluded that carbonation of cement products represents a substantial carbon sink that is not currently considered in emissions inventories.

So how does this compare with carbon sequestration in wood? Research carried out from many sources and reported in a study by the Pacific Northwest Building Resilience Coalition[3] suggests that a relatively small amount of the carbon that was originally stored in a living tree makes its way into a long-lived building product such as dimensional lumber or a piece of engineered wood such as cross laminated timber.

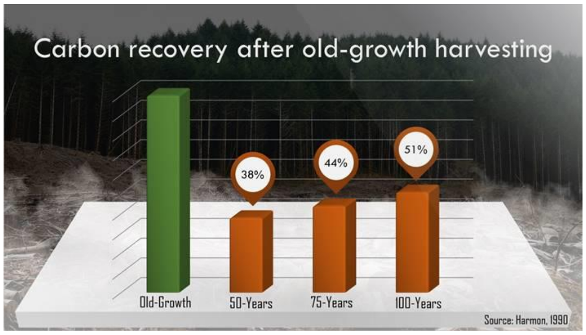
The estimates vary due to factors such as tree species, geographic location or forest management practices, but in general research tracking tracked the flow of carbon from the forest ecosystem to the built environment suggests that only 18-30% of the carbon from the initial living tree ends up in a long-lived building product. Most of the originally sequestered carbon is lost during harvesting or is emitted when non-merchantable wood is burned for energy, disposed as waste, or used to produce pulp, paper and other short-lived products.

Leaving aside current conventions on carbon accounting that conveniently do not reflect these carbon losses in official greenhouse gas emission statistics, it takes a considerably long time before this carbon is reabsorbed by new forest growth. As noted in the Building Resilience Coalition study, 75 years after reforestation only 44% of the original carbon sequestered in an old growth forest is recovered in a replanted managed forest. Even at the 100-year mark, only half the original carbon lost is reabsorbed from the atmosphere by new forest growth. And there is no 100-year rotation of managed forests anywhere. See the chart below.

[1] Substantial global carbon uptake by cement carbonation, Fengming Xi, et al, Nature Geoscience, Source

[2] Cement contributes to 10-15% of the total volume of concrete . Source

[3] Carbon Sequestration in Forest Based Wood Products" (2017)



But there is more to the story.

Estimates vary on how much carbon sequestered in a living tree remains stored in a long-lived wood building product after being harvested. Given the wide spectrum of products that are manufactured from harvested timber, these figures are not intended to describe any given individual tree. A pulp log that is chipped directly, and a log used to manufacture dimensional lumber, have entirely different carbon storage consequences.

According to one study, as little as 15% of the initial living tree carbon is stored in long-lived wood products. One of the more commonly cited studies on this question concludes that 18% of the biomass initially stored in living trees is ultimately transferred to long-lived wood products.[4] A report from the B.C. Ministry of Forests and Range reports that an average of between 40-60% of the living tree biomass is transported to the sawmill, and of this portion, 45-50% is converted to long-lived wood products.

Regardless of the precise volume estimates, when a tree is harvested and converted into long-lived wood products, only a small portion of the original carbon stored is preserved, and then only for a matter of decades as most buildings will be replaced and the wood products contained therein eventually will rot or be burnt.

A further complication arises with the end-of-life disposal or landfilling of long-lived timber (wood) products when the remaining sequestered carbon is released or converted to methane. Methane is known to have a Global Warming Potential (GWP) 28-36 times greater than CO_2. By definition CO_2, has a GWP of 1 regardless of the time used, because it is the gas used as the baseline reference for global warming studies.

CO_2 remains in the climate system for a very long time. Atmospheric concentrations of CO_2 will last literally thousands of years. Methane (CH_4) is estimated to have a GWP of 28–36 over 100 years.[5] CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2.

The net effect of the shorter lifetime and higher energy absorption is reflected in the climate impacts (GWP) of methane. This more powerful greenhouse gas also accounts for some indirect effects, because methane is a precursor to ozone, and ozone, which is itself a greenhouse gas.[6]

So, the oft quoted mantra – that wood is a sink and concrete a source of atmospheric carbon - noted above is rather more complicated than it first appears. In fact, while concrete continues to act as a carbon sink over time, wood after harvest, becomes a chronic CO_2 emitter as well as a potential source of methane emissions.

All this shows that scientific progress in comprehensive life cycle analysis, from cradle to grave, provides a more realistic basis upon which to evaluate the true carbon impacts of building materials. It also can help to better our abilities to curb the impacts of global warming.

A final thought, it is wise to keep in mind that there are no simple answers with respect to carbon accounting metrics, and statements to the contrary should be regarded with caution. Much more research is required to determine exactly how much carbon is being reabsorbed by exposed concrete, and how significant this might be in terms of countering the effects of climate change.

Nothing is more effective in storing carbon than a living tree and neither concrete nor a piece of lumber can compete in this regard.

Nonetheless, perhaps it is time to reconsider the value of concrete in the built environment as an important carbon sink as opposed to being cited as the villain in the global warming equation. Great strides are being made to reduce the carbon footprint of concrete, the most widely used building material in the world. But that's another story.

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[4] Ingerson, A. 2009, Wood Products and Carbon Storage: Can Increased Production Help Solve the Climate Crisis? Washington, D.C.: The Wilderness Society. Source

[5] Learn why EPA's U.S. Inventory of Greenhouse Gas Emissions and Sinks uses a different value.

[6] *https://www.epa.gov/ghgemissions/understanding-global-warming-potentials*

