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Sawdust concrete: Researchers in quest to replace gravel with wood

David Smith[†]

Timber-concrete composite structures have been around for some time, but they involve sticking together timber beams and concrete slabs to add stiffness and to resolve the acoustic and vibration issues that can afflict pure timber constructions. Now a team of Swiss researchers have devised a "recipe" for a lightweight, pourable concrete that uses wood chips as aggregate. Claiming it might limit the destructive and indiscriminate mining of river beds, they say the new material is recyclable and could be commercially available within 10 years.

The claim that load-bearing concrete can be made out of wood sounds like the kind of water-into-wine miracle that meets with scepticism today. But on closer inspection, the process is not only feasible, but potentially revolutionary for construction. Swiss researcher Daia Zwicky fabricates his wood-based concrete using sawdust to replace the usual sand and gravel content and, in many of his "recipes", the volume of wood exceeds 50% of the finished product. The wood component can be supplied from waste from the wood industry and then recycled at a later date and the wood-based concrete is much lighter than conventional concrete with both good flame retardance and high levels of thermal properties.

Compared to most researchers probing the combination of wood and concrete, Professor Zwicky has taken a different approach. Timber-concrete composite structures have been around for some time, but they involve sticking together timber beams and concrete slabs to add stiffness and to resolve the acoustic and vibration issues that can afflict pure timber constructions. With the Zwicky method, the wood is added to the blend and becomes an integral part of the concrete itself.

"For me it never made sense to take lightweight timber and pour heavyweight concrete on to it", said Zwicky, head of the Institute for Construction and Environmental Technologies (ITEC) at the School of Engineering and Architecture of Fribourg. "That's one reason I came up with the solution of lighter wood-based concrete, which I think could be a very significant discovery. Our tests showed we can build load-bearing structural slab and wall elements for schools, offices and houses out of wood-based concrete. That's a potentially huge market."

Over the past five years Zwicky and his team have tested various recipes using standardised laboratory equipment to measure the strength of the concrete. They concluded that the highest possible proportion of sawdust that can be added whilst maintaining enough strength is about 55%. Although such a high percentage of wood creates quite a soft concrete, it is strong enough for structural elements that are not too heavily loaded. These wood-cement compounds, structurally collaborating with timber elements, are strong enough to make building slabs spanning 8 metres between two walls. That is twice the length of a small car. "Usually, a living room span is not beyond 6.5 metres and with 8 metres you can already create a school room", he said.

One of the major achievements of the research project was the proof of concept for the creation of a pourable material that Zwicky says can be made into almost any possible form. Most of all, he would like his pourable blend to be used in the pre-manufacture of housing structural elements to be used in combination with timber, because pouring the concrete on site involves waiting weeks for it to dry.

Zwicky wants to study new applications for his material, such as using it for artificial lightweight gravel, for the supporting structures for photovoltaic panels, and even 3D printing it. But first he needs more money. The investment for the wood-concrete tests largely came from the Swiss National Science Foundation (SNSF), which financed more than 20 projects looking into the properties of wood for CHF18 million. Zwicky is applying for more funds to conduct further investigations starting next year. "We need more tests to learn how to work with this new material. We know what we can do with steel, concrete and timber, but we have to work out the best ways to produce and apply lightweight wood-based concrete. It will take some time, but we think we could start with pilot projects in five years and it could be commercially available within 10 years", he said.

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In some "recipes" the volume of wood exceeds 50% of the finished product (credit: ITEC).

The environmental case

When Zwicky came up with the idea for his wood-based concrete five years ago, he was inspired by ecological arguments. Conventional concrete production is notoriously damaging to the environment, partly because of the emissions produced in the creation of cement but also because of the destruction of the natural environment to provide the gravel and sand that gets mixed with the cement. It takes about 1,800 kWh of heat to make one ton of cement and the construction industry's heavy reliance on coal leads to high emission levels of CO2, nitrous oxide and sulphur, among other pollutants. For every ton of cement produced, assert Babor, Plian, and Judele (2009), 1.25 tons of CO2 is released into the atmosphere.

Although Zwicky's wood-based concrete still contains cement, he has improved its negative environmental impact by replacing the sand and crushed gravel with sawdust. Unlike traditional concrete based on Portland cement, the wood-cement compound can easily be recycled when the building is demolished at a later date by burning it to create a porous cement stone while achieving a net gain in thermal energy. The stone can be broken into small pieces and sieved to form a new "granulometry", he says. "At that point we can reuse it as lightweight aggregate to create more concrete so we don't have to exploit natural resources", Zwicky said.

A second option, he says, is to grind the cement stone gained from the combusted wood-cement compound into a fine material that is used to replace sand in the production of concrete. One final possibility is to burn the material at a very hot temperature to create "second-hand cement". "It's not as efficient as regular Portland cement, but we can reactivate 70% of it to be used in regular concrete. Then we can keep reusing it again and again", he said. Recycled materials will become more important in the construction industry, he argues. The current focus of building regulations is on the energy required to heat and cool buildings but, as these problems are solved in the future, the focus will turn to the "grey energy" stored in construction materials. "That's why ecological methods and materials will have a big future", he said.

Aside from reducing emissions, using wood to create the concrete rather than gravel and sand protects river beds from the unchecked mining of channels and floodplains. Zwicky believes that because of the scale of concrete production, the planet's river beds face irreparable damage within a generation. A considerable amount of research supports this view. Rinaldi et al. (2005) have shown how bed sediment mining increases both the likelihood and severity of flooding. Meanwhile, Brown et al. (1998) have shown how gravel extraction from the river bed leads to bank erosion and failure. The mining of river beds is especially damaging

A slab of wood-based concrete undergoes stress testing at Institute for Construction and Environmental Technologies (ITEC) (credit: ITEC).

when there is a lack of gravel bedload to replace the mined sediment, the researchers concluded. "It takes millions of years to renew these natural resources as the rock in the mountains has to be broken apart and washed down rivers before it can be used in concrete", said Zwicky.

In contrast, timber is in plentiful supply in many European countries, including Zwicky's native Switzerland. He says there are so many large forests in his country that two million cubic metres per year could be removed without deforestation occurring. Much wood and wood waste is being composted or burned. "The average building in Switzerland is replaced by a new one every 50 years. Why not stock all that carbon in a building for that period?" he asked. Germany and Austria have similarly benefited from reforestation programmes that began in the 19th century. Scandinavia and large swathes of France and Italy are also blessed with large forests that could be exploited without deforestation.

Zwicky was careful to assess all the characteristics of his hybrid material, not just its load-bearing ability. His team studied its combustibility, its thermal and acoustic insulation properties, and its potential to be recycled. "The greatest lesson we learned was the need to take a holistic approach. You can judge the whole impact of using wood for the creation of concrete rather than just one aspect", he said. The ideal was to create very lightweight components, but there was a balance to strike between adding as much wood as possible and the need for strength. Ultimately, lighter material facilitates the transport of materials and reduces the overall costs of fabrication. "The more wood we can use, the more it benefits thermal insulation and thermal storage mass, big issues in construction today. Ideally, we want to store heat during the day and release it at night. In the end the amount of sawdust has to be a compromise", he said.

Not alone

In his pursuit of methods to introduce more wood into construction processes, Zwicky found an ally in Professor Wolfgang Winter, a structural engineer from the Technical University in Vienna (TU Wien). The pair have been collaborating on tests and sharing ideas over a number of years, although Professor Winter is taking a somewhat different approach. "Daia Zwicky is coming more from the concrete side and we are coming more from the timber side. He uses more sawdust even though there is quite a lot of humidity and shrinkage, and there's a danger of getting too much water. But he compensates by pumping the material to create a kind of porridge and adding mineral powder to increase the quality of the mix", Winter said.

His approach does not use sawdust. He makes panels that are like oriented strand board (OSB) by placing 1cm to 3cm strands of timber offcuts in baths of liquid cement, which acts as a hydraulic binder. He then presses this into a timber-concrete panel for use in sandwich packages between a pure timber layer and a thin layer of normal concrete.

Professor Winter's panels are a compromise solution. In an ideal world, he says, it would be possible to mass-produce the types of large pure timber panels that are being used to construct Brisbane, Australia's 5 King Street tower. When that building is completed in

2018, 45 metres of the 52-metre office block will qualify it as one of the world's highest to be held aloft by timber and glue. The engineers are using the same cross-laminated timber (CLT) panels that were adopted to build the Waugh Thistleton Timber Tower in London, in 2010, which at the time was the world's tallest residential wood building.

That quantity of engineered wood acts as a huge carbon sink, but timber is too expensive to make it a viable option for the majority of buildings, he says. A cubic metre of dried sawn boards has an approximate market value of €250, whereas a cubic metre of concrete costs between €50 and €100, he says. "That's why instead of a 22cm panel of pure timber, we are using an 8cm timber panel, then we add the lightweight concrete panel and then on top a 6cm pure concrete panel. We have half the weight, but it's heavy enough."

Professor Winter says the German company Cemwood has invented a third innovative method of introducing wood into building materials. The company produces mineralised wood chips as floor filler by placing 4-5mm small cubes of timber into cement liquid. "It's like a stone in the middle with a shell of cement. It looks like a sweet that a child might eat", Professor Winter said.

All three methods show an awareness of the importance of protecting the environment, he says, by using more natural and sustainable materials. Professor Winter has also experimented with combining timber and steel and with glass and timber. "We need to go stronger in the direction of bio-based industries and work more closely with nature. Right now, Zwicky and I and our hybrid solutions are seen by people on both the timber and concrete side as 'traitors' to their cause. We are mixing materials and not using pure timber, or pure concrete. But our shared philosophy is to look at the environmental side and to try to combine elements in practical ways", he said.

The wood-cement compound can be recycled by burning it to create a porous cement stone, which can be ground into aggregate (credit: ITEC).

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