James Dyson Foundation Undergraduate Bursary

Case Study Resource – Self-Shaping Wooden Structures

Sam Dixon (Self-Shaping Wooden Structures)

We need to get better at making buildings without emitting loads of CO_2. At the moment, over a third of the carbon dioxide worldwide comes from the buildings that we use to keep warm and dry. As the global population grows, we need to build more but without emitting as much CO_2. Wood is an excellent construction material that actually absorbs CO_2. This is because trees absorb CO_2 during their lifetime and the wood locks in this CO_2 for the life of the building. When a material stores CO_2 like this we call it ***sequestration***. Although wood is often used for small buildings, even much larger buildings can now be made safely out of wood, like this block of flats in Norway.

Figure 1 - This building is made entirely from wood.

Sequestration: Absorbing and storing greenhouse gases. Buildings made from wood ***sequester*** $CO2$.

However, there are difficulties with using wood. One of these problems is that wood changes shape when it gets wet. You can see this by looking at a pinecone during a rainstorm. Before the rainstorm, when the air is dry, the pinecone will be open so that its seeds can spread. When it starts raining though, the pinecone closes up. This is because the wood gets wet and expands. After the storm, the pinecones dry back out again and so the needles open.

Figure 2 - A pinecone in the wet state (left) and dry state (right).

My project was about understanding how other bits of wood change shape. It turns out that this happens because wood **expands** when it is wet. What's even more weird is that wood expands by different amounts in different directions. This is because of something that's obvious but surprisingly easy to forget: wood grows in trees. This is why wood has ***growth rings***. These are circles that appear when you cut across a tree and they show how old the tree is. They also show the directions that matter in wood: 'around', 'out' and 'up'. If you follow along a growth ring, this is the 'around' direction and if you go across the growth rings towards the edge of the tree, this is the 'out' direction. Although these directions are really obvious when you're looking at a tree, they become a lot less obvious when you're looking at a plank of wood that has been cut from a tree.

Growth rings: The rings that are formed as a tree grows. They can normally help tell the age of the tree.

You can experiment with this using an ordinary carrot. If you cut the carrot in half width ways, you can see the circle of the carrot. This is exactly like wood. However, if you cut the carrot into matchsticks, it becomes a lot harder to work out the important directions. This is what makes it tricky to work out how wood will behave.

One way in which wood changes shape is called ***warping***. Warping happens when a plank of wood changes shape when it dries out or gets wet. This is a real problem because it means that pieces of wood don't fit where they're meant to. If it happens after a building has been built, it can change the shape of the floor. If it happens too much, the building could become unsafe. Because of this, it's important that we understand how and why wood changes shape so that we can predict it and make sure that a building is safe.

Figure 3 - This wood has warped

Warping: When wood changes shape as it gets wet or dries out. It's normally annoying.

Although warping is normally annoying, my project also investigated whether wood changing shape could be a useful thing. There are two ways in which it could be: first, to make things that change shape when the weather changes (a bit like a pinecone) and second, to make big bits of wood that are permanently curved. For example, if a boat is made of wood it needs to be bent into shape. This is hard work and can be expensive. However, if the wood just changed shape itself, then there would be no need to bend it into shape. To do this, we need to be able to predict and design these changes. One way to do this is using a mathematical equation. These can get very complicated though, and it's

$$\frac{1}{\rho} = \kappa = \frac{\Delta\omega(\alpha_1 - \alpha_2)}{\frac{t_1+t_2}{\ } + \frac{2(E_1 I_1 + E_2 I_2)}{\ }\left(\frac{1}{\ } + \frac{1}{\ }\right)}$$

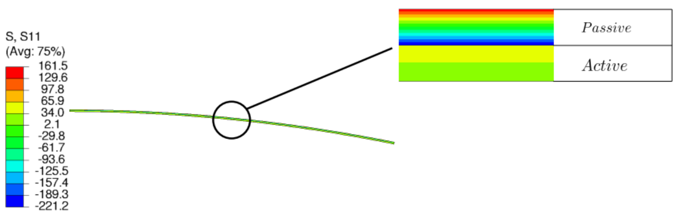

Figure 4 - An equation to predict the wood's behaviour, and the result of a Finite Element model.

difficult to tell the maths everything that you want it to consider. Another way is to use a ***Finite Element programme***. This is a computer programme that divides up an object into lots of blocks (which are called elements). It then works out how each element changes shape and responds to forces. These programmes can be extremely complicated if they are performed on something like a car, or an aeroplane.

Finite Element programme: A computer programme that makes predictions about physics by dividing an object up into hundreds, thousands, or millions of little boxes.

It turns out that predicting how wood will change is quite tricky to do accurately, so if someone could do a better job at it then that person would become very successful!

One thing that's really important when doing a project like this is **communication**. You might have to explain what you're doing to a lecturer, or another student, or to someone who is building something for you. This can be tricky to do if you're not sure how well someone understands what you're doing, so it's a very important skill to have. One way to develop it is teaching others about something you've learnt. It doesn't have to be another student – it's also helpful to try and explain something to friends or family who are older, or younger. If you can explain it to a toddler, then you can be sure that you understand it yourself!

Hopefully I've been able to communicate to you why we need to build more stuff out of wood, and also why this might be tricky. It's really enjoyable to investigate things like this that make a huge difference in the world, and it's even more exciting to encourage other people to get involved. I hope you've enjoyed this case study, and know a bit more about wood than you did!

- Sam