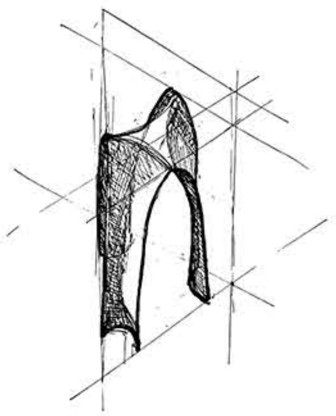


REPLACEMENT REPLACEMENT

Concrete, a composite material made by bonding fillers like sand and gravel with a hydraulic binder, called Portland cement, is one of the most frequently used construction materials worldwide due to its abilitiy to be formed into almost any shape and high compressive strength. It's also cheap and easily available anywhere in the world. Because of these aspects, a massive industry has evolved around the material, projected to exceed 600 billion dollars in revenue by 2025. A global infrastructure has been implemented, with short transportation distances, also because the material is curing very fast and needs to be produced near the constructon site. While this material has a lot of positive aspects and revolutionized the world we're living in today, it also has a huge impact on the global CO2 emissions. It is estimated to produce about 8% of the global greenhouse gas emissions and is liable for about 2.8 billion tons of carbon dioxide per year. These numbers mostly occur because of the huge amount of energy needed in the production of Portland cement. In this process, clinker, consisting largery of limestone (CaCO3), is first produced by burning it at about 1450°C. After that, it is mixed with calcium sulfate and grinded to achieve the final product.
In the end, the decarbonation of limestone, the fuel combustion of the kiln as well as the elctrical power generation and the transportation are producing CO2 emission at all stages of the process. Because of these big environmental impacts, other alternatives have been gaining more popularity in the recent years.
In this project, Magnesiumoxychloride cement (MOC) is analyzed and applied into a small scale structural system, in this case a chair, demonstrating the possible potential as a more sustainable alternative to Portland cement.

Magnesiumoxychloride cement (MOC), also known as „Sorel cement", was first produced in 1867 by its inventor Stanislas Sorel. The non-hydraulic binder consists of the dissolution of Magnesiumoxide (MgO) in an aqueous solution of Magnesiumchloride (MgCl2), forming an homogenous gel-like cement. It is able to bind all kinds of fillers, from granite to sawdust, resulting in good compressive and tensile strengths. Especially in the 20th century, MOC cement mixed with sawdust called „wood stone" was often used as flooring because of its marble like appearance.
MgO is usually obtained either by the calcination of mined magnesite (MgCO3), called dry route, or by the wet route, in which MgO is extracted from magnesium rich solutions by the precipitation of Mg(OH)2. Typical are solution mining brines, but the precipitation can also happen with seawater. Since the wet route happens to be complex and needs a lot of energy, MgO is mostly obtained by the dry route. MgO is also considered to be carbon neutral or even carbon negative because of its ability to carbonate with atmospheric carbon dioxide.

Caustic calcined Magnesiumoxide (CCM) burnt at 800°C suits best for MOC usage because of its high reactivity.

Magnesiumchloride flakes (MgCl2) are dissolved in water before mixing with CCM to create MOC.

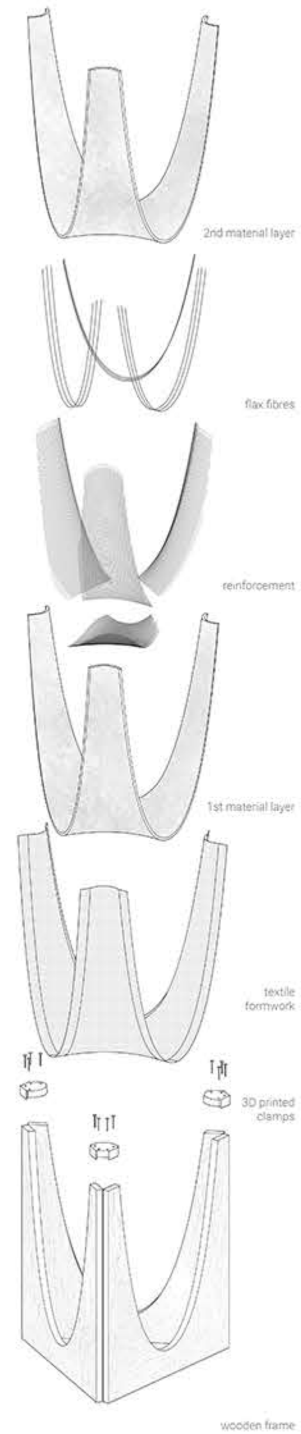
Sawdust (filler) is a wasteproduct of the timber industry.

While the principle of this procedure stays relatively simple, the process is actually quite complicated. It is uncertain if it could work or not since the material wasn't undertaken any long-term tests, but there is definitely a lot of potential of MgO taking up atmospheric CO2.
The second mineral needed for MOC, magnesium chloride, is naturally found in nature as bischofit (MgCl2 x 6H2O) or in seawater. It is hygroscopic and depending on the way of production there are various degrees of purity. MOC cement isn't suitable for steel reinforcements, but for newer types of reinforcement, such as fiberglass or natural fibers, because it bonds very well with them.
Currently, the raw materials for MOC cement are more expensive than those for conventional cement. In the long term the extraction of raw materials from sea water could be a good source, also in order not to remain/be dependent on finite resources from quarries.

Regarding the desirable properties of a chair, which should be usable, durable, lightweight and somehow also nice to be touched, we decided to use sawdust as a filler. Some simple properties tests showed it's definitely not left behind by sand concerning the strength. The sawdust is sieved to make the material smoother and suitable for applying it onto the formwork.
For upscaling a structure built with MOC, especially the weather resistance should be considered. Our test showed that sawdust has a negative effect on the resistancy to water because it is soaking it up over time.

The shape of the chair is a 1.2 cm thick shell, generated by 3 curves on the ground, 3 curves on the side and 3 curves on top controlling the size of thesitting area. While being very light and material efficient, double curved surfaces are one of the strongest geometries in nature. Like for example, egg shells.
To test different variations of the geometry and to be sustainable in the design process in which the shape and the thickness of the shell would change, a parametric model 3D model (Rhino/grasshopper) was used.This also enabled a structural optimization concerning the forces inside the shell.
In general, double curved surfaces are very hard to produce and need a lot of material for the formwork. Using textiles is simplifying the process.
The formwork is made out of a jute fabric, clamped into a simple wooden frame made out of three planar sheets.
Using a close mesh weave prevents the material from pushing through the fabric. Because of its rough surface it provides enough grip for the vertical application of the material.
For the reinforcement a loose mesh weave also made out of jute fabric was used. Small gaps in between the mesh are insuring a proper connection with the material on the opposite site of the reinforcement layer, as it is applied in the center of the intersection of the shell. In higher stressed areas of the shell such as the outer edges and as some kind of „connection" in between the 3 legs we additionally applied some individual flax fibres.

The final chair can be cut out of the frame after around 10h of curing time. It weighs around 4.2kg and is able to support a person.



The material was applied by hand on the textile formwork.

Comparison of a 3D scan of the finished prototype and the computer model showing the formwork accuracy.