

Application of Fibre Reinforced Bio-Composites Intended for Cradle to Cradle Shell Structures.

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This abstract is based on a master thesis carried out in the fall of 2011 and works within the context of sustainability and structural design. Traditionally do concrete, steel and timber constitute the load-bearing elements of structures but with the emerging awareness of carbon footprint new possibilities have emerged.

The objective of the thesis was to design a mobile structure for a *Cradle to Cradle* (C2C) Pavilion – a project originally designed by 3XN and COWI – which communicates a new green, holistic approach to building design. The purpose of the pavilion is to demonstrate new building technologies within the framework of C2C worldwide, thus the pavilion can be disassembled, moved and reconstructed at another location.

Cradle to Cradle is an environmental paradigm that aims to design consumer goods and products with a positive influence on society by eliminating the concept of waste. Basically should all materials used in production be constituted in a cyclic metabolism (either a technological or biological) and function as *nutrition* for new production.

Through an integrated design process and material test results from the WOODY Project obtained by DTU Wind Energy (former Risø DTU) an *umbrella shell* structure consisting of four hyperbolic paraboloid shells is designed to constitute the C2C pavilion. The shells are made in flax fibre reinforced composites; a material which safely can be decomposed, thereby respecting the requirements of the biological C2C metabolism. Due to the high tensile strength (237MPa) and stiffness similar to concrete (20 GPa) is the material highly suitable for application in shell structures. These structures are known to be highly effective due to the in-plane force flow, which enables slender and elegant designs.

Besides from the ability to be recycled or decomposed the materials are evaluated upon hard and soft factors. Hard factors are environmental material data (CO₂ emission, water usage etc.), while soft factors primarily are related to the green experience/appearance generated. Both factors are fulfilled in a successful design.

In the process of material selection is it important to consider the context and thus the phrase *sustainable materials* is discussed in relation to a temporary mobile structure where weight and lifetime is of importance. As a result is it rephrase to *sustainable use of materials*, which means sustainability is related to the context instead of an ultimate expression.

The structure has been analyzed through a finite element model in Abaqus, where the principal in-plane force flow have been located in an equilibrium stress state in order to ensure an optimal placement of fibres to fully utilize the mechanical properties.

It results in a two cm thin and light (3.5 times lighter than concrete shells) structure combined with a visual green dimension, which relative easy can be transported around world to communicate sustainable solutions of Cradle to Cradle. All materials used in the project enter either the closed technological or biological metabolism after use.