Holcimawards
for sustainable construction

Regional Holcim Awards competition

"Next Generation" 1st prize 2008 North America

Microstructure research for building skins, Cambridge, USA

Project data

Type of project Architecture (research/development)
Estimated start of construction February 2009

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Comment of the Holcim Awards jury North America

This project deals with new construction materials. The visionary and novel idea consists of developing a building skin that offers construction without joints and assembly and is also able to accommodate different functionalities such as load bearing capacity, natural ventilation through osmosis, thermal and noise insulation and changing light penetration wherever and whenever requested. What might sound like a miracle shall be achieved by a hierarchical combination of carbon nanotubes, polymers and traditional building materials such as steel, wood and glass. Although the invention is still at the level of computer simulations, lab tests and prototyping at small scales, the jury is convinced that this fantastic vision possesses a realistic potential to design, fabricate, construct and maintain a material architecture which is specifically assigned to accommodate particular structural, functional and environmental conditions.

Project description by author

Construction in vivo explores and offers a novel approach to designing, fabricating and maintaining building skins by controlling the mechanical and physical properties of spatial structures inherent in their microstructures. The method offers construction without assemblies such that material properties vary locally to accommodate for structural and environmental requirements. This approach stands in contrast to functional assemblies and kinetically actuated façades which require much energy to operate, and are typically maintained by global control.

Next-generation construction materials offer spatially-differentiated material compositions and structural forms. This facilitates a combination of structural, optical, and fluidic behaviors which are governed by the material architecture, and the environment. Such material architectures could simultaneously bear large structural load, change their transparency so as to control light levels within a spatial compartment, and open and close embedded pores so as to ventilate a space. Here we demonstrate an exemplary material architecture which can be enabled by hierarchical combinations of carbon nanotubes (CNTs), polymers, and traditional building materials such as steel, wood and glass. The CNTs are unique molecular structures, which have exceptional properties; the growth process for CNTs can be controlled to give hierarchical organization of CNTs into functional networks which act as a scaffolding for impregnation of the functional matrix materials which interact with the CNTs to give a multifunctional skin.

We demonstrate the notion of a breathable façade by controlling passive material distribution and actuation that is ideally and potentially self-powered by the façade itself. We propose to develop full-scale skin prototypes (250mm x 250mm) demonstrating embedded structural, optical, and fluidic behaviors governed by the hierarchical organization of CNTs within selected matrix materials. Using a combination of shape-directed CNT growth, 3D printing, and layup techniques, we will produce a monolithic panel with bearing and breathing regions. The bearing region will feature structural ribs made of dense aligned CNTs impregnated with structural epoxy resin. The breathing region will feature a multi-layer and spatially organized composite of thin, transparent CNT networks which act as electrodes, electrochromic oxide and electroactive polymer molecules, and fused glass particles. Starting with the shaped CNT skeleton which acts as a scaffold, this structure will be fabricated as a single piece. These behaviors are enabled in vivo by the material construction, particularly the micro- and nano-scale organization of constituent CNT and polymer elements.

Relevance to target issues by author

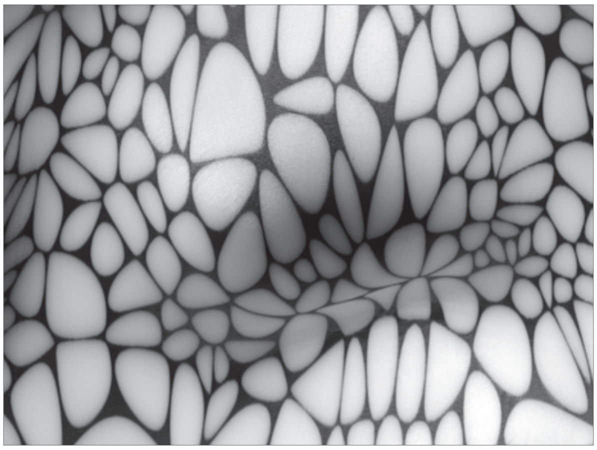
Quantum change and transferability
The work presents a transformative material concept which enables and promotes new construction methodologies. At prototype stage, we measure energy flows through test panels; at implementation stage, we monitor material response over time, and relate to environmental conditions, weather, and building occupancy. We also aim at benchmarking energy usage and occupant comfort.

Ethical standards and social equity
The architect will follow strict ethical principles and transparent practices during the design and construction phases of the project. All researchers are required to meet high standards of social responsibility, especially concerning safety. The research implementation provides a unique opportunity for conducting interdisciplinary research combining design, material science and engineering.

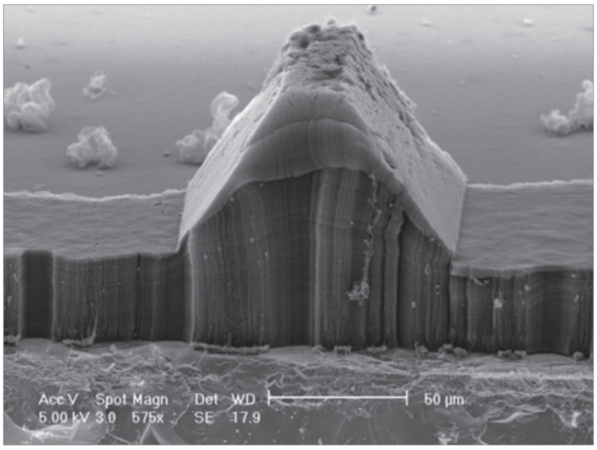
Ecological quality and energy conservation
The approach supports local, passive and non-linear response to environmental conditions. Local assignment of fibers and matrix promotes lower energy usage in buildings, blockage of radiative heat from sunlight, passive ventilation, improved occupant comfort, and space utilization. The materials offer an opportunity to reduce structural mass: CNT and polymer densities are approximately 25% of steel.

Economic performance and compatibility
Flat glass demand is estimated at 6.1 billion m^2 per year. In addition, buildings represent 39% of US energy consumption. These figures suggest a significant challenge for the development of sustainable solutions in façade elements. We demonstrate the notion of a breathable façade by controlling passive material distribution and potentially self-powered actuation using photovoltaic cells.

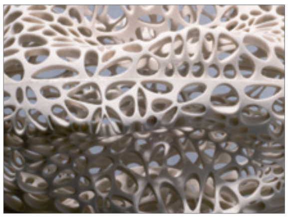
Contextual and aesthetic impact
The project offers the possibility to design, fabricate, construct and maintain a material architecture which is specifically assigned to accommodate particular measured structural and environmental conditions.
The project proposes a new aesthetic by which we may begin to think of buildings as organic entities, passively controlled, and responsive at material, structural and spatial scales.



3-D printed structurally- and environmentally-differentiated skin demonstrating the polyjet matrix technology.



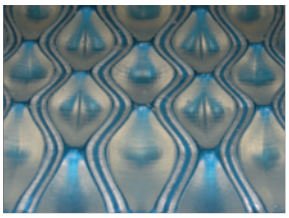
Mechanically shaped carbon nanotube rib for varying the structural cross section in micro scale.



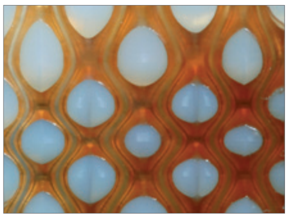
Open-cells skin prototype.

Closed-cells skin prototype.

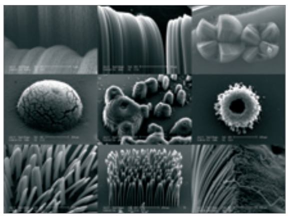
Curvature range in prototype.



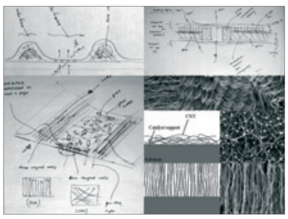
Mold prototype for porous skin.



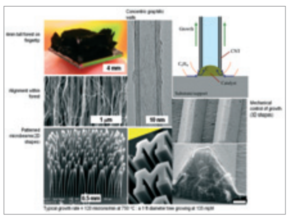
Composite porous mock-up.



Microstructural organizations.



Performance control mechanisms.



Growth control mechanisms.