Ray 3: The Performative Envelope

Marie Davidová, MArch.
marie.davidova@tul.cz
PhD research fellow at Faculty of Art and Architecture at Technical University of Liberec, Czech Republic
member of Collaborative Collective

(insert Figure 1 here)
Fig1. System Ray2 - Prototype (photo: Davidová 2013)

Ray 3 is a fully functional envelope that reacts to relative humidity and temperature of air. Based on the material properties of pine wood, it is allowing dry air into semi-interior, while closing in humid weather. This is due to the tangential section of the panelling that warps based on the different fibre density on the left and right side of the plate in low relative humidity percentage and high temperature. The envelope is meant for non-discrete architectural spaces, the spaces between exterior and interior. This design is a continuation of proposal Ray 2, The Performative Screen. Compare to the previous prototype of Ray 2, Ray 3 is a fully solving the performance, durability and is equipped with solved joinery and thermal, humidity permeable solution. Recent samples observations are leading to currently produced prototype that will close its panels at 75% relative humidity level, will be treated by salt water against biological decay and fastened by plugs attached at lower moisture content to the construction frame. The glass bubbles based thermal comfort solution, performing on reflection, originated from NASA technologies was selected instead of any kind of thermal insulation.
This partly trans-, partly inter-disciplinary project, next to the architects involving carpenters, forest and wood engineers, wood preservation architectural and ships historians, environmental engineers, insulation material engineers as well as climatologists or even marketing engineers, suggests future applications for built environment and reflects upon the past. However, the conclusion has to be taken that material based building industrial practice is far behind contemporary trends in different disciplines.

(insert Figure 2 here)
Fig2. System Ray2 - Prototype Detail (photo: Davidová 2013)

Introduction:

Wood belongs to so called 'self-x materials' described by Speck, Knippers and Speck as:

'…materials that show – typically in addition to their main mechanical or protective functions – intrinsic properties that enable them to react to external or internal stimuli or disturbances. Examples include: self-organisation, self-adaptation, self-healing and self-cleaning. Self-x materials are suitable for many technical applications and are currently becoming of increasing interest in materials and biomimetics research.' [1]

Its self-organisational capacities of warping related to humidity and temperature has been used in traditional Norwegian panelling over generations on solid wood in tangential section [2] and are explored today through Research by Design at academic institutions. The first published prototype of recent research realized by Asif Amir Khan at AA School of Architecture under the leadership of Michael Hensel and Achim Menges in 2005 was mentioned in Morpho-Ecologies publication in 2006 [3]. That time, it was a screen made out of laminated veneers. Since that time, the research under Michael Hensel at the Research Centre of Architecture and Tectonics at the Oslo School of Architecture and Design developed into experiments with ply-wood, also enabling a double-curvature [4;5;6] and the research lead by Achim Menges at the Institute of Computational Design at the University of Stuttgart leads towards creation of synthetic material of similar properties and exploration of solid wood, cut in tangential section [7], as proposed by the author for the durability reasons[8]. The ply-wood solution is durable but the results of LCA comparison of solid wood and plywood for Czech environment, performed for prototype of screen Ray2 by Vladimír Kočí and the author suggest, that use of solid wood is more sustainable, when it comes to given product in given location [9] Prototype Ray 3 (in fabrication) is following prototype Ray 2, explained by the author as follows:

'Ray 2 is wooden environment responsive screen system that reacts to changes in relative humidity. Based on the material properties of wood, cut in the tangential section, the system opens in dry weather thus airing the construction. Whilst in the humid conditions it closes, not allowing the moisture into the structure.' [10]

Cut from green wood, Ray2 prototype closes when already wet not in latter proposed 75%RH. When fully wet, the panels warp the opposite direction, while overlapping is not enough. The coming prototype uses the data from samples and the previous prototype observations. Programed for certain relative humidities combined with temperatures, it should also solve wood's durability issue and temperature permeability of 0,8cm thick panels.

Proposed for generating non-discrete architectural spaces, the envelope is designed to exchange the environmental conditions between exterior and interior when suitable. As shown on the example of the application on 'På Vei' project, designed by Collaborative Collective as competition entry for Sogn and Fjordane Muzeum and Depository in Norway, it has its meaning in Hensel's and Turko's proposal:

'… we propose grounds and envelopes as potentially correlated spatial devices that can give rise to approaches towards non-discrete architectures for the purpose of a spatially and performatively enriched build environment. As this shift is predicated on grounds and envelopes as a way of staging spatial organization and transitions, it involves careful consideration of sectional articulation and organization of such architectures, including the way in which these are embedded within their specific local settings.' [11]

A bit different approach is suggested by Reichert, Menges and Correa, putting their interest in '...opening roofs for semi-interior spaces, such as sports stadiums, and adaptive facades for fully enclosed buildings.' [12]

The Panelling:

The wooden layer:
Wood in tangential section generates so called cup when warping. [13] The project Ray is using this property to close the system in high humidity and open it in dry weather. The previous prototype of Ray 2 is closing at too high relative humidity level based on the fact that it was made from green wood. Plates, in the exact dimensions of the panelling, cut from one trunk in the period of March and April 2015 per two weeks have been observed to find out in which moisture content the wood should be cut so that it's narrow at 75% RH. It has been previously observed by the author, that the greener the wood is, the more instable it reacts. [14] The samples were measured from June to November 2015. While in June, it seemed that the plates cut in 18% moisture content (MC) were the most appropriate, latter it got stabilised on the samples cut in 22%MC that seem to be narrow from around 70%RH up and from around 10°C lower.
The samples were treated with salt water, as according to Jon Bojer Godal such wood can last for more than 200 years in dramatic environmental conditions of Nordmøre in Norway as sugar and amyl had been washed out (Godal, personal correspondence), and tested for its hygroscopicity performance. In Mari Sand Austigard's report from Mycoteam as for Røros Kommune, the samples of pine wood samples were sank in salt water for four month. [15] As my pine samples were 0,8cm thick, one week period was tested. The samples seem to sustain their hygroscopic properties such as warping and moisture content.
The wood properties has been widely consulted at the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences and with Jon Bojer Godal from Nordmøre Museum, Norway.

The Joinery:
The joinery is inspired by Erwin Thoma's Holz 100. Holz 100 is panel such as CLT but joined by oak plugs dried to 0% moisture content when fastening instead of polyurethane glue. [16] Pine wood plugs were dried in microwave oven and tested in natural environmental conditions on panelling samples by the carpenters from Defio, s.r.o. producing the prototype. Different radiuses in circular or oval shapes of plugs were tested in relation to different moisture content of the samples. At the end, the 0.8cm in diameter, circular shape was selected, as there never appeared cracks on 0.8cm thick panels' samples.

(insert Figure 3 here)
Fig3. Test of Plugs in Natural Environmental Conditions (photo Bouma 2015)

The Thermal Comfort:
The 'insulation' AZ ThermaCoat, based on the micro glass bubbles M3 from NASA technologies, was selected due to its thinness, sustainability and revolutionary concept. Generating great thermal comfort by having warm surface, the inner temperature doesn't need to be so high. In a way, it is not really thermal insulation as the concept works not only on low thermal penetration of the hollow glass bubbles (from 0.05 to 0. 26 W/mK at 0°C) that cover 90% of its ingredients, but most importantly, on their reflection of electro-magnetic heat radiation. The paint is vapour permeable and should keep elastic enough for warping of the 0.8cm pine wood board, therefore perfectly suitable for the task. It is applied in about from 0.5 to 1.0 mm thin layer that does not evaporate any chemicals, is harmless to health even when recycled and fully washable. The company AZ Tech, s.r.o. will apply their product directly on the prototype with their technology and will cooperate on the development of the product, solving its possible failures.

(insert Figure 4 here)
Fig4. Test of AZ ThermaCoat Paint (photo Davidová 2015)

Vision for Possible Application:

Non-discrete spaces, the spaces between the exterior and interior, are common in vernacular architecture also in colder climates [6; 11]. For the author, the "Onion System" is in particular attention. The Onion System is unclimatised, more or less ventilated, space between exterior and climatised interior, divided from the exterior by semi-permeable envelope. It could be such as veranda or winter-garden or working semi-interior space, as shown on the pictures from Norway. The upper example of Lillehammer farm seems to be equipped by open ventilation, compare to the lower image of city house in Tønsberg that has windows.

Similar proposal could be applied for example to competition proposal for museum of vernacular culture by Collaborative Collective [17] "På Vei". As the gallery artifacts were very sensitive to relative humidity and temperature, we proposed an onion system between the exterior, the unclimatised gallery space that receives warmth from the climatized neighbouring offices with facilities for researchers and administration in the ground of the sloping valley between two hills, lightened by fans. The gallery, and in accordance to it, also the attached spaces, is designed as path walk from ramps crossing the steep landscape between two mountains. The proposed envelope Ray3 would do the best for the unclimatised gallery space that has to keep stable humidity and lower temperatures for the wooden artifacts. While the screen evaporates the moisture absorbed at night, when the relative humidity is high; in the time of too dry weather, it doesn't allow exterior high humidity into the semi-interior space. This space receives heat energy from climatised rooms attached to the mountain or green roof on the other side, which secures temperatures above zero (or not too high during summer), when thermal comfort for visitors is generated by the semi-interior side of the envelope.

Such conditions might be also well suitable for residential buildings, introducing a different approach to 'thermal loss' and different temperatures for different purposes in the house as in examples from Norwegian traditional architecture.

(insert Figure 5 here)
Fig5. The Unclimatized Spaces, so called Onion System, in Norwegian Traditional Architecture (photo: Davidová 2015)

(insert Figure 6 here)
Fig6. På Vei, from up to down: axonometry, detail and sections (competition entry by Collaborative Collective 2011)

The concept was proposed to marketing specialists from InovaCentrum, CTU in Prague, where was the research conducted at that time, for support and cooperation on the research with the creation of author's start up. The marketing engineers, coming from different discipline, seemed to be open to the topic. Unfortunately today building market in the Czech Republic is not open to long terms visions and the proposal was rejected by civil engineering reviewers who concluded it as a façade system that just brings disadvantages compare to existing ones and is more difficult for production.

Conclusions:

Ray3 is taking the concept of Ray2 further by replacing the façade and roofing system by fully functional envelope for non-discrete architectural spaces, while both of the products will be offered on the market.
The new prototype (in production) will have a programmed performance when it comes to warping, durability and thermal comfort through the wood cut in 22%MC that will be treated by salty water and connected to frame by wooden joinery in 0%MC of circular shape 0.8cm in diameter and painted by environmental-friendly product with reflection of electro-magnetic heat radiation. Thus the project keeps its sustainability of the material and its future recycling.
The cooperation among the disciplines of architecture, carpentry, forest and wood engineering, wood preservation architectural and ships history, environmental engineering, insulation material engineering, climatology as well as marketing engineering was fruitful for the project that could not happen otherwise. The project was only facing the wall when it came to the engineers neither from research, nor from fabrication industry, but private practice related to academy as no fast income in accordance to building laws was seen. At the parts, where the cooperation is transdisciplinary, the co-working becomes more enthusiastic as each of the profession searches for the use of the research. However, not all the professions can be involved at such level, as some of the disciplines are represented based on consultancy of, for the experts, trivial information that is creatively used by other field of research. It was surprising to meet such interest from production side of the fabricators.
The speculations of future applications, as well as the historical references, sound promising but the approach of building laws and industry will have to change in order to accept such concepts. The square meters of built up area are considered valuable only when fully climatised. It is an unfortunate fact that even the non-discrete spaces of historical buildings are getting thermally insulated by thick layers of either toxic, or at least unsustainable materials, when renovated, disabling any exchange of the exterior with the interior. Such tendencies are even financially supported by the government of the Czech Republic. This leads to the conclusion that the practice of our profession is far behind contemporary trends of interaction through the boundary condition such as Internet of Things in Service Design. Furthermore, the presented research is just using primary resources, based on the bio-morphology through material's self-organisational capacities. More popularisation has to be done in the topic.

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