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SELF-FORMED MICRO ARCHITECTURE FOR SUSTAINABLE HABITATIONS

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ABSTRACT

This paper presents the relevance and the potentials of self-formed, small-scale architecture for sustainable habitations. Three aspects interact in one integrative approach to achieve a minimized impact on nature concerning the whole life time cycle of buildings: Firstly, the use of regional material only. Second, the philosophy of micro-architecture based on the approach of Richard Horden, and as a third point, self-formation to simplify the assembling process of wooden lightweight structures. Complex site-responsive geometries can be realised out of straight wooden members, which are bent into statically self-interlocking configurations reducing material- and energy-consumption to the maximum.

Keywords: Sustainability, Assembly, Self-formation, Lightweight Timber Structures, Micro-Architecture

Introduction

Autochthone rural architecture consists of local resources only. Farmers used the natural materials of the surrounding area of the building site to assemble their shelters. As a result, there was very little transportation and exclusively renewable energy necessary. At the end of the lifetime cycle, such buildings can be left to nature without any negative impact. The untreated materials can be reused for

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other projects, for recycling or bio-based products or at least as firewood.

Micro architecture – as defined by Architect Richard Horden – is based on the philosophy to reduce the use of material to the maximum and to create a close relation between humans and nature [1]. Architecture is understood as an instrument for living.

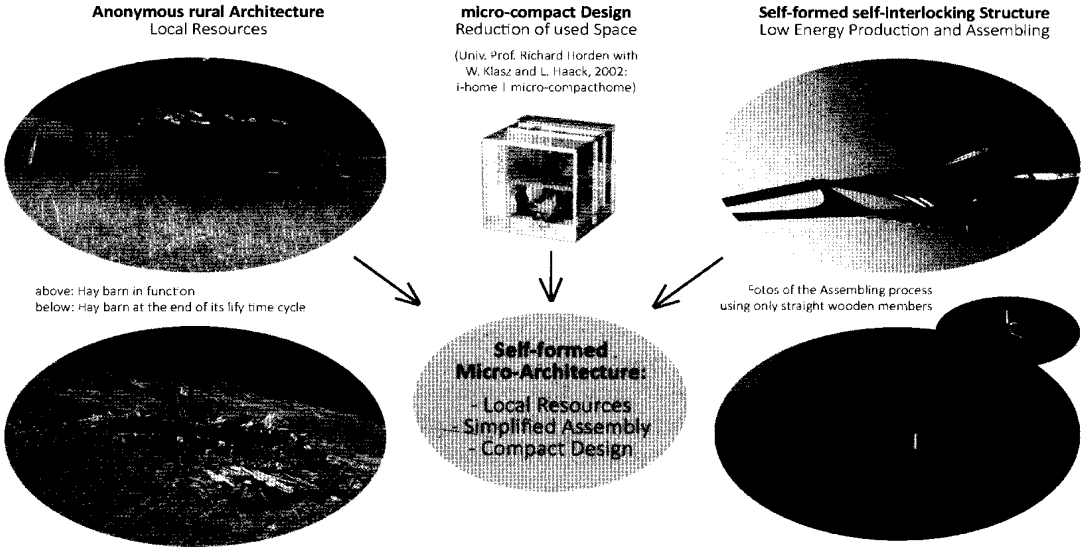

Figure 1. Scheme A of self-formed micro-architecture; Photos and collage by W. Klasz

As follows, one specific issue of self-organized forms is combined with micro-architecture: The bending behaviour of wood is used to simplify the installation process of statically self-interlocking lightweight structures. This method and the use of primarily local resources complement the philosophy of micro-architecture on a structural and sustainable level.

The case study *bird_04* is a research vehicle to study the combination and integration of the three issues, presented in the following three chapters. The second chapter deals with local resources due to autochthone constructions. Chapter number three focuses on the reduction of built space based on the design theory of Richard Horden. Chapter number four describes the method of self-formation to reduce material- and energy-consumption in the production and the

assembly of curved wooden habitable structures. Chapter five focuses on the balanced integration of the previously discussed issues to achieve sustainable small-scale habitations – described with the term *self-formed micro architecture* (figure 1). Beside its direct positive influence on nature, this new strategy may reduce rural flight by offering high quality sustainable buildings meeting the emotional and technical demands of contemporary people wanting to lead a sustainable life in a close relation with nature.

Local Resources for Autochthone Constructions

Worldwide autochthone constructions were primarily built out of local resources. Ancient rural alpine buildings consist mainly of local wood and local stones intelligently joined together without any use of metal. On the other side of the world, the Polynesian boat – including all details and add-ons like the woven sail – has been optimized in its functional form and construction over thousands of years also using local materials only. One reason why many environmentally critical materials are used is the aim to reduce the cost of intensive labour for mass production ignoring negative effects of the materials on nature. Contemporary digital drawing- and production-tools allow again refocusing on this ancient knowledge of working with exclusively local materials because labour intensive details can nowadays be realized automatically by e.g. CNC-cutting machines. The important point is not to overestimate these new achievements but to implement the techniques in the ancient knowledge. This would allow building in equilibrium with nature – using the nature inherent qualities of wood in a contemporary way.

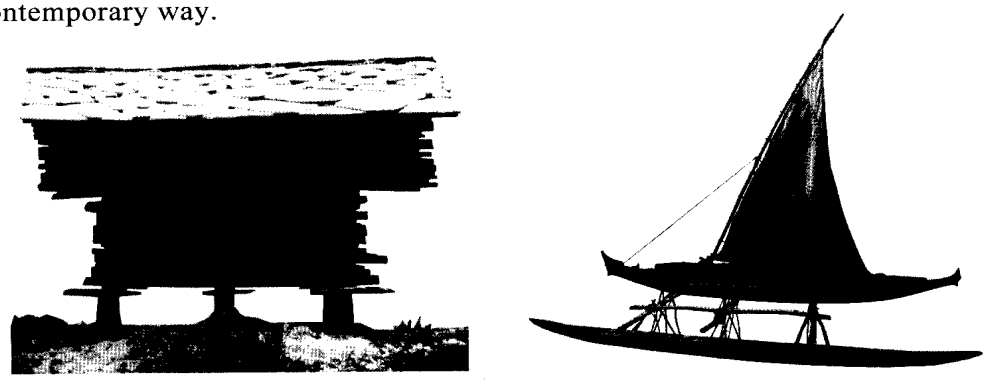

Figure 2.
Autochthone alpine building and a representative ancient Polynesian boat.
Both constructions use local materials only; Photos W. Klasz

These autochthone constructions have been one major source for the research presented in chapter 4, the case study *bird_04* [2]. This new habitable lightweight construction is structurally based in-between a boat and a building. While the

alpine architecture – lifted of the ground because of moisture and mice – works with self-weight to resist wind forces, the Polynesian boat is woven together out of several wooden members with flax in order to move securely over thousands of miles. The case study *bird_04* touches the earth lightly as the ancient alpine architecture does, but it uses flax for the assembling of its wooden members – an ancient Polynesian boat building connection technique (see chapter 7 - perspective). *Bird_04* is based on the concept to use local wood, which has to be individually tested in its bending- and load bearing-behaviour in order to adapt the possible scale of the building and the appropriate proportions of the components. For example in New Zealand the appropriate local material is bamboo, in Austria it can be larch using bone glue to get the necessary lengths of boards without huge knots. The choice for the selected local wood has to be done by evaluating the energy necessary to get the prepared components to the building site.

Reduction of Built Space Due to Richard Horden

"We feel more free, when we have less" [3] was said by Richard Horden explaining that humans don't need a huge living space nor many products or furniture but rather a close relation to nature. This attitude to life leads to the design theory to reduce built space and material-consumption to the maximum.

The *i-home* – further developed to the so-called *micro compact home* – is the result of iterative experimental research, done at the institute of architecture and product design at the Technical University Munich [4]. Within a cubic volume of only 2,66m side length, it presents highest living quality and design. It proves the concept that living quality and reduction of space can merge.

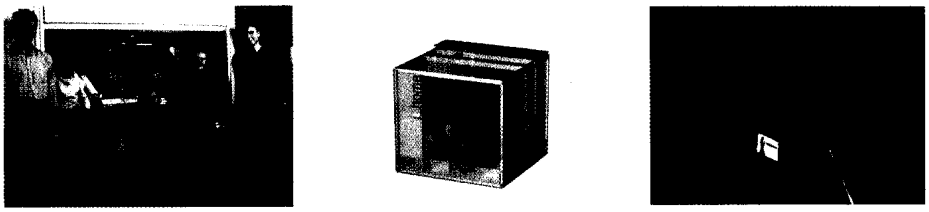

Figure 3. *i-home* mock-up design team under R. Horden: W. Klasz (middle), Lydia Haack (right) and Students | Rendering of the spatial concept | Realisation; Photos: http://www.microcompacthome.at

Reduction of space can simultaneously reduce material-consumption and the use of building land. With 2.3 tons, the weight of the micro compact home is similar to a large car and it can be installed easily as one unit by a crane (figure 3).

Self-Formation to Reduce Material- and Energy- Consumption in the Production and the Assembly of Curved Wooden Structures

"The most sustainable material is the one we don't use" was said by Knut Göppert at the conference *Structural Membranes* in Barcelona in 2015 [5]. Co-leading the engineering office *Schlaich Bergermann und Partner* he stressed the importance to improve constructions in the sense of reducing material-consumption as much as possible.

There are several approaches to reduce material on a structural level. As mentioned in the introduction of this paper the concept of Walter Klasz is to use the bending behaviour of wood to simplify the installation process of statically self-interlocking, lightweight structures of long-term load bearing capacity. Figure 4 presents the new assembling approach: The membrane-like wooden surface is not realised by tensioning the material (like the textile membrane in the upper part of the figure) but by bending its members while simultaneously bending the boundary conditions – respectively the initially straight tetrahedron in the spatially curved form. In the final construction, the continuously reducing bending force of wood has no negative impact on the load capacity of the chosen configuration. Whereas in *Active Bending* material fatigue is regarded as a disadvantage [6], this new concept takes advantage of the only temporarily strong bending force of wood: At the beginning – during the assembling – the bending force is important to enable the largely self-organised form-finding process. In the end, in the statically self-interlocking configuration there is no bending force necessary any more: The arches of the boundary condition of the wooden membranes have only axial pressure forces [7] and the thin wooden surfaces themselves have only tensile forces – acting like membranes.

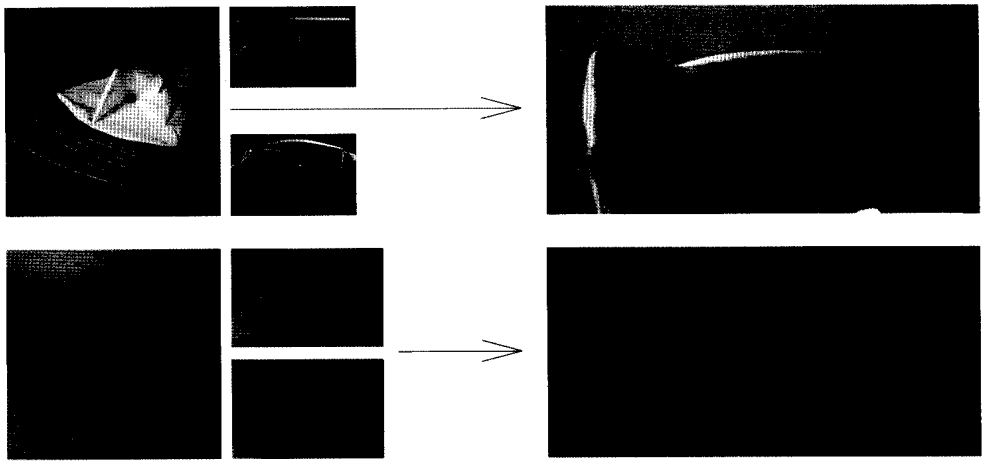

Figure 4. Comparison of the self-interlocking configuration of textile membranes and bent wooden members (above) with the bent only wooden configuration based on the same static principle (below)

Whereas the concept shown in Figure 4 (upper part with membrane) was realised as a 150m³ huge research lab to produce snow in a natural, more sustainable way than the conventional snow guns [7], the following case study *bird_04* presents an architectural application of the new bent-only, self-interlocking assembling concept. The complex curved structure is formed and assembled out of straight wooden members without any scaffold or pre-curved element – except the relatively small part C (figure 5).

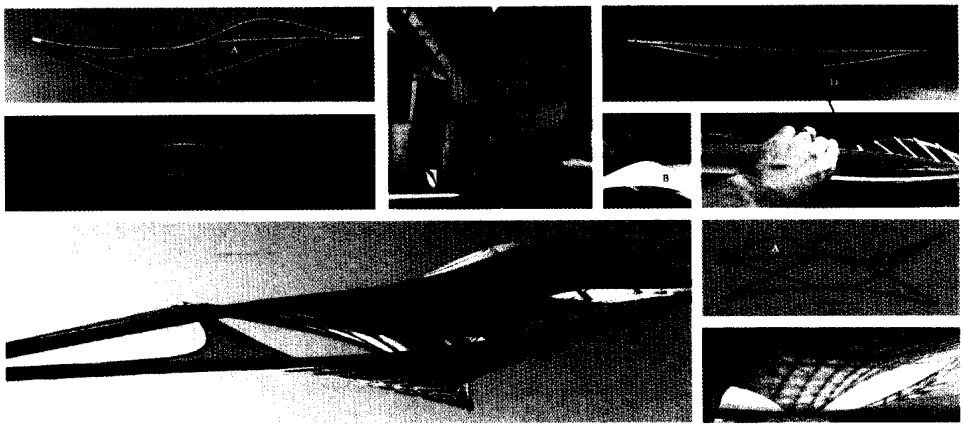

Figure 5. Case study *bird_04, developed* by W. Klasz at Unitec (NZ)

The construction consists of two primary forms: The first, bird-like looking form needs one temporarily member in the middle (figure 5-A), which can be removed as soon as the closed surfaces are realised. The second, primary form consists of only two self-interlocking bent wooden members. All four remaining members of the two primary forms become part of the surfaces of the final configuration in a way that they merge structurally and aesthetically with the building. The four side openings are realised through two primarily straight members each (figure 5 – D) – fixed with loose-jointed details to the four ends of the primary forms. The angles of the openings are self-organised by the emerging forces during the assembly of the wooden surfaces. The construction is lifted off the ground at three points – chosen individually according to the site conditions. To spread the three point forces into the statically self-interlocking construction, an offset wooden layer is comfortably realised at the inside of the already erected building to provide an individually adapted sandwich-construction – matching the heights with the calculated shear forces. Depending on the climate-conditions of the building site, such a sandwich-construction can be done for the whole surface to provide protected space for insulation with appropriate local material like sheep wool or wood fibre and to achieve a high-end inside wooden skin.

Balanced Integration of the Three Aspects

In the context of autochthone architecture and life style, sustainability can be described as the nature inherent art to live and to build in balance with nature. In our globalized world, many natural cycles are in disorder facing us with major problems such as global warming, migration from the land to the cities and sociocultural conflicts. In his book *building the future,* Ulrich Pfammatter points out the importance of interdisciplinary schools of thoughts to develop sustainable strategies [8]. While the previous chapters of this paper discuss the three topics local resources, reduction of built space and self-formation, this chapter focuses on the approach on how to integrate these aspects in the field of small-scale architecture.

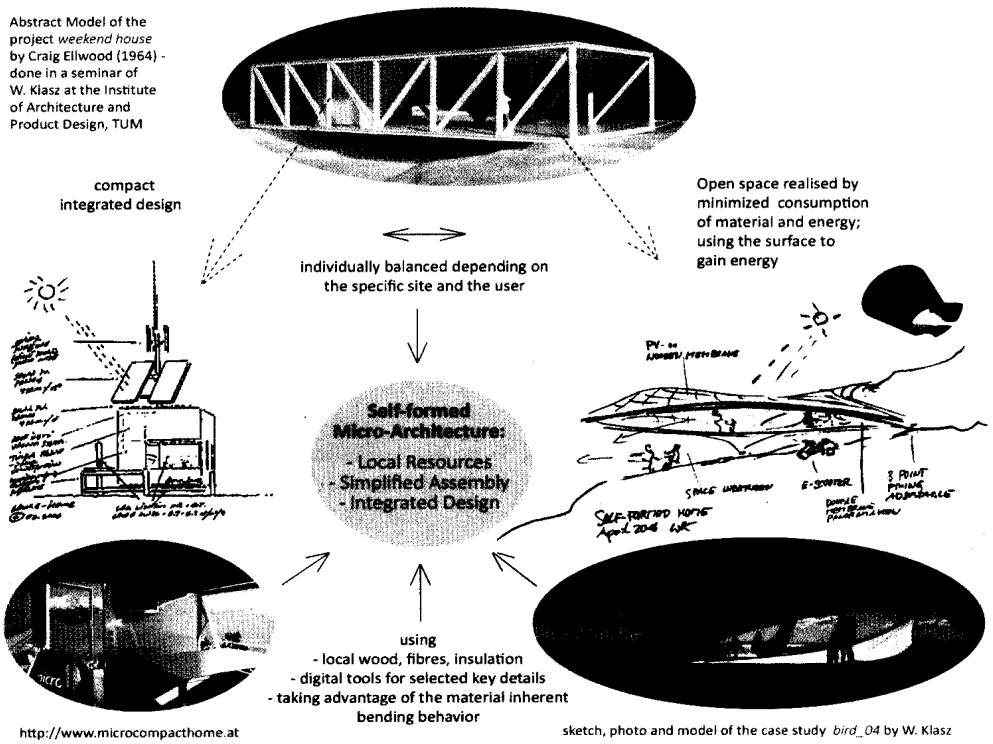

Figure 6. Scheme B of self-formed micro-architecture; Collage by W. Klasz; left side: http://www.microcompacthome.at; right side: Sketch and Photo W. Klasz

The project of Graig Ellwood from the year 1964 – shown on the upper part of figure 6 – represents exemplarily the deep desire of so-called modern society to live close to nature. He has designed this structure as a weekend-house. Since approximately ten years, digital communication has advanced in a way that an increasingly amount of people perform their modern professions from their homes. Architecture can support this positive trend to avoid the environmentally critical "weekend-culture". Instead of working in the city and relaxing at the weekend in the country, people can stay in the country most of the time – enjoying a balanced life with their families reducing built space, material-consumption and energy for transport. Self-formed micro architecture provides open architectural space of a minimal use of energy- and material-consumption. Functions like a separate compact working space, body hygiene and cooking facilities are designed as an integrated compact part of the architecture. As shown in figure 6, the curved waterproof roof surface integrates a flexible PV-foil [9], which can be combined with an evaporative cooling system to achieve an energy-self-sufficient system. The right

balance between local resources (except PV-foils and installation technique), compactness and open space is found in a self-organised interdisciplinary planning process focusing on the prioritization and the design of the boundary conditions [10].

Summary

This paper presents an alternative strategy to develop sustainable small-scale habitations based on three principles:

- Reducing built space by compact integrated design
- Providing open space of minimal energy- and material-consumption
- Using primarily local materials and contemporary tools

I summarize the self-organised balance of these three principles with the term *self-formed micro-architecture.* Structural invention determines the character of the design exemplarily presented in the case study *bird_04*: Straight wooden members out of local wood are assembled easily by bending them at the site taking advantage of the long lasting load capacity of hybrid configurations consisting of pressure-bending and tensile structures statically self-interlocking each other.

Perspective

Ongoing research focuses on two areas: Firstly, there will be an experimental study in a larger scale to prove the simplification of the bent only assembling process. Flax will be used to weave the straight wooden members at the CNC cut joint holes to the curved configuration with very little forces - avoiding any use of not putrescible materials. Secondly, limits and freedom of the behaviour of double curved wood – merged with photovoltaic-foil – will be investigated and optimized for full-scale realisations.

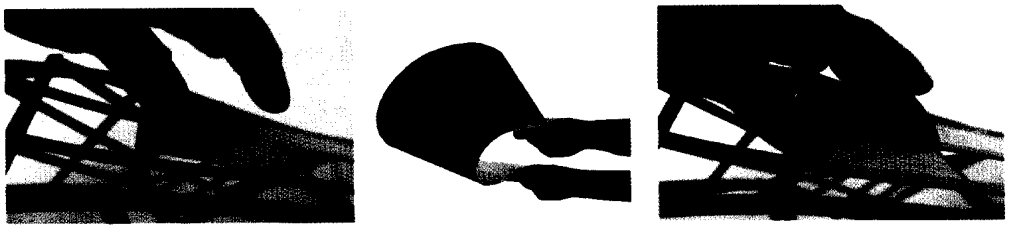

Figure 7. Scheme of the structural wooden membrane integrating flexible photovoltaic foil; Photos of the model by W. Klasz;
Photo of the foil by www.sunplugged.at

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