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A New Generation of Structures

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Abstract

In recent years, the necessity of using renewable resources and sustainable solutions in the building sector has become obvious, and interest in timber as a building material has revived. Novel timber-derived products, such as massif block panels, have emerged and the use of such products is spreading. The IBOIS research concerns the development of a new generation of timber constructions, made out of innovative timber-derived products, derived by applying textile principles on a building scale. It aims at the unprecedented exploration and study of timber related structures and their structural analyses within a framework integrating the mechanical and structural principles of textiles. The validity of this approach is based on the fact that both, wood and fabrics, are fibre-based tissues. Since timber can be viewed as a fibre-derived product it follows that the analogy between micro scale fibre structures and timber-derived wooden structures can be explored at micro-and macro-scale. The concise observation of existing textile techniques and fabrication methods combined with investigation lines such as textiles, mathematical descriptions, study of timber rib shells, woven wood fabrics, architectural and structural applications, digital modelling, scalar relationships, structural analysis and optimisation processes lead to a new family of timber constructions based on the logic and principles of textile fabrics.

Keywords: timer constructions, shell structures

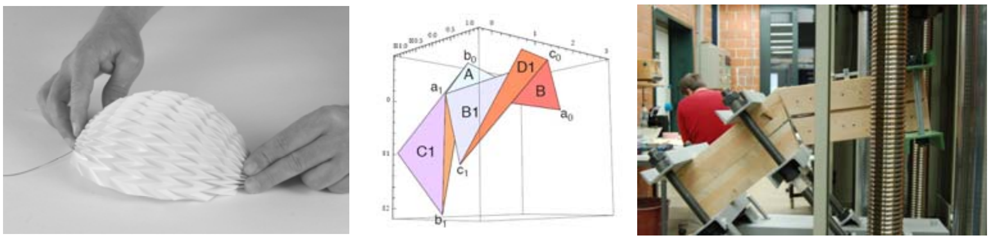

Figure 1: Origami folded plate structures

Figure 2: Digital chain and automotive production of folded plate structures

Figure 3: Shell structures made out of timber block panels

Figure 4: Studio Weinand: woven structures

1. Introduction

Architectural production in recent years has been heavily focused on the digital outcome. With the growing development of CAD (Computer Aided Design) tools architects have tried to integrate those new digital tools into their conception. For instance, one such conceptual trend has become known as “Blob-architecture”. But the way the architects use the new digital tools has until now more to do with a role of virtual representation than a role of fabrication.

On the civil engineering side, the structural productions derived from the new output of such digital tools have yet to address many formal issues that have arisen from the digital design revolution. Civil engineering structures remain relatively conservative. New research concepts such as ‘structural morphogenesis’ have emerged recently from within interdisciplinary research environments, but the implications for physical and structural investigations that constitute an active part of the form-finding process have not been addressed yet and need to be explored if such digital tools are to realise their true potential in the fields of architecture, design and civil engineering.

The research being undertaken in the IBOIS Laboratory aims both to explore and to challenge the traditional relationship between engineering sciences and architectural conception. It is ultimately concerned with questions of construction in “real” space, as perceived and used by society. Therefore we took right from the beginning a quite different and unique point of view, devoting our attention to exploring in depth how materialization and physical aspects of “real” structures are related to their representations in the digital world. We seek to accomplish construction solutions, which could be successfully disseminated throughout a construction market, meaning that the realisation of unconventional structures at a reasonable cost must be an obligate goal. Developing specific, specialised IT tools appears to be increasingly necessary to pursue the many new questions arising from our ongoing research and a significant part of our approach is concerned with generating and linking together software which works on various levels, from tasks such as the creation of complex shapes to controlling and sizing finite elements, as well as to operate computerised numerical control machines (CNCs).

2. Timber constructions

Timber is usually thought of as a “traditional” material, and this is an advantage when it comes to socially legitimating more advanced research into complex shapes and free-form surfaces. Taking an interest in complex geometry from a (timber) construction point of view, instead of only a morphogenetic point of view is a fundamentally different approach than blob architecture’s “stylised mode” phenomena and the two should not be confused. Numerous recent buildings designed in the formalistic mode of “blob architecture” show a total lack of awareness of the problem of sustainable development. This can be seen in the choice of construction materials and in how difficult it is to maintain their energy needs, as well as the high cost of material handling. In contrast, timber as a raw material for construction purposes certainly has a great future in the face of global sustainable development challenges.

In recent years, the necessity of using renewable resources and sustainable solutions in the building sector has become obvious, and timber has been promoted to the centre of interest again. New timber-derived products -such as massif block panels -are emerging and the use of such products has largely increased over the past years. Their advantages are well-known as far as low energy consumption for the production of building components (planks, boards, beams, etc.) is concerned, and research into welded timber could, because of this, lead to extremely interesting industrial opportunities. Savings in time and energy consumption are also notable in timber structure assembly and dismantling processes. But we have also observed that the challenges of sustainable development also concern the issue of architectural form. So a fundamental challenge is: How can one integrate a process of formal and technological innovation within a perspective of sustainability?

A possible solution may lie in the rethinking of construction techniques and the expansion of the formal repertoire linked to the use of wood, while affirming the “traditional” values of timber construction. Together its technical, aesthetic and environmental appeal can contribute to encouraging an increase in the use of this material in contemporary construction and set the context through which the present paper’s interest should be understood.

The IBOIS research work links the three areas -‘architecture’, ‘civil engineering’ and ‘timber’ -and proposes to develop further the interdisciplinary research spirit. The purpose of the IBOIS research is to open the way to a new era of innovative timber constructions and timber construction techniques. It sets out to initiate the unprecedented exploration and study of timber related structures, their structural analysis and how the principles of origami and textiles can be applied to their design. This approach is based on the fact that both, wood and fabrics, are fibre-based tissues and we propose to investigate the analogy between micro scale fibre structures and timber derived wooden structures on multiple levels.

3. Collaborative approach

The collaborative approach of architects, civil engineers, mathematicians and computer scientists in the IBOIS team as practiced today, proposes a unique blend of skills and enables us to reveal hitherto unsuspected potential for novel construction applications of a renewable resource. Our strategy of treating morphogenetic aspects and structural aspects on the same level is likely to produce exceptional structural solutions.

The application of origami and textile principles in the context of timber creates a fascinating association of contrasting physical phenomena, namely rigidity (civil engineering structures) and smoothness (textiles). It is of more than anecdotal interest to relate that for one of our first woven prototypes, we were unable to measure its ultimate load-bearing capacity because the prototype’s structure would always slip away and deform under the load and consequently could not been destroyed. This ability of a structure to adapt is a highly interesting novel property and can be further explored (for instance in terms of a parameter known as “dimension at Ultimate state”).

Furthermore the aspect of the use of a large number of small pieces which interact in timber textile fabric will be a factor of major importance in order to determine the probability of failure of the structure as a whole (global failure); The anatomy of timber as a natural, fibre-structured, composite should be able to reach higher structural performances when local weak points can no longer affect global stability. This consideration has lead in the past to the invention of plywood. Since plywood is made out of several layers of timber sheets, the sum of those layers is stronger and more rigid or subject to less local failure than the same among of materiel taken out of one naturally grown piece of wood. In the case of plywood, the random existence of local nods plays a less important role since they are covered with stronger layers. Taking advantage of this same principle on another scale, we intend to compensate such randomly appearing weak points – contained in a given timber fabric -by a multitude of adjacent and slightly more resistant members who will sustain each other as a fabric using their woven quality and thus not more working independently. This will raise the parameter characterizing a value we call “global failure ratio”. A specific performance factor might be derivable, which takes into account the natural anatomy of timber, which is a disadvantaged construction material in terms of the coefficient of material (γm) defined in Eurocode 5.

In addition to the woven aspects, timber fabrics performance may be assessed on the following levels: since a basic module can be repeated for an overall structure, a tremendously wide range of combinations can be reached and each of them can be optimized. The basic system for producing interwoven elements allows to add or to adapt every single element of a given system in a quite free way; thus we expect to be able to generate novel structures with highly specific performance profiles, characterized by lightness and robustness in an equal manner. Such constructed materials would become fascinating both for their architectural and spatial qualities in terms of light transmission and deceptively flimsy structure.

By applying textile principles on timber structures the overall performance of timber as a material in general will be improved.

Figure 5: IBOIS prototypes of woven structures

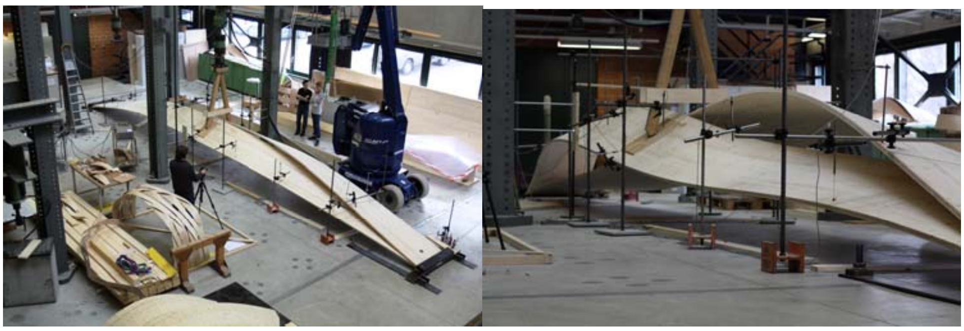

Figure 6: IBOIS test prototype

6. Conclusion

A project to design a new generation of timber-derived structures in which textiles principles have been applied at the building scale, IBOIS aims to promote efficient use of a renewable material with appealing design; as for example in the construction of buildings with a higher seismic resistance. I expect it to lead to the establishment of an entirely new category of timber-derived products and timber applications in construction and to contribute to the improvement of the aesthetic, structural and environmentally sustainable use of timber for public and private buildings on both the European and worldwide scale.

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