DOI: 10.24904/footbridge2017.10515

INTELLIGENT FABRICATION - DIGITAL BRIDGES

Matthew TAM
Architect
Bollinger + Grohmann
Vienna, Austria
mtam@bollinger-grohmann.at

Louis BERGIS
Civil Engineer-Architect
Bollinger + Grohmann
Paris, France
lbergis@bollinger-grohmann.fr

Dragos NAICU
Structural Engineer
Bollinger + Grohmann
Berlin, Germany
dnaicu@bollinger-grohmann.de

Klaas DE RYCKE
Civil engineer-Architect
Professor, ENSA-Versailles
Partner, Bollinger + Grohmann
Managing Partner, Bollinger Grohmann Sarl
Paris, France
kderycke@bollinger-grohmann.fr

Adam ORLINSKI
Architect
Bollinger + Grohmann
Vienna, Austria
aorlinski@bollinger-grohmann.at

Ewa JANKOWSKA
Architect
Bollinger + Grohmann
Paris, France
ejankowskakus@bollinger-grohmann.fr

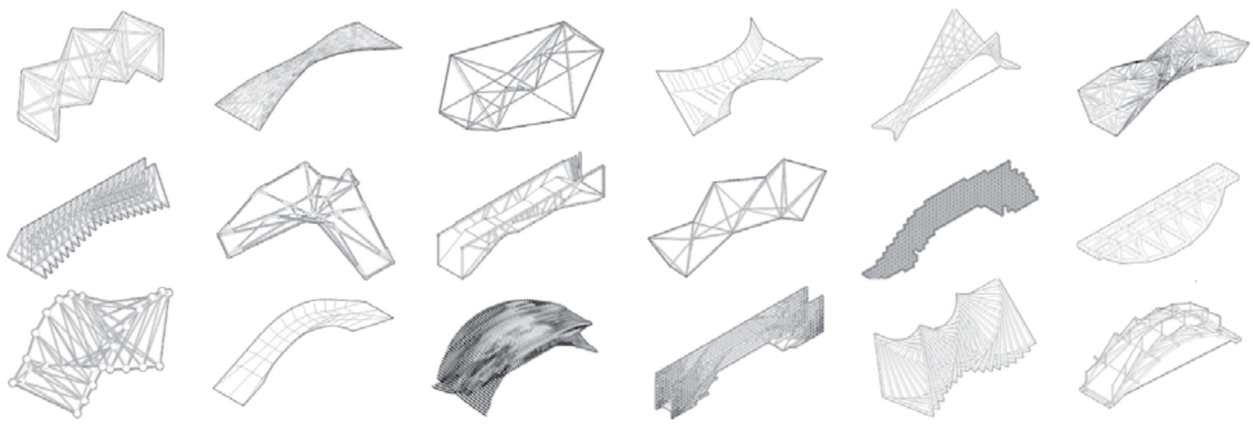

Fig. 1. Bridge designs developed over the two week workshop

'Intelligent Fabrication – Digital Bridges' was a two week long intensive workshop at the Ecole nationale supérieure d'architecture de Versailles with students from the third year Bachelor's course. The students investigated bridge designs in collaboration with architects, engineers and fabrication experts using parametric tools such as Grasshopper and Karamba. Paired with computation techniques in topological and geometric optimisation, students were able to develop comprehensive footbridge proposals spanning ten metres. Students examined the basic structural systems and types of bridge design: beam, arch, truss, suspension and cable stayed bridge and drew inspiration to develop their own concepts. Three of the bridge designs were selected to be constructed at full scale, while others developed their proposals at 1:10 and 1:5 scale using computational tools like genetic algorithms, topological optimisation and node design.

The overall idea of the workshop environment is to show students that several ways of design approach are possible which all can add value to design. All the design steps of physical modelling, physical construction constraints, and structural aspects, digital modelling or sketching are considered non-hierarchical in this approach and have mutual beneficial aspects and overlaps. One valuable insight with respect to parametric workflows was that, on the whole, the creativity of the students was significantly aided by learning to set up parametric geometric models for the bridge designs. Tools such as Karamba present a perfect pedagogical tool given the possibility to explore a large number of structural and topological possibilities necessary.

'Hyperbolic Paraboloid' applies the geometry as the basic form of the bridge, presenting a unique interpretation of the standard bridge. This shape is a double curved, grid shell based on a ruled surface geometry imitating compression and tension forces in a beam on two supports. Analysis was performed using Karamba with a particular focus on the asymmetry of the hypar in elevation. 'Domestical Wildness' interprets a conventional truss bridge by displacing the diagonal members to create two irregular trusses. Paired with optimisation algorithms, a vast array of design options were generated to meet a specific set of criteria, from which an informed design decision were made. The fitness criteria to meet included minimizing the maximum displacement of the structure and the length of timber struts. As no single best solution exists when performing such optimisation processes, many solutions which are optimal in one respect are produced and one can decide from the various members of the pareto set produced by the optimisation engine. The third bridge Triangle Reciprocal Structure is a play on the standard Da Vinci bridge using triangular module and with duplication and rotation to create an interesting modular system that is self-supporting. Figure 2 & 3 depicts the completed bridges and their corresponding structural analysis in Karamba.

Fig. 2. Constructed Bridges - Domestical Wildness, Triangle Reciprocal Structure, Hyperboloid Paraboloid

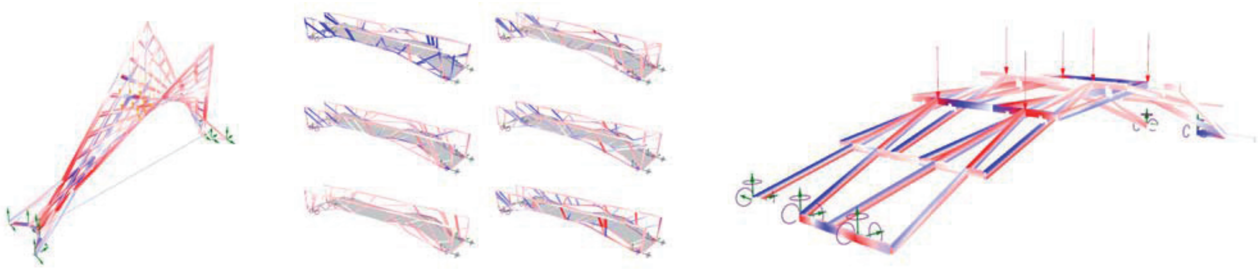

Fig. 3. Hyperboloid Paraboloid - Constructed Bridge; Analysis in Karamba showing the utilisation

The remaining groups were tasked in the second week to further develop their initial bridge concepts with topological and geometrical optimisation, further calculations or detailed construction techniques. Some focused on designing unique joint connections between the timber elements with 3d printing, whilst others transformed their originally frame bridge designs into surfaces and looked at dissolving them through topological optimisation. Groups that were primarily engaged with modular systems looked towards optimising their structures according to structural performance and following bidirectional evolutionary structural optimisation (BESO) techniques to reduce material. This design starts rather from a detail and through additive/subtractive design methods get to a bridge typology. Figure 4 presents a range of the different techniques from 3d printing to various topological optimisation techniques.

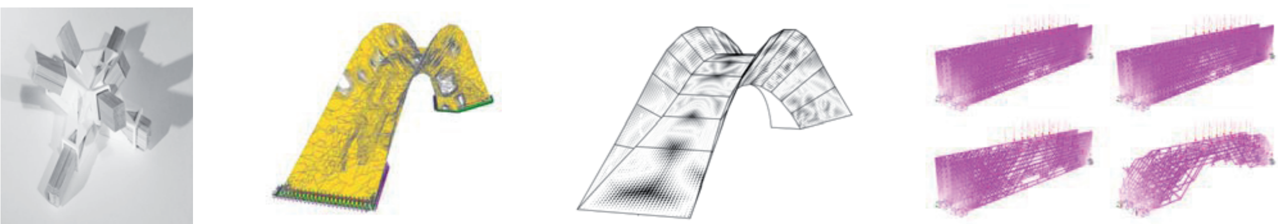

Fig 4. 3d Printed Joint designs; Topological Optimisation of surfaces; Topological Optimisation of Beams