THE HABITABLE BRIDGE: EXPLORING AN ARCHITECTURAL PARADIGM THAT COMBINES CONNECTIVITY WITH HABITATION

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ABSTRACT

The research focuses on bridges, as architectural gestures whose aim is to connect the two sides of a natural or artificial obstacle (river, gorge, highway). More specifically, the paper investigates the characteristics, design and typology of a habitable bridge that, besides being merely a passageway, it accommodates different uses and offers "habitation" experiences that relate to its context. Bridges, from antiquity to present times, have often been landmarks, both when located in the urban context as well as in the natural landscape. This research explores the concept of connectivity in its architectural manifestation, taking into consideration the spatial interpretation of movement and stop, as well as the geo-environmental parameters that inform the design process. The research methodology involves the study and analysis of existing habitable bridges from the international architectural scene, extracting the design principles, morphogenetic mechanisms and programmatic requirements. A habitable bridge has a manifold function: to connect and to transform the existing urban or suburban landscape. Therefore, it combines the concept of connectivity, movement and habitation which has a direct repercussion on the design and typologies of the bridges. The research concludes in a design brief that was further developed into an undergraduate design studio agenda. The students employed digital tools to experiment with geometric and topological transformations with the aim to design and deliver an architectural proposal of a habitable bridge which combines connectivity with habitation. The paper will present examples of habitable bridges that employ digital media not merely as a means of representation and visualization, but as a morphogenetic tool that integrates design thinking, programme, architectural and urban design.

Keywords: Bridge design; architecture; urban design; digital media; public space

INTRODUCTION – BRIEF HISTORY OF BRIDGE CONSTRUCTIONS

A bridge is a man-made construction and very often also a concept, that refers to the crossing over an obstacle, or a large span. Bridges are often found over rivers, valleys or cliffs, to connect one side with the other, enabling passage over the obstacles. In current days we often encounter bridges connecting buildings, or over motorways, to enable safe crossing of the pedestrians. Tracing back the history of bridges, the origin of their existence and typology remains unclear. It is believed that the first bridges were created by nature, when a fallen tree or log would fall across a river, or a group of rocks that would fall off a nearby cliff, would act as a step stone to enable crossing. Natural events have become a

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source of inspiration for early civilizations, and the basic tree trunk over a stream is believed to be the first type of simple beam bridge. Bridges were already being constructed in Mesopotamia during the ancient times, and across the years, the development of their form structure and material was refined. Tropical and forest regions with dense vegetation, it is believed that gave rise to suspension bridges, as they were simple rope constructions, which have evolved from vine and creeper. The first rope bridges were used to connect villages over deep gorges, some of such constructions are still present in Peru and the Himalayas. It was much later, around 4000BC, that the Sumerians started building with adobe and bricks that gave rise to arched constructions. It was much later that the arch constructions were evolved by Greeks and Romans. Herodotus refers to a bridge built across the Euphrates around 600BC, which is the first written record of a bridge construction (Ryall, Parke, and Harding 2000). Greeks were mainly using simple post and lintel constructions, while the Romans were those that mastered arch construction, they are regarded as the pioneers of bridges, as the Roman arch is considered to be among the greatest achievements of Roman architecture and technology. Both Romans and Chinese realised early on the ephemeral character of timber bridges and they were the ones to initiate stone construction. It was not until the middle ages that the first inhabited bridges appeared, the Ponte Vecchio in Florence, built in 1345 is probably the most well-known example. The London bridge is another well-known example of covered bridges that incorporated commercial uses. The Renaissance also witnessed the erection of remarkably engineered bridges that became landmarks and defined the place around them. One of the most significant examples of that era is the Rialto bridge in Venice. During the 18th century masonry arch bridges were believed to reach perfection, and this also coincided with the founding of the first school of bridge engineering in Paris in 1747. It was after the Industrial revolution that timber and stone were replaced by cast iron, and evidently this led to a whole new era in bridge construction, which continues to be present in contemporary designs of our times. The tradition for habitable bridges like Ponte Vecchio and London bridge was significantly declined after the 19th century (Chen and Duan, 2014) however there are still few examples that emerged later and in modern times. It is not a frequently encountered architectural paradigm, however it is seen as a unique opportunity to combine habitation with movement, and therefore a hybrid architectural archetype that affords itself to exploration and design experimentation with a strong impact on the place where it's located.

MAIN BRIDGE TYPOLOGIES AND THE QUEST FOR UNIQUE DESIGNS

Bridges mainly fall in 3 generic typologies, depending on their form and structural principle, therefore we can distinguish between beam-type, arches and suspension bridges (Gade 1972; Ryall, Parke, and Harding 2000). Combinations of the above have given rise to trusses, cable-stayed, cantilevered, tied-arch, frames and moveable spans (Fernandez Troyano 2003). Contemporary engineering is moving towards new construction methods and typologies, which employ digital tools for the design and construction. Therefore bridges made with drones (Pietri 2017), 3D printers and robots (MX3D 2018) give rise to new emergent formations that push the boundaries of the established knowledge towards new building methodologies and formal vocabularies.

With regards to the aesthetic value of bridges, there is no straightforward definition of the aesthetic appreciation and visual beauty of a bridge, it may relate to the proportions, the material qualities we perceive, the shape, colour and texture. *"Certain arrangements in the*

proportion of shape and form result in pleasurable sensations" (Bennett 1997). As Fritz Leonhardt, one of Germany's leading bridge engineers explains, referring to the aesthetic value of bridges, *"The question of aesthetics cannot be understood purely by critical reasoning"* (Leonhardt, 1984), he attempts however to provide some definitions, alluding to the Pythagorean proportions, but also highlighting the importance of observation of the nature. Torroja believed that the aesthetic pleasure from a built construction is associated to the knowledge of the rules of harmony (Miret 1958).

Henry Tyrrell in his 1912 treatise on the Design on "Artistic bridge design" provides some guidelines with regards to bridge aesthetics, he claims that bridges are considered beautiful when they fulfil the following requirements (Tyrrell 1912):

1. *Conformity with environment*
2. *Economic use of material*
3. *Exhibition of purpose and construction*
4. *Pleasing outline and proportions*
5. *Appropriate but limited use of ornament*

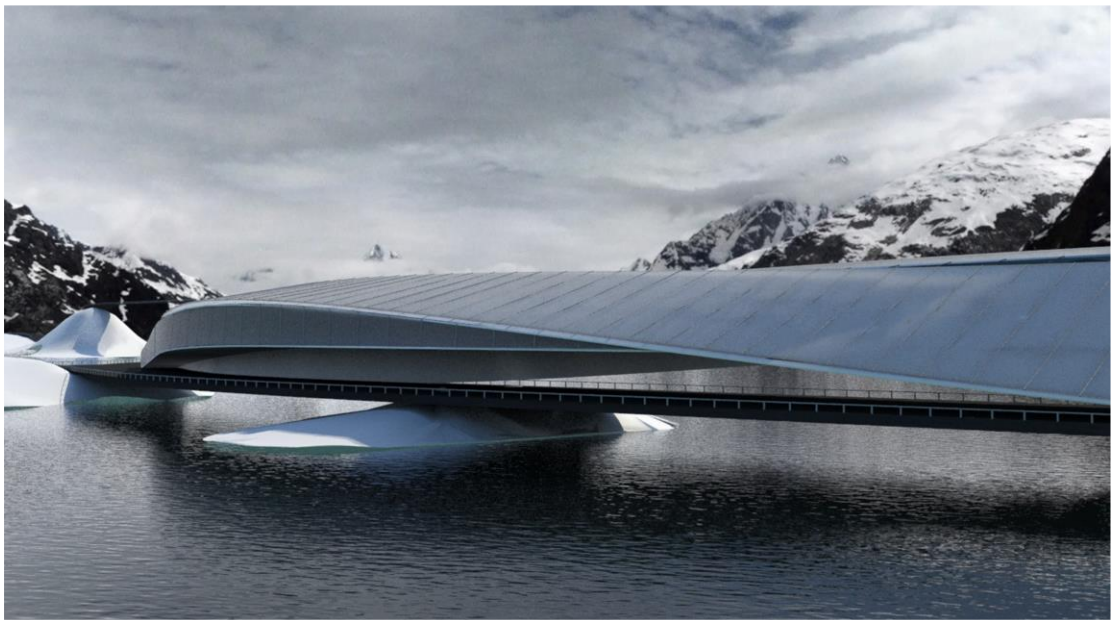

Figure 1: Bridge concept on the Atlantic Ocean Road in Norway by students Argyrou and Papoutsi

The influence of bridges to our culture is of great importance, as they have enabled travelling and connectivity, and therefore the exchange of products and culture. Bridges have become important landmarks and have always acted as hubs for commerce and transportation. They define the are around them in new ways, provide public space and new opportunities for space use and occupancy, and contribute to the place identity. Bridges are iconic and recognizable constructions, and in often cases constitute contemporary monuments due to their architectural qualities. In the quest for a unique design, we often allude to the design process itself. What triggered certain design decisions, how do we develop efficient form, what are the factors that will make a bridge design aesthetically pleasing and unique? Engineers Fernandez and Manterola affirm that *"it is difficult to analyse what it was that led to design a particular bridge, since every creative process is essentially intuitive and hence hard to rationalize"* (Fernandez Troyano and Manterola

Armisen 1997). Design explorations may follow nonlinear processes with several cycles of analysis and design refinements with regards to form, context, structure and function. With regards to habitable bridges in particular, the hybridization of architectural program, public space, covered spaces of mixed use and passage way for pedestrians and/or vehicles becomes a great challenge and a design opportunity for integrating places and technologies.

Figure 2: Tower bridge concept over the Niagara Falls by students Routsias, Ntampegliotou and Agrafioti

"The Eiffel Tower and the Brooklyn Bridge became great symbols of their age because the general public recognized in their new forms a technological world of surprise and appeal" (Billington 1985). We are currently witnessing an era of new architectural paradigms that emerge from the diffusion of digital design across media, this has direct repercussion on the architectural form. Over the centuries, while the different typologies of bridges evolved *"the architectural style of the period was superimposed on them, to create order and homogenetity"* (Ryall, Parke, and Harding 2000). Therefore, the digital era would form no exception to this rule. How does new technology influence architecture? How do new tools affect the design? Architects exploit the possibilities offered by digital media, which has an impact on the architectural style as well as on the design process. Digital design media are often criticized that they prioritize aesthetics and morphology, over efficiency, sustainability and program. This is however only partially true, as new media can be used in so many different ways, incorporating performance criteria through Computer Aided Engineering (CAE), which means that it exclusively relies upon the designer how he will use the immense power of computation to make the best of his designs. As it was expected, the advancements of technology have influenced the entire "fashion" in the architecture and construction industry, and it is no surprise that contemporary bridges have so often smooth organic shapes, that are topologically optimized and refined to meet the structural criteria and the desired structural and environmental performance. Patrick Schumacher in his famous *parametricism manifesto* claims that *"there is a global convergence in recent avant-garde architecture that justifies the enunciation of a new style: Parametricism"* (Schumacher 2009). This "style" has been evident in major architecture projects for over 15 years,

however, the constant development of digital design tools and scripts has accelerated a cumulative build-up of virtuosity, resolution and refinement. Schumacher explains that aesthetically speaking the hallmark of this new style is *"the elegance of ordered complexity and the sense of seamless fluidity, akin to natural systems".*

Within this culture of digital explorations of *"continuous differentiation, versioning, iteration and mass customization"* and fostering the quest for uniqueness in bridge design, the design studio at the University of Thessaly, explored innovative designs through experimentation with digital media and algorithms, aiming to incorporate design aesthetics, functionality and integration to the context, both when located in urban areas, as well as in the natural environment.

Figure 3: Bridge concept in Paris by students Kalama and Tzoni

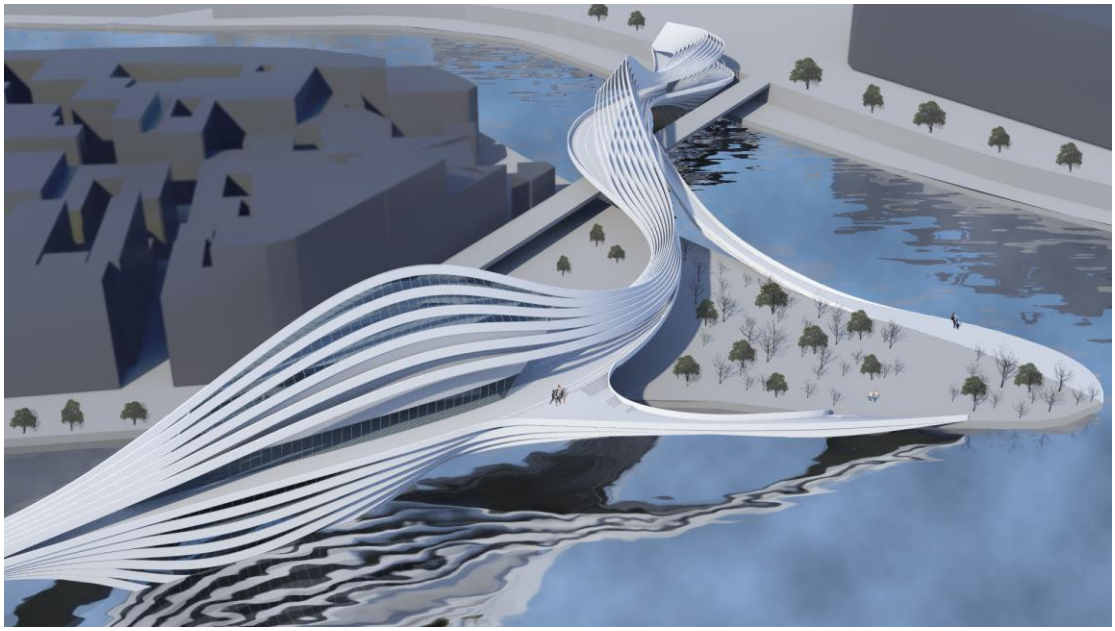

Figure 4: Bridge concept in Paris by students Kalama and Tzoni

DESIGN OBJECTIVES

Among the objectives of a bridge design is the integration to the environment, which may refer to rural, urban or suburban context (Fédération Internationale du Béton 2000) together with aesthetic requirements for proportions, slenderness, transparency and harmony. The proportions relate to the height and thickness of the piers, the length of the spans, the general mass and the voids created, the contrast of light and shadow. Slenderness may appear elegant in comparison to heavy structures, and the transparency created underneath the bridge is a major asset, which permits visibility from oblique angles. Harmony between the different bridge elements also appear pleasing to the eye, therefore coherence between shapes and sizes. A clear display of the structural concept together with effective detailing is also a positive feature. Colour, materials, textures and decoration complete the appearance of a bridge structure.

DESIGN RESEARCH AND EXPERIMENTATION

The initial phase of the design studio involved the design research and analysis of selected habitable bridges. The role of case studies is of great importance for bridge design, the primary goals of case studies are *"to look carefully at all major aspects of the completed bridge, to understand the reasons of each design decision, and to discuss alternatives, all to the end of improving future designs"* (Chen and Duan 1999).

Based on the knowledge gained the students initiated their design experimentation, initially with topological transformations and different schemes for connectivity, and eventually enriching their ideas with hierarchical levels of detail, examining concepts of porosity, stability, proximity and adaptation to the environment. The students mainly explored design variations in 3D, understanding the reciprocities of form and function and challenging the limits of established paradigms, revisiting the Vitruvian request for firmitas-utilitas-venustas (safety-functionality-beauty) with the use of digital media.

The students were free to choose the site for the project, therefore there was a great variety of urban locations for the bridge project, as well as a number of natural sites in the mountains or rivers. The selected site had a very strong influence on the design, as one of the major criteria was the integration to the environment. The selected sites were European cities such as Amsterdam, Genova, Frankfurt, Paris, as well as some natural sites like the Meteora rocks or the Atlantic Road in Norway. Therefore, among the projects we could find corresponding programs that would include closed viaducts and habitation units, recreation, concert areas, galleries, museums, sports facilities and libraries. Each of the above would define a morphogenetic strategy, corresponding to both the site and the program.

The aim was to move away from the merely utilitarian appearance, the studio objective was to explore diverse habitation possibilities, mixed uses and even unconventional scenarios. The results presented in this paper mainly refer to the aesthetic, functional and cultural role of bridges. It is understood that a bridge design has a very important structural component and requires a thorough engineering analysis to minimize torsion and deflection, the materials and fabrication methods. However within the scope of this paper, the research is mainly targeting conceptual design and architectural development focusing on morphological and geometrical qualities, the form in relation to the function and the impact

on the place where the project is located. Within this scope, the studio often explored extravagant or even utopic designs that would create a strong landmark and remarkably contribute to the development of a new place identity. Mark Foster Gage claims our generation as the first one to be defined by *"creative powers and freedoms never before experienced"*, he is supporter of open ended experimentation not contained in a particular style or *"forcing cohesion through ill-fitting manifestos"*. He suggests that new ideas *"should be free to accelerate unencumbered in wild and unexpected new directions"* (Gage 2011).

Figure 5: Bridge concept in Genova by students Georgouli and Karagianni

CONCLUDING REMARKS

As Bennett explains *"the role of the designer and architect in the planning and design of bridges is undergoing radical change, with architects now being appointed before the engineer on a growing number of projects. The relationship between the two roles is therefore on a different level than either will have previously experienced"* (Bennett 1997). In this realm, the design explorations presented by the students become of crucial importance, as the necessity for a clear concept and morphological scheme is to precede the analysis and engineering input.

Tyrrell and Hastings exemplified the importance of the design of bridges with regards to the place and context. *"Among all the varied problems of construction which present themselves to human ingenuity, it may be said that the bridge most influences the landscape or transforms the general character of a city"* (Thomas Hastings in Tyrrell, 1912). The majority of student proposals display a strong urban character; they act as transition areas but also as meeting points, there are different velocities of vehicles and people crossing, stopping and experiencing the space. New habitation scenarios ranging from commercial to community use, create hybrid conditions and program. The majority of bridges do not comply with the main bridge typologies mentioned above, but they do represent the era of digital design and production. It is evident that style and technology affect each other reciprocally. Mario Carpo remarks that *"all tools feed back onto the actions of their users, and digital tools are*

no exception […] manufactured objects can easily reveal their software bloodline to educated observers" (Carpo 2011). At the same time, contemporary aesthetics continue pushing the technological boundaries encouraging the utilization and development of new media, while new technological achievements in architecture give rise to morphological experimentation, resulting in a feedback loop between technology and architectural expression that leads to fresh ideas and design innovation.

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