

Case studies on architectural design methodologies



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How We Build: The Parts and the Whole – Precedent Case Studies

The two philosophies introduced above, mechanism and systems thinking, have influenced many aspects of our lives. One can arguably note their influences in our built environment, as can be seen in the variety of design methodologies present in architectural design.

Both academics and practitioners in the design field have often argued that the architectural practice can be classified as a holistic enterprise. This argument is founded on the fact that many players have a key role in the process of designing a building: the architect, the client, the consultants, the engineers, the planners, the builders and so on. In this context, holism does indeed propel an all-inclusive design process realized as a result of the many members collaborating on a given project. In fact, this trait is even said by many to be unique to architecture as a profession.

However, when analyzing the conventional design methodologies employed in architecture, one cannot ignore the hierarchical and sequential separation of design, detailing, documentation, modeling and fabrication that has become prevalent in today's day and age. This type of hierarchical separation and compartmentalization of processes can be seen in many aspects of design, but more specifically between material, form and structure. In order to explain this phenomenon more clearly, two built architectural projects have been chosen for analysis based on these two ideologies in architecture. Analyzing the two built examples below may shed more light on the ways in which machine thinking and systems thinking have influenced architectural design philosophies and methodologies.

The first project is considered by many as being the most contemporary technological application of timber construction. The second project was completed approximately three decades ago and continues to be an inspirational precedent regarding the use the inherent material properties of wood, specifically Tiber. Distinguishing between these two projects and their approaches is of great relevance to this research. The aim is not to assess the two projects with the intention of promoting one over the other, but rather to identify the contrasting design methodologies. For this comparison, the focus will lie namely on the design and realization of the roof structures.

The inspiration for the roof of the Centre Pompidou in Metz, designed by Shigeru Ban, Jean de Gastines and Ove Arup & Partners, was a traditional Japanese straw hat (ill. 3). The form that resulted from this inspiration was based on two components: a specified freeform surface with a hexagonal edge, and a flat, kagome lattice consisting of triangles and hexagons that is projected onto the free-form surface. The lattice structural grid was developed using digital processes such as CAD software (ill. 4). The digital model created from this step was then developed into a highly complex geometric construction in which every element of the structure was unique in its curvature and shape. The digital form-giving process was used only to establish the geometry of the roof structure. Following this design phase, engineers and consultants working in the realm of computer-based geometry optimized the design of the structure and rendered it buildable.

The actual physical construction of this roof structure involved a series of glue-lam girders arranged in three layers (ill. 5). Each of these girders is comprised of several segments, fastened to one another in order to achieve <https://assignbuster.com/case-studies-on-architectural-design-methodologies/>

the “curved” appearance of the girders. In total, the entire roof assembly is made up of 1,790 segments, which were classified into three categories (straight, single curved, double curved) (ill. 6). The 1,790 individual segments were fabricated by a computerized numerical control (CNC) joinery machine. In order to achieve the final form of the structure, it was necessary to mill away fifty percent of each individual glue-lam beam to obtain the required building component geometry (ill. 7). In the next phase of the project, the individual components making up the complex geometry of the roof were transported from the fabrication shop with trucks and were assembled incrementally using scaffolding and cranes to make up the final form of the structure (ill. 8).

This project followed a relatively linear flow of data, beginning with the initial design inspiration, and working up towards a formal design, the development of a CAD model, the refinements and optimization achieved by engineers in rationalizing the process, and finally ending with the computer aided manufacturing of the highly specified components. A similarly linear approach then took place on site for the duration of the incremental assembly process. Overall, this design approach is a direct reflection of mechanistic ideologies.

The second project is the “Multihalle” located in Mannheim and designed by Frei Otto, Carlfried Mutschler, and Ove Arup and Partners (1975). Like the Centre Pompidou this project consists of a double-curved lattice shell, but the design was not the result of a form-giving process (ie. one in which the form was pre-conceived by the designer and a structural system was developed to actualize the form). Instead, this project consists of a more <https://assignbuster.com/case-studies-on-architectural-design-methodologies/>

integrated form-finding process informed by material experimentation, material behaviours and constraints along with an extensive series of models and prototyping. It is important to note that the form finding process for the Multihalle involved upside-down hanging chain models (ill. 10). This was important because it allowed the architects to determine the three-dimensional geometry of the shell. These models were especially effective in creating pure tension shapes due to gravity's pull on the chains. When an appropriate geometry was achieved, the model was then inverted to create a pure compression shell. This resulted in a geometry that was structurally stable, devoid of in-plane shear stresses in the lattice structure.

In the development of this project, the lattice shell structure was based on two fundamental questions:

- 1) Could a shell structure be constructed with a tensile uniform mesh and be capable of supporting its own weight without buckling and causing no moment bending?
- 2) Could a shell structure be constructed using the natural bending properties of wood laths, which were initially assembled as a flat system?

The structure of Multihalle is called a *grid shell*. A grid shell is a "double curved surface formed from a lattice of timber laths bolted together at uniform spacing in two directions." [1] There are two types of lattice shell systems: strained and unstrained. The difference between strained and unstrained shells is that the unstrained shells are made of pre-bent members. In the unstrained shell, curved members experience no strain

during the erection process because they have been previously curved to the <https://assignbuster.com/case-studies-on-architectural-design-methodologies/>

desired shape. This method was used for the Centre Pompidou in Metz. The Multihall shell structure however, consists of a strained lattice shell, comprised of a 2 double-layer wooden lath system, assembled flat in a square diagrid pattern (ill. 11). The initially flat grid is held together by pinned joints (ill. 12) that permit the laths to move parallel to one another (ill. 13). This allows the grid one degree of movement when flat. However, once the structure is erected and the grid takes on the double-curved geometry of the shell, the forces will deform the square grids into parallelograms (ill. 14). In this manner, the structural web can take on specific forms by changing key parameters in the assembly such as scissor-like deformation, adjustable pins, cambering and edge definition of the system. As a result of this double curved design, the members increase in strength and stiffness.[2]

Erecting the shell on site required that the entire flat system be lifted at a number of key points with the aid of cranes. Once the web was lifted at these points, the network of wood laths naturally took on the desired geometry due to the flexible bending behaviour of the continuous wood members and the deformation of the network (ill. 14).

The system's joint connections were then tightened to obtain shear-resistant connections that would maintain the desired shape of the structure (ill. 15). Next, steel cable ties were added to provide diagonal stiffness to the shell (ill. 16). The grid shell was then fastened to the substructure at specified support points, thereby stabilizing the complex roof

The critical difference between these two projects is that one was designed and geometrically defined by the designer and subsequently rationalized for construction, while the other was a result of an extensive form-finding process based on material behaviours, experimentation and structural behaviours. The Centre Pompidou is often referred to as a state-of-art, digitally designed wood construction project. It required six layers of glue-lam beams with cross section of 140 x 440 mm to achieve a 50m clear span. In addition, it was necessary that 50 percent of the glue-lam material be milled off during the CNC fabrication process in order to achieve the desired shape of each member. In contrast, the double layered grid of the Multihalle in Mannheim spans up to 60m and consists of members that only measure 50 x 50 mm in cross section. As a result, the " Multihalle" project emerged as a grid shell that was extremely cost-effective and material efficient. It also proved much easier to construct than many of today's contemporary lattice structures like the Centre Pompidou in Metz.

The intention of this comparison is to demonstrate the differences which exist between these two design methodologies. One is the digital continuation of the long-standing hierarchical process in which form-giving takes precedence over rationalization. The other concerns a design process which undergoes constant transformations due to an integrated and informed approach that can anticipate the possibilities of materialization.

Frei Otto's work with lightweight structures as well as the design methodologies employed in his projects serve as exemplary precedents in demonstrating the theory and design methodologies adopted in this research. Similar to Frei Otto's approach, this research will propose a <https://assignbuster.com/case-studies-on-architectural-design-methodologies/>

lightweight structural system that seeks to incorporate an integrative approach to form-finding using the material properties and behaviours of wood. In order to fully understand the capabilities of this material, the following chapter explores the material science and characteristics of wood.

[1]Happold and Liddell, " Timber lattice roof for the Mannheim Budesgartenshau," *The Structural Engineer* 53 (1975): 99-135.

[2]Burkhardt Berthold and Frei Otto. *IL 13: Multihalle Mannheim* (Stuttgart: Freunde und Fo^l^rderer der Leichtbauforschung, 1978).