Gothic Architecture: Application Of Principles Of Gothic Architecture In A Modern Design For A Community Center

Gothic Architecture

Belgium is known for architectural movements such as Rococo, Classicism, Art Nouveu, Gothic, Art Deco, and Modernism. For this project Gothic architecture will analysed and used in some way. The sub-question then being:

“To what extent can principles of Gothic Architecture be used in a modern design for a community center?”

Gothic architecture has a long and rich history in Belgium and Ghent. Belgium has a total of one hundred and twenty-four gothic structures. The oldest structure was built around 1035. A complete list of gothic structures in Belgium can be found in the appendix. Ghent Hosts eleven gothic structures with eight of them centered around the inner city (Belgiumviewcom, 2019):

- Guildhall of the free Boatmen
- Ruins Saint-Bavo’s Abbey
- Novotel
- St. Jacob’s Church
- City Hall
- Saint Bavo’s Cathedral
- Bijloke Abbey
- Belfort and Laken Hall
- Waepen van Zealant
- Our lady of the nativity

Gothic architecture’s start can be traced back to a new choir at the Abbey of Saint-Denis, near Paris, France, in 1140. However, one theory suggests that the origins of the pointed arch can be traced further back to early Islamic architecture. Gothic architecture revolutionized architecture for at least 300 years. Gothic architecture went through many design transformations during its three hundred year reign during three major periods: Early gothic, High gothic, and Late gothic (fig). With the gothic revival in the nineteenth century, its influence extended, indirectly centuries further (Hopkins, 2015).

Gothic architecture is characterized by the pointed arch, the flying buttress and the rib vault. Compared to the round arches of the preceding era of Romanesque architecture, the Gothic pointed arch offered structural advantages that allowed cathedrals to be built higher (Hopkins, 2015).

The Gothic builders created intricate designs of arches and vaults, ever-increasing in complexity. They introduced the rib vaults, which allowed much lighter construction than Romanesque barrel vaults which were made of extruded round arches (Allen & Zalewski, 2010). The ribbed vault started in early Gothic with simpler designs like the sexpartite vault, that is a vault divided into six parts by two diagonal ribs and one transverse rib. By the high Gothic

period the vaults evolved to what is known as the quadripartite vault. This vault was essentially the same as the sexpartite vault but omitted the transverse rib (Hopkins, 2015). From there ribbed vault designs increased ever more in complexity with the introduction of Tierceron vaults which featured additional ribs emanating from the main supports to the transverse ribs, sometimes with Lierne ribs between (Hopkins, 2015) (Willis, 1842). The last example was also known as the Lierne vault (Willis, 1842). In England this evolved into the fan vault (Hopkins, 2015).

In rib vaults, the compressive forces flow to the ribs, while the webs between the ribs are filled with thinner, lighter shells of usually masonry, reducing the weight and thrust of the vaults and the weight of the material required for the buttresses (Allen & Zalewski, 2010). The ribbed vault of the middle ages differs entirely from the vaults of the Romans. It consists of a framework of ribs or stone arches, upon which the real vaults or actual coverings of the apartment rest. These vaults are usually constructed of a lighter material and with rougher workmanship than the ribs upon which they rest, and between which they constitute, in fact, a kind of thin panel (Willis, 1842). Flying Buttresses, half arch structures providing lateral support to a wall, helped carry the thrust of the nave’s vault . Together these features gave gothic cathedrals a dramatic verticality. The use of piers instead of thick walls as more efficient load bearing elements enabled the interior spaces to be opened up, creating an overarching feeling of lightness and making possible Gothic architecture’s other great innovation; stained-glass windows (Hopkins, 2015).

The innovations of gothic era allowed for much lighter construction taller and expressive architecture. However unbeknownst to the builders they were closely approximating a secret structural principle in the pointed arch, which allowed for the lighter construction, known as the catenary arch (Allen & Zalewski, 2010). In 1675, English scientist Robert Hooke (1635-1703) discovered “the mathematical form of all manner of arches for building,” which he summarized with a single phrase: “As hangs the flexible line, so but will stand the rigid arch” (Allen & Zalewski, 2010). Hooke described the relationship between a hanging chain, which forms a catenary in tension under its own weight and an arch, which stands in compression (Fig). Both the hanging chain and the arch must be in equilibrium (Fig). Hooke’s principle describes the funicular shape that a string or chain takes under a set of loads.

In the centuries that followed, this simple idea has been used to understand and design numerous important structures (Allen & Zalewski, 2010).

The line of thrust for any arch can be found by using either a physical model of hanging chains or rope or graphic statics. Either method will provide the geometry of the thrust line and estimates of the forces throughout the arch (Allen & Zalewski, 2010). Though an infinite number of compressive forces thrust lines may be found in a typical masonry arch, the geometry of the arch will establish the minimum and maximum horizontal force that is possible within the arch (Allen & Zalewski, 2010) (fig). This is of course also possible for the romanesque rounded arch. The difference being that more material is needed to be able to complete the funicular shape. Arches shaped to contain the funicular path of compressive forces can span space and create architecture. The forces must lie within the structure all the way to the foundations. In most cases supporting buttresses became necessary as the arches are raised higher above the ground (Allen & Zalewski, 2010).

Structures with classical romanesque geometries are easier to lay out and build, but they use

more material in forcing the structural thrust lines to fit within a predefined geometrical section. In contrast, funicular geometries locate all material close to the thrust line and thereby use less material; but funicular arches, with their constantly changing angles and radii, are somewhat harder to lay out and build than classical arches (Allen & Zalewski, 2010)(fig).

Architect Antoni Gaudi (1852-1926) and others of his time in the Barcelona area, working from a rich local tradition of masonry vaulting, created their buildings from complex arrangements of funicular arches and vaults whose shapes were derived both from hanging chain models and graphic statics. Their expressive,exciting structures demonstrate solutions to the inherent challenges of funicular geometries (Allen & Zalewski, 2010). Catalonian builders used a method of vaulting using thin shell masonry structures known as the catalan vaults. This method of building was also widely used by architect Rafael Guastavino. He not only used this method of construction in Spain but also in his works in the United States. These methods also inspired Engineers such as Eladio Dieste and was also used as formwork for floors by le Corbusier (Ochsendorf, J. 2011).

As mentioned before form finding for any arch structure can be done by using either a physical model of hanging chains or rope or graphic statics. The hanging chain method is a powerful funicular form finding tool. Apart from different modeling possibilities of for example hanging chains off of other chains, combining directions of different chains to form a 3 dimensional model, small weights can also be added to the chain to mimic any actual load distribution (Allen & Zalewski, 2010). This method was made most famous by architect Antoni Gaudi's model for the design of Colonia Guell which took his office eight to ten years to finish (Ochsendorf, J. 2011).

Later funicular form finding methods involving more complex funicular structures was done by architect and structural engineer Frei Otto (1925-2015) using soap film suspended between various forms. Other physical form finding methods were also done by Swiss structural engineer Heinz Isler (1926 - 2009) involved hanging membranes and cloth (Liem, 2011). This last method was also used by Frei Otto. !!!!!FURTHER EXPLANATION!!!

Form finding can be defined as the "forward process in which parameters are explicitly / directly controlled to find an 'optimal' geometry of a structure which is in static equilibrium with a design loading" (Adriaenssens et al., 2014). For the design process of funicular shells, the geometrical constraints are even more restrictive, since possible shapes must carry loads by pure compression. The design exploration within this constraining framework demands form-finding methods that allow a well controlled flexible, fast and intuitive design process (Rippman 2016).

Through computation, funicular form finding methods are now possible and easier using software such as Active Statics developed by MIT, Kangaroo Physics, Karamba, and RhinoVault developed at ETH Zurich by Matthias Rippmann and Prof. Philippe Block. Since the use of computers in architecture and engineering practice became widespread in the 1990's computational form-finding techniques became particularly popular to design funicular structures, both for compression and tension structures (Rippman 2016).

The Block Research Group at the Institute of Technology in Architecture at ETH Zurich, led by Prof. Dr. Philippe Block and Dr. Tom van Mele, is a leader in research in the field of funicular structures, analysis of masonry structures, graphical analysis and design methods,

computational form finding and structural design, discrete element assemblies, and fabrication and construction technologies. In their research they've explored the various modern possibilities of funicular structures using computational form-finding. Particularly the work of Matthias Rippman's phd thesis shows computational funicular form-finding possibilities such as modification of force distributions, creating openings and unsupported edge arches, changing boundary conditions, redirecting the "flow of forces", using fixed and continuous tension elements, altering loading conditions, and designing forms with overlaps and undercuts. The use of continuous tension elements is a radical concept. This involves the use of compression-only vaults in combination with tension rings (fig). This combination is known from masonry domes where continuous tension rings are often inserted to resist the tensile hoop forces at the base. By modifying the support conditions an unsupported, cantilevering edge is formed that acts as a circular tension tie (fig). This method is also capable of more complex forms (fig).