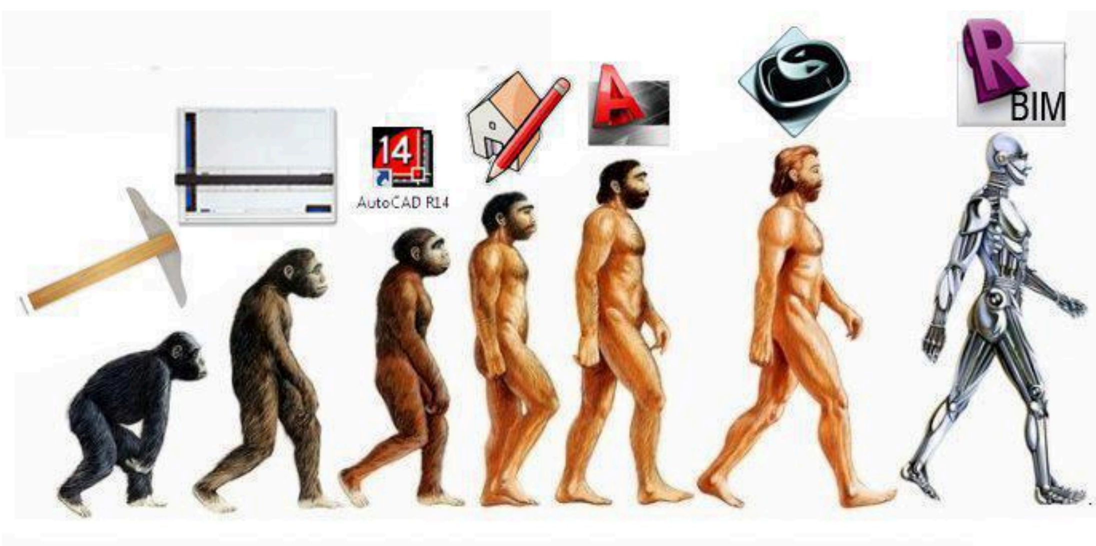
CU Boulder

Technology and Building Design

Johnson-Wax Headquarters

History and Theory of Architecture 2, Professor Georgia Lindsay



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Precedents and experience play a significant role in the designs produced by architects. Through the history of architecture, many common design elements are seen. Architecture students today are taught that traditional architectural elements, such as pediments and colossal orders can remain components of good design. Is it because these baroque elements are optimal? No. It is because they have precedents. They have been hypothesized and implemented by early building designers and have been proven to "work" with regard to both structural supports and aesthetic appeal. Until recently, building structural design relied solely on intuition and experience, rather than science and mathematics. This limited knowledge of structural analysis had significant implications to what designers were able and willing to attempt. This is seen with early daylight designs. Ancient builders were fearful that poking large holes in their buildings would compromise the structural integrity and, as a result, only very small and deliberate daylight openings are seen in pre-20th century structures. Modern design technologies such as electric lighting and structural analysis have had a significant impact on architecture and will continue to shape building designs into the 21st century.

Before William Murdoch invented the gas lamp in the late 18th century, architects were required to confine their lighting designs to daylight. This was accomplished using small and deliberate openings because large openings had several problems. Early architects were unaware of how to do structural calculations and relied only on intuition and experience to determine whether a daylight opening was too large for the structural integrity of an architectural element to be maintained. Additionally, in the days before active air conditioning, large openings resulted in concerns about over heating. These concerns led to very elegant daylight designs, such as that of the pantheon, constructed in Rome in 126 AD.

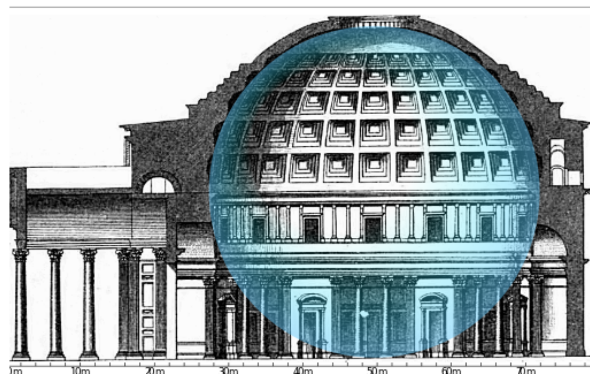

Figure 1. Pantheon, Rome Italy

The well-known pantheon structure consists of a 142 foot diameter half-dome and is lit using a 30 foot oculus at the top of the dome (See figure 1) (Rasch, 1985). The oculus is relatively small when compared with the size of the structure overall and encompasses only 0.95% of the total building surface area. This is in stark contrast with modern building codes which allow window to wall ratios of 40 % or even higher in cases of high performance windows (ASHRAE). Twentieth century design, however, took an even more liberal approach to daylight openings, with window to wall ratios much higher than 40%. The Johnson-Wax headquarters, built in 1936 in Racine, Wisconsin, is an early example of this continuing trend.

Architect, Frank Lloyd Wright who was well known for challenging conventional design paradigms, designed the Johnson-Wax headquarters. This research campus consisted of two parts; the 14-story research tower and the low-rise administrative building. The research tower was intended as a laboratory space while the administrative building consisted of the so-called "great-work room", which can be seen as an early example of the modern day cubical farm seen in offices. Wright recognized the benefits of daylighting in this building design but held the belief that Racine was too ugly of a city to be viewed through vision windows (Lipman, 1968). Instead, Wright designed the building to be lit using translucent windows only.

Figure 2. Johnson-Wax research tower

The research tower was wrapped with translucent glass tubes that spanned floor to ceiling, and were augmented with single pane windows on the interior (see figures 2 and 3). This allowed employees to appreciate the benefits of daylighting, without the issue of distractions from the outside world. This had the effect of producing a window to wall ratio of well over 50%, and marks a substantial shift from the minimalist of philosophy of ancient builders. Wright incorporated a similar design philosophy in the neighboring administrative building by electing to omit vision window, and light exclusively with top-lighting. The same tubing scheme was utilized in the great work room to bring light in through the roof. This was intended to preserve a connection with the outdoors for the Johnson employees and was supplemented with a structural design that made occupants feel as if they were in a forest.

Figure 3

The structure of the great-work room was supported with an unconventional column design, to replicate the aesthetic of trees in a forest (Carter, 1998). This proved problematic, however, as this design was inconsistent with building codes of the day. To achieve the desired tree aesthetic, Wright, designed the columns to be widest at the top and gradually become narrower toward the bottom (see figure 4). The bottom of the column was designed to be a mere nine inches in diameter, while thirty inch diameter columns were required by the applicable building codes (Carter, 1998). Using sophisticated structural analysis techniques Wright was able to convince himself that his design was sufficient to hold the design load of 6-tons and was willing to prove his idea using a public demonstration. A replica test column was constructed and loaded with stones until it was shown to hold sixty tons (ten times the design load) without buckling. The building inspector had previously agreed to let construction proceed if the column could be shown to hold twelve tons, which Wright's design greatly exceed. This truly marked a paradigm shift in which architects began to prove their designs mathematically, and allowed for much more innovation in building construction.

Figure 4

Today, architects have very sophisticated software tools at their disposal to perform previously infeasible calculations with regard to both structural and daylight design. Structures that were once impossible for humans to analyze can now be trivially evaluated and proved using computers. This allows architects to be limited not by by fear that a design might fail, but instead be limited only by their own imaginations. The same is true for daylighting. Modern rendering software allows designers to see their lighting prior to implementation, thus allowing much more optimal designs to be reached. And with ever increasing pressure to produce energy efficient building design, low energy lighting solutions will undoubtedly be at the fore-front of architectural consciousness.

There are several objective reasons as to why daylight should be incorporated into modern designs. The United States Green Building Council (USGBC) provides strong incentives for the incorporation of daylight through its LEED certification program (U.S. Green Building Council, 2009). This results in daylight being taken as synonymous with sustainable building design. An extreme example of daylighting can be seen in the Apple retail store located in New York City (figure 5). Constructed in the 21st century, this building design maximizes daylight by using a 100% window to wall ratio; a technique only possible with modern structural engineering techniques. High performance glazing makes this design possible and allows ample daylight to be introduced without overheating the space. Though this is an efficient solution for the time, the future may show a different sustainable design landscape.

Figure 5. Apple Store, Manhattan

Modern light-emitting-diode (LED) technology is rapidly changing the world of electric lighting, with lighting power densities decreasing at an astonishing rate. Recent LED luminaire prototypes have shown potential to be more energy efficient than sunlight with efficacies of 200 lumens per Watt (Cree, 2014), compared with 110 lumens per Watt for daylight (Littlefair, 1985). This suggest that the most energy efficient building designs may be achieved by minimizing daylight and relying more heavily on electric lighting. And though daylight has been linked to several positive human factors such as reduced absenteeism in work place and educational facilities, the threat of global climate change may override these concerns and bring energy efficiency forward as the primary concern. It is a delicate balance to strike. In the coming years it is likely that building designers will harken back to the more careful daylight designs of the Pantheon days and will strive to bring daylight in using the smallest openings possible. This will allow the human benefits of daylight to be realized, while not bringing unnecessary heat into buildings.

A modern day example of this older design style can be seen in figures 6 and 7. This proposal for the Museo Arte Nurgica, in Cagliari Italy seeks to implement the same daylight design seen in the

Figure 6. Proposal for Museo Arte Nurgica, Cagliari, Italy. Unbuilt.

Pantheon two millennia ago. A large, open floor plan is lit with a small oculus on the roof. And though this design was not selected to be used for the Museo Arte Nurgica, it is probable that many similar designs will be seen in the future as architects seek to incorporate daylight without incorporating heat.

Figure 7. Oculus of Museo Proposal.

Regardless of the precise methods with which architects choose to implement daylighting, technology will play a significant role in designs. Rendering and structural analysis software remain in their infancy and it is currently unknown how architects will choose to apply this technology. Will we see more glass cube designs or more oculus designs? The sky is the limit in terms of what architects can visualize, and new daylighting methods will certainly emerge.

Bibliography

ASHRAE. (n.d.). ASHRAE Standard 90.1-2013 Energy Standard for Buildings Except Low-Rise Residential Buildings.

Carter, B. (1998). *Johnson Wax Administration Building and Research Tower.* London: Phaidon Press.

Cree. (2014, January 23). Cree Shatters Efficiency Benchmark with First 200-Lumen-Per-Watt LED Luminaire. *Cree Press Release*. Durham, NC.

Hertzberg, M. (2010). *Frank LLoyd Wright's SC Johnson Research Tower.* Petaluma, California: Pomegranate Communications.

Lipman, J. (1968). *Frank Lloyd Wright and the Johnson Wax Buildings.* Mineola, NY: Dover Publications.

Littlefair, P. (1985). The luminous efficacy of daylight: a review. *Lighting Research and Technology, 17*(4).

Rasch, J. (1985). *Architectura* (Vol. 15).