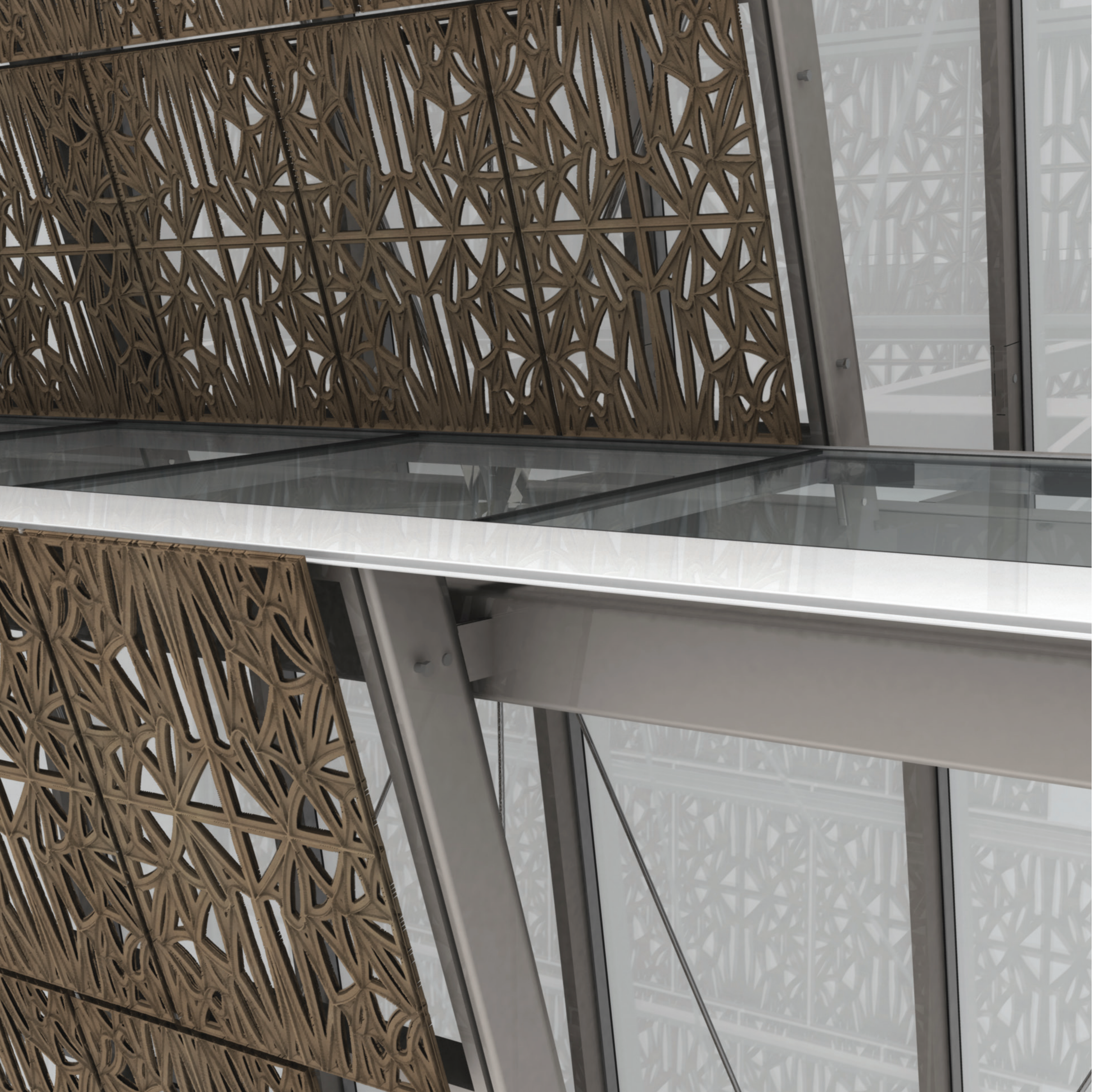


THE DESIGN-ASSIST PROCESS: UNIQUE SOLUTIONS THROUGH THE HYBRIDIZATION OF CULTURES AND KNOWLEDGE

AUDE WEBANCK

As new material, structural and geometric technologies emerge, different fields of expertise are required early in the design process to achieve unique solutions. Architects and engineers have very different backgrounds and ways of approaching the design process, but their knowledge is complementary. A close collaboration between these two players is required in order to create efficient design solutions for unique buildings.

While there are many different types of collaboration between architects and engineers today, we will focus primarily on the emerging design-assist method which has proven to be very efficient in innovative architecture and developing constructible systems reaching new standards of performance. Many clichés exist concerning both the relationship between architects, engineers and their respective roles, as the roles of each project team is increasingly broadened. While many outstanding buildings are associated with famous architects, it is quite rare to associate a building with the name of an engineer. There are a few reasons for this, but in order to understand them we will first need to explore the history of architecture, the relationship between architects and engineers, boundaries of their scope of work, and the emerging design-assist (DA) process.

FROM VITRUVIUS TO MODERN ARCHITECTURE

During the first century B.C., Vitruvius wrote his *Treaty of Architecture*, which officially set the boundaries of the architectural field. He had a very specific definition of an architect: a multi-cultural man with knowledge in various fields. According to Vitruvius, architecture was based on three fundamental principles: firmitas, utilitas and venustas (meaning solidity, usefulness and beauty), which had to meet in all architectural achievements. During this time, the architect's role included theory based on proportions, geometry and the imitations of natural phenomenon, in addition to construction, where the architect was in direct contact with the builders. While the architect had a scientific understanding of proportions, the construction methods were very primitive — architects had no knowledge of statics and no precise way of taking measurements.

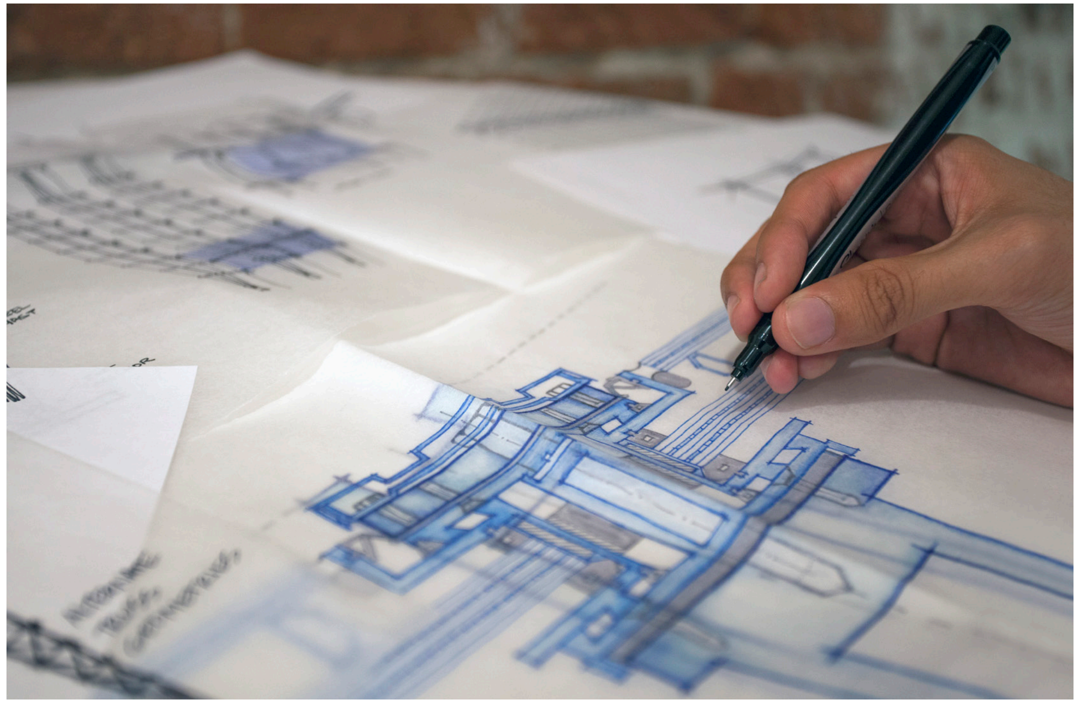
Leonardo da Vinci and then Galileo seriously endangered Vitruvius' theory by introducing new scientific discoveries into the building process. Galileo wanted to look for the cause of construction difficulties in order to build better structures rather than react to problems after the building was erected. He tried to demonstrate that the theory of the proportions, which had been leading architects since antiquity, was wrong in terms of construction. During the 18th century, mechanics found a full formalization in the mathematical language thanks to both Galileo's geometry studies and Lagrange's analytic approach.

This was the first point of tension between architects following the traditional approach, and the scientists, physicians and mathematicians wanting to use a more methodical approach.

In 1716, the Bridge and Highway Corps in France, from which grew the École Nationale des Ponts et Chaussées (National School of Bridges and Highways) marked the beginnings of civil engineering. The Corps were created to address the need to organize the road network of the French territory, and its teachers wrote books that became standard works on the mechanics of materials, machines, hydraulics and other parts of the construction process. Since the Renaissance, the construction of machines, fortification, major structures and infrastructures had belonged to the field of architecture, but now engineers were breaking away from architects to create a new ideal distinguishing itself from classical architecture. These engineers sought progress, rationalization and optimization of the construction process with the help of new mathematical tools.

During the second half of the 18th Century, we see the development of divergent engineering and architecture schools. Engineering knowledge was organized horizontally, with a series of stages following the process of the project – describe, calculate and build. Meanwhile, architects' knowledge followed the same hierarchical structure that had been established during the classical era: the decoration is most important, followed by the distributive art, construction art and drawing skills.

Engineers were now characterized by knowledge acquired in various technical areas. Great importance was given to exercises and experiments that were designed to validate theory. On the other hand, architects were expected to read and acquire knowledge in fields other than technical ones, but instead expected to have taste and talent. While architects took classes that covered both theory and practice, a growing divide separated the two aspects of design. This testifies to the different cultures that developed amongst the two actors: a culture of performance versus a culture of the project.



At the end of the 19th century and beginning of the 20th century, new divisions appeared with the industrial revolution and golden age of metal. The building of train stations and great exhibition spaces marked the triumph of metal, including Joseph Paxton's Crystal Palace at the Great Exhibition of London in 1851, and the Eiffel Tower at the Great Exhibition of Paris in 1889. Architects accused the engineers of a complete absence of aesthetic preoccupation, while Gustave Eiffel defended the aesthetics of the laws of calculus as the "beauty characteristic of the tower."

Modernism can be said to have started after the Great Chicago Fire in 1871, which sparked a renewal in architecture and its practice. After the fire, it was important to rebuild quickly, economically and efficiently to densify the city. For economic reasons, there was a standard plan for all the buildings in Chicago linking form and function. The strict symmetry of classical architecture was abandoned, and the three fundamental principles – solidity, usefulness and beauty – were replaced by convenience, comfort and pleasure.

The rise of modern architecture required a more prominent role for engineers. Walter Gropius and Le Corbusier contributed heavily to the recognition of the engineer's aesthetics, while architects like Frei Otto and Konrad Wachsmann made significant contributions to the knowledge of structures. In 1919, Gropius created the Bauhaus movement, which aimed to find collaboration between each contributor of the project, bringing art and industry closer. The Bauhaus school taught both artistic and technical fields to familiarize students with materials and simple, formal problems. Walter Gropius expressed the spirit of the age when he said, "The real creation work can only be done by someone who knows and masters the laws of statics, dynamics, optics and acoustics to give life and form to his inner vision. In a piece of art, the laws of the physical world, of the intellectual and spiritual world, work and are expressed simultaneously." The development of modern architecture gave birth to a new kind of collaboration between architects and engineers, where both cultures and sets of knowledge were found to be complementary. Major actors of this include architects Walter Gropius, Le Corbusier, Mies Van der Rohe and Frank Lloyd Wright.

TWO CULTURES, TWO APPROACHES

"Since the beginning of the century, architects and engineers look at one another more with bewilderment than with good will, as if god a+b and the goddess Fantasy were glaring at each other.[1]"

César Daly's statement is probably still true today in certain situations, but it is important to note that architects and engineers are ultimately collaborating together to achieve the same goal: the successful construction of a building. Today it is important to understand who plays which role in this process.

In the minds of most people, the architect is considered an artist: they need to be creative with buildings corresponding to their style. The engineer's function, on the other hand, is rarely well understood and remains fuzzy. Many people don't know exactly what engineers do, and the engineer's contribution to a building is hardly publicized. People generally only see the final product of a design process without fully understanding the design effort or the specific contributions of each actor. This can partly be explained by the fact that there is an extremely different attitude of engineers and architects to the question of artistic paternity: engineers like to think of themselves as objective interpreters of the laws of nature, and they are typically reluctant to regard themselves as artists or authors. Architects, on the other hand, are generally happy to think of themselves as authors or artists.

Clichés still exist: engineers often accuse architects of gratuitous aestheticism, and architects reproach them for their purported disregard of architectural values and codes. However, the duality and complementary nature between engineers and architects remain important today, as buildings increasingly become more and more complex.

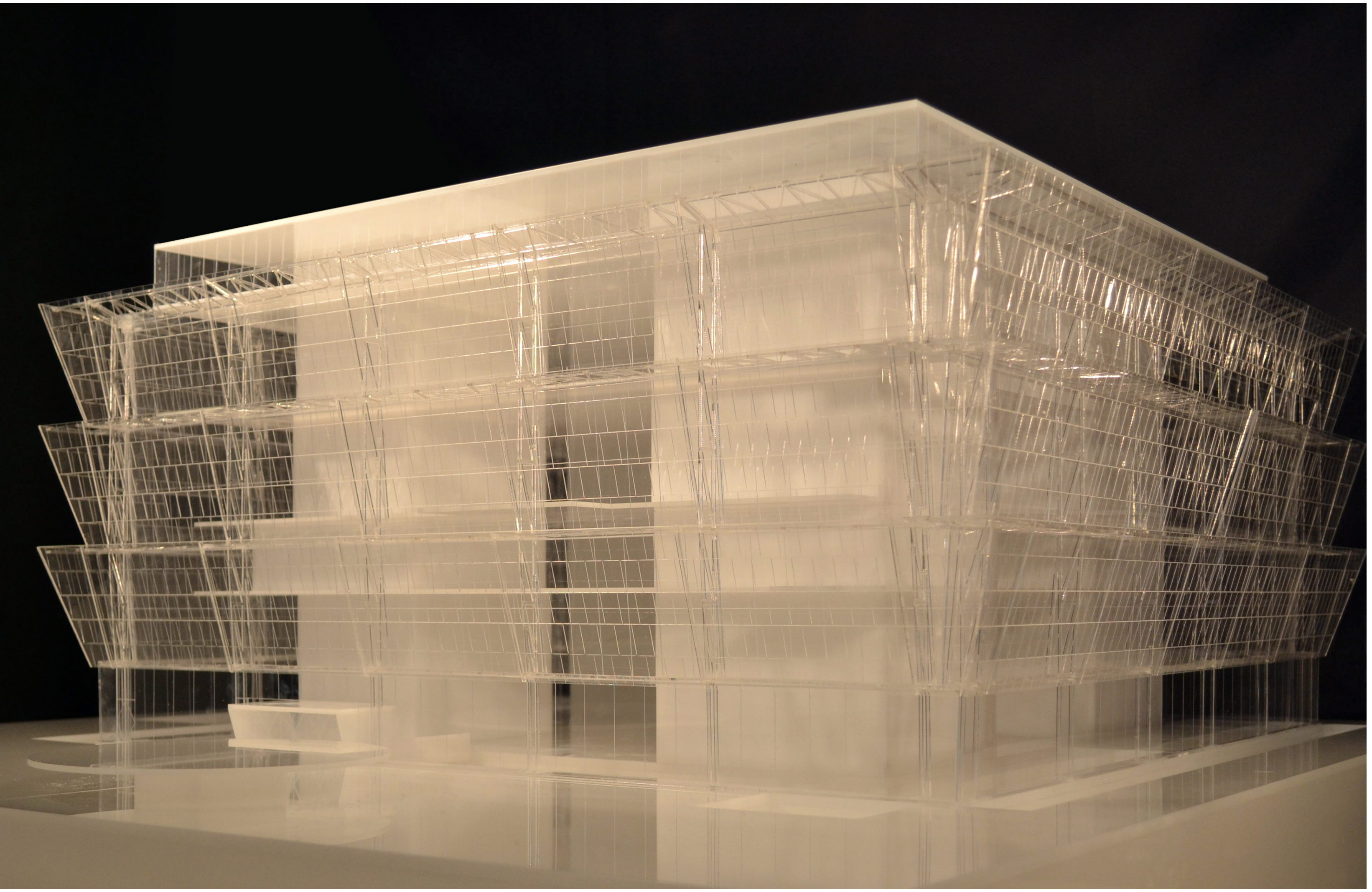
It is not always understood that innovation and creative thinking are the basis of every aspect of the engineering design of buildings. Good engineers can help architects realize their projects, especially when they are involved as early as possible in the design process. An engineer's knowledge of scientific principles can allow freedom in materials, structural actions and construction techniques. Additionally, it is important to balance the structural performance of a building with the cost of achieving it.

The traditional relationship between architects and engineers follows a linear process, where the different participants come one after another. In this case, the architect designs the building and decides on all the architectural aspects of the building, after which the engineers act as technicians, making sure that all the performance criteria are respected. The architect is considered as the team's leader while the engineers have a secondary role, bringing little input to the visual and functional aspects of the project.

A modern kind of relationship is conceived more as a collaborative partnership, setting up a design team consisting of architects, engineers and other participants. This relationship enables the development of a new kind of architecture that allows for levels of complexity never before encountered. The advantage of this kind of relationship is that it creates a dynamic in which everyone's input is valuable, and it allows for the project to evolve in the best possible way. The engineer joins the design process as early as possible in order to provide technical value to the project and alternative approaches. French architect and engineer Marc Mimram expresses the philosophy behind this new approach when he says, "Architecture is not a beam, but we are looking for a sublime beam." Though architecture is not limited to construction, construction is a major part of a project, and engineering concerns and contributions must be taken into account during the design phase.

THE DESIGN-ASSIST PROCESS

The design-assist process is an answer to the demand for a new relationship between architects and engineers. Design-assist is a collaborative partnership developed within the past ten years that has proven effective in mitigating risk posed by complex design requirements, emergent materials and specialized technology. It involves architects and engineers as early as possible in the design process, along with all other necessary specialty expertise. For a firm like Enclos, there are usually two different approaches to a project: a prescriptive approach, where the architects say exactly what they want, and a performance-based approach, which involves bringing an expert to further develop the details that meet both the architectural intent in terms of aesthetics and performance requirements. In the performance-based approach, the architect works on the outer appearance and leaves the inner performance work to an expert who will design anchors, details and assemblies to bring about a functional and constructible solution. This kind of approach typically involves a design-assist phase including the following steps:



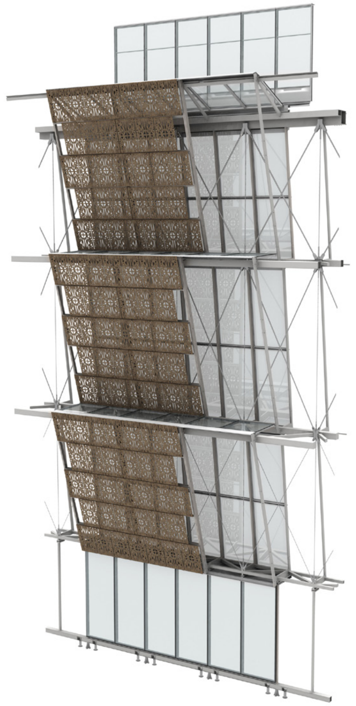


FIGURE 1
Acrylic model of the National Museum of African American History and Culture, scale 1:100.

FIGURE 2
The original cable and tension rod wall design.

FIGURE 3
Alternate design with a vertical steel truss instead of vertical cables.

- Development of a clear scope of work, budget, schedule, aesthetic, and performance goals by the building owner and architect
- Qualification and selection of design-assist contractors
- Collaborative research and development of project specifications and documents, with the design-assist contractors performing most of the work with direction from the architect
- Confirmation of scope, budget and schedule by the design-assist contractors for the developed design
- Contracting of build services with design-assist contractors
- Development of means and methods
- Development of trade coordination

To better understand how this collaborative process works, let us examine a recent project that benefited from a design-assist phase: the Smithsonian Institute's National Museum of African American History and Culture (NMAAHC) in Washington D.C., designed by the FABS design team—Freelon, Adjaye, Bond and Smith Group.

The NMAAHC facade is composed of sloped glazing and an external architectural screen made of cast aluminum panels. The full facade system is very deep, with a complex reverse design steel structure made of articulated profiles situated on the outside of the curtain-wall, making the system atypical and very challenging in terms of thermal performance.

The design-assist phase started in June 2012, with the design team meeting first on a weekly

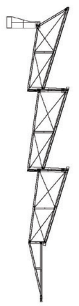
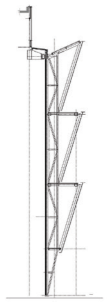
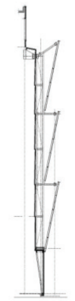
	ALTERNATE A	ALTERNATE B	ALTERNATE C
			
GEOMETRICAL CONSIDERATIONS			
Profile	Original – Articulated 37°	Modified – Straight	Original – Articulated 31°
Support geometry	Original	Moved (-800 mm)	Original
Face of glass at top	Original	Moved (-800 mm)	Moved (-800 mm)
Face of glass at bottom	Original	Moved (+75mm)	Same
Soffit dimension	1000 mm	0	100 mm
Interior clearance issue	Original	Some impact	No impact
PERFORMANCE CONSIDERATIONS			
Thermal performance	–	Best	Better
Structural performance	Same	Same	Same
Smoke performance	–	Some impact	Less impact
Thermal bridge at Truss 1	Present	Eliminated	Present
Visual Glass Distortion	Less	More	Less
SYSTEM CONSIDERATIONS			
Glazing system	Unitized	Unitized	Unitized
Exterior platforms	Glass	Grating	Level 1 only
Storefront	Exterior	Interior	Exterior
Truss 1 soffit	Present	Eliminated	Present
Glass	Lami-IGU	Lami-lami-IGU	Lami-IGU
BUILD CONSIDERATIONS			
Construction schedule	+1 month	0 months	+1 month
FABS design schedule	Some impact	More impact	More impact
Cost	Most expensive	Cheapest	More expensive
Fabrication	More difficult	–	Slightly difficult
Erection	More difficult	–	Slightly difficult
Maintenance (exterior/interior)	Difficult	Simplest	Simpler

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TABLE 1
Comparison between the three vertical truss alternates proposed by Enclos.

basis and later on a bi-weekly basis. The design-assist phase ended in early January 2013 with the final design of the facade system being very different than the one that was originally designed by the project's structural engineers.

The original design was a cable and tension rod wall that supported a perimeter horizontal truss. This horizontal truss in turn supported the exterior screens (the Corona) and the curtain-wall. Enclos proposed this initial design in addition to an alternate where a vertical steel truss replaced the vertical cables. The truss came as a significant saving for both the curtain-wall and the structure. The truss system strategy was ultimately selected by the project team.

An unusual aspect of this project was that Enclos was responsible for the steel that supports the whole facade system, whereas in most projects, the curtainwall is hung from the building's slabs. In addition, the building was required to provide a level of blast protection to its occupant.

The original bid had both the interior and exterior lites laminated. The intent of this lamination was for the exterior lite to resist the blast and the interior lite to catch any glass fragments. Based upon previous experience, Enclos engineers were able to propose replacing the exterior laminated lite with a monolithic lite, which realized a savings in the glass, the curtain-wall system, and reduced the loads to structure. Enclos was able to implement the change and review it quickly since all the required parties — including architects, engineers, and other specialists — were in place and openly collabo-rating. With the saving from the glass, additional curtainwall features could be included.

Additional features included changes in the glazing geometry that brought the design closer to the original architectural vision. In addition to providing solutions that allowed a wall with more architectural features, design-assist also enabled the project team to discuss design issues and begin to address them. With the change from a cable wall to a truss system, the building movements and loads to structure changed. The loads to structure decreased, but at the cost of a convenient means to adjust for the building movement. While cable walls have built-in means to adjust tension in the cables and accommodate building movement, the truss system does not have that feature. Thus, extensive coordination between the structural engineer of the building and the Enclos team allowed us to determine the loads to structure and the expected building movement/deflec-tions. Several cycles of loads to structure and expected deflection were done to develop a system of support that minimized differential deflection and to ascertain the magnitude of anchor movements that the anchor needs to accommodate.

Three vertical truss alternates were proposed by Enclos during the initial weeks of the design-assist process: Alternate A was very close to the original design's geometry with a sloped glazing, while Alternate B and C included flat curtainwall (only one degree slope for the Alternate C glazing). This was due to the cost of the sloped glazing. Table 1 shows which comparisons were made in order to decide which system was the best in terms of aesthetics, cost and construction.

Enclos was able to reduce the costs of the glass and propose an Alternate C1 with the truss system of Alternate C and the sloped glazing originally desired by the architects, shown in Alternate A. In order to design this solution, the designers set points on the inner and outer limit the system had to respect. These points became the outmost corona points, and the outmost glazing points of this reverse design system. This solution was selected, and Enclos' designers moved forward with the details from

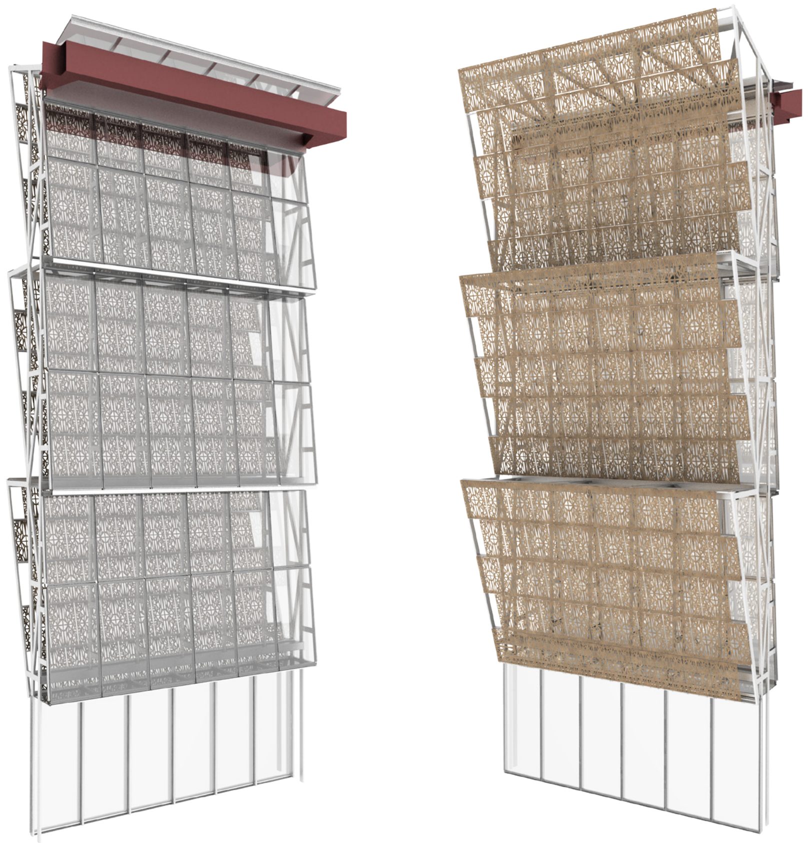

FIGURE 4
Final design-assist truss system proposal.

there. The design-assist meetings with the full design team became a bi-weekly occurrence, and Enclos submitted drawing sets of details at each of these meetings. (See Figure 4)

After the entire project team agreed upon the vertical truss design, Enclos started specifically working on the test mockup, which served as both a performance and visual mock up. The design and dimensions of the mockup were agreed upon by all parties, and further details were developed. All the connections between the steel vertical and horizontal trusses were designed and modeled at this point with constant communication between Enclos' designers and engineers. The NMAAHC mockup is one of the largest the Studios have ever built, measuring approximately 60 feet tall (18.3 meters) and 37 feet wide (11.4 meters). (See Figure 5)

All the changes in the system design were made possible thanks to the design-assist phase. Without this phase, the design team would have had to do all this work on its own, analyze the different options, choose one, and then send it out to the subcontractors. The success of design-assist in this case shows that it is a powerful means to develop a solution that can maximize the return, both for the client and the subcontractor.

Design-assist is time and resource intensive, but if it is done successfully, it will be a time and cost saver in the end. It is a process that is still very new, and a lot of people do it differently. There are several keys to a successful design-assist phase. First, it requires a collaborative and open environment — the design subcontractor needs to be brought on as early in the design process as possible, and second, all members of a subcontractor team need to be dedicated and in place for the design-assist process to fully realize.

FIGURE 5
Full-scale mock up and chamber.

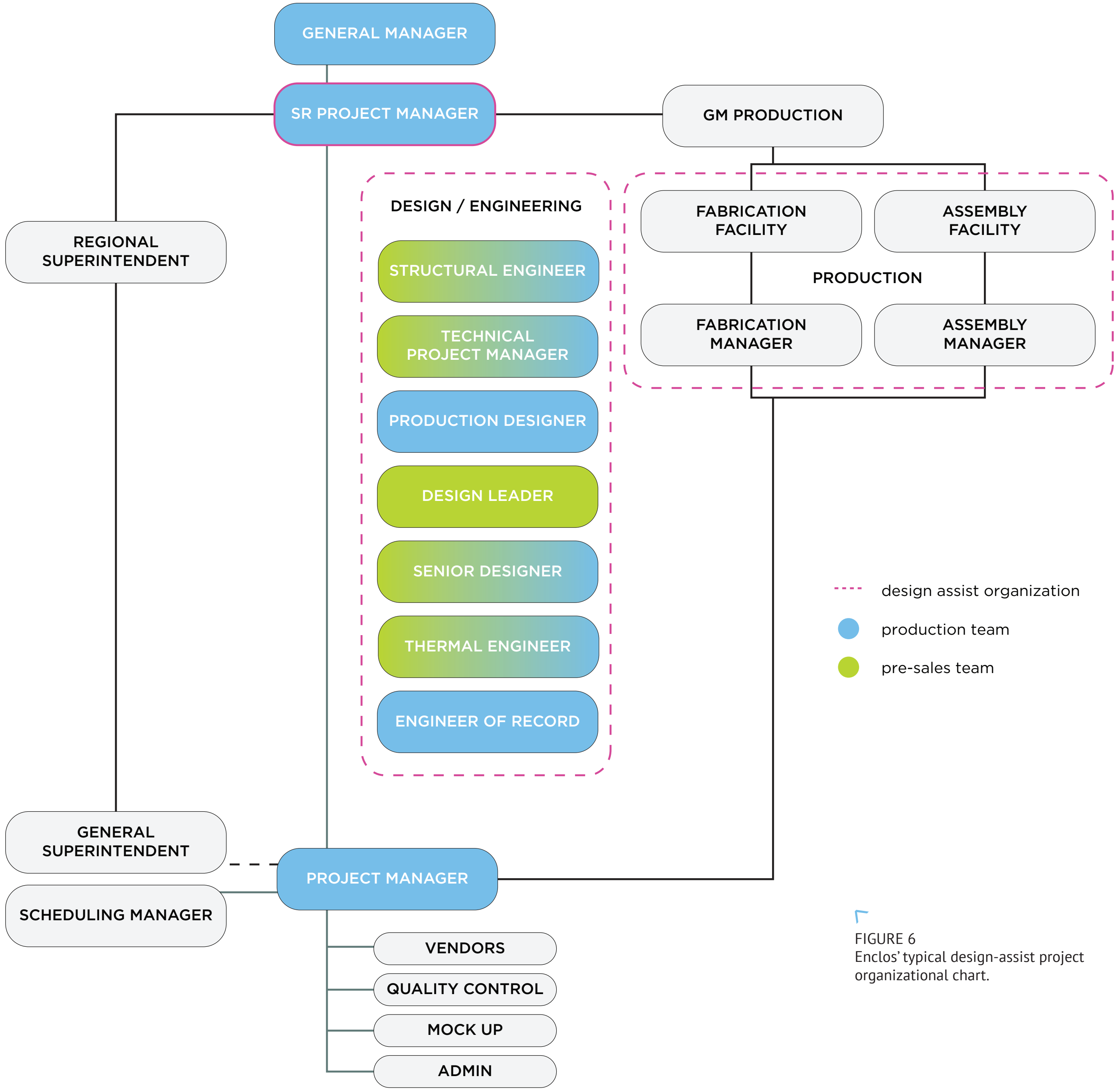

FIGURE 6
Enclos' typical design-assist project organizational chart.

A very important aspect of this phase is to develop a plan for the project. Every project is unique, so there is not one typical process that you can apply across the board, and it is very important to clearly define each of the project's specific goals. In order to do that, the project needs to be broken down into different systems and segments. These need to be treated one after another, in order to avoid trying to deal with everything at the same time. Once these different goals are set, an elaborate schedule needs to be in place so as to respect the different deadlines. From there, the process is to create and distribute the "deliverable" items (i.e., details, drawings) which enable us to fulfill the different goals set prior to each meeting, during which they will be reviewed, along with the agenda and the cost-tracking log. After these meetings, each member of the design team publishes notes about the drawings or other documents which then need to be updated according to those comments. These updates then become the deliverables, and the cycle repeats itself.

During the meetings, it is important to organize time in order to cover all the important points listed on the agenda. It is important to allow as much time as possible for these discussions in order to have the confidence that what the Studios design and size during the design-assist phase will work, keeping in mind that it is not a fully developed solution, and that it will still change once the production phase starts.

Another important aspect to a successful design-assist phase is the organization of manpower. Figure 6 shows the typical organizational chart for an Enclos team on a project such as NMAAHC.

On a hard-bid project, the design and engineering team is usually split in two different groups: the pre-sales team and the production team. In Figure 6, the pre-sales team is represented in green, and the production team is represented in blue. Only the thermal engineer remains for both phases, while the pre-sales structural engineer and the production structural engineer are usually two different persons. At first, the pre-sales team would be the one taking on the design-assist phase. However, it is of primary importance to have a smooth transition between pre-sales, design-assist and production teams. In order to do that, the technical project manager, a designated senior designer, and a designated senior structural engineer need to be involved right away in the design-assist phase. They will then be the ones taking the project to the production phase. It is important to have this team set up in order to go as deeply as possible into details during the design-assist phase and not have to change them much afterwards. Also, this allows for the whole design team to keep communicating, even after the end of the design-assist phase. This process is a very good way to communicate with all the members of the design team, and a great way to start the project, but it is very important to maintain a privileged communication between the whole design team after the design-assist phase is over in order to ensure a follow up on the next phases.

CONCLUSION

The history of building design has seen the evolution of the architect and engineer relationship develop from ignorance of each other's contributions, to open hostility and the intensive collaboration used today. It is vital that architects, engineers and other specialists collaborate as early as possible in the design process so that their complimentary skills and knowledge can be put to use in order to plan and realize the most advanced architectural undertakings. Enclos believes that the design-assist process goes a long way towards answering this new demand. Each new project requires a custom, unique solution, and the collaborative design process established during a design-assist phase can enable the design team and the specialty contractors to achieve their design and performance goals. Making the right decisions early in the design process can allow major costs and time savings, and have major impacts on the final design and production process. Preventing future problems by providing critical inputs at the start of the project is a specialty of Enclos. The design-assist process not only enables the development of a facade system that will meet both the architect's vision and the performance requirements, it also allows for site logistics and installation planning to happen much earlier, and it benefits the subcontractor who will be doing the work. Overall, design-assist is about maximizing efficiency and minimizing surprises that could come up during the production phase. As was the case on NMAAHC, design-assist can also help manage costs in order to try and save money on some areas of the project which can then be reinvested in other areas. Thus, in an architectural landscape where collaboration is the key to success, design-assist helps resolve some of the old antipathies and confusions between architects and engineers in order to channel both of their energies into a productive partnership early on in the design process.