Clyfford Still Museum: The art and science of daylighting design

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ABSTRACT: This paper explores the immeasurable and measurable dimensions of daylighting design strategies, methods, and tools used by Brad Cloepfil of Allied Works Architecture at the Clyfford Still Museum in Denver, Colorado. The author interviewed Brad Cloepfil and Chelsea Grassinger of Allied Works and Christopher Rush of Arup New York to assess design intentions, strategies, processes, and the diverse daylighting design methods and tools used to integrate the poetic and practical dimensions of daylighting design. The paper will consider three issues: 1) daylight design intentions and program, 2) daylight strategies, and 3) daylight design processes, methods, and tools. The case study reveals the diverse processes and methods used by the design team to work back and forth between exploratory methods such as drawing, diagramming and physical study models; performance based analysis and calculations; and spatial and atmospheric renderings and visualizations. The Clyfford Still Museum reveals that the processes of discovery, experimentation, and serendipity are equally as important as is a rigorous analytical approach to the art and science of daylighting design.

KEYWORDS: Clyfford Still Museum, daylighting design, daylight assessment

INTRODUCTION

Throughout history, "masters of light" have artfully bridged the poetic and practical potentials of daylighting to reconcile objective attributes of site, climate, program, and performance with subjective qualities of atmosphere, beauty, and human experience. Skillful integration of daylighting requires balancing the art and science of architectural design, as Louis Kahn, a modern "master of light" explained: "A great building, in my opinion, must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable (Twombly 2003, 68)." The scientific dimensions of daylighting have matured as today's researchers demonstrate tangible benefits of natural light in the areas of energy, greenhouse gas reductions, human comfort, productivity, and health. Advances in digital rendering, analysis tools, and an ever-increasing number of daylight metrics have allowed designers to more effectively integrate daylight with other design and performance issues. Yet, with the promise of scientific and analytical advances, there also lies a risk of too narrowly framing the parameters of daylighting to those that are measurable and empirically defined. Architectural daylighting and its design processes are complex, multi-faceted, and oftentimes messy and unpredictable, as Alvar Aalto suggested:

> [A]rchitecture has often been compared with science. . . But architecture is not a science. It is still the same great synthetic process. . . Its essence can never become purely analytical. Architectural study always involves a moment of art and instinct. Its purpose is still to bring the world of matter into harmony with human life (Schildt 1989, 272).

This paper explores the measurable and immeasurable dimensions of daylighting design used by Brad Cloepfil and the design team at Allied Works Architecture for design of the Clyfford Still Museum in Denver, Colorado. The author interviewed Brad Cloepfil and Chelsea Grassinger of Allied Works and Christopher Rush of Arup New York to assess design intentions, strategies, processes, and the diverse daylighting design methods and tools used in their design process. The paper will consider three related issues: 1) daylight design intentions and program, 2) daylight strategies, and 3) daylight design processes, methods, and tools.

1.0 DAYLIGHTING DESIGN INTENTIONS AND PROGRAM

1.1 Luminous program

The artist Clyfford Still was a founding member of the abstract expressionist movement and a renowned color field painter of the 20th century. When Still died in 1980, his will bequeathed 95% of the body of his artwork to an unspecified American city that would create a museum dedicated solely to his paintings, drawings, and other studies. Still's widow Patricia selected the city of Denver as the beneficiary of the estate. From the very beginning, daylighting was integral to the museum program. Architect Brad Cloepfil describes the Clyfford Still Museum as a "chapel to Clyfford Still" (Cloepfil, 2015). Cloepfil's intentions were to effectively display and protect the artwork and to create a contemplative and reflective architectural experience. Natural light was at the heart of the design: "From the beginning, because Denver has 300 days of sunlight, the body of the building was to be a source of light from outside to inside. No one has ever seen the work in natural light. Our mission was to make the paintings come alive in light (Cloepfil, 2015)." Christopher Rush, Senior Lighting Designer at Arup New York, explains the relationship between the artwork, daylighting, and program:

> It was decided early on that the character of the space, materials, and daylighting can embrace the mood of Clyfford Still's artwork. Brad [Cloepfil] really liked the idea of a moodiness, a raw emotion in all aspects of the building design and that influenced the daylight. One thing we took away from that was to embrace the variability of daylight on a particular day, or a week, or throughout the year as clouds come and go. Not to actively manage it. Not to make it a uniform, sterile, consistent, constant condition - to accept this natural variation (Rush, 2016).

In response to the program and daylighting goals, the 7,620 square meter (25,000 square foot) museum is vertically zoned on two floors (Figure 1). The ground floor contains the entry lobby, reception area, research lab, storage and administration, archives, and circulation corridors, which include an exhibition of the historic timeline for the artist. Visitors circulate around the ground level to look into the conservation lab, painting storage, and archive areas. An elegant glass and wood staircase leads visitors to the nine upper-level galleries. More dynamic and variable daylight is allowed in the lower level entry and public spaces while strict conservation and lighting requirements are met within the upper galleries, including regulation of illuminance levels, distribution of light, ultraviolet radiation, color rendering, temperature, and relative humidity. Six of the painting galleries are illuminated by skylights, while light sensitive works are exhibited in more intimate electrically-illuminated galleries. The upper level also includes an education gallery, a conference room, and two sheltered terraces on the southwest and northeast corners that provide screened views to the surrounding city.

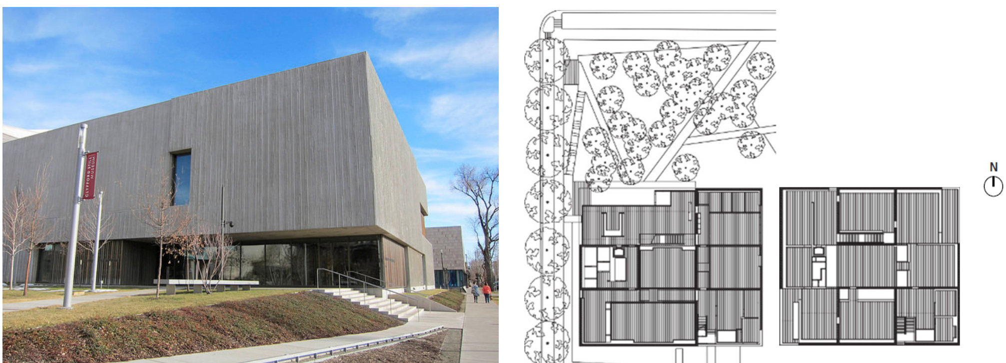

Figure 1: Site and building view looking south (left) and ground and second level plans (right). Source: (Left: Jessica Sheridan 2013; right: Allied Works 2015)

1.2 Site and the luminous journey

Located in the city center, the 0.4 hectare (one-acre) rectilinear site is bound on the east by Daniel Libeskind's Denver Art Museum Addition, to the north by Gio Ponti's original Denver Art Museum, to the south by a two-story building, and by busy streets to the west and north (Figure 1). Cloepfil set the museum back from the north boundary of the site to create a landscaped forecourt and a journey through light and shadow on approaching the entry and moving through the building:

> The first act prepares the site by creating a dense grove of deciduous trees - a place of shadow and light, a place of refuge from the endless summer sun. The second act of architecture looks to the earth, the weight and stillness of it. The new building derives its presence from the earth, pressing down into it, being held by it. The Museum is conceived as a solid, a mass of concrete, crushed granite and quartz - a single construction that is opened up by natural light. The body of the building becomes the source of light for the art. Light is amplified, diffused and obscured by each surface of the building (Allied Works, 2018).

On the outside, the sheltering building mass is animated by a dramatic play of light and shadow as sunlight grazes the vertical striations of the concrete facades and wooden slats of the screened windows and terraces. An experience of discovery unfolds as visitors move from the landscaped exterior of the building through the dappled light of the trees, sheltering entry, and into the light-filled interiors. From the interior, direct views to the site are provided only by recessed glazing at the north entry and select windows on the lower and upper floors. After entering the museum, visitors are welcomed to the upper galleries through a light-filled double-story volume in the main stairway. Vertical light shafts in the lower level circulation corridors capture soft indirect daylight from the upper floor while providing glimpses to the daylit galleries above. Ascending the stairway, visitors move through a sequence of daylit and electrically illuminated galleries, of varied size and intimacy, corresponding with the media, scale, and program requirements for the artworks.

2.0 DAYLIGHTING DESIGN STRATEGIES

2.1 Gallery daylighting

Cloepfil explored a variety of toplighting strategies for the galleries before choosing a deep skylight monitor and perforated-concrete interior screen (Figure 2). The ceiling structure and its interaction with natural light provide a dramatic visual counterpoint to the bold and textural paintings in the galleries below. The intimate scale and relatively low height of the galleries, ranging from 3.6-4.9 meters (12-16 feet), enable visitors to engage smaller drawings and to be fully immersed in the larger canvases. In addition to creating a sublime mood and character of light, the galleries needed to meet practical conservation requirements and lighting goals, which were achieved through a combination of diffuse toplighting, vertically screened and filtered sidelighting, borrowed indirect light from adjacent galleries, and supplemental electric lighting.

Oriented on an east to west axis, the gallery skylights include translucent triple-glazing with an ultraviolet polyvinyl butyral (PVB) interlayer. Below the exterior glass surface is a deep 2.1 meter (7 foot) lightwell that reflects daylight before it enters the gallery. A shade with 50 percent visible light transmittance is provided within the skylight to mediate seasonal light levels and to darken the galleries. The perforated-concrete ceiling plane on the interior, which is suspended beneath the skylights, contains oval openings that provide 25 percent visible light transmittance into the gallery (Figure 2). Rooftop photo-sensors and dimming switches coordinate the diurnal and seasonal integration of daylighting and electric lighting, which includes HIR PAR38 wall washers for large paintings and MR16 lamps for smaller works. Small heaters are integrated into the skylights to prevent condensation.

2.2 Systems integration

Mechanical, electrical, and plumbing engineers worked with the design team to optimize other building systems and overall performance. The integration of daylighting strategies, daylight photo-sensors, dimming controls, high performance glazing, and electric lighting systems resulted in an electric lighting power density of .062 watt per square meter (0.67 watt per square foot), with exclusions, for a code compliance at 30 percent below ASHRAE 90.1-2004 standards (Madsen, 2013). A demand-control ventilation system with CO_2 sensors adjusts fresh air based on occupancy loads and reduces the volume of air that is conditioned for heating and cooling, while monitoring humidity and temperature. Arup, which had also provided the engineering services for the Denver Art Museum Addition by Libeskind, proposed and developed shared building systems. By absorbing excess chilled water and hot water capacity from the neighboring building, steam-to-hot water heat exchangers and other accessories were eliminated from the Clyfford Still Museum (McConahey 2013, 16).

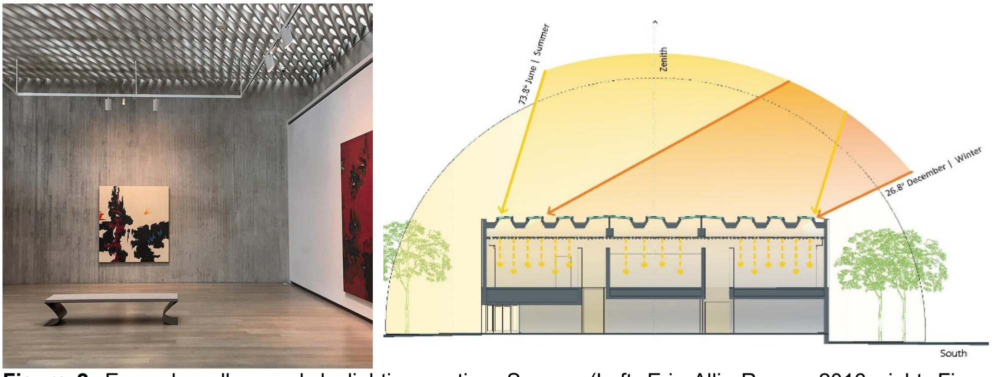

Figure 2: Example gallery and daylighting section. Source: (Left: Eric Allix Rogers 2016; right: Fiona Wholey and author 2017)

3.0 DAYLIGHTING PROCESSES, METHODS, AND TOOLS

3.1 Art and science of daylighting design

On the one hand, daylight is tangible, measurable, and predictable. Luminous characteristics such as light levels, distribution, glare, and contrast ratios can be measured using standardized metrics such as lux, footcandles, daylight factors, and candelas per square meter. Yet there are also dimensions of natural light that are more difficult to quantify, including ephemeral luminous qualities created by the changing weather, climate, time of day, and site forces. Luminous effects on “real materials” of “real natural light” (including the interactions between daylight, color, and surface characteristics such as transparency, opacity, and reflectivity) can also be difficult to anticipate. Physical models and mock-ups using real materials are particularly well suited to exploring daylight as an atmospheric phenomenon and ephemeral architectural material. Mock-ups allow designers to view the serendipitous interactions between the changing moods and qualities of light and material attributes in ways that are oftentimes surprising and unpredictable: the shifting ambiance as a cloud passes over the sun, the visual warmth of morning light, or color changes as light reflects between material surfaces. There is a necessary element of intuition and experimentation required to discover the unanticipated and emergent qualities of natural light as it interacts in time with changing sky conditions, architectural form, and material properties. Juhani Pallasmaa suggests that the atmospheric quality of space is subconscious, holistic, and beyond measure: “[T]he character of space calls for our entire embodied and existential sense, and it is perceived in a diffuse, peripheral and unconscious manner rather than through precise, focused and conscious observation. . . spaces and true architectural experiences are verbs (Pallasmaa, 23).”

3.2 Immeasurable dimensions of daylighting design

Brad Cloepfil and the design team used diverse methods and processes to explore, develop, and refine the daylighting. Early studies included charcoal and pastel concept studies, sketches, iterative concept diagrams and models, freehand and digital renderings, photo-collages, and conceptual and experiential material studies (Figure 3). Physical study models and digital renderings were critical in the early phases, as Cloepfil explains:

> The way we work on this kind of project is with physical models, which you can see in front of you and turn around, or to work in a digital 3D space that you can work on quickly. The Clyfford Still Museum was the first project where we explored the interior of the building through a digital 3D model study. We made sure that we could see through the building the way we wanted to, that everything was supporting the experience we were after (Chopra, 2012).

At the site scale, early studies included massing explorations using charcoal sketches and diagrams, iterative cardboard spatial models, concept massing models of wood and plaster, and material experiments (Figures 3 and 4). Cloepfil explained that sketches were used to explore how the massing of the building could be penetrated with shafts of light to the lower level displays and circulation: “I did this really early sketch; in fact it was one of my first sketches where I wanted light to penetrate deep into building. That’s what created those shafts and [to go] metaphorically deeper into Clyfford Stills life (Cloepfil, 2015).” Plaster models explored the connection to the earth and the play of light and shadow on the exterior and interior, in contrast to the neighboring Denver Art Museum Addition: “With Liebskind as such an expressed object, I wanted to de-objectify the Still. This is why we built the huge plaster model. I wanted the building to be surrounded by trees. You would walk through the dappled light of trees, then the surface of the building would have shadows of dappled light and the concrete would cause shadows of dappled light. And the thing would sort of dissolve in the patterns of light. That was the original intent (Cloepfil, 2015).” These early sketches and physical model studies were essential in developing the overall spatial organization, massing, and materials qualities of the museum. The siting, scale, form, and heavy concrete mass with few windows emphasize the quiet internal focus of the building. Within the galleries, Cloepfil sought to transform the solidity of concrete into a light-emitting surface suspended beneath deep skylights.

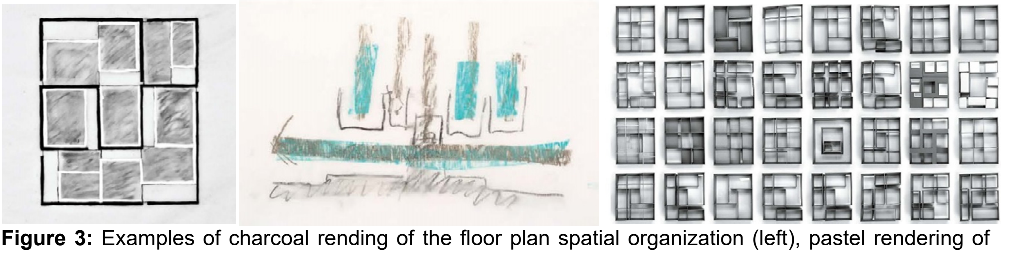

Figure 3: Examples of charcoal rending of the floor plan spatial organization (left), pastel rendering of sectional volumes (center) and iterative spatial physical paper massing models (right). Source: (Allied Works 2015)

At the gallery scale, Cloepfil and the team explored a variety of daylight strategies using freehand renderings, diagrams, and small physical models (Figure 5). Interior renderings using Rhino models and Maxwell Render helped to clarify the desired quality of light, as Cloepfil explains: “We did this one rendering using Maxwell lighting software that has that quality [of water]. I said if we could just get that sense of it, almost not being an obvious pattern, but a kind of ripple of light up there [from the ceiling] (Cloepfil, 2015).” At one point, Cloepfil did a sketch and asked the question to the team and engineers how to create light emitting concrete?: “I wanted the light to come through and off the concrete and I wanted the ceiling to be perforated in some way. I wanted it to be like the concrete was emitting light through the ceiling. We tried it with the structural engineers and with the daylighting and it worked. One of the visiting curators said it was almost like ‘liquid light’ and I think they nailed it. It has a visceral quality (Cloepfil, 2015).” Cloepfil emphasized how effective new lighting software is in rendering the quality of daylight: “Software now is so amazing that you can get that qualitative feel (Cloepfil, 2015).” The appearance of a heavy concrete ceiling screen was transformed in density and weight through the ovoid openings, pattern, and detailing to create a water-like quality of light. As though immersed in an underwater world with a dappled play of light on the surface, the direct sunlight is transformed and diffused by the depth of the skylight section and perforated concrete surface of the light-emitting ceiling.

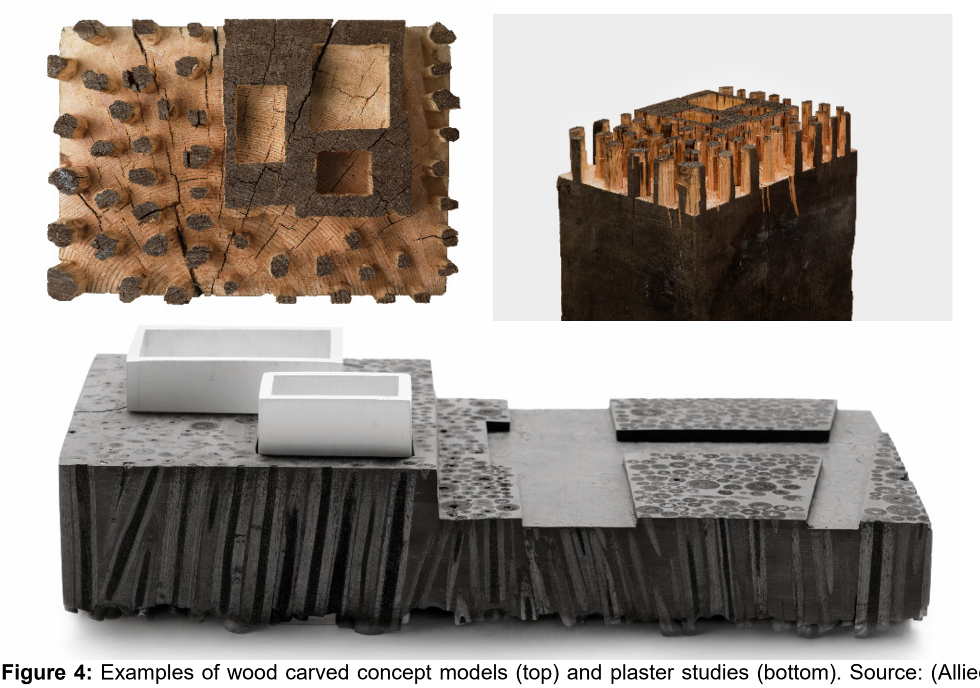

Figure 4: Examples of wood carved concept models (top) and plaster studies (bottom). Source: (Allied Works 2015)

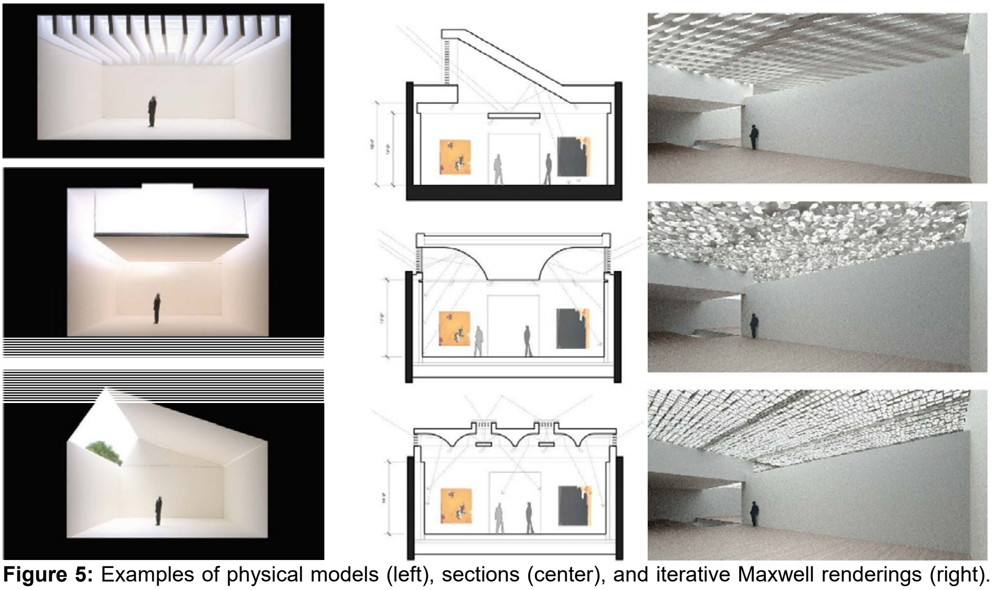

Figure 5: Examples of physical models (left), sections (center), and iterative Maxwell renderings (right). Source: (Allied Works 2015)

Cloepfil explained that concrete was his material of choice to capture the desired atmosphere and experiential intent: “It's the idea of compression; the building compresses you. That's why we chose concrete. All these things come together. I wanted you to feel like one body. It wasn't about a minimalist aesthetic. It was about keeping the building as elemental as possible. So, when you walked into the building you were being held in the building with those paintings and with natural light. That was it, the body in the building, the light, and the art. And that they are all somewhat indistinguishable (Cloepfil, 2015).” Mock-ups at ½” and 1” to the foot were constructed to study the ceiling and wall detailing. These included ceiling studies using grey-painted foam, a full-scale mock-up of half the gallery with skylight details and layering, and exterior wall details to study the effect of light and materials (Figure 6). Reminiscent of the heavy impasto of Still's paintings, the striated concrete surfaces on the museum's exterior and interior include vertical fins with rough edges that were created using two depths of formwork with beveled edges and varied gaps. Cloepfil describes his fascination with concrete: "Concrete is like alchemy, you add a little of this or a little of that and you can make it into an entirely different entity. I love the mystery of concrete and how much it can do (Cloepfil, 2015)." He characterizes the surfaces as "corduroy concrete" with the textured surfaces fostering a dramatic play of light and shadow that results from the material details: "I love material dimension and the way light expresses that dimension. Pushing back concrete two inches there or raising something out an inch and a half and seeing what it does with the shadows is beyond belief (Cloepfil, 2015)." Physical mock-ups were essential to gain hands-on experience of the luminous effects and to confirm construction details and methods that would result in the desired quality of light and shadow.

Figure 6: Examples of full-scale mock-ups: gallery (left) and wall detail tests (right). Source: (Arup 2015)

3.3 Measurable dimensions of daylighting design

The challenges of daylight design in the galleries were to celebrate the changing character of natural light, create the desired moods and atmospheric qualities, and obtain an appropriately uniform distribution of light and illuminance levels on the gallery walls. In addition to creating a sublime mood and character of light, the galleries needed to meet practical conservation requirements and lighting goals, which were achieved through a combination of diffuse toplighting, vertically screened and filtered sidelighting, indirect light borrowed from adjacent galleries, and supplemental electric lighting. Collaborations with Brian Stacy and Christopher Rush, engineers at Arup New York, were essential in creating desired atmosphere and mood while also meeting the highest standards for lighting performance. Mock-ups and physical model studies that were used to consider atmospheric and spatial characteristics also served to investigate performance issues. Rush explained how Arup worked with the team to support an integrated daylighting design process:

> We used small-scale physical models with accurate geometry and computer simulations throughout the design process to be sure we were on target and that the design allowed some flexibility….This caliber of project usually includes a full scale mock-up to fine tune the design when the gallery is nearly complete and to do some measurements for exterior conditions so the interior condition tracked with predictions. In the final stages of this design we did a full scale mock-up for one section of gallery on the ground next to building while it was under construction. This was a last check to confirm everything . . . and it was partially a confidence booster to be comfortable with the construction, the skylight details, water proofing, finishes . . . and that the daylight levels were correct (Rush, 2016).

Iterative physical and computer models and on-site construction tests verified that the design was successful at meeting conservation goals of limiting daylight exposure to less than 65,000 footcandle-hours per year (65 Kfc-h) while achieving a consistent 20 footcandle (215.2 lux) illuminance on the gallery walls at a 5 foot (1.5 meter) height (Figures 7 and 8). Arup described their approach to lighting targets: "[The] approach was based on cumulative exposure on the art for a typical year instead of maximum illuminance at any one time. The Museum agreed with this, enabling the daylight systems to be designed for appropriate annual exposure, rather than the single brightest hour of the year (Rush, 2016)."

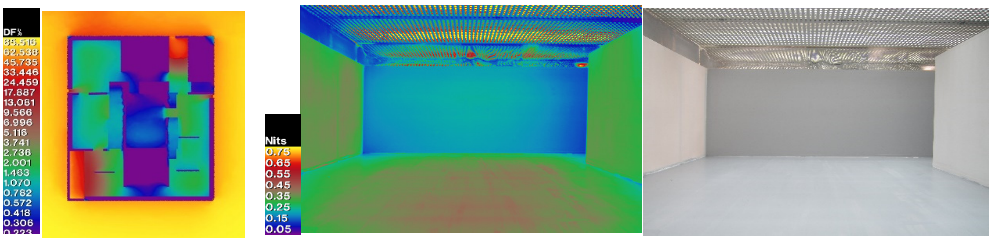

Figure 7: Examples of daylight analyses using Radiance software: daylight (left) electric (right). Source: (Arup 2015)

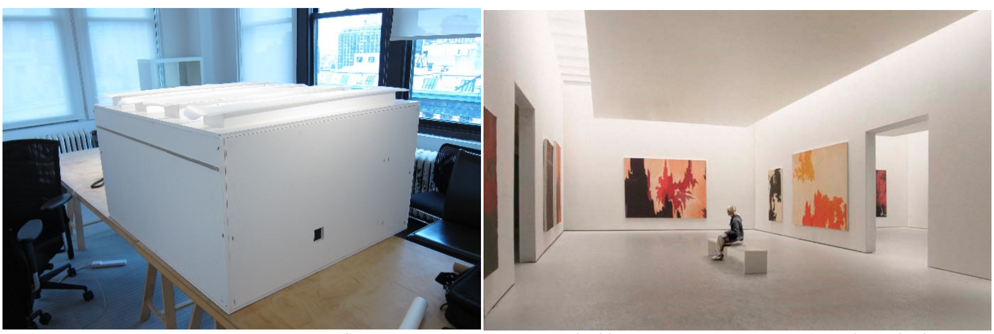

Figure 8: Physical daylight model of gallery: exterior model (left) and interior photograph (right). Source: (Arup 2015)

Cloepfil emphasizes that daylighting design is a collaborative process that requires careful selection of correct design methods and media, based on what the designer and team are trying to understand and explore (Cloepfil, 2015). Longtime collaborations with trusted daylighting designers and engineers from Arup have been essential in Cloepfil's ability to integrate experiential and performance goals. Cloepfil explains that data is not an end in itself. He suggests it is necessary to know when design intuition and experience must go beyond the data:

> You have to trust your eye. [Arup] will give us the data and light ranges . . . and then I always push back. We might need more light or find ways of controlling and diffusing it. It's a back and forth all the time between the data and what you want the experience to be. That's why it's nice working with Arup, they have worked on so many museums. We can talk about different museums and the quality of light and they know the light levels. There are things from Brian [Stacy] that I learned about the eye. There can be a certain level of change of quality of light across a surface and your eye will unify it, if it stays within a certain range. There are certain things your eye does that you have to take into account. That's where the data really doesn't work; because you look at the data and you have this range of light across the wall, but yet it's not perceived. So here is this data, now what do we want to do with it? They understand that the data is not an end, just a base to work from. It gives you a reference that you desperately need, but it's not an end. That's a good engineer (Cloepfil, 2015).

In the search for the desired quality of light and atmosphere, the design team used multiple methods and tools, as Cloepfil explains: "We're just continually searching and trying to understand the available light and trying to understand what to do with it. It's always about a level of protection, protecting the art and people in the workspace. It's about general energy control and keeping sun out of spaces, but then after that it's the quality of things. And that's the part where you use every tool (Cloepfil, 2015)."

CONCLUSIONS

At the Clyfford Still Museum, Cloepfil and the design team have achieved a meaningful conversation between the body of art and the body of architecture. Light, materials, structure, and space come together to create a tangible architectural and luminous presence that compliments and reveals the power and mystery of Clyfford Still's artwork. The key lessons from the case study include the following:

1. *Employ Diverse Daylight Design Methods, Media, and Tools*: The case study reveals the diverse processes and methods used by the design team to work back and forth between exploratory methods such as drawing, diagramming and physical study models; performance based analysis and calculations; and spatial and atmospheric renderings and visualizations. The diverse processes and methods used by the design team enabled them to engage the physical and emotional potential of daylight as a dynamic building material.
2. *Integrate Performance Based Analysis and Calculations*: Computational tools provide insight into both performance and experiential dimensions of design. As Cloepfil explains: "We'd want any tool we use to help us realize our vision for what the space is going to be like, in terms of its experience. I'd say that materials are key, light is key, and the order of the space is key (Cloepfil, 2015)."The attempts are from an analytical point of view [from Arup] and the leaps we [Allied Works] have to make beyond analytics to try to find the quality (Cloepfil, 2015)."
3. *Use Physical Models, Photography, and Renderings to Investigate Experiential Phenomena*: Physical models at multiple scales and levels of detail combine with digital renderings to study, test, and refine the luminous atmosphere and spatial characteristics. As Cloepfil explained: "Something magic happened there. There is design intention and then there is experiential phenomena. The experience is so much richer than hoped. We have a language between us [Arup] that is a quest for the qualities we are looking for [in the museum].

For Cloepfil, design always returns to creating a meaningful human experience in which light plays an essential role: "The goal is that architecture should move you in a way you haven't been moved before. . . Moments of wonder are what we all want (Cloepfil, 2015)." The Clyfford Still Museum reveals that the processes of discovery, experimentation, and serendipity are equally as important as is a rigorous analytical approach to the art and science of daylighting design.

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