Piano Pavilion at the Kimbell Art Museum: Daylighting Strategies and Methods

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ABSTRACT: This paper presents the findings of a qualitative daylighting case study analysis of the Renzo Piano Building Workshop’s (RPBW’s) new Piano Pavilion at the Kimbell Art Museum. Three issues are explored: 1) Piano and Kahn’s approaches to the daylit art gallery, 2) RPBW’s approach to integrated design, and 3) RPBW’s design methods and tools. Research methods for the paper included 1) qualitative evaluation of design strategies, and 2) assessment of quantitative daylight analyses by Arfon Davies at Arup (2016) and Kacel and Lau (2013). Renowned for their commitment to design excellence, architectural innovation, and sustainable design practice, the Piano Pavilion by RPBW provide insights into a holistic approach to contemporary daylighting design strategies and methods that can inform and inspire architectural practice and design education.

Keywords: daylighting, art museums, Renzo Piano Building Workshop, Piano Pavilion

INTRODUCTION
Exquisite qualities of light in space, exceptional craft and detailing, structural clarity, and material properties have made Louis Kahn’s 1972 Kimbell Art Museum in Fort Worth, Texas an architectural masterpiece. Despite a growing need for additional exhibition and educational spaces, it was not until 2007 that Renzo Piano, principal of Renzo Piano Building Workshop (RPBW), was commissioned to design the museum expansion. This paper presents the findings of a qualitative and descriptive case study analysis of the Piano Pavilion to assess Piano’s approach to architectural daylighting strategies four decades after Kahn’s museum was built. Three issues are considered: 1) Kahn and Piano’s approaches to the daylit art gallery, 2) RPBW’s integration of architectural design, daylight strategies, and technology, and 3) RPBW’s design methods and tools used to develop and assess the new galleries.

The research methods for this case study include: 1) Qualitative assessment of Kahn and Piano’s daylighting strategies, and 2) Comparative assessment of quantitative analyses for the Piano Pavilion by Arfon Davies (2016) and the Kahn Museum by Seda Kacel and Benson Lau, University of Nottingham (2013).

DAYLIGHT PROGRAM
The goals of the museum expansion were to honor Kahn’s beloved building and create a worthy architectural companion. The new museum was to be physically minimal, open, and distinct from the internally-focused and sheltering enclosure of the Kahn Museum, while retaining daylight as a design priority.

The program for the museum expansion aspired to set new standards for the integration of daylight and electric lighting while supporting the conservation and exhibition requirements for art, including the following daylighting criteria (James, 2014): 1) To provide a condition where daylight is the primary source of light for the display of art, 2) to have the ability to tune daylight transmission, and therefore change the mix of daylight and electric light within the gallery, 3) to be able to reduce daylight levels within the gallery to allow the display of sensitive objects requiring 50 lux or less, and 4) to reduce daylight in the galleries to a minimum when the museum is closed.

Additional qualitative and experiential daylighting goals for the expansion were clarified by architect Onur Teke (2015): “It’s a different time and different society. We were trying to achieve the feeling like taking a shower of light. You’re washed with light from the sky, with as much light as possible.” Teke explains that they also sought a direct visual relationship to the site: “There is always a connection between outside and inside. You can see people on bicycles while looking at a Caravaggio... You’re not in a closed box. The most important thing for Renzo’s architecture is the transparency and openness. You see the roof structure and light. It takes you outside.” RPBW sought to minimize the visual distinctions between inside and outside and to foster an open expansive sense of space, as Piano explains in an interview with critic Jerome Weeks (Kimbell, 2013): “It’s fundamentally a roof flying above the ground, open, accessible, visible, transparent... The two buildings work in a complementary way. Kahn is more introverted, and the pavilion is more extroverted.”
CLIMATE, SITE, AND LIGHT

The Kimbell Art Museum and Piano Pavilion are shaped by the climate and site conditions of Fort Worth, which lies at 32.7° north latitude. This region of Texas experiences the variable and dynamic weather conditions of a humid subtropical climate, with clear and sunny days offset by brief periods of overcast skies. Temperatures range from an average low of 44° F (7° C) in January to the average high of 84° F (29° C) in August. Fort Worth experiences fairly consistent daytime length throughout the year, with approximately 14 hours of daylight on the summer solstice and 10 hours on the winter solstice. The sun reaches a noon altitude of 80.8° in the summer and a low of 33.8° in winter. The high summer sun angles underscore the need to provide a sheltering roof to mediate solar gains, temperatures, and light levels. Despite the presence of sunlight on over 230 days per year, there remains a monthly rhythm of clear and overcast skies, including an average of 6-7 overcast days per month (with the exception of July and August which average 4-5 overcast days) (NOAA, 2015). The designs of the museums foster relationships to climate, site, and the changing qualities of light (discussed below).

KAHN AND PIANO BUILDING FORM

Kahn’s Kimbell Art Museum is composed of sixteen linear galleries organized on a tartan grid, elongated on the north-south axis (Figures 1 and 2). This orientation ensures an even distribution of natural light throughout the day as the sun moves from east to west. The tripartite plan was designed by Kahn to be entered on the west through the sheltering portico and grove of trees into the central zone, which contains the lobby, shop, and library. Stairs provide a link to the lower level gallery and east entry. The north zone contains two galleries, a restaurant, and an auditorium. Located in the south zone are a series of five parallel galleries. The building plan is punctuated by three intimate light courts. Each court has a distinct luminous quality, including the “Blue Court” which celebrates the sky and water, the “Yellow Court,” filled with sunlight, and the soft sheltering “Green Court” integrating garden and sculpture (Kimbell, 2013).

Introverted in plan and section, diagonal views are provided in openings between galleries and punctuated by glimpses into the courtyards. An indirect relationship to the site is defined by Kahn, with the architecture creating protective and sheltering contemplative spaces for artwork. A sense of place and time is experienced through subtle diurnal and seasonal changes of the lighting quality in galleries and courtyards, with only a direct view to the site provided at the west entry.

Sited sixty-five feet west of Kahn, Piano’s Pavilion is also a tripartite scheme, with three parallel layers of spaces from east to west (Figures 2 and 3). The addition is composed of two contrasting wings linked by glass passageways. The “pavilion” or east wing is light-filled, open, and minimal in structure and detailing. In contrast, the west wing is earth-sheltered and internally focused, containing the west gallery (for light-sensitive work), auditorium, and educational spaces. In the daylit galleries of the “pavilion,” views to the site and sky are provided through shaded south and north glass walls and translucent luminous ceilings in the galleries. Glazed lobbies in both wings provide visual and physical connections between the two wings. Since much of the expansion is hidden below ground, the light-filled and seemingly delicate east wing “pavilion” creates a respectful, even humble, relationship to Kahn’s museum.
KAHN AND PIANO GALLERIES

In a 1972 film on the Kimball, Kahn explains his desire to create a quiet and contemplative sanctuary in which to experience the beauty and mystery of art in natural light (Falkenberg, 2013): “Every work of architecture should be in natural light. And this [the Kimbell] in particular because you are seeing works of art that are really poetry.” Kahn further explained that each room has a particular quality of light and relationship to the sun (Falkenberg, 2013): “An architect is a composer; truly his greatest act is that of composing and not designing. . . Steven Douglas’ inspired statement about architecture . . . said ‘What slice of the sun does your building have?’ and I added, ‘What slice of the sun enters your room?’” Kahn allows a very specific “slice of the sun” to enter his galleries, which are all the same size at 100’x23’. The ingeniously designed skylight and reflector gathers a small amount of direct sunlight and extends its potential by redistributing it through multiple reflections (Figures 4 and 8). As sunlight enters the 3’-wide Plexiglas skylight, it strikes a perforated aluminum reflector below the skylight, which reflects diffuse light onto the silvery concrete cycloid vaults and then back to the travertine clad side walls. Indirect light is also diffused through the perforated reflector to the space below. The room becomes a light fixture with interactions between the direct sunlight from the skylight to the reflector, ceiling, walls, and space. Adjustable track lighting is integrated with the reflector design, while mechanical and electrical systems are discreetly integrated into concrete channels in the lower space between galleries. The room proportions, skylight, and reflector designs were carefully tuned by Kahn and lighting designer Richard Kelly to achieve the desired atmosphere and quantity of light.

Building on his extensive experience designing museum projects, many of which are toplit, Piano takes a decidedly different approach by using indirect north daylight rather than direct sunlight. The atmospheric qualities of Piano’s daylit galleries are reminiscent of the vast horizontal landscape of this region of Texas, which emphasizes the overhead sky vault. In his interview with Jerome Weeks (Kimbell, 2013) Piano describes Texas as “a place of big skies and brilliant light.” In contrast to the intimate silvery light and shadow of the Kahn galleries, Piano opens his gallery ceilings to the spacious overhead sky (Figure 5). Where Kahn admits a “slice of the sun,” Piano admits a “slice of the sky.” Where Kahn creates a series of intimate galleries, Piano provides two large daylit galleries, also 100’ in length but of varied widths (approximately 70’x100’ and 43’x100’ to the south and north). Toplight and sidelight are used in both galleries. A translucent glass roof spans the entire gallery, above which is located a series of shading louvers oriented on the east-west axis and open to the north. Piano creates a series of parallel views to the north or “slices of the sky” through which indirect light enters the gallery. North daylight is further diffused through a translucent glass roof, the depth of the beams, and the translucent scrim before reaching the concrete walls and gallery space. Piano’s luminous ceiling acts like a parasol that protects against the direct sun but transmits soft diffuse light. The exterior endwall of each gallery is glazed and shaded by exterior overhangs.
PIANO PAVILION INTEGRATED DESIGN

An exploded axonometric and section of the gallery reveals a layered and integrated approach to the daylight design (Figures 6 and 7). Architect Onur Teke (2015) argues that rigorous design integration results in a clarity and simplicity with each layer of the gallery roof serving multiple purposes: “The main difference with this building compared to other [Piano] roofs, is that with this roof there is a single layer with multiple functions.” The outside layer of the roof contains a series 2,322 extruded aluminum louvers containing thirteen photovoltaic cells each for a total of 30,186 cells. Six louvers are grouped into 5’x10” panels, which can be adjusted individually or in groups to provide variable light levels within the gallery. The louvers provide sun shading, generate electricity, and allow flexibility in the amount of light admitted to the gallery. Flexible space configuration is also provided with moveable partitions that can be choreographed with different louver settings to create “luminous subspaces” on a 20” by 20” grid (Teke, 2015). The automated louvers can be opened from 45 degrees to nearly closed, with variable tilt angles opening at 2-4-6-8-10-15-20-30 and 45 degrees. In severe weather, the louvers can be inverted to protect the roof and PV cells.
The Kimbell (2016) and Davies (2016) estimate that the photovoltaic cells offset up to 50% of the annual carbon production from building operations and generate enough electricity to meet annual electric lighting demand. Integration of design goals and technological performance were considered in all aspects of the gallery detailing (Teke, 2015). Below the louvers, the roof is clad with acid-etched krypton-filled double glazing, which includes a UV filter to protect the artwork and a low-emissivity film to mediate solar gains. The volume of space between the roof and the bottom of the laminated Douglas fir beams further softens the indirect light, which is finally diffused through a fixed translucent fabric scrim at the lower edge of the beams. The transparency of the acid-etched glass and the fabric scrim allow a view to the sky and changing weather. Fire suppression systems are integrated into the void within the beams and the electric lighting is suspended below the structure. Low-volume air supply is provided through a plenum beneath the raised oak floor, which contains narrow gaps that “breathe” to regulate ventilation and thermal comfort. During much of the day, the artwork is illuminated by daylight. This is supplemented, as needed, by electric lighting. Control systems monitor light levels, thermal conditions, humidity, and ventilation. Sidelight is controlled by adjustable translucent shading at the floor-to-ceiling double glazing to alter the lighting levels, control glare, and provide views to the site. Exterior overhangs further mediate light and solar gains.

PIANO PAVILION ENERGY PERFORMANCE

In the Piano galleries, daylight is used as the primary source of illumination, with the goal of limiting the use electric lighting to the early and later hours of the day and winter months. Daylight combined with LED electric lighting effectively reduces lighting energy consumption by 75% compared to the Kahn building (Davies, 2016, James, 2014).

The overall building energy consumption for the pavilion minimizes external heat loss and gains as well as storm water run-off by locating two-thirds of the building below ground and beneath a green roof. The pavilion employs 36 geothermal wells to harvest ground water for heating and cooling, which combine with a displacement air system from the “breathing floor,” to optimize energy performance and comfort. Arup and RPBW estimate that the integration of daylighting, energy efficient LED electric lighting, control systems, photovoltaic cells, and a geothermal system reduces energy consumption and carbon emissions by 50% as compared to the Kahn building (Kimbell, 2016). (Energy Use Intensity in kBtu/ft² is not available for publication at this time. The author acknowledges the difference in energy prices and lighting technologies available between the two projects.)

PIANO DESIGN PROCESS AND TOOLKIT

Kahn and Kelly developed and refined the contemplative quality of light at the Kimbell through iterative refinement and testing of over 100 daylighting variations using drawings, scale models, and full-scale mock-ups (Seward, 2011). Refinements to the reflector were evaluated by computer analyst Isaac Goodbar from Edison Price Lighting (Seward, 2011). The Piano Pavilion was designed with the same spirit of iterative exploration, testing, and integration. Onur Teke (2015) explains that RPBW worked with Arfon Davies and associates from Arup using a “workshop approach.” This collaboration including initial studies of Kahn’s museum, iterative design scenarios, quantitative analyses, and prototype testing. Teke emphasized that collaboration continued throughout the design and construction phases, with RPBW focusing on design and Arup overseeing daylight analysis and artificial lighting.

Teke (2015) stressed that RPBW used a variety of qualitative daylighting tools, including physical models, photography, renderings, scale prototypes, and full-scale mock-ups. Underscoring the importance of physical models, Teke (2015) estimates that 150-200 physical models were used to test design strategies, as well as five full-scale mock-ups to explore the quality of light, measure daylight performance, and resolve construction detailing. Despite today’s digital rendering and computer analysis, Teke (2015) recommends that architects continue to use hands-on models and mock-ups.

DAYLIGHT ASSESSMENT

Throughout the design phases, iterative quantitative analyses were conducted to evaluate and refine the architectural and daylight strategies, roof system, and detailing to achieve the four daylighting performance goals: 1) Using daylight as the primary source of light, 2) the ability to tune daylight transmission, 3) the ability to reduce light levels to 50 lux or less, and 4) minimizing daylight when the museum is closed. An example quantitative daylight analysis of the Piano Pavilion by Arfon Davies and associates at Arup is illustrated in the transmission analysis in Figures 9 and 10. These transmission simulations evaluated the effect of the louver “tilt position” open to 5-10-15-20 degrees and the resulting illuminance levels and uniformity of the light distribution on the vertical wall. The simulations studied “average” annual conditions at noon on the spring/fall equinox under sunny sky conditions. Illuminance levels on the vertical gallery walls range from a minimum of six footcandles (60 lux) with louvers open to five degrees and up to a maximum of 40 footcandles (400 lux) open to 20 degrees. The example demonstrates that program goals were met for the use of daylight with supplemental electric lighting and control systems.
A quantitative analysis of the Kimbell Museum by Seda Kacel and Benson Lau (2013), illustrates Kahn’s approach to illuminating the art galleries. Kacel and Lau developed a thorough daylighting analyses of the northwest and southwest galleries (Gallery A and B respectively). Ecotect Radiance was used to evaluate illuminance levels and light distribution in Gallery A under “worst case” sunny sky conditions in June at noon (Figure 11). This aspect of the study illustrates an average of five footcandles (50 lux) on the vertical wall, with the following conclusion by Kacel and Lau (2013, p.4): “The average daylight factor in the entire Gallery A is 2.0 percent. This indicates a luminous environment which requires supplementary artificial lighting.”

Their study of Kahn’s southwest Gallery B, adjacent to a light court, estimated a daylight factor of 2.3 percent under overcast sky conditions (Figure 12). Kacel and Lau drew the following conclusions (2013, pp.4-5): “While the court zone is a well daylit space with daylight factor around 5 percent, inner zone has a rather low daylight factor around 1 percent. . . In Gallery B facing the south court, the average daylight factor is 2.3 percent suggesting a relatively low daylit appearance for the gallery space.” Daylight is most effective in providing ambient illumination, while electric lighting illuminates the artwork. Despite the need for electric lighting, the atmospheric quality and experience of light is perhaps Kahn’s greatest daylight legacy.

CONCLUSIONS
Kahn and Piano use daylighting to create their own architectural languages of light for the same client and site. Forty years later, in the Piano Pavilion, there was an expanded daylight program, with the goals of illuminating the artwork and ambient space with daylight, as along with integrating new construction methods, technologies, and energy efficient design strategies. Yet, each building stands on its own merit, reflecting the visions of two very different master architects and their respective eras. Renzo Piano achieves a respectful and elegant luminous conversation across the decades with his mentor Louis Kahn.

The Piano Pavilion by RPBW, in collaboration with Arup, provides insights into a holistic approach to contemporary daylighting design strategies and methods that can inform and inspire architectural practice and design education. The following lessons are revealed in this daylighting case study:

1. **Role of Daylight**: Kahn effectively uses daylight for ambient illumination, while electric lighting is the primary source of illumination for the artwork.
Piano’s galleries illuminate the artwork with daylighting, while electric lighting is supplemental.

2. Reflected versus Diffused Daylight: Kahn uses reflection and Piano uses diffusion to create “luminous ceilings” in the galleries. Kahn captures a small “slice of the sun” while Piano captures a “slice of the sky.” Kahn provides sidelighting and views to inner courts while Piano provides direct views to site.

3. Atmospheric Effect: Kahn uses light, shadow, and darkness to create a contemplative and introverted atmosphere. Piano dispels the darkness and shadows to fill the gallery with diffuse light, creating an open and spacious atmosphere connected to site.

4. Integrating Architecture, Daylight, and Technology: An elegant integration of daylight, structure, materials, and systems is found in both projects. After four decades, Piano raises the bar for energy design performance in contemporary museums.

5. Qualitative and Quantitative Assessments: Kahn and Piano designed and tested the galleries through rigorous qualitative and quantitative methods, including physical models, sketching, renderings, mock-ups, prototypes, and computer simulations.

Next steps for further research studies include comparative quantitative energy analyses, design evaluations of the building envelope and thermal properties, and daylight integration.

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ENDNOTES