Louis I. Kahn and Richard Kelly: collaborative design in creation of the luminous environment

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[COM1]Can we write the name of the gallery with capital letters as 'The Yale University Art Gallery'? Thank you for your review.

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Recto running head: ARCHITECTURAL ENGINEERING AND DESIGN MANAGEMENT

Louis I.Kahn and Richard Kelly: collaborative design in creation of the luminous environment

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ABSTRACT

As one of the most prominent architects of the twentieth century, Louis I.Kahn aspired to use natural light to shape his architecture. The lighting designer Richard Kelly, one of his close collaborators, had significant influence on modern architectural lighting design in the twentieth century. Kahn and Kelly designed the luminous environments in three art-gallery and museum buildings, the Yale University Art Gallery, the Kimbell Art Museum and the Yale Center for British Art. Collaboration between the architect and the lighting designer resulted in well-resolved lighting solutions. This research investigated the collaboration between Louis I.Kahn and Richard Kelly from both theoretical and pragmatic perspectives. In terms of the theoretical perspective, a detailed overview of their collaborative work is provided through literature review. In terms of the pragmatic perspective, the background of their cooperation and the technical details are presented. In addition, daylighting performance analysis of these three buildings through digital modelling was undertaken. This study found that the lighting design solutions produced together by Louis I.Kahn and Richard Kelly, especially the way of using daylight, have had significant impact on architectural space and the luminous environment. More importantly, this kind of collaborative working method could provide a useful reference and guidance for contemporary architecture and lighting design.

KEYWORDS: Louis I.Kahn; Richard Kelly; collaborative lighting design; luminous environment; daylight modelling

Introduction

In architectural and lighting design practices, an interdisciplinary approach provides opportunities for developing holistic design solutions, satisfying the requirements of the building programme, the occupants' needs and environmental comfort. Between these two disciplines, collaboration is vital for the well-thought through decisions in the design of the luminous environment. In modern architecture, Louis I.Kahn was a pioneering architect. Richard Kelly was a competent lighting designer knowing how to integrate lighting design into architecture. Kahn and Kelly worked in close collaboration in order to achieve the desired luminous environments of the three art-gallery and museum buildings; namely the Yale University Art Gallery, the Kimbell Art Museum and the Yale Center for British Art. This collaborative work shaped the atmospheric character of these art spaces and the distinctive lighting conditions in all three museums.

The aim of this research was to study the collaborative work between Louis I.Kahn and Richard Kelly as an exemplar for current architectural and engineering practices and inter-disciplinary working. The collaboration between Kahn and Kelly deserves in-depth study and can provide guidance in terms of: interdisciplinary design approach; evidence-based design and collaborative experience in design education.

First, Hawkes expresses interdisciplinary design as presenting the disappearance of the established differences between disciplines for a more productive collaboration (2001). Louis I.Kahn and Richard Kelly's collaboration is an exemplar of joining expertise in architecture and lighting disciplines. The insights derived from this study provide useful reference for current architectural and lighting design practices, which can be integrated through collaboration to achieve a more holistic solution. Second, Kahn believed that architecture needs to embrace both 'measurable' and 'unmeasurable' aspects, and *unmeasurable* should be the starting point of a great building. Kahn also believed that a building could be built through *measurable* mediums, but upon completion the starting point returned to the *unmeasurable* *(Lobell, 1979, p.48).*) ~~(Lobell, 1979)lobell.~~

This research investigated the collaboration between Kahn and Kelly through an evidence-based approach, based on the technical details and daylighting performance analysis. This showed how the collaborative design efforts could produce robust outcomes and revealed how Kahn and Kelly achieved their design aspirations. The evidence-based approach examined the *unmeasurable* collaborative notions of the luminous environment through the *measurable and* integrated design strategies. Published literature points out that learning (Herazo and Lizarrelde, 2015)[AQ1]) and education (Soetanto, Childs, Poh, Austin, & Hao, 2014) are noteworthy mediums to help disseminate the merits of innovation and ~~inno~~collaboration to the professionals of the future. This research not only highlighted the collaboration of Kahn and Kelly, but also evidenced the significance Kahn and Kelly contributed to knowledge, learning, analysis and the use of design tools. Thus engagement of interdisciplinary curricula, integration of tools and encouragement for teamwork are all vital for enhancing knowledge acquisition through collaboration in learning environments.

Research method

The literature review uncovered the collaborative design process adopted by Kahn and Kelly through their design ideas and the realized art-gallery and museum projects they worked on. In order to evaluate their collaborative work holistically, this research employed both theoretical and pragmatic approaches. From the theoretical perspective, background information on

collaboration in architecture was researched. The professional careers of Louis I.Kahn and Richard Kelly were closely looked at through the literature review, which included their individual distinctive careers and their collaborative efforts in architecture. The theoretical research provided useful insights for better understanding of the collaboration between Kahn and Kelly. From the pragmatic perspective, the design process and the lighting solutions for the art-gallery and museum buildings were investigated~~p~~. During the research process, the literature provided published information on the projects, the details related to how Kahn and Kelly worked together and the aspects of their collaboration. The daylighting performance analysis of the three buildings was conducted through digital modelling. The daylighting performance analyses revealed how the design decisions were realized and applied in the actual luminous environments of the three art-gallery and museum buildings. The analyses evidenced how Kahn and Kelly achieved the desired lighting conditions through their collaborative efforts.

Background

Collaboration in the architectural design process

This paper approaches the multi-faceted term 'collaboration' through the following definition. According to Emmitt and Ruikar, collaboration is working together in order to accomplish a shared goal through bringing together the individual efforts (2013). In this definition, it is evidenced that the teamwork is positioned at the centre of collaboration. This definition is relevant for an extensive range of areas. Collaboration can be expressed as users' involvements in an art or design process in a community as 'participatory design' (Lundström, Savolainen, & Kostiainen, 2016; Sanoff, 2012); meeting with colleagues in a workspace in order to exchange information (Vischer, 2012); or a methodology to actualize the term 'integrative design process (IDP)' as developed from the term 'integrated design process' (McDonald & Persram, 2012). In this paper, the term collaboration expresses the third of these meanings in order to highlight its relationship with integrated design processes (IDP).

Individual expertise from distinct disciplines comes together in a project to perform the architectural, engineering and construction work. These disciplines' contributions constitute the IDP of the architectural project through articulated design solutions, and resembles a collaborative work environment. Novak (2014) noted that the involvement of multiple professionals and their points of view in the IDP required collaboration. Collaboration is significant for IDP as it underlines numerous shareholders during the design process (Olsen & Mac Namara, 2014).

The way in which team members communicate, interact and perform will influence the success of the collaboration. Having the enthusiasm, working with pleasure, benefiting from knowledge, aspiring to learn and reflecting a positive personality contribute to the success of a project (Pressman, 2014). The alliance between the team members, clear and timely communication are the crucial factors as professionals coming from various disciplines and working with divergent terms may unwittingly cause inadequacy and misinterpretation in communication (Foley & Macmillan, 2005). Both the project performance and the quality of the building are related to the successful communication between professionals and organizations during the project; as the success of the end product depends on how the team can efficiently working together (Emmitt & Ruikar, 2013). Chiocchio etal. stated that the supportive impact coming from trusting each other enhanced the project success and the adverse impact of disagreements related to work could be reduced by collaboration, which in turn resulted in performance enhancement (Chiocchio, Forgues, Paradis~~,~~ & Iordanova, 2011).

Modern architecture

Advancements in technology and the separation between architecture and engineering by establishing the first engineering school *the Ecole des Ponts et Chaussées* in Paris in 1747 were among the events that prepared the basis for modern architecture (Frampton, 1992). Having introduced innovations in the construction industry, the Industrial Revolution underlined the rational thinking that subsequently spread through modern architecture. Following the fragmentation on the grounds of rational thinking in the late nineteenth century, the glass box started to emerge (Lobell, 1979). Considering the guidance of rational thinking for 'understanding things that are', a stronger experience was indicated as being needed, such as what Louis Kahn described as 'Order' (Lobell, 1979, pp.62–63).

Louis I.Kahn: a pioneering architect in the modern architecture

Louis I.Kahn studied architecture at the University of Pennsylvania in the 1920s. Kahn was educated with *the Beaux-Arts*, which was an education system influenced by the Greek and Roman principles and started at the beginning of the nineteenth century (Lobell, 1979)~~)~~. Through this system, Kahn became familiar with the classical architectural elements and was aware that modern transformation was required (Curtis, 1996). Being aware of the need to search further on rationalism, Kahn turned his search to a comprehensive theory which was relevant for the entire circumstances, where Order started to take place in his words and Order connected consciousness and nature which was different from rationalism (Lobell, 1979).

Louis I.Kahn believed in the strong connection between material, light and shadow (Lobell, 1979). In published literature, Kahn is credited with the way he controlled light, the relation of light and shadow and the dynamism in his buildings as natural light changes. Considering the impact of light on the spaces Kahn created, wall and ceiling openings were some of the key architectural elements he worked with (Büttiker, 1994). Natural light played a special role in the architecture of Kahn. Steane claimed that it went back to slightly before 1960 that Louis Kahn was aware of the reason for the essential desire of architects to use daylight to good advantage (2011). According to Plummer, the poetic of Kahn's architecture derived from his ability to connect light with existence (2009~~, p. 9~~). The opinion of Hawkes was focused on Kahn's poetry, in which his poetry was influenced by his inspirations from natural light and its interplay with building form and material. Hawkes further emphasized that Kahn integrated the functional and the poetic in his buildings, and this aspect was the principal factor for his projects to become global (2008).

Louis I.Kahn believed in the power of collaboration. His collaboration with the structural engineer August Komendant, between 1950s and late 1970s, developed innovative structural solutions related to reinforced concrete (Olsen and Mac Namara, 2014). Kahn also collaborated with the lighting designer Richard Kelly and this collaboration had significant impact on the luminous environments they collectively created and turned into a professional friendship toward the end of the 1960s and beginning of the 1970s (Neumann, 2010b).

Richard Kelly: a professional remark for lighting design in the twentieth century

Richard Kelly graduated from Yale with the Bachelor of Arts degree in architecture. Kelly was involved in theatre lighting design during his study at Columbia College (Neumann, 2010b). Petty described Kelly as a supreme American professional on architectural lighting design in the middle of the twentieth century (2010). Neumann stated that Kelly worked on architectural lighting design at the time when various technological developments in lighting took place, and the façades of buildings were changing as a result of innovative materials and structural principles (Neumann, 2010a).~~n~~

Kelly considered lighting design as an essential component in the architectural programme (Petty, 2007). The interior space was an entire setting for Kelly to work on and he integrated the surfaces and their appearances into the lighting design at peak possibility (Petty, 2012~~)(Petty,~~)[AQ2]~~)~~. Through his inspirational engagement with light, Kelly created drama, transformed the spatial qualities and brought sparkle on materials (Neumann, 2010a). Daylight was a significant medium for Richard Kelly (Neumann, 2010b)~~n~~. Arranging the shape and size of windows, using devices such as 'baffles and reflectors' and types of 'blinds' were among the design principles he adopted (Kelly, 1952, pp.27–28).

Many of the pioneer architects of the modern movement wanted to work with Richard Kelly, and his collaborators included Eero Saarinen, Ludwig Mies van der Rohe, Philip Johnson and Louis Kahn (Neumann, 2010a)~~y~~. Richard Kelly also collaborated with the lighting designer, inventor and mechanical engineer Edison Price; who developed many of the luminaires that featured in Kelly's projects (Neumann, 2010b).

Collaboration between Louis I.Kahn and Richard Kelly

This section focuses on the collaboration between Louis I.Kahn and Richard Kelly for the creation of light in the three art-gallery and museum buildings in the United States, in chronological order, the Yale University Art Gallery, the Kimbell Art Museum and the Yale Center for British Art.

According to Neumann, Richard Kelly's collaboration with Louis I.Kahn for the lighting design in the Kimbell Art Museum and the Yale Center for British Art were the two largest commissions of Kelly at the later stage of his career in the 1960s and 1970s (2010b). Tanteri considered these two projects as the outstanding precedents on how Richard Kelly utilized daylight, which was a result of the direct collaboration of Kahn and Kelly, through encouraging each other to achieve the desired architectural objective (2010)~~.~~. As a witness of this constructive design process, Marshall Meyers, who was the project architect of the Kimbell Museum, defined this noteworthy collaboration as 'a perfect communion' (Tanteri, 2010).

The collaboration between Kahn and Kelly was especially noteworthy during the decision-making process of the lighting systems employed in the three art-gallery and museum buildings. The collaborative work of Kahn and Kelly demonstrated how an architect and a lighting designer could combine their individual intuitions and design priorities in order to create the distinctive lighting design satisfying the spatial and functional requirements of each project. In the Yale University Art Gallery, their collaborative work was mainly on the artificial lighting system, in which track lighting was designed. In the Kimbell Art Museum, the design intention was to provide effective day lit exhibition spaces which could also protect the exhibits from direct sunlight. Kahn and Kelly's collaborative engagements started with designing the reflector at the early stage of the design process. Kelly drew the curve of the reflector and it was further developed and modified by Khan. Kelly also contributed to the choice of the material for the reflector. In both daylighting and artificial lighting systems, Kelly`s design solutions aimed to prevent glare in the museum and gallery environments. In the Yale Center for British Art, Kahn and Kelly worked together and designed the wide skylights combined with exterior shading devices in order to provide day lit indoor environment with diffuse light. Kelly designed the profiles of the shading devices and the lower diffuser layers.

The sections below further explain the collaboration of Kelly and Kahn and daylighting performance analysis was used to support the qualitative studies of the three projects.

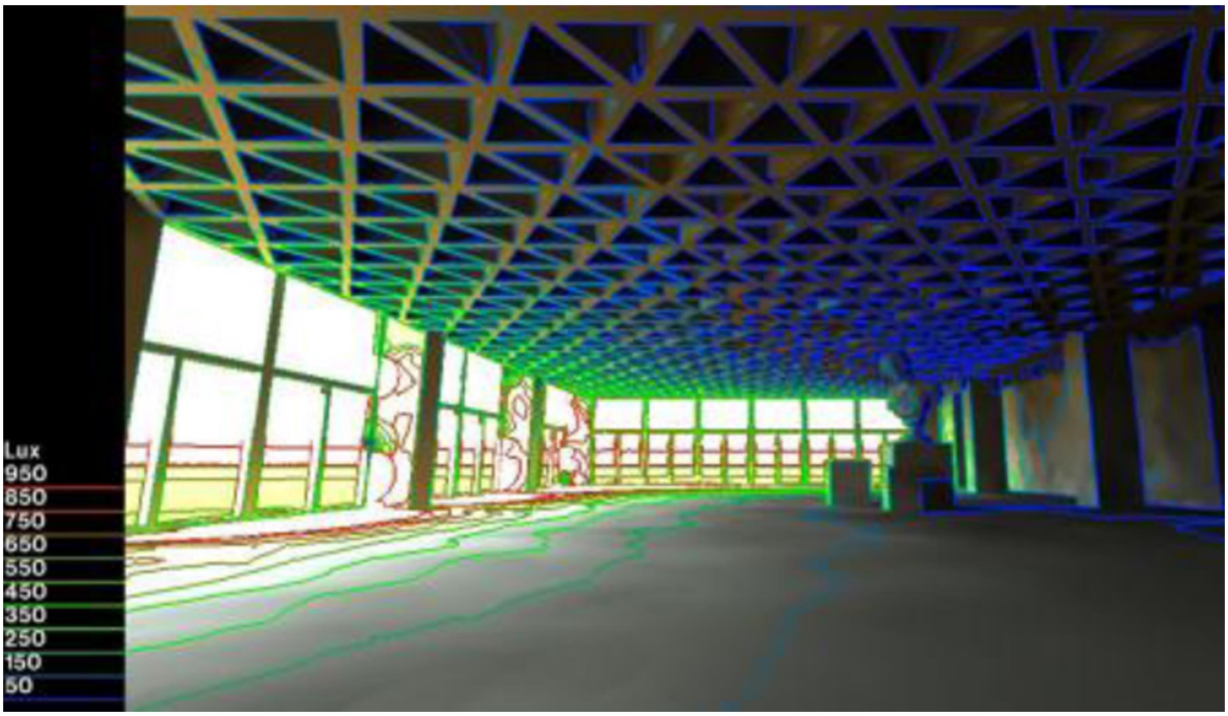
The Yale University art gallery [COM1]

The Yale University Art Gallery (1951–1953) is located in the city of New Haven in Connecticut. The gallery is adjacent to the two existing buildings; the former being the Street Hall (1866) housed the Yale School of the Fine Arts and the latter being the Old Yale Art Gallery Building (1928) housed the art collections of the Yale University (Yale University Art Gallery, 2016) ~~(Yale University Art Gallery, 2016)~~. This urban surrounding was described as having a diverse range of patterns containing various architectural styles (Curtis, 1996). The Yale University Art Gallery designed by Kahn consisted of exhibition spaces and studio spaces for art and architecture students at the time the building was opened. Hawkes observed that the studio spaces and other functional spaces related to the Yale School of Architecture shaped the building design with several storeys, side lighting strategies without any roof lighting system (2008).

In this building, the concrete tetrahedral ceiling is one of the dominant architectural features (Frampton, 1992). Light on the concrete tetrahedral ceiling provided subtle luminosity (Curtis, 1996) ~~(~~. The surface of the tetrahedral ceiling, which consists of thin concrete bands, reflects the light downwards. Büttiker described the thin concrete bands as 'light blades'. Differing from the bright concrete bands, the hollow spaces inside the ceiling remain in shadow with a dark appearance (Büttiker, 1994). Approaching from the circulation core, the visitors are directed either left or right towards the exhibition spaces. The brick blind wall, the glazed façades and the tetrahedral ceiling are observed as the predominant spatial elements. The brick blind wall on the Chapel Street façade is orientated towards the southwest, which constitutes one side of the exhibition spaces. Daylight defines the luminous environment of the Yale University Art Gallery with predominantly side lighting through the glazed façades. The intensity of daylight decreases towards the circulation core and the brick blind wall. This pattern can be perceived inside the exhibition spaces and on the ceiling surface.

In order to investigate the daylighting performance, daylight modelling of the gallery building was undertaken. This study was conducted by using Autodesk ECOTECT/RADIANCE software. The illuminance plot under the overcast sky condition indicated that the light levels decrease and remain at a lower range approximately after one-third of the gallery space from the façade, as shown in Figure 1. The illuminance levels fall between 100 lux and 200 lux in the inner zone. The contrast ratio is significant for the perception of an exhibit ~~to be perceived from the surrounding surfaces~~. Hopkinson defined the optimum contrast ratio for providing an attractive appearance and prevent glare in the visual field. The luminance ratio of the visual task to immediate surround and far surround is defined as 10:3:1 (Hopkinson, Petherbridgde, & Longmore, 1966). The contrast ratio between the luminance on the sculpture in the inner zone and the back wall was calculated as 2:1 under the sunny sky condition for Equinox at noon time. This ratio is close to the recommended ratio of 3:1 (SLL, 2015) for a good three-dimensional (3D) modelling. The artificial lighting system provide~~d~~s supplementary lighting, further enhances the illumination of the 3D artworks. The solid surfaces of the concrete tetrahedral ceiling reflect light. The hollow parts of the ceiling remain dark, some of which help reflect the artificial light flowing downwards.

Figure 1. Illuminance plot under overcast sky condition [AQ18]with isolux contour lines (~~RADIANCE simulation~~daylight modelling by the author) (Kaçel and Lau, 2014).



Being a close collaborator with Louis I.Kahn, Richard Kelly was commissioned to design the lighting system in the Yale University Art Gallery. Track lighting was used as the main artificial lighting sources (Petty, 2007, March 02). The hollow parts of the concrete tetrahedral ceiling accommodated the luminaires. Kelly'~~s~~ collaborated with Edison Price to design the luminaires, Price designed the light fittings with an aim to provide desired illumination but avoid glare. ~~Among these 'two special fixtures' two types of luminairesd, o~~One type of the luminaires was for the illumination of the exhibits and the other ~~one~~type was for illuminating the gallery's non-exhibit areas (Neumann, 2010b, Neumann, 2010c~~, p. 47~~).

The Kimbell Art Museum

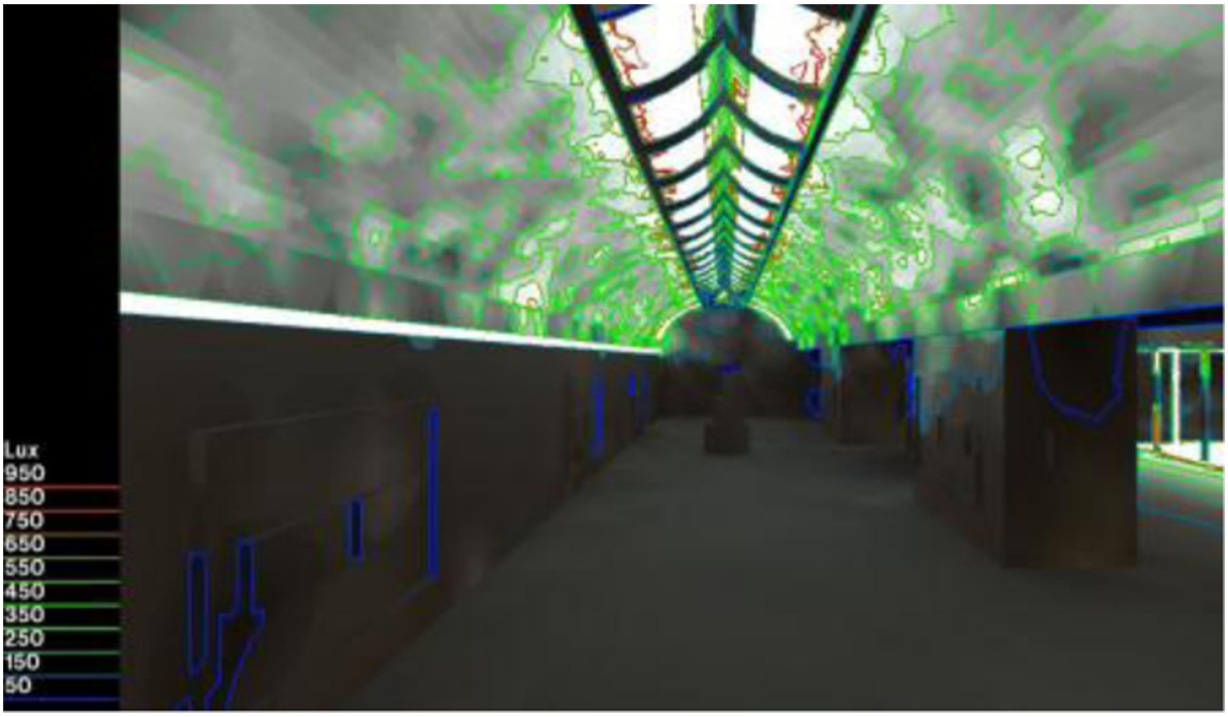
The Kimbell Art Museum (1966–1972) is located in the city of Fort Worth in Texas. Opened in October 1972, the museum was designed to house the art collection of the Kimbell Art Foundation (Kimbell Art Museum, 2016). The museum is situated in an area with a wide landscape surrounding this distinctive building.

The building form was intended for the meeting of the museum visitors and the paintings in day lit space (Lobell, 1979). According to Curtis, the interior, which is surrounded by the concrete vaults in a cycloid geometry and planned in bays, provided crosswise sights throughout long distances (1996). The internal spatial configuration has been designed in a way highly related to the luminous environment. The inspiring atmosphere of this building was appraised as created from 'the fusion of structure and light' (Curtis, 1996).

In the Kimbell Art Museum, creating a luminous environment through top lighting and utilizing concrete vaults were the design approach from early stages of the design process (Hawkes, 2008). Fort Worth being located on latitude 32.5°N and the almost overhead position of the sun at noon in summer required careful consideration of impact from direct sun within the design strategy (Tanteri, 2010). Narrow roof lights were positioned at the centre of the concrete vaults, which created a unique luminous environment, in which the ceiling is the brightest surface. Direct sunlight is redirected towards the vault by the reflector and reflected to the exhibition spaces. The light intensity decreases on the concrete vault gradually towards the walls.

The daylight modelling study of the inner zone of the Kimbell Art Museum showed that the daylight illuminance had its highest values on the vaulted ceiling surface and it decreased towards the vertical wall surfaces, as shown in Figure 2. As a result, the ambience light remains as controlled and diffuse light, which enhanced the overall luminous environment. The daylighting performance analysis revealed the impact of the light courts on the internal lighting conditions. Under overcast sky conditions, the light court intensified the modelling of the sculptures. In the exhibition zone of the gallery close to the north court, the contrast ratio between the 3D exhibit and the rear wall is about 5:1 under the sunny condition on Summer Solstice at noon time. This indicates satisfactory 3D modelling effect because the contrast ratio achieved was beyond the recommended contrast ratio of 3:1 (SLL, 2015). This evidenced the significant impact of the light court on the 3D modelling of the sculpture under sunny sky condition.

Figure 2. Illuminance plot of the inner zone in the Kimbell Art Museum under sunny sky condition for Summer Solstice 12 pm with isolux contour lines (~~RADIANCE simulation~~daylight modelling by the author) (Kacel and Lau, 2013).



This design of the reflector in this museum acted as a 'screen' balancing Kahn's preference for natural light and his intention to prevent the art objects from harmful impacts of the direct sunlight (Lobell, 1979, p.94). The studies of the structural and lighting systems were carried out in a long time frame through the guidance of consultants, the structural engineer August Komendant and the lighting consultant Richard Kelly (Hawkes, 2008). The reflector was developed with 'the deep involvement' of Kelly (Neumann, 2010b, p.37–). Kelly involved in the lighting design for the Kimbell Art Museum at the early stages of the design process. The collaboration between Kahn and Kelly in the Kimbell Art Museum could be considered as the merge of their individual qualities and skills. Kelly combined his technological expertise and design enthusiasm with the design philosophy of Kahn and collectively they have produced distinctive luminous environment for this museum (Tanteri, 2010).

Based on the daylighting suggestions provided by Richard F.Brown, the founding director of the Kimbell Art Museum, Louis I.Kahn and Richard Kelly integrated their daylighting solutions into the concrete vault ceiling as a narrow linear cut. One of the key challenges during the collaborative work between Kahn and Kelly was to choose the material for the reflector. Kahn's initial idea was to one-way mirrored glass. However, Kelly's idea was to use plastic considering it as more practical. The final material chosen was perforated aluminium and Kelly was conscious of using a material which offers both transparent and reflective properties. Thus, the initial cost and maintenance requirement were reduced (Tanteri, 2010).

Kelly also considered glare in the reflector design, both for daylighting and artificial lighting. For daylighting, the middle part of the reflector below the linear cut was solid to prevent direct sight of the sun. For artificial lighting, Kelly designed a linear artificial light source concealed to the bottom of the reflector in order to provide light towards the vaults without direct sight of the light source. Due to the budget constraint, Kelly also designed the track lighting and provided a recommendation for filtering the ultraviolet light and landscape lighting (Tanteri, 2010).

The Yale Center for British Art

The Yale Center for British Art (1969–1974) is located in the city of New Haven in Connecticut. The museum was founded by Paul Mellon in order to exhibit the collection of British art Yale Center for British Art (2016). The Yale Center for British Art is located at the Yale University Art Gallery on Chapel Street, which was designed by Louis I.Kahn and opened in 1953. This building is positioned within an apparent urban context, and situated opposite to the campus of the Yale University (Tanteri, 2010). According to Lobell, technology was an important medium in the façade design. Kahn used an innovative finish such as steel on the façade, and the dark facade finish contrasted with the brightly lit interior spaces (Lobell, 1979).

During the design process, the museum director Jules Prown sent the programme of the lighting scheme to Kahn. This programme contained the various desired lighting conditions in response to the changing sky conditions. Considering the overcast, partly cloudy skies and direct sunlight; the lighting solution proposed by Kahn and Kelly was rectangular-formed skylights with external shading devices. This design aimed to provide diffuse day lit environment throughout the diurnal and annual time frame. Kahn worked with Kelly to design the structural elements, which bear the weight of the roof and provide the distinctive quality of light through the skylights. By using computer, Kelly calculated the form of the louvres and this guided him to design this louvre system. Although the exterior lighting conditions vary, consistent diffuse light is provided through the skylights (Tanteri, 2010).

Daylight penetrates vertically through the roof lights covering the light courts. This signifies the bright day lit museum entrance and then this leads to a passageway with relatively low brightness. The light courts enhance the luminous environment of the galleries through the vertical openings on court walls. The galleries on the top floor are prominently lit by the roof lights. The diffuse light entering through the roof forms a bright, translucent surface as the inner layer of the roof light. The daylight study of this museum showed that the illuminance values on the roof light decrease in a gradual manner. The luminosity first decreases towards the inclined concrete beam surfaces and then this decreases further towards the display wall surfaces of the galleries, as shown in Figure 3. In the side-lit galleries, the windows adjacent to the display walls supplement the diffuse light as well as providing the view out. In his analysis of light in the buildings of Kahn, Büttiker explained that window not only served its functions but also belonged to the spatial organization of Kahn's architecture (1994). The top-floor galleries benefit from the roof lights, windows and the light court. The contrast ratio between the 3D exhibit close to the window and the back wall is 3:1 under the sunny sky condition for Summer Solstice at noon time. This meets the recommended contrast ratio of 3:1,

which indicates that the 3D modelling is significantly enhanced by the sidelight.

Figure 3. Selected illuminance readings of the upper floor gallery under overcast sky condition, presented in numerical values (~~RADIANCE simulation~~daylight modelling by the author) (Kaçel and Lau, 2014).

The roof lights, overlaying the building's entire roof, cover each of the four-subdivisions inside each of the structural grid (Hawkes, 2008). Unlike the design challenges in Fort Worth, consideration was focused on the daylight coming from the overcast and partly cloudy skies in addition to the direct sunlight. The collaborative design task for Kahn and Kelly was to create a well-balanced luminous environment diurnally and annually by means of the roof light and shading devices. The concrete beams supporting the roof was designed through their close collaboration, and they enhance the distinctive qualities of the roof light (Tanteri, 2010).

During the design process, a full-scale mock-up was built for testing and collaborating with other consultants for developing the design solutions. The final solution of the roof light consists of the exterior louvre and interior diffuser. The fixed exterior louvre system tunes the dynamism of sunlight related to its quantitative and qualitative attributes. It aims to balance the indoor day lit spaces. The high beams of direct sunlight are prevented but the beams with lower angle penetrate through the louvre system and interior diffuser. The interior diffuser consists of a sandblasted plastic sheet, a specular parabolic cube louvre and two prismatic acrylic lenses respectively (Tanteri, 2010). The light becomes moderated and diffused, in a way that the character of the English light as taking place in an English building is characterized and the artworks on the walls of the Yale Center for British Art are expressed (Hawkes, 2008). For supplementing daylight, artificial lighting fixtures were integrated below the roof light in the form of track light containing wall washer and narrow-beam luminaires (Tanteri, 2010).

Discussion

The collaborative work between Louis I.Kahn and Richard Kelly focused on achieving well-balanced solutions for daylighting with the use of new technologies as shown in the design of Kimbell Art Museum and the Yale Center for British Art. Kahn and Kelly's collaboration focused on the following aspects: creating a glare-free day lit space, enhancing the spatial quality and considering conservation of the artworks from direct sunlight. Kahn comprehended natural light as an essence in spaces and Kelly contributed to the design solutions for daylighting. This collaborative work provided well-balanced day lit museum environments. Kahn and Kelly adopted a design approach, which considered artificial lighting as supplementary to daylighting and integrated the luminaires as part the roof light designs in the Kimbell Art Museum and the Yale Center for British Art. This approach is highly relevant for the design challenge of energy-efficient lighting.

During all stages of the projects 'clear and consistent visual communication' is crucial when complications and challenges of contemporary design are considered (Olsen & Mac Namara, 2014, p.164)[AQ3]. The sketches and drawings of Louis I.Kahn and Richard Kelly demonstrated the noteworthy act of expressing design ideas and possible solutions.

The interdisciplinary approach should involve the contribution of experts from different disciplines working together as partner to achieve a common goal (Olsen & Mac Namara, 2014). This exactly simulates the way Louis I.Kahn and Richard Kelly worked in collaboration with other experts in order to carry out their responsibilities on the projects in the best way.

Conclusion

The design solutions that Kahn and Kelly collectively achieved helped to shape the unique art environment with skilfully designed lighting conditions. Louis I.Kahn and Richard Kelly both gave significance to the use of technology, developing knowledge, creating a new language in their designs and holding awareness of daylight in their professions. They used materials, lighting technology and design tools of the time and combined with their knowledge and experience.

The collaborative work between Louis I.Kahn and Richard Kelly provides relevant guidance for the current architecture and engineering practices. This guidance is multi-dimensional involving the development of the design philosophy and ideas, articulated solutions in the project, realization of the solutions assisted by technology, use of design tools and enhancement of knowledge. The collaboration of Kahn and Kelly is an excellent example of the integrated design approach, which has high relevance in the contemporary architecture and engineering practice.

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