The $125-million extension to Fort Worth’s Kimbell Art Museum takes the form of a separate building that was designed to evoke the original structure both architecturally and structurally while establishing its own unique identity. The two buildings together define a vision of excellence as creative as the artwork that each displays.

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THE KIMBELL ART MUSEUM, in Fort Worth, Texas, is an established private arts institution renowned both for its exceptionally fine collection of European and Asian art and for its iconic building, which was designed by the celebrated American architect Louis Kahn, who died in 1974. Located in a section of Fort Worth that is home to a number of cultural institutions, the Kimbell has a unique character that reflects its institutional mission, which was set forth in a document on acquisitions issued by the Kimbell Art Foundation’s board of directors in June 1966.

This document, developed in consultation with the museum’s first director, Richard F. Brown, emphasized the clear goal of quality over quantity: “The dominating principle involved in the acquisition process is that the stature of the Museum depends more upon the quality of the definitive objects that it contains than on the historical completeness of its collections.... The goal shall be definitive excellence, not size of collection.”

The museum’s resulting collection has slowly developed from the private collection of its founders, Kay and Velma Fuller Kimbell, to what is now widely regarded as one of the best small art collections in the world. This singular and individuating focus is reflected in the quality of the Kahn building itself in that every detail is unique and significant.

The Kimbell Art Museum was commissioned in 1966, the same year that the acquisition document was issued. Kahn’s design featured an open layout for the galleries, which allowed a flexible display of the works. Most important of all, the design incorporated natural light into the gallery spaces, which were located on a single level. The structure opened in 1972 and is widely regarded as one of the great buildings of the 20th century.

Kahn worked on the Kimbell with the structural engineer August Komendant, a longtime collaborator, who died in 1992. The original museum building is divided into two levels: the service and administration spaces are located on the lower level, which is at the elevation of the parking area on the eastern side of the museum, whereas the upper level is at the elevation of the museum park grounds to the west and hosts the public spaces, including galleries, a bookstore, and a café. The open floor plan of this upper level is punctuated by courtyards and modulated by the profile of the roof, which is a series of cycloid-shaped shells, each 102 ft long, 20 ft wide, and 20 ft high at their crowns. The shells are arranged in rows in three bays in the north–south, or longitudinal, direction and include a 5 ft gap between the bays to accommodate vertical service circulation. All told, there are 16 rows of shells: 6 in the north bay, 4 in the center bay, and 6 in the south bay.

The galleries are distributed in the north and south bays, and the lobby and the bookstore are located in the center...
bay, where the reduced number of shells provides space for an entry court of yaupon trees adjacent to the park to the west. The introduction of natural light into the galleries is managed through continuous slots that are located in the middle apex of each shell. Curved and perforated aluminum reflectors—designed by Kahn and the American lighting designer Richard Kelly, who died in 1977—diffuse the light back onto the curved, exposed concrete surface.

The continuous slots indicate that the roof structure is not in fact a series of simple barrel vaults spanning in the short direction; rather, the underlying structural design is more nuanced. The roof is actually composed of a series of long-span curved concrete beams that form the full cycloid shell shape in section and span in the long direction. The cycloid shell beams are posttensioned both to balance the loads and to restrain the warping of the section at the midspan point. The Kimbell’s posttensioned cycloidal beams are discussed in greater depth in Guy Nordenson’s Patterns and Structure: Selected Writings (Zürich, Switzerland: Lars Müller Publishers, 2010). The floor system is similarly made of posttensioned concrete and involves a 14 in. deep two-way hollow slab that features posttensioning in the orthogonal rib beams.

The overall material palette of the building is spare. Travertine panels were applied to vertical surfaces, the floors are clad in wood, and exposed concrete was used for the roof and many of the primary structural elements. The warmth of the travertine and wood complements the exposed concrete cycloid vaults, which take on a silvery glow from the reflected natural light.

Beautiful as it was, the Kimbell building faced a perennial problem. For many years, the museum lacked sufficient gallery space to permanently display its collection while also hosting traveling exhibitions. Over the years the museum leadership had studied various options for increasing its exhibition space. Success, however, proved elusive. Even a scheme from 1989 to add north and south extensions to the original building on the basis of a sketch by Kahn met with vehement criticism from both the Kahn family and the architectural community and thus was abandoned.

But the problem of inadequate space for exhibitions remained. In 2006, under the leadership of Ben and Kay Fortson (a niece of the founders), another expansion plan was considered. This time, however, the scheme involved the construction of a separate building that would leave the original Kahn structure untouched. Renzo Piano Building Workshop (RPBW), based in Genoa (Genova), Italy, was selected as the architect, and the initial plans focused on a site to the east of the original building across Van Cliburn Way and adjacent to another cultural facility, the Modern Art Museum of Fort Worth.

When the initial studies proved that this eastern site would be too distant from the original museum building to be viable for operations, the expansion plans were shifted again to a site on the western side of the existing building. This site is on museum property and faces the Amon Carter Museum of American Art, which is located across Will Rogers Road West.

The $125-million expansion of the Kimbell Art Museum
that has since been constructed on that western site is referred to as the Piano Pavilion. It is a freestanding, 89,000 sq ft addition to the original museum structure, which is now referred to as the Kahn Building. Located 65 yd from the Kahn Building across the museum’s publicly accessible park grounds, the Piano Pavilion is connected to the original building by an underground walkway. A 45,000 sq ft underground parking garage also was constructed beneath the park grounds and is designed to serve both buildings.

RPBW has described the Piano Pavilion as having been developed “in conversation” with the original Kahn building. With the pavilion and the new parking area placed on the west side of the Kahn Building, this architectural conversation has reemphasized the museum’s western facade. Although the western side of the original building had been designed by Kahn as the main entrance to the museum, that entrance had long been underused. Instead, the eastern entrance, technically the back door, had actually served as the primary entry point for years because of its proximity to the existing surface parking lot. But thanks to the expansion project, the roles of the two entrances now conform to Kahn’s original intent.

Moreover, the new pavilion also aligns itself with the original building by mirroring its scale and organization. It too features three 102 ft long bays separated by 5 ft gaps that both articulate these bays and provide space for the vertical distribution of services from mechanical systems located below grade. The main entry to the new pavilion is located directly across from the western entry of the original building and is in the middle of the central bay. The overall height of the new pavilion has also been carefully calibrated to align just below the roof of the Kahn Building.

The expansion features three main components: a light-filled East Pavilion, which includes north and south galleries flanking a central lobby space located on a single above-grade story, all of the spaces covered by a fully glazed and shaded roof; a partially buried West Building, which is covered by a publicly accessible green roof that blends into the surrounding parkland and includes additional gallery space, an auditorium, and education rooms in its single above-grade story; and an underground structure that includes the parking garage located between the new and existing buildings, as well as a basement to house the service and circulation zones that are located beneath the pavilion’s eastern and western sections. An additional feature is a 36 ft 4 in. deep light well that was cut into the earth to define the western edge of the...
The new building’s structure combines cast-in-place concrete framing, primarily in the sections below grade, with long-span laminated timber framing at the roof of the Pavilion’s eastern section.

The structural engineering design of the Piano Pavilion was conducted by New York City–based Guy Nordenson and Associates (GNA), which had been selected through a competitive process by the museum and RPBW. Houston-based Kendall/Heaton Associates, Inc., was the architect of record. Although GNA had previously worked with Kendall/Heaton, this was its first collaboration with RPBW.

During the selection process and throughout the project, GNA emphasized that a strong expression of the new pavilion’s primary structure would be central to engaging the original building, which through the bold expression of its structural form is a singularly iconic structure. This approach also complements the play of light and expressed structure evident in other Renzo Piano projects, especially the building housing Houston’s Menil Collection, which resulted from his collaboration in 1987 with the Irish engineer Peter Rice, who died in 1992. To meet the new challenge, GNA proposed a rigorous collaboration to ensure that the structure of the new building would be expressive and worthy of Kahn’s original structure.

The new building’s structure combines cast-in-place concrete framing, primarily in the sections below grade, with long-span laminated timber framing at the roof of the pavilion’s eastern section. Where it is exposed in the public areas and galleries, the cast-in-place concrete features a high-quality architectural finish. And while the overall form and structure of the building are relatively simple, there is a great deal of refinement and complexity in the scale and layering of these exposed concrete surfaces, as well as in the double walls and floor slab construction, and in coordinating the tightly woven integration of mechanical and other building systems. The heating and ventilation system, for instance, is a displacement system in which the air passes in both supply and return through the interstices of the structure.

Several challenges presented themselves during the design and construction of the exposed concrete walls, including wide swings in the Texas temperatures, the large scale and construction of the concrete walls, and the coordination of systems in the cavities of the perimeter gallery walls. However, the challenge most relevant to the primary structural design was the decision to expose the concrete structural walls, which was made late in the construction documents phase. With exposed concrete at both the interior and exterior surfaces, the gallery walls had to be thermally isolated to prevent thermal staining.

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South Elevation Piano Pavilion and Kahn Building
bridging and had to be able to accommodate the return air plenum. This was accomplished by doubling all of the walls to form an inside wall and an outside wall separated by a vertical cavity. Different details were developed to incorporate this double-wall section at the various enclosure conditions around the building.

In the pavilion’s eastern section, the double gallery walls are independent vertical cantilevers and thus are thermally separated. The cavity between the two walls was formed by using a precast-concrete and open-web floor system placed vertically against the first wall to form the cavity and the inner surface of the second wall. In the western section, where the interior concrete is integral to the primary building structure, the exterior concrete surface is tied back to the interior walls with structural thermal breaks manufactured by Schöck USA, Inc., of New York City.

The building is founded on drilled and poured concrete piers that extend down through layers of clay to reach limestone. The presence of clay meant that all components nominally in contact with the soil—for example, the slabs and grade beams, had to be cast on cardboard void forms to prevent possible pressure from the expansion of the clayey soils.

In some locations the moisture of the clay was adjusted to help ensure long-term stability.

Movement joints separate the new building into four parts. The west light well retaining wall and the adjacent mechanical yard are fully exterior and therefore separated from the main building. The parking garage is separated from the main building for fire protection reasons; thus the main building could have exposed structure with only sprinklers for fireproofing. At the same time, the fire separation requirements necessitated movement joints that would allow expansion of the parking garage structure during a fire without causing a possible collapse of any of the building structure.

As a consequence of this separation, the lateral soil pressure on the garage is unbalanced in the east–west direction and is resisted by diaphragm action at the north and south walls. Moreover, the lateral loads on the museum structure are resisted only at the basement foundation level in the east–west direction, even though the structure abuts the soil at both ends at ground level in the north–south direction.

The parking garage roof structure supports the overhead museum park grounds, which feature a 4 ft soil depth to accommodate the possible return of an allée of elm trees that previously had graced the site. The garage roof structure is composed of 56 ft long beams that have paired webs spaced at 10 ft intervals; the beams are individually supported on the structure’s walls and thin
round columns. This arrangement reflects the geometry of the timber beams in the pavilion’s eastern section and also avoids the visual interruption of header beams. The single line of concrete columns is made of high-strength (10 ksi) cast-in-place concrete, and each column has a maximum diameter of 16 in.

The gallery floors at ground level are designed throughout with a double-slab system that consists of a one-way concrete slab on metal deck supported on concrete masonry unit knee walls that are spaced 10 ft on center and bonded to a two-way concrete flat plate floor. The double slab creates a floor plenum that integrates the supply air distribution throughout the building. It is minimally pressurized, the air rising through continuous strips located in the spanning direction of the floors, which feature one-way slabs on metal decks. The air proceeds to a secondary, thin plenum beneath the wood flooring before finally being distributed through gaps located between the wood floor planks. The design team could thus eliminate floor grates in the ground-level spaces while still having a floor-supplied air system.

The 5 ft wide service bays between the galleries and the lobby provide vertical connections for the mechanical, electrical, and plumbing systems in and out of the mechanical rooms in the basement, as well as maintenance access to the plenum between the ground-floor slabs. Thus, most of the walls are formed in pairs, and in the cavities between the wall surfaces there is either insulation or, in some locations, a vertical plenum for return air.

The 102 ft long bays in the pavilion’s eastern section are column-free spaces that are open to natural light above via a modulated glass and louvered roof surface that extends past the building enclosure on all sides. This system is supported by a distinctive primary roof structure that consists of long-span laminated timber beams (LTBs) spaced 10 ft on center and supported on the structure’s walls. Each LTB is composed of a pair of laminated beams 8 in. wide and 52 in. deep fabricated from Douglas fir. The LTBs are separated by 16 in. gaps, making the overall dimension 32 by 52 in., the glass roof rafters spanning the 8 ft intervening space. The wood components were produced by Structurlam Products LP, of Penticton, British Columbia. The LTB pairs were formed in the shop with custom metal connection hardware made of steel, stainless steel, and aluminum fabricated by TriPyramid Structures, Inc., of Westford, Massachusetts.

The design of the timber beams addressed three particular conditions. The first was that the glazed roof did not provide a conventional diaphragm for stabilizing the beams. The second was that in some locations the beams passed through the vertical building enclosure envelope, whereas in others the envelope passed up between the paired beams. This meant that thermal bridging had to be considered. The third was that allowance had to be made for moisture expansion and contraction in the exterior beams. For the design team, the acronym LTB also denoted the limit state of lateral torsional buckling, which, together with the requirements regarding stiffness and camber, dictated the system design.

The cantilevered glazed roof and shading system was developed by seele GmbH, of Gersthofer, Germany, as an independent structure supported by and transferring lateral load to the primary timber structure below. Thus, in the absence of a conventional roof diaphragm, an alternative system for bracing and transferring lateral shear was developed. This...
alternative system featured a combination of thin steel pipe struts and tension-only steel diagonals of circular cross section that are located between the LTB pairs and also support the rigid internal connections of the LTBs. Since the diagonals provide lateral stiffness and wind load distribution in the east–west direction and minimize lateral deflection, the size of joints in the glazed roof could be minimized. The north–south lateral loads do not transfer to the east and west walls because of glass-filled slots between the LTBs and the cantilevered concrete cavity walls below. Instead, the north–south lateral loads transfer via the LTBs to the 5 ft wide cavity walls between the galleries and the lobby.

The rigid connections within the LTB pairs, which feature metal connector plates in the shape of a dog bone, provide a stiff transfer between the lines of diagonals laterally. They also tie the beam pairs into an effective horizontal ladder that forms discrete H shapes with vertical legs against each laminated beam at 5 ft intervals. This also addresses the lateral torsional buckling stability of the beam pairs by developing a combination of combined torsional resistance, which is resolved at the ends of the beams and through the vertical stiffness of the heavier centerline pipes at 5 ft intervals, and lateral bracing by the diagonals on the centerline of the beam for the composite H section of the beam rather than the more slender individual elements.

The east–west lateral shear from the roof is transferred from the LTBs through end beam stands to the columns at the extreme north and south and to the walls adjacent to the central lobby. The stands are placed on cylindrical bridge bearings to prevent the development of bending in the beam stands caused by this transfer; additional sliding is allowed in the north–south direction at one end of each beam, typically at the column, to prevent any arch action resulting from the vertical offset of the support and the centerline of the LTBs. The lateral load in the north–south direction is transferred in axial compression or tension to beam stands that provide reactions at the lobby walls.

Like the concrete walls of the galleries, the laminated timber beams are partially interior and partially exterior: the beams above the galleries pass from inside to outside at their extreme north and south ends, the pairs of beams over the gallery walls have one beam inside and one outside, and the beams at the extreme east and west ends are wholly outside. While possible thermal bridging through the timber at the gallery ends was not considered critical for the durability of the LTBs themselves, there were locations at which the building envelope passed up through the paired beams. This required the insertion of structural thermal breaks in the metal components at those locations to mitigate thermal bridging and the condensation that could possibly result. Structural thermal breaks were applied at these locations to allow for the transfer of the bending and shear forces within the paired sections while simultaneously reducing most of the thermal transmission.

Of greater importance, the LTBs (Continued on Page 78)
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(Continued from Page 59) that are exposed to the exterior will see a variation in moisture content over time, resulting in expansion and contraction of the timber section. Given the dimensions of the section—8 in. wide and 52 in. deep—the resulting variation will not be trivial in absolute terms. Therefore, careful consideration was required with respect to the detailing of the metal component connections within the beam pairs and at the beam ends. The metal dog bone plates embedded on the inside faces of the beams and the cross pipes serve to tie the beam pairs into unified H sections. This required a moment connection from the metal to the wood. But given the expected reversal of the contact against the vertical legs of the dog bone plates, in addition to possible section change, any connection formed by simply bolting the plates tight to the wood would probably have loosened in the long term. Therefore, to ensure long-term durability, the connection hardware was designed to always work in compression against the wood. The dog bone vertical legs bear directly against the inside face of the wood in compression, and in those locations at which the plates might pull away, finger rods—also in compression—were installed through the beams to bear against the outside face. Oversized holes around the finger rods allow vertical expansion from the center, and the insertion of neoprene pads between the timber and metal plates allows lateral expansion while maintaining bearing under all conditions. The end supports for the beams are designed in a similar way.

In this case the dog bone vertical leg extends down to the bottom of the beam so as to support the full section height from below, as it is not practicable to support the beam from the center without splitting the wood. At the beam end supports, the vertical section variations deriving from the variations in moisture content will occur from the bottom up the full height rather than effectively from the centerline, as in other locations. The connection components are similarly designed in oversized holes with neoprene pads for the particular variation expected at each location.

The design of the structure for the Piano Pavilion was developed with a conscious and deliberate relationship to the adjacent building by Kahn and Komendant, as well as the Menil Collection building by Piano and Rice. In keeping with the general architectural strategy for the expansion, the new structure used the language of Komendant’s design while attempting to add a unique aspect to the new building and satisfy the technical criteria. From this vantage, a thematic architectural interest in natural light becomes evident, and becomes a louvered and glazed roof supported by a series of whitewashed beams modulating the light, an effect that is closer in character to the building housing the Menil Collection than to some of RPBW’s later light-filtering scrim systems. The crescendo of reflected light in the Kahn Building contrasts with a staccato rhythm of lines of structure against a luminous roof. As the concrete of the Kahn Building’s roof turns to become the walls of the Piano Pavilion gallery, it becomes smoother and more refined to reflect this change of function.

Taken as a whole, the structure of the timber roof and the architectural concrete dominate the visible forms of the building. The extensive use of glass walls, while sharper and more technical in appearance, emphasizes the minimal palette and the spirit of refinement in both the original building and the new pavilion. The two separate structures together define a vision of excellence as creative as the works of art that each displays.