Mathematical Skins:
The Meyerson Symphony Hall

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MATHEMATICAL SKINS

The Morton H. Meyerson Symphony Center in Dallas completed in 1989 after eight years of design and construction work, received little recognition from the architectural press.

The late modernist work of famed architect I.M. Pei fell out of favor from critics who were after the more intriguing theories and lines of Deconstructivism, Critical Regionalism, High Tech and Neomodernism.

Pei's non-intellectual attitude coupled with the negative criticism to heroic modernism of the 70's and 80's may explain the cold reception to this building.

On second readings though, it can be argued that the apparent modernist simplicity is deceiving. There is a serious attempt on the part of the designer, to explore a dynamic series of spaces opened by the walking eye in the manner of late Baroque sequences. The three-dimensional layering of vertical spaces on curvilinear plans, illuminated by cylindrical and conical skylights, makes this an original and significant work. Arches, balconies and vaults intersect in a dizzying combination of curvilinear forms, leading the eye ever to new spatial discoveries.

Although the building thrives in exacting curvilinear geometries, soaring spaces, inventive acoustics and densely accommodating a vast program, my focus is on the technical virtuosity and complexities of the main skylights.

THE BUILDING

The Dallas Concert Hall can be explained at ground level as the overlapping of four distinct volumes.

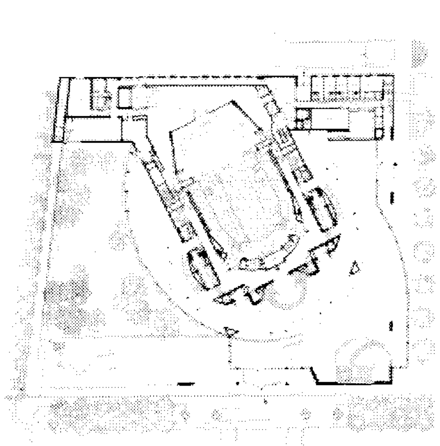

Fig. 1.

A long and slim rectangle on the north side contains the performer's quarters and offices, a skew rectangle holds the "shoebox" concert hall; a circular ambulatory space embraces three sides of the concert hall, and finally a group of curvilinear spaces around the ambulatory on the south side, contains the lobby and main entrances.

MAIN SKYLIGHTS

Pei called the "lenses", three curved skylights that seem to have been extruded from the hard-edged forms of the limestone auditorium box.

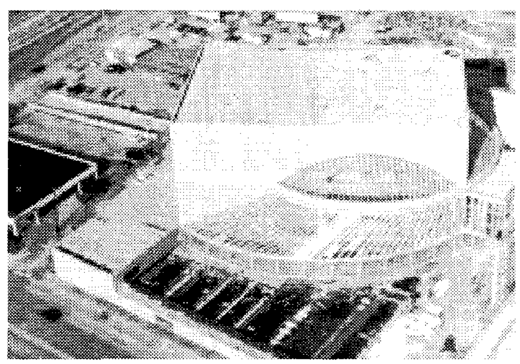

Fig. 2.

They are amplified by the so-called "conoid", a sloping skirt-like form that sweeps around and below the southernmost lens. The curved steel members supporting hundreds of glass panes (each of which was a unique shape) intersect with the stone verticals and horizontals in such a way that the glass appears to have been draped rather than assembled. The interior spatial effect of the skylights was even made more fluid by the insertion of a freestanding balcony in the form of a catwalk that curves gently through the upper lobby.

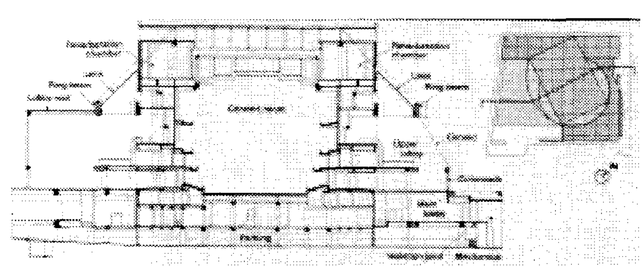

Fig. 3.

Leslie Robertson, the structural engineer of the skylights, struggled with the bracing of the delicate trusses of the conoid. The standard way to do so would have been to run heavier horizontal members through the trusses at regular intervals parallel to the roofline. Pei changed the horizontals to diagonals, which added to the visual interest of the framework and solved some of the bracing problems as well, (see figure 2).

LENSES

One of the qualities of Pei's designs is to render architectural effects with a seemingly effortless precision. The reputation for refined detail can only come from a long and laborious process.

The lenses and more importantly the conoid are products of that trying and time-consuming ingenuity.

The geometry of the lenses is derived from a segment of a cylinder tilted at 45 degrees. A glass cylinder, figuratively speaking, seems to intersect the auditorium box at an incline on each of three sides, (see figure 2). The angular intersection of the cylinders creates large arches on the surface of the auditorium box. The bottom of the lenses, is supported by a ring beam that is vertically aligned with the circular ambulatory corridor on the upper lobby (see figures 2,3).

Since lenses are perpendicular in plan to the auditorium box, framing elements were also designed perpendicular to the auditorium sides.

To find true dimensions for these curved surfaces, analytical drawings of the tilted cylinder were prepared in plan, elevation, and as a developed surface. A lozenge shaped figure in elevation was the product of this effort.

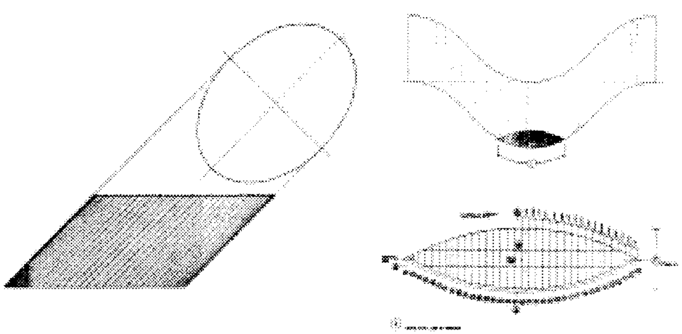

Fig. 4.

From these preparatory drawings, plans, elevations and sections of the lenses were devised.

Framing of the lenses consists of flat trusses of different lengths but equal depth. Each truss has a top cord of 1"x4 ¼ " steel plate and a bottom cord of steel tube 4 ½ " in diameter separated approximately 1 foot. The stem is made of ½" thick perforated steel plate making the assembly work like a composite "I" beam as well as a flat truss.

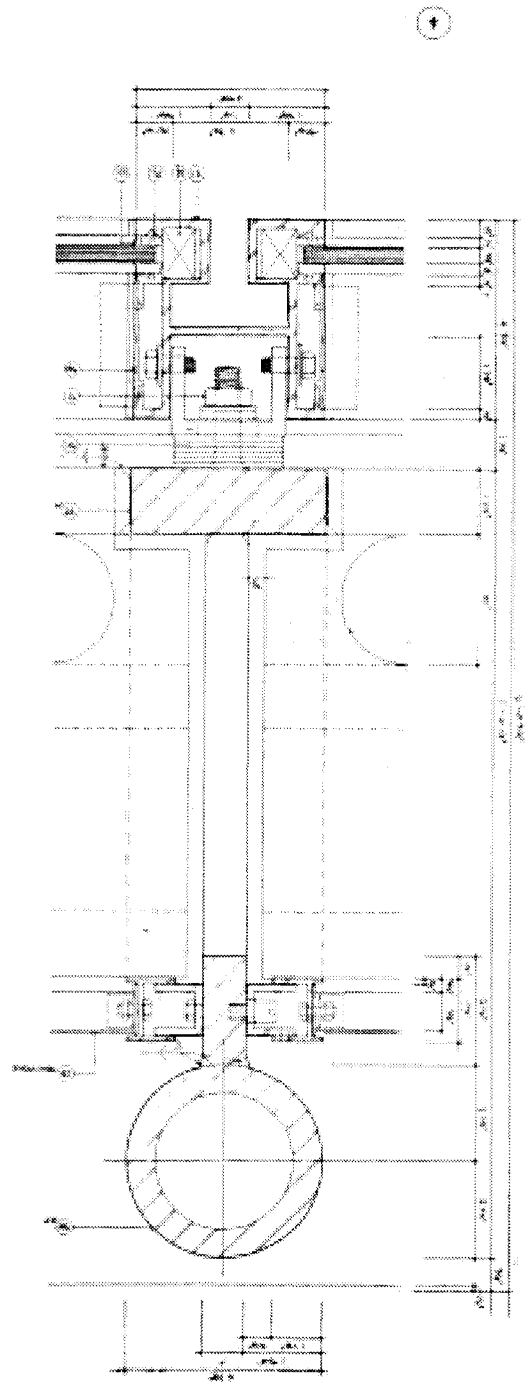

Fig. 5.

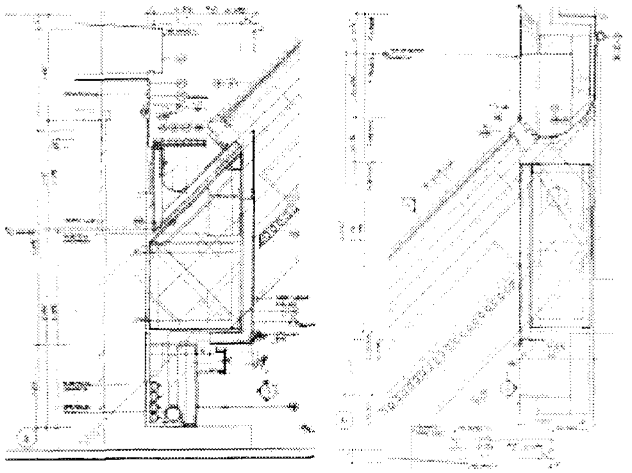

Fig. 6.

The tubular bottom cord is also used to carry electrical conduits for ighting the lenses.

At the bottom of the truss and between them, a sunscreen device made of polished 7/8" aluminum tubes was attached, (see figure 5).

The connection of the lens trusses to the building is of particular interest. To avoid clumsy joinery outside, a depression was made above the vertical arch that intersects with the lens, (see figures 3,6).

The top reveal solves several visual and technical problems: it prevents the dusty run off of the walls from staining the lenses; water is diverted and collected by a perimeter flashing/gutter. It allows the eye to see the lenses "inserted" into the body of the auditorium box; it eases the transition between the stone cladding and the glazed surfaces, and finally it makes the insulated flashing invisible.

The bottom of the truss was also hidden from view; it connects to the building below the top of the ring beam that acts as a parapet, (see figures 3,5).

The bottom of the truss has the same ingenious flashing/ gutter system as the top with the addition of a continuous grilled strainer to stop leaves or flying debris from clogging drains.

The interior connection of trusses to building have a similar reveal as the outside, but a light painted metal surface supported by metal angles cover the structural joinery, electrical conduits and sprinkler piping from view.

Monolithic clear safety glass is held by prefabricated aluminum mullions laid over an aluminum channel system bolted to the steel trusses. A 7/8" separation between glass panels acts as expansion joint and also as exterior gutters, (see figure 6).

CONOID

The challenges presented by the lenses are magnified in the conoid. Several factors contribute to this: it is a curved asymmetrical form with different curvatures top and bottom and different side conditions. Spans are larger and more varied; framing trusses change from completely vertical at right to close to horizontal at the left hand side, (see figure 2).

Without the aid of computers, finding true dimensions for such a curved plane became a defying mathematical proposition.

Analytical drawings were made to arrive at a developed elevation. The initial drawing was a skewed cone whose vertex aligns with the outer edge of the base. Radii coming from the vertex to the base are vertical on one side and slanted on the other, (see figure 7). Opening the figure allows to obtain true dimensions.

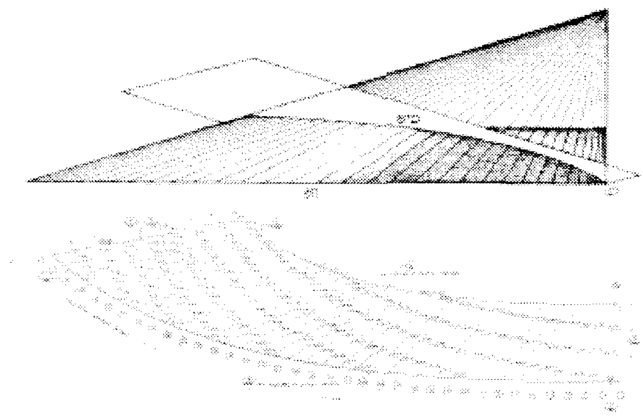

Fig. 7.

Because of Pei's intention to produce a more dynamic form, the parallel bands were made almost perpendicular with the vertical radii and not parallel to the horizontal building lines. This peculiarity could only be met geometrically by slanting the top surface of the cone in relation to the base and then making parallel rings to the slanted top surface.

Designing the structural framing presented even greater challenges. Each truss required greater individual description, because of the different spans and orientations. Bowstring trusses were chosen for their lighter look and 37 of them produce a convex plane inside, (made more visible when the sunscreen rods were added). Two equations were devised to calculate the depth each truss as well as their relative horizontal and vertical angles.

The formulas also allowed finding the location of exterior mullions, which in turn established the size, and shape of each one of the glass panes, (see figure 7).

The conoid seats on a trabeated structure at ground level. Although columns have similar spacing between them, they have progressively greater depths in plan echoing the varying depths of the bowstring trusses, (figure 2).

Two horizontal beams support the conoid's framework. The top support is the underside of the ring beam, (see figure 8).

The bottom is the top of the trabeated structure mentioned before. The conoid has a similar gutter/flashing system than that of the lenses and also a similar metal closure to hide the interior structural connections between the trusses and the building. Bowstring trusses also have similar top and bottom cords and sunscreen devices as the lenses.

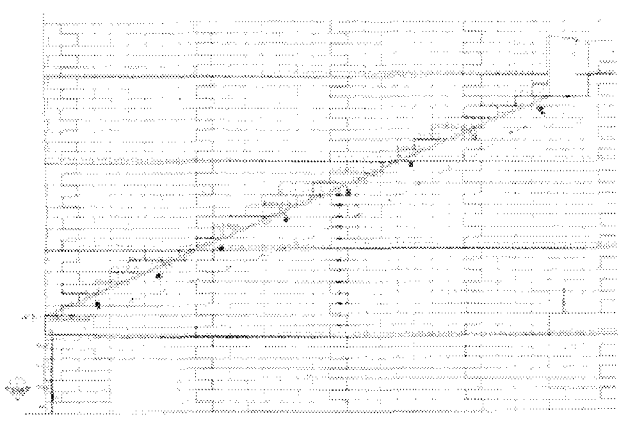

Fig. 8.

CONCLUSION

Regardless of having achieved greater control of curvilinear shapes with the computer, boldly curved skylights like those presented, are as much a challenge today as ten years ago. The computer can do the math faster and help visualize shapes with greater accuracy; but the overall effect, connections, details and specifications of such skins, are very much part of the willingness of designers to invest on countless trials and errors to arrive at the desired results. Pei's obsession with enduring quality has been the ultimate challenge to the staff that assists him. This constant charge is always intended to arouse the passion more than the patience required to achieve such outstanding results.