■ david s. ingalls hockey rink
new haven, connecticut 1956–1959

Intentions in Tension

Peter C. Papademetriou

"The Yale Whale", as it is popularly known on the Ivy League university campus where Eero Saarinen was a student (class of 1934), heralds the biomorphic imagery that began to appear in Saarinen's work by the mid-1950s[1]. That it was also referred to as a "Viking vessel" can perhaps be construed as a compliment to Saarinen's collaborator, the civil engineer Fred N. Severud, who was Norwegian by birth[2]. Whatever name it goes by, the David S. Ingalls Hockey Rink is one of the most remarkable structures of the 1950s and reflects an intense collaboration between architect and engineer. Yet its unconventional form presented critics with a problem. In what terms should the building be judged? Was it a sculptural and thus a formal problem? Or was it determined by the logic of engineering?

As an engineer, Severud was drawn to the study of nature. Observation of the structure of flowers, for example, had led him to develop new design applications. These were outlined in an article of 1945 on extreme efficiency in the uses of material, a wartime need that inevitably led designers «to simplify and integrate structure»[3]. The structural principles observed in natural forms suggested new applications and the appropriate materials to achieve them. In the 1950s, Severud's studies expanded into the area of suspended cable structures, which interested him precisely because of their efficient use of materials. «Working stresses in steel cables», he noted, «are as high as 80,000 psi, whereas those of steel in bending are only 40,000 psi»[4]. The most dramatic example of the day was the North Carolina State Fair Livestock Judging Pavilion in Raleigh, North Carolina, completed in 1950. The pavilion's architectural concept was proposed by its architect, Matthew Nowicki, shortly before his death, but the engineering was the work of Severud. It comprised a pair of crossed oblique compression arches supported on columns, with a catenary roof slung on cables between them. A secondary cable system at right angles formed a two-way grid, then guyed at the intersection points to posts to tighten down the roof and eliminate flutter (a natural problem with slung roofs, due to suction from wind flow across the concave surface)[5]. Saarinen much admired the pavilion design and invited Nowicki to collaborate with him on the development of a master plan for the new campus of Brandeis University in Waltham, Massachusetts (1949–51)[6]. It was Severud, though, who provided the engineering vision for some of Saarinen's more lyrical designs, beginning with the famous 630-foot Jefferson National Expansion Memorial in St. Louis in 1948[7].

The Ingalls hockey rink brought twentieth-century building technology to Yale University. In-

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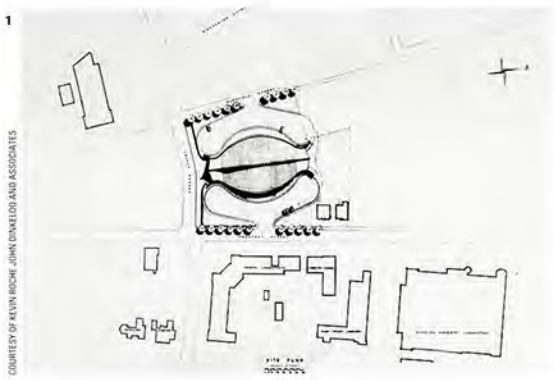

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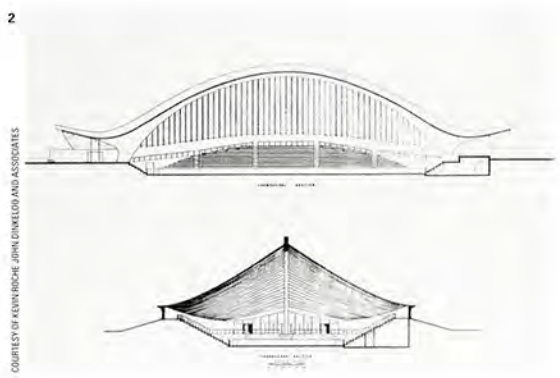

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galls was the first tensile suspension structure at Yale, a campus dominated by masonry compression buildings. It was deliberately located "in town" in order to initiate expansion of the campus and generate large crowds in a spectacle setting. It was, not surprisingly, a controversial building. Yale President A. Whitney Griswold felt compelled to justify the design in a letter to the donors: «[T]he conventional style of hockey rinks seems to me so ugly and barnlike—witness the Harvard rink and the drawings of the new Cornell one [both Ivy League ice hockey rivals of Yale]– that we all concluded it would be a mistake to put such a building on a site that will soon be developed as an integral part of the campus». He continued, «Eero Saarinen... has shown the most lively appreciation of the traditional forms already here... He had before him a site which would make any

did not compare in quality[10].

According to Saarinen himself, Ingalls' bulging form was the result of arranging the 2,908 seats in an oval around the 200 x 85-foot skating area so that more «seats could be clustered around the fifty-yard line», that is, at the center of the rink[11]. The shape was also determined by the requirement that the seating capacity be able to be doubled for occasional use during commencement exercises in the event of bad weather or for other types of assembly, and that it have excellent acoustical properties[12].

The 333 x 183 foot building is enclosed by walls and roof that follow reverse curves. A central parabolic reinforced concrete arch rises to a height of 75 feet above the rink to provide a column-free span, and cantilevers 40 feet on each end to support the roof over the entrances. At its

horizontal reference wood member attached to the falsework. A flat section 1.5 x 7 feet at the top of the enclosing walls acts as a kind of inclined arch stiffener, taking the roof thrust at these points of anchorage and distributing it. In plan, the walls are two reverse-curve parabolas connected by a 160-foot radius arc. Held at the center portion by three struts running from wall to wall under the rink and a tie between two opposite points on the foundation, the pair of perimeter walls is interrupted at opposite ends of the building to form the entrances. They are in turn connected to the two central arch supports by horizontal bent-steel truss braces over the entrances, 6 feet wide and 50 feet in span.

The steel cables supporting the roof are suspended as a catenary curve between the center spine arch and the curved exterior walls. The roof

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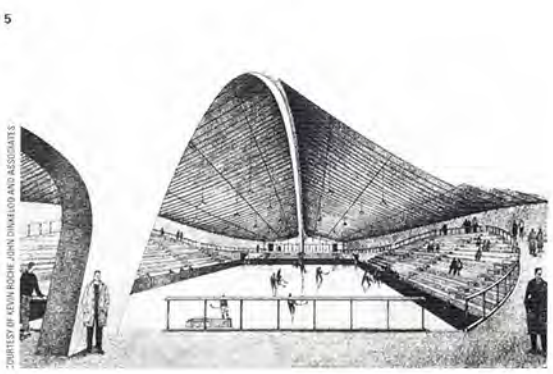

COURTESY OF KEVIN ROCHE JOHN DINKELOO AND ASSOCIATES

building that was to occupy it a near neighbor of Gothic, Tudor and Modern—and this was his solution... The enclosed letter... shows that in the minds of these serious students of architecture, all of them devoted alumni who comprise our Department of the History of Art... Eero Saarinen has solved the problem with imagination and distinction»[8]. The letter mentioned by Griswold from the art history faculty stated, «Around a structure of this quality it should be possible in the future to develop a really fine group of buildings... [to] become a focus in the same idiom of architecture. As architecture, [the rink] has its place quite rightly in the city and in a part of the city and University where there is sufficient space for its really monumental form and for expansion in its vicinity»[9]. Griswold also boasted that Harvard's architects and others close to them envied Yale's selection of Saarinen and realized that their own rink

center, the arch structure is 3 feet wide and 5 feet high, sweeping on a smooth curve into the two internal end supports, where it is 6 feet high. It was constructed with metal-pipe scaffolding; the forms were adjusted to proper curvature with hydraulic jacks atop the centering. The perimeter walls, constructed of reinforced concrete, are 9 inches thick above grade and slope 15 degrees outward, resisting the lateral thrust of the roof and acting as a curved, cantilever beam. To lay out the reverse curve of the central spine arch and walls, the contractor worked with coordinates measured from three straight base lines, one for each of the major elements. The coordinates shown on the architect's drawings were computed at 6-foot intervals, coinciding with the attachment of cables to the spine arch and perimeter walls. The adjustments of the hydraulic jacks were achieved by coordinates measured from a

cables, 15/16 of an inch in diameter, are spaced 6 feet on center horizontally, in order to form a web support for the wood roof and prevent flutter. Nine longitudinal main cables, also 15/16 of an inch in diameter, installed on each half of the roof, are prestressed to act as tie-downs for the roof deck, preload the roof construction, and resist horizontal loads on the center arch. The longitudinal cables span between the four horizontal truss braces at the pair of entrances. The main cables drop 43 feet from the crown of the spine to the wall anchorages, 9 feet from the spine supports to the walls, and 11 feet from the ends of the spine cantilevers.

The roof deck is constructed of random lengths of 8 x 2 inch tongue-and-groove treated wood planks. These are nailed to two 2 x 6 inch nailers that are bolted to the cables, which run through pipe sleeves at the connections. Three

bracing cables, 1 3/4 inches in diameter, located on either side of the exterior of the roof, complete the resistance to asymmetrical loading from wind and snow[13]. This element, while structurally consistent, was characterized by some critics as unjustifiable visually. Peter Blake, writing in «Architectural Forum», stated, «the guy-wires that connect the center spine to the tension walls... were an afterthought... very disturbing... like the guy-wires on a great big transplanted tree»[14]. Robin Boyd, in an extensive critique of tensile structures within the modern movement, cited «[Saarinen's] famous hockey-rink, with its central humped spine and symmetrical saddles, [as] a characteristic piece of his Expressionist sculpture in extension of an engineering concept». In his view, «Saarinen managed to retain

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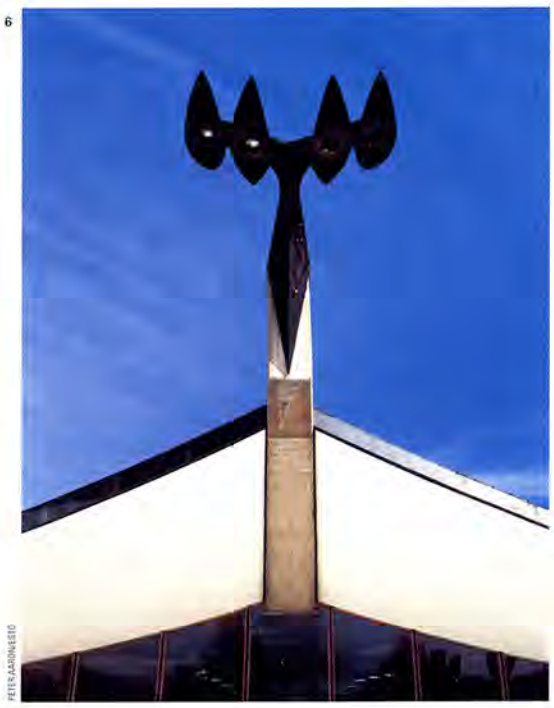

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the lightness of the cable web, and almost made the tensile and compressive elements jell into an architectural whole, although three stabilizing guy wires to the top of the spine on each side stood out rather rudely, refusing to accept the architect's discipline»[15]. Yet Boyd also noted, «It is more relaxed and much more convincing as a form derived from functional and structural requirements... [and] the body of the building has an authentic and imperative air»[16]. In fact, the external guy wires, bothersome to both Blake and Boyd, are the most logical solution to the problem of "lift" that affects a lightweight roof membrane on a tensile structure. This was pointed out by the critic Lawrence Lessing: «Indeed, up to now nearly all attempts to solve this problem have been by the "brute strength" or empirical method, adding weight and multiplying anchorages, which cut into the economy and *esprit* of the form»[17].

For Saarinen, the collaboration with Severud opened new avenues of formal expression. Although the site was virtually flat, he had it contoured up toward the center of the enclosing walls. This was in part to add weight to solidify the foundation, but also to enhance the appearance of the building, causing it to look as if it were "plowing" through the site. A sculptural light element in metal by Oliver Andrews, a California artist, paid for and donated by Saarinen, projects from and extends the thrust of the entrance beam, furthering the building's dynamism. Saarinen himself said of the rink, «I like the story of the boy on the Yale team who said... it made him feel "go, go, go!"»[18].

Notes

1 *Yale's Whale*, «Sports Illustrated», February 1959, pp. 52–53.

2 Walter McQuade, *Yale's Viking Vessel*, «Architectural Forum», December 1958, pp. 106–11. The question of imagery has always been central to the evaluation of the Ingalls rink. Peter Blake disparaged it as «a "Scandivegian" soup tureen, complete with artsy lid», and compared it to «enlarged Danish Modern salad bowls». Peter Blake, *No Place Like Utopia* (New York: W. W. Norton, 1993), pp. 206, 259. Saarinen preempted such criticism before the building was built, observing that, in construction it looked «like the spine of a giant dinosaur... It may be called "The Roller Coaster", or "The Pregnant Whale", or "The Turtle", or "The Giant Boat Upside-Down"». *Reports Indicate Opening of New Rink on March 1*, «Yale Hockey Letter», December 1957, pp. 1–2. On Severud, see Peter C. Papademetriou, "Severud (Fred N.)", *L'Art de l'ingénieur: constructeur, entrepreneur, inventeur,* ed. Antoine Picon (Paris: Centre Georges Pompidou, 1997), pp. 453–55.

3 Fred N. Severud, *Turtles and Walnuts, Morning Glories and Grass*, «Architectural Forum», September 1945, pp. 149–54, 158, 162.

4 Fred N. Severud and Raniero G. Corbelletti, *Hung Roofs*, «Progressive Architecture», March 1956, pp. 99–107.

5 See *Parabolic Pavilion*, «Architectural Forum», October 1952, pp. 134–39, and *Parabolic Cable Roof*, «Architectural Forum», June 1953, pp. 170–71.

6 Eero Saarinen and Associates, "Planning the Campus of Brandeis University", *American School and University Yearbook,* 1951–52, pp. 313–26.

7 Fred N. Severud, *Structural Study: Jefferson Memorial Arch*, «Architectural Record», July 1951, pp. 151–53.

8 Letter of A. Whitney Griswold to David S. Ingalls, December 28, 1956, including copy of letter of December 12, 1956, to A. Whitney Griswold signed by Sumner McK. Crosby, George Heard Hamilton, Charles Seymour, Jr., and Vincent J. Scully, Jr. Griswold Papers, YR6 2A16, Box 36, Folder 332; Rare Books and Manuscripts, Sterling Library, Yale University.

9 Ibid.

10 Letter of A. Whitney Griswold to Yale provost Norman S. Buck, July 30, 1957. Griswold Papers, YR6 2A16, Box 200, Folder 1823; Rare Books and Manuscripts, Sterling Library, Yale University.

11 See comments by Saarinen cited in *Yale's Hockey Rink*, «Architectural Record», October 1958, pp. 151–58.

12 The prospects for a multi-use facility were doubted by Donald Vesley, *Yale Architecture and the Hockey Rink*, «Criterion», January 1959, pp. 15–18.

13 See discussions by Fred Severud, *Cable Suspended Roof for Yale Hockey Rink*, «Civil Engineering», September 1958, pp. 60–63, and *Arches and Catenaries Carry Rink Roof: Yale's Hockey Rink, New Haven*, «Engineering News-Record», April 10, 1958, pp. 30–31, 33.

14 Memo from, Peter Blake to Douglas Haskell, et al., "Yale Hockey Rink", September 18, 1958. Douglas Haskell Papers, Box 1, Folder "Pending-Eero Saarinen & Assoc.", Department of Drawings and Archives, Avery Architectural and Fine Arts Library, Columbia University. Blake also expressed his rather purist ideology in another internal memo dated October 16, 1958, ibid., and objected to other features that were largely pragmatic solutions for a building that had overrun its projected budget. Virtually all of Blake's points were directly rebutted by Walter McQuade in the positive review that appeared in Blake's own magazine, *Yale's Viking Vessel*, «Architectural Forum», December 1958, pp. 106–11.

15 Robin Boyd, *Under Tension*, «Architectural Review», November 1963, pp. 324–34. Saarinen knew Eric Mendelsohn and became acquainted with Paolo Soleri's work through his friend Charles Eames. However, the literature on expressionist architecture was virtually nonexistent at the time; one of the first books on the subject, Ulrich Conrads and Heinrich Sperlich's, *Architecture of Fantasy,* would not be published in English until 1960.

16 Robin Boyd, "The Counter-Revolution in Architecture", «Harper's Magazine», September 1959, pp. 40–48.

17 Lawrence Lessing, *Suspension Structures*, «Architectural Forum», December 1957, pp. 134–41.

18 Quoted by Aline B. Saarinen, *Eero Saarinen on His Work* (New Haven: Yale University Press, 1962), p. 54. On the issue of expression and meaning Boyd notes, «it might appear that the hunch-backed curves express the movements of Ivy Leaguers on skates», in a sense confirming Saarinen's most basic intentions. See Boyd, *The Counter-Revolution*, p. 46.

Peter C. Papademetriou *is a professor and director of the graduate program at New Jersey Institute of Technology. He is the author of a number of articles on the work of Eero Saarinen.*

PRECEDING PAGES

1
Roof plan and site plan illustrating contextual strategy of absorbing the shift in the street grid
2
Longitudinal and transverse cross sections
3
Model prior to refinement of external bracing cables
4
Interior illustrating low soffit at entrance and central support structure, cardboard study model
5
Interior illustrating low soffit at entrance and central structural support, perspective rendering

6
Sculptural metal light fixture projecting over entrance
7
Perimeter concrete walls curved as double parabolas. Top section acts as cantilever horizontal arch as well as integrated roof gutter

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8
Dusk view looking east toward Osborn Laboratories. Typical example of traditional masonry architecture on Yale campus
9
Interior lobby view to south showing extension of cantilever central spine arch and wide multiple entrance door to facility entry and exit
10
Side exits tucked under cantilevered perimeter edge illustrate 15-degree outward slope of the perimeter walls, designed to resist lateral thrust of the roof. Two of the three exterior bracing cables serve to bolster resistance to wind or snow loads

FOLLOWING PAGES
11
Exterior view looking west. Central spine arch cantilevers 40 feet beyond its support, further extended at entrance by sculptural metal light fixture designed by Oliver Andrews.

9

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12
Interior panoram with 228-foot-high central spine arch
13
Central spine sweeping to height of 75 feet above rink

FOLLOWING PAGES
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Perspective concept sketch. Drawing by Eero Saarinen
15 16
Site plan, longitudinal and transverse sections
17
First floor plan

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PRINCETON
IKON
Office Solutions
YALE
GUEST
PLAYER
PENALTY
PERIOD
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NEW HAVEN SAVINGS BANK

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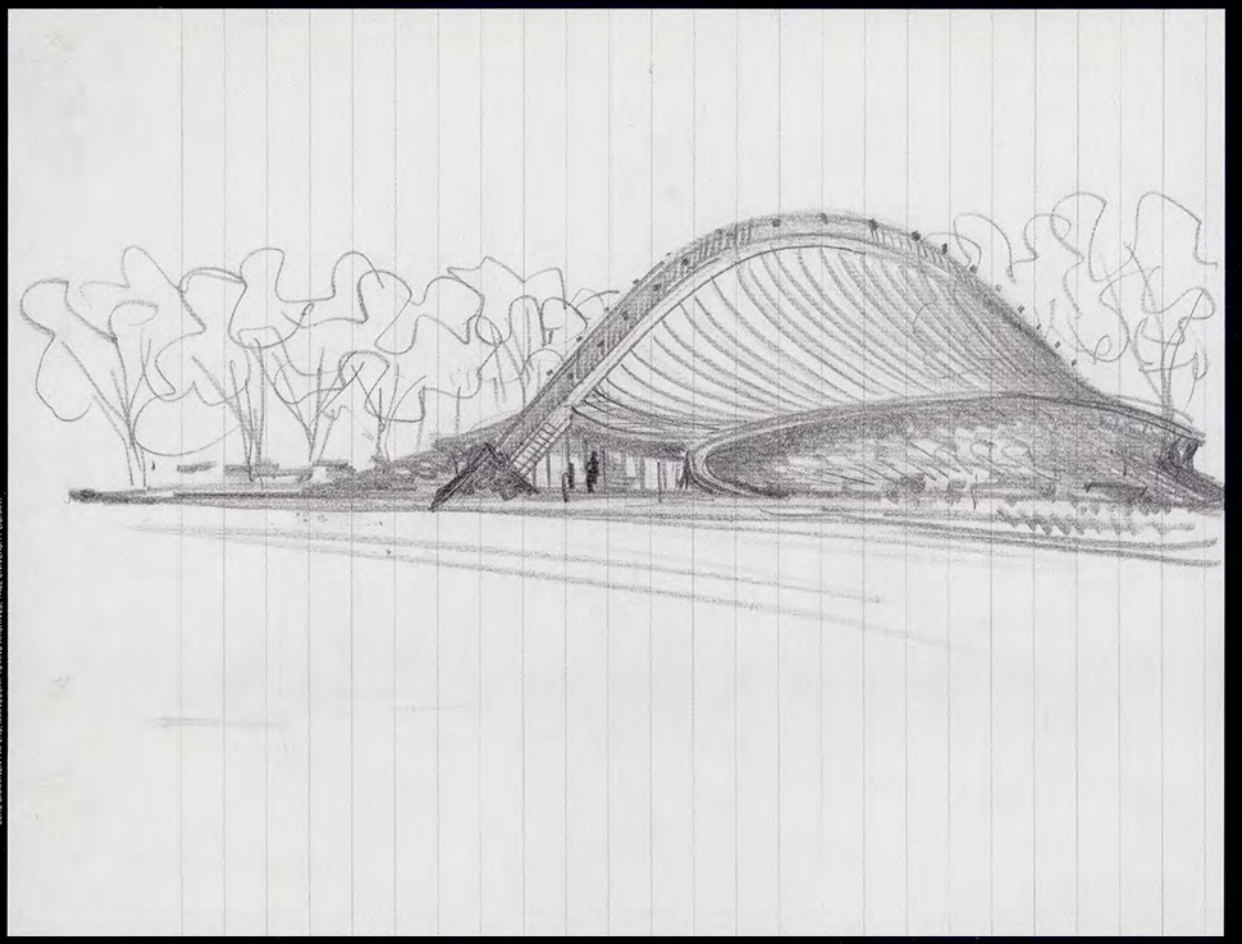

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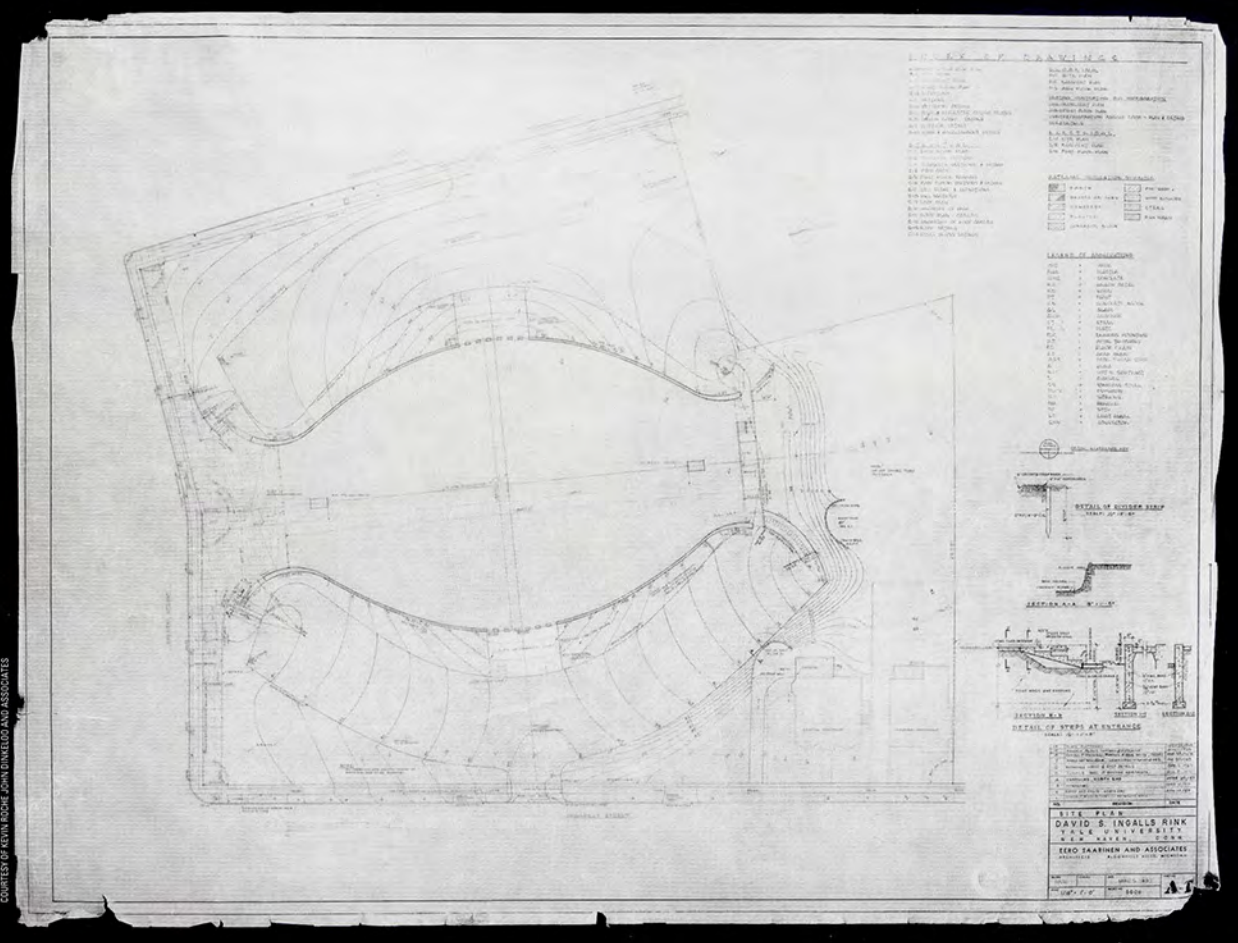

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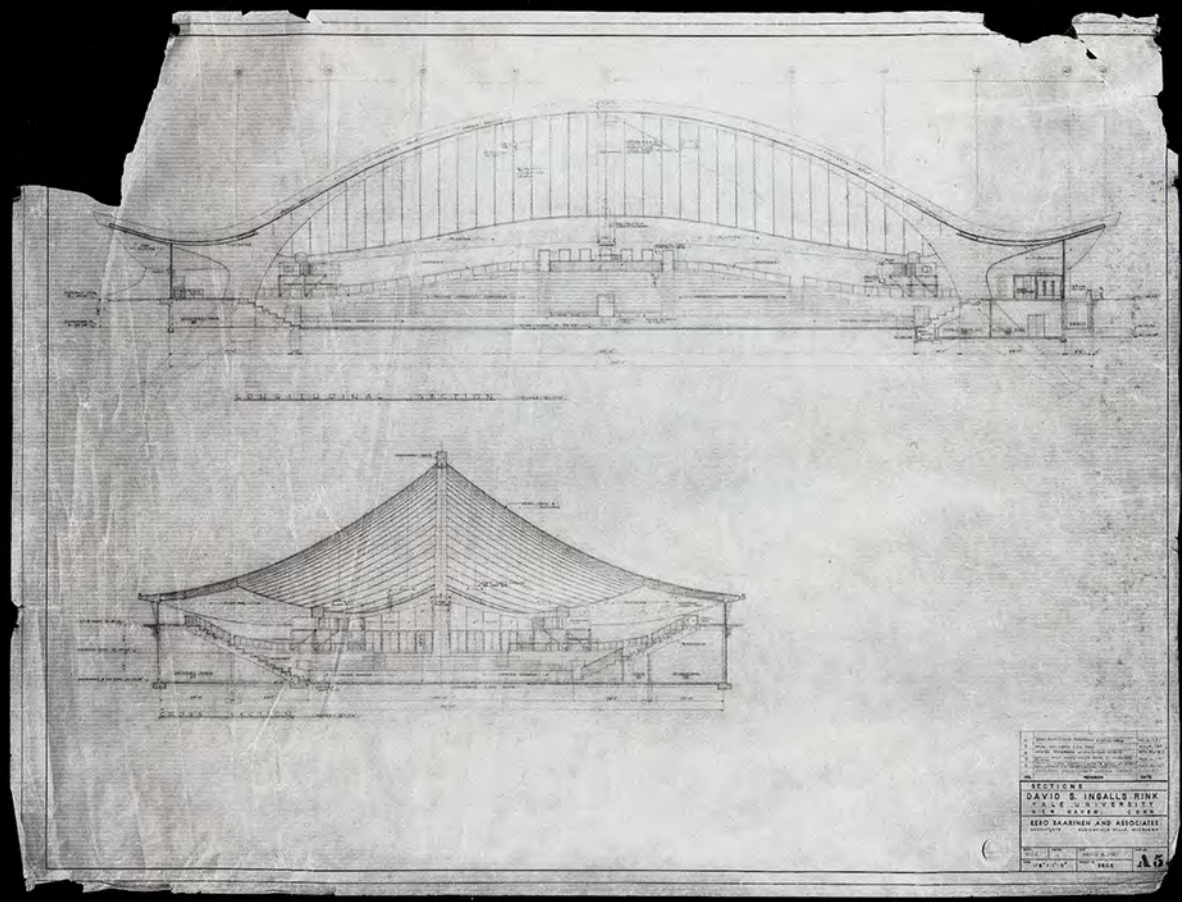

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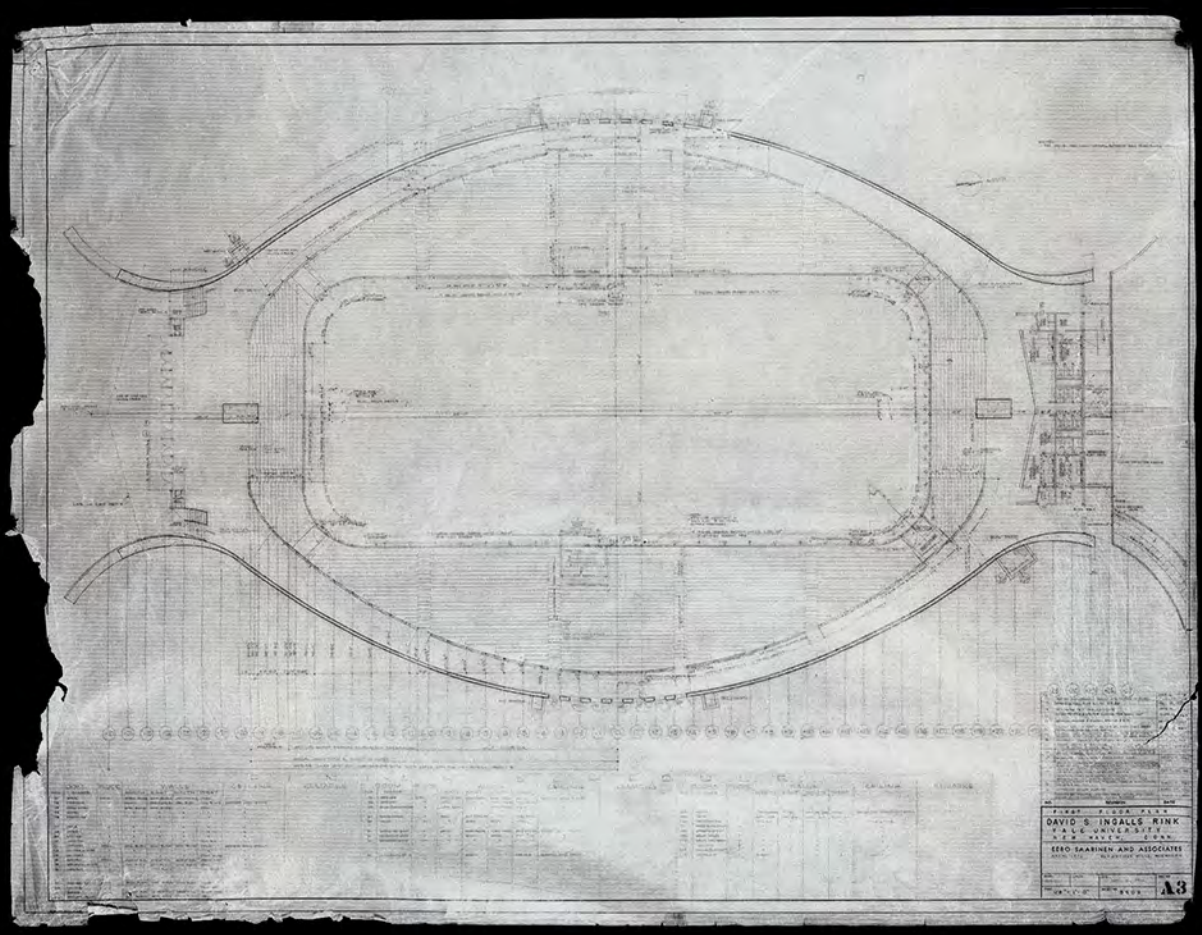

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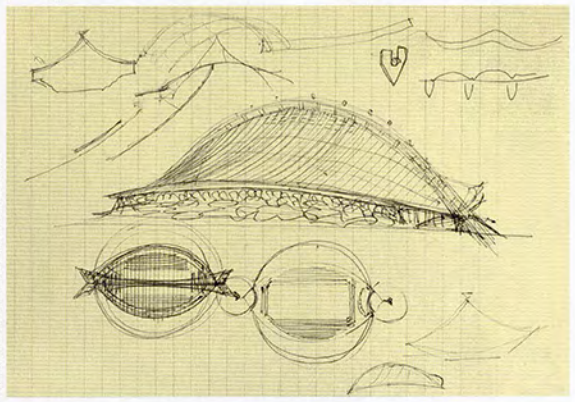

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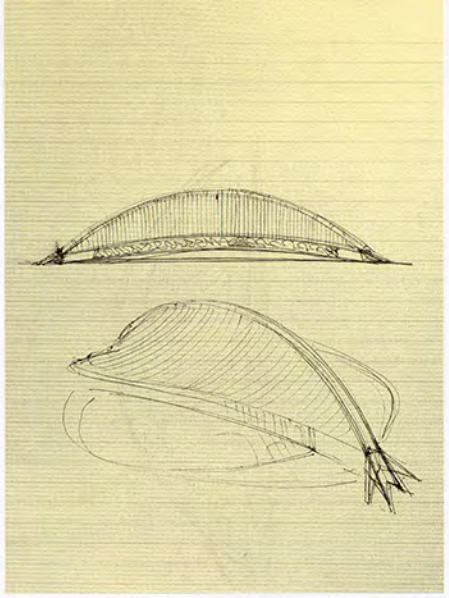

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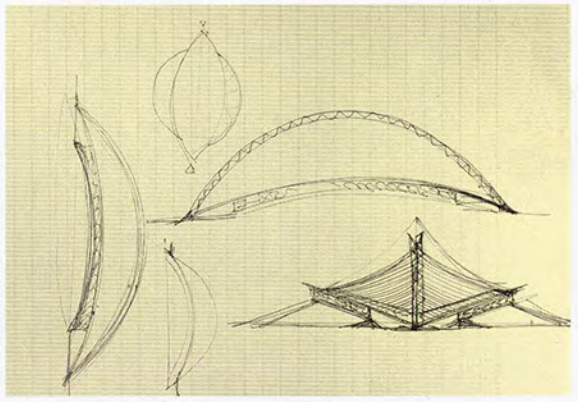

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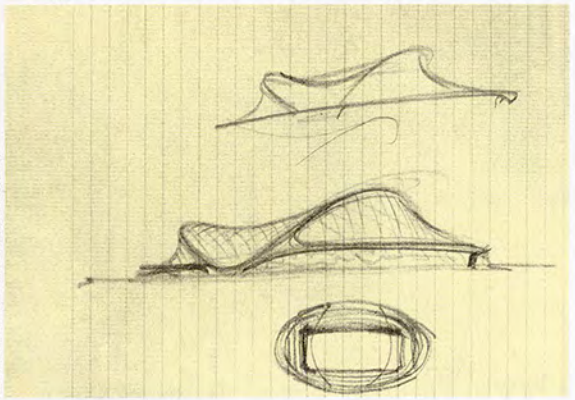

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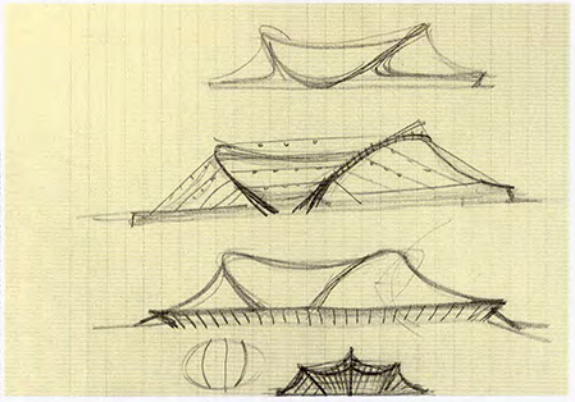

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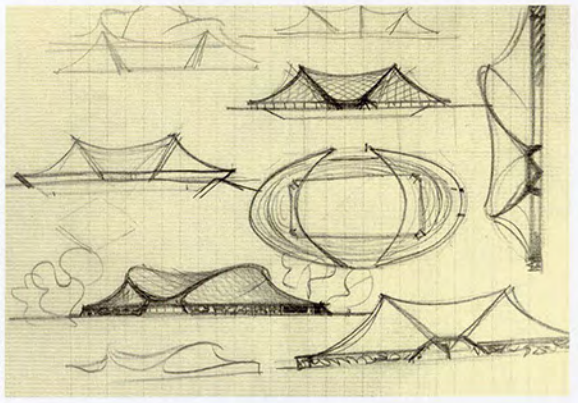

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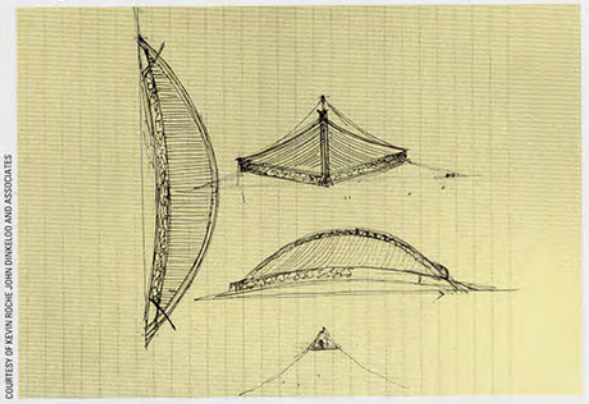

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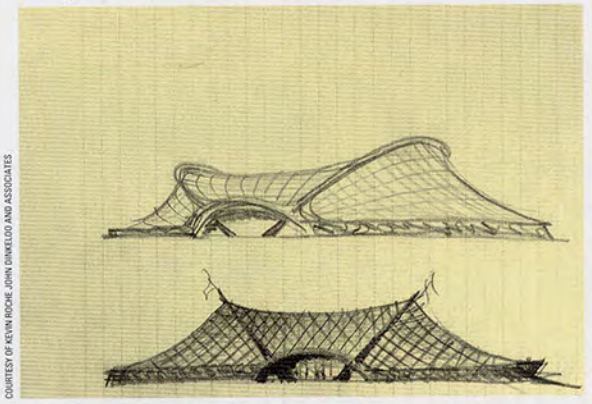

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Elevation and perspective sketch.
19
Elevation studies, including resolution of entry with roof structure defining spatial volumes.
20
Elevation studies including resolution of entry with roof structure defining spatial volume.
21
Elevation studies, including resolution of entry with roof structure defining spatial volume.
22
Alternative "tent" version of roof with entrance on side elevation.
23 24 25
Combination of "tent" structure and end elevation entrance.
26
Central spine arch defined by metal-pipe scaffolding with concrete being poured in sections
27
Metal-pipe scaffolding adjusted to define curvature of central spine arch
28
View from end support of central spine arch showing curvature defined by metal-pipe scaffolding with concrete being poured in sections
29
Central spine arch and perimeter walls completed with tensile cable being slung into position
30
Central spine arch completed, seating and perimeter walls in progress. Horizontal truss braces seen to left of central support with tensile cables being installed
31
Detail of perimeter wall with top acting as an inclined arch stiffener taking roof thrust at points of anchorage and distributing it
32
Detail of the perimeter concrete walls curved as double parabolas

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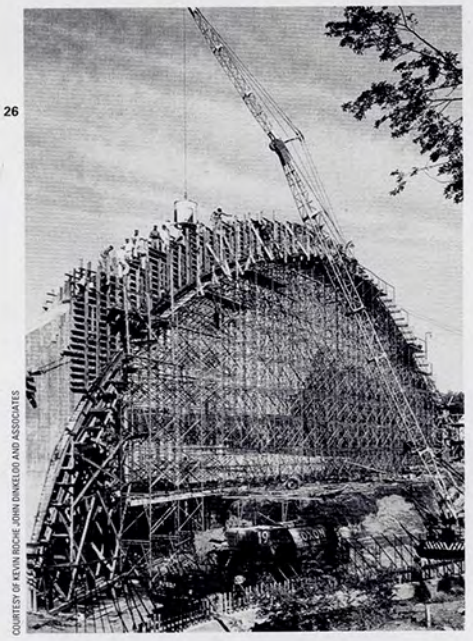

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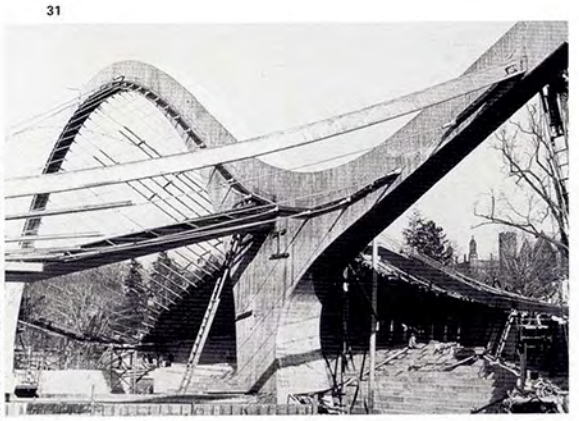

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