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The architectural highlight of the last Olympic Games at Tokyo was the linked pair of covered stadiums. The major contribution they make to world architecture, both aesthetically and structurally, is discussed here by Robin Boyd. The team responsible for the buildings was: Kenzo Tange and the Urtec group, planners and and architects; Y. Tsuboi and Associates, structural engineers; U. Inoue and Associates, mechanical engineers. 1 *(opposite) shows the end pylon and entrance to the main stadium.*

criticism

Robin Boyd

Architect: Kenzo Tange

Olympic Buildings in Tokyo

By the end of 1963 the tensile movement in architecture was drawing to the close of its adolescent or probationary period. The circular roof had been done successfully a dozen times in saucer and bicycle-wheel and other variations, culminating in the biggest ever, panelled in primary-coloured plastic, over the New York State pavilion by Philip Johnson at the New York World's Fair. The simple saddle had been demonstrated beautifully in Nowicki's State Fair Pavilion at Raleigh, NC, eleven years earlier, and had been reworked three or four times since without promise of new discoveries in that direction. Eero Saarinen had tried to stretch out the ends of his twin saddles over the Yale hockey rink and to reverse their curves into a more sculptural form, and had run into a bit of trouble with the engineering. After that Saarinen had returned to a plain suspended roof for the Dulles Airport terminal at Washington. This he handled so confidently and at such monumental scale as to say practically the last word on the subject.

And so, despite (or because of) Frei Otto's continuing, exciting gymnastics with multiform tensioned tents, there was a rather dispiriting feeling in the air that the real promise of tensile construction to make the transcendental structures once expected of it lay in a future of better technology. The movement seemed to be waiting for a permanent building material as continuous and workable as canvas. Nevertheless, the tensile movement was only musing; it was not in anything like the state of shock suffered by the shell concrete movement after Sydney Opera House had had to change its early plans. For every problem involving the covering of a large area in a clear span, tension was still inevitably to be considered. But was it possible to do anything new and creative with it, pending the arrival of a miracle fabric?

Then Kenzo Tange built the National Gymnasium for the Tokyo Olympic Games, held in 1964. Fairly soon in the course of examining the problem, Tange relates, he elected to use tensile construction. He had three main reasons. The most compelling was simply his conviction that tension is heir to the future, that the natural evolution is from beam, to vault and dome, to suspension. His second reason was practical: the concave form of a suspended structure encloses a great deal less space per unit of floor area than the convex form of any vault or dome, thus reducing the load on air conditioning and the problems of acoustics. Thirdly, he likes tension's flexibility, its promise of spatial freedom. In his Tokyo buildings he wanted to avoid a closed form; he wanted free space to greet and to disperse the great numbers of visitors, to rid the enclosure of any sense of restriction, and to permit a spatial continuity between different elements in the complex. In the result he demonstrated that there were still unexplored avenues for spatial adventure in tension, even using the old steel web with the cables crossing at right angles and pulling against each other in contrary curves. Thus Tange brought the first tension period to a conclusion on a much happier note. Or, one is tempted to hope, he led it into a second, less experimental and more creative period.

The complex called the National Gymnasium consists of two separate gymnasiums, a building which connects them, and extensive ground works on a roughly triangular and rather limited site. It is alongside the Olympic Village in one of the more sightly suburbs of Tokyo. The main gymnasium contains Olympic swimming and diving pools, which convert to ice-skating rinks in winter, and seats for 15,000 spectators. The smaller gymnasium, seating 4,000, is quite separate. It was even built by a different contractor. It housed basketball during the Games and was designed to suit a variety of more intimate sports afterwards: table tennis at the time of my visit. The connecting building contains administrative offices, a dining hall, and a training pool at each end. It is long, straight and narrow, and its roof makes a promenade which is linked to a higher level of natural ground by a built-up podium, massively buttressed where the ground falls away. This low building, the stony concrete walks above and around it, the hard plazas, the snorkles to subterranean spaces—all the parts of the site development—make up an angular and robust foundation.

The two gymnasiums, despite their feeling of masterful strength and the monumental size of the bigger one, are feminine objects on that masculine base. They are unrelated to anything around them while being closely related to each other. This relationship deserves attention. They are not twins, which were in style at the time, and they are not mother and daughter—the same thing seen through alternate ends of a telescope. They are more like sisters, one big and capable, the other small and playful, both composed in softly rounded continuous curves with hardly one straight line in either of them. The bigger one, with its central pools and longitudinal tiers of seating, has a roof hung in two separate sections from either side of a central catenary lantern slung between two colossal masts. These masts are diametrically opposite across a circular plan. Branch cables which carry the roofs are attached below the lantern and run out, parallel, to the perimeter, where their ends are fixed to the concrete structure behind the last rows of seats. The seats naturally rise in the centre to follow sight lines, and the points of attachment thus form inclined arches which give the necessary counter curves to the sag of cables.

There are two main longitudinal or spinal cables. Each side roof clings to its own. The twin cables can be seen running parallel down the outside stays, but when they span between the masts they are pulled apart by the stress of the side roofs, and this opens up a slit eye or spindle shape to the sky, which becomes the shape of the central lantern.

The smaller building, with a comparatively modest circular arena and a concentric saucer of seating, has a roof which spirals up a single vertical mast set behind the back row of seating. The cables here are radial rather than parallel. In principle this smaller building is not unlike the Bavinger House of 1951, but in effect it could hardly be less like that earlier spiral. Whereas Bruce Goff's mood was rustic and romantic, Tange's is precise and formal.

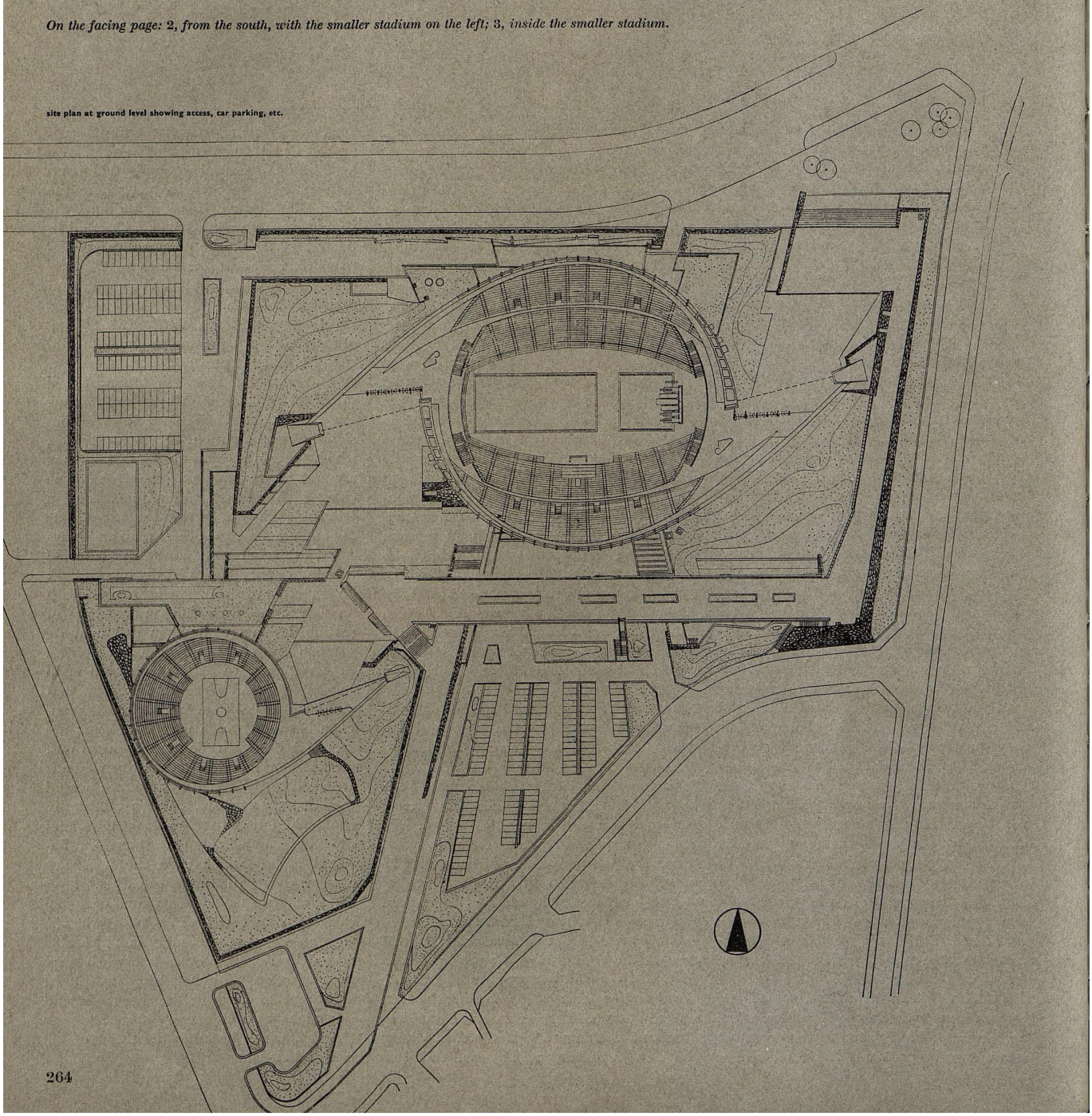
Apart from the different means of suspension, the two gymnasiums follow the same discipline in structural materials and details. In each case the perimeter ring to which the cables are attached is carried high above ground on a recessed under-carriage. Closely spaced columns, or fins, break the strip windows cut into these compression rings and mark the points of attachment of the roof cables. Tailored steel decking covers the cables. A corner of each roof membrane is stretched far out to a point like a jib-sail, staying the mast, and at the same time providing an opening underneath, which becomes the entrance to the building—two entrances, one at each end, in the case of the double-roofed pools building. Indeed, the structure and the functional plan of both buildings support each other so convincingly that a first impression of beautiful arbitrariness is soon dispelled and the interwoven logic of the forms, the structure and the function becomes apparent.

This interweaving of parts and problems into a whole solution was worked out consciously and conscientiously, step by step. 'Gradually,' Tange says, 'in the interplay between structure and space, we intensified these co-ordinations and we

[*continued on page* 269

On the facing page: 2, *from the south, with the smaller stadium on the left;* 3, *inside the smaller stadium.*

site plan at ground level showing access, car parking, etc.



Olympic Buildings, Tokyo

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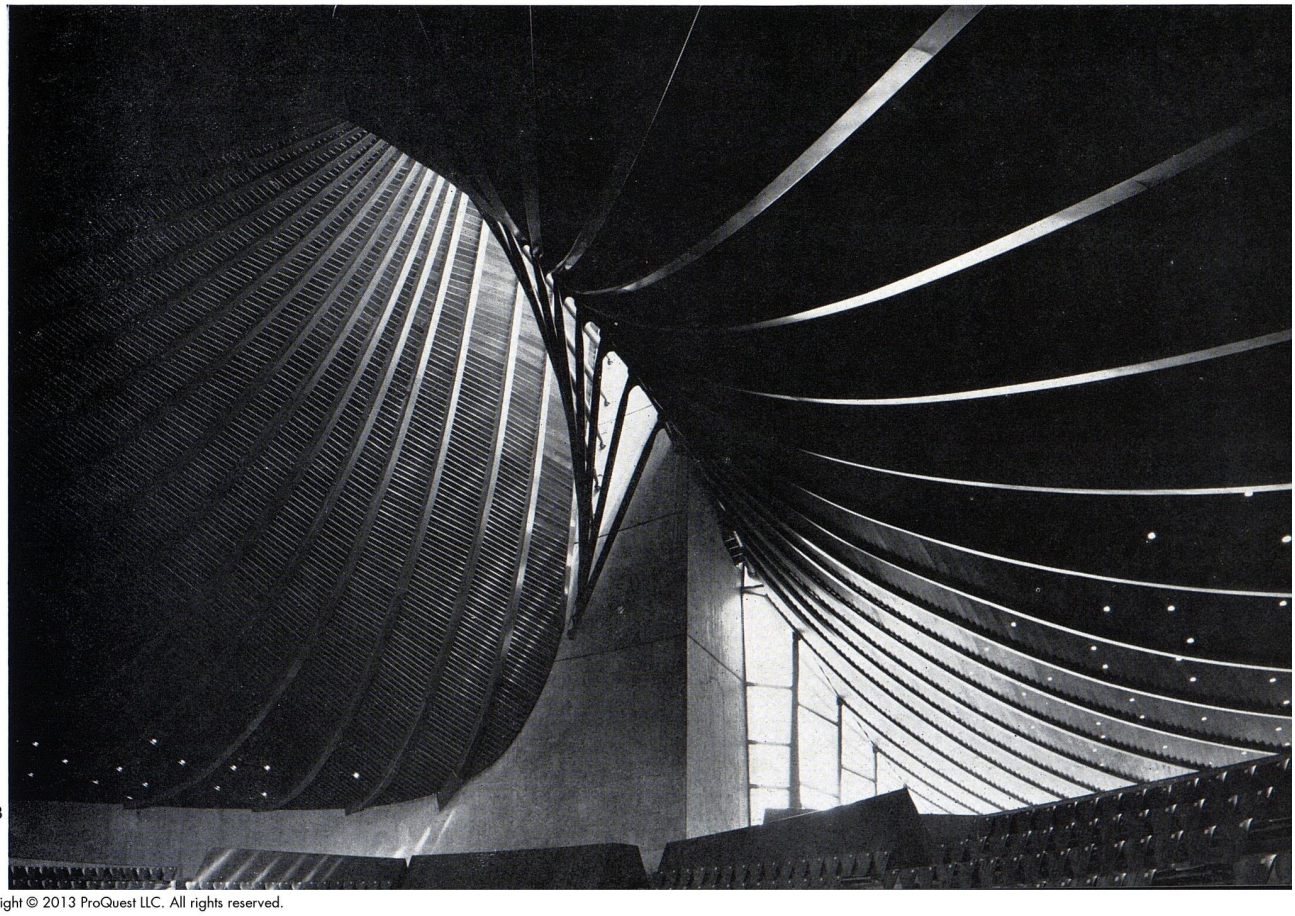

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4, *the main stadium from the east.* 5, *from the direction of the smaller stadium, part of the structure of which can be seen on the right.*

6 (*facing page*), *interior of the main stadium, in use for swimming races. The pools become an ice-skating rink in winter.*

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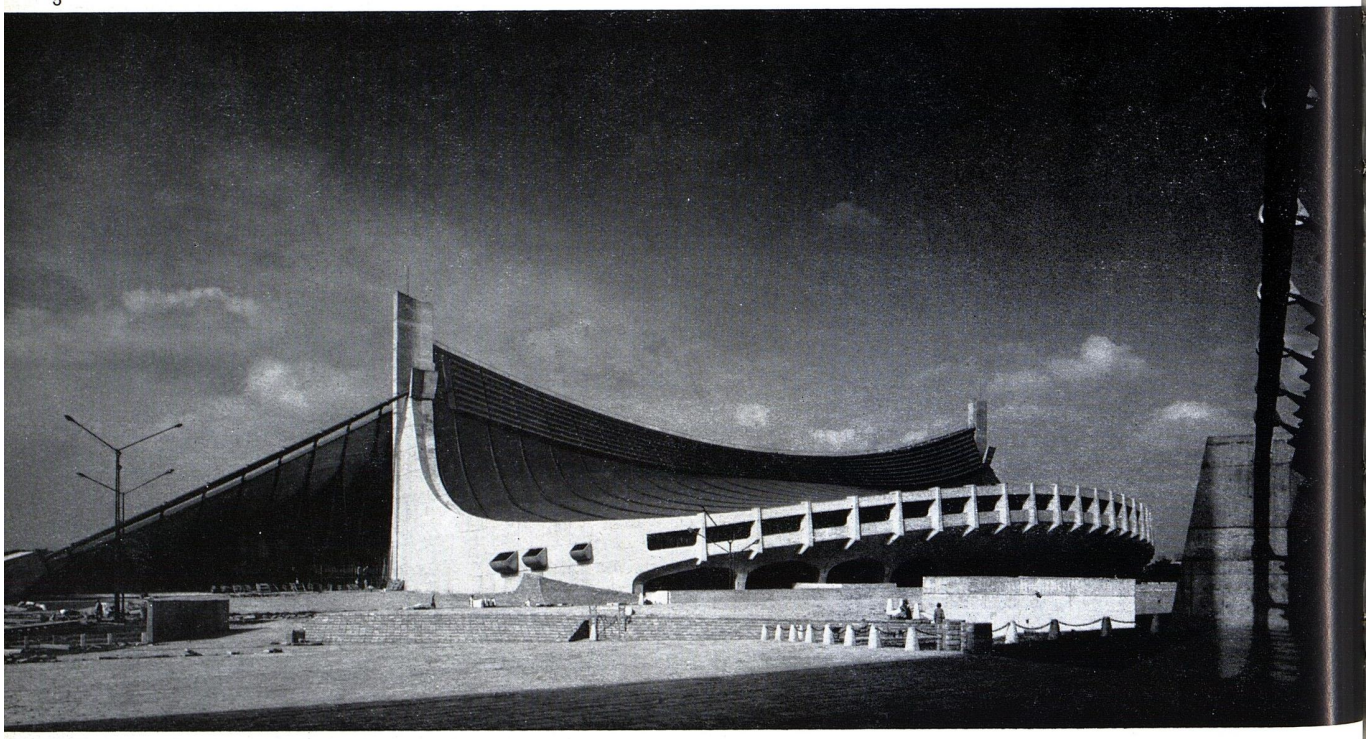

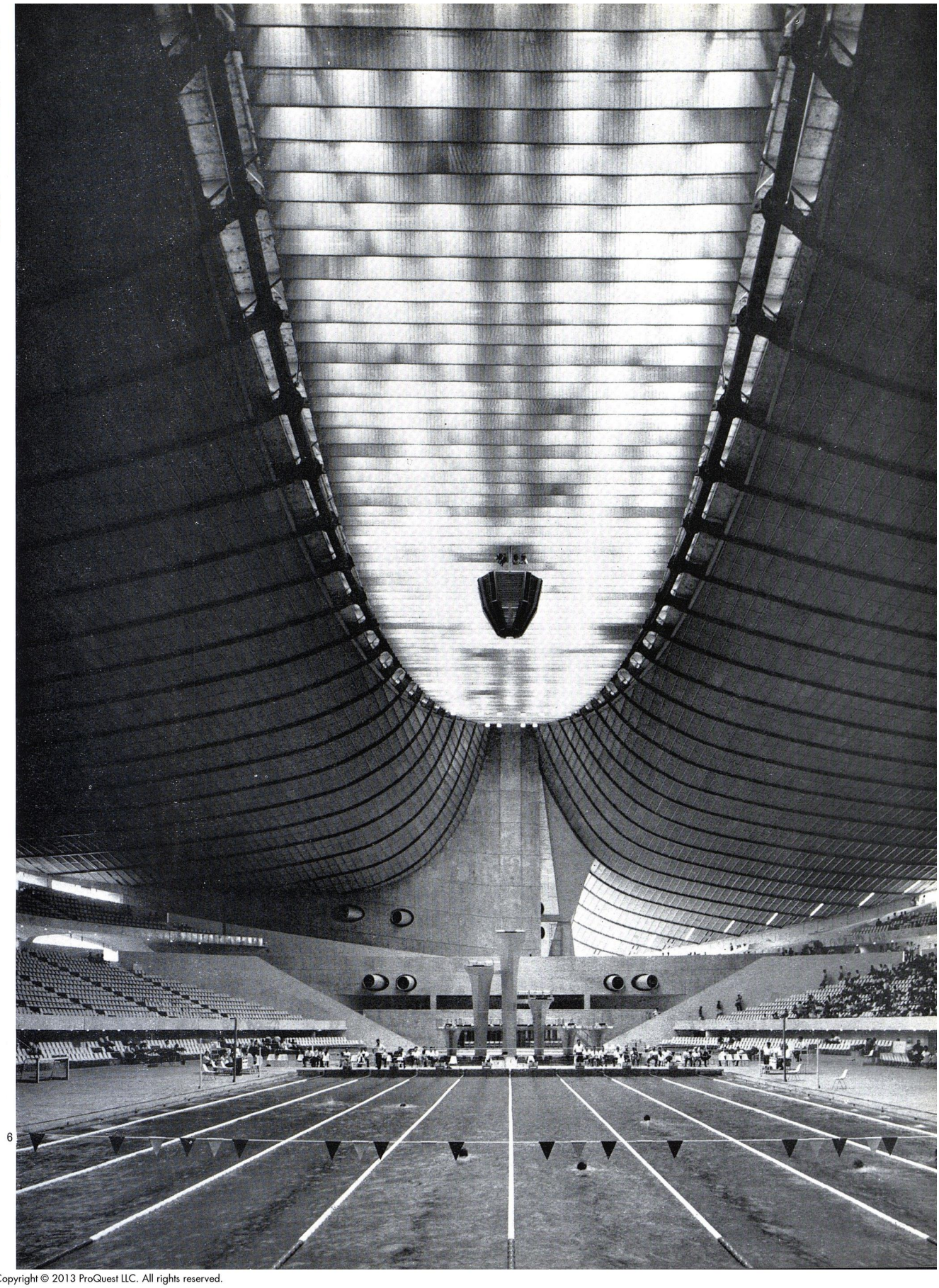

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made it difficult to unravel the mutual connection between the various elements.' For instance, the determination of the slope of the seating tiers involved a study not only of sight lines but of the sag of the branch cables, the pull of the cross ropes and the drape of the main cable. None of these could be determined independently. More than twenty people were in the design team, and they found that if one man decided to change the amount of sag a little in the set of cables which he was studying, his action affected nearly all the others, even sometimes so critically as to endanger the lines of sight. Co-ordination was much more difficult than anticipated. The origin of the forms was almost literally sculptural. Tange and his team finally determined them after long work on large-scale study models. Yet the intense interrelation of structure and function, and the geometrical regularity of the shapes—circle, spindle and jib-sail—tie them to architecture in a way that was positively avoided at Ronchamp and has been unknown in most sculptural architecture, including the Giant Bird. For all its visual complexity, when the Tokyo buildings are viewed as a ground plan, or from the air, the order and exactness of the sisterly scheme is as clear as in any brainwave building of the 1950's or any glass box. They are seen to be formal buildings, ceremoniously acknowledging each other with their wide jib-sail openings parallel and opposite. The variety and complexity increases as one drops to earth, but the sense of formality is always present. Perhaps this is only because the exacting discipline of tension has been constantly observed, and is expressed again and again in the details.

In earlier examples of the tensile movement*, back in its adolescent period, the tension was often expressed in a rather crudely Brutalist way, great ham-fists on the ends of one set of cables gripping a bunch of cross cables, all under visible stress, as in the Melbourne music bowl. At other times more elegance was gained at the expense of eloquence. There was concealment, or less than frank explanation, of the tensile stresses. Even in the assured and adult Dulles terminal, Saarinen was ambiguous about the tension at the crucial points where the hung roof connected to the end beams. He curled the latter up in a continuation of the catenary so that it was hard to tell where the junction was between pulling and pulled elements. But the act of prehension is the essence of tensile construction, and if the architect is to put his occupants at ease he must ensure not only that prehension is done but that it is seen to be done. In the Tokyo gymnasium all the connections are explicit, and each of the main stay cables comes to a decisive termination in a massive concrete ground anchor which is pierced through, exposing the cable embedded there convincingly enough for the most suspicious and sceptical eye. These ground anchors also terminate the walls of the concrete structure, and this is typical of the way the compressive and tensile elements are integrated. Another nice example is to be found beside the mast in the smaller building. Cigar shaped steel spars, mounted on ball and socket ends, hold the spiralling main cable clear of the mast. Each member is almost as communicative about the stress it is undergoing as a jockey scales.

The concrete which makes up the major compressive, or conventional, building elements is bulky and immensely strong, as is to be expected in Japan, but it stops safely short of the muscle-bound condition which afflicted some of the best Japanese buildings of the 1950's. It complements precisely the lightness of the tensile members. It too has curves, but they are curves which relate first to concrete structure. They don't mock the tensioned curves or try to project these into more interesting sculptured shapes. On the contrary they are quite explicit about their equal and opposite stresses, not only in the ground anchors but also in the spectacular cantilever of the outer ring walls beyond their foundations, looking as if they might sag to the ground were they not being pulled up by the main roof cables attached so regularly to them.

There are other universal kinds of delight in this remarkable pair of buildings. The spaces, for instance, are just as moving as one expects from the first exterior view, given the presumption that they are true negatives of the external forms. The pools building is a majestic, almost symmetrical, enclosure under the long central lantern. It is a bland volume, soaring up a mast at each end, almost wholly revealed at once, though animated by the space which runs out under the jib-sail beyond each mast.

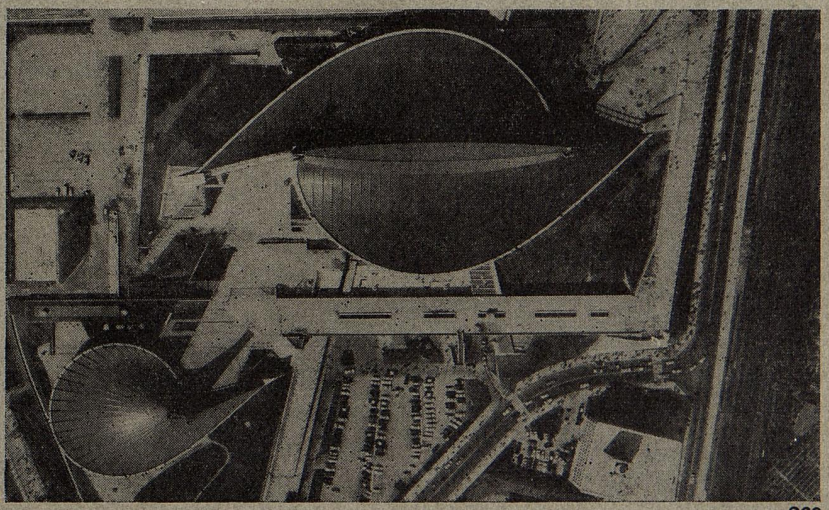
The royal suite, foyers and other rooms in the concrete ring structure are rounded, cornerless, and finished in a crunchy roughcast, stark white, which Tange has used before to good effect. But the greatest delight is in the smaller building. To enter this giant snail-shell is a unique experience. The materials here are warmer, mostly wood and a grey-brown paint on the steel that reflects both the wood and the concrete. Overhead the space is gathered in by the roof as in an inverted anti-clockwise whirlpool, and is finally sucked up the dark, narrow, up-ended well beside the mast, crossed by its twisted ladder of compression spars.

One of the main fascinations of these buildings, however, is even narrower than that space chute; it is the extraordinarily intense regional character—the strong scent of Japanese tradition—which these entirely modern and international buildings wear, with grace, like a kimono. Most of the scent comes surely enough from the strange ambiguity of the curves. Are they free or are they geometrical? The answer seems to be that they are only as free as is good for them, and they are bound by a geometrical conscience.

Tange has been working, or perhaps playing, with such shapes for years. Now the shapes follow rules; now they don't, like the pagoda's proliferative eaves. The central lantern which forms the spine of the pools building droops in a natural catenary, but after all there are taut catenaries and loose catenaries, and the point at which Tange called halt to the fellows operating the cable winch is a distinctly Japanese point. Then there are some extraordinarily evocative details. Where the twin cables of the main gym-

*See Robin Boyd: 'Under Tension', AR, November, 1963.

7 (facing page), the low-level courtyard between the two stadiums. 8, aerial view.



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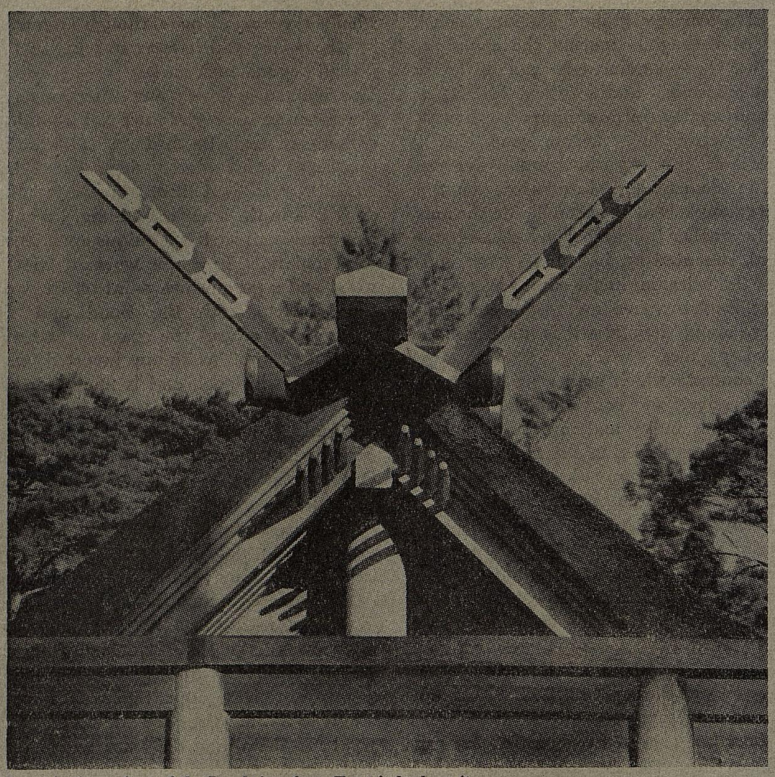

9, *projecting rafters of the Ise shrine, from Tange's book on it.*

nasium pass over the tops of their two great concrete masts they sit in cradles. A central finger of the mast shoots up between them; it carries the top of the lantern which sits above the cable web and then continues irrepressibly a little further, no doubt to establish the important identity of the masts. The outside member of the cradle on each side is a fin of concrete, canting out at a slight angle. Again, these fins are undoubtedly higher than absolutely necessary, yet their task deserves some celebration. They restrain the main cables from slipping off the shoulders of the mast in response to the side pull of the roof cables. And they look as if they are doing just this.

They also look remarkably like the symbolic *chigi*, or projecting rafters, which form V-signs above the gable ends of Shinto shrine buildings. The end view of the main gymnasium is a striking visual reflection of the gable end of the main sanctuary at Ise, a definitive book on which Tange was writing at the time he designed the gymnasium.* Then the plan of the main building, the circle with the two jib-sails—or the double snail shape, or the loosely gripping hands shape—reflects a symbol in the Tange family crest. There are other allusions to traditional shapes, and the more a Westerner will find the more Kenzo Tange is likely to repudiate them all, because none of his shapings is deliberately Japanese. The traditions which Tange has studied so thoroughly just constitute one of the moulds in which his ideas are formed.

How much higher than this can modern architecture aspire? For what else had the twentieth century been searching during sixty-four years? A functional stance, a consistent order, variety within unity, a compelling structure, a sculptural form, a transcendental space, universal principles but a regional flavour, all achieved simultaneously and with a spartan simplicity.

In a new edition of *Space, Time and Architecture*, Sigfried Giedion examines another exciting sculptural building of the 1960's in a new chapter called 'Joern Utzon and the Third Generation.' Giedion discusses the disturbing lack of relation between the inner theatres and the outer sails of the Sydney Opera House. They give rise, he writes, to a question of conscience which we must again answer. 'Are we prepared to go beyond the purely functional and tangible as earlier periods did in order to enhance the force of expression?' He explains that the sails, the ex-shells, are superfluous, non-functional, if one means by functional a direct coherence between cause and effect. Can Giedion approve such non-functioning superfluity? Yes. Not only approve it; he blesses it, 'After half a century of development,' he writes, 'contemporary architecture demands something more than [the functional]. The autonomous right of expression must again assert itself in building. . . .' Giedion warns that the independence of expression from function is only for master hands as yet and not for minor talents, but even with this proviso his statement seems to take us round full circle back to Chapter Two and the Late Baroque.

Do we have to capitulate yet? Do we have to admit the defeat of the revolution in order to explain a beautiful building, as the Opera House will be? There are other and better explanations for Utzon's apparent lapse of conscience; but that is another story. Tange's gymnasiums seem to me to be convincing proof that it is early yet to capitulate.

No doubt these sister buildings are not perfect. If there is a significant flaw in the functional logic it is in the height of the mast of the smaller, snail-like, sister. If there are no real structural flaws there may at least be some surface difficulties in the concrete cantilevers. If there is an aesthetic hitch it may occur in the roof of the pools building, at the centre where the side saddles pull a little too abruptly at the bottom of the lantern. Imperfect perhaps, yet in sixty-five years how very few buildings have come as close to the goal sought by at least half the modern movement: to be transcendental and soberly convincing at the same time.

* *Ise: Prototype of Japanese Architecture*, MIT Press, 1965