INDOOR STADIUM COVERED BY DOUBLE-LAYERED PNEUMATIC STRUCTURE

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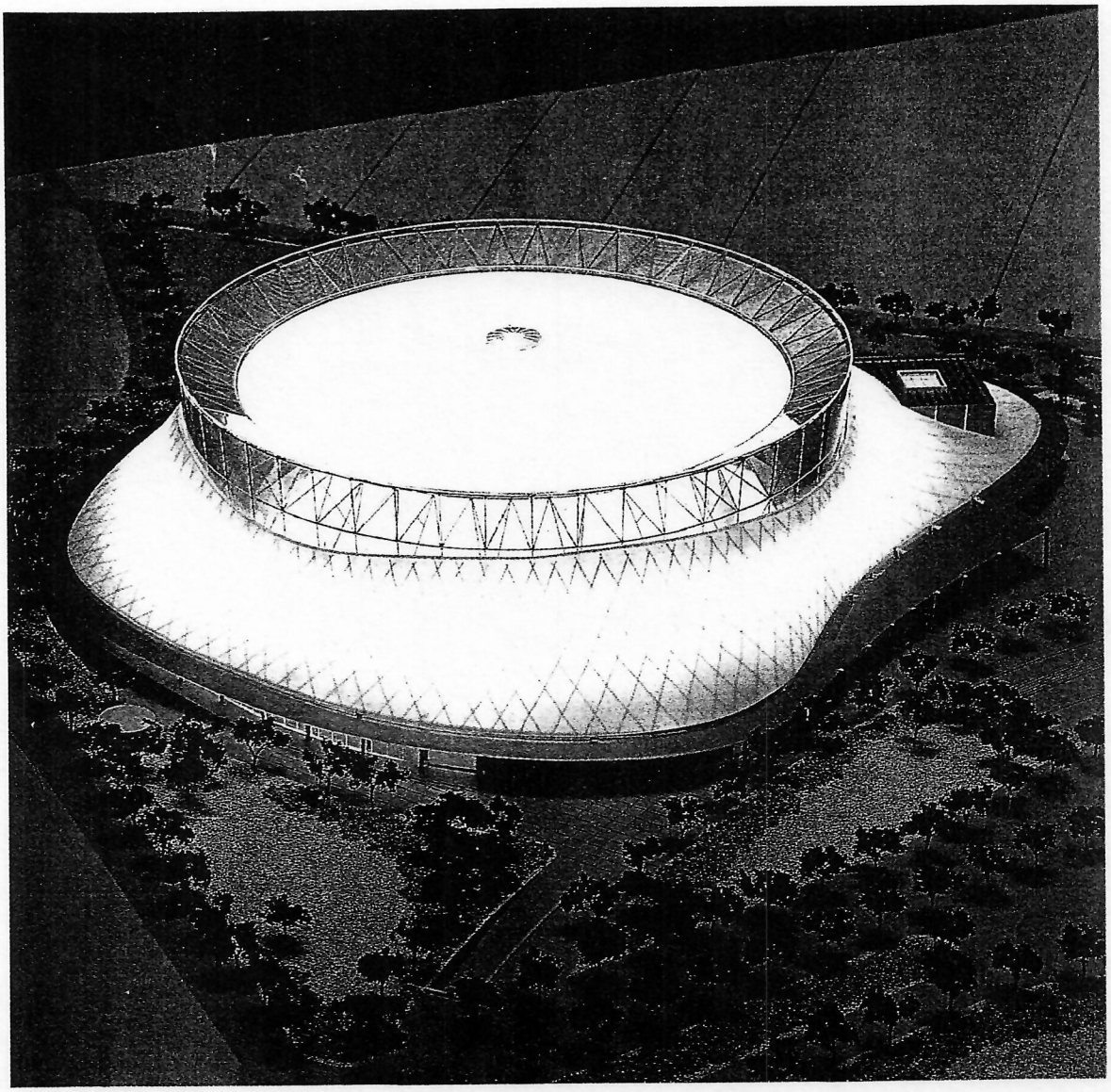
ABSTRACT

Design of an Indoor Stadium covered by double-layered pneumatic structure is currently being developed. It will be built in Kumamoto, Japan, and the construction is scheduled to start in coming July. Hybrid double-layered pneumatic structure proves to be extremely effective as a structure, but also as an architecture that houses favorable interior environment.



Aerial view

1.PROGRAM

This Indoor Stadium is an integral part of Kumamoto Prefectural Sports Complex located in the suburbs of Kumamoto city, on the island of Kyushu.

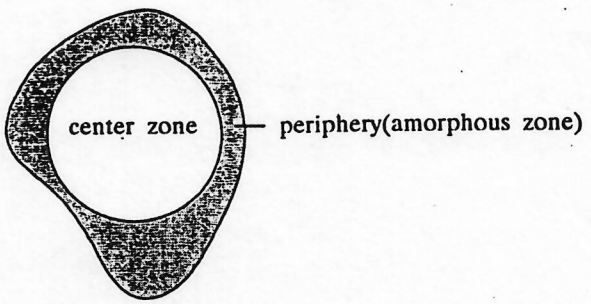
The facility includes a swimming pool, and is intended to support activities for citizens of all ages. The building will be dedicated in the summer of 1997, corresponding in time with the World Handball Tournament. It will have a seating capacity of 10,000 people, including temporary seatings.

2.DESIGN CONCEPT

Suppose there was a cloud that provided shelter for athletes, protecting them from strong daylight as well as from wind and rain--such was the notion behind the design of Kumamoto Indoor Sports Stadium. Thus, we gave the name " Buoyant Cloud Dome."

3.FORMAL ORGANIZATION

Central part accommodating the arena is of rigid circular geometry measuring 130 meters in diameter. The periphery, on the contrary, is amorphous in shape, and its form being determined according to spatial demands called for by various athletic functions (Fig. 1).



The principal structural components of the arena are: " Buoyant Cloud," hence the double-layered pneumatic membrane that has a central aperture, encircling ring truss, and eight sets of three-column-clusters that directly support the ring truss (Fig. 2). Lateral and upper sides of the ring truss are covered by special glazing called " Honeycomb Glass," a double-layered glass in between which aluminum honeycomb is sandwiched.

Structure of the amorphous periphery is of steel lattice shell that is covered by Teflon membrane.

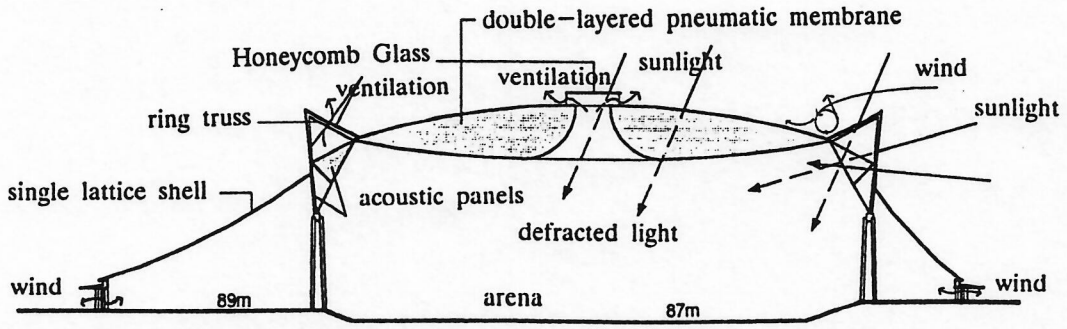


Fig. 2

4. "BUOYANT CLOUD" AND "HONEYCOMB GLASS"

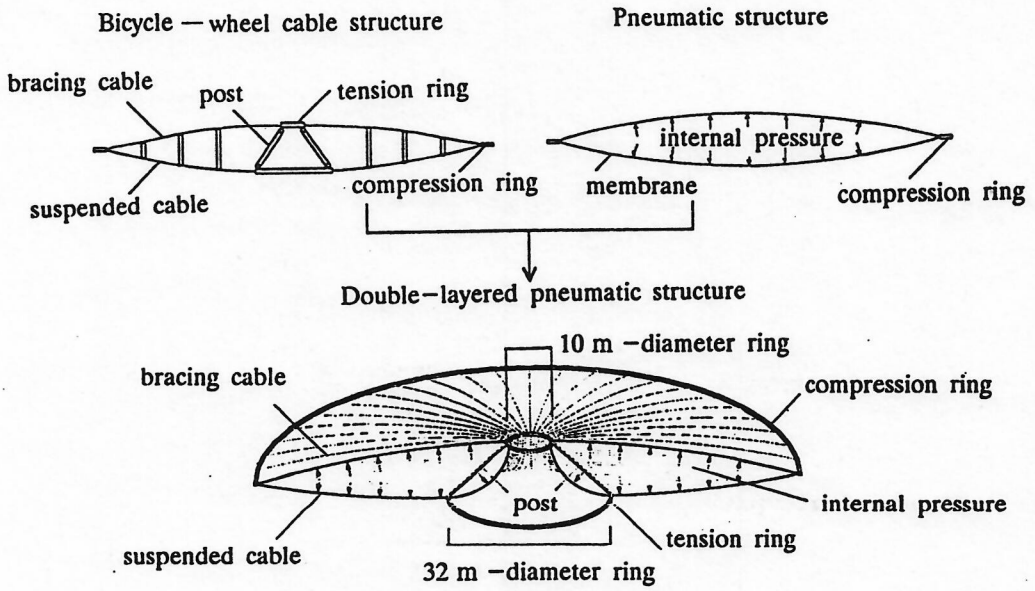
Two most important factors in the design of this Indoor Stadium are "Buoyant Cloud," and "Honeycomb Glass." The property and performance of these elements are key determinants that give unique feature to the building.

4.1 "Buoyant Cloud"

4.1.1 Structure

The Structure of "Buoyant Cloud's" double-layered pneumatic membrane is hybrid in composition, and consists of bicycle-wheel skeleton and Teflon membrane that covers the skeleton on either side. Overall diameter of "Buoyant Cloud" measures 107 meters, with a 10 meter aperture in the center. The depth measures a maximum of 12 meters near the center, while around the perimeter is tapered to 1 meter.

Hybrid double-layered pneumatic structure combines positive aspects of both the bicycle-wheel cable structure and the pneumatic structure. Its lightness and structural stability make it an extremely efficient system of structure (Fig. 3).



The bicycle-wheel cable skeleton consists of 48 equal segments. Each cable is of rust-proof steel wire cable, approximately 40 mm in diameter. Tension of the cable is introduced only after the skeleton is wrapped by Teflon membrane and internal pressure being applied within the double membrane. The applied pressure, on the average, is a mere 30 mmAq; and at most 60 mmAq in time of strong wind.

Center of the bicycle-wheel cable skeleton is held together by tension rings of different diameters on both the upper and lower sides. The two tension rings are of wide-flange steel beam with 350 mm depth, and have diameters of 10 meters and 32 meters respectively. The two rings are propped up by steel pipe posts of approximately 250 mm in diameter (Fig. 3).

Considering that this pneumatic structure is airtight, foreseeable air leakage is minimal. The total air volume necessary to sustain the structure is one hundredth that of conventional pressured air dome. Even if the air supply is to be suspended, the hybrid nature of this pneumatic structure would maintain the interior environment unaffected.

The pressure applying mechanism is located under each of the eight column–clusters, and air is supplied through void shaft in the center of the column–cluster. In summers the double–layered Teflon membrane acts as effective insulation against heat. The air supply, in turn, draws in cool air near the ground surface via floor of the grandstand; therefore, securing ventilation, and reducing sensible heat at the same time.

4.1.2 Ventilation

Ventilation openings are provided for around the central skylight as well as along the upper portion of the ring–truss–skylight. Exhaust air flow initiated by an automatically controlled heat–exhaust valve at the apex of the double–layered pneumatic membrane induces air circulation within the stadium, achieving efficient ventilation. Peripheral window openings also contribute to the fresh air flow.

4.1.3 Natural Lighting

In addition to diffused natural light through the double–layered pneumatic membrane, defracted light from the central skylight as well as from the skylight along the ring truss result in luminance equivalent to nearly one tenth that of illumination from unobstructed sky.

Interior view of the Dome

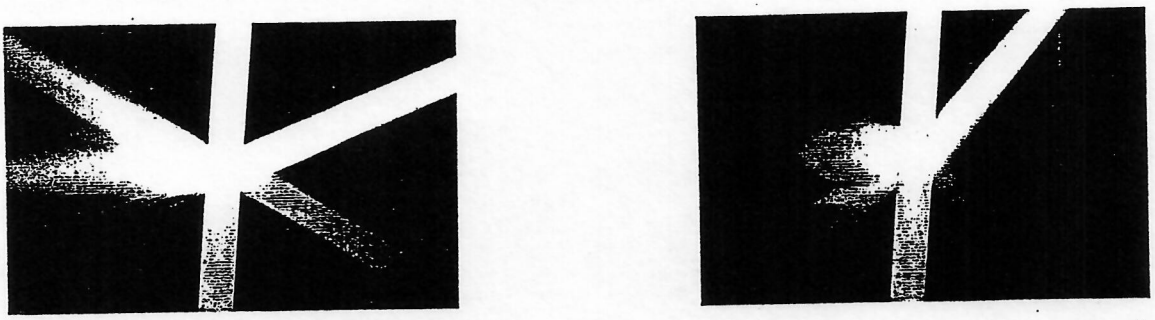
4.1.4 Acoustics

The lower half of the pneumatic structure, in other words the ceiling surface of the stadium defracts sound originated from the arena. It is due to the shape of the ceiling in section which, in turn, has been the result of creating an aperture in the center, effectively improving the acoustic environment of the arena.

The lower segment of the ring truss is finished on both sides by applying acoustic material. Moreover, oblique structural members of the ring truss allow butterfly-wing shaped acoustic panels to be secured along the circumference, so as to accomplish desirable clarity and reverberation in terms of interior acoustic environment.

4.2 " Honeycomb Glass"

" Honeycomb Glass" is equipped with transparent quality of glass while, at the same time, has the ability to screen glare from the sun. My personal involvement with the development of the product has been successful, and it has already been applied to many large scale buildings with most favorable results. Figure 4 shows diagrams explaning some characteristics of the product. In our design of the Indoor Stadium, this " Honeycomb Glass" is used along the lateral surface of the ring truss, on top of the truss on the peripheral roof surface, and the central skylight.



angle of incidence 25 °　　angle of incidence 50 °

Experiment showing natural light defraction

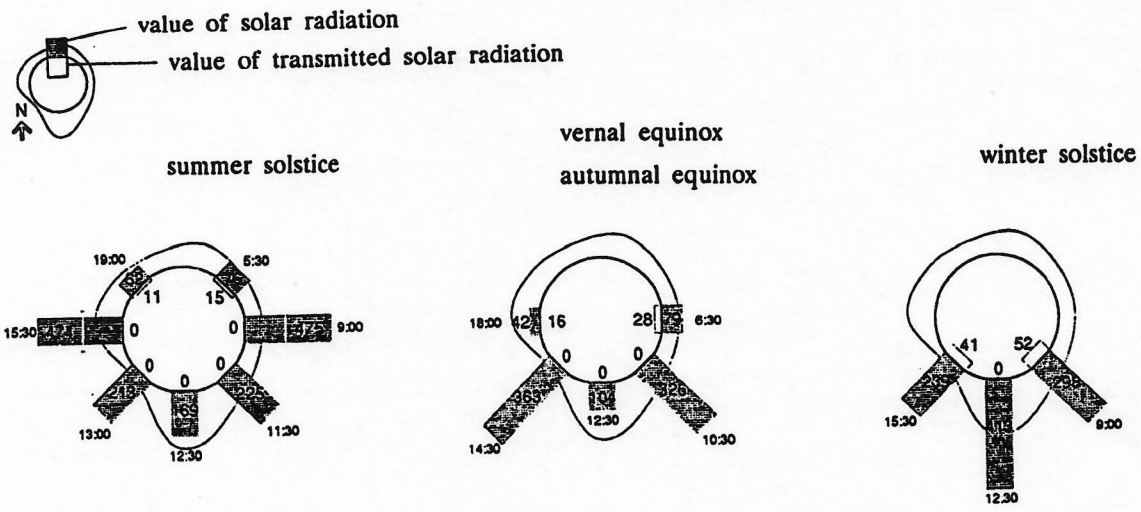


Fig. 4　Value of solar radiation transmitted through " Honeycomb Glass" along the ring truss

CONCLUSIVE REMARKS

In summary, the structural composition of our Indoor Stadium is tripartite, consistiting of " Buoyant Cloud," the ring truss with eight column-clusters that support the " Buoyant Cloud," and the surrounding amorphous Teflon membrane. Following are notable characteristics of this unique structure:

· It is extremely light-weight (approximately 15 kg / m^2), and most likely, is the world's largest double-layered pneumatic structure.

· Providing a circular opening in the center of the double-pneumatic membrane results in advantages listed below:

1.Increase in stability against exterior forces.

2.Mechanical equipments weighing several tens of tons could be hung from the central tension ring.

3.Decrease in total air volume of the double-pneumatic membrane reduces supply of air necessary for refill against leakage.

4.Compared to single-layered pneumatic structure, the ceiling form remains hardly undisturbed even in case of air leakage, so as to guarantee structural safety.

5.Creation of the central aperture improves interior environment in terms of natural lighting, ventilation, acoustics, and smoke elimination.

· Double-layered pneumatic structure allows complete freedom in opening up the periphery of the structure to its exterior.

· Double membrane prevents condensation, while ensuring insulation.

· Sunlight passing through three essential structural components produces three different qualities of light--diffused light through double-layered pneumatic membrane, defracted light through " Honeycomb Glass" of the ring truss, and filtered light through the amorphous single Teflon membrane--that illuminate the interior with sufficent natural light.

· Three essential structural components that are independent of each other allow for simultaneous fabrication of each component during construction; and thus reduces construction schedule in comparison to the time required for a structure of similar scale built by conventional method.