Fazlur R. Khan

Fazlur Rahman Khan is a thoughtful innovator whose buildings have won great aclaim. He is undoubtly one of the world's leading structural designers. *Born in Dacca, Bangladesh, Fazlur Khan completed his undergraduate work at the Bengal Engineering College and worked as an assistant engineer. In 1952, as a Fulbright scholar, he enrolled at the University of Illinois, Urbana, where he received his doctorate in structural engineering.*

He joined Skidmore, Owings and Merrill (SOM) for a few years and then returned to Pakistan in 1957. He worked for the Karachi Development Authority as an executive engineer but spent much of his time in administrative tasks. He returned to rejoin SOM in 1960 as an assistant engineer.

Khan's first job was a 38-storey office building in Chicago. He soon earned a reputation as an innovator in the field of structural engineering of high-rise buildings. He became known for Tubular steel design in 1963; a system widely used for many of the world's tallest buildings. His advances in design are contained in the diagonally braced John Hancock Building in Chicago; Shell Plaza in Houston, the world's highest all concrete building; and the Sears Tower in Chicago, the tallest building in the world.

He has written countless technical papers and has lectured all over the globe. He has been an adjunct professor of architecture at the Illinois Institute of Technology for many years. At the age of 52, a partner in SOM, he combines technical genius with a sensitivity for people. Some of his work, in recent years, has been in the Middle East, with the University building and the much publicised Haj Airport Terminal in Jeddah. MIMAR's Hasan-Uddin Khan profiles Fazlur Khan, in relation to the Terminal's structure, where he played a major role in the tent roof's design.

MIMAR: As an expert in tall structures, you appear to be breaking new ground with the lightweight roof canopy of the Haj terminal buildings.

Khan: I have never taken the initiative to become an expert on anything — as problems arose, I simply solved them, and in the process have been fortunate in devising and developing new solutions. I look at each possibility individually in its own cultural context. I strive for structural simplicity. It is in this spirit that I have worked on many projects — so I have no preconceived solutions. The technical man mustn't be lost in his own technology. It was with this philosophy that we approached the Haj terminal.

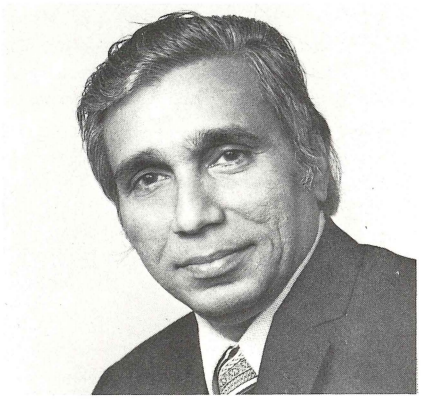
Although many people know me as a designer of tall structures, I have been fortunate enough to design many different kinds of projects — tall buildings, long-span structures, stadiums, theatres and universities.

Many architects think that they are the creators of buildings and that engineers are technicians. This must stop. The engineer has to also be an architect and the architect an engineer — so that, in consultation, they can produce a creative building. I have been lucky in SOM — where the roles of the two professions are not totally rigidly separated — to be able to involve myself in conceptual design. I think that the best structural solutions emerge from a conceptual approach to a problem. The idea of the terminal, for example, began to dictate its structure.

MIMAR: The Haj terminal, with its soaring tent-roofs, creates a strong visual image. Perhaps you can tell us something about how you thought about this particular structure.

Khan: The Haj to Mecca, the spiritual centre of Islam is, of course, very important to Muslims. In the Haj, the people spend most of their time literally under the sun — as the activities are in that environment. Therefore one of the first decisions was to not make a huge totally air-conditioned environment.

We felt that from a local and cultural viewpoint, the main terminal space should be an open, shaded space. What were the possibilities, then? We could create roof structures in concrete, or some such material. We could develop a series of umbrellas that could simply be scattered all over the large site. We tried these 20 metre square umbrellas — although larger concrete shells would be appropriate for such a large area it would be too expensive to build them. While we were studying these alternatives, we kept in mind that we did not want an environment that required artificial lighting during daytime or artificial air-conditioning at any time. We were hoping to create a free open shaded but naturally-lit environment.



"I strive for structural simplicity ... the best solutions emerge from a conceptual approach to a problem."

MIMAR: Did you ever think in terms of temporary structures — tents that could be taken down after the Haj?

Khan: We did consider that, but only briefly. We considered convertable structure, one that would dismantle, but it would need repair as wear and tear on it was inevitable. And just think of the size of it: 450,000 square metres of covered space! What an operation that would be! So we decided on a permanent structure that you do not have to worry about for fifty years. I also personally feel that in a country that has a tremendous shortage of highly-skilled labour and depends on foreign contractors to build things, I would not produce a high technology environment that has to be handled with high technology on a day to day basis.

MIMAR: So you settled on a permanent high-tech tent. In a way isn't that a contradiction in terms — a high-tech structure to produce an essentially low-tech solution?

Khan: In a way that sort of paradox is the key to our solution. We took a high-technology material — a translucent material developed to our specifications by Owens-Corning — and produced the thin fibre character of the roof. Not the form of the roof but the character of it.

The solution became large-scale vernacular: the requirements were so big that the buildings were no longer buildings but a place. A place in which there are avenues, shops, places for prayer, eating and even cooking, and all kinds of other activities. Temporary though the activities may be, they are also permanent features in the religion of Islam. I think that our "permanent tent" symbolically answers these seeming contradictions.

The terminal creates the spirit of the act; it gives you a feeling of tranquility and a sense of transition into the important place — which is Mecca.

MIMAR: Do you think you have succeeded in reflecting what is Saudi Architecture?

Khan: I believe that the powerful roof form is evocative of Saudi Arabia. Perhaps if you look at more traditional Saudi architecture would you equate it with *mashrabiya* (wood screens), mud-brick houses or nomadic tents? Perhaps a little of each, but the tent is the key. This tent does not copy tents of the past — it is a form for the future and here it caters for today's needs — air travel. The camel has been replaced by the car and the aeroplane.

In the same way new forms, reminders of the past but free from it, suggest to me the contemporary Saudi outlook. Yes, in that way you could call the terminal a very Saudi place.

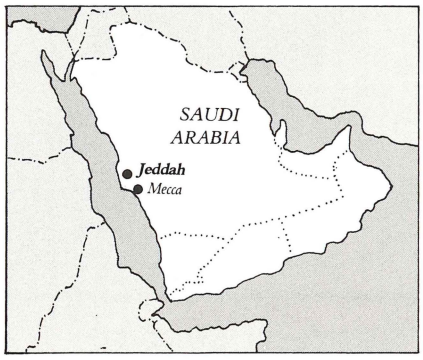
Haj Terminal, Jeddah

Tents for the future

The New Jeddah King Abdulaziz International Airport Haj terminal is already well known. It has been published on numerous occasions since its opening in May 1981, but work on it continued and completion is expected in April 1982.

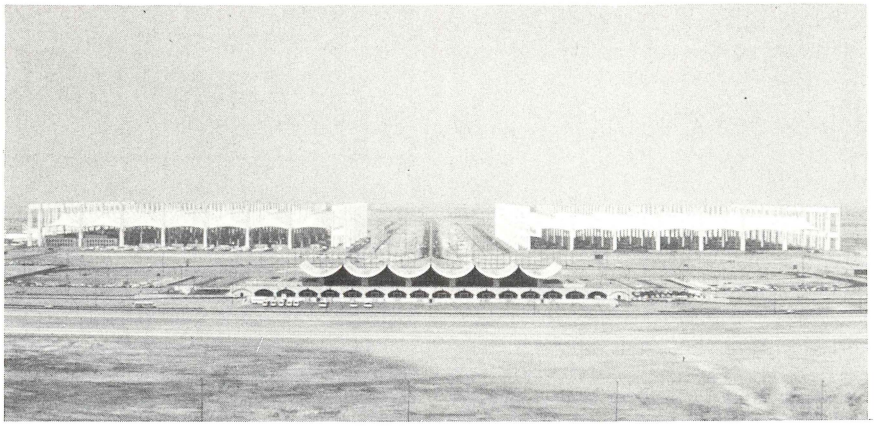
This project is the amazing culmination of the expertise and coordination between a wide range of companies and this alone makes it one of architecture's recent triumph. It is also one of the world's largest contracts, costing a total of around (US) $5 Billion although the Haj terminal itself cost $80 million.

MIMAR presents the saga — it can indeed be called a saga — the contemporary tents designed by Skidmore, Owings and Merrill (SOM) for the airport: their technological and design features which may indeed create a whole new attitude to the development of tent structures.



Project Data

King Abdulaziz International Airport, Haj Terminal, Jeddah, Saudi Arabia
Completion: April 1982.
Site Area: 35 square miles.
Building Area: (ESF): 105 acres.
Cost: US$80 million ($18 per square foot).
Owner: Ministry of Defence and Aviation, Brigadier General Said Y Amin, Director.
Architects and Engineers: Skidmore, Owings and Merrill — New York and Chicago, U.S.A.: Gordon Wildermuth, Roy O. Allen, Raul De Armas, Gordon Bunshaft, Perambir Gujral, Fazlur R. Khan and John Winkler, Partners-in-Charge.
Construction Manager: Saudi Arabian Parsons Ltd/Daniel International Ltd — a joint venture company.
General Contractor: Hochtief Ag, Essen, West Germany.
Fabric Roof System Contractor: Owens-Corning Saudi Co. — a joint venture between Owens-Corning and Olayan Saudi Holdings Co. Ltd Fabric Manufacturers and Roof Panel Fabricators: Owens-Corning Fibreglass Corp., U.S.A. in association with URS Corp., Geiger-Berger Associates, Engineering Consultants.



Above: King Abdulaziz International Airport showing terminal two in front with the Haj Tent structure terminals in the background.
Right: The world's largest covered space echos traditional Arab tents but creates a new high technology for them.
Photographs: Jay Langlois — Owens-Corning Fibreglass.

The Haj terminal, located some 40 miles from Jeddah, occupies 35 square miles (100 square kilometres) of desert, north of the city — an area larger than the combined acrage of the international airports of New York, Chicago and Paris.

Muslims from all over the world use this facility as the entry point for their yearly pilgrimage to Mecca. This year some 600,000 pilgrims are expected (i.e. around 30,000 a day) but the airport has been designed to cater for the 900,000 people expected by 1985. The Saudi Government began planning for this in the early 1960's and construction started in 1974 with Skidmore, Owings and Merrill as architects and engineers.

The white tent clusters of the Haj terminal canopies is the world's largest fabric structure enclosing the world's largest covered space. The covered area is actually two separate identical structures separated by a central landscaped strip. The airport can handle 5000 passengers an hour. The Haj aircraft land at one of 20 positions and passengers disembark to a second-floor

Article by the editors based on materials courtesy of Skidmore, Owings and Merrill.

level air-conditioned building to go through immigration formalities. This process takes about sixty to eighty minutes. Baggage collection and customs is at ground floor level, after which the Haji (pilgrim to the Haj) may have to wait for up to 30 hours before being able to leave for the final destination of Mecca.

The enormous problem of the numbers of people to be catered for and the time delays in waiting channelled the designers into creating basically two zones — the first consisting of a number of air-conditioned buildings and the second, the vast waiting and support areas (restaurants, shops, mosque, toilets, etc.) to shelter the Hajis. This area is used for short periods every year; its main function is to provide a sort of nomadic hospitality for the traveller in terms of shade, water and food — a tradition in desert travel.

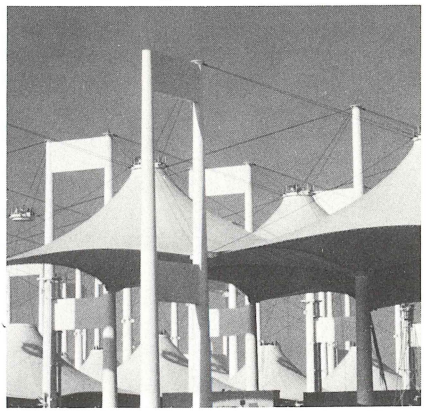
The Shaded Tent

Each tent's fabric roof is 150 x 150 feet at its bottom rising conically to a 16-foot diameter contre support ring at the top. The bottom of each unit is 66 feet from the terminal floor with the fabric rising to 110 feet. A network of 32 radial cables strengthens and shapes the fabric of each unit.

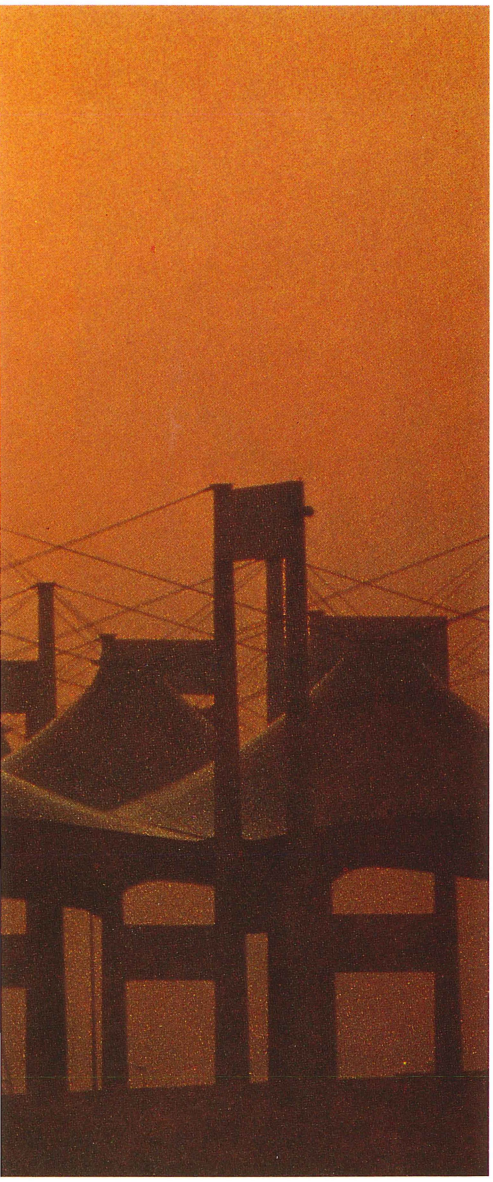
The unit is connected to form a module seven units long by three wide. Each structure consists of five modules and measures 1050 x 2250 feet. The two identical structures cover 105 acres.

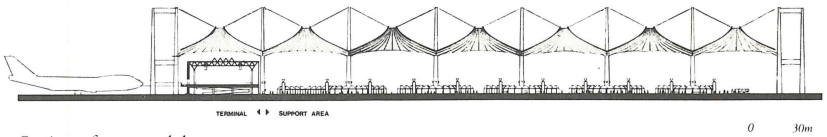
The architects and engineers, Skidmore, Owings and Merrill, explored designs for the fabric system and with the aid of a computer determined that the optimum shape for the individual roof units would be a double-curved conical form. In 1979 a prototype was completed and a $2.5 million testing programme proved that the initial design required only minor adjustments.

In creating the design, the architects made use of a Teflon-coated Fibreglass fabric manufactured by Owens-Corning. This

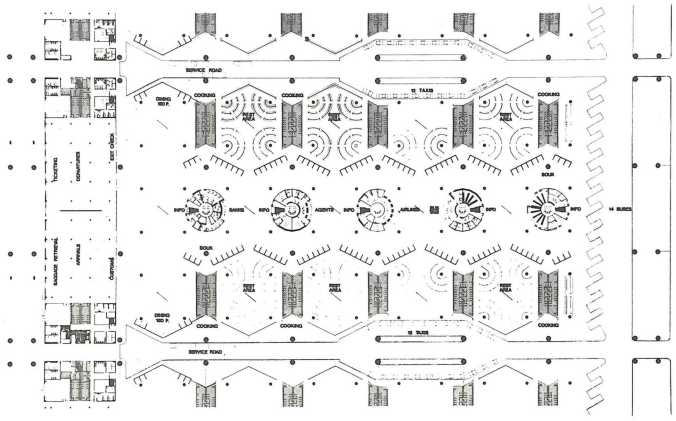


white fabric reflects 75% of solar radiation, and as the structure allows for air circulation, temperatures are kept in the mid 80°F (26.5°C) range, where the outside temperatures are often 130°F (54.2°C). The fabric is also translucent and transmits some 7% of sunlight in the structure eliminating the

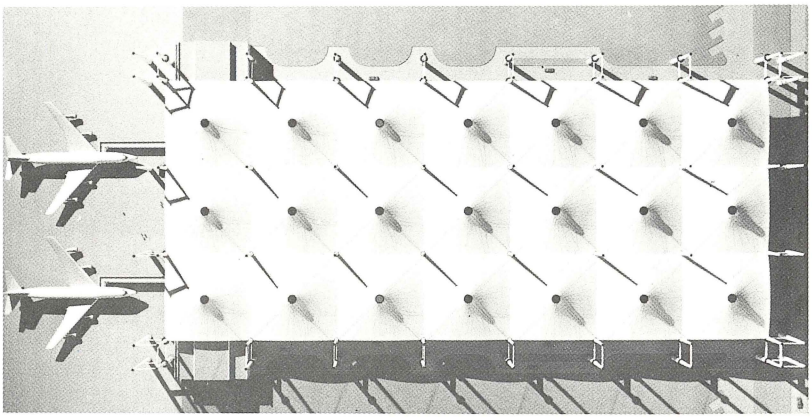




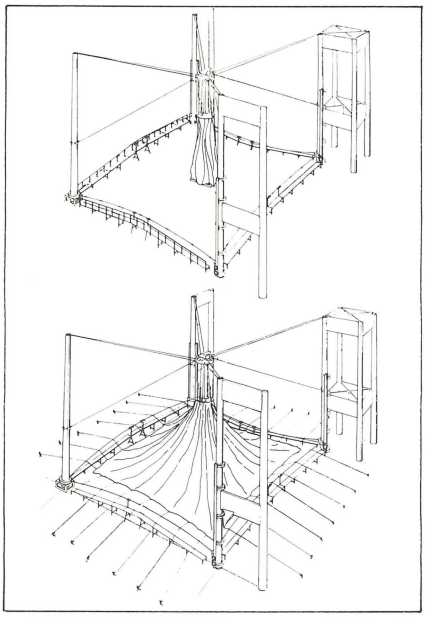
Section of one module.

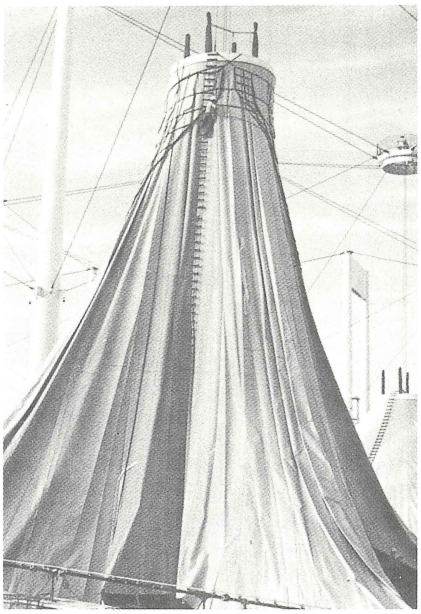


Ground floor plan of one module.



Roof plan of one structure, three by seven modules.





Top left: The structure dramatically silhouetted at sunset. Photograph: Jay Langlois — Owens-Corning Fiberglass.
Above: Plans and sections. Photograph for roof plan: Louis Checkman.
Far left: The general view of the structure by day. Photograph: Horst Berger.
Centre: Drawing showing the method of erecting the tent covering.
Left: The tent is hoised from the ground by crane. The cables are gradually tightened to bring the tent to the centre ring suspended some 110 feet above ground level. The process to erect one unit takes about 45 days.

The aeroplanes taxi upto the terminal where passengers disembark onto the second floor. Photograph: Jay Langlois — Owens-Corning Fiberglass.

need for artificial daytime lighting.

The fabric is very strong — reputed to be finer than silk but pound for pound stronger than steel. Its tensile strength is 800 pounds per lineal inch (a design prestress load of 66 psi). The roof has a life expectancy of 30 years.

5.5 million square feet of fabric was manufactured in the U.S.A. It can withstand temperatures to 1500°F (700°C) and will not alter colour due to the sun's ultraviolet rays.

The tent structure cost a total of US$80 million or $18 per square foot.

The Organisation

This mind-boggling project in terms of bringing people and components from all parts of the world together is a triumph for contemporary organisation. The bulk of the construction labour force came from the Philippines with their own foremen (who spoke English). The labourers had to be trained on site to work with tent technology. The field supervisors were mainly British and Americans. Components for the project were manufactured in the U.S.A., Japan and elsewhere. The task of running the project was done by a joint Saudi-American venture.

Construction of the tents and the installation of the fabric roof involved a very sophisticated and unique construction method. Unlike most tents, the roof does not touch the ground — indeed its lowest edge is some six storeys above the ground. The many elements of the structure, the pylons, the ring sections and the detailed fabric joints, etc., required a concentrated management effort to coordinate the manpower, equipment and materials.

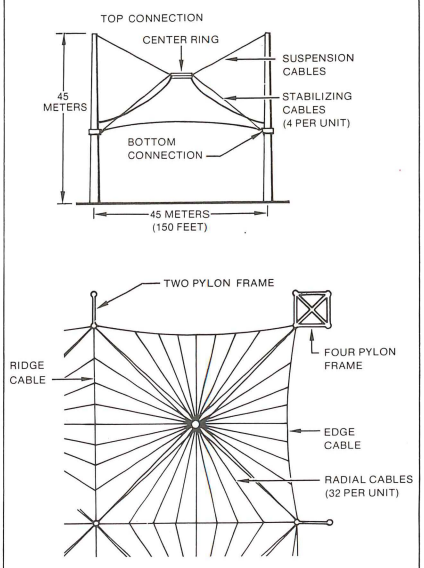
This project has indeed created a new symbol for the Middle-East using a traditional form (rather in the way the Kuwait water towers have also been done). This hi-tech tent is here to stay.

Pylons

A key structural element of the roof is the group of steel pylons. The 440 steel pylons (using 30,000 tons of steel in all) were fabricated at the shipyard city of Tsu, Japan.

Nippon Kokkan, the supplier produced the pylons from a cold-rolled process. The pylons are tapered from 8 feet in diameter at the base to 4 feet at the top. The rings, flanges, diaphrams and pylons were fabricated by welding. The steel elements were then cleaned, treated and coated with four layers of epoxy paint. Each pylon was then wrapped and placed on a special barge for ocean transport to Jeddah.

Each pylon weighing 68 tons was bolted onto a concrete pad — lowered into place by a 280-ton crane — the largest of its kind in the world.



The tent is suspended by cables from the 150 feet tall pylon frame made of steel sections bolted to concrete footings.

Left: The Hajis (pilgrims) wait in the vast non-airconditioned support area. Left, below: Buses take most Hajis from the airport to Mecca to perform Haj. Photographs: Jay Langlois — Owens-Corning Fiberglass.