

CASE STUDY: SIX TENSIONED MEMBRANE STRUCTURES IN JORDAN

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Abstract

Skyspan has recently completed the design, fabrication and erection of a series of six tensioned membrane structures in Jordan. The structures are at the Grand Hyatt Hotel, Amman (2No); Movenpick Dead Sea Resort (3No), and at the Intercontinental Hotel, Amman (1No). These structures all had their unique engineering design challenges, but overall the projects tell something of the work required to develop new markets, maintain efficiency and economy in tensioned membrane structures.

Introduction

Exchanging olive branches in the Holy land has recently lead to a boom in hotel and resort developments all along the previously militarised Jordan Valley. In Jordan's capital, Amman, along the Dead Sea coast, in historic Bethlehem and in Damascus, new developments are sprouting as the peace process continues its push to reverse the effect of 50 years of war and enmity.

Jordan is the place where romance and history combine in the florid tale of Lawrence and the Bedouin army, living in the traditional black tents and riding across immense distances upon camels in their efforts to push the Ottoman empire out of Transjordan. These images of the tent encampments figure strongly in the psyche of Jordanian people.

Thus it was not without irony that a Jordanian Developer should tender a series of tensile structure tents to a group of western nation companies. Three projects were in process simultaneously:

- The **Intercontinental Hotel**, comprising a refit to Amman's premier hotel
- The **Amman Grand Hyatt**, a new five star hotel and two tower blocks.
- **Movenpick Dead Sea Resort**, a sumptuous, vast resort on the shores of the Dead Sea.

The climate in Jordan is best defined as arid. Although there can be snow in the high plains in winter, it is predominantly a dry and hot, desert environment. Shade in this climate, is a necessity. US Architects, WATG designed these projects to include a series of tent structures around the edges of the buildings and in strategic entry zones. The detail design work was left largely to the "specialist" contractor. Thus the drawings required considerable interpretation to enable tenders to be properly submitted.

Ove Arup (UK) had put together a specification, which formed a good basis for performance, while the individual structures required quite a deal of work to bring the forms into harmony with the architecture while preserving their functionality and not breaking the budget.

After tender submission Skyspan was invited to visit for a meeting to finalise contracts. During this time we became aware that all structure schemes had to be filtered through an approval process involving the US and UK based architects, the local Architects, the local engineers and finally the Chairman, Mr Talhouni. Substantial work was done developing and refining each structure proposal in conjunction with the project manager. The finalisation of this process produced a presentation set of designs for re-costing, this forming the basis for a handshake as the deal was done and the real work began.

Modern tensile structures are totally new to Jordan; thus there was a knowledge gap to fill out so that the designers (architects and engineers) have a proper understanding of the constraints associated with the technology. Most construction in Jordan is concrete structure with stone cladding. This stone work can be quite fine and detailed, it being the product of several thousand years of the art of stone masonry in their culture.

Each building was largely designed and nearly complete before the impact of the tensile structure loads were considered or computed. Finishes were substantially in place well before the tensile designs were developed. Extensive opening up and stonework and rectification were required. In many connection positions, there was no accurate survey data of the as built structure, due to stone cladding cover over concrete beams or columns.

With all this uncertainty, we developed designs with an approximate fit approach so that we could accommodate variation in position of connections.

Fabric

As the projects involved all five star hotels or resorts, finishes were required to be first class. The natural selection for fabric was PTFE/Glass with its superior performance life and fire properties. Amman can be quite dusty and automobile fumes exacerbate this surface soiling. Rare rains would assist to remove dust and other materials from the surface.

Cables & Fittings

The proximity of a large body of salt water at the Dead Sea project necessitated stainless steel cables but we chose to use stainless cables and fittings exclusively on all projects, for their high aesthetic qualities, particularly with respect to end terminations and rigging screws.

This came at some cost to the job and cost over-runs were incurred as the engineering process developed.

The stainless cables were mostly run outside of the fabric, fixed with chain clamp plates linked to the cable using stainless stirrups. This presents the cable as object in a superior fashion to the use of cable in sleeve and forms a strong visual outline. Considering the quality of the project buildings, we selected this finish well.

Steelwork

The dry, arid landscape around Amman, at 800m elevation and not close to an ocean, allows for best performance from metals in the slow speed of corrosion effects. UV is quite high in this rather elevated location.

We selected hot dip galvanising for protection followed by a two-pack polyurethane coat system for the best presentation finish.

At the Dead Sea, the efficacy of the protection system was particularly important. This is an environment of extremely high salt corrosion, with the wind blown soil containing large a quantity of salts. The soil gathers on surfaces and become wetted with the irrigated landscape watering, thus becoming a formula for fast corrosion.

Where practicable we had steelwork produced in Jordan to reduce cartage, handling and surface damage. Most connections were made using chemical anchors fixing steel cleats to building elements. Local manufacture allowed for the cleats to be modified to suit the as built structure conditions.

Amman Grand Hyatt Structures Shop Canopies

A series of exclusive boutique shops form the Western Wall of the Hyatt building. In summer, the sun's heat can be enormous on this face. The canopy structures were required to ameliorate solar bombardment and to decorate the otherwise plain building facade.

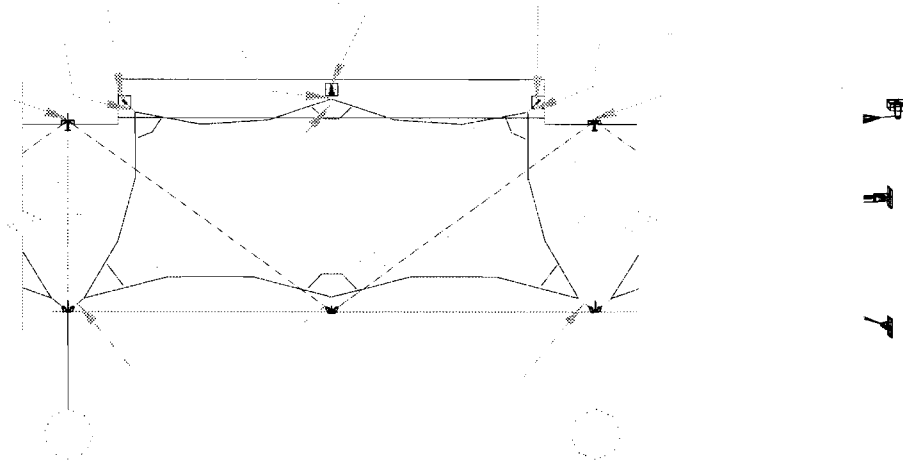


Fig 1. Plan – Typical Shop Front Canopy

We tried to be quite inventive with the series of, largely stayed cantilevered structures with extensive use of cables and minimal use of steel supports. The effect is one of structure standing unsupported, horizontally from the wall face.

Six structures form the array with all but one being identical. Small PTFE/Glass modules always produce more work and difficulty to obtain correct fit than large structures. It is natural that scale issues are worsened with small spans.

Fig 2: Shop Canopies Perspective

Porte Cochere

The architect's design had originally included substantial steel trussing supporting a fairly planar folded form which resembled a hooded entry to the hotel. In design we substituted these using three structures acting together to filter sun and rain.

The major requirement was for sun protection and to make a strong statement about the Hotel entry. Strong cable lines in the major structure contrasted with the lighter, highly curved hypar forms which created side wings to the Porte Cochere.

Existing major cantilevered beams behind stone cladding formed the major upper connection restraint while three new cantilevered columns were placed in clear regions in front of the drive. Clearance heights for buses set a low level while the soffit of the cantilevered beams formed the upper level of amplitude.

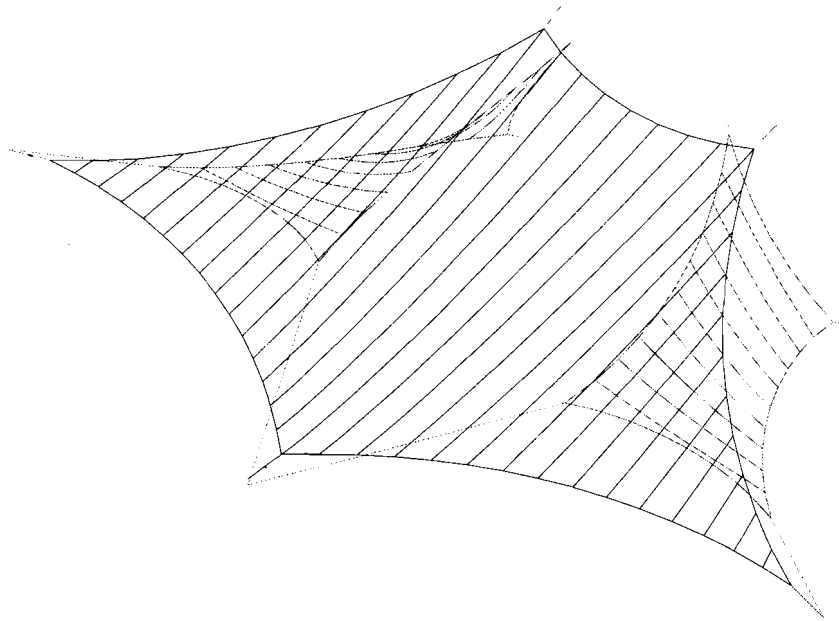


Fig 3. Porte Cochere Perspective

This created a fairly flat main structure which, when allowing for imposed (snow) loads, produced quite large reactions and cable forces. The edge cables would require at least 32mm diameter single cables, a size that was not readily available. Our solution was to pair 22mm diameter cables in these high load spans. The effect enhanced the outlining of the structure.

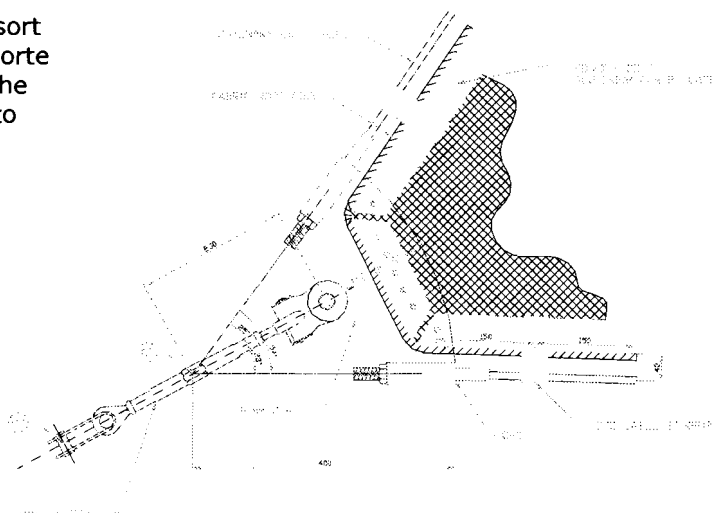
A major difficulty developed around the construction process, which required closing the main Hotel entry during the Pan Arab Games in Amman. The Hotel had an occupancy rate of some 99% during the games making it impossible to close the entry. It required re-scheduling of the erection sequence to other sites until the games and its associated frenzy and excitement was over.

Movenpick Dead Sea Resort Structures, Porte Cochere

This structure was substantially the same in principal as the Porte Cochere at the Hyatt in that it made a signature entry to the hotel. Again we outlined the structure with expressed cables and highly visible stressing hardware.

Similarly to the Hyatt, the major connections were able to be accommodated by the existing major transfer beams, columns and suspended floor slabs. Foundations and new columns were required only at the base of the two front cantilevered masts.

The curved face of the entrance to the resort rough stone finish. In the design of the Porte we sought to minimise the gap between the building, thus maximising the protection to guests, whilst ensuring that there was no between the elements. The curved wall surveyed both prior to design and prior to fabrication, and extensive was designed into the connection to the to address and deal with this problem.



has a Cochere fabric and the clash was confirmed flexibility building

Fig 4. Typical Membrane Plate Detail

Hydropool Roof

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The Hydropool is part of a "Wellness" complex that contains a gymnasium, thermal pools, mud baths, massage centres and of course the series of pools containing different mixes of Dead Sea water. The Hydropool is a highly decorative pool set in quiet surroundings with an overlooking view toward the mountains of Jerusalem and over the Dead Sea to Jerico. The outlook is unsurpassed.

This pool combined corrosive Dead Sea water and fresh spring water. It contains strong water jet zones, which produce a massage effect.

The design developed from the need to not intrude into the wonderful architecture. We sought to make a simple structure statement with minimal blocking of views to and from the existing building and its many fenestration's. An inverted cone, supported

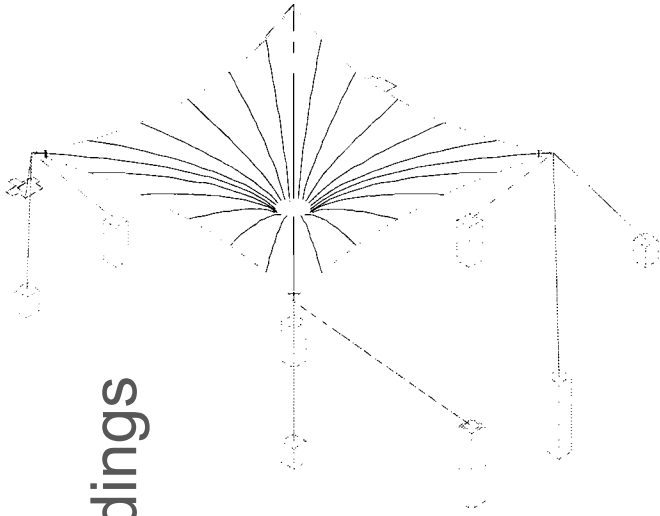


Fig 5. Hydropool Roof Perspective

on strongly inclined perimeter masts produced an elegant shade structure with its funnel annulus tied to the existing strong concrete centrepiece of the pool with three tie down cables.

Considering the corrosive nature of the pool water polished grade 316L stainless steel was selected for use for all the metal elements. This structure was fully manufactured in

Australia.
Wellness Entry

A small wave shaped canopy was placed to the entrance of the "Wellness" complex. The connection of the fabric onto the face of the building was compressed as much as possible to maximise the coverage of the small entrance area. The entrance to the centre is recessed and thus not readily visible. By flaring the outer corners of the canopy up and out the structure helps to direct and welcome the approaching guests to the entrance.

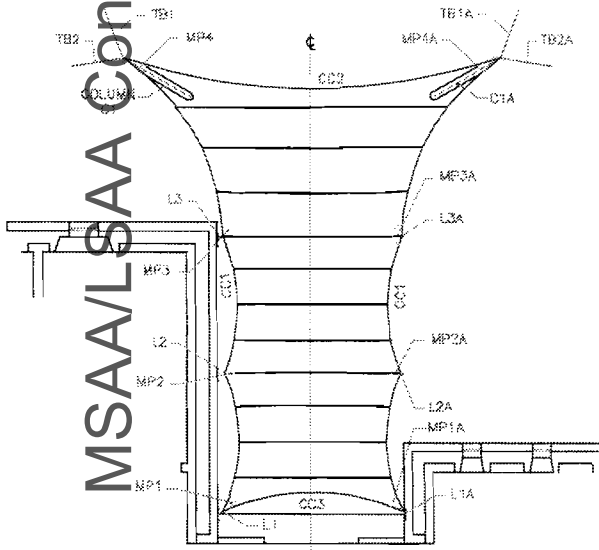


Fig 6. Wellness Centre Entry Canopy Roof

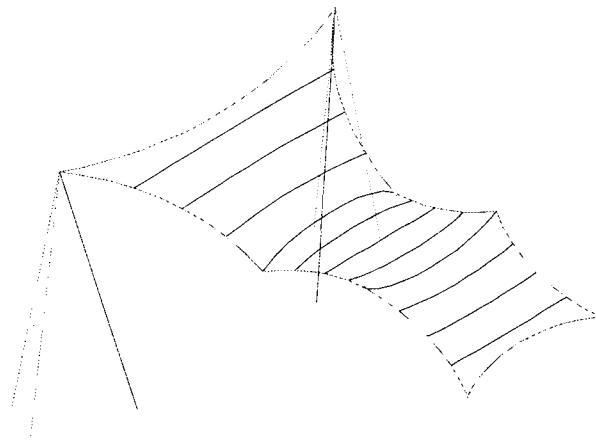


Fig 7. Wellness Centre Entry Canopy of Perspective

Intercontinental Hotel Courtyard

Amman's premier hotel is the Intercontinental Hotel. Two banquet halls face across a landscaped courtyard. Winter events were always jeopardised by the open link. Here was the site for a canopy to link the banquet facilities and access to the washrooms. Existing palm trees in the four corners truncated the available space and the structure also was not to intrude visually into the busy upper level terrace.

We chose a simple cone for its soaring ceiling height, using a cable supported central mast for its lack of clutter at ground level and simple magic, along with clamped edges to the perimeter walls to ease the transition to the existing walls.

For the erection of the structure crane access was not available and the hotel required access across the courtyard to be maintained. The erection sequence developed for the structure was to use a scaffold platform at some 3-4 metres above the ground level. On this the fabric and central mast could be placed, and fabric fixed to

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the perimeter arches. The mast was then raised and structure stressed using a pair of 5 tonne jacks either side of the flying mast. The central mast was carefully detailed to leave virtually no evidence of the erection elements after erection.

The conical shape of the structure suited the space ideally, providing the shelter required in a manner that enhances the courtyard space.

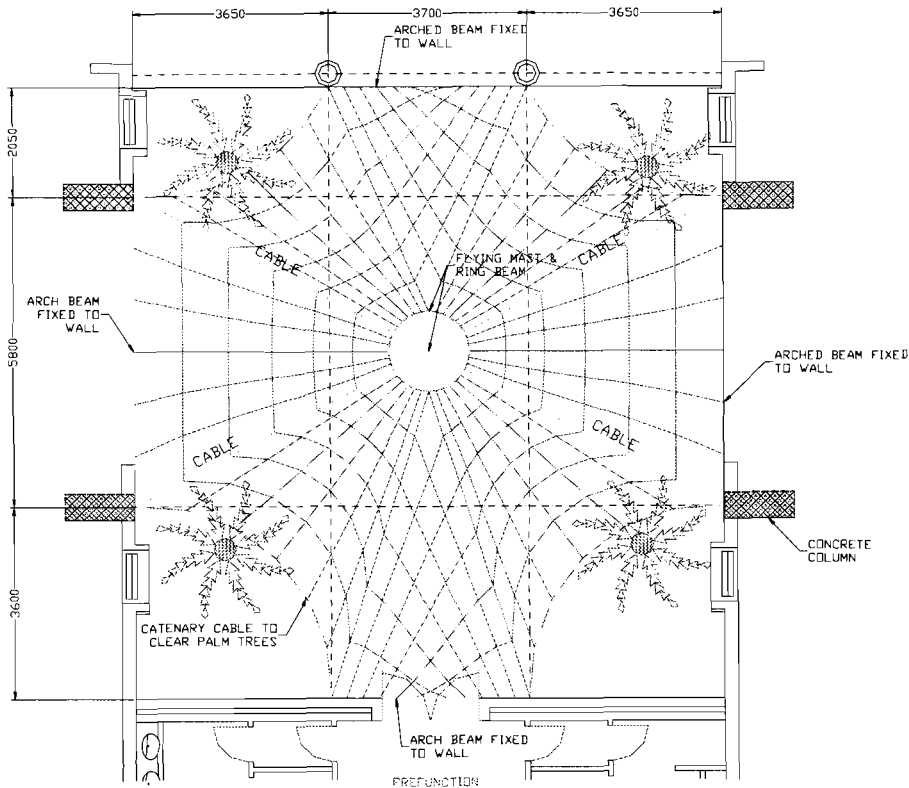


Fig 8. Intercontinental Courtyard Structure – Plan

Summary

Developing new markets in different cultural regions requires a refined patience and a capacity to embrace different lifestyles, values and attitudes. The Middle East region is a place where the person, as distinct from the company, is important. Developing a personal relationship based on mutual trust is primary. Often one has to go the extra mile for no monetary return. This is usually the case with the development of new contacts.

In this case, Skyspan's previous experience in the Negev solar project had, by proximity, given us some feeling for the area and the working culture. Our preparedness to press forward with ideas and suggestions at tender was undoubtedly a key to the subsequent contract award. Being prepared to assist is appreciated, and so it should be.

Success in all respects, with remote project works such as these, is based not only on a contented client but also on the efficiency of the team developing the structures. For them, planning and preparation is a greater process where everything possible must be imagined (and sent) to allow for a construction process with no hiccups.