Kazakhstan: Building the world's largest tent

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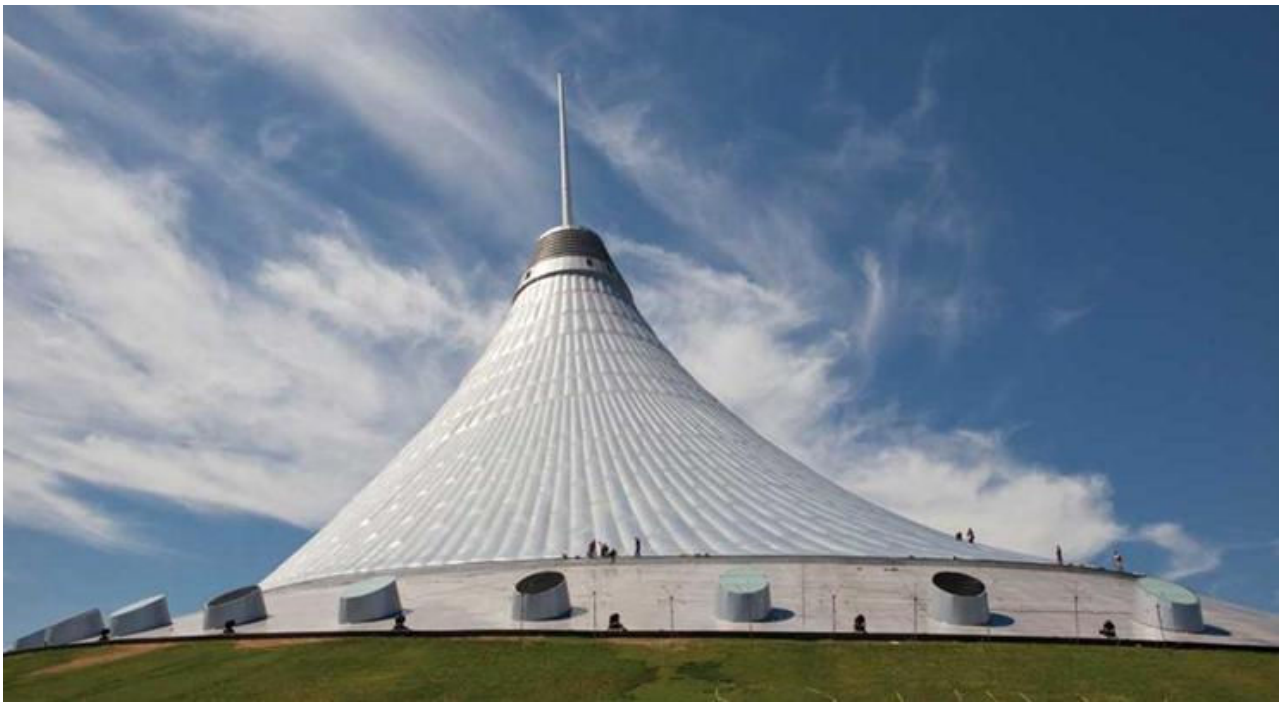


In the capital of Kazakhstan, Buro Happold, Foster + Partners and developer Sembol have built the world's largest tent. And their heroic attempts to heave that 90m mast upright are enough to make fair-weather campers weep

The world's largest tent opened just under two weeks ago to considerably more fanfare than your typical campfire singalong. Located in the remote city of Astana, the capital of Kazakhstan, the world's press and key eastern European dignitaries assembled to witness a spectacular show that included Italian tenor Andrea Bocelli, traditional horse riding displays and some very loud fireworks. It was quite an event to mark the opening of what is, after all, just a shopping centre and theme park.

It brings to mind our own Millennium Dome, another giant fabric clad structure that housed a theme park including a beach with real sand - although the Khan Shatyr, as the new building is called, manages to include real water too. Like the Dome, the 150m high Khan Shatyr is a spectacular architectural and engineering achievement. It even shares a structural engineer, Buro Happold, and a famous British architect, although this time it is Foster + Partners rather than Richard Rogers practice. So how was this amazing structure designed and built, and could it share the same fate as the Millennium Dome?

Unlike the Labour government, which commissioned the Dome then struggled with what to put in it, the Kazakhs knew exactly what their tent was for. Astana has one of the most extreme climates on Earth, with temperatures plunging to -40ÞC in the winter and up to a ferocious 40ÞC in the summer. So why not create a space where people could go shopping, socialise and have fun without the risk of freezing or scorching? And as Astana is in the middle of an enormous, grassy plain several thousand kilometres from the nearest beach and tropical forest, why not give the locals a chance to experience something they can only dream about?

Maintaining a constant temperature

With an 80ÞC temperature swing between winter and summer, keeping the building at a comfortable temperature was always going to be a challenge.

“You get small weather systems set up inside the building that you need to manage, particularly when conditions outside are so different,” says Neil Billett, the partner at Buro Happold responsible for the Khan Shatyr M&E strategy.

For example, in the winter the surface of the ETFE cladding is very cold. This means warm air that hits the cold surface immediately cools and drops down, creating a wind inside the building. This was one of the reasons why the team decided to restrict the height of the ETFE-clad part of the building. “If the ETFE element had been bigger you would have created a surface that was so long, and so cold it would cause the air to tumble and create a wind that would be very difficult to control,” he says. “By making it shorter, you can mitigate this.” Warm air is also directed against the surface of the ETFE to ameliorate the problem and stop ice forming on the surface.

There was also a risk of condensation caused by water evaporating from the high level sea-cum-swimming-pools at the top of the building when it met the cold surface. The answer was to enclose the pool areas inside a secondary ETFE clad space. The good news is the ETFE is a good insulator and helps harness solar gain. “In the winter you have got this huge volume warming up, it’s like the building is wearing a huge fur hat,” Billett says. He says on a cold, sunny day with temperatures of -35ÞC outside the tent is 12ÞC at the top of the tent. “It can be -30ÞC outside but boy it’s beautiful and sunny by the beach with bright blue skies under the ETFE”.

Obviously the building needs to be heated in the winter and cooled in the summer. This is done fairly conventionally by pulling air from outside, heating or cooling it and directing the conditioned air into the lower inhabited spaces, and out again at low level. Air can be directed out of the top of the tent if it gets really hot inside. Energy use is mitigated by being generous with internal temperature tolerances. For example the landscaped areas are maintained at 15ÞC in the winter and allowed to rise to 30ÞC in the summer.

Happily for the developer and contractor, Sembol, the design team and Nursultan Nazarbayev, the president of Kazakhstan, a giant tent was the perfect answer to their respective ambitions. For Sembol, which is just 10 years old, this was a chance to prove it could build something really challenging. Foster and Buro Happold had already been talking about large tents being the most efficient way of enclosing big spaces; they got the chance to test their theories on a building with a floor area of 100,000m2. And Nazarbayev got a landmark building that marks the end of a mall and includes a tower topped by a golden ball, a “pyramid of peace” and a presidential palace.

What’s more, the people of Kazakhstan, who are descended from tribes of yurt-dwelling nomad, now have a national monument that is drawn from the oldest traditions. The traditional yurt has a single central pole that supports a wooden frame and is clad in felt. This principle is followed at the Khan Shatyr: a cablenet is supported by a central mast and clad with ETFE because it allows light into the building.

But there some key differences. For a start, the Khan Shatyr leans, and is elliptical rather than round. “We talked with the president about a marker that could be clearly seen along this axis,” says Nigel Dancey, Foster’s senior partner in charge of the project. “The idea was that it was symmetrical when looking at it head on but leaning away from the palace when viewed from the side. We didn’t want it to be symmetrical so it marked the end of this very strong axis.”

On a purely practical level, the building’s size meant it was never going to replicate a simple tent. “People build far more complex buildings than this, but it’s the scale of it that makes it challenging,” says Mike Cook, a principal of Buro Happold. “It’s on a par with a suspension bridge. It’s simple once it’s built but difficult to get there.”

Putting up a single pole is fairly easy when erecting a small tent but not when the tent in question is 90m high (the mast extends 60m beyond the top of the building). The mast needs to be able to support 192 cables that can move independently of it in response to changing loads imposed by wind and snow. Erecting a 90m-high single pole would have been very difficult as it would have needed substantial temporary works to hold it in place while the cables were connected. Also it would have been difficult to determine when the mast was in its final position.

“We decided it would be better to provide a stable working platform and a definitive way of placing it accurately, so we decided to have a three-legged tripod where the only thing that moved was the head supporting the cables,” says Cook.

The scale of the task was also minimised by keeping the tent structure to 75% of the building height - it sits on top of an above-ground concrete ring that houses most of the retail and entertainment elements. This makes the tent element easier to build.

Who is Sembol?

In the space of 10 years Turkish company Sembol has come from nowhere to being a major force in Turkey, Russia, the UAE and Kazakhstan. It gained a foothold in Kazakhstan by building a 168-bedroom five-star hotel in just nine months. It has since built the Foster + Partners peace pyramid, a football stadium complete with retractable roof and a university.

Kazakhstan has huge mineral wealth, including oil and gas, but surprisingly the Khan Shatyr is actually a speculative development funded by Sembol and a Russian partner. Why didn’t they just build a cheap, straightforward box? “If you build something iconic you can charge more than the local market rates,” says Aytekin Gultekin, Sembol’s chairman. “But profit is not the first priority. Our company is only 10 years old and we have to prove our ability and capacities. We believe this project will take us to another level.”

The project is design and build. Sembol worked on the peace pyramid with Foster + Partners and Buro Happold so both firms were the natural choice for the Khan Shatyr. The UK firms did concept design with detail taken on by local firms.

One of the key challenges facing Sembol was that all materials had to be brought thousands of miles across the empty grassy steppe. Bringing in a 90m-high steel tripod weighing hundreds of tonnes was out of the question so it had to be welded together on site. Buro Happold envisaged the tripod being built in its final position but Selami Gurel, Sembol's leading engineer, had other ideas. His plan was to build the whole on the ground then pull it upright. This had the advantage of requiring minimal temporary works, fewer cranes and less risky working at height.

There was one other key advantage. Normally, construction work in Kazakhstan stops during the bitterly cold winter but not here. "Everyone thought this was impossible," says Aytekin Gultekin, Sembol's chairman. Welding the tripod together on the ground meant temporary covers could be erected to keep the worst of the weather off the workers. Another wheeze was running heating wires through the concrete so it could cure in the freezing conditions.

This approach impressed Cook. "It's a brave and brilliant idea as it solves so many problems," he says. "We thought this was something a contractor would never do as it concentrates all the risk into one event."

"We like that sort of challenge," says Gultekin. "It's not all about money - we like our job and doing something that hasn't been done before."

"It's so refreshing for us after working with so many other contractors. Sembol has a real can-do attitude," beams Cook.

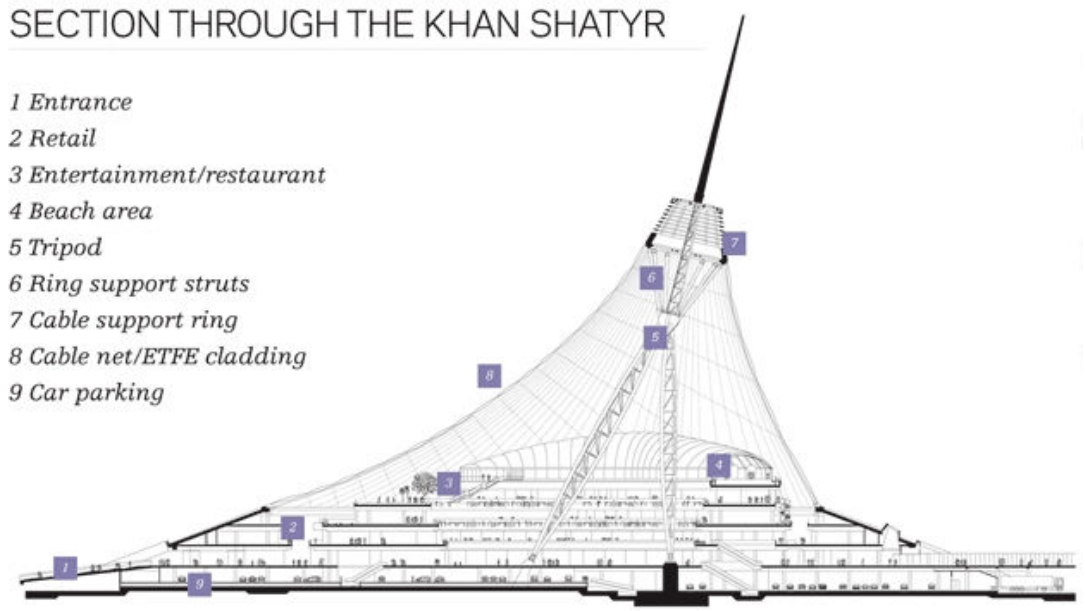
Sembol welded the tripod together during the winter of 2008, ready for the big lift in early December. The tripod consisted of three legs supporting the head, which supports the cables. The head was made up of 12 struts that were attached to bearings where they joined the tripod so the struts could move. The other end of the struts was attached to a 20m diameter ring supporting the cables. The tripod had been built so two of the three legs were attached to the final anchoring points. The legs were pinned so they could move as if on a giant hinge. The other leg was also hinged but attached to the top of the tripod rather than the bottom. This third leg extended beyond the head of the tripod so the mast was in the middle - rather like someone with spread legs that they bring together to stand upright. The bottom of the third leg was supported on wheels running along a specially built railway line - the idea being that as the tripod was pulled upright, the base of the third leg would move along the railway to its final anchoring point. There it could be pinned, locking the whole tripod into its final position.

To haul the tripod upright, temporary cables were attached to the top of it, hooked over a 90m-high temporary tower and fixed to strand jacks on the ground on the other side of the tower. The trickiest part - and biggest leap into the unknown - was the beginning of the lift. "It is such a weight and at such an angle, there is huge tension in the cables," says Cook. "The most critical bit was the first couple of millimetres as you knew once you had got over that you would be okay, although there was the risk if you pulled too hard, the whole thing could flip up in the air. This is much more like bridge design and construction, where they are much braver."

As it happened, the lift went as the team had expected. "All the excitement was concentrated into one day," says Gultekin.

What's in the Khan Shatyr

The building initially feels like a conventional shopping centre. Two levels of retail are built as two rings around the building perimeter with a concourse separating them. Shops include Marks & Spencer, Debenhams and an Apple store. Go through the inner ring into the centre of the building and there is a huge multipurpose circulation space where the tripod sits. On the third level, the cool retail spaces change to a rather tacky seaside feel with dodgem cars and games machines. There are eating areas, a cinema, a mini golf course and at the top of the building the beach areas with golden sand and pools that gradually get deeper. A monorail with plastic cars gives visitors a bird's eye view of proceedings and braver souls can enjoy a 37m drop tower.



Section through the Khan Shatyr

The next job was to attach 192 cables to the support ring at the mast's top. The cables are paired, which has two advantages. First it keeps their diameter down, which means they can be bent around a tighter radius; this was important as they had to fit into a standard-sized container for the journey to Astana. Also, paired cables provide a stable base for the ETFE support points.

Actually, attaching the cables to the support ring was the easy bit. The more difficult task was to pre-stress them to minimise deflection under loading, and to work out the degree of pre-stressing: higher levels were needed on the longer side of the tent because they had to support greater snow loads. The overall aim was to arrange the cables in such a way that they would keep the stresses on the mast equal around the building's circumference.

The cables were attached to long adjusters at the base which were wound in for the final tensioning. But attaching the loose cables to the adjusters wasn't straightforward as the cables had to be winched tight so the connection could be made. According to Gultekin, the specialist charged with this job wasn't properly equipped, as it hadn't brought enough winches to enable several cables to be attached at once around the circumference. Also, their winches weren't up to the job. Gultekin took matters into his own hands. "I bought 20 old Russian cranes and dismantled them so we could use them for the winching operation," he says. "I said to the subcontractor, 'Go home; we will do the job ourselves.' They didn't want to take the risk."

With all the cables attached to the adjusters, the tension was progressively increased. When they were correctly tensioned, the ETFE cladding was installed. Meanwhile Sembol was busy installing the finishes inside the building to meet the deadline of Nazarbayev's 70th birthday.

On the day the building opened to the public it was packed with 140,000 visitors. People appeared to love it, with families taking snaps in front of the beach and the giant tripod. If this turnout is anything to go by, there could be one big difference between the Millennium Dome and the Khan Shatyr: it will be a roaring success.

Project team

developer/contractor **Sembol**
concept architect **Foster + Partners**
concept structural/M&E engineer **Buro Happold**
landscape architect **Charles Funke Associates/University of Ankara**
executive architect **Linea Tusavul Architecture/Gultekin Architecture**
executive steelwork structural engineer **Arce Muhendislik**
lighting **Claude R Engle**
concrete engineer **Ozun Proje**
cablenet design **Teschner Ingenieure**
tripod lifting **VSL/Samko**
ETFE **Vector Foiltec**
HVAC **Vemeks Engineering**
electrical **HB Teknik**