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¡Ay, caramba!

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Jan-Carlos Kucharek reports. Photography by Hufton + Crow

Shading it: the Metropol Parasol looking north gives the scale of this enormous timber lattice structure

... or what the devil's this? It's actually a giant parasol in Seville, constructed from laminated veneer lumber, and is a breathtaking demonstration of what can be achieved using offsite manufacture.

Standing in the shade in Seville's Plaza de la Encarnación, beneath the Metropol Parasol's vast, amazing timber canopy, it's hard to believe that 11 years earlier the only proposition for the city's largest urban square was to excavate beneath it and build a car park to deal with the city's traffic problems. But after the pile drivers started churning up Roman mosaics, the archaeologists were moved in to reveal significant Roman remains buried 5m below the square.

With excavations ongoing, in 2004 the Seville city government held an international competition to come up with a landmark scheme that would incorporate the Roman find into a larger vision for the plaza. Won by German architect Jurgen Mayer H, Metropol Parasol (dubbed "Las Setas", or "mushrooms") comprises six, 21.5m high timber trunks and a great lattice canopy that covers nearly all of the old square. It provides solar shading and is a marker for the museum, sunk beneath it, allowing visitors to view the remains exactly where they were found.

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Above this the square's old market has been reinstated as an indoor one, and on its roof a new $3,000m^2$ raised plaza sits in the canopy's shade. This April, the €90m Las Setas opened to the city's excited, curious or downright outraged residents. But whatever you might think about the design, being arguably the largest timber structure in the world — with a surface area of more than $11,000m^2$ — there's no doubting the scale of the ambition.

The highly distinctive mushrooms, made of laminated veneer lumber (LVL), cover an area of 150m x 75m and are a feat of engineering as well as logistics. Prefabricated off-site, the structure was brought in by road and installed piece by piece by Spanish contractor Sacyr above the square.

Less visible, though just as impressive, was the engineering strategy that ensured the loads of this enormous timber structure were brought to ground among the precious ancient ruins with deftness and lightness of touch that belies the ingenuity required to achieve it.

Mayer's original competition-winning design went through a number of structural iterations through the design development process (see box, page 34) in conjunction with structural engineer Arup Madrid, but it was decided to go with a hybrid composite approach that dealt with the building's structural demands on an ad-hoc basis. There was also an obvious desire to minimise points at which loads are transferred to ground, resulting in the fact that only two of the six "mushrooms" transfer their loads directly to the Roman remains via their 6m diameter, 40cm thick concrete cores. Their connecting steel platforms, for the restaurant area and rooftop walkway, are supported by a number of profiled hollow steel struts, which transfer their greater loads back to the concrete core using a saw-tooth connector.

City view: A walkway above the lattice roof offers stunning views over Seville

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But in the basement, they had to tread carefully. “Four of the six trunks pass through the raised plinth level to impinge with the ground, but only two within the Roman remains,” explains Arup associate Jan-Peter Koppitz. “The plinth itself is made up of huge Vierendeel trusses forming a box that sits atop five enormous steel trident columns rising out of the museum level, which measure 3m at their base and fan out to 13m at their top. To deal with the forces that make the trident columns want to splay apart, these are connected to each other with thick 100mm diameter steel ties,” he adds.

But it is the Kerto-Q laminated veneer lumber (LVL) free-form 1.5m x 1.5m rigid grid superstructure that forms the design’s centrepiece. “The decision to go for LVL was based on economics as well as its inherent strength, stiffness and durability. The form was developed using 3D finite element analysis using an iterative tool that automatically analysed and optimised the thickness of each timber element to create a static calculation model of the whole structure,” says Dr Volker Schmid, Arup consultant on the Parasol project. This would determine not only the size of individual timber members, but also the weight of the steel connection pieces at their intersection.

This was no mean feat. In total the Metropol Parasol is made up of 3,400 LVL timber elements. Depending on their position within the structural matrix, elements range from between 1.5m-16.5m in length and 68-311mm in thickness. At the trunks, where the largest occur, elements can be 3.5m deep. Connecting them all are nearly 11,000 steel moment-connection pieces, weighing from 2.9kg to nearly 70kg.

This structural connection was a key concern for the engineers as it allows the loads to be evenly spread throughout the structure. Engineers at Arup and Finnforest Merk developed the innovative fork-headed connection detail based on glued-in steel bars — an optimised bonding approach to aid with rapid erection on site.

Koppitz explains that Seville’s hot climate was a concern for the glue performance, which can be compromised in temperatures in excess of 60^{o}C, and it was only once the engineers had liaised with an epoxy adhesives expert, and had carried out thorough testing, that the proposed detail could be adopted, with each of the 35,000 holes for gluing in the threaded bars manually drilled through the Kerto-Q.

All of the elements were precision drilled at Finnforest’s component factory in Aichach outside Munich using a computer controlled trimming robot, with the cutting data transferred from the structural engineer’s 3D model. Once cut, they were then transported by truck to Seville and stored in warehouses outside the city to await painting and installation.

The paint coating was not just to achieve an aesthetic intent, but to protect the timber from the drying processes associated with exposure to strong sun. In conjunction with Finnforest a new system for timber preservation was developed consisting of a waterproof but non-permeable 2-3mm thick, two-part polyurethane coating flexible enough to cover possible cracks. Together with the cream-coloured topcoat, which also provides UV protection, the engineers say that it also gives the structure a high level of heat protection, with potential creep deformation of the structure limited to nearly half of that anticipated if there was no protection at all.

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Construction of the shading structure was carefully considered by Sacyr. Connections between the trunks of the mushrooms and the canopy were site welded. Arup's Schmid says building the lattice canopy was a logistical feat in itself, being constructed off 96,000m^3 of temporary scaffolding, built at high level over the square. To plan it, Finnforest used a 3D contour of the Parasol, allowing the scaffolding contractor to work out the potential loads that it would have to take to allow the canopy to be constructed on it. Stepped platform scaffolding followed the shape of the canopy, which meant that the whole structure remained accessible throughout the construction process for re-coating and checking.

Koppitz says that ensuring the accuracy of set-out was fundamental. "Datum levels were taken relative to the concrete tower of the restaurant core and checked against our model to ensure that they were correct prior to installation. The pre-fabricated elements had the steel connector pieces attached at ground level before being raised onto the temporary scaffolding deck. Moved into place, they were then fixed and adjusted," he explains.

As the scaffolding was taken away and the nodes were placed under normal loading stress, all were checked for deformation. Once the foundation works and the new plinth level had been built, construction of the timber structure began in June 2008 and completed in March 2011.

The design was procured using a form of PPP contract between the Seville city government and the contractor Sacyr, which involved them putting up half the construction cost, the architect working under the contractor, and the other consultants being appointed by the architect. Under the PPP, the contractor maintains ownership and management of the site for 40 years, before the whole building is handed back to the city in perpetuity.

This may be a blessing in disguise, for the reaction to the daring new structure in the ancient city seems to be a mixed one, and though it offers magnificent shade, it may take that long for Seville's residents to happily siesta beneath it.

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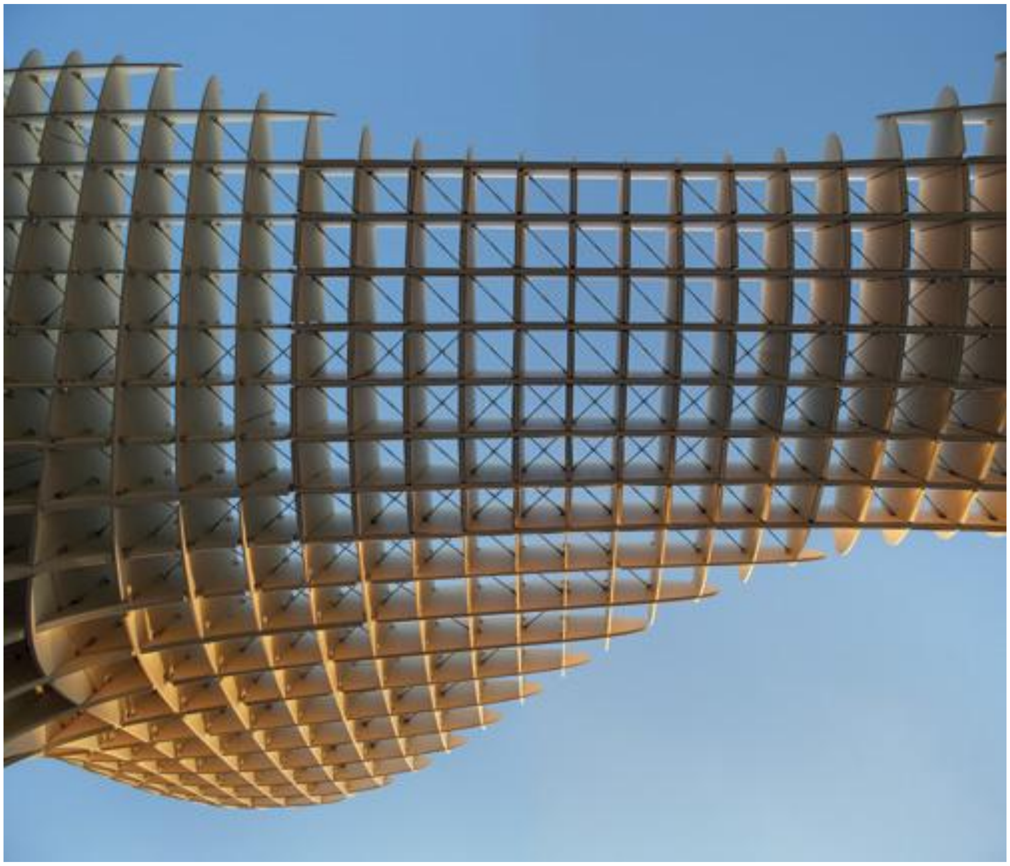

Looking up, the diagonal steel bracing for the orthogonal timber lattice structure is clearly visible

Metropol Parasol: how they opened the urban umbrella

Phase 1: Concrete structure

The steel structure of the museum and marketplace and the steel/concrete structure for the high-level cafe are completed. Two of the concrete cores that house lifts and four concrete plinths have been constructed.

Phase 2: Timber trunks

Construction of the timber trunks starts with the base plates at the top of the concrete plinths. The timber panels, which are up to 16m high, are then set up according to a sequence which ensures temporary stability at all times.

Phase 3: Main structure

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The individual elements immediately above the trunks are prepared at the plaza level before they are hoisted into place at high level. The fire protection is constructed at the lower half of the trunks.

Phase 1: Concrete structure

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Phase 2: Timber trunks

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Phase 3: Main structure

Jan-Peter Koppitz, associate, Arup

Phase 4: Scaffolding up

Scaffolding is built to temporarily support the main timber structure outside the area of the trunks. Work started at the rear of the site and
two cranes were needed to attend to the simultaneous erection of scaffolding and timber.

Phase 5: Scaffolding down

Scaffolding is taken down zone by zone, from the outside of the structure inward, with continuous control of the structure ensuring safety. The overall plaza is repaved and all urban infrastructures finished.

Phase 6: Finishing touches

The entire scaffolding has been taken down, and the high-level walkway constructed on top of the timber structure. All services, such as lightning protection, are installed within the timber structure.

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Phase 4: Scaffolding up

Phase 5: Scaffolding down

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Phase 6: Finishing touches

Developing a structural strategy

Optimising Jurgen Mayer H's design was one of the first things that needed to be addressed. The scheme as proposed maintained a classic separation between the outer visible cladding and the hidden structure required to make it stand up, making use of steel structural tubes that would then be covered in metal cladding.

Engineer Arup and the architects revisited this approach in the design development phase. This involved looking at dual-layer steel shells and the use of steel foam. In the end, the design team chose to concentrate on a supporting structure made out of curved lamina.

There were two options feasible: a radial disc configuration directed outwards from the supporting beams, or an orthogonal arrangement supported from the trunks. Although the former would be statically more efficient and saves material, there would be problems with the constantly changing geometry of the connecting interfaces, so the latter was chosen.

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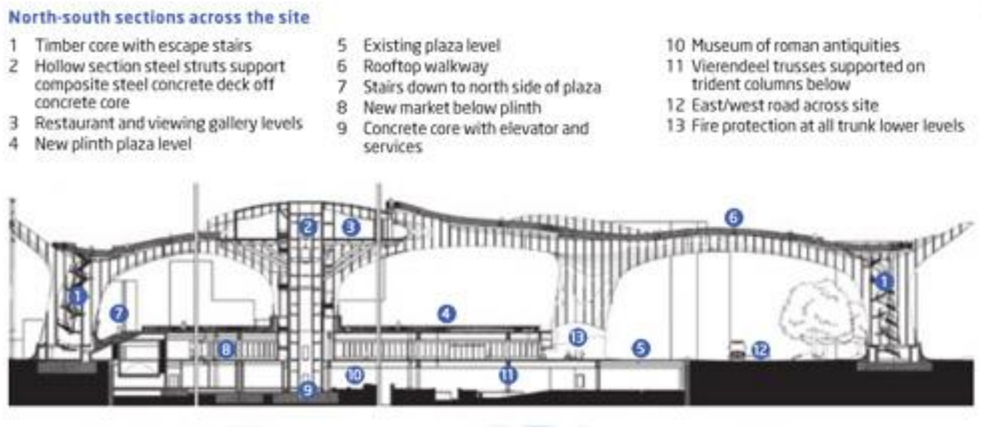

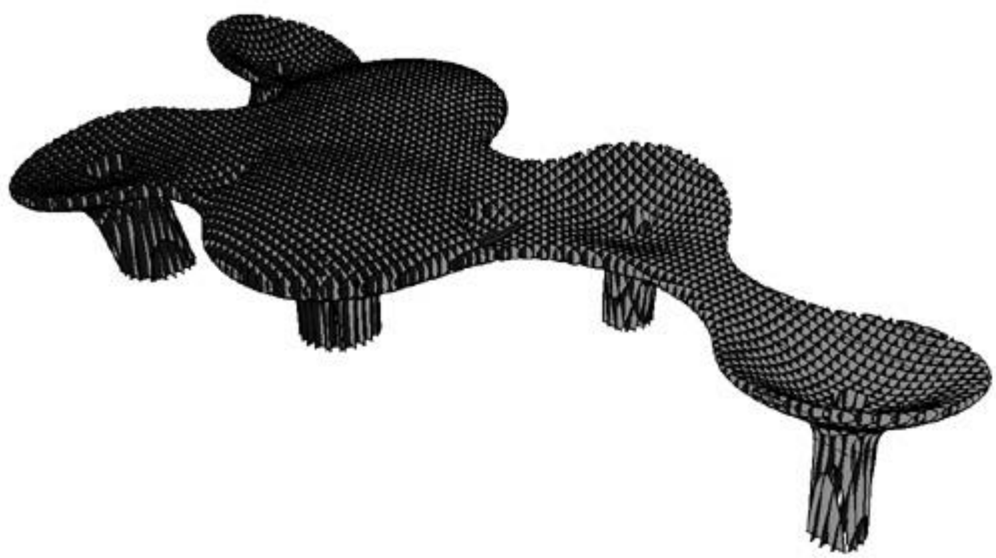

Given the enormous number of connections, it was presumed that the structure should consist of welded steel sheets, but analysis of the structure showed that these thin steel sheets would buckle long before the required loading capacity was reached. In the end team opted for Kerto-Q LVL. Even though these would be thicker than the steel sheets, they would weigh less and would also be more stable and would not suffer from crumpling, due to their thickness.

Because the roof is not closed, to give the form rigidity, additional steel diagonals were needed to give the timber structure the rigidity to carry the load. These are positioned around the concrete cores and lend stiffness to the structure. However, since the arrangement of the steels influences the appearance of the Parasols, these are positioned as inconspicuously as possible.

The use of cross-laminated timber ensured that the structure could work at optimum loading strengths, as well as making it resistant to the deleterious effects of moisture, making it eminently suitable for use outdoors.