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Some pointers on reaching the top

The team working on Renzo Piano's Shard at London Bridge used modular techniques to rise to the challenges of building Europe's tallest tower

Text Pamela Buxton

Not many buildings can count clouds as a potential construction hazard. But at the Shard, Renzo Piano's soaring 310m-high tower at London Bridge, the potential for clouds, fog and hostile weather conditions to disrupt construction led the design team to devise a complex off-site assembly process for the very top.

As a result, when the spire of the Shard was safely installed at the top of the tower at the end of last year, it was the second time it had been put together — the first was in a dry run by steelwork contractor Severfield-Reeve Structures (part of the Severfield-Rowen group) at its works in Yorkshire.

The spire, which comprises levels 69-95, contains the last inhabited floors — including the public viewing platform on the 72nd floor. This increased the need for a high-quality finish to the steel. The remaining levels, being installed from this month, are the very tips of the Shard, which cantilever above 87 up to 95.

The Shard is a composite structure, with a steel structure through the office floors up to level 40 followed by a post-tensioned concrete frame through the apartment and hotel levels up to 69 topped by the steel-framed and steel-cored "spire". In all, there are 12,500 tonnes of structural steelwork, 530 of which form the spire.

"It's very important to Renzo Piano as a public space within the Shard," says Mace senior project manager Adrian Thomson. "It's a work of architecture rather than just a piece of steelwork."

It was decided very early in the process to find an alternative to lifting the steelwork up individually, especially as there were a lot of relatively small pieces, some only 1.5m long. With winds of more than 100mph at that height, conventional construction would have raised safety, weather and time issues.

In all, there are 12,500 tonnes of structural steelwork, 530 of which form the spire

Instead, a modular system was devised to minimise both safety risks to contractors on site and weather-related delays, as well as ensuring that the quality met the aspirations of the client. The aim was to limit the number of pieces and connections that had to be lifted. This was done by modularising the steel main members horizontally and vertically, based on a 3m module in response to the 3m width of the trailers used to bring the steelwork to site. Flooring panels were fitted to the modules before installation.

The structure was also pre-assembled to enable the team to identify and eliminate any risks and difficulties. "It was a two-stage modularisation — one at the factory, one on site," says Severfield-Rowen chief operating officer Peter Emerson.

"We developed a structure where as many pieces of steel as possible were put together as sub-assemblies determined by transport size. When they got to site, as much of these were bolted together as could be carried by the crane. This significantly reduced the number of lifts we had to make," says Emerson.

Devising the modularisation was a complex task involving the whole design and construction team including Renzo Piano's London representative, Giles Reid, who visited the test assembly in Yorkshire.

"There were several criteria that could potentially conflict — aesthetics, engineering, safety, predictability. We all collaborated on the evolution of the concept into a working model," says Emerson.

The off-site assembly gave invaluable learning experience to Severfield-Rowen's Steelcraft Erection Services, which also installed the spire in its final position on top of the Shard. The modules were assembled in three-storey slices then dismantled for adjustments and repainting. The process was then repeated for the next three levels. Some aesthetic changes were made as a result — for example, the attachments to the cladding were made less cumbersome and steps were taken to improve the quality of the welding in areas that were visually important.

"It has been a very active design debate. The architect was very keen that when the public were standing at level 72 they could see the seamless nature of the wing walls, which are a major part of the building's expression," says Thomson.

"Reaching the peak has enhanced the look of the Shard," says Flan McNamara, project director of developer Sellar, adding that it'll look even more elegant once the tips have been installed — "like it's disappearing into the sky".

The Shard will provide approximately 55,800sq m of hotel, luxury apartments and office space, and will be the tallest mixed-use building in Europe.

PROJECT TEAM
Client
Sellar Property Group
Architect
Renzo Piano Building Workshop
Executive architect
Adamson Associates
Structural engineer WSP
Main contractor Mace Group
Steelwork contractors
Severfield-Reeve Structures,
Atlas Ward Structures,
Steelcraft Erection Services

SUPPORTING THE SHARD FROM THE GROUND UP


At 310m the Shard will be the tallest building in the EU when it completes later this year.

PHOTO: MACE; MAIN DRAWING: SEVERFIELD-REEVE STRUCTURES

The lower part of the Shard — ground to level 40 — consists mainly of public areas, retail and offices. It has been constructed with structural steelwork around a vertical concrete spine and lift core. This was the biggest part of the steel package, involving 15,000 pieces weighing 12,000 tonnes.

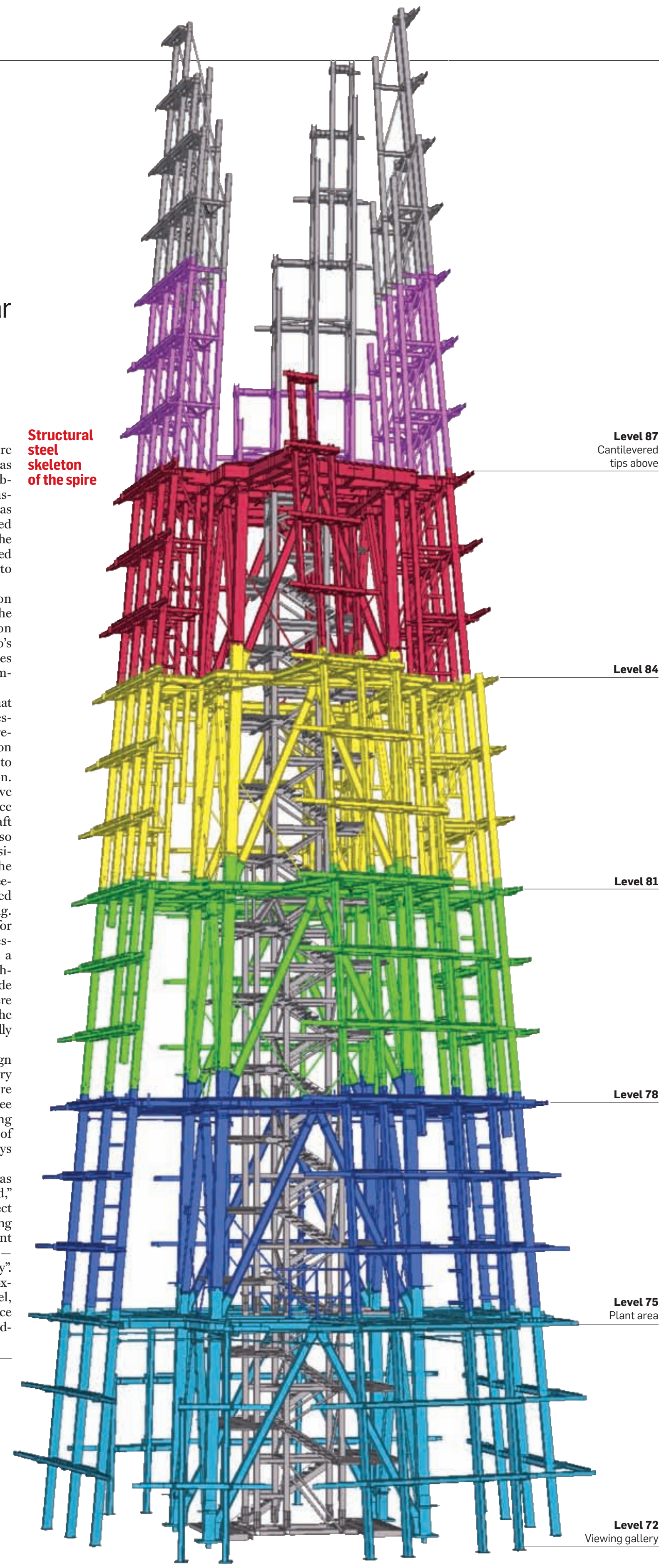
To maximise floor-to-ceiling heights, fabricated I-beams spanning up to 15m were used to perform a dual function — as well as being structural, they allow the services to pass through. These are 500mm deep with standard holes for the servicing.

Each office floor includes three perimeter winter gardens where the steel frame is exposed and detailed as an architectural feature.

Steel framing is also used in the lower levels of the hotel from 37-40. Here, edge transfer beams carry loads from perimeter columns at 6m spacing in the offices to 3m spacing in the hotel as the building tapers.

At the very top, the columns are just 1.5m apart.

Structural steel skeleton of the spire




CGI showing the Shard spire complete with cantilevered tips.

CGI: SELLAR PROPERTY GROUP

SPIRE CONSTRUCTION

The spire is constructed from 460 pieces of steel weighing 530 tonnes. It consists of a central core supporting the stairs and an outer structure that forms the main frame.

These were structured in a 1.5m grid framework forming 3m-wide panels spanning from the core out to the outer edge. Eight wing wall beams cantilever from the main Shard frame beyond the extent of the floor area. Apart from the box section columns, cladding rails and the wing wall beams that were fabricated sections, most of the rest of the steelwork was in standard sections.

The spire includes an enclosed, triple-height viewing gallery on level 69 and an external platform at 72 with a hardwood timber floor to suggest the deck of a ship. Plant and chillers are on 75. The lift extends up to 78 and the same standard of finishes continue to this level.

In the viewing levels, the architects were keen to reduce the amount of visible connections. "We're very conscious that people will be looking up and out through the structure so we added refinement to the steelwork which the public will see," says Giles Reid, London representative of Renzo Piano Building Workshop. "It was very important to us to push as hard as we could to get a high standard."

Making connections

Where bolted connections couldn't be avoided, the architect worked with the steelwork contractor to dress the connections with cover plates. For example, on the connection between the vertical, horizontal and diagonal bracing Severfield-Reeve produced curved plates.

Other connections were dressed with filler after erection, and over-coating such as those on the wing walls, which have flush welds or hidden connections.

"They went to a lot of trouble to minimise the size of connections and make the welding neat," says John Parker technical director of engineer WSP.

The spire has a steel stair supported by a steel core structure built in three-storey units. The stair extends from floor 67 to 87. It wraps around the central core and is tied to the structure at landings on every third floor.

First the stair tower was installed then the landings were hoisted into place. It was installed complete with aluminium treads, handrails and flooring to minimise the number of trades needed after the spire's installation. The stair core structure alone weighs 100 tonnes and consists of 110 pieces.

Trial assembly

The stair structure was pre-assembled in Sherburn near Scarborough by Severfield-Rowen's subsidiary company Atlas Ward Structures — Light Steel Division. The spire main structure was trial erected in three sections at Severfield-Reeve's Dalton plant in North Yorkshire.

"During [trial] assembly we made sure that we put every piece of steel, handrail and mesh into place so that we knew it would fit," says Severfield-Reeve contracts manager Doug Willis.

The very last pieces of steelwork to be installed will be the cantilevered tips. Above level 87 the three highest tips — Shards 1, 6 and 14 — will be lifted, bolted into place and glazed. These are fabricated, vertical trusses joined together to create a 3D frame that holds the glass tip of the shard up. The largest one is a box truss 10.4m long, reaching up some 18.2m above level 87.

All spire steel is finished in a high-quality corrosion protection system of three layers topped by a glass flake product for added durability — a specification similar to that used for extreme conditions such as on the Forth Road Bridge.

Mace had built in an allowance for temporary works once the spire was installed on the Shard but this wasn't needed — each piece was within 5mm of what was expected. "From my point of view the spire has taken the incorporation of safety planning, design, production and installation of steelwork to a new and advanced level," says Mace's Adrian Thomson.


During the trial assembly, the spire was erected in three sections at Severfield-Reeve's Dalton plant.


Vertical trusses create a 3D frame that will hold up the glass tips.

PHOTOS: ABOVE: NICOLA EVANS/ WSP GROUP; LEFT: GILES REID/RENZO PIANO BUILDING WORKSHOP

Maggie's Nottingham occupies a sloping site in a secluded part of the hospital grounds.

Care centre's fearless symmetry

The unconventional geometry of CZWG's Maggie's Nottingham is made up of simple steel elements

Text Pamela Buxton **Photographs** Martine Hamilton Knight

A distinctive elliptical steel frame forms the structure for Maggie's Nottingham, designed by CZWG at the Nottingham City Hospital Campus. The centre opened in November with interiors by Paul Smith and is the 15th in the network of Maggie's centres for cancer patients and their families.

High-quality architecture has always been important to Maggie's centres, as demonstrated by the starry list of architects already engaged, including Zaha Hadid, OMA and Frank Gehry. Not that this has led to lavish budgets — the Nottingham centre, like many of its predecessors, is low cost — with a build cost of £1.45 million, working out at £4,000 per square metre.

The site was sloping and full of trees, providing a secluded environment despite its proximity to other hospital buildings. CZWG's Piers Gough came up with the idea of designing an almost entirely symmetrical building held within a steel frame of interlocking ovals. The oval elevations give the building a friendly, welcoming appearance. Initially, the intention was to have a predominantly timber frame with a steel roof structure but it became clear that this was impractical to build given the site constraints, and a steel structure with timber infills was used instead.

"A steel skeleton to form the overall shape with a timber infill was the quickest and most economic solution," says Gary Lynch, a director of engineer Adams Kara Taylor. "What looks like a quite complex shape is broken down into very simple elements."

The structure gives the impression of floating on a pedestal.

The 360sq m building stands 11m high and is arranged in two storeys within a steel superstructure above a reinforced concrete basement pedestal. The basement is pulled back as far as possible from the roots of nearby trees and this, combined with the overhangs created by a 45-degree rotation to the superstructure, gives the effect of the building seeming to "float" on the smaller basement. This arrangement limits views in from ground level, giving visitors to the centre privacy from passers-by.

Visitors enter via a steel bridge into a central lobby and travel down to a double-height area housing the kitchen, library and meeting rooms or up to two consultation rooms, a day bedroom and a large meeting space. This upper area is intended as a more secluded area for resting or private conversations, while the generous balconies extending from the kitchen and sitting rooms encourage visitors to enjoy the leafy setting if they desire. The exterior is clad in green glazed tiles and the building is topped off with an aluminium roof. Inside, colourful furnishings and furniture designed by Paul Smith are intended to be both comfortable and conversation points.

For steelwork contractor Shipley Structures, the big challenge was the unconventional geometry of the 40-tonne steel carcass, which was erected in just two weeks.

"There is a lot of curving on the building — the overlapping elliptical structure that creates a cantilevered effect and the roof itself, which is created in an 's' shape which meets in a central raised point," says Glynn Shepperson, a director of Shipley Structures.

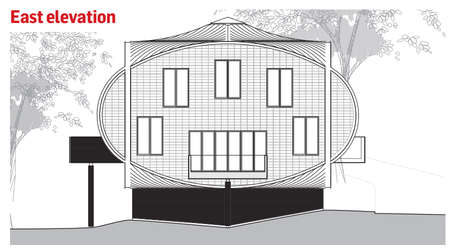
"It's beautifully detailed," says CZWG's Gough. He had the idea for the ovals when he was looking through a book by Maggie's centres co-founder Maggie Keswick Jencks on Chinese gardens, on which she was an authority.

"I saw these Moon Gates which are circular holes that you walk through and I played with that as a solid form. A circle was too high so it became an oval, which was the shape that fitted the two-storey building we'd decided to do.

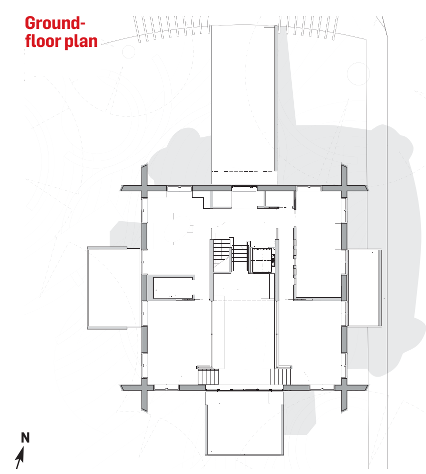
"The idea was to make a refuge nestling into the tree. It is almost perverse in its symmetry. It seemed intriguing to do a building that wasn't free-form; the landscape around it is quite loose and free so the building could become symmetrical. The conceit is that the elevations are all ovals and they interlock like a Canadian log house."

PROJECT TEAM
Client Maggie's Cancer Caring Centres
Architect CZWG
Interior design Paul Smith (Interiors)
Structural engineer Adams Kara Taylor
M&E consultant KJ Tait Engineers
Main contractor Bowmer & Kirkland Building Services
Steelwork contractor Shipley Structures Ltd

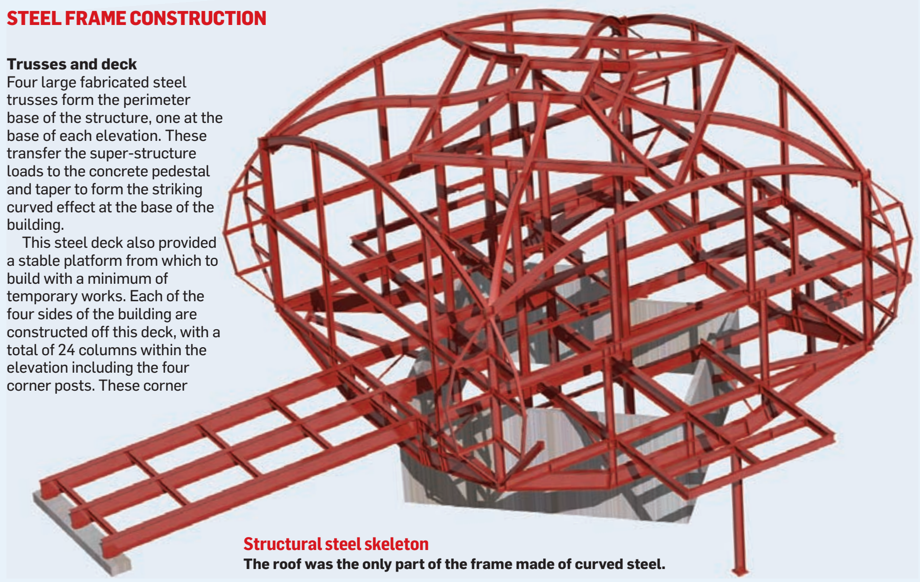
East elevation



Ground-floor plan



STEEL FRAME CONSTRUCTION



Structural steel skeleton
The roof was the only part of the frame made of curved steel.

Trusses and deck

Four large fabricated steel trusses form the perimeter base of the structure, one at the base of each elevation. These transfer the super-structure loads to the concrete pedestal and taper to form the striking curved effect at the base of the building.

This steel deck also provided a stable platform from which to build with a minimum of temporary works. Each of the four sides of the building are constructed off this deck, with a total of 24 columns within the elevation including the four corner posts. These corner columns link the lower curve to the four curved eaves beams that link to create the symmetrical and elliptical form.

Steel support is provided internally for a central lift shaft and three split-level floors. The light steel, fully bolted skeleton is infilled with straight timber members. According to engineer Adams Kara Taylor, this system provided a simple and fast construction method to create an otherwise complex shape. The timber stiffens the steel frame against wind loads and out-of-balance loads created by the slight asymmetry of the steel frame.

Entrance: each elevation is framed in an oval of steel.

Cantilevered balconies

Cantilevered, steel-framed canopies project from three sides, along with a pedestrian bridge to the rear elevation that provides direct access into the building at first-floor level.

All four external frames were provided with perimeter balustrading, integral seating and are clad in a combination of glazed, timber and metal louvre panels. Of the balconies, one is a true cantilever and two are cantilevers with prop supports.

Roof contours

In order to maintain the slim-line effect of the structure and create a more cost-effective solution, the design used higher strength steel sections in grade S355 material.

This provided one of the biggest structural steelwork challenges. Where at all possible on the building, curved steel was avoided but its use was essential to create the desired roof contours.
Here, the eaves are formed by curved 12.9m beams.

From each corner spring S-shaped fabricated rafters that converge at a square glazed roof light at the crown of the roof. Four further curved beams link the corner of each roof light to the centre of the eaves. Otherwise, straight members are used to form the roof structure.

"I'm particularly proud of the roof. It's really pretty and comes out of the geometry of the corners," says Gough, adding that the similarity to a Chinese pagoda is a homage to Maggie's interests and background.

Left and above: The ears' steel members spring out from the main frame and create the illusion of overlapping ovals.

Corner 'ears'

The projecting "ears" — two per corner — give the illusion of intersecting but the oval form of the main steel frame actually terminates at a concealed corner column.

"It does look like it's one continuous shape that's curving round," says Shipley Structures' Glynn Shepperson.

Instead, members on welded ladder frames spring out to give the corners of the building their distinctive overlapping form.

Although these appear curved, each ear curve is made up of four members tied to the corner column by three horizontals that pick up the wind load. The top diagonal member takes the load of the rest of the ear, which is infilled in timber.

Each ear aligns with the curve of the roof and the underside of the building to create an oval.

Sustainability centre finds ways to push the envelope

The Sustainable Building Envelope Centre has been established to harness the building fabric to generate energy. Here is a look at its ambitions and some of the key technologies under development

Text by Pamela Buxton

The SBEC building on the Shotton Steelwork site in Flintshire, north Wales, has been split into zones which can be monitored to test new building products.

How can the building envelope be better used to actively capture, store and utilise energy? And how can pioneering research in this area be developed and applied commercially as an integral part of a building system?

These are two of the big questions being tackled by the Sustainable Building Envelope Centre (SBEC), which was set up last year by Tata Steel, the Welsh government and the Low Carbon Research Institute (LCRI), an organisation led by the Welsh School of Architecture at Cardiff University with involvement from five other Welsh universities.

Construction of the SBEC facility was funded by Tata Steel and is based at its Shotton works in north Wales. The centre, designed by the Welsh School of Architecture, reuses part of a production facility and consists of three floors of offices around an area for tests and exhibitions. It works as a proving ground for emerging building envelope technologies, whose performance will be evaluated over the initial three-year programme.

"We're trying to create an end-to-end process for transferring knowledge from research institutes into the commercial world," says director Daniel Pillai.

"It's about transforming the role of the building fabric. Traditionally this has played a passive role in energy conservation. We believe it will become far more active in the future, capturing energy, storing it and using it. We're trying to functionalise the surface of the roof and walls to capture as much of the solar energy that lands on it as possible."

New building products

The centre is developing solar thermal and photovoltaic technologies that can generate renewable energy independently, in combination or as part of integrated energy systems that incorporate boost, storage, delivery and control elements.

As well as piloting building products, the hope is to develop design methodologies and best practice guidance to enable designers and specifiers to incorporate these energy systems into their buildings."If we can find a way to store summer heat and release it in winter, we can make a lot of buildings self-sufficient," says Pillai.

Research includes the application of coatings to a steel roof or wall surface to superimpose functions such as solar energy absorption. Transpired solar collectors, frameless photovoltaic, phase change material and embedded pipes in a steel floor deck slab have also been tested at SBEC.

'If we find a way to store summer heat for release in winter, we can make buildings self-sufficient'

DANIEL PILLAI

The challenge has been to make new technologies part of a building system, and to tackle energy storage and release, issues which the SBEC is currently working on. Meanwhile, both the TSC and frameless PV products have reached commercialisation. The TSC system will be supplied via SBEC collaborators and their extended supply chain, and the Solon frameless photovoltaic panels will be marketed as Solbond Integra. Both are due for launch this spring.

The products being tested at SBEC are steel-intensive and are being tested on a steel-framed building, although the technologies are expected to be more widely applicable throughout different building types.

SBEC's findings will be disseminated through CPD. Given that buildings account for around 40% of all carbon emissions, the potential benefits of the SBEC work are "enormous", according to professor Phil Jones, head of the Welsh School of Architecture and chair of the Low Carbon Research Institute.

"In this country we often come up with bright ideas but don't necessarily take them to market. The SBEC work will take basic research on new products through to manufacture and demonstrate them in practice as part of a building system — all essential for getting new technologies into the market," he says.

"The potential for using the envelope of the building to collect energy is huge if you can integrate this function into the building design rather than have it as a bolt-on. Then the envelope can perform two tasks — both envelope and generator."

As well as installation at the SBEC building, the plan is to test the new technologies in eight buildings including housing, offices and factories in Wales so that their use can be monitored in real life situations. This £3 million project, announced last month is being backed by £1.8 million from the European Social Fund through the Welsh government.

WWW.SBEC.EU.COM

'The potential for using the envelope to collect energy is huge if you can integrate this function into the building design rather than have it as a bolt-on'

PHIL JONES

PHOTOS: SBEC

TATA STEEL BCSA In association with The British Constructional Steelwork Association and Tata Steel

The Linden Green cassette facade system (left) was installed to part of the SBEC building to heat the offices, while the Anthracite collectors (right) feed pre-heated air into the prototyping bay.

TRANSPIRED SOLAR COLLECTORS

Transpired solar collectors (TSCs) work by heating a boundary layer of air about 5mm thick on the external surface of the collector, which is fixed to a southerly elevation. Negative air pressure created within the cavity by a ventilation fan draws the pre-heated boundary layer air through the micro perforations in the surface into the cavity. Fresh heated air from the cavity is then fed into the building, either directly as ventilation air or ducted into a HVAC unit as a pre-heater to the main heating system.

A TSC system can meet up to 50% of space heating requirements. They can be installed as an additional steel skin on to both new or existing walls (metal and non-metal) to create a cavity between the wall and the metal skin.

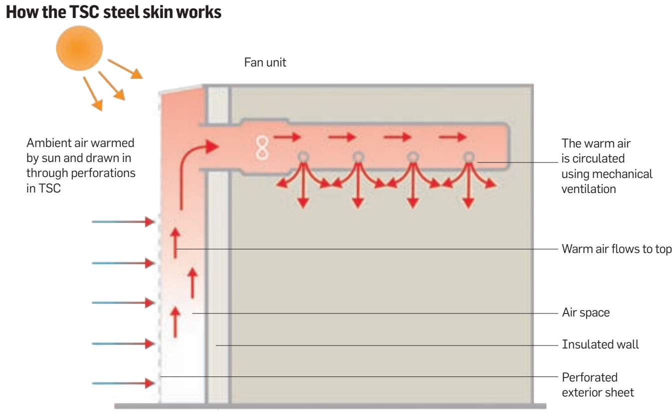
The pre-finished Colorcoat Prisma steel (made by Tata Steel) has enhanced thermal absorption properties and absorbs the sun's radiant energy, heating the boundary layer of air to the exposed side of the metal skin.

According to the SBEC, a TSC system, when combined with a pump, can deliver 250k@h/m2 per year and would pay for itself within three to seven years.

Two types of TSC are being trialled on the SBEC building. On the south-facing wall Anthracite trapezoidal profile collectors feed large volumes of pre-heated ventilation air into the prototyping bay, reducing the need for non-renewable heat sources.

The Linden Green solar collectors — a cassette facade system designed for commercial applications — feeds pre-heated air to the air handling unit for the office areas. This can be boosted by an air source heat pump when necessary.

How the TSC steel skin works



LIGHTWEIGHT PHOTOVOLTAICS

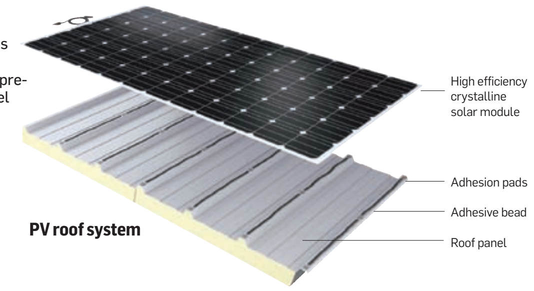
The Sustainable Building Envelope Centre is trialling a frameless lightweight PV system on both its own roof and that of the newly refurbished Deeside Leisure Centre.

The panels have a weight of less than 10kg/m^2 and use 3.2mm transparent toughened safety glass. This uses 42 high-performance Solon Solbond crystalline PV panels covering an area of 84m^2.

The modules are capable of producing 9.69MWh of electricity per year and are bonded directly on to the roof surface with an advanced industrial adhesive. In this way it is suitable for roofs with low static load capacity without reinforcement.

The anchoring methodology relies on a stable, Colorcoat Prisma pre-finished steel panel beneath the crystalline solar module.

A frameless crystalline solar system was installed directly on to the Deeside Leisure Centre's metal roof.



PV ACCELERATOR

This £11 million development project is researching the application of dye-sensitised solar cell "paint" to a steel substrate to generate electricity.

The project — a partnership between Tata Steel and Dyesol — is expected to be prototyped at SBEC within the next year. The ultimate aim is to incorporate this energy-generating technology within the fabric of the building, eliminating the need for a separate element.

The project is a development of technology patented in Switzerland some years ago and arose from Tata Steel's research into anti-weathering pigments. According to Rodney Rice, Tata Steel's business development manager — photovoltaics, the accelerator is a series of coated and printed layers that build up the structure of a PV cell.

This active material is just 50 microns thick (each micron is one-thousandth of a millimetre). It is sandwiched between a steel base and a polymer packaging material.

"The potential benefits are that it is flexible and lightweight so would have applications on buildings that currently can't carry the load of PV panel. It also has implications for appearance because it is the roof rather than something bolted onto the roof, so would give freedom and flexibility," says Rice. The product is expected to be ready for commercialisation in three to five years' time.

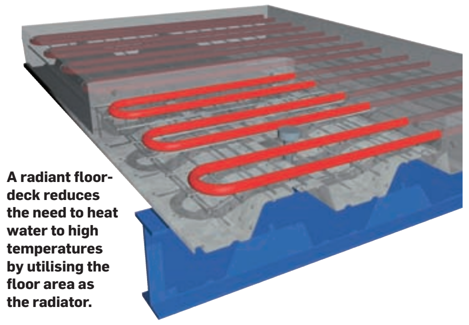
In a separate project, other new coatings for steel and other substrates that can generate power are being developed in the £20 million Specific project at Baglan in south Wales. This innovation centre, led by Swansea University with Tata Steel as the main industrial partner, aims to develop functional coated steel and glass products that will transform the roofs and walls of buildings into surfaces that will generate, store and release energy.

THERMO ACTIVE FLOOR

Pipes embedded in the concrete/steel floor deck enable the slab to be chilled by circulating cold water, absorbing thermal gains during the day and storing the captured heat so that it can be released at night.

For heating, water warmed by heat pumps or a transpired solar collector can heat the radiant floor slab — requiring temperatures of only 30-35°C.

At the SBEC, a radiant composite floor deck — ComFlor 60 — has been installed in the first-floor offices and is connected to the building management system to use renewable solar-heated TSC air on a sunny day and an energy-efficient heat pump on a dull day or at night time.



A radiant floor-deck reduces the need to heat water to high temperatures by utilising the floor area as the radiator.

PHASE CHANGE MATERIAL

SBEC is testing the application of phase change material (PCM) as an addition to the thermal mass of the building.

The micro-encapsulated paraffin wax melts at 24°C and is incorporated into the composite floor slab. When the building is overheating, this melts and absorbs the excess heat by changing from solid to liquid. This heat is released when the temperature drops below the specified level and the liquid becomes solid again.

This can be used in floors, walls or ceilings to capture, store or buffer thermal energy and enable a constant room temperature to be maintained.

The PCM at the SBEC is above the ground floor meeting room and is a ComFlor 60 Active floor deck by Tata Steel. This takes the form of BASF's Micronal PCM within a concrete mixture above the steel deck.