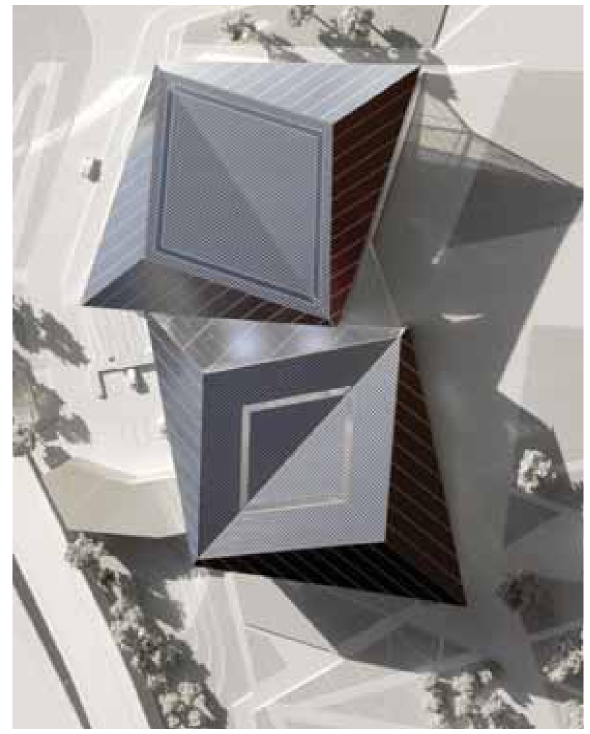
Crystal amazes as sustainable urban showcase

The Crystal, a dramatic urban sustainability centre built for Siemens in east London's docklands, uses an innovative steel framework to enable its complex crystalline form

By Pamela Buxton

One side of the Crystal houses an exhibition space, the other contains offices for 250 Siemens staff.



The two parallelogram forms are linked by an internal street.

Originally known as the Siemens Urban Sustainability Centre, this £30 million building has been renamed the Crystal as the design of its eponymous faceted geometry has evolved. According to Siemens, the shape is intended to represent the many facets of sustainability and the complexity of urban life.

Designed by Wilkinson Eyre Architects, the building is located on the western edge of the Royal Victoria Dock in east London and is intended as a showcase for sustainable design for both businesses and the public.

The Crystal, which is nearing completion, will be Breeam Outstanding and LEED Platinum. Conceived as an exemplar project for sustainable construction, this structural steel-framed building includes high-performance glazing, PV panels and energy-efficient services including a ground-source heat pump. Grey and black water recycling is expected to reduce water demand by 90%. Designed to be all electric, the building will be able to operate free of fossil fuels. It will make use of a mixed mode ventilation strategy and, where seasonally possible, will be naturally ventilated in both the office and exhibition crystals, using opening vents in the facades and roofs.

The dynamic building form is driven by this sustainable agenda and incorporates two parallelogram "crystal" forms broken into a series of triangulated facets and linked by an internal street. Because the facets have varying orientations, they will reflect the light differently to create, according to the architect, a dynamic and reciprocal reflection of its waterside setting.

Each of the two crystal-shaped sections is supported by 14 tapering steel columns. The north side houses an exhibition space exploring best practice in urban planning and design. To the south are offices for 250 Siemens staff plus conference facilities including meeting rooms, a café, a restaurant and a 300-seat auditorium.

At either end of the triangular street are public and private entrances, the public one to the east nearest the dock. In the centre of the street is the main reception with views into the exhibition hall.

"No piece of glass or angle of steelwork is the same, which is a very interesting challenge," says Sebastien Ricard, a director of Wilkinson Eyre.

"While the facade appears to be made up of a set of random shapes, we created a rational geometry by defining the overall building form around two main parallelograms in plan with a very large span structure inside.

"Working with Arup, we designed a diagonal grid, a set of variable span portal frames. The columns/roof beams vary in height/depth and thickness in relation to their respective span in a parametric way, offering an optimised lightweight structure which 'picks up' all the key nodes defining the roof geometry."

The lightweight facade structure of the exhibition section is self-supported from the roof to the floor and is cranked to follow the geometry of the main facets. The main structural components are formed of bespoke steel mullions which are approximately 2m apart.

Located within London's Green Enterprise District close to the new cable car and the Olympic Park, the Crystal is on course to complete ahead of the Olympics and will host the world's largest exhibition focused on urban sustainability, which is expected to attract 100,000 visitors per year. The aim is that it will provide a global knowledge hub to help a diverse audience understand how to build better cities.

'No piece of glass or angle of steelwork is the same, which is an interesting challenge'

PROJECT TEAM

Client
Siemens
Architect
Wilkinson Eyre
Interior architect
Pringle Brandon
Multi-disciplinary engineering
Arup
Project management/cost consultant Turner & Townsend
Main contractor ISG
Steelwork contractor
Rowecord Engineering

The Crystal is located beside the Royal Victoria Dock in east London.

IMAGES: WILKINSON EYRE

ROOF STRUCTURE

The complex irregular geometry of the building, with each column and beam a different height or span, led the design team to consider many options for the roof including fanning and spider web approaches before settling on a diagonal solution formed by seven portals.

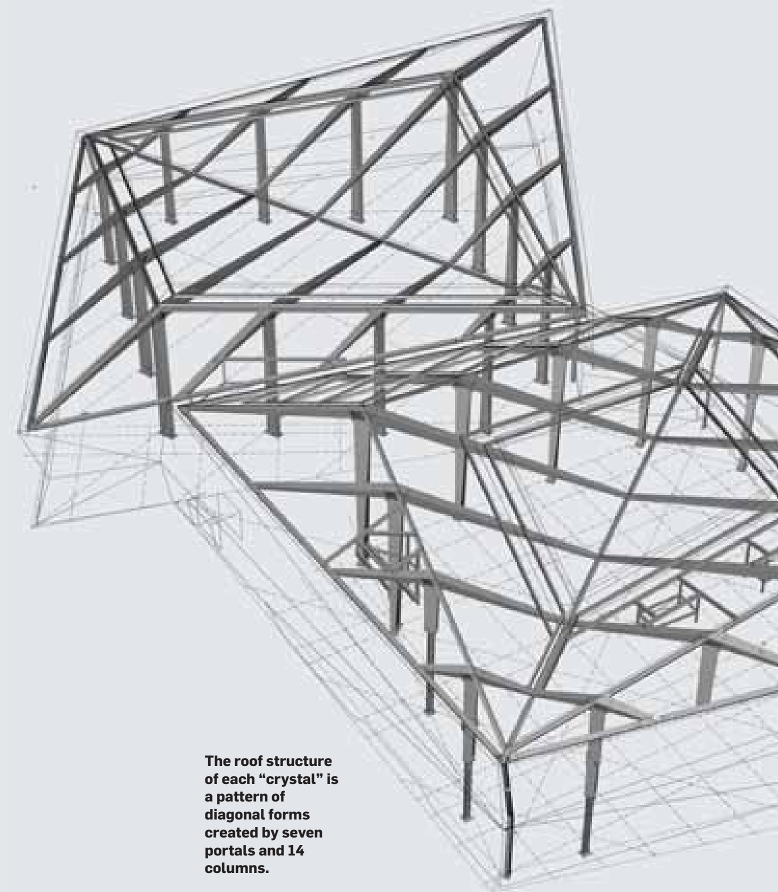
The roof surface is in six planes with the outer one cantilevering out from the grid of columns by a maximum 15m.

The roof plate is carried by steel plate box girders, prefabricated and bolted together. These are shaped to match the stress demands so are deeper where necessary and stronger and shallower elsewhere to optimise the amount of steel plate used.

All the primary steelwork including columns and edge beams are fabricated box sections. Eighty-five per cent of the roof connections were welded in situ, including the 72m longest main rafters, which arrived in two pieces.

"One of the biggest problems was making connections work that would be aesthetically acceptable," says Richard Cherrington, contracts manager of steelwork contractor Rowecord.

"We had to come up with some quite imaginative welding."



The roof structure of each "crystal" is a pattern of diagonal forms created by seven portals and 14 columns.

The roof cantilevers up to 15m from the grid of steel columns.

TAPERING COLUMNS

The columns rotate through 90 degrees for greater rigidity.

The most interesting and elegant part of the structural design is that of the tapering and twisting columns, according to structural engineer Chris Carroll, director of Arup.

The columns — 14 per crystal — are located in the points where the roof plane folds in order to maximise the column-free spaces, and range in height from 8-17m above slab level.

These are connected by roof girders to make a portal frame with spans ranging between the columns from 9m to the maximum span of 42m. However, they also act as cantilevers.

WIND LOADS
To provide sufficient wind load rigidity, the columns rotate through 90 degrees and taper towards the ground. By transforming in section over its height in this way, it is strong in one direction at the top (in the direction of the portals) and strong in the other direction at the bottom (to allow the columns to cantilever from the base in this direction).

All have "collars" for the floor to slot neatly beneath.

"Our aim was to deliver something structurally elegant that minimised the amount of material and optimised construction time by prefabricating and modularising as much as possible, given that the geometry had inherent complexity," says Carroll. "The structure was reacting to the design rather than driving it."

RAINWATER COLLECTION
Four of the corner node columns — two per crystal — have integral stainless-steel drainpipes that unobtrusively deliver water into the rainwater collection system and are cranked to follow the facade. This was achieved by cutting a section out of the hollow column section to insert the kinked 200m-diameter downpipe and then welding it all up again.

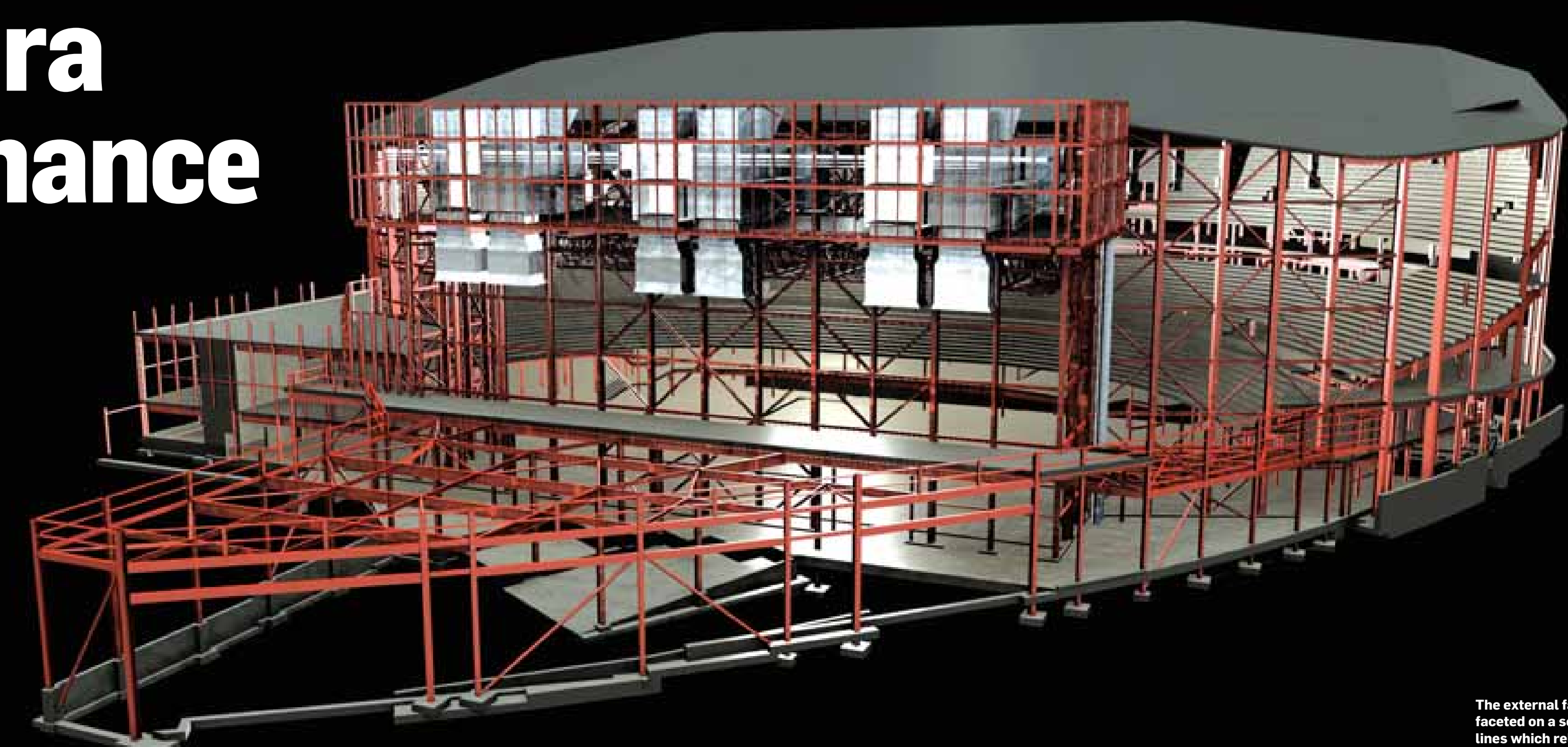
"All you see is a square hollow section column coming down but the amount of work that went into it was immense," says Rowecord's Richard Cherrington.

ISG senior project manager Mike Jenner said: "The design concept led to the decision to use structural steelwork. To achieve the project's slenderness and get the detailing correct would have been extremely difficult with any other framing material."

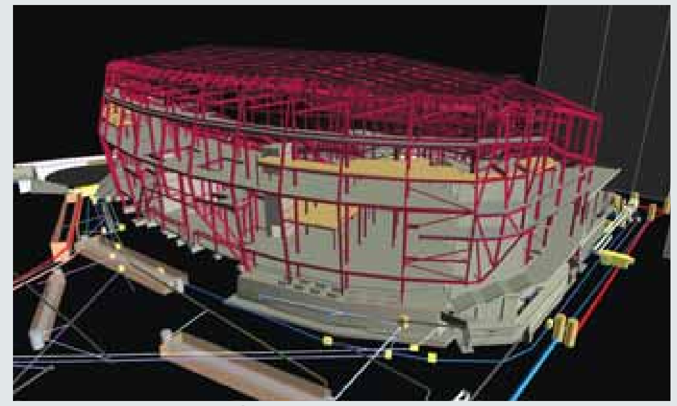
A bravura performance

Steel-frame construction has enabled Populous and Arup to deliver the complex geometries of their Leeds Arena to a tight budget

By Pamela Buxton



The external facade is faceted on a series of grid lines which relate to the seating bowl inside. Three tiers of seating hang off the main structure.



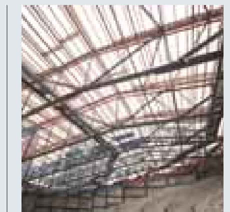
Leeds Arena master model showing the steel skeleton.

ROOF TRUSSES

Thirteen trusses form the main skeleton of the roof, with spans ranging from 40m to 72m, and up to 75 tonnes in weight. These were spliced in the air and took 15 weeks to install.

The trusses span at 9m centres with five spanning onto the 54m-long proscenium arch truss, which was delivered to site in 32 sections and assembled there ahead of a 75-hour continuous installation.

When Arup joined the BAM Construction project team, after first acting as technical adviser to the council, one of its first innovations was to rework the roof design. Originally the trusses were combined, with two layers of expensive



Roof trusses were assembled on site and continuously installed over 75 hours.

acoustic cassette build-up.

Arup's more economical solution was to make the trusses deeper in combination, with a 150mm top layer of in-situ concrete and metal decking that forms the roof.

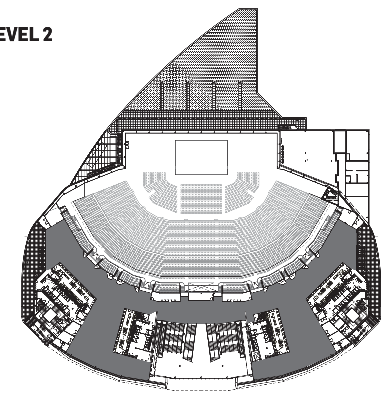
A second internal acoustic layer of boards and insulation is positioned 1,250mm down from the concrete, thermally isolated from the main structure.

In such a city-centre location, acoustic efficiency was a high priority to limit the impact of noise on the surrounding area, so a similar approach has been used for the walls. Here there is a gap of 500mm between the external precast concrete and internal walls.

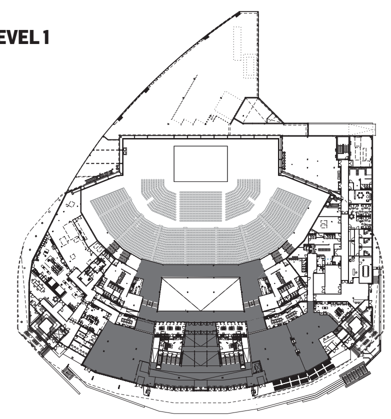
"We increased the overall mass of the roof to make the acoustics work, pushing up the trusses into the void and making them deeper so they could take the significant mass," says Arup's Jim Bell.

PHOTO: KATIE ROGERS

LEVEL 2



LEVEL 1



Leeds Arena will be the UK's first "supertheatre", according to its architect, Populous. Under construction on a tight city-centre site, the 12,300-seat venue will host both music and sports events and feature a distinctive cranked and faceted steel-framed form.

American-style sports arenas usually have in-the-round or horseshoe configurations, but the £60 million Leeds venue will be based on a traditional theatre format built on a much larger scale aided by both an enhanced acoustic performance and a massive 54m-long by 10.5m proscenium arch that supports one-third of the roof structure.

Leeds was one of the few British cities that didn't have an arena. The council is developing the scheme to attract regeneration in the area surrounding the Claypit Lane site north of the city centre — the highest part of the city.

The design takes advantage of the 8m drop in height across the site to allow the arena to nestle slightly, reducing its visual impact. At the rear, it is bounded by the ring road but the front will open on to a public plaza.

Externally, the facade is faceted on a series of grid lines relating to the geometry of the seating bowl within, where three tiers of seating hang off the main structure, with a row of boxes between the lower/main and upper tiers.

Around the column-free bowl are a lower concourse and catering facilities on the ground floor, and a main concourse on the second. VIP areas are on the third floor with another concourse on the fourth. In the fan-shaped arrangement, all seats face the centre of the performance area, with a longest distance to the stage of 68m compared with a standard arena's 95-110m.

The arena contains 4,200 tonnes of steel, which enabled the team to create long-span roofs and overhangs.

"We wanted to create a cathedral-like experience," says Populous associate principal John Rhodes.

The arena's structure contains 4,200 tonnes of steel. "A steel frame was a really good solution for this building. We have some quite long-span roofs and complicated geometries and overhangs and to have created that in another material would have been very difficult," says Arup associate director Jim Bell, adding that nothing on the building was orthogonal.

'A steel frame was a really good solution for the complicated geometries'

"The building is a really nice balance between steel for the spanning and concrete as an acoustic barrier."

At £4,800 per seat, the cost is two-thirds that of a traditional arena seat, according to Rhodes, who describes the building as rugged and economical. Crucial to achieving such a tight budget was the team's use of a co-ordinated bim model estimated to have saved a tenth of the overall building cost, including £300,000 on steelwork alone.

"Leeds Arena was designed as compact as possible for specific volumetric and acoustic purposes, so the thorough integration of all built components was key," says project architect Nuno Guerreiro.

The building is designed to be flexible enough to cater for all types of events and formats with the help of two floors of internal rigging above the stage and a 60-tonne loading capacity.

The first 16 rows will be retractable to create room for a thrust stage or mosh pit, and for smaller events a curtain can be pulled around both sides to reduce capacity and create a more intimate atmosphere.

Externally, the honeycomb-like elevation is conceived as a "kaleidoscope" of glass, mesh and metal "shingles" set at 45 degrees and animated by a tracery of LEDs plus projections tailored to suit the event taking place. Windows are located to take advantage of key views over the city. Shingles fade to white towards the top of the building to reduce impact.

"The overall shape of the building and the geometry of the steelwork was the most challenging part," says Robin Hamill, project manager at Fisher Engineering. "It didn't lend itself to very easy structural steel detailing."

Another issue was an accelerated timetable in order to procure the steel in the most cost-effective way. The arena is due to complete next spring in time for a summer 2013 opening.

PROJECT TEAM

Client
Leeds City Council
Lead architect Populous
Structural engineer Arup
Main contractor
BAM Construction
Steelwork contractor
Fisher Engineering

CRANKED FACADE

Fifteen buttresses from the main steel structure enable the building to crank at a height of 30m.

Initially, the engineers looked at making this part of the primary structure, but this presented difficulties because of the interface with the glazing system, so the facades are instead supported by a secondary structure.

"The main challenge was the geometry. Every element was inclined in two directions and it's very difficult to draw that, which is where the power of 3D modelling comes in," explains Arup's Jim Bell.

Because of the 45-degree angle of the glazing system, a lot of the steel connections had to be co-ordinated within hidden connections. With the crank creating an incline of 22 degrees, drainage was also an issue, especially over the entrance where the audience would be vulnerable to rain run-off.

The solution was a system of hidden gutters and pipework within the tracery of the facade to take the water away to the sides and into the rainwater storage system.

Above: The 22-degree incline on the facade uses a system of concealed gutters and pipework to protect the audience from rain run-off.

Partial section shows how cranked columns form the building's exterior shape.

IMAGES: POPULOUS

Steel steps up to satisfy thermal mass demands

Despite belief to the contrary, thermal mass can be achieved in steel-framed as well as concrete buildings

By Pamela Buxton

Want to achieve thermal mass? You'll need a concrete-framed building then, won't you? Not necessarily, say building engineering experts and the steel industry — which is understandably keen to show that thermal mass can be used successfully within steel-framed buildings too, despite common perceptions to the contrary.

Indeed, in recent research by the British Constructional Steelwork Association and Tata Steel only 9% of respondents associated thermal mass with steel.

The capacity of buildings of all construction types to provide a comfortable and stable internal environment in the most energy efficient way possible is a growing priority, given rising energy prices and the projected increase in average temperatures over the next century due to climate change.

"Building performance engineers can have a beneficial effect on carbon performance" **Edward Murphy**

"It is a common misconception that a building needs lots of concrete or masonry to achieve thermal mass. In fact we only require a thin skin of concrete or masonry, and this can be constructed on a steel frame every bit as easily as on a concrete frame, provided the concrete or masonry surface is exposed directly to the internal environment," says Edward Murphy, technical director of engineering and development consultant Mott MacDonald.

Doug King, visiting professor of building engineering physics at Bath University and founder of consulting engineer King Shaw Associates, believes that building designers need to make more use of thermal mass in buildings of all construction types, including lightweight steel and timber as well as concrete.

'We only require a thin skin of concrete or masonry, and this can be constructed every bit as easily on a steel frame'

"I'd estimate that 40% of the energy used to control temperature in buildings is just wasted," says King.

Of course there is nothing new about thermal mass — the Romans after all were experts in exploiting it in hypocaust heating systems. But King says its application today is hampered by a lack of skills and understanding within the industry and education, although he does acknowledge that this is improving.

Fabric energy storage

Thermal mass — also known as fabric energy storage — is the ability of the building fabric, in particular the exposed concrete slab, to absorb excess heat, thus improving thermal comfort and reducing the need for mechanical cooling.

Over a 24-hour cycle, the concrete can absorb and store heat during times of peak temperature, then release it later as internal temperatures fall at night time. After the concrete has cooled sufficiently, it can re-absorb heat when temperatures rise again. Such an approach works best in buildings, such as schools and offices, which do not have round-the-clock occupancy, rather than those that do, such as hospitals.

Concrete is effective for this use because it readily absorbs heat by radiation, but its relatively low conductivity means the heat remains isolated within the material.

"You can warm concrete and it will absorb an awful lot without its temperature changing a great deal. If we can have that exposed in a point of direct contact with the space, we can use it to absorb the heat of sun, people, computers and other electrical devices," says Mott MacDonald's Murphy.

The thickness of the concrete slab required is a moot point. A thickness of 100mm of concrete, which can be accommodated in both steel and concrete buildings, is generally considered the optimum amount as long as the concrete is exposed directly to the internal environment, with the first 25mm playing the greatest role.

Beyond 100mm, there is little gain in thermal performance. King says it is a myth that the thicker the concrete, the more the thermal mass benefits over a typical 24-hour cycle. In thicker constructions of 1.5m-2m, the response is seasonal. According to King however, only a very thin skin — as little as 30-50mm — is needed to moderate temperatures over a 24 hour cycle for general purposes.

For thermal mass to work, the concrete soffits must be exposed to the air and not covered up — for example with dry lining or a suspended ceiling that would thermally isolate the concrete and limit its capacity to absorb excess heat. Instead, casting in provision for service ducts allows the soffits to be exposed, but this must be planned in upfront to be an integral part of the design.

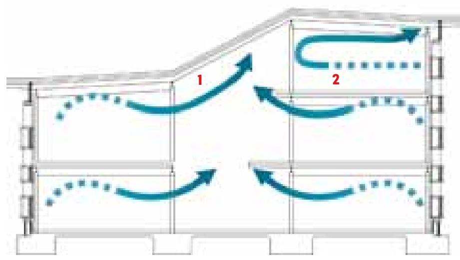
Although high quality commercial buildings, such as AHMM's Angel Building in north London, demonstrate the appeal of an exposed concrete aesthetic, there are many precast flooring systems available with a finely finished surface. And King says that plastering the soffit doesn't reduce thermal performance greatly. Acoustic mineral fibre baffles that hang down from the ceiling are another solution where an exposed concrete soffit is felt to be aesthetically undesirable.

No-one is claiming that thermal mass in itself is a panacea — its full potential can only be exploited within a considered whole building environment strategy alongside factors such as building orientation, glazing and solar gain — but the building fabric can be used to regulate internal temperatures. However, this is achieved most successfully only if it is considered early in the project by the whole design team, says Murphy.

"It's important that architects talk to building performance engineers when they start because we can have a very beneficial effect on the carbon performance of the building without curtailing innovation in the design process."

FOR MORE INFORMATION
www.tatasteelconstruction.com/en/sustainability/thermal_mass/

HOW THERMAL MASS WORKS



1 The structure allows the free flow of air across exposed surfaces
2 Heat is stored in the structure by day and expelled at night by the flow of cool air across the exposed surfaces

CASE STUDY ONE TRINITY GREEN

One Trinity Green won the Breeam award for the UK's most sustainable office building.

Architect
+3 Architecture
Location
South Shields, Tyneside
Completion date
Summer 2012

One Trinity Green is a three-storey, managed workspace containing 41 office, workshop and hybrid units within a 2,700sq m structure. It recently won the Breeam award for the most sustainable office building in the UK.

Thermal modelling was undertaken to inform a detailed mathematical simulation of the building's thermal environment. This highlighted the opportunity to achieve thermal mass by combining the building's steel frame with exposed concrete floors. The design team made this a key part of the proposal, seeking to create the look and feel of a "modern Victorian warehouse".

Using the building's thermal mass was one of a number of sustainability measures that contributed to a Breeam Outstanding rating, with a score of 87.77%. One Trinity Green is Energy Performance Certificate A-rated, with a 20% improvement over the requirements of Part L.

The £5.1 million building is due to open this summer and is being developed by South Tyneside Council in partnership with environmental organisation Groundwork South Tyneside and Newcastle. Funding included £2,466,500 of finance from the European Regional Development Fund.

The new Aston offices of Birmingham Council are expected to achieve Breeam Excellent.

CASE STUDY BIRMINGHAM CITY COUNCIL WOODCOCK STREET OFFICES

Birmingham Council's steel-framed office has exposed concrete floors.

Architect
Associated Architects
Location
Aston, Birmingham
Completion date
Autumn 2011

Birmingham Council's new £38 million Woodcock Street offices in Aston provide 22,000sq m of accommodation over five floors for more than 3,000 Birmingham City Council employees.

To meet the fast project timetable, the architect designed a steel-framed structure combined with exposed concrete floors to achieve the necessary thermal mass to reduce mechanical cooling needs.

Open-plan office floor plates are arranged in three accommodation wings of four storeys each, interconnected by bridges.

A two-storey internal street acts as the primary circulation route through the building.

Built by main contractor Thomas Vale, the project expects to achieve a Breeam Excellent rating, having reduced CO_2 emissions by around 31%, compared to the minimum standards required for Building Regulations Part L compliance.

Sustainability features include CHP, rainwater harvesting and brown roofs.

WOODCOCK PHOTOS: THOMAS VALE

CASE STUDY CHESHIRE POLICE HEADQUARTERS

Cheshire Police's Blacon HQ.

Architect
Fairhurst Design
Location
Blacon, Cheshire

Cheshire Police's new 2800sq m headquarters accommodates 120 combat training spaces for staff and a public inquiry area.

With a tight timetable to deliver the building, the design team chose a steel-framed building with a hollow core deck to incorporate an exposed concrete soffit. According to engineering and development consultant Mott MacDonald, this produced time and cost efficiencies which saved approximately four weeks in time and 5% on the cost of the frame.

The steel-framed building has a hollow core deck with an exposed concrete soffit.