

Steel Intelligence

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PHOTO: MONUMENT PLACE, TIMOTHY SOAR



Welcome to our new *Steel Intelligence* supplement, published in association with Tata Steel and the British Constructional Steelwork Association. These pages will showcase the latest design solutions for steel framed buildings, such as FaulknerBrowns' Derby Arena and Monument Place, David Walker Architects' new office on a tricky City of London site. It will give valuable insights into technical aspects of designing with steel, kicking off with thermal mass in lightweight buildings. As well as looking at the latest projects, we will celebrate the best from the past, with structural engineer Jane Wernick choosing Stansted Airport as her most inspirational steel structure.

Pamela Buxton, supplement editor

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A greater game

Widening ambitions for Derby's new multi-sports centre created a complex set of demands. A lightweight steel frame was the answer

Words Pamela Buxton

London may have its Pringle, but Derby will soon have not just a velodrome but a multi-sports centre covered in gold, silver and bronze metal shingles that incorporates a cycling track among its many sports and uses.

Designed by FaulknerBrowns, the 14,500m² arena is nearing completion at Pride Park on a former car park close to the city's football stadium. The arena grew out of Derby City Council's leisure strategy for two major new dry and wet sports centres. After advising on the strategy, FaulknerBrowns was part of the Maclellan team that won an OJEU competition for the dry sports part of the scheme, and was later novated to contractor Bowmer

and Kirkland. As the project developed, so did City Council ambitions, leading to the inclusion of a velodrome and scope to host entertainment and conferences, all within the same £26m budget.

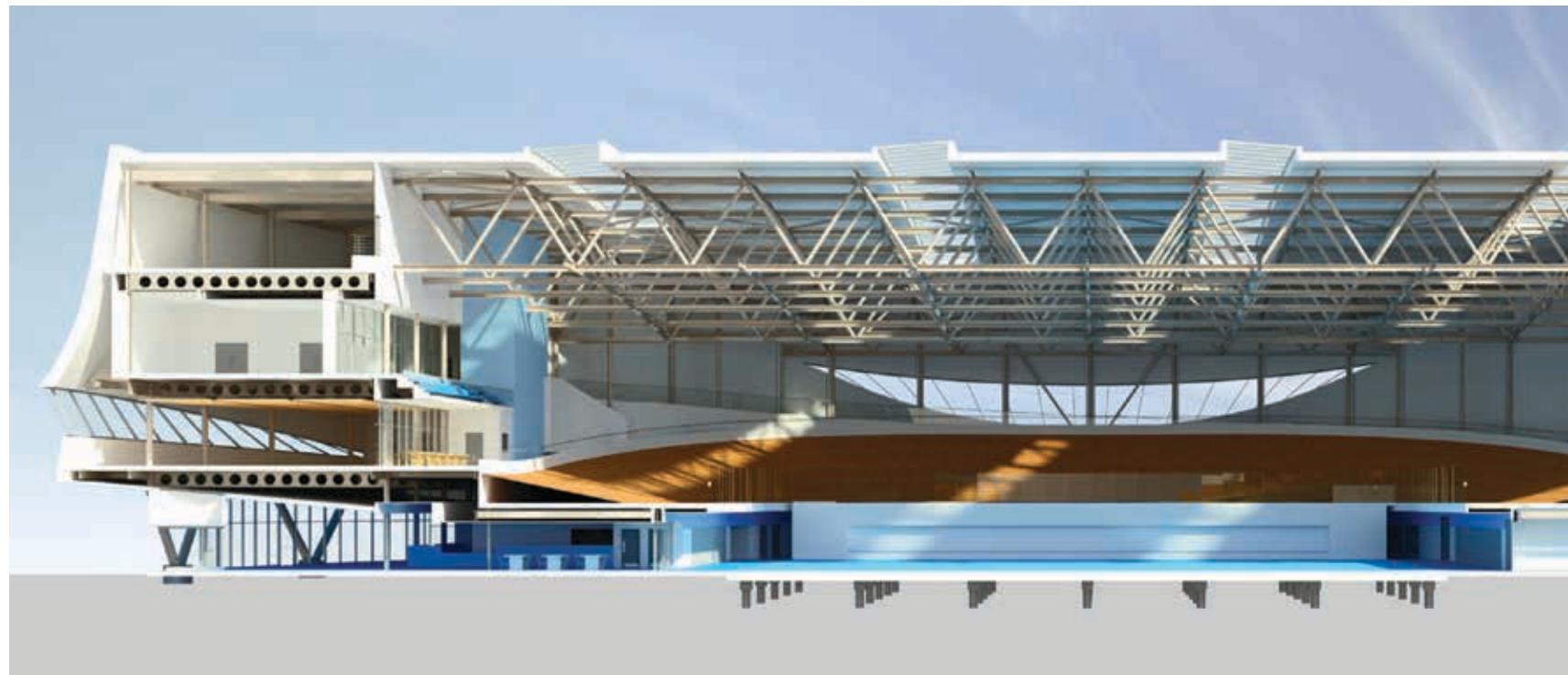
With such a complexity of sports and functions, flexibility and cost-effectiveness were essential. Another factor was the site's landfill past, which meant piled foundations and a relatively lightweight structure were required.

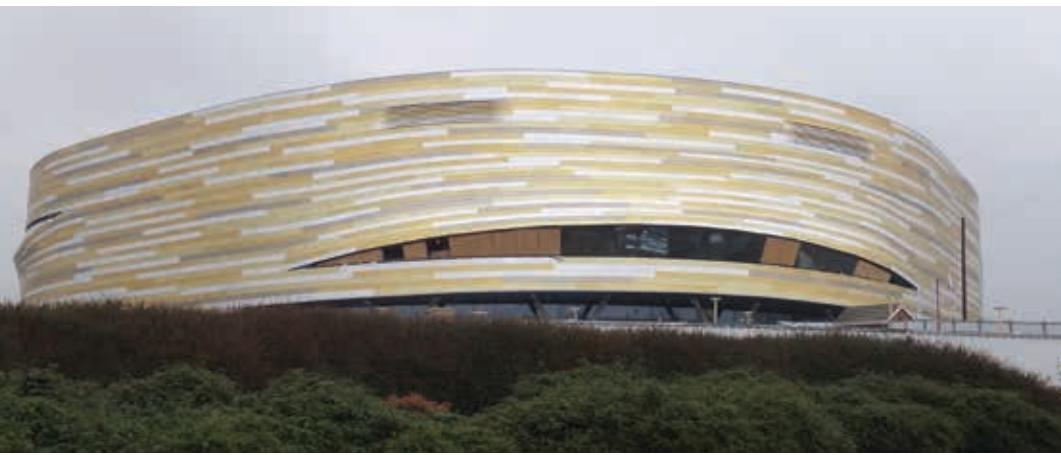
Engineer Arup says a steel frame was the only option to deliver all this with the 85m-wide roof spans needed to create the column-free arena. The 1300t steel structure, delivered by Barnsley-based Billington

Structures, is configured using a perimeter column grid of 6.5m, each picking up the huge trusses that support the roof.

'The aim was to design it as efficiently and rigorously as possible, delivering maximum functionality and operational flexibility. Architecturally, it needed to co-ordinate with the sports overlay so there was no need for additional structure for netting and lighting,' says FaulknerBrowns director Nigel Tye.

The design team was faced with an extremely tight site sandwiched between two boundary fences and with a car parking requirement for match-day access for the football stadium. As a result, the only set-down area for construction materials was





Left Aluminium shingles cover the exterior of the arena.

Below left Section showing the 85m span roof trusses above the elevated cycle track.

Below right The main auditorium seating is positioned at the south of the arena.

the centre of the arena itself.

'The key constraint was the tightness of the site with boundary fences on two sides of the arena. So we had to rotate the track by 45 degrees to make it fit, and configure the other accommodation below and around it,' says Tye.

Unusually, it was decided to lift the 250m cycling track to first floor level to give easy access to the infield, which is the size of 12 badminton courts. Main auditorium seating is to the south, opposite the entrance, with sightlines designed to give good views of the infield courts as well as the cycling.

'There is completely unimpeded access to the central area – you can even drive vehicles in, which opens up a wealth of opportunities

for using the central space,' says Tye.

The concourse follows the contours of the cycling track to curve up at the north end to meet the hospitality area, where there is additional balcony seating over the arena. In total, the arena can seat 5,000 including 3,500 in temporary infield seating.

Externally, the architect began with a square form, then rounded the corners and pared it back further to reconcile the balance between accommodation and budget. This was then 'peeled' up by 4m at front and back to mark the entrance and service point. At the front this creates an imposing entrance, with fitness facilities, hospitality and plant room stacked above. After first considering

a cantilever, the engineer came up with columns in 'V' pairs to provide structural support and visual interest.

As well as the roof, the perimeter column grid supports the auditorium seating and the track. Columns are 400mm in diameter and spliced at second floor level, giving two 11m stretches. All connections are bolted via short stub plates, pre-welded to take the beams.

Seating is supported off the main columns via steel raker beams that follow the line of the terracing. These support precast concrete terrace units.

One of the main challenges on the project was avoiding the timber structure of the cycling track, which was installed by a





BILLINGTON STRUCTURES

velodrome specialist. Below the track, the arena floor – in-situ concrete on a steel deck – supports the 4m wide cantilevered run-off inside the cycling track. Another issue was the dynamics – it was essential, for example, that activity in the fitness suites didn't transfer through the structure to other areas. Arup ran dynamic analysis modelling tests during design development to establish that the proposed stiffness of beams was sufficient.

A distinctive slash of windows over the entrance emphasises the point of arrival with further slashes at the end of the track. Long aluminium lapped shingles are intended to give an impression of movement, as well as suggesting the cycling track itself.

A secondary steel frame creates the cladding substructure. Anodised metal shingles were fixed to plywood that was attached to curved hot rolled purlins, in turn fixed to the columns.

Tye points out that the arena has been delivered for a fraction of the cost of the Olympic velodrome while providing a wider variety of uses and potential for community participation. 'We're on a journey to deliver as much for their money as possible,' he says.

The arena is being fitted out and is due to open at the start of next year. ●

See the video case study online at: www.steelconstruction.info/Video_case_studies

ROOF TRUSSES

Twelve huge roof trusses (above) up to 85m long enabled the design team to achieve the column-free interior essential for sports arena use. The combination of the trusses' size and their position 22m above the ground created a considerable challenge, according to Billington senior design engineer John Camm, who says the 5m truss depth was at the upper limit of what could be transported on a trailer without a police escort. The trusses have diagonal members at angles of 30-45° between the 305mm open section parallel chords. Each truss weighs 34 tonnes and was formed from four sections, bolt-spliced on site. During erection, the middle two sections were bolted together and lifted into position before being joined by the two end pieces. Hot rolled steel purlins link the trusses at 6m spacings, topped with the profiled roof deck, which naturally adapts to the gentle curve of the roof.

Trusses are deliberately aligned with the three 6.5m wide sports courts to accommodate netting and lighting for each space and so avoid additional secondary members. They also incorporate access walkways.

Credits

Client Derby City Council

Project manager MACE

Architect FaulknerBrowns

Engineer Arup (Structural, Civil, Services, Fire, Acoustic)

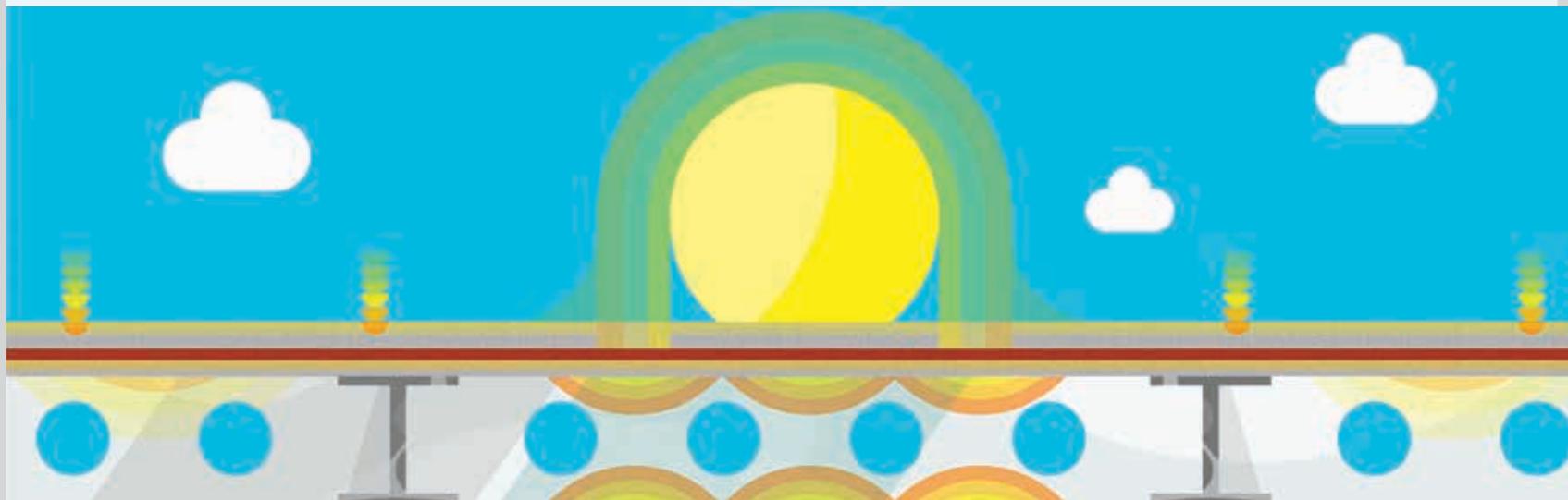
Contractor Bowmer and Kirkland

Steelwork contractor Billington Structures



V-COLUMNS

According to Billington, the eight pairs of feature ground floor columns (above) at the arena entrance were the most challenging part of the structure. Each pair of V-shaped columns, made from 457mm circular hollow sections, required very careful support before being anchored into the floor slab. The columns support the structure from first floor upwards and help provide a focal point for the entrance.



The heat is on

Lightweight as well as heavyweight frames can achieve optimal thermal mass in multi-storey buildings. Steel expert Michael Sansom outlines five key thermal mass issues to consider

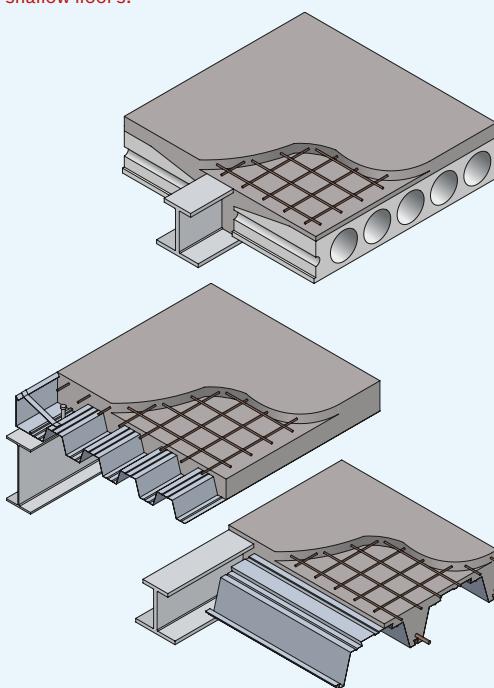
Illustration Jamie Cullen

Frame choice

Thermal mass is a controversial and complex subject that often leads to argument over the merits of lightweight vs heavyweight frame construction. However, effective thermal mass solutions can be achieved with any well-designed structural solution as part of an integrated Fabric Energy Storage (FES) solution, and all steel framed buildings incorporate the optimum 100mm concrete needed for this in their floor slabs. In multi-storey buildings, the upper floors provide the most thermal mass potential.

Three common floor forms can be used to achieve this in steel framed buildings: precast concrete units, composite slabs and shallow floors. Solid or hollow core precast units can be supported on the top flanges of beams or on the bottom flanges of Asymmetric Slimflor Beams (ASBs). Composite slabs comprise reinforced concrete cast on profiled steel decking and are usually supported on the top flange of downstand beams. Shallow floor systems such as Slimdek comprise composite ASBs supporting deep profiled metal decking.

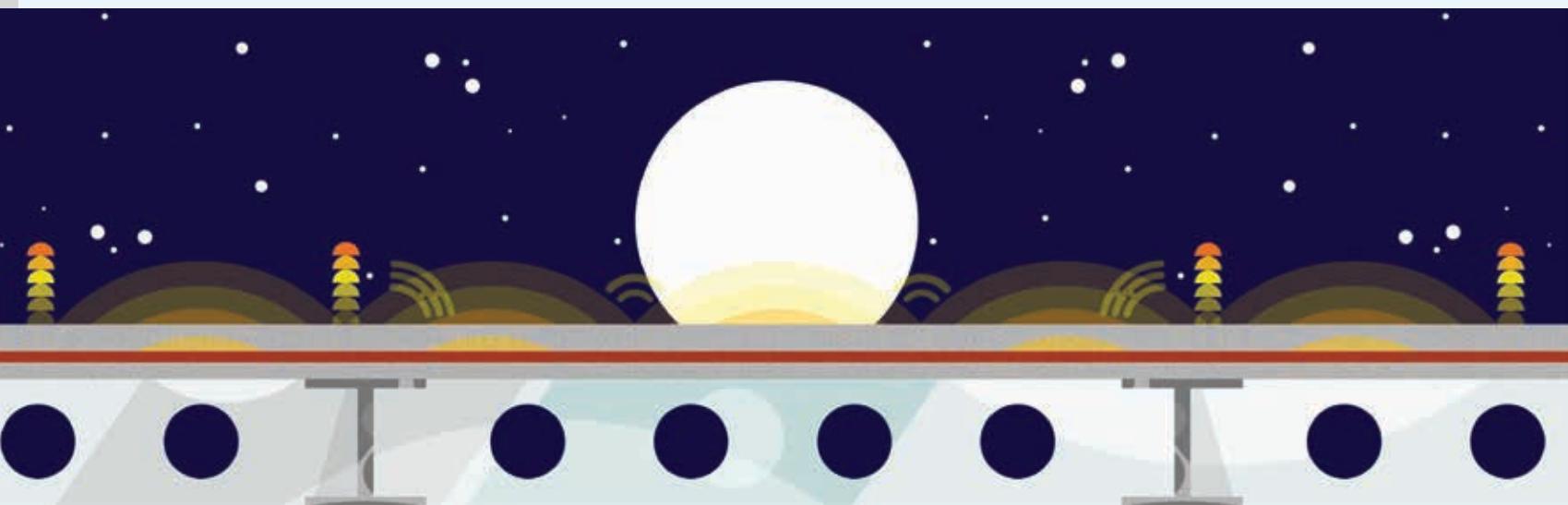
Three ways to the ultimate thermal mass:
From top, precast concrete units, composite slabs, shallow floors.



Thickness

Thermal mass works by using the ability of materials within the fabric of a building to absorb, store and release heat energy and in doing so reduce variation in internal temperature. This helps maintain thermal comfort and prevent daytime overheating by absorbing heat from solar gains, human activity and electrical equipment. Heat stored during the day is purged overnight by using either natural ventilation and/or mechanical means so that the building is then able to repeat the process the next day.

There is general consensus among the BRE, Concrete Centre and CIBSE that when considering a diurnal 24 hour cycle in a UK-type climate, a thickness of 75mm-100mm of concrete in the floor slab is optimal since heat energy cannot easily be extracted from anything any deeper than that. There is therefore nothing to be gained in thermal mass performance by a greater thickness of slab. Anything greater than the optimal level is potentially wasteful and raises extra cost and embodied carbon issues. →



Exposure

One of the biggest misconceptions about thermal mass is that having sufficient mass is enough in itself. What really counts is not just that the optimum level of thermal mass is present, but that it is exposed so the heat energy can get in and out. This means that it remains accessible and is not masked or isolated by raised floors, suspended ceilings, carpets or, in the case of walls, dry lining. However, accessibility can bring acoustic, aesthetic and cost considerations to achieve a pleasing finish to a floor slab. Exposed soffits aren't appropriate for every situation but there is a greater acceptance of them in, for example, more informal office environments. There is also scope for the use of permeable suspended ceilings that still allow a large proportion of the heat to be absorbed by the floor slab.

Integration

Thermal mass is not an isolated design concern but should be considered as part of an integrated, holistic solution – simply exposing the upper floor soffits is not enough. Building orientation, fenestration, shading and servicing should be considered to optimise natural ventilation and limit heat gains. A natural or mixed-mode ventilation system is also needed so the building can be ventilated and cooled at night.

Both passive and active FES systems can be used in steel framed buildings. Passive systems that use natural ventilation to disperse the heat absorbed by the upper floor slabs depend on wind direction and speed and are only suitable for buildings with relatively low cooling loads. Active systems use mechanical ventilation to enhance the heat

exchange with the structure. They may use underfloor ventilation with exposed soffits, exposed hollow core slabs with mechanical ventilation, or water cooled slabs using pipes embedded within the floor slabs.

Building location and type

Location is an important factor – thermal mass with passive FES is not always appropriate in city centres where air quality, external noise and security may preclude a natural ventilation strategy. Generally it is easier to ventilate naturally in a rural or suburban environment. It is also much easier to do so in buildings with intermittent occupancy like offices and schools than in hotels and restaurants that don't allow for the night time cooling phase.

Building form is also an issue. In deep plan offices it is much harder to get the cross ventilation needed although atria can be used to provide and enhance natural ventilation. The difficulties of ventilating highly compartmented buildings naturally however may preclude effective FES strategies in building types such as hospitals and hotels.

Thermal mass is no panacea, but with enlightened designers and the right type of building it can work well. It's independent of frame material, so the design team can use a steel frame and take advantage of other benefits. ●

Michael Sansom is associate director of the Steel Construction Institute and lead author of the publication *Steel Construction: Thermal Mass* which can be downloaded from www.steelconstruction.info/Steel_construction_news

HOW WAS IT FOR YOU?

Engineering experts discuss the issues they encounter when incorporating thermal mass in steel buildings.

Fergal Kelly, director of structures, development consultancy Peter Brett Associates

There isn't much formal education on thermal mass at degree level – it's something you pick up from industry literature – and the general misconception among clients, architects and even M&E engineers is that concrete buildings have inherent thermal mass, and steel buildings don't. Steel construction can achieve the same performance – although an expanse of exposed composite decking isn't always what people want to see. A good compromise is a precast concrete slab with a flush soffit within a steel frame. Systems that use water pipes embedded within a concrete slab seem encouraging from the steel frame point of view since this gets around the potentially difficult issue of exposed soffits.

Angus Palmer, technical director, Buro Happold

People have got the message now that thermal mass doesn't need 400mm of concrete. As a structural engineer I have no problem mixing steel and concrete. Using concrete planks on a steel frame is a good solution – you get the best of both worlds. One of the biggest challenges is the aesthetics of exposed ceilings. You have to manage expectations so that everyone understands what they're getting and careful attention to detail is needed as everything remains visible.

Edward Murphy, technical director, Mott MacDonald

There is a lot of interest in using thermal mass to meet the new CIBSE TM52 and Education Funding Agency guidance on thermal comfort limits in schools. Contractors with lightweight standardised solutions are asking how they can add mass to steel framed structures, perhaps not realising there is already enough mass in the concrete floor slabs. What's important is a good connection between the room air and the available concrete, so we maximise the amount of cooling from the available soffit area.

Monumental win

Lightweight construction made rebuild a better bet than refurbishment on an archaeologically-rich Roman site in the City of London

Words Pamela Buxton

Any redevelopment in the City of London risks opening a Pandora's Box of archaeology, none more so than at Monument Place, a location steeped in history. Close to the site of the Roman bridge over the Thames, not only was the spot likely to be rich in Roman remains, but it is also bounded by Pudding Lane, starting point of the 1666 Great Fire of London that the Monument commemorates.

This important historical context was a major influence on the unusual path to redevelopment of Centurion House and its £22m rebirth as Monument Place.

David Walker Architects was approached

by developer Rockspring as part of a developer competition to come up with a refurbishment and extension of the 1980s building, which provided 61,000sq ft of offices but failed to maximise the potential of the site, suffering from inadequate energy performance, layout and cladding.

Initially, to avoid lengthy archaeological investigations at this sensitive site, they chose refurbishment rather than redevelopment. But as the design developed, it became apparent that to expand the building and improve the efficiency of its floor plates – which had three separate cores and escape stairs – would be

Monument Place viewed from Monument Square.





WSP

extremely complex without achieving all that a new build could.

'By the time we rationalised the plan into a single core (with a single stair), rearranged the bulk and massing, and replaced the cladding, there was very little of the existing structural frame left,' says Walker.

Instead, the design team eventually proposed demolition and redevelopment to increase the accommodation while using the existing foundations. This called for a careful design of the new steel structure – provided by Severfield-Watson Structures – so as not to overload the piles. Some archaeological digging was inevitable with the relocation of the core – revealing a remarkably well preserved stretch of 2000 year old timber wharf piling and a small bath house – but retaining the foundation raft and pile caps meant that the extent of this was greatly limited. 'New build construction was pretty much cost neutral [compared with

refurbishment] but qualitatively it was much better,' says Walker.

As a result, there was a net gain of 30% additional area despite a gross increase of only 15%. The building height was extended from 9 to 10 storeys, but the extra space was primarily due to the inclusion of a single stair rather than three as part of a fire engineered solution – thought to be the first time this had been done in a City office. By positioning the stair core in the middle of the plan, the design team could demonstrate – with the aid of evacuation models – that it did not exceed 18m evacuation distances, avoiding the need for a second core. This translated directly into savings, estimates Walker, of around £5m in terms of additional usable office space.

The key to the success of the structure, says WSP associate director Aret Garip, was locating the building's original construction calculations and verifying the loads. They could then establish that the existing piles

would support the new building, which was of lighter construction than the original but one storey higher. The new building follows the same basic footprint with a column every 3m, but with a relocated single core.

'We worked with the existing site constraints and turned them into a positive outcome for the project,' says Garip. 'The 3m column grid maintained the existing load paths and also suited DWA's facade. We achieved stiffer floors and incorporated shallow beams around the perimeter.'

But whereas its predecessor had floor plates with 10 scattered columns, at Monument Place, WSP could limit the columns within the plan to two by using 15.5m span 525mm beams, picked up by columns every 3m along the perimeter. The only variance from the original perimeter grid pattern was along Upper Thames Street.

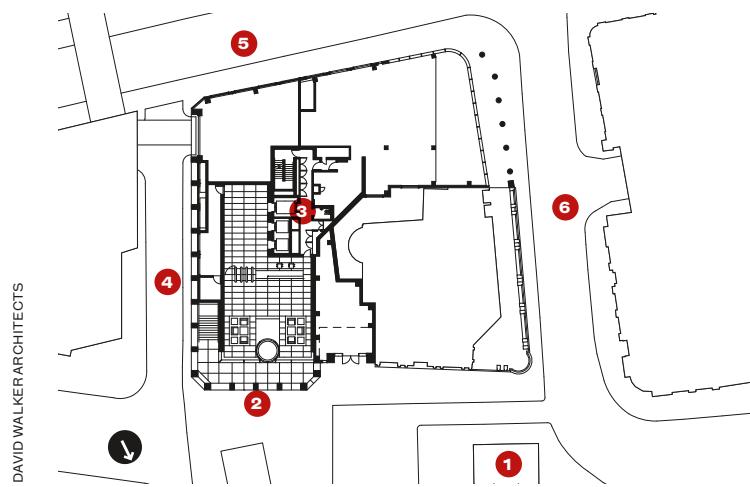
To achieve the extra storey within the massing suggested by the refurbishment

TRANSFER BEAM

The Upper Thames Street elevation required the most structural gymnastics to reconcile the new structure with the existing foundations. Here, the original building had a zig-zag line which was regulated in the new build. To achieve this, the engineers concealed a 1035mm deep perimeter beam spanning 33.6m on the underside of the first floor. Severfield-Watson Structures supplied this in three pieces due to the size of the cranes, and joined them using traditional bolted splices. This beam supports nine storeys of 3m column grid along the upper Thames Street facade and takes the load back into the existing piles.



Ground floor plan



- 1 The Monument
- 2 Monument Place entrance portico
- 3 New single stair and lift core
- 4 Pudding Lane
- 5 Upper Thames Street
- 6 Fish Street Hill

THREE-METRE GRID

Universal Columns measuring 305mm by 305mm are arranged every 3m to align with the existing foundation pads (above). These are linked by 250mm deep, 3m long perimeter beams. Within the plan, floor plates are spanned by a combination of 15.5m rolled beam and fabricated steel I-sections measuring 530mm deep and 250mm wide. In response to the tight floor to floor heights, the engineers used a metal deck with a very shallow profile of 46mm compared with the more usual 50mm.



TIMOTHY SOAR

option, the architect had to work with tight floor to floor heights of 3.5m, giving eventual floor to ceiling heights of 2.6m.

Walker repositioned the entrance from Lower Thames Street to Monument Street, designing it as a colonnaded loggia which incorporates the re-routed High Walk. This walkway previously proceeded along the Upper Thames Street facade of Centurion House, blocking out views from the office inside. Unable to remove it entirely, it was instead re-routed along the Pudding Lane facade. On Monument Street, the building is chamfered and rises to 10 storeys, but on Lower Thames Street it steps down to seven, with landscaped roof terraces at fifth and sixth floor level and continuous glazing between horizontal bands of stone.

The resulting stone facade delivers the transformation of the site that the developer was after. On the Monument Street facade David Walker was keen to combine generous

2.6m by 2.2m floor to ceiling glazing with stone cladding to give the building a solid character suitable for the City of London context rather than a more ethereal one of glass. Here, a stainless steel frame gives the windows more emphasis and sparkle – part of Walker's interest in achieving texture and specificity within a facade without ornament.

Portland was chosen for its texture, using a total of 2,500m² shell-rich Roach Portland on the lower levels and the clearer Basebed Portland above. The stone acts as a rain screen and is mechanically attached to continuous rails fixed to the unitised aluminium frame. It is left open-jointed to ventilate the cavity and to emphasise each stone element while being clearly legible as hung rather than load bearing. 'It's a City material. This building is very London,' says Walker.

In total, the project increased net lettable area by a third to 75,000sq ft and achieved a BREEAM 'Excellent' rating. ●

Above The entrance loggia is clad in shell-rich Portland stone and incorporates access to the re-routed High Walk.

Credits

- Client:** Rockspring
Architect: David Walker Architects
Structural engineer: WSP
Services engineer: MTT
Quantity surveyor: Bond Davidson
Steelwork contractor: Severfield-Watson Structures

Only connect



Structural engineer Jane Wernick chooses her favourite steel structure: Stansted Airport

I could equally have chosen the beautiful and amazing engineering achievement of the Golden Gate Bridge in San Francisco, or Peter Rice's station roof at Lille TGV with its ingenious arches and cable truss-supported roof. But in fact Stansted Airport is for me one of the most inspirational steel structures.

The clear organisational structure of the airport itself is both enabled and enhanced by the expressed, prestressed, steel towers which support the uncluttered roof, 12m above the concourse. They are on a 36m grid, with branches that splay out to support the roof on an 18m grid.

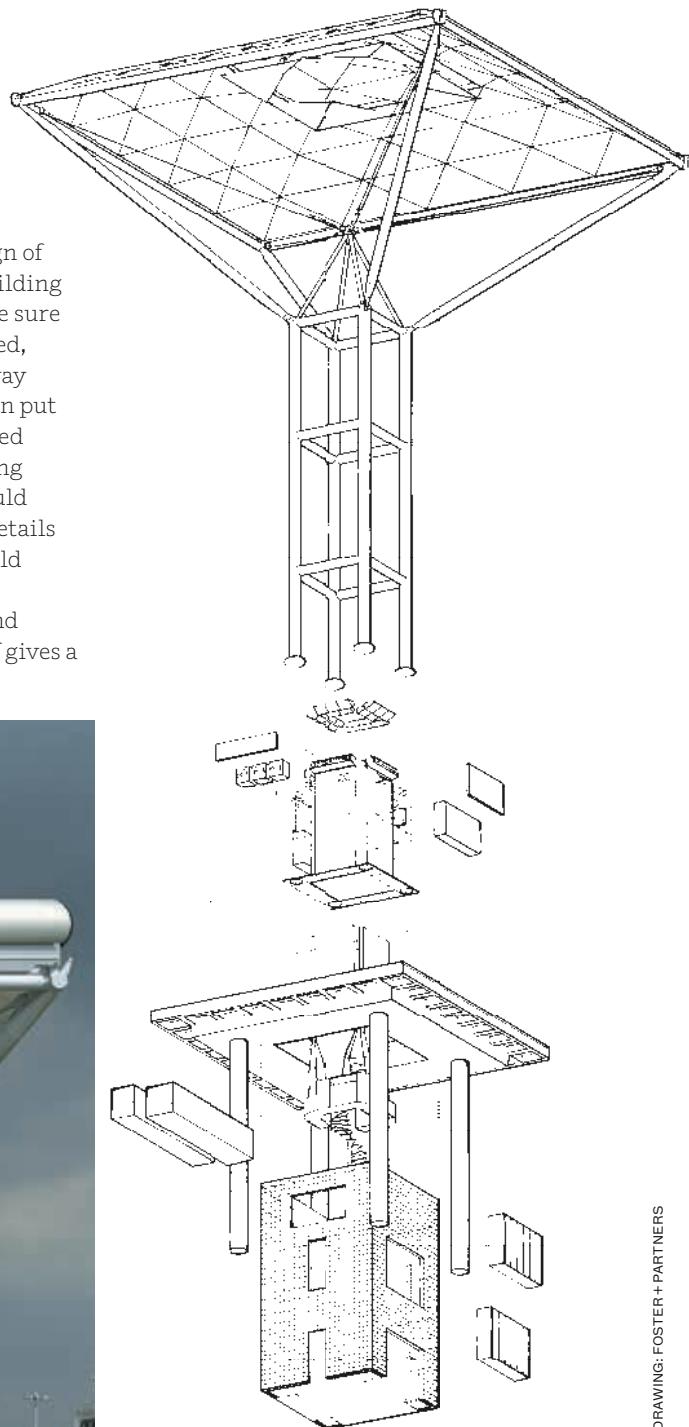
We [at Arup] had the – now rare – luxury

to spend 18 months refining the design of the towers. Normally, we design a building to tight deflection limits so as to make sure the finishes don't crack, but at Stansted, the towers are actually allowed to sway quite a bit – up to 100mm. Rather than put in more steel to stiffen them, we agreed that so long as the structure was strong enough, and wouldn't buckle, we would work with Foster's team to develop details for the perimeter glass walls that could accommodate the movement.

As a result, the towers are light and elegant and the high, undulating roof gives a great feeling of light and space. ●



KEN KIRKWOOD



Foster + Partners collaborated with Arup to create Stansted's distinctive steel towers, designed with a built-in 100mm sway tolerance.

DRAWING: FOSTER + PARTNERS