CONCRETE QUARTERLY | SUMMER 2010 | ISSUE NUMBER 232

LIKE CLOCKWORK
The technical tour de force behind Switzerland's Pritzker Prize-winning Rolex Learning Centre

CLASS ACT
How concrete can help solve the problem of overheating schools, and cut carbon emissions at the same time

IN THE FRAME
A building's structural frame can make a big difference to its embodied energy – so what type should you specify?

mpa The Concrete Centre

WELCOME

TOP OF THE CLASS

Building readers, welcome to CQ – which is now published alternately between Building and Building Design. This will enable a wider range of professionals in the project team to appreciate the benefits of concrete design and construction. And from this issue, you will see there is a lot to appreciate.

The sheer brio of concrete design and construction is realised by the new Rolex Learning Centre, which combines a striking sensual curvature with the pragmatic efficiency of exposed concrete. No other building material can affect such a marriage. The inherent thermal mass of concrete is a winning card in the material's hand. A new report from Arup has found that concrete has the edge on steel when it comes to minimising the embodied carbon dioxide of structural frames. That advantage is even greater when the ability of concrete's thermal mass to reduce operational CO_2 is properly taken into account.

The long-term, holistic benefit of concrete to reduce a building's operational heating and air conditioning is being increasingly recognised and is the reason why it was specified on Montgomery primary school, the UK's first zero-carbon school built to the stringent Passivhaus standard. Elsewhere, the thermal mass provided by the installation of exposed concrete ceiling radiators enabled the new Woodland Trust HQ to realise its green aspirations.

It seems that concrete's market share (see right) is growing. The benefits demonstrated in this issue go a long way to explaining why.

Guy Thompson, head of architecture & housing

Back issues of CQ can be downloaded from www.concretecentre.com/cq

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On the cover: Sanaa's Rolex Learning Centre in Switzerland

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CONCRETE QUARTERLY IS ISSUED AS A SUPPLEMENT TO BUILDING DESIGN AND BUILDING

NEWS ROUND-UP

Concrete structures' market share rises in key sectors

Concrete's market share for structural frames has risen in the key office, education and health sectors, while it continues to be the material of choice for the high-rise domestic sector.

Market research, commissioned by The Concrete Centre and carried out by Leading Edge, found that concrete's market share for education for the second half of 2009 had increased to 49.8%, up from 28.3% for the first half. Meanwhile, for healthcare buildings, concrete's 12-month rolling market share for 2009 was 60.8% compared with mid-year figures of 53.7%. The office market also showed an increase, from the 12-month rolling mid-year figure of 26.1% share for the first half of 2009 to 38.2% for the end of 2009. For the domestic high-rise market, concrete continues to be the material of choice, with concrete structural frames and load-bearing walls taking 83.3% of the 12-month rolling market share of 2009.

Data was collected from 900 projects during 2009 and used to calculate the 12-month rolling market share by floor area and by number of projects.

Andrew Minson, executive director of The Concrete Centre, said: "These are positive market share figures for the concrete structures sector which are supported by a greater appreciation of the free, built-in benefits of concrete construction that include robustness, fire resistance and flood resilience. There is also a greater understanding of the long-term sustainability benefits of concrete with its inherent thermal mass, which can help to significantly reduce operational CO_2 emissions. This appreciation and understanding offer a strong foundation for further market share growth as the construction industry revives."

> THESE ARE POSITIVE MARKET SHARE FIGURES FOR CONCRETE STRUCTURES, AND ARE SUPPORTED BY A GREATER APPRECIATION OF THE FREE, BUILT-IN BENEFITS OF CONCRETE CONSTRUCTION
> ANDREW MINSON

The concrete sector's optimism for the future is supported by recent statistics from the NHBC that show that the market share of timber frame for housing dropped from 27% in the first quarter of 2009 to 18% in the fourth quarter of 2009. While explicit figures for masonry are not collected by NHBC, the results indicate a significant rise in masonry construction. The NHBC figures represent over 80% of all new-build homes in the UK and so provide an authoritative overview of the new home market.

GRAND PIANO
The Shard, designed by Renzo Piano and destined to become Europe's tallest building, does things big. Contractor Mace recently undertook one of the UK's largest ever single concrete pours. Over 36 hours, 700 trucks deposited 5,500m³ of concrete.

Concrete takes central role in cutting construction waste

New guidance from The Concrete Centre explains how to make significant reductions in construction waste. "Material Efficiency: optimising performance with low waste design solutions in concrete" explains how concrete is a low waste material with inherent performance benefits that can improve the overall material efficiency of a building and lower its associated waste production.

The guidance says the designer has a range of efficient concrete solutions that can avoid over-specification and, therefore, waste. These include:

> THE DESIGNER HAS A RANGE OF CONCRETE SOLUTIONS THAT CAN AVOID OVER-SPECIFICATION AND, THEREFORE, WASTE

- Regular plan forms that result in more efficient use of materials, particularly in association with good dimensional co-ordination to avoid off-cuts.
- The omission of downstand beams
- The elimination of bends in services
- Walls and partitions that require less time, cost and off-cuts to install
- Formwork that is simpler and well suited to multiple re-use
- Thinner, flat soffits, provided by post-tensioned slabs
- The use of voided slabs that incorporate air voids into the slab, which can reduce the weight and use of materials while providing an efficient flooring system with spans up to 14m.

The guidance adds that the performance benefits of concrete construction can enable the designer to reduce or even eliminate the use of additional materials and finishes, thereby reducing waste still further.

Download "Material Efficiency: optimising performance with low waste design solutions in concrete", free of charge, from www.concretecentre.com/publications

Emergency shelter solution rolls out to a wider audience

Originally developed for concrete canvas emergency shelters, Concrete Cloth is now available in a roll format and is increasingly gaining the attention of construction firms for building and infrastructure projects.

The material works by trapping a dry concrete mix within a fibre matrix and sandwiching it between a waterproof membrane and a fabric skin. In its dry form it behaves like a thick carpet and can be unrolled in lengths of up to 200m.

The material is flexible enough to conform to complex curves and can be draped over uneven surfaces.

Once wet, the rapid set concrete hardens to 80% strength within 24 hours and becomes a robust, durable, fireproof and waterproof

surface with a design life of over 25 years.

Users of the product include the British Army, Network Rail, the Highways Agency and Costain. Concrete Canvas is now exploring its potential with a number of building designers and contractors.

For further information visit www.concretecanvas.co.uk

WHAT'S COMING UP
www.concretecentre.com/events

Holcim Awards for Sustainable Construction
Open for entries 1 July
For further details, visit www.holcimawards.org

Building Design to Eurocode 2
8 July, Imperial College, London
Course on the features and changes in Eurocode 2 and the National Annex for UK-specific conditions

Concrete Elegance: Museums and Galleries
22 Sept, The Building Centre, London
Projects include the Medieval and Renaissance Galleries at the V&A and the Oriel Mostyn Gallery, Llandudno

BODY OF EVIDENCE

Research by Arup has found that concrete has the edge on steel when it comes to minimising the embodied carbon dioxide of structural frames

New research has shown that most construction methods have similar embodied carbon dioxide (eCO_2) and that the variation is small compared with the variability in calculation method and the reductions possible through concrete material specification. Having chosen a design solution, the structural engineer can play an important role in reducing eCO_2 by as much as 100kgCO_2/m² for a typically sized building. This equates to the personal eCO_2 of a lifetime of goods and services for a UK citizen.

The research, carried out by Arup and commissioned by The Concrete Centre, focused on the structures of three building types – commercial, hospital and school buildings – and compared the eCO_2 impacts of different materials and structural frame solutions. Schemes were developed for flat slab, in-situ and precast, post-tensioned flat slab, composite, steel and precast, and Slimdek. Arup also examined how the choice of structural frame can affect the impact of construction, cladding, substructure and fit-out. M&E are excluded. All the buildings were medium rise and were reasonably regular in layout. In all, 20 structural solutions were evaluated across the three building types in order to determine typical values for "cradle-to-site" eCO_2.

> THE STRUCTURAL ENGINEER CAN PLAY AN IMPORTANT ROLE IN REDUCING A TYPICALLY SIZED BUILDING'S EMBODIED CO_2 BY AS MUCH AS 100KG OF CO_2/M²

FOCUS ON THE FRAME

The sensitivity of the results to variations in impact data for different materials was taken into account and differences in method were separated from material specification choices. This was to show which decisions will actually change the impact of the element under construction. Removal of many of those variables and unknowns not related to structural design provided a powerful set of results that could be used to investigate the detailed design and specification decisions of structural frames and so reduce the eCO_2.

The research did not consider operational or end-of-life impacts and in considering these eCO_2 results the operational energy savings potential of concrete solutions should be borne in mind.

"It was important that the focus was on the eCO_2 of the structural frame only. The question was, what was the impact of the frame and the contribution of the structural engineer on the overall eCO_2 of a building?" says Jenny Burridge, head of structures at The Concrete Centre. "Therefore, the additional long-term operational CO_2 emissions were not factored in. The emphasis was on the eCO_2 of a building's structural frame and how that can be reduced through specification and design. Operational and end-of-life impacts can be added to the cradle-to-site approach of the research in order to obtain a whole life cycle comparison."

RESULTS FOR VARIATION IN SPECIFICATION AND METHOD

The research found little variation between the cradle-to-site eCO_2 of many of the structural solutions. However, the minimum-depth steel solution, Slimdek, consistently had the highest eCO_2, adding some 2,000 tonnes of CO_2 to the lowest eCO_2 scheme. Minimum-depth concrete solutions, such as post-tensioned concrete, provided low eCO_2 impact due to the efficient use of materials. Also, surprisingly little variation was found in substructure impact.

The first important conclusion is that most of the different design methods have similar eCO_2. The material specification can effect a real difference: for example with a typical-sized office building there is the potential to save at least 1,000 tonnes of CO_2 through specification and design.

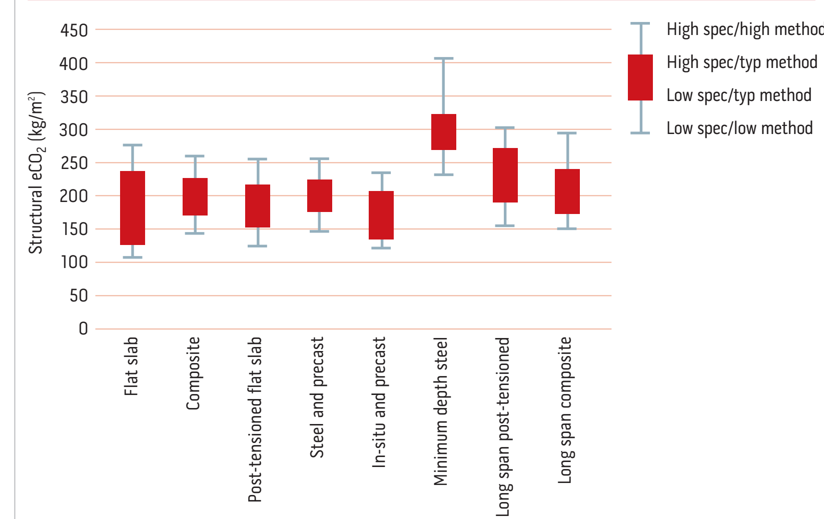
> DESIGN AND MATERIAL SPECIFICATION HAS THE POTENTIAL TO SAVE OVER 1,000 TONNES OF CO_2

Second, the research found that the knock-on effects of changing the structural scheme are relatively small as the changes in facade, foundation, finishes and construction impacts were only 2-5% of the range in the superstructure impacts. However, the knock-on effects on operational energy can be significant.

The specification of concrete was determined to be the main factor in achieving a low eCO_2 solution. The impact of steel cannot be influenced through specification whereas for concrete, it can. For example, the specification of a post-tensioned flat slab can save 15% of eCO_2 and the specification of an RC flat slab can save 35%. This can be achieved by the use of blended cements containing other cementitious materials, such as fly ash or GGBS. However, use of other cementitious materials can affect the construction programme and this must be considered. Furthermore, although not part of this study, the lowest impact frames examined, such as the RC flat slab, hybrid insitu and precast concrete, also offer the opportunity to mobilise the benefits of thermal mass through exposed concrete floor soffits.

"The research proves that the material specification has the potential to reduce the embodied CO_2 of a building," says Burridge. "The potential savings of over 1,000 tonnes of embodied CO_2 are real and demand examination by structural engineers."

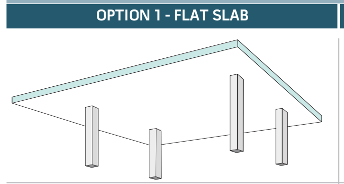
All build types



Frame options

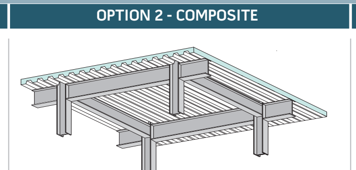
SHORT-SPAN OPTIONS - BUILDINGS A AND B

OPTION 1 - FLAT SLAB



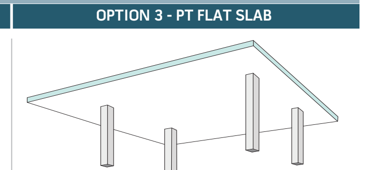
Reinforced in-situ concrete flat slab and columns

OPTION 2 - COMPOSITE



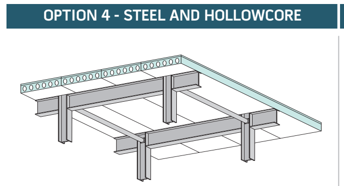
Steel beams and metal decking, acting compositely with in-situ concrete floor slabs. Steel columns

OPTION 3 - PT FLAT SLAB



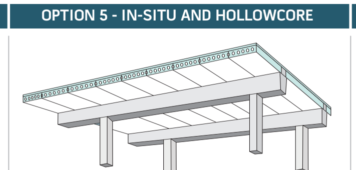
Post-tensioned in-situ concrete flat slab and reinforced in-situ concrete columns

OPTION 4 - STEEL AND HOLLOWCORE



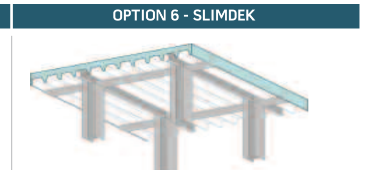
Steel beams acting compositely with precast concrete hollowcore floor slabs. Steel columns

OPTION 5 - IN-SITU AND HOLLOWCORE



Reinforced in-situ concrete beams and columns with precast concrete hollowcore floor slabs

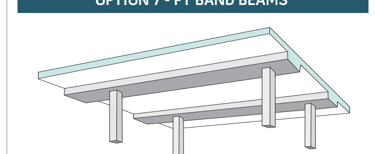
OPTION 6 - SLIMDEK



Slimdek system comprising asymmetric beams and metal decking, acting compositely with in-situ concrete floor slabs. Steel columns

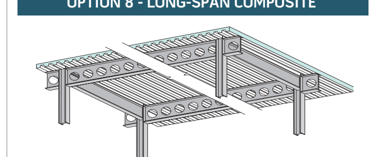
LONG-SPAN OPTIONS - BUILDING B ONLY

OPTION 7 - PT BAND BEAMS



Post-tensioned in-situ concrete flat slab and band beams with reinforced in-situ concrete columns

OPTION 8 - LONG-SPAN COMPOSITE



Long-span cellular steel beams and metal decking, both acting compositely with in-situ concrete floor slab. Steel columns

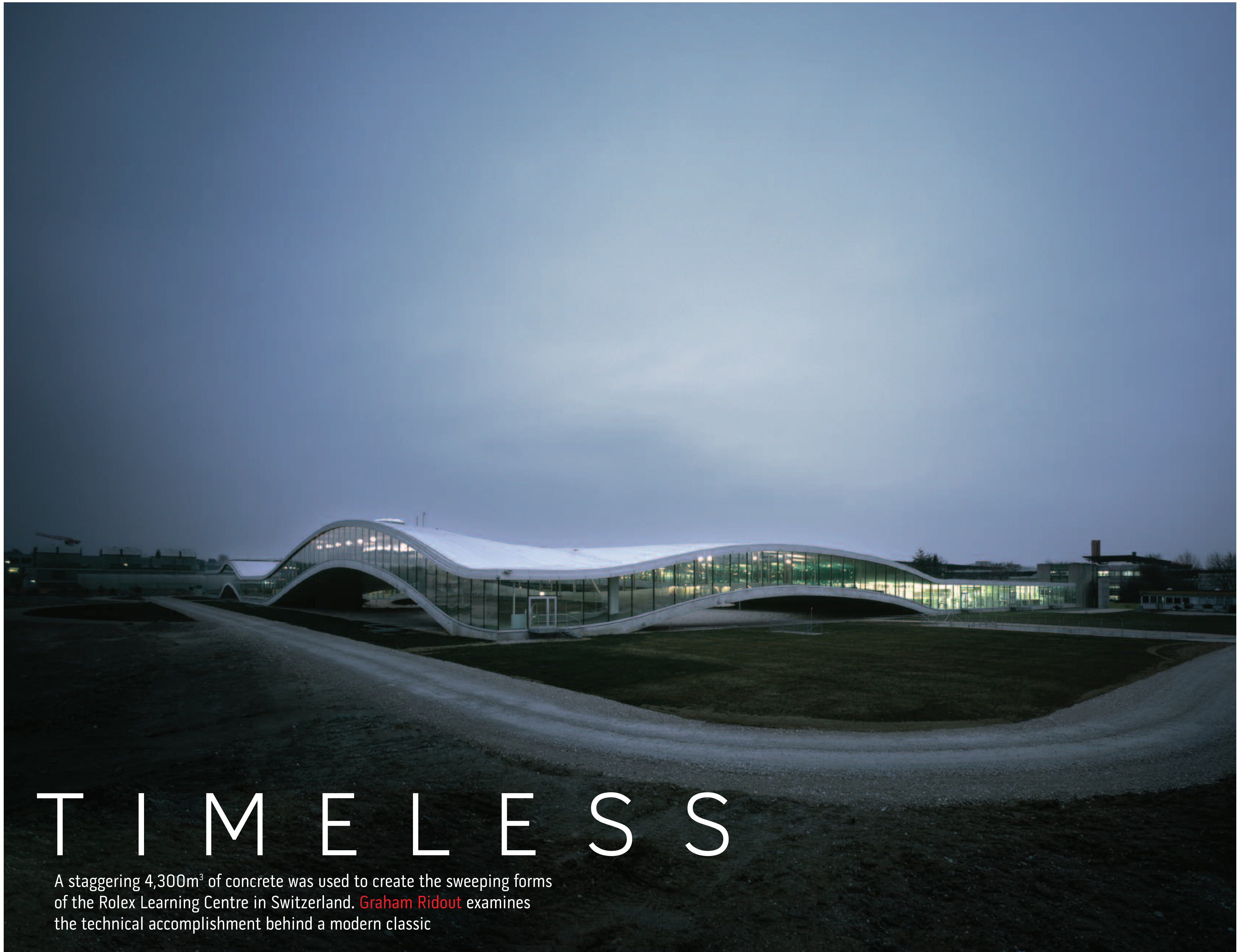
Flat slab vs slimdek

For the office example, the lowest impact scheme is the flat slab option:

	Total eCO_2	kgCO_2/m²
Lowest bound spec	2,000	120
Typical spec	2,900	180
Upper bound spec	4,000	240

The highest impact scheme is Slimdek. The same investigation was done for this scheme:

	Total eCO_2	kgCO_2/m²
Lowest bound spec	3,900	240
Typical spec	4,500	275
Upper bound spec	5,200	320



TIMELESS

A staggering 4,300m^3 of concrete was used to create the sweeping forms of the Rolex Learning Centre in Switzerland. Graham Ridout examines the technical accomplishment behind a modern classic

When you're a world-leading university with a reputation for excellence in the fields of engineering, technology and computer sciences, you're going to want your brand new learning centre to be pretty special. But the Rolex Learning Centre at the Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, which opened in February, is not only extraordinary to look it, it's also a tour de force of cutting edge structural engineering, computer design and construction.

EPFL has a reputation as a centre of excellence for education and research, and is currently ranked equal with Cambridge as the top university in Europe in its specialist fields. In 2004, Japanese architect Sanaa won a competition to design its new library and learning centre. The £65m result is a masterclass of sweeping forms and gently undulating concrete that has wowed the architectural community and earned its designers the 2010 Pritzker Prize. Although the Rolex Learning Centre has a 20,200m^2 rectangular footprint, this is disguised by elevations that twist and turn in many directions as the building sweeps around external courtyards or is perforated by lightwells. Inside the building, the concrete ground floor flows up and down throughout the structure, supported by arches that whisk the slab above the outside concourse area and lower it to ground level. The roof is contoured to rise and fall in harmony, creating a constant floor-to-ceiling height, and there are no walls or partitions to enclose the many different zones within the building.

THE £65M BUILDING IS A MASTERCLASS OF GENTLY UNDULATING CONCRETE THAT EARNED ITS DESIGNERS THE 2010 PRITZKER PRIZE

Sanaa's design is unusual in that the whole of the 20,200m^2 floor area is in effect a single room, albeit one with many different levels. Within its confines are a traditional 500,000-volume library coupled with a multimedia library giving access to 10,000 online journals and 17,000 e-books with workspaces for 860 students, a 600-seat multi-purpose hall, 80-seat restaurant, 128-seat food court, cafe and bar, bank, bookshop, precious book collection, spaces for library staff, careers centre, and areas given over to various student and postgraduate organisations.

EPFL says: "The large, open space is defined by its artificial geography. It groups silent and calm zones along its hills and slopes, rather than offering traditional cloistered study rooms. It recognises the importance of social interaction to learning."

Sanaa's lead architects Kazuyo Sejima and Ryue Nishizawa explain: "Unlike a traditional library, the client wanted a new type of space where many different fields of study exchange knowledge freely and easily. We hope that there will be many different ways to use the space and that there will be more active interaction, which in turn will trigger new activities."

But the real story is how the team behind the building managed to construct it to fulfil the architects' grand vision. Over the last five years, they have stretched the boundaries of concrete design, using extensive computer modelling to configure the shapes of nearly 1,500 formwork panels, for a process that culminated in a massive two-day concrete pour of 4,300m^3.

After winning the architectural design competition, Sanaa worked with Japanese structural engineer Sasaki and Partners to develop an outline structural design. This was then handed over to Frankfurt-based structural engineer Bollinger & Grohmann (B&G) for full detailed design. B&G worked with Swiss engineer Walther Mory Maier to ensure the structure would meet all Swiss building standards.

B&G's project director Agnes Weilandt says concrete was always a prime contender for the structure. Sanaa wanted a high-quality concrete finish for the underside of the slab because visitors walk beneath the arches to enter the building and the arches also provide shelter for alfresco meeting areas. "Structural steel was not a solution, due to the wishes of the architect," she explains. "Also, it would have been too complicated and probably too expensive. For a while, we discussed a composite (steel and concrete) solution, but that was also too expensive. To handle the very shallow curves of the arches, it would have been necessary to provide very high amounts of reinforcement in the concrete sections."

The floor slab consists of two three-dimensional curved concrete shells. The smaller shell is supported by four arches with spans between 30m and 40m long, while the larger shell is supported by seven arches with spans from 55m to 90m.

Each arch has post-tensioning steel cables that are attached to steel anchor blocks at either end of the arch. After the concrete had been poured and gained sufficient strength, the tendons were stressed by jacks to increase the compressive strength and load-bearing capacity of the arch.

Weilandt says: "To analyse the shallow curved concrete shells, we had to find a totally new approach as the building standards don't give us any information about structures with this geometry. So we had to define limits for the stability and deflections according to current standards."

The structural analysis started towards the end of 2005 and was completed in July 2008, with a 12-month break while planning issues were resolved. "We used standard analytical software, but we had to develop several programs to produce results in a more automatic, comprehensive manner. We also developed several programs to automatically produce plans for the

Constructing the shells

B&G's project director Agnes Weilandt says the biggest challenge facing both design and construction was developing a computer model that defined the geometrical shape of the structure. This was achieved by creating a grid of 10,000 datum points that represented the horizontal plane of the building. Each point was given co-ordinates along the horizontal x and y axes – a process similar to Ordnance Survey map references. Then the curvature of the shells was developed by inserting values for the vertical distance from ground level to the underside of the shells (the z axis) for each point - akin to a contour height on a map . The shape of the shells was then manipulated by varying the heights until, many hundreds of computer hours later, the exact form was finalised.

The computer model was a godsend for main contractor Losinger Construction as it was used to define the precise dimensions for the 1,458 formwork panels that were needed for the curved deck for the concrete slab.

Instead of using plywood for the shuttering panels, Losinger opted for sheets of oriented strand board, some measuring up to 2.5m x 2.5m, which were all laser cut for a perfect fit. The panels were overlaid with special membrane to give the concrete a highly-polished finish. The model also helped with the design of the steel trestles required as falsework to support the shuttering and concrete.

With the support structure in place, Losinger set about fixing the 820 tonnes of steel reinforcement, while Freyssinet inserted the post-tensioning cables.

The inclusion of post-tensioning in the design dictated that the structure had to be concreted in one go, which set in train a logistical headache for a building the size of four football pitches. Concrete supplier Holcim mobilised a fleet of truck mixers and Losinger assembled 250 workers together with an array of pumps and cranes to place the concrete. Some 20 truck mixers per hour were needed, for which a series of dedicated access routes was set up to prevent long queues from forming.

At 5am on 11 July 2008, the first batch of the 4,300m^3 of concrete arrived on site. From then until 3am on the Sunday, concreting continued unabated. Workers did eight-hour shifts while the truck drivers notched up over 600 deliveries.

The final act was stressing the post-tensioning cables after the concrete (a C50/60 grade mix with a compressive strength of 80N/mm^2 at 28 days) had cured sufficiently to withstand the tensioning forces.

scaffolding to support the formwork for the concrete."

The resulting analysis defined the thickness of the two shells and the number and size of the post-tensioning cables required in each. In the larger shell, the concrete depth varies between 800mm at the base of the arches and 600mm at mid-span. The smaller shell has a thickness varying between 400mm and 500mm. For the large shell, each cable consists of 31 wires, each with a cross-section area of $150mm^2$; for the smaller shell, each cable comprises 19 of the $150mm^2$ wires. Specialist contractor Freyssinet installed a total of 70 cables in the two shells, with the highest concentration in the longest spanning arch at the northern end of the building. There, 14 cables were required, which were stressed to exert a total load of 86,500kN on the arch to eliminate any horizontal movement.

Weilandt says the completed structure has given B&G great satisfaction. "From our point of view, it shows what is feasible in terms of creating a structure with long, shallow spans, and it was also completed within budget and the given time schedule. At the beginning, many experts didn't believe that it would be feasible but we have proved it is."

Building envelope

The roof structure consists of slender circular steel columns anchored to the concrete floor slab. Steel I-beams are bolted to the top of the columns with timber joists spanning between the I-beams to form the roof deck. The roof is topped with a Sika Sarnafil flexible waterproof membrane.

The curved glass facades on the perimeter, plus those that frame the lightwells that perforate the building, have been designed to adapt to any movements of the concrete floor slab and the lightweight roof structure. Each glass panel is housed in a jointed frame that allows it to move independently of adjacent glazing units. In total, $4{,}800m^2$ of glazing encloses the centre.

TOP
In total, 820 tonnes of reinforcement was required for the floor slab
MIDDLE AND BOTTOM
The concrete pour started at 5am on Friday and lasted for 46 hours. An array of pumps and tower cranes were used to place $4{,}300m^3$ of concrete

Harnessing concrete's thermal mass

A major plus in using concrete for the floor slab is the embodied thermal mass that has been harnessed for heating and cooling the centre. This has helped the building achieve the highly coveted Minergie label – the standard used in Switzerland for measuring environmental excellence.

Underfloor heating pipes were laid into the screed overlaying the concrete floor to warm the building during cold spells. In summer, the cooling load is provided by thermal pumps that have been drawing water from nearby Lake Geneva for 25 years. The installation provides cooling not just for the new building, but also for all the other facilities on the university campus.

The energy efficiency has been further boosted by installing 200mm of insulation in the roof and up to 350mm in the floor, together with high efficiency double-glazed windows. Natural ventilation is used throughout the centre, apart from the restaurant and multimedia library areas, which are controlled by cold ceilings.

Campus-based energy consultant Sorane SA undertook extensive computer modelling to ascertain periods when natural ventilation would suffice or when the underfloor heating needed to be turned on. The computer simulations had to be continually refined because the complex shape of the building exposed certain areas to different climatic conditions.

The building's open-plan format – there are no internal walls or partitions – also meant Sorane had to arrive at a solution which created a steady temperature that didn't vary between different sections of the building.

The vast expanses of glazing that run around the perimeter allow natural daylight to flood into the building, reducing the amount of artificial lighting required. During the summer months, the solar gain within the centre is controlled by external blinds.

The combination of all these measures has reduced energy consumption to $38.5kWh/m^2$ ($139MJ/m^2$) – an impressive rating for such an open-plan space.

PROJECT TEAM
Client: Ecole Polytechnique Fédérale de Lausanne
Architect: Sanaa, with local practice Architram
Structural engineer: Bollinger & Grohmann with local practice Walther Mory Maier Bauingenieure
Mechanical engineer: Enerconom
Electrical engineer: Scherler Ingénieurs-Conseils
Surveyor: Truffer-Renaud-Burnand
Project manager: Botta Management Group
Facade consultant: Emmer Pfenninger
Energy consultant: Sorane
Main contractor: Losinger Construction
Principal subcontractors and suppliers: Roschmann Konstruktionen aus Stahl und Glas (facade); Freyssinet (post-tensioning); Holcim (concrete); Sottas (roof steelwork); Ducret-Orges (roof timberwork); EP Electricité together with Etablissements Techniques Fragnière (electrical installations); Consortium Alvazzi/Atel (mechanical and ventilation installations); Baruchli (underfloor heating); and Pilatus Flachdach (Sika roofing membrane)

MASS APPEAL

The lack of thermal mass in timber-frame buildings makes them liable to overheat, so the team behind the Woodland Trust HQ in Grantham came up with an innovative solution ...

Having realised that timber frame alone would not provide the necessary thermal mass to prevent overheating, the project team of the new naturally ventilated Woodland Trust headquarters hit upon an unusual yet simple solution.

When the employees of the Woodland Trust enter their new $2{,}800m^2$ headquarters in Grantham, Lincolnshire later this summer, they may look up and wonder about the precast concrete panels bolted onto the ceilings. The panels act as thermal radiators and are a novel solution to providing thermal mass to a timber-frame building. The panels cover 50% of the ceilings by area. During the daytime, the exposed concrete panels absorb heat and provide a radiant cooling effect. At night, air is introduced through high-level windows to cool the concrete ready for the next day.

A major issue was the weight of the panels, which had to be thick enough to work thermally but light enough to be supported by the timber structure. Computer modelling and thermal software calculations were undertaken by the environmental engineer to determine what panel thickness would provide the required thermal mass. The panels have a ribbed pattern, and range in length from 5m to 6m. They are 2m in width, and the the ends have a thickness of 250mm, which decreases to 80mm. Some 81 panels were manufactured by Trent Concrete and grout-bolted onto the cross-laminated timber by contractor B&K Building Services. Those panels running down the central part of the offices are articulated on one side to accommodate fluorescent lighting tubes.

A MAJOR ISSUE WAS THE WEIGHT OF THE PANELS, WHICH HAD TO BE THICK ENOUGH TO WORK THERMALLY BUT LIGHT ENOUGH TO BE SUPPORTED BY THE TIMBER STRUCTURE

The building, designed by Feilden Clegg Bradley Studios, has already received a BREEAM "excellent" rating. The timber and concrete combine to provide a solution that is architecturally interesting and performs both structurally and thermally. There is growing recognition of the central role that thermal mass can play in cutting operational carbon emissions by reducing both air-conditioning and heating requirements. As much of the working thermal mass is found in exposed concrete soffits, the incorporation of concrete ceiling panels can help to overcome the limited thermal mass of timber buildings.

PROJECT TEAM
Client: Woodland Trust
Architect: Feilden Clegg Bradley Studios
Environmental engineer: Max Fordham
Structural engineer: Atelier One
Concrete panels: Trent Concrete

ABOVE RIGHT
Some 81 concrete panels have been grout-bolted onto the timber
RIGHT
Feilden Clegg Bradley's design for the BREEAM "excellent" rated headquarters building

COOL FOR SCHOOL

Overheated classrooms are as much a part of the summer term as exam crises – a situation that is set to get worse as schools forgo energy-guzzling air-conditioning to improve their eco credentials. Can concrete and Passivhaus methods provide an answer?

The bets are on for a scorching summer. This could cause misery for many students and their teachers and increases awareness of the need for schools to be designed and constructed with not just climate change mitigation in mind, but also comfort.

Good school design and construction needs to provide efficient facilities and an environment that is both stimulating and comfortable. The need for the latter was underlined when, during the summer heatwave of 2006, many schools reported classroom temperatures of more than 36˚C with pupils suffering from heat exhaustion. Many schools sent their pupils home – which could become a regular occurrence if this summer's forecast comes to pass.

Realising the potential of thermal mass as part of passive solar design (PSD) could help keep schools cool without recourse to energy-guzzling air-conditioning. PSD involves use of the thermal mass potential of heavyweight school buildings, together with solar shading and natural ventilation. It is an approach that is advocated by both the CIBSE Technical Memorandum 36, and by the Department for Education and Skills' Building Bulletin 101 which states: "Summer time overheating can be largely eliminated by the provision of sufficiently ventilated thermal mass."

As a building material, concrete has a high thermal mass capacity. It acts as a thermal sponge, absorbing heat during the day and hence cooling and moderating the daytime peak temperatures. This stored heat is released at night as the building is cooled by night-time ventilation.

The combination of concrete's thermal mass, solar shading and night-time cooling was the most popular strategy used by the DfES Exemplar School Design teams to curb the summer heat.

The previous government vowed to make all its buildings carbon neutral by 2012 and to cut emissions 30% by 2020. In the report Procuring the Future from the Sustainable Procurement Task Force, the £55bn Building Schools for the Future (BSF) programme was singled out as an opportunity to make a real difference. The report called for "the Treasury and the DfES to work with the BSF programme to ensure that it is meeting high sustainability programmes". Concrete construction can help meet these objectives.

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The reduction of energy consumption by minimising the need for air-conditioning is only one way of ensuring that a school building minimises its impact on the environment. Concrete also provides high levels of sound insulation, minimum vibration, inherent fire resistance plus robust, easily maintained wall surfaces all without the need for additional surface finishes or coverings. This minimises the environmental impact of a school's initial construction as well as its day-to-day operation. All this equates to reduced CO_2 emissions and, therefore, a reduced impact upon the environment.

School Construction: High performance buildings using concrete frames and cladding is available from The Concrete Centre. To download a free copy visit www.concretecentre.com/publications

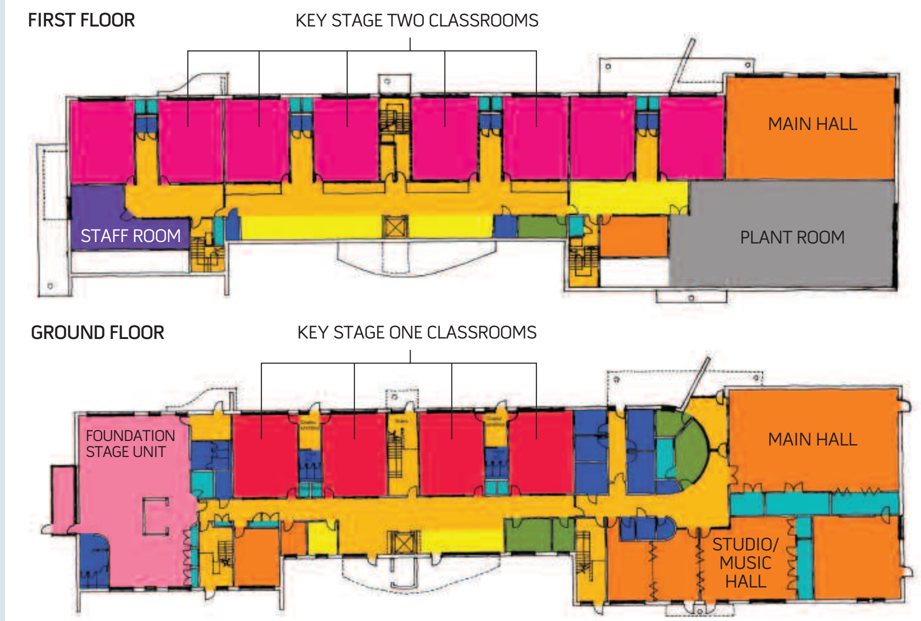
The full Monty

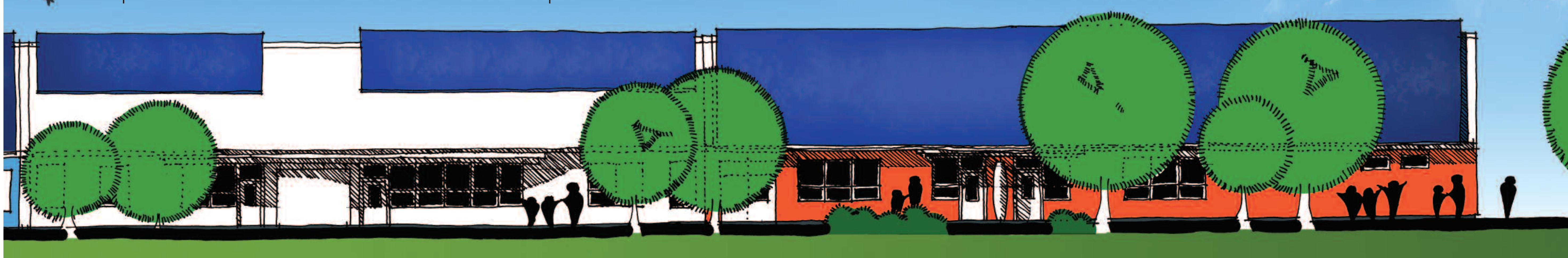
Montgomery primary school in Exeter, designed by NPS Group Exeter, is on target to be the UK's first zero-carbon school built to the Passivhaus standard. Due to start on site in July 2010, the £9m school will cater for 420 pupils, as well as a nursery.

NPS Group Exeter started from the premise that the simplest way to deliver a zero-carbon design would be to build a typical school, replace the gas boiler with biomass and buy electricity via a green tariff. However, it was soon determined that such an approach is unsustainable and without value. In addition, NPS Group Exeter wanted to produce a scheme that had a modular design approach that incorporated relevant modern methods of construction such as off-site prefabrication techniques.

The design philosophy behind the school is based upon achieving the zero carbon "point of build" standard as outlined in the government's document, Zero Carbon for New Non-domestic Buildings: Consultation on Policy Options. ▶

Plan





The rear elevation of the £9m scheme, which is due to start on site in July

▶ This calls for buildings to be operated at their full design potential and determines zero carbon as a net calculation of the building's expected emissions over a year – reflecting imports and exports of energy and smoothing the variances in energy uses throughout the year. In addition, the school is designed to meet the stringent standards of Passivhaus, which require buildings to have extremely low energy usage while providing excellent comfort conditions in both winter and summer. The Passivhaus design approach has a successful track record in mainland Europe and covers the construction of 25 schools in Germany and Austria. The Flemish region of Belgium has recently implemented a school building programme in which every school is to be Passivhaus certified. Montgomery is the first Passivhaus school in the UK.

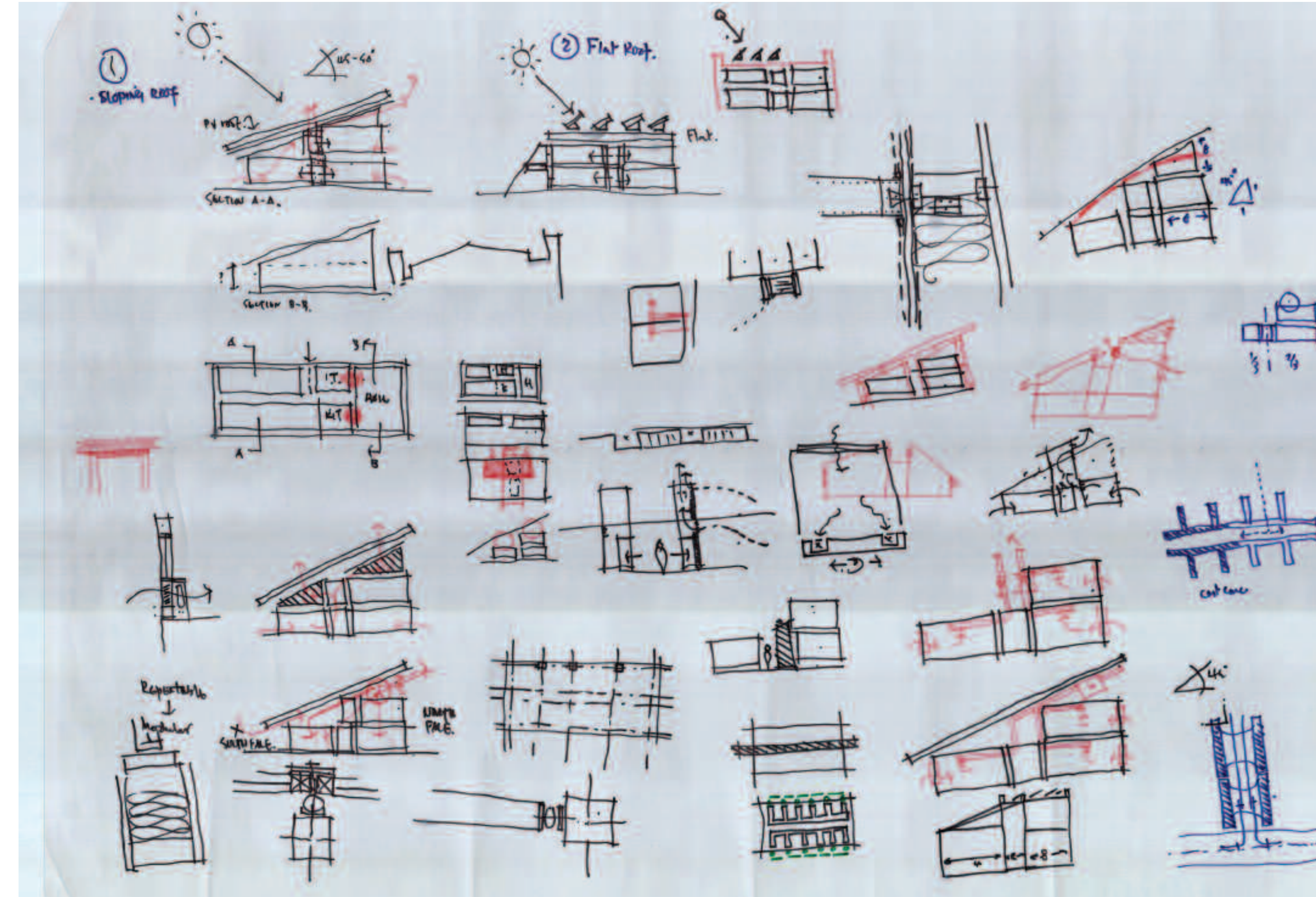
Taking the requirements of zero carbon and Passivhaus on board demanded that the following criteria be met:

- Resource lean – adoption of the Passivhaus standard set a limit of 15 $kWh/m^2/yr$ for heating (compared to 113-164 $kWh/m^2/yr$ for a school built to current building regulations)
- Super insulated – all components of the building envelope insulated to a U-value below 0.15 $W/m^2/K$
- Airtight – minimal air leakage (<0.6 air changes/house/volume/hour which equals an air permeability value of less than $1m^3/hr/m^2$ @ 50Pa)
- Controlled ventilation – comfortable, healthy and sustainable
- Heat recovery – the major part of the warmth from exhaust air is fed again to the fresh air supply with a heat recovery rate above 80% with air being moved from high occupancy spaces to low occupancy ones
- Zero carbon – all electricity provided on-site via photovoltaics
- Robust – the design is expected to not only pass current requirements but to meet the demands of future climate to 2080.

These are tough demands that called for a construction approach that offered future-proofed long-term performance. NPS determined that the high thermal mass and airtightness of precast concrete panels offered the solution. In order to increase the cost-effectiveness and buildability, a modular approach was developed where all the classrooms were designed as identical units incorporating toilets, cloakrooms and stores between. This also allowed the provision of a draught lobby to maintain air temperature and control air leakage while providing direct access to the outside.

The high thermal and airtightness of the precast concrete panels means that no traditional boiler is required. Rather, the "body" of the "heat source" is the pupils and teaching staff. A mechanical ventilation system will also be provided with trace heaters to individual classrooms for extreme weather circumstances.

The new Montgomery primary school is to be built alongside the existing 1920s school, which will then be demolished. In addition to the sustainable construction, it will provide landscaped educational resources including a SUDS pond and wetland area, wildflower meadow, tree walk, and tranquillity court and a horticultural area. Montgomery primary school is due for completion in August 2011 when pupils and staff will find a building that shows that 21st century design and construction can combine to provide an enhanced teaching and learning environment.



LEFT
These sketches were developed at a workshop prior to a successful application to the Zero Carbon Task Force for grant funding

NURTURE FUTURE: A BLUEPRINT FOR ZERO-CARBON SCHOOLS

Tarmac Building Products has unveiled a design blueprint for the delivery of low and zero-carbon schools. The Nurture Future initiative, a partnership with Cartwright Pickard Architects, provides an integrated design combining all the structural, environmental and architectural elements required to develop a low-energy school. WSP is the consultant for the environmental performance of the system.

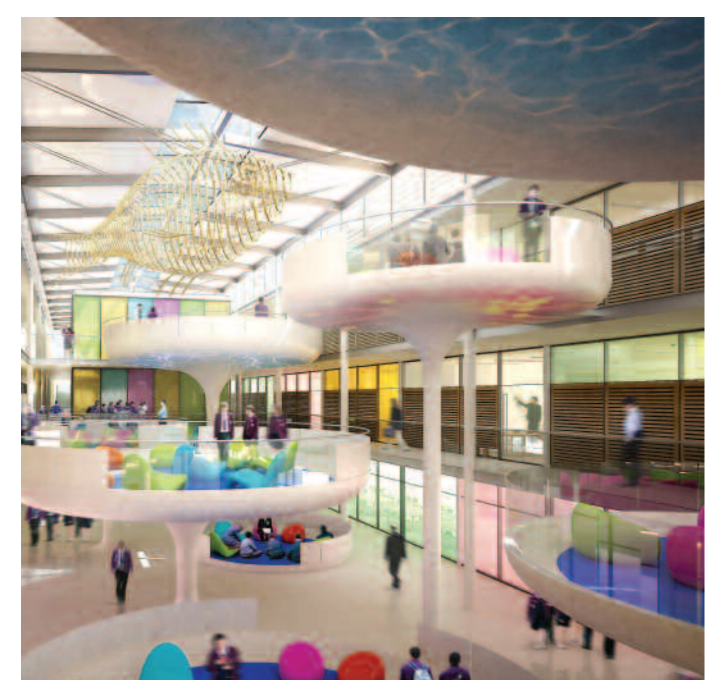
The system uses exposed precast concrete panels and frame components to maximise the potential of thermal mass, together with new heating and cooling technology to cut energy use.

The exposed concrete ceilings can be heated or cooled using circulated water or air to provide comfortable internal ambient conditions. Incoming ventilated air can be pre-heated or pre-cooled through a patent-pending phase change earth duct chamber, which uses the thermal mass of the ground to minimise the seasonal effect of the climate.

The robust, precast design increases speed of construction and has the potential to lower build costs and reduce onsite waste. The system's flexibility means that it can be tailored to suit individual site requirements and offers schools the long-term ability to reconfigure classroom space with moveable internal walls.

Darren Waters, executive director - commercial of Tarmac Building Products, says: "Nurture Future is the first education concept to bring together the expertise of a building product supplier, architect and environmental consultant to provide a viable blueprint for zero-carbon schools."

James Pickard, director at Cartwright Pickard, also highlights the design potential of the system: "This is an exciting proposition from an architectural perspective. Good design is a great influence on well-being and has a positive impact on the experience within a learning environment. Combining this with the latest thinking in creating low-carbon construction has been an exciting journey."



ALL IMAGES
Examples of what a Nurture Future school could look like. The intention is to provide a very flexible solution, with most of the aesthetic features, such as the external cladding, being selected by each school