CONCRETE STRUCTURES

The Concrete Centre™

For the engineer wanting to ensure the optimum structural solution, there is a new resource alongside the Concrete Society – The Concrete Centre. Established to provide a focal point for designers to the UK concrete industry, The Concrete Centre has developed a wide range of initiatives many of which are aimed specifically at the structural engineer and some of which are examined in ‘Concrete Structures’. In addition, to specific initiatives, structural engineers can take full advantage of the free national helpline service, the CPD programme, network of regional engineers and industry events.

A new generation of innovative concrete products and construction techniques has been, and is being, developed. New construction philosophies aim to improve design and construction efficiency, generate innovation and enhanced performance as both client and members of the project team strive to achieve even greater quality and profitability.

For these reasons, together with new building regulations Part E for sound and Part L for energy, engineers are re-examining the use of concrete.

Concrete’s range of structural solutions, its thermal efficiency, inherent fire resistance, acoustic and vibration performance, durability and low maintenance ensure that concrete can offer best value solutions.

The Concrete Centre is committed to providing the engineer with the necessary tools so that these solutions are identified and chosen. Some of these tools are examined in ‘Concrete Structures’. All of them have been developed to allow both client and engineer to successfully achieve the optimum structural solution.

Andrew Minson
Head of Framed Buildings
The Concrete Centre

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CONCRETE
STRUCTURES

The Concrete Centre™

front cover image
Project: City and County Museum, Lincoln
Architect: Panter Hudspith
Engineer: Price and Myers

above
Project: Idea Store, Whitechapel Rd, Tower Hamlets
Architect: Adjaye/Associates
Engineer: Arup

COST AND **VALUE**

Frame cost should not dictate the choice of frame. Rather it should be just one of a number of issues that should be considered when making the choice of frame material. Only then can you be confident that you have the best and optimum structural solution. The following checklist should assist designers and cost consultants to achieve the best value solution. Consider:

Frame costs
The recent rises in reinforcement and steel prices have increased frame costs but the difference between steel and concrete frame costs remains insignificant. (See box right.)

Foundation costs
The foundations typically represent approximately 3% of whole project initial cost. For the heaviest reinforced concrete solution, the foundations will be more expensive, but this represents only a small cost and can be offset by using post-tensioned slabs typically 15% lighter.

Cladding costs
The thinner the overall structural and services zone, the less the cladding costs. Given that cladding can represent up to 25% of the construction cost it is worth minimising the cladding area. The minimum floor-to-floor height is almost always achieved with a concrete flat slab and separate services zone.

Partitions
Sealing and fire stopping at partition heads is simplest with flat soffits. Significant savings of up to 10% of the partitions package can be made compared to the equivalent dry lining package abutting a profiled soffit with downstands. This can represent up to 4% of the frame cost.

Air tightness
New Part L of the Building Regulations require pre-completion pressure testing. Failing these tests means a time consuming process of inspecting joints and interfaces and then resealing them where necessary. Concrete edge details are simpler to seal and have less risk of failure. Some contractors have switched to concrete frames on this criterion alone.

Services co-ordination/ installation/adaptability
The soffit of a concrete flat slab provides a zone for services distribution free of any downstand beams. This reduces co-ordination effort for the design team and therefore the risk of errors. It permits flexibility in design and allows co-ordination effort to be focused elsewhere.

Services installation is simplest below a flat soffit. This permits maximum off site fabrication of services, higher quality of work and quicker installation. These advantages should be reflected in cost and value calculations. Indeed, M&E contractors quote an additional cost of horizontal services distribution below a profiled slab of up to 15%.

Flat soffits also allow greater future adaptability. New layouts and cellular arrangements plus different service requirements are straightforward.

Fire protection
For concrete structures fire protection is generally not needed as the material has inherent fire resistance. This removes the time, cost and separate trade required for fire protection.

Acoustics
To meet the more stringent Part E of the Building Regulations, additional finishings to walls and floors are often required. The inherent mass of concrete means these additional finishings are minimised or even eliminated. (See Tunnel Form feature page 9)

Vibration
The inherent mass of concrete means that concrete floors generally meet vibration criteria at no extra cost without any extra stiffening. For more stringent criteria, such as for laboratories or hospital operating theatres, the additional cost to meet vibration criteria is small compared to other structural materials. (See Hospital Vibration feature page 4)

Exposed soffit
A concrete structure has a high thermal mass. By exposing the soffits this can be utilised through fabric energy storage (FES) to reduce initial plant costs and ongoing operational costs. Furthermore, the cost of suspended ceilings can be reduced or eliminated.

Programme
Concrete frames have short lead-in times and with modern framework systems floor-to-floor construction periods are reduced. Most CONSTRUCT members quote 500m²/week/crane on reasonably large and simple flat slab projects and more where Hybrid Concrete Construction can be used. For example, where precast columns are used in conjunction with post-tensioning, one-week cycle times are possible.

However, more important is whole project programme. Concrete provides a safe working platform and semi-internal conditions so that services installation and follow-on trades can commence early in the programme. And concrete has the flexibility to accommodate design changes later in the process.

Net lettable area
The difference in net lettable area provided by different solutions for a building can be of significant value. Whilst concrete structures may have larger columns, finishing is not necessarily required and typically columns below 0.25m² are not deducted from net lettable area. Reduction in column size can be achieved by the use of high strength concrete.

Concrete structures have reduced floor-to-floor heights, hence fewer steps between floors and less plan area. Alongside these, RC shear walls can be narrower than braced steel frames. Therefore, the stair/stability core area is minimised freeing up more net lettable area.

Whole life value
Concrete’s range of inherent benefits – fabric energy storage, fire resistance, sound insulation – means that concrete buildings tend to have lower operating costs and lower maintenance requirements. This is an important consideration for owner-occupiers and PFI consortia.

Steel v Concrete: the impact of recent price rises
A 50% increase in European steel prices during 2004 has left many in the construction industry reviewing design solutions that have a heavy reliance on steel. A study by leading construction economists Franklin + Andrews* examining the impact of the steel price rises has found that the full fit out whole project costs for concrete framed buildings are marginally less than for steel framed buildings. Costs are for the 2nd quarter of 2004.

Full fit out cost

	Concrete	Steel
3-storey	£5,107,845	£5,190,067
7-storey	£10,796,986	£10,962,115

*Economic Bulletin Volume 7. 2 , July 2004, Franklin + Andrews

HOSPITALS AND FOOTFALL **INDUCED VIBRATION**

The vast majority of hospitals are constructed in reinforced concrete. There are many reasons for this. Construction in concrete is fast and cost effective, and is particularly suited to hospitals because of the inherent benefits of simple services distribution beneath flat soffits, fire resistance, acoustic and vibration performance and the robustness which permits future adaptability.

Recently, steel/composite floors have been marketed as suitable for hospital use on the basis that they can be designed to meet the stringent vibration criteria of hospital night wards and operating theatres. However, until now no study has considered the additional construction costs required to meet the vibration criteria.

It has been previously assumed that concrete floors would meet stringent vibration criteria at no or little extra cost, and that steel/composite solutions would require significant additional material to provide mass and stiffness. This hypothesis is based on the observation that, for a given span, concrete floors are heavier than composite floors, and that mass is a key factor in the dynamic response of floors to footfall forces.

Therefore an independent study was commissioned to quantify the additional steel, concrete and reinforcement required to upgrade 'normal' structural floor designs to meet vibration criteria for night-time wards and operating theatres.

Arup was commissioned to undertake the study because they have developed a method of vibration prediction (described by Young[1]) which has been extensively validated against measurements on both concrete and composite floors. In addition the method used in the SCI's Design Guide on the Vibration of Floors in Hospitals references Young, but is simplified and only applicable to a limited range of cases.

Arup Study

The Arup study consists of four stages:

- Survey of recent hospital structural solutions, examplar designs recommended by healthcare clients and published literature by industry bodies

Structure Type	Location	Response factor[2]	Total Mass % change	Construction depth % change
Composite	Office Night Ward Operating Theatre	– 1.4 1.0	0 131 188	0 37 46
Flat Slab	Office Night ward Operating Theatre	– 1.4 1.0	0 9 15	0 10 17
Post Tensioned	Office Night Ward Operating Theatre	– 1.4 1.0	0 13 31	0 14 32
Slimdek	Office Night Ward Operating Theatre	– 1.4 1.0	0 59 82	0 34 49

- Choice of structural solution type (flat slab, post tensioned slab, conventional steel and concrete composite floor and slimdek construction)
- Choice of design criteria (grid, loadings, durability, fire resistance, deflection criteria and vibration criteria from NHS Estates guidance)
- Design of structures for:
  - Strength and deflection criteria only
  - Night-time ward vibration criteria
  - Operating theatre vibration criteria

Dynamic analysis of a finite element model of a floor structure is used to determine the modal properties (natural frequencies, mode shapes and modal masses[2]) required to make a prediction of the vibration caused by applied forces. Then, using footfall loading functions derived from hundreds of measurements, the footfall–induced vibration response is calculated.

The results of the study, tabulated above, are expressed as the % increase in mass and construction depth required to meet hospital vibration criteria relative to values for a normal 'strength and deflection' design - which would generally be suitable for offices.

Whilst each of these structural forms can be designed to meet stringent vibration criteria, concrete solutions can do this with small increases in depth and material - and minimal additional cost. Material quantities and structural depth must be significantly increased for steel solutions.

(1) Young, P. Improved Floor Vibration Production Methodologies. Arup Vibration Seminar 2001

(2) Acoustics. Design Considerations. Health Technical Memorandum 2045. NHS Estates. HMSO.

Design for Footfall Induced Vibration

A number of simplified methods have been developed to predict footfall-induced vibration and have been incorporated into codes and guidance documents. Typically, the simpler the method, the less precise is the prediction – because simple methods necessarily do not take account of all the parameters that affect the vibration performance. To ensure that safe predictions are obtained, the simpler methods should be conservative. However, this is not always the case in vibration prediction.

The Arup method (to be published in full in the forthcoming revision of the Concrete Society TR43) is based on first principles. The analysis itself uses accurate dynamic representations of floor structures. The footfall loading effects have been developed from the analysis of over 800 footfall force measurements. The overall process has been calibrated against measurements in scores of buildings in the UK and the USA.

Mike Willford and his team in Arup Advanced Technology Group developed their method in response to the lack of reliability they identified in all the pre-existing methodologies. Mike Willford writes "different methods gave completely different predictions and conflicting directions in which to change a design to optimise its vibration performance. We could see that there was little basis for some of the methods, and this was borne out by comparing predictions with measurements in buildings, particularly buildings requiring low-vibration environments". Willford continues "simplified methods currently adopted by practitioners in the UK can give unconservative results and should be used with caution".

SELF COMPACTING CONCRETE

Self-compacting concrete (SCC) is a relatively new product that sees the addition of superplasticiser and a stabiliser to the concrete mix to significantly increase the ease and rate of flow. By its very nature, SCC does not require vibration. It achieves compaction into every part of the mould or formwork simply by means of its own weight without any segregation of the coarse aggregate. Developed in Japan and Continental Europe, SCC is now being increasingly used in the UK where apart from health and safety benefits it offers faster construction times, increased workability and ease of flow around heavy reinforcement. Having no need for vibrating equipment spares workers from exposure to vibration. No vibration equipment also means quieter construction sites.

SCC is a generic term for mix designs that differ from traditional concretes at the molecular interface between the cement compounds and the admixture polymers. The fluidity of SCC ensures a high level of workability and durability whilst the rapid rate of placement provides an enhanced surface finish. SCC's high strengths – overnight strengths typically reach 30-40N/mm2 and 2 day strengths can break the 100N/mm2 barrier – enable easier and more reliable demoulding.

SCC is certainly the way forward for both in-situ and precast concrete construction. The health and safety benefits and the improved construction and performance results make it a very attractive solution.

CASE STUDY 1

Trent Concrete recently produced what is believed to be the world's largest precast structural element using SCC for the new Oxfam building at Oxford. SCC was specified for its high quality finish The single column weighs over 32 tonnes, measures 11.5m in height and 2.1m in width. It was cast in a white self-compacting concrete with an acid etched finish. The column is complemented by 26 smaller but similar shaped columns in buff SCC which weigh 18 tonnes each.

CASE STUDY 2

Used on the new City and County Museum in Lincoln, SCC proved to be the best solution for sloping roof slabs. Architect Panter Hudspith required a formed finish for the top surface and specified SCC which not only reached those parts where other concretes could not but gave a consistent high quality finish to both sides of the slab. The saw tooth roof of the museum has slopes of 22° and 28°. The SCC successfully negotiated the complex reinforcement in nine $25m^3$ pours. Concrete sub-contractor for the project was Northfield Construction Limited and main contractor was Caddick Construction Limited.

POST-TENSIONED CONSTRUCTION

Over the last 5 years, the UK has begun to take note of the potential of post-tensioned (PT) suspended concrete floors with an increased number of buildings being constructed using PT.

The use of PT offers several benefits, not least of which is the fact that the PT floor slabs are generally thinner than an ordinary reinforced concrete slab. They can also be up to 300mm thinner than a floor in a steel frame. This minimises the building's height to the extent that this could mean an extra storey on a ten storey building. The amount of prestress can be adjusted to control deflection, thus enabling the minimum depth of slab to be used. Deflection calculation can also be simpler than for reinforced concrete because the section is uncracked.

PT slabs can economically span further than a reinforced concrete slab. This in turn reduces the required number of columns and foundations and increases flexibility for space planning. Flexibility is further enhanced by a PT slab being able to accommodate irregular grids.

The clear flat soffits of PT slabs enable complete flexibility of service layout. The absence of trimming beams around service cores avoid conflicts between services and structure. There is also flexibility in positioning holes through the slab because tendons are widely spaced and can be positioned around openings.

In addition to all the above benefits, PT equals rapid construction. Thin slabs equals less concrete which equals fewer lorries. There is less reinforcement which reduces fixing time and early stressing of the concrete allows the formwork to be struck quickly.

There are two methods of PT: unbonded and bonded. With bonded systems, the prestressing tendons run through small continuous flat ducts that are grouted up after the tendons are stressed. The bonded systems generally develop high ultimate strengths. However, the bonded ducts are larger than for unbonded. This reduces the effective section depth for design purposes but there is less reliance on the anchorages after grouting.

With unbonded systems, the tendons run through a small protective sheath that allows the tendons to move independently of the concrete. They can be manufactured off-site thereby reducing the on-site programme. The tendons are more flexible and can be deflected in plan to be placed easily around holes. There is also no need for another trade to carry out the grouting.

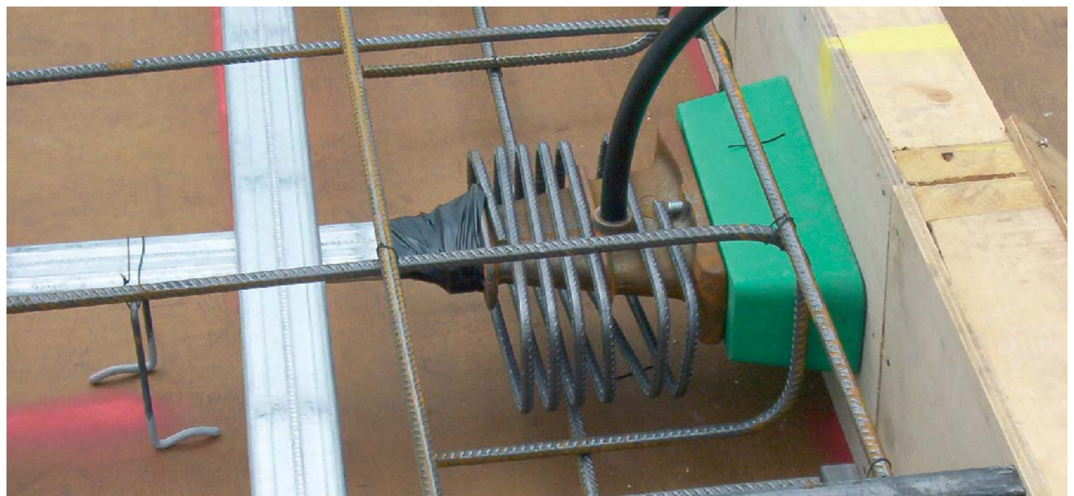
PT slabs generally become economic at spans greater than 7.5m. Typically three main forms of construction are used: flat slab, band beams and slab and ribbed slab.

A flat slab, generally spanning 6m to 13m, provides the minimum construction depth and allows rapid construction. The slab's depth is controlled by deflection criteria and punching shear. The speed of construction makes this form of PT the most popular. Band beam and slab provide large clear spans with the beams spanning up to 20m and the slabs spanning 12m. They still permit relatively simple formwork. Ribbed slabs can span up to 10m and are more structurally efficient than the other two options but because the formwork is more complicated ribbed slabs may be less cost-effective.

Construction of PT slabs is by large pours which are limited only by early thermal shrinkage, the maximum tendon length and the ability to pour and finish the concrete. Where construction joints are required they can be accommodated by:

- Stressing the bays once they have all been cast – this relies on the pours being undertaken on successive days.
- Introducing an intermediate anchorage at the joint location, which can be stressed prior to an adjacent pour.
- Casting reinforced concrete infill strips between prestressed bays.

Post-tensioned slabs can be designed for required fire resistance periods by use of relevant clauses in BS8110. These clauses have their basis in full scale fire tests on post-tensioned slab elements.



Stressing of the tendons should be carried out as soon as possible. Generally, an initial prestress of up to half the final force should be applied once the concrete has reached a compressive strength of 12-15N/mm^2. Final stressing takes place when the concrete has reached its design strength.

Contrary to popular opinion, PT slabs are no more difficult to alter or demolish than other structural forms. Small holes can generally be accommodated between tendons, and larger holes can be accommodated away from the column strips as with RC slabs. With bonded systems, tendons can be cut without the risk of uncontrolled release of the prestess. More care is required for unbonded systems because cutting the tendon will de-stress the element over its full length.

PT slabs are an efficient form of construction and offer a significant range of benefits. It is expected that the use of PT will grow as designers and engineers become more familiar with the construction method, as has happened in other countries.

top left
AMS House showing bonded PT slab with conventional reinforcement over columns and at construction joints. Specialist subcontractor Freyssinet Ltd.

left
Anchorage, bursting reinforcement and grout tube in bonded system. Courtesy: Structural Systems Ltd.

top right
Flat soffits are ideal for services distribution. The locations of PT ducts are marked in yellow. Courtesy: Laing O'Rourke

CASE STUDY

AMS House
Contractor hbg chose post-tensioned in-situ concrete flat slab construction for the £15.4m AMS House development currently under construction at Frimley, Surrey. The three storey, 8,700m^2 office block plus two storey partially underground 470 space car park development is by Kier Property. Architects are ESA Architecture. Structural engineer is Gifford.

The use of post-tensioned flat slabs offered lower costs, increased space for services and lower column and foundation loads due to thinner floor slabs. The floors span up to 9m and are only 250mm deep. A further advantage is the reduced floor deflection under live load. This eliminates concerns about incompatibility with the curtain walling system.

SPREADSHEETS ENABLE EXAMINATION OF **ALL STRUCTURAL OPTIONS IN CONCRETE**

Spreadsheets are an important tool for the structural engineer, and are an ideal medium for investigation and comparison of a wide range of concrete structural options. Two products from The Concrete Centre allow the engineer to fully utilise the power of spreadsheets.

Conceptual design tool

Concept.xls is an invaluable tool for the conceptual design of reinforced concrete frames which enables the comparison and determination of the optimum structural solution. It assists with concrete frame choice, member sizes and reinforcement estimates. Concept provides an extremely fast way of choosing between different concrete frame options for a scheme design. It can be used for time and cost comparisons and gives initial member sizing, quantities of formwork, reinforcement and concrete - all useful information when making a choice of frame. The optimised solution takes full account of the interaction between frame, cladding and foundation costs, as well as, frame construction time.

Data from the publication Economic Concrete Frame Elements[1] is used for member sizing. Spans up to 12m (16m for wide beams) are catered for. Information such as the number of bays, spans, and load is simply entered. Cost and time data, and many of the base assumptions may be changed. The program sizes up and compares conceptual designs to BS 8110 for 13 forms of reinforced concrete frame construction, then ranks them in order of total or construction cost.

Concept.xls will automatically choose the best cost-optimised scheme from the following forms of reinforced concrete frame, or allow the user to investigate their preferred options:

- Flat slab
- One-way slab
- One-way slab, wide beam
- Two-way slab
- Two-way slab, wide beam
- Ribbed slab
- Ribbed slab, wide beam
- Waffle slab, no beams

As it is spreadsheet based, much of the program's work and data is available for inspection, avoiding the 'black box' scenario.

The engineer can then proceed with verification and detailed design in the normal way. Alternatively, the automatic choice can be over-ridden, allowing alternative solutions to be investigated. Printed outputs include floor plans, sections, isometric stick diagrams, cost comparisons and material quantities. A construction cost summary can also be produced, based on default rates for construction costs or those put in by the user.

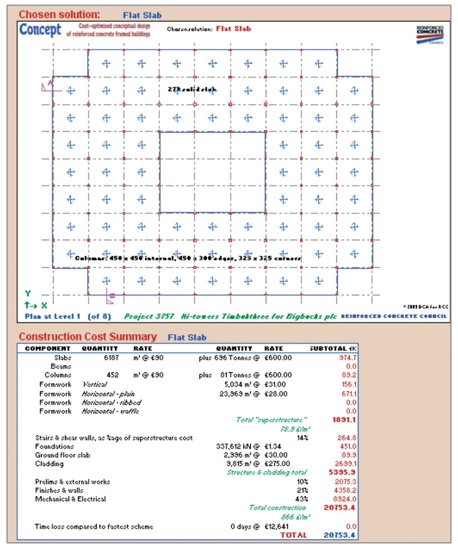
Once the structural frame has been determined the engineer can then use the Design Spreadsheets for detailed design.

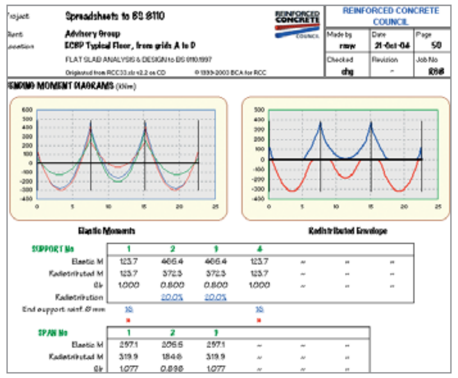
Detailed design tool

Since their release in 2000, the Design Spreadsheets have proved to be enormously popular. An updated Version 2.x introducing new spreadsheets to BS8110 and to the more finalised EN 1992-1-1 (Eurocode 2) and with an over-arching spreadsheet has now been made available by The Concrete Centre.

For the experienced engineer, the spreadsheets allow the rapid production of clear and accurate design calculations. For graduates and new engineers they encourage understanding of concrete design and help the gaining of experience by studying 'what if' scenarios. The individual user is able to answer their own questions by chasing through the cells to understand the logic used. Cells within each spreadsheet can be interrogated and can have their formulae checked and values traced.

Version 2.x introduces four new spreadsheets to the BS 8110 suite. Three of these cover the rigorous design and analysis of one-way slabs, ribbed slabs and beams. The fourth new BS 8110 spreadsheet is RC43 Wide Beams analysis and design, which allows both top and bottom steel to consist of different size bars. RCCen55 looks at the axial shortening of columns according to prEN1992. In addition to a new over-arching menu spreadsheet, 2.x contains updated versions of the previously issued 24 spreadsheets. It also allows for future integration of spreadsheets to prEN 1992, Eurocode 2, as and when they become available.





Concept.xls is available on CD or as a free trial download from www.concretecentre.com. Design Spreadsheets Version 2.x may also be downloaded for trial and examination from www.concretecentre.com. They are shareware products. For commercial use there is a registration fee of £50.00 plus VAT for each product. Access to any updates is available only to registered users.

(1) Goodchild, CH. Economic Concrete Frame Elements. BCA 1997.`

TUNNEL **FORM**

Tunnel form is becoming one of the most common methods of cellular construction in the UK as its cost effectiveness, productivity and quality benefits are being realised on a wide range of projects.

Tunnel form is a fast-track method of construction that is well suited to repetitive cellular projects such as hotels, apartment blocks and student accommodation. Recognised as being a modern method of construction, tunnel form simplifies the whole construction process by enabling a smooth and fast operation that can result in frame costs being reduced by 15 per cent and provide frame programme time savings of 25 per cent.

During the tunnel form construction process, a structural tunnel is created by pouring concrete into steel formwork to make the floor and walls. Each 24 hours, the formwork is moved so that another tunnel can be formed. When a storey has been completed, the process is repeated on the next floor. A strong, monolithic structure is thus constructed that can reach 40 or more storeys in height. The use of high strength concrete ensures fast construction. For the 16 storey, 268-room, Radisson Edwardian hotel in Manchester, early striking strength of 15N/mm^2 was achieved at 14 hours.

Tunnel form creates cells which are 2.4 to 6.6m wide. These can be easily subdivided to create smaller rooms. Where longer spans (up to 11m) are required, the tunnel form can be extended using a mid-span section. The walls can be designed as deep beams and supported at low level on fin columns to permit car parking.

With tunnel form, the structural engineer designs the one-way spanning slabs and walls in accordance with BS 8110. The innovation is with the formwork system. As long as the architect has chosen or is prepared to work within the constraints of regular wall alignments, tunnel form is an excellent structural solution.

The techniques used for tunnel form are already familiar to the construction industry. On average, a team of nine site operatives plus a crane driver can strike and fix some 300m^2 of formwork each day, including placing 35m^3 of ready-mixed concrete: typically 2.5 cells. The speed of construction is underlined by the recently completed student accommodation blocks for Queen Mary and Westfield College, University of London. Here, the superstructure for a 175-bedroom block was built in only 32 days. In addition to speed of construction, the technique provides further inherent benefits of concrete: high levels of thermal mass, sound insulation and fire resistance.

The smooth face of the formwork results in a high quality finish that can be decorated directly. This reduces the need for finishing trades thereby providing additional cost savings and speeding the entire process. A hotel chain explained that the 3mm accuracy of construction meant that carpets, which are typically replaced every 3 years, can be made on a fixed loom and fitted with no trimming.

Tunnel form provides a winning combination of the speed, quality and accuracy of factory production with the flexibility and economy of in-situ construction.

above
Tunnel form construction is becoming one of the most common methods of cellular construction.

right
A strong monolithic structure is quickly constructed.

Photographs on this page Copyright © Grant Smith

Meeting Part E Regulations

The new tunnel form block of student accommodation at the University of East Anglia was acoustically tested in September 2004 with excellent results and proved that with tunnel form there is no need for expensive floor finishes or suspended ceilings.

Two separating floors in the new block, consisting of 250mm of concrete with a stuck-down carpet and no ceiling finish beneath, were tested. They both exceeded the requirements of the new regulations by more than 5dB for both airborne and impact sound insulation.

Two separating walls were also tested, each comprising 180mm concrete with a 2mm plaster skim finish. Both met the pre-completion testing requirement.

The tests carried out at University of East Anglia will give confidence to those choosing tunnel form construction that the construction technique will pass pre-completion testing requirements.

This test, no. 040901, is downloadable from The Concrete Centre's website www.concretecentre.com

STRUCTURAL **SANDWICH**

Precast manufacturer, Techcrete, has expanded the range and potential of the sandwich panel concept for residential, commercial and industrial applications. It is not limited to being a cladding element but can also be used as the perimeter structure.

Comprising of an outer leaf of precast concrete which can be finished with a wide range of stone-like finishes or facings, a layer of insulation and a backing leaf of concrete, sandwich panels offer many advantages. They provide quality-assured factory produced strong, durable, energy-efficient, fire-resistant cladding system. Construction is fast with a fully integrated structure and skin system where panels provide both structural support and external finish.

The two layers of the panel are connected by steel connectors which typically consist of wind and shear connectors. Shear connectors are placed in an orthogonal direction to ensure suitable suspension of the outer leaf. The thermal bridge through the steel connectors is minimal, with a typical diameter of 4mm. Importantly, the system has the advantage of providing structural integrity without placing any reliance on the insulation for load transference.

A Dublin residential development, designed by architect O'Mahony Pike, features 11,000m^2 sandwich panel cladding. Innovatively the panels have been used in a structural capacity on a residential development. The inner leaf of the panel becomes the structural wall and is designed in the normal manner to support vertical loads. Both vertical and horizontal ties are provided at joints to ensure robustness. The outer leaf is separated via connectors and is free to expand and contract. The outer leaf does not support load.

Using the inner leaf of the sandwich panel as a load-bearing structural element to support floor units offers further construction economies and minimises the need for the co-ordination of different trades.

For further information on structural sandwich panels contact the Concrete National Helpline on 0700 4 500 500 or visit: www.concretecentre.com

THERMOCAST FLOORING SOLUTION

Architects are increasingly seeking to design with exposed concrete soffits to gain the benefits of fabric energy storage from the thermal mass of the concrete structure space. Many excellent examples of bespoke precast units used in this way exist. For example the headquarters buildings for both Toyota and Powergen. Tarmac Precast have introduced Thermocast, a coffered floor unit which is produced on long pre-stressing beds in units up to 16m. The method of production makes it a very cost effective flooring solution, particularly since it provides both the floor and the ceiling.

An additional optional feature is that the Thermocast units can be cast with polybutylene pipes through which cooling or heating water can be run. By using radiation and convection to exchange thermal energy the system provides a clean and low energy solution. In this way, Thermocast is a form of 'structural conditioning' as it uses part of the structure of the building as a heat exchange.

Each Thermocast concrete coffered unit is 2.4m in width and up to 650mm deep with spans of up to 16m laced with unseen pipework 50mm below the surface. The system incorporates two circulation systems and uses a plate heat exchanger to transfer the energy from the primary circuit to the secondary circuit. This prevents the possibility of cross contamination from corrosive waters and pollution to the natural water tables through water treatment systems used in the units.

The floor units absorb the heat from solar gain, equipment, lighting and people and so cool the room. The water pumps are the only part of the system requiring energy. Thermocast offers a massive energy saving of 80 per cent compared to conventional fan-coil systems.

The benefits of the system are explained by Christian Struck, an engineer with Buro Happold, "Water at 12 to 14°C can lower the surface temperature of the concrete units to 20°C which can cool the room. You can forget about mechanical ventilation generally if you are able to use windows for natural ventilation."

For further information on Thermocast, contact The Concrete National Helpline on 0700 4 500 500 or visit: www.concretecentre.com

HYBRID CONCRETE CONSTRUCTION

The UK has been slow to realise the benefits of hybrid concrete construction (HCC), despite the widely appreciated construction benefits. One of the barriers to the use of HCC has been the lack of comprehensive guidance. This has now been addressed by The Concrete Centre's 'Best Practice Guidance for Hybrid Concrete Construction'.

Hybrid concrete construction can be described as being 'best of both worlds'. It marries together the advantages of precast and insitu concrete construction with often significant benefits. For example, the adoption of a hybrid concrete frame instead of a composite steel frame on a shell-and-core office project in central London resulted in construction savings of 29 percent and a 13 percent increase in net lettable floor area.

The time is right for hybrid construction. Reports such as *Accelerating Change* from the Strategic Forum for Construction and the *Egan Rethinking Construction* report have focused attention on the need for the UK construction industry to move on from its inherent conservatism and modernise and increase efficiency. The business environment of the UK construction industry is changing. If the industry is to answer its critics and modernise, then it has to examine the potential of different construction techniques and contractual arrangements.

In terms of costs, insitu reinforced concrete is commonly viewed as being the most economic framing option while precast concrete promotes speed and factory quality. Combining the two as a hybrid frame results in even greater construction speed, quality and overall economy. Traditional formwork typically accounts for up to 40 percent of an insitu frame costs. These costs can be significantly reduced by increasing the use of precast concrete which has no on-site formwork requirement. This reduces the duration of operations critical to the overall construction programme. Precasting is not constrained by site progress or conditions and can continue independently of on-site operations. Some HCC techniques can remove the need for follow-on trades such as ceilings and finishes. This allows for an even faster programme. HCC also encourages speed of construction by promoting increased buildability, which should be a fundamental design objective.

Concrete produces robust, and adaptable buildings that are inherently fire resistant, vibration free and quiet. Exposure of the hybrid concrete frame can be used to exploit concrete's inherent thermal properties in naturally ventilated, low-energy buildings. The finish and shape of the exposed units can also assist with even distribution of lighting levels and the reduction of noise levels. Long spans can be easily achieved using large units or by pre-stressing.

HCC is about providing best value. It is not necessarily about first cost, although this alone can result in hybrid concrete construction being chosen. Gains from improved buildability on site soon overtake any material cost differences. Inherent benefits, such as occupier comfort and increased efficiency, lead to potentially massive cost benefits in comparison with other structural approaches. For the full potential of economy, safety, speed, buildability and performance to be realised then HCC should be considered at the beginning of the design process. The new best practice guidance shows how that full potential can be achieved.

For further details on 'Best Practice Guidance for Hybrid Concrete Construction' contact the Concrete National Helpline, tel: 0700 4 500 500 or visit: www.concretecentre.com

HCC structural design involves the following stages:

Stage 1 – Construction stage (dead load and construction loading)

Stage 2 – Depropping (dead load and construction loading)

Stage 3 – Full composite action (dead and live load)
- Flexure
- Shear
- Interface shear transfer
- Anchorage and bearing
- Differential shrinkage
- Deflections
- Cracking
- Toppings
- Openings

In general, composite concrete elements may be considered as being monolithic and homogeneous. Usually, the precast concrete will be stronger than the in-situ concrete. It will generally be conservative to design the elements on the basis of lower strength but the different concrete properties should be acknowledged and reference should be made to BS 8110 Part 1 Clause 5.4. It should also be appreciated that not all the information required will be available at the beginning of the design process. Methods of construction, timescales, materials, etc., should be discussed and agreed with the contractors and other members of the design team as the design develops.

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Gatwick Office Project, courtesy of J Doyle

STRUCTURAL **ASSISTANCE**

The Concrete Centre has developed and implemented a wide range of initiatives aimed at all members of the professional and project team. For structural engineers these include:

Lunchtime CPD presentations:

The following CPD presentations are examples of those available from our regional advisors.

Specifying Appropriate and Durable Concrete Mixes
The presentation will explain how – following the recommendations of the new British Standard BS 8500 (which supersedes BS 5328) – to specify the appropriate concrete.

Post-tensioned Slabs
Over the past 5 years the number of post-tensioned slabs has increased dramatically. This presentation introduces the technique and will give designers the confidence to consider PT at the early stages of project procurement.

Tunnel Form Construction
Reinforced concrete floors and walls are ideal for residential buildings, assisting with compliance of part E of the Building Regulations. This presentation will introduce a technique that allows 24 hour cycle times, greatly speeding up construction.

Hybrid Concrete Construction (HCC)
HCC uses the benefits of both precast and in-situ concrete to improve the speed of construction, surface finish, thermal efficiency and acoustic performance. To gain the most benefit HCC should be considered at the early stages of procurement – this presentation will demonstrate how this can be done.

Design tools:

Concept.xls
Concept.xls is a sophisticated new spreadsheet for the conceptual design of reinforced concrete frames. Concept assists with frame choice, member size and reinforcement estimates. Concept.xls is offered as shareware, i.e. try before you register. Registration costs £50 plus VAT. For full details visit: www.concretecentre.com.

Design Spreadsheets
The design spreadsheets help with the rapid production of clear and accurate design calculations for reinforced concrete elements. The spreadsheets are offered as shareware, i.e. try before you register. Registration costs £50.00 plus VAT. For full details visit: www.concretecentre.com

CALcrete
CALcrete is a comprehensive suite of 16 computer-aided e-learning modules on concrete materials, design and construction. Contains up to 20 days worth of essential CPD learning material and is fully updated to the latest EC2, January 2004. Trial downloads are available from: www.concretecentre.com.

Practical yield line design
This publication is intended for use by experienced engineers wishing to extend their portfolio of methods of analysis and design for more efficient and effective designs. The publication is an outcome of the European Concrete Building Project at Cardington. For further information and pdf downloads visit: www.concretecentre.com

Publications:

Best Practice Guidance for Hybrid Concrete Construction
Definitive guidance and case studies on how to realise the benefits of hybrid concrete construction where the construction techniques of precast and in-situ concrete are married to complement each other. For further details tel: 0700 4 500 500 or visit: www.concretecentre.com

Ecoconcrete
Ecoconcrete is aimed at all who are interested in the ways in which cement and concrete can contribute to a sustainable built environment. Most designers know that concrete is a popular and robust building material. Fewer will appreciate that it is a key material choice for eco-designers. For further details tel: 0700 4 500 500 or visit: www.concretecentre.com

Best Practice Guides
A new series of case studies based on the St George Wharf development in Vauxhall, London, where the recommendations and innovations resulting from the European Concrete Building Project at Cardington were trialed. The first three studies to be published include: St George Wharf Overview; Early Age Concrete Strength Assessment; Early Age Construction Loading. For free copies tel: 0700 4 500 500

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