mpa
essential materials
sustainable solutions

Jersey College, Jersey. Acknowledgement Architecture plb

Offering the most cost-effective construction solution

School Buildings

Post-tensioned in-situ concrete is **6.8%** cheaper than the equivalent steel option in terms of overall construction costs

Contents

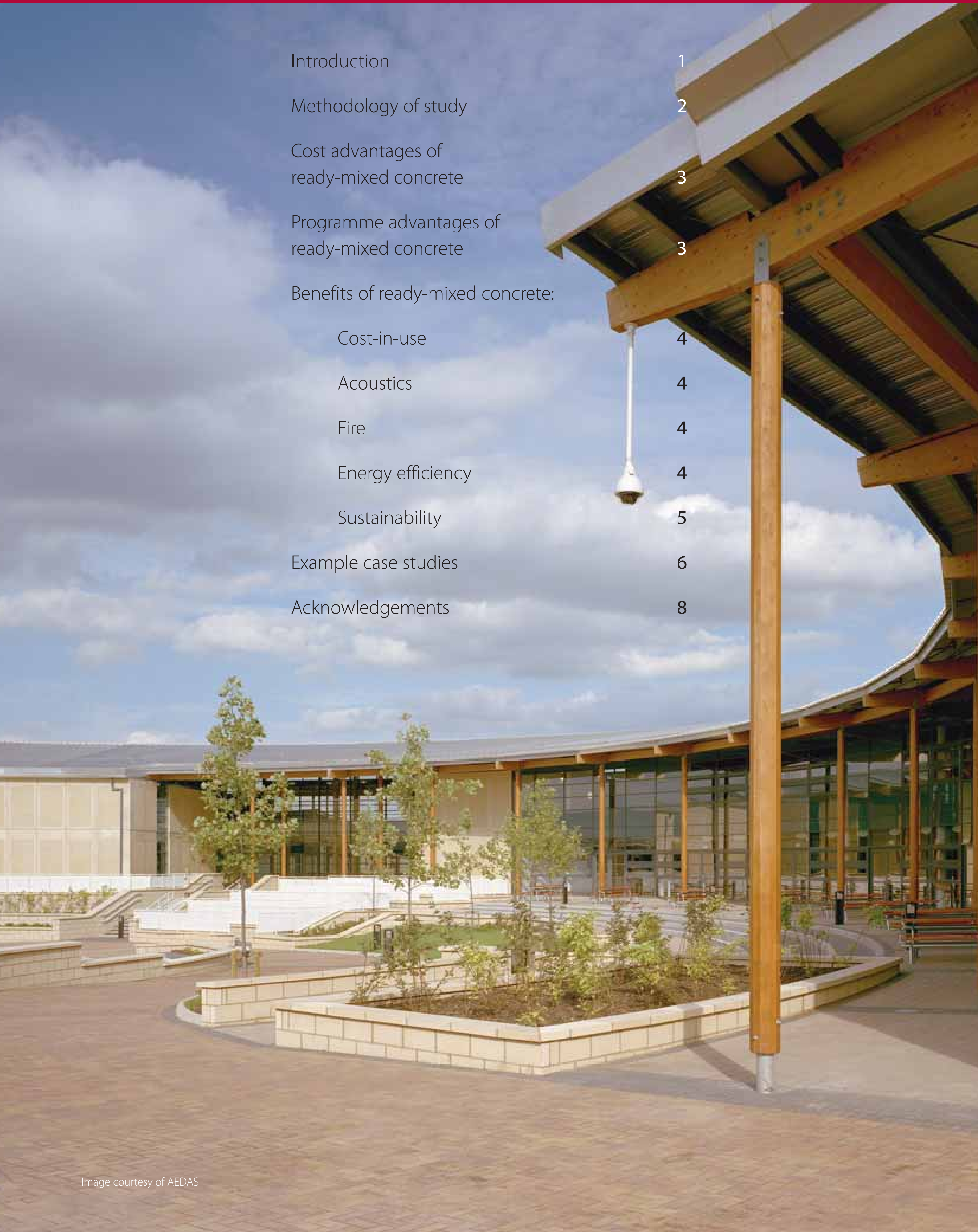
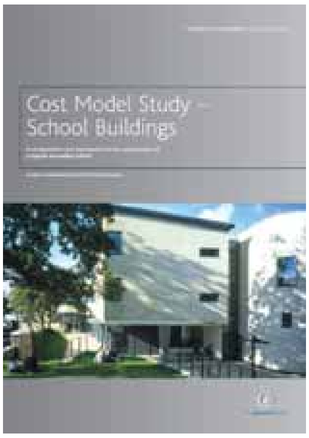


Image courtesy of AEDAS

Introduction

This publication summarises the findings of the previous published 'Cost Model Study - School Buildings' (right) published by The Concrete Centre:

The study compares the costs of constructing a typical secondary school, using a variety of structural options.



A design was commissioned for a typical 1,400 place secondary school, based on the different school typologies commonly seen in contemporary school design, to enable an evaluation of the relative costs of a selection of different structural solutions in school design to be carried out.

The school is a hybrid arrangement, combining courtyard and street typologies, which is the most common model at present and is currently being used by both schools and larger city academies. The form of plan is scaleable for future expansion and size of institution.

Structural designs were developed for alternative framing solutions and the designs were taken to normal outline design stage, the only differences being directly attributable to the structural frame material. Budget costings were assigned to all elements of construction - from substructure, superstructure and external envelope through to preliminaries, with the exception of external works. Adjustments were made to the costings to reflect time-related costs attributable to differences in construction programmes.

Whilst identifying the variation in the costs of frames, the study also considers the effects that the choice of framing material and method of construction have on other elements of the building, as well as the other benefits that the choice of frame can generate.

The study demonstrates the need to consider all elements of the building cost, rather than simply the cost of the structure, and highlights the extent to which elements other than the structure are affected by the choice of frame solution.[1]

Methodology of study

The brief given to the design team asked for outline designs for a typical school, to reflect current design practice and the design team's best judgement.

The design of a secondary school is the combination of numerous criteria. These range from physical elements such as the building's location and context within the site, the site's topography, environmental issues and site constraints, through to the educational brief, which will dictate relationships between departments, year groups and the school's pedagogy and pastoral care. The type and size of the building were to be determined by consideration of all of these drivers.

The building was taken up to normal outline design stage, with associated outline specifications. The only differences were directly attributable to the structural frame material.

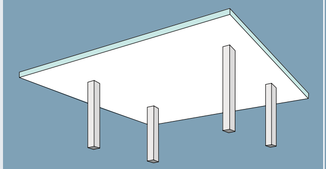
The extent, layout and complexity of external works are to a large extent dictated by the size, configuration and orientation of the site for each particular project, together with constraints imposed by location and external factors such as planning. The extent to which external works are likely to be influenced to any significant degree by the choice of structural solution is considered to be minimal.

Consequently, whilst the programmes allow notional periods for the elements of external works to ensure completeness of preliminaries, consideration of such works in detail is beyond the scope of this study.

The final structural zones represent those considered, by the design team's experience and judgement, to be optimum depths for the structures. A fire engineering approach was not undertaken for the building. Indicative diagrams and descriptions for each of the structural options considered are given in the illustration (right).[2]

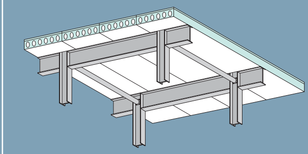
Structural frame options[3]

Option 1 - PT Flat slab



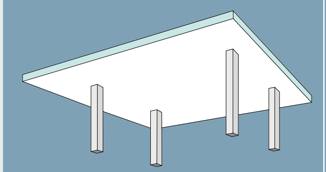
Post-tensioned in-situ concrete flat slab and reinforced in-situ concrete columns

Option 2 - Steel + Hollowcore



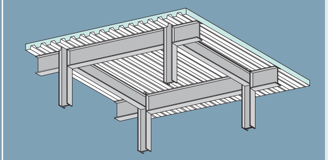
Steel beams acting compositely with precast concrete hollowcore floor slabs. Steel columns

Option 3 - Flat slab



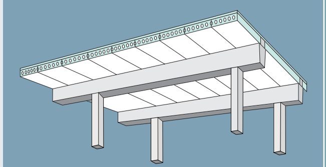
Reinforced in-situ concrete flat slab and columns

Option 4 - Composite



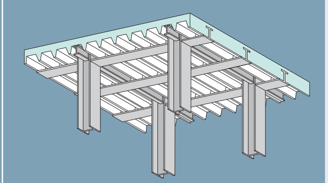
Steel beams and metal decking, both acting compositely with in-situ concrete floor slabs. Steel columns

Option 5 - In-situ + Hollowcore



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

Option 6 - Slimdek®

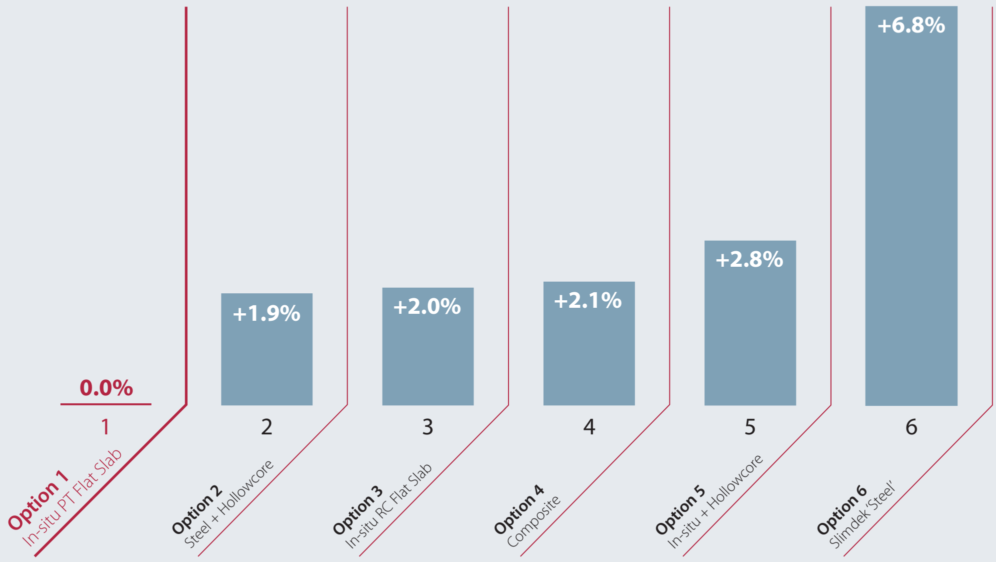


Slimdek system comprising asymmetric beams and metal decking both acting compositely with in-situ concrete floor slabs. Steel columns

Cost advantages of ready-mixed concrete

'School Building'
cost analysis[4]

In terms of the overall construction cost, the most economic solutions are given in order opposite.



Programme advantages of ready-mixed concrete

In-situ concrete-framed† options offer an advantage in lead times, from start of package procurement to commencement on site,[5] over steel-framed options, and in terms of the overall programme.

As can be seen, the most economic PT in-situ 'option 1' is completed in 65 weeks, whilst the least economic Slimdeck 'option 6' is completed in 67 weeks.

† Fire protection used to be a critical activity, but modern details such as site-applied intumescent coatings have removed fire-proofing from the critical path altogether. However, although not on the critical path, the fire-proofing activity requires a greater level of detailing and may cause disruption that adversely affects other trades, for example, due to difficulties caused by fixings penetrating through fire-proofing and other damage that needs repair.

Off-site intumescent coatings have been introduced in an effort to reduce construction time, but these can suffer from significant damage in transit, requiring remedial work on site which can eliminate the original saving.

The durations of first-fix, second-fix and M&E installations are essentially the same, with slight differences in phasing appearing to make little difference to the overall programmes.

However, it is becoming increasingly common to use prefabrication for the M&E services distribution, which can offer programme advantages when used in conjunction with the open flat soffits provided by the Flat Slab, PT Flat Slab and Slimdek options.

Prefabrication of sections of the M&E installations also offers advantages in subsequent maintenance and refurbishment of the building. No account is taken within the programmes of any construction time savings resulting from such prefabrication.[5]

Comparison of construction times for School Building [6]

Structural option	Procurement time (weeks)	Lead time (weeks)	Overall construction time (weeks)
PT Flat Slab	10	8	65
Composite	10	12	66
In-situ + Hollowcore	10	8	67
Steel + Hollowcore	10	12	67
Slimdek	10	12	67
Flat Slab	10	4	69

Benefits of ready-mixed concrete

Cost-in-use

There are several areas where cost-in-use benefits arise for concrete-framed buildings, such as:

- Increased durability of the structure, resulting in lower repair and replacement costs.
- Ability to apply a painted finish directly onto the structure, reducing repair and maintenance costs.
- Operational energy savings arising from concrete's greater thermal mass.

These represent an additional benefit over and above insulation U-values and can result in lower repair and maintenance costs for mechanical plant.[7]

† Initial capital cost is not, of course, the sole driver for clients, whose main objective is optimum value from an overall solution.

The wider value aspects of structural solutions in relation to framed buildings are therefore considered further[8] under the following headings:

Acoustics
Fire
Energy efficiency
Sustainability

Acoustics

† Acoustic considerations are an important part of the design, with intrusive noise pollution, both within the building and into and out of the building,[9] being detrimental.

† Factors to consider are the need for mass to reduce transmission of impact noise between floors and the complexity of detailing.[10]

It should be noted that †concrete achieves the required acoustic performance with a minimum of extra acoustic finishes.

To meet the robustness of finishes demanded by a heavily used school environment, as well as to exploit the performance of the thermal mass, the tendency can be to lean towards many hard interior finishes. It should be borne in mind that the requirements for acoustic absorption within spaces can conflict with gaining the benefits of thermal mass through fabric energy storage.

A construction method using concrete walls offers a more durable form of construction that can often be simply painted, with no need for plaster finishes, giving both initial and whole-life cost benefits, with reduced repair costs, disruption and maintenance downtime.[11]

Fire

Fire resistance is an important issue both in design and in constructability. †Fire-proofing to a steel construction generally requires one or more separate trades to follow on after the steel frame has been erected, either using intumescent coatings or fire-resistant boarding.

Concrete is inherently fire resistant and normally requires no added fire protection.

Detailing at the heads of partitions is an area where proper fire-proofing can be difficult to achieve in a simple manner, with the junction of the vertical and horizontal structure often combining with perforations through partitions for services. With concrete Flat Slabs, effective detail is generally easy to design and construct in such cases.[7] Even a concrete beam, as in the In-situ + Hollowcore option, is easier to detail than steel downstand beams and metal decking.

† With profiled metal decking and steel beams the detailing tends to be more complex, particularly since primary and secondary steel beams have different profiles, and can lead to buildability and rework problems later in the programme.

Also of importance is the reusability of the structure after a fire. A concrete structure can often be repaired and reused, whereas a steel structure will usually require rebuilding.

The choice of building material is a factor in fire risk assessments by insurance companies, which recognise the inherent performance of a building material in the event of a fire, and this can affect insurance premiums.[7] Concrete is generally regarded as a robust material that provides an element of safety to property.

Energy efficiency

Structures with a high thermal mass offer potential value to a client.

Because of the internal temperatures that have to be maintained in school buildings, energy efficiency is important.

Thermal mass can be exploited by exposing the soffits, thus utilising Fabric Energy Storage (FES). This reduces initial plant costs by minimising or eliminating the need for air conditioning and substantially reduces the lifetime operating costs of the asset.

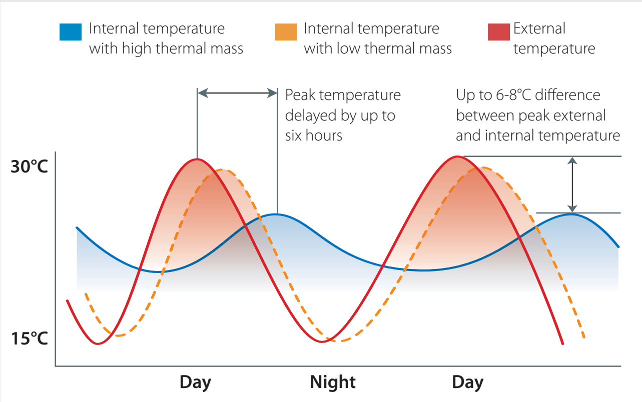
Indeed, greater benefits can be achieved by better overall design, taking account of thermal mass and the use of High Strength Concrete (HSC) offering a form of temperature regulation and increased floor space respectively.

Basically, concrete acts as thermal sponge, absorbing heat during the summer and so cooling a building, and storing heat from the sun or heaters to release it at night.

Utilisation of FES permits the designer to create naturally ventilated buildings, giving occupants the chance to control their environment, with consequent improvements in employee productivity.

Furthermore, suspended ceilings can be reduced or eliminated, giving valuable initial cost and programme benefits and reduced maintenance costs over the lifetime of the building.

Stabilising effect of thermal mass on internal temperature[12]



Sustainability

UK GREEN BUILDING COUNCIL Associate Member

BRMCA member companies are committed to utilising 'sustainable resources', protecting the environment for years to come and reducing CO_2 emissions.

BRMCA and its members formally 'signed up' to the 'Sustainable Construction Strategy for the Concrete Industry' led by Sir Jonathon Porritt 30 July 2008.

BRMCA members are committed to:

- Sustainability management - Working with Government and the Building Research Establishment (BRE) to enhance current performance and reduce CO_2 emissions
- Governance and business ethics
- Working with local communities
- Environmental performance
- Responsible sourcing and procurement
- Utilising locally available constituent materials wherever possible
- Material suppliers demonstrating ongoing efforts to reduce CO_2 emissions
- Fair trade products
- Research and development to find alternative and/or more 'eco-friendly' products

Ready-mixed concrete offers one of the most sustainable and cost effective methods of construction, with the final product and its constituents already providing the following benefits in terms of sustainability and responsible sourcing:

- The majority of concrete contains cement produced as a by-product of other industries such as fly ash from coal-fired power stations and ground granulated blast-furnace slag from the iron industry; both of these would historically have gone to land-fill
- Concrete has inherent thermal mass properties. When used in buildings, concrete reduces the need for air conditioning and so saves energy and reduces CO_2 emissions
- At the site, the 'plastic' product is placed into purpose made moulds (formwork), and with good site supervision this results in virtually zero waste
- Any excess concrete returned from site is re-constituted and is very rarely sent to tip
- All reinforcement bars produced in the UK are manufactured from recycled scrap
- The majority of concrete is produced using UK sourced cementitious materials
- A large proportion of constituent materials are transported by rail or barge, thus reducing CO_2 emissions
- The average delivery distance is only 6 radial miles, again saving on transport fuel and CO_2 emissions
- All cement products are produced by BS EN ISO 9001 certified suppliers, also operating BS EN ISO 14001 and OHSAS 18001 certified systems
- The majority of aggregates used within concrete are sourced locally and travel minimal distances to ready-mixed concrete plants

Example case study Hadley Learning Centre, Telford

Project Description

The Hadley Learning Centre site accommodates a new 800 pupil primary school, a 1300 - 1400 pupil secondary school and a special school for pupils with profound and multiple learning difficulties, plus a children's centre and a range of community learning, arts and sport facilities.

Sustainability was at the top of the agenda for the design team. A key feature was the natural ventilation design utilising the thermal mass of the reinforced concrete structure to maximise "free" cooling.

Rainwater harvesting was also used to recycle water for toilet flushing. Faber Maunsell provided a comprehensive engineering service to this landmark project.

Construction

The structure consists of a number of reinforced concrete flat slabs supported on 200mm by 400mm concrete columns. The 200mm column dimension fits within the thickness of the external precast concrete cladding.

The flat slabs are supported on typically a 7.5m by 7.2m column grid. The roof slab is 275mm thick and the floor slabs are 300mm thick. Concrete strengths classes were C32/40 for the slabs and C40/50 for the columns.

The Concrete Benefits

The thermal mass of the reinforced concrete flat slabs at first floor and roof levels were used to maximise "free" cooling in conjunction with natural ventilation.[13]

Architect: Aedas
Engineer: Faber Maunsell
Contractor: MPB Structures Ltd and McDermott Bros. Ltd

Images courtesy of Aedas

Example case study Bilborough College, Nottingham

Project Description

A new high quality building comprising purpose-built teaching and administrative accommodation, and a sports hall facility for 1,600 students. The contract period was 94 weeks, with a project value of £20m.

Construction

The new college has three post-tensioned suspended floors (from post-tensioning contractor Structural Systems), and a reinforced concrete ground bearing slab. The three blocks are divided by movement joints, with the load carried across them by 'Staifix' dowels.

Each block comprises a rectangular northern section of 7.8 x 7.2m grid and a triangular southern block of 8.7 x 7.2m typically. Slabs are post-tensioned flat slabs of 250mm thickness for college loading and 275mm thickness for plant rooms. There are numerous penetrations for atria, services and feature staircases and the tendon layout has been arranged to suit.

What concrete brought to the project

The post-tensioned slabs give the minimum slab thickness and floor to floor height for the given spans. This in turn reduces the amount of the slab's concrete and steel reinforcement materials and cladding.

Reduced material quantities also give the sustainability benefit of reducing transport energy. The exposed concrete soffit is designed to act as a thermal flywheel to reduce the impact of external temperature fluctuations upon the internal environment.[13]

Architect: CPMG Architects
Engineer: ARUP
Main Contractor: Bowmer and Kirkland
Frame Contractor: PC Harrington Contractors Ltd

Photography: Martine Hamilton Knight/Builtvision

Acknowledgements

The Concrete Centre, as the organisation who commissioned this independent study, would like to acknowledge the contributions of the following companies on this project:

Architecture plb - Architectural Design

Education architecture is at the core of Architecture plb's work. They have been involved in over 100 projects, from early years to higher education, new build and refurbishment, and advise on school design with professional and government bodies. Recent award-winning commissions include Jersey College for Girls, Tanbridge House School, Horsham and Haute Valley School, Jersey.

Arup - Structural Design

Arup is an international firm of consulting engineers, with over 55 years of international experience in providing consultancy in engineering, design, planning and project management services in every field related to building, civil, and industrial projects. Arup aims to provide a consistently excellent multi-disciplinary service, helping its clients meet their business needs by adding value through technical excellence, efficient organisation, personal service and a strong commitment to sustainable design.

Davis Langdon LLP - Quantity Surveying

Davis Langdon LLP provides a range of integrated project and cost management services designed to maximise value for clients investing in infrastructure, construction and property, with extensive experience in projects and programmes across a broad range of sectors and building types. Davis Langdon has a culture of achieving excellence and delivers success through limiting risk, forecasting and controlling cost, managing time and resources, and maximising value for money according to the specific needs of the client and brief.

Costain Construction - Programming

Costain is a multi-disciplinary contractor with over 140 years involved in the building, civil engineering and specialist process contracting industries. Since its formation, Costain has been involved in many major construction projects throughout the world including the recent Channel Tunnel Rail Link and St Pancras Station refurbishment, restoration of St-Martin-in-the-Fields in Trafalgar Square, Bradford Schools BSF and King's College Hospital PFI. Costain are committed to providing the highest quality facilities and environments in the primary, secondary and tertiary education sectors where students can excel.

Notes

Slimdek® is a registered trademark of Corus UK Ltd.
Ribdeck® is a registered trademark of Richard Lees Steel Decking Ltd.[14]

References

1 - 11 Cost Model Study - School Buildings, CCIP-011, The Concrete Centre, 2008.

12 Diagram from Thermal Mass Explained, TCC/05/11, The Concrete Centre, 2009.

13 Page 13, School Construction, TCC/03/25, The Concete Centre, 2007.

14 Inside front cover, Cost Model Study - School Buildings, CCIP-011, The Concrete Centre, 2008.

mpa
essential materials
sustainable solutions

BRMCA is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, lime, mortar and silica sand industries

BRMCA
Gillingham House
38 - 44 Gillingham Street
London SW1V 1HU
Tel +44 (0)20 7963 8000
Fax +44 (0)20 7963 8001
brmca@mineralproducts.org
www.brmca.org.uk

Ref. MPA-BRMCA/SS2/09
First Published September 2009