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Coventry New Hospitals Project PFI courtesy of Nightingale Associates

Offering the most cost-effective construction solution

Hospital Buildings

Post-tensioned in-situ concrete is **7.2%** cheaper than the equivalent steel option in terms of overall construction costs

brmca british ready-mixed concrete association

Mineral Products Association

Contents

Introduction

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

† The study compares the costs of constructing both a typical Acute Care Hospital (also known as a district general hospital) and a Community Hospital (also known a local general hospital) using a variety of structural options, taking into account the construction cost itself as well as costs arising from the different programme durations.

Designs were commissioned for a typical 480-bed Acute Care Hospital and a typical 96-bed Community Hospital, based on the various different ward templates and bed mixes commonly found in contemporary hospital design.

Architectural design was undertaken by Nightingale Associates; all structural designs, together with mechanical and electrical (M&E) services design and costing, were carried out by Arup; and all other costings were undertaken by Davis Langdon.

Six structural options were considered. These were: Post-Tensioned (PT) Flat Slab, Flat Slab, In-situ Concrete + Hollowcore, Steel + Hollowcore, Composite Steel Deck and Slimdek®. The designs were taken to normal outline design stage, the only differences in specification being the structural frame option. 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.

While identifying the variation in the costs of structural frames, the study also quantifies the cost implications that the choice of framing material and method of construction have on other elements of the building. The study demonstrates the need to consider whole construction costs allowing for the cost implications of the choice of frame, rather than the frame cost alone, when choosing the frame.[1]

Methodology of study

The brief given to the design team asked for outline designs for two typical hospitals on a flat, 'brownfield' site located in the Midlands. They were to reflect current design practice and the design team's best judgement. The first was an Acute Care Hospital, often referred to as a district general hospital, and the second was a Community Hospital, often known as a local general hospital.

The design of a hospital is influenced by numerous factors, ranging from physical elements such as the building's location and context within the site, the topography of the site, constraints imposed by the site and environmental issues through to the care brief, which dictates the configuration of space within the building, measures for infection control, relationships between departments, etc.

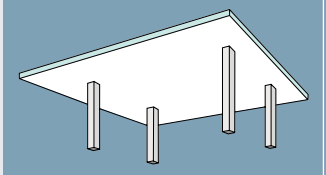
The types and sizes of the buildings were to be determined by consideration of all of these drivers, in conjunction with appropriate Department of Health (DH) and National Health Service (NHS) guidelines and current regulations. These are listed in the references section. The designs for the buildings were developed up to normal outline design stage, with associated outline specifications. The only differences were directly attributable to the type of structural frame chosen.

The architectural scheme, layout and specifications were based on contemporary practice, prevailing DH and NHS funding guidelines and current design guidance and regulations. The 2006 revision to Part L of the Building Regulations (which required further increases in the energy efficiency standards of buildings) had not come into effect at the time the designs were undertaken and was not therefore taken into account in the study.

The final structural and service zones represent what the design team considered to be optimum depths for the structures. Indicative diagrams and descriptions for each of the structural options considered are given in the illustration (right).[2]

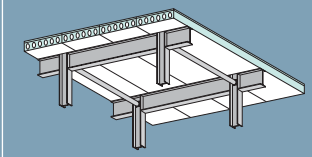
Structural frame options[3]

Option 1 - PT Flat slab



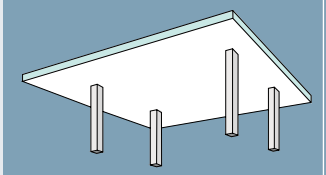
Post-tensioned in-situ concrete flat slab and reinforced in-situ concrete columns

Option 2 - Steel + Hollowcore



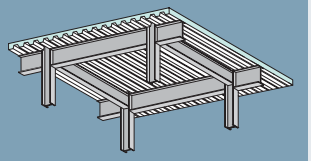
Steel beams acting compositely with precast concrete hollowcore floor slabs. Steel columns

Option 3 - Flat slab



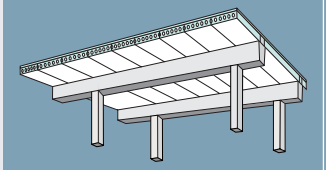
Reinforced in-situ concrete flat slab and columns

Option 4 - Composite



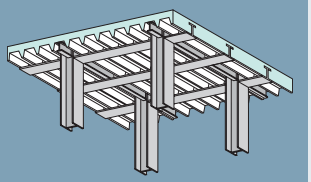
Steel beams and metal decking, both acting compositely with in-situ concrete floor slabs. Steel columns

Option 5 - In-situ + Hollowcore



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

Option 6 - Slimdek®

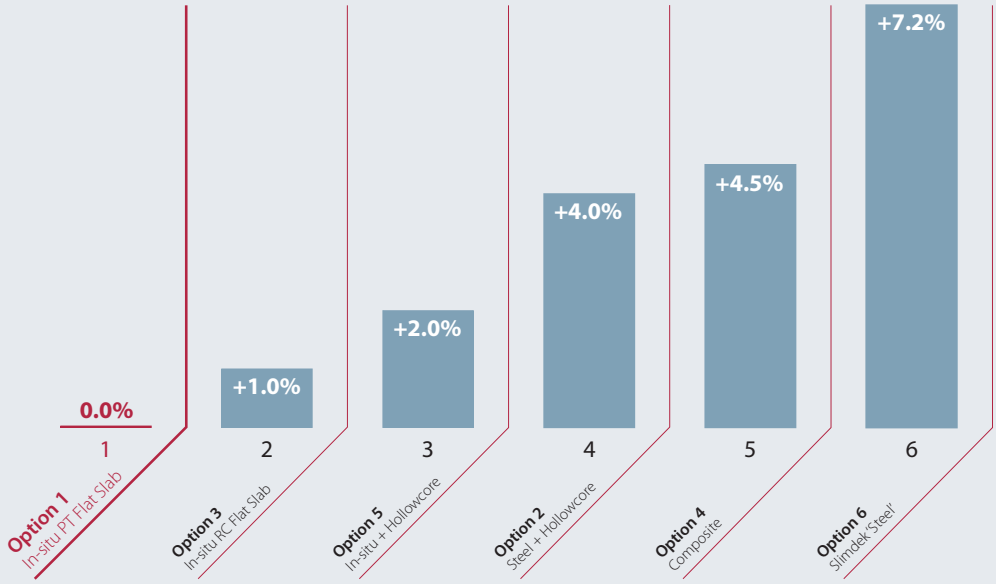


Slimdek system comprising asymmetric beams and metal decking both acting compositely with in-situ concrete floor slabs. Steel columns

Cost advantages of ready-mixed concrete

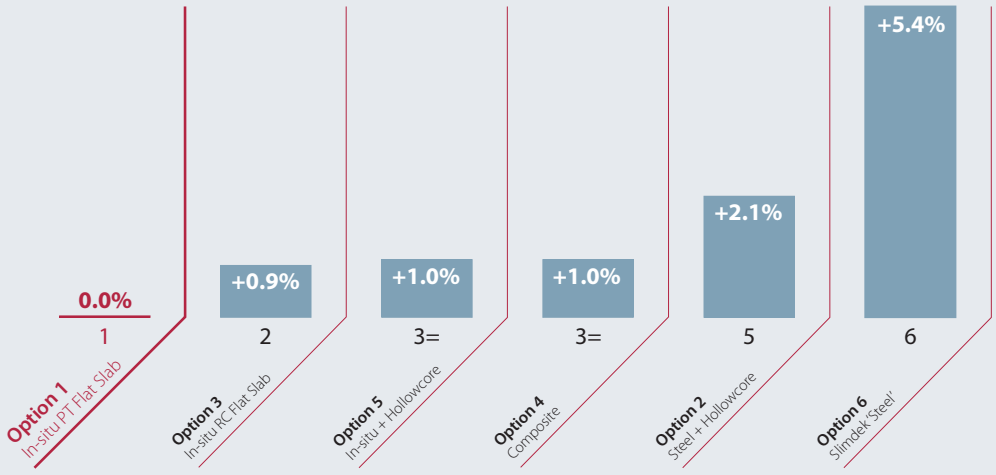
'Acute Care Hospital' cost analysis

In terms of the overall construction cost for the Acute Care Hospital, the most economic solutions are given in order opposite.[4]



'Community Hospital' cost analysis

In terms of the overall construction cost for the Community Hospital, the most economic solutions are given in order opposite.[4]



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, over steel-framed options, and in terms of the overall programme.

† 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.

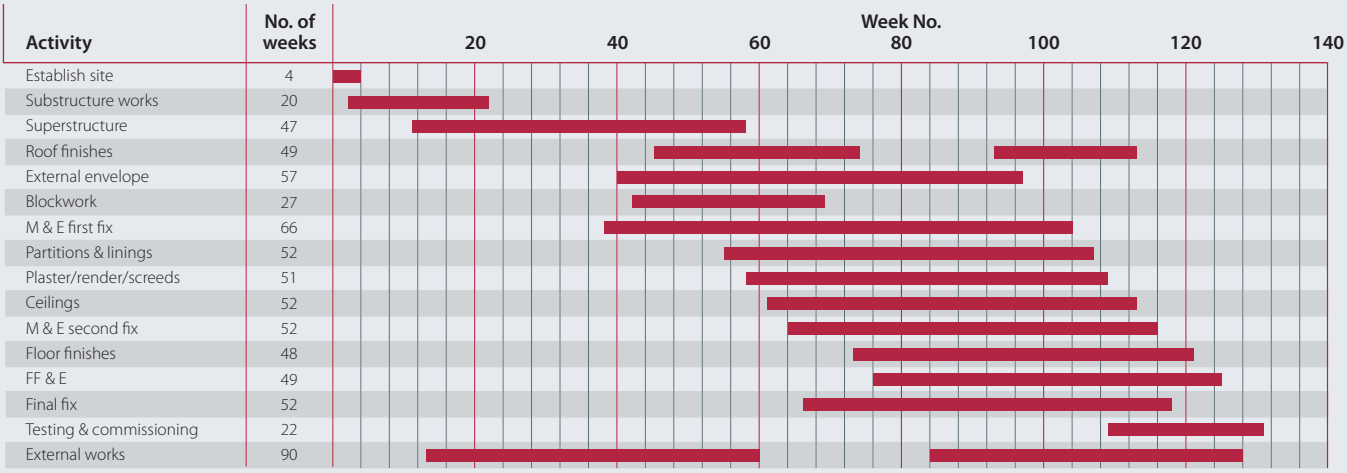
Off-site intumescent coatings have been introduced in an effort to reduce construction time, but these can suffer from significant damage in transit, requiring remedial work on site which can eliminate the original saving.

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.

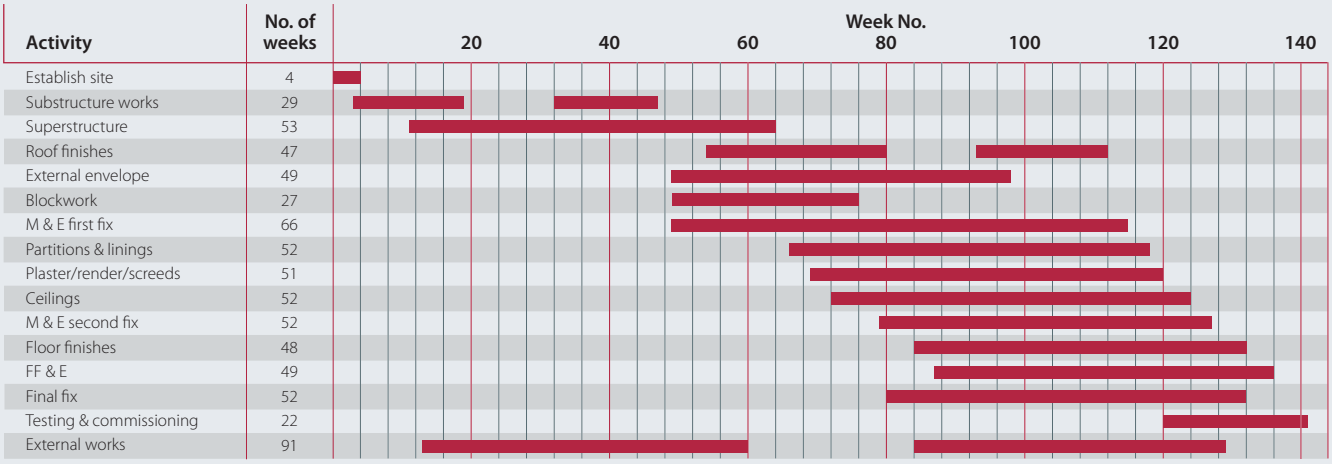
However, it is becoming increasingly common to use prefabrication for the M&E services distribution, which can offer programme advantages when used in conjunction with the open flat soffits provided by the Flat Slab, PT Flat Slab and Slimdek options.

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]

PT In-situ 'Option 1 for Acute Care Hospital (131 weeks)[6]



Slimdek (Steel) 'Option 6 for Acute Care Hospital (142 weeks)[6]



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.

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[7] 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, being detrimental.

Evidence indicates that high background noise levels, whether generated outside or amplified sound from inside the hospital space, can be detrimental to patient recovery times and causes stress and reduced performance among staff.

Factors to consider are the need for mass to reduce transmission of impact noise between floors and the complexity of detailing. Concrete's mass and damping qualities meet the acoustic performance requirements of HTM 20452 and contribute to a better patient environment isolated from noise and vibrations transmitted from floor to floor.

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 hospital 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.[7]

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. 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. Concrete is generally regarded as a robust material that provides an element of safety to property.[8]

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 hospital buildings, energy efficiency is important.

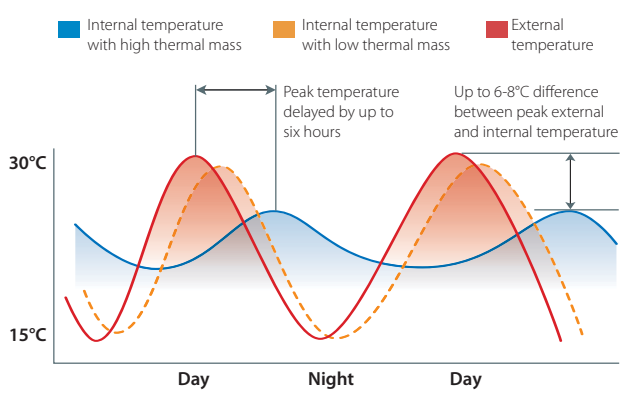
Thermal mass can be exploited by exposing the soffits, thus utilising Fabric Energy Storage (FES). This reduces initial plant costs by minimising or eliminating the need for air conditioning and substantially reduces the lifetime operating costs of the asset.

Benefits of ready-mixed concrete

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.

Stabilising effect of thermal mass on internal temperature[9]



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.

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 St James' Hospital, Oncology Wing

Project Description

The new oncology wing at St James' Hospital in Leeds is a PFI project creating one of Europe's largest cancer treatment centres. The 66,500m^2 building is built on 12 levels and contains 12 linear accelerator treatment rooms housing 15MV and 25MV high energy equipment. Also contained within the Centre of Excellence are simulators, PET Scanners, nuclear medicine and shielded accommodation. In addition to the hospital accommodation the site has a 7,000 space concrete car park.

Construction

Concrete flat slabs were adopted for the building frame providing a structural solution which enabled construction speed to be maximised through repetitive layouts whilst facilitating the installation of building services.

Initial design considerations included the use of reinforced concrete ribbed slabs with wide flat beams. However, consideration of follow-on trades such as fire separation and partition head fixings steered the team away from this original concept on the grounds of programme and cost. The structural grids are 8.1m x 8.1m in the research accommodation and 8.1m x 7.2m in the ward accommodation. The slab thickness is 350mm deep including provision for shower recesses.

Concrete is used for the 12 linear accelerators (Linac) treatment rooms in the basement. They required significant radiation shielding properties and thick concrete sections provided the solution generally. Some walls of the Linac chambers are formed with heavyweight concrete using magnetite aggregate imported from Sweden. The density of these sections is 3,900kg/m^3. Local areas of the deep concrete roof sections contain multiple steel plates, each 50mm thick, up to a total thickness of 350mm to provide the required radiation resistance.

What concrete brought to the project

Concrete's excellent vibration and inherent fire resistance performance made it the natural choice for the construction of the hospital housing sensitive medical equipment. The repetitive layout of the building made it ideal for maximising the benefits of adopting standard construction components such as formwork and cladding support systems. Risk management and availability of normal and heavyweight concrete made concrete the natural choice to successfully contain radiation leakage from the Linac chambers.[10]

Main contractor: Bovis Lend Lease
Frame contractor: Heyrod Construction
Architect: Anshen + Allen
Structural and services engineers: Faber Maunsell Limited

Images courtesy of AECOM

Example case study Queen Alexandra Hospital, Portsmouth

Project Description

The redevelopment of the existing Queen Alexandra Hospital is a PFI contract tasked with providing additional beds, operating theatres, car parking and other healthcare services. The new build extension totals 76,000m², making the entire hospital a 1200 bed acute general hospital. The PFI contract is for a period of 33 years.

Construction

The eight-storey building utilises post-tensioned slabs which were originally selected for economy, speed of construction and future flexibility. This form of construction can be designed to conform to the stringent vibration criteria of a hospital building.

Further to this, the use of post-tensioned concrete meant that the frame could economically span long distances plus it provided the full range of inherent benefits of concrete, including fire resistance, flexibility of layout and speed of programme.

Concrete was well suited to this project. It simplified the design and installation of the considerable amount of mechanical and electrical (M&E) services required and the miles of partitioning, which needed to be airtight. Concrete also provided a high level of acoustic performance with minimum additional finishes. Concrete's mass and damping qualities met the required level of HTM 2045 acoustic performance and contributed to a better patient environment which is isolated from invasive noise and vibration.

The Linac chambers also benefited from concrete's proven mass qualities, in order to ensure that radiation could safely be used within.

What concrete brought to the project

The use of post-tensioned concrete at this hospital extension ensured that the many inherent benefits of concrete were fully utilised, whilst also ensuring that the material was used economically and sustainably.[10]

Client: Carillion plc
Architect: Building Design Partnership
Structural engineer: Buro Happold

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:

Nightingale Associates

Nightingale Associates have an international reputation for the design of healthcare buildings. They balance the functional, economic, aesthetic and environmental aspects needed to create therapeutic and sustainable buildings.

The largest hospital to be procured by the NHS in recent history, the new £350m University Hospital at Walsgrave, Coventry represents a major achievement in quality of design and construction as enhanced by the PFI process. This included a 1200-bed acute hospital with 32 theatres including 4 for day surgery, and a 130-bed mental health unit.

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 programs 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 an international engineering and construction group with a track record in the health sector based on delivering successful health projects and providing innovative solutions in partnership with healthcare clients.

They work in a cross section of public and private health procurement routes and provide equity investment, financing and construction services to successful PFI projects. They also work successfully with the NHS in framework and partnering environments, the most high profile of which is the ProCure21 initiative. Recent successful projects include the Kingston Hospital PFI project and King's College Hospital London.

Notes

Slimdek® is a registered trademark of Corus UK Ltd.
Ribdeck® is a registered trademark of Richard Lees Steel Decking Ltd.[11]

References

1 - 4 Cost Model Study - Hospital Buildings, CCIP-012, The Concrete Centre, 2008.

5 Cost Model Study - Commercial Buildings, CCIP-010, The Concrete Centre, 2007.

6 - 8 Data sourced from Cost Model Study - Hospital Buildings, CCIP-012, The Concrete Centre, 2008.

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

10 Page 14, Hospital Construction, TCC/03/044, The Concete Centre, 2008.

11 Inside front cover, Cost Model Study - Commercial Buildings, CCIP-010, The Concrete Centre, 2007.

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

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