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Offering the most cost-effective construction solution

Commercial Buildings

In-situ reinforced concrete is **5.1%** 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 - Commercial Buildings' (right) published by The Concrete Centre:

† The study compares the costs of constructing three- and six-storey commercial buildings using a variety of short-span and long-span options in two different locations, taking into account construction and Category A fit-out, and the effect of programme times on cost.

Designs were commissioned for a three-storey office building in an out-of-town business park location in the south east and a six-storey office building located in central London. The buildings were based upon appropriate structural grids commonly in current use, with designs and specifications suited to current market conditions.

Architectural design was undertaken by Allies and Morrison, all structural designs were carried out by Arup, and costings were undertaken by Davis Langdon.

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, which were considered to be too highly site-specific to permit accurate costing. 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 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 the outline designs of multi-storey buildings on open clear sites, one case being an out-of-town business park in the south east and the other case being in central London. The designs were to reflect contemporary commercial practice and the design team's best judgement. They would be used for preparing budget costs and for making comparisons of the effects of the choice of different structural frames.

Designs were commissioned for a three-storey office building in an out-of-town business park location in the south east (Building A) and a six-storey office building located in central London (Building B). The buildings were based upon appropriate structural grids commonly in current use, using pad or piled foundations. Specifications were suited to current market conditions, which suggested that Building A be an air-conditioned, L-shaped building with curtain walling and some natural ventilation and that Building B be a rectangular, air conditioned building with curtain walling.

Building A was chosen to reflect a framed building of average size (4,650m^2) in a commercial/business park setting. It is representative of a typical low-rise building in the centres of current development activity. Building B, containing retail space at ground floor level, was chosen to reflect a high-quality framed building of average size (14,200m^2 of offices and 2,300m^2 of retail space) in Central London. It is acknowledged that a building of this type in London would normally have a basement. However, it was considered that inclusion of this element could unduly favour some of the structural options over others above ground. Accordingly, the basement construction has been excluded from the study.

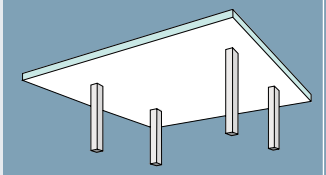
For Building A, six options were developed. For Building B, six options were developed for the short-span situations (7.5m) and two options for a long-span situation (15.0m), giving eight options in total.

The structural options were chosen as being representative of current best practice and most likely to be proposed by the design team for a commercially viable project. Indicative diagrams and descriptions for each of the structural options considered are given in the illustration (right).[2]

Structural frame options[3]

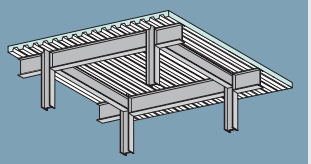
Short span options - Building A and B

Option 1 - Flat slab



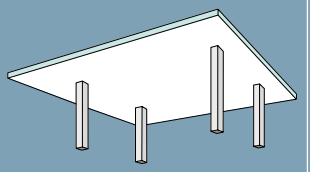
Reinforced in-situ concrete flat slab and columns

Option 2 - Composite



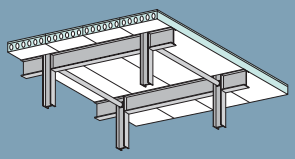
Steel beams and metal decking, both acting compositely with in-situ concrete floor slabs. Steel columns

Option 3 - PT Flat slab



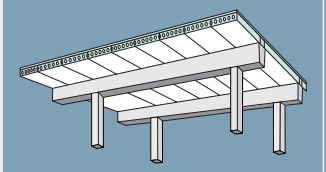
Post-tensioned in-situ concrete flat slab and reinforced in-situ concrete columns

Option 4 - Steel + Hollowcore



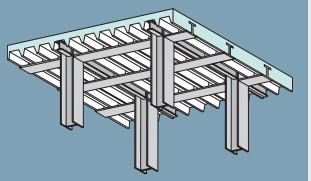
Steel beams acting compositely with precast concrete hollowcore floor slabs. Steel columns

Option 5 - In-situ + Hollowcore



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

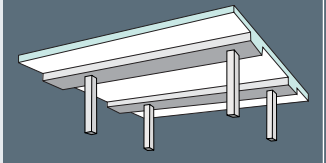
Option 6 - Slimdek®



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

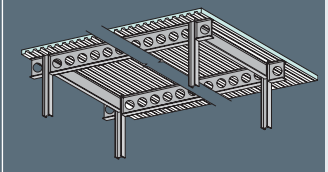
Long span options - Building B only

Option 7 - PT Band beams



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

Option 8 - Long span composite

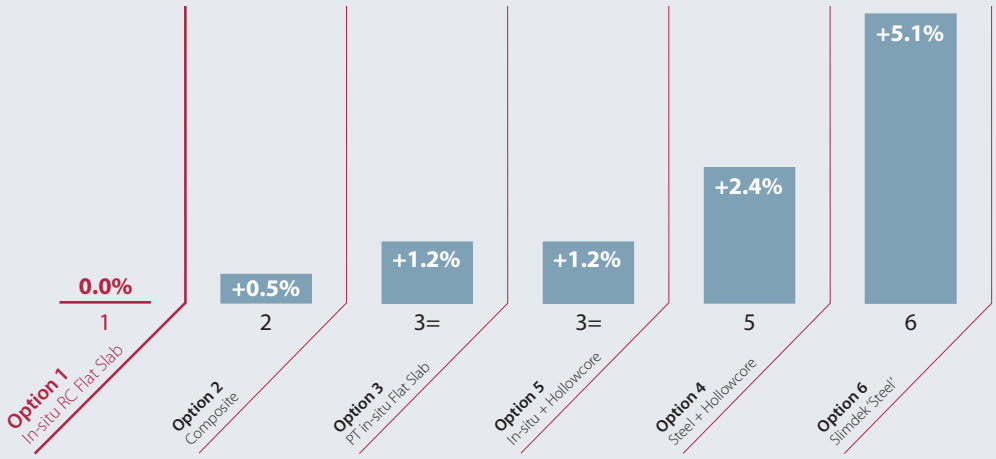


Long-span cellular steel beams and metal decking, both acting compositely with in-situ concrete floor slabs. Steel columns

Cost advantages of ready-mixed concrete

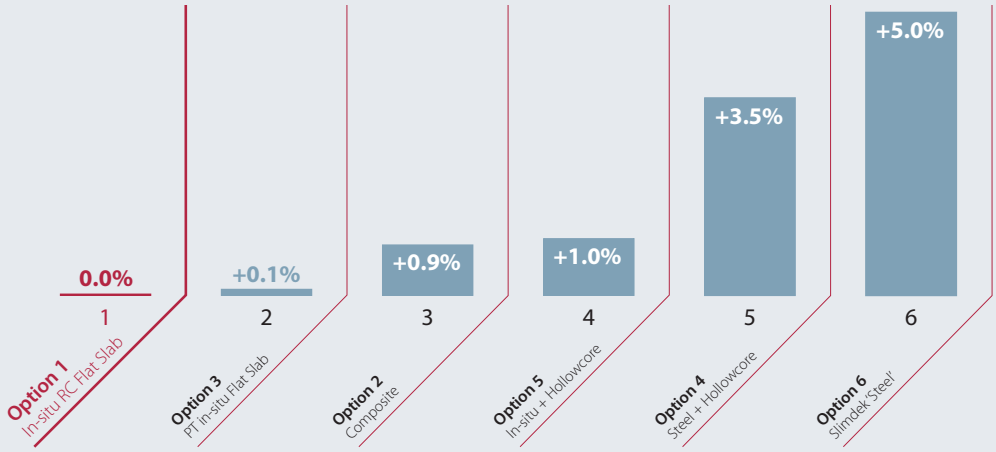
'Three Storey Building' (A) cost analysis

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



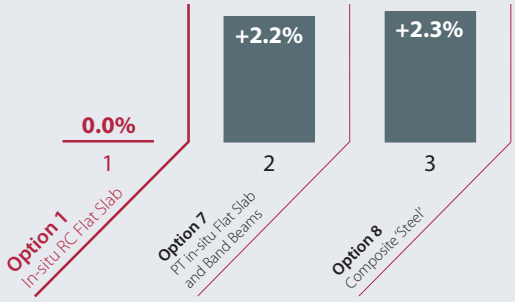
'Six Storey Building' (B) cost analysis

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



'Six Storey Building' (Long Span) cost analysis

In terms of the overall construction cost for the six storey building, 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.

The lead times for the In-Situ concrete options are significantly shorter than those for the Composite, Steel + Hollowcore, Slimdek and Long-Span Composite options.

For Building A, during the eight-week saving in lead time, nearly 90% of the frame for the Flat Slab option could be constructed, whilst the 50 weeks overall construction programme for the Flat Slab option is only marginally longer than the 48 weeks for the Composite solution.

For Building B, the ten-week saving in lead time equates to the period required to construct the frame for the Flat Slab up to fourth-floor level and commence the walls and columns from the fourth to fifth floor, i.e. approximately 60% of the complete frame.

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.

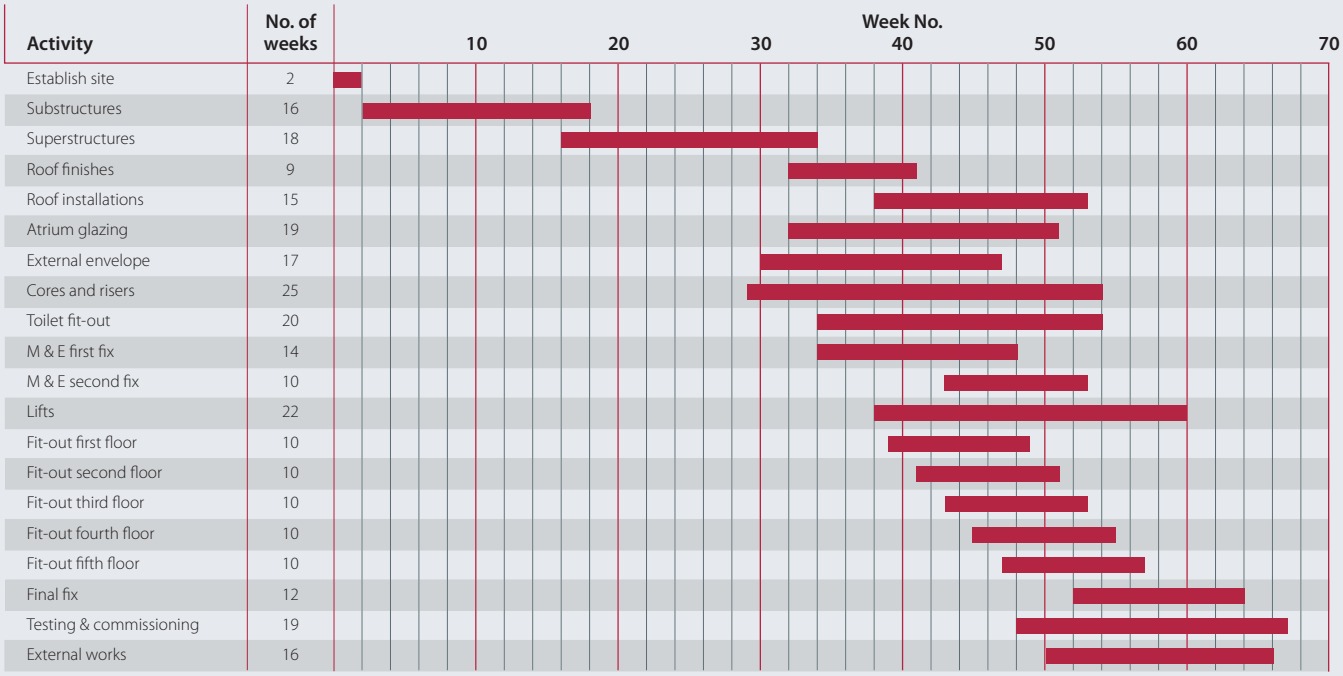
Off-site intumescent coatings have been introduced in an effort to reduce construction time, but these can suffer from significant damage in transit, requiring remedial work on site which can eliminate the original saving.

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]

In-situ RC Flat Slab 'Option 1 Six Storey Building (67 weeks)



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[6] 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.

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

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 commercial 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.[6]

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.[7]

Energy efficiency

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

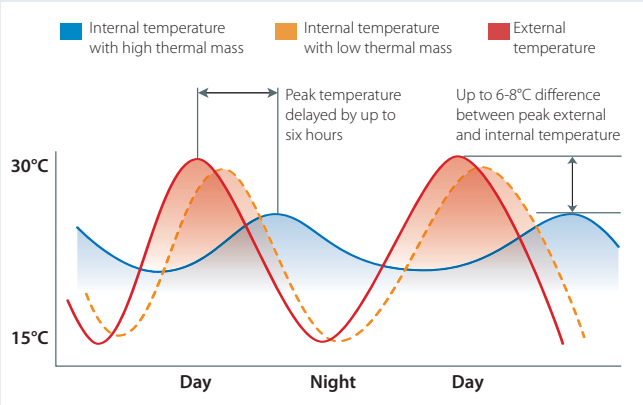
Because of the internal temperatures that have to be maintained in commercial buildings, energy efficiency is important.

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.

Benefits of ready-mixed concrete

Stabilising effect of thermal mass on internal temperature[8]



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.

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 Edinburgh City Council, Waverley Court

Project Description

Waverley Court, situated next to Edinburgh's Waverley Station, is the £80 million home to the administrative centre of Edinburgh City Council. Waverley Court was delivered to programme and on budget by Miller Construction, and represents a complementary contrast to the historic centre of Edinburgh's World Heritage Site.

Construction

Managing the transition from the old to the new is always complex. Beneath the Old Town area of Edinburgh, where Waverley Court is located, lie intricate networks of underground vaults that conceal the city's historic past. Following demolition of the underground vaults below the site, the architects, Building Design Partnerships, chose to replicate them by creating new vaulted ceilings in the interior design of the offices. Rob McCallum from PJ Carey, the concrete frame contractor, suggested that it was the versatility and flexibility of concrete that allowed the project team to achieve the rustic look of these vaulted ceilings, thereby preserving a glimpse of the city's rich past.

Achieving these aesthetic features required some innovative thinking. Fibreglass moulds fabricated by Production Glassfibre Ltd were integrated within the design of PERI's formwork system to produce curved beams that gave the vaulted-ceiling effect. Indeed, high quality finishes also featured as top priority elsewhere on the project. PERI utilised its proprietary VARIO Column formwork to produce the required blemish-free finish on the vertical structure.

What concrete brought to the project

To add to the difficulty of the project, the design also veered away from standard shapes. Some column shapes, for example, were parallelograms, and so the formwork had to be prefabricated and brought in just-in-time.

Had concrete not been chosen as the structural material, such boldness in the design of the building shape would not have been possible. Furthermore, the specification of exposed concrete to the high quality finish adds to the artistry that resulted in the rustic look of the interiors of a modern-day office building. Of course, concrete displays other quintessential properties such as inherent fire resistance, sound insulation and thermal mass benefits that are necessary in a public sector building of this kind.[9]

Architect: Building Design Partnerships
Structural engineer: Beattie Watkinson
Main contractor: Miller Construction
Frame contractor: PJ Carey Ltd

Photography: Martine Hamilton Knight/Builtvision

Example case study BBC Scotland Headquarters, Glasgow

Project Description

Opposite the renowned Armadillo building (the Scottish Exhibition and Conference Centre) is the new £129 million headquarters of BBC Scotland. With the reflection of the River Clyde on its glass façade, the new building marks the beginning of Glasgow's desire to become the media capital of Scotland.

Construction

Although the building design was straightforward - a 5-storey concrete framed building with a total floor area of 32,500m^2 - the one critical factor that posed a challenge was the short build time. Construction began in August 2004 and the frame was completed in May 2005.

In order to meet this tight programme, there was a design requirement of maximising the formwork table size to speed up the construction process. A nine metre grid was successfully achieved with the introduction of PERI's MPB 24 aluminium beams. Accelerating admixtures were added to the concrete mix to ensure that the design strength of the concrete slabs was reached quickly. Another added complexity of the project was the different floor-to-floor heights within the building. The typical floor-to-floor was 3.85m, but the ground to mezzanine was 2.65m and the ground to first floor was 6m.

This enabled the building to be designed as multi-functional in terms of accommodating different spaces including studios, offices and television dubbing rooms. Here, concrete frame contractor, PJ Carey, and formwork contractor, PERI, worked closely to design and fabricate appropriate wall, slab and column formwork systems that could deliver a single-source solution, whilst maintaining high levels of flexibility for the formwork to respond to different height requirements.

What concrete brought to the project

Aesthetically, BBC Scotland's new headquarters building is aspirational, with all internal columns constructed with exposed concrete to a high-quality, the building now rivals the Armadillo in terms of showing how building materials can be showcased in practice. Of course, the inherent sound insulation properties of concrete are also extremely appropriate for a broadcasting centre. Overall, BBC Scotland's headquarters building is testimony that concrete frame buildings can be procured within a short time-scale.[9]

Architect: Chipperfield Ltd, London (Conceptual)
Keppie Ltd, Glasgow (Detailed)
Structural engineer: Faber Maunsell
Main contractor: Bovis Lend Lease
Frame contractor: PJ Carey Ltd

Images © Renzo Mazzolini

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:

Allies and Morrison - Architectural Design

Established in 1984, Allies and Morrison's expertise includes master planning, architecture, landscape, design, interior design and conservation. Allies and Morrison routinely work on a number of master plans and played a key role in preparing master plan proposals for the London 2012 Olympics and the regeneration of the Lower Lea Valley.

Past award winning commissions include One Piccadilly Gardens, Manchester; the BBC Media Village at White City; Girton College Library and Archive and the British Council in Lagos, Nigeria.

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 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.

Mace - Programming

Mace is one of the world's most diverse management and construction companies and is a renowned global business providing management and construction services to the public and private sectors, with a reputation for finding the best solutions to complex projects. Mace has been responsible for the successful delivery of a number of award-winning projects, including the More London development incorporating City Hall, Heathrow T5 and the City of London's fourth tallest tower, 51 Lime Street.

Notes

Slimdek® is a registered trademarks of Corus UK Ltd.
Ribdeck® is a registered trademark of Richard Lees Steel Decking Ltd.[10]

References

[1 - 7] Cost Model Study - Commercial Buildings, CCIP-010, The Concrete Centre, 2007.

[8] Diagram from Thermal Mass Explained, TCC/05/11, The Concrete Centre, 2009.

[9] Benefits of In-situ Concrete Frames - Project Case Studies, CONSTRUCT/The Concrete Centre, 2007.

[10] 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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