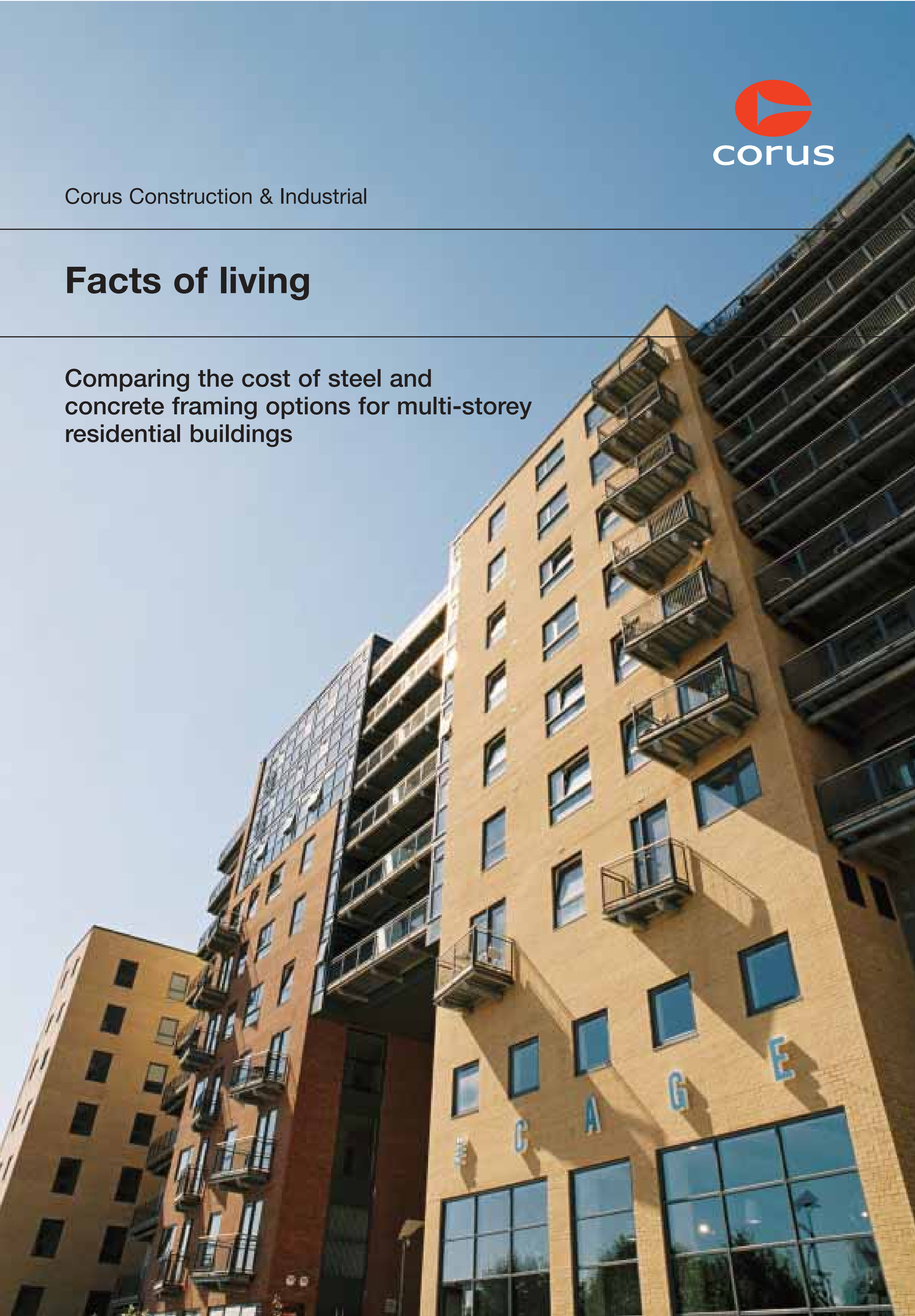
Corus Construction & Industrial

Facts of living

Comparing the cost of steel and concrete framing options for multi-storey residential buildings



Material choice

What material to use for the structural frame of a multi-storey residential building is one of the most significant early decisions on any project.

The choice of material for the structural frame has a wide-ranging effect on many subsequent aspects of the building design, programme and performance. These, in turn, all have an impact on the cost and value of the project and are fundamental to its overall success.

Steel is already the dominant form of construction for commercial buildings due to its proven benefits in terms of speed cost and quality. It is now developing an increasing presence in the market for the frame of multi-storey residential (MSR) buildings based on the same proven benefits.

The financial and programme benefits of building in steel are illustrated by the results of the latest independent cost comparison study, funded by Corus. This study looks in detail at the costs and construction programme associated with a typical MSR building, examining a range of steel and concrete framing options.

In conducting the study - and to ensure that it drew on the most up to date knowledge and expertise - Corus employed the services of leading practitioners in the industry, including Arup, MACE, Davis Langdon and the Steel Construction Institute.

This publication sets out the results of the independent study, which examined steel and concrete structural options for a typical fully designed and programmed MSR building. It takes into account all the major variables of structure, cladding and services and the results enable us to make detailed comparisons of the costs and other related benefits of the different structural framing options.

Benefits of steel construction

The results of the independent study demonstrate that steel-based options are, in all cases, the most cost effective solution.

The cheapest option, both in terms of structure costs and total-building costs, is composite beam and slab construction. Illustrating why this form of construction is currently the most popular multi-storey flooring solution in the UK.

When variable costs such as external cladding costs are considered, the Slimdek® and ASB with pre-cast hollow core units (ASB+PC) options become almost as cost effective due to the reduced height of the building - these schemes also bring additional inherent benefits such as unobstructed flat ceiling soffits. The reinforced concrete option is up to 2 percent more expensive than the steel options.

These cost and design benefits, allied with superior speed of construction, flexibility and consistent quality make steel the informed choice for the structural frame of multi-storey residential buildings. Add to this the minimal disruption caused during construction - and its limited impact on the environment - and steel truly deserves its increasing prominence in the UK multi-storey residential frame market.

The Building in detail

The building is typical of MSR developments throughout the UK and for the purposes of this study is located in outer London. The building is of a rectangular plan form of approx 17m by 60m with a nominal height of 18m, and a gross floor area of 6060m^2.
It consists of:

- below-ground car parking
- ground floor retail outlets
- five residential storeys

Access to the below ground car park is provided by an access ramp that runs along the rear of the whole building. The column spacing, dictated by the layout of the car park, is continued throughout the building removing the need for an expensive transfer structure. The retail floor level is generally open plan (it can be divided into shop units as required by the developer) and has a glazed façade to the street. The retail level is not sprinkler protected and has been designed to have a fire resistance of 60 minutes.

For the residential levels the building is divided into a number of 2 person (approx 50m^2) and 4 person (approx 65m^2) flats, serviced from zones at each end of the building, where the stairs and lifts are located. It has a fire resistance of 60 minutes, and is not sprinkler protected. These levels are clad in an insulated render, with regularly spaced individual windows making up a quarter of the façade. For the residential floors the ratio of habitable space to gross floor area is 0.85:1

The roof construction is designed to take the same loads as all other floors, but does not support any additional roof structures.

Minor pipework in this building is passed underneath or through the beams or floor. Provision for lighting units, fire protection, ceiling depths and an allowance for deflections are included in the depth of the floor zone.

Mixed Used Residential Building

Structural systems

Four structural systems for this Building are detailed in this publication. They are:

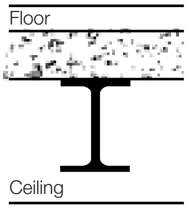
• composite beam and slab • Slimdek® • ASB with pre-cast hollow core units • reinforced concrete flat slab

The building in the study represents a typical modern MSR structure, for which a number of steel and concrete framing systems were examined.

Floor zones

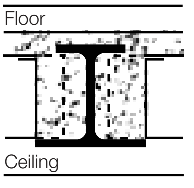
Composite beam and slab

= 70mm raised floor
+ 135mm slab
+ 260mm beam
+ 88mm ceiling
= 553mm ≈ 550mm



Slimdek®

= 70mm raised floor
+ 300mm slab
+ 88mm ceiling
= 458mm ≈ 460mm

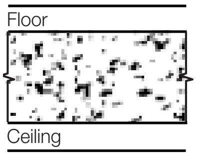


ASB with precast hollow core units

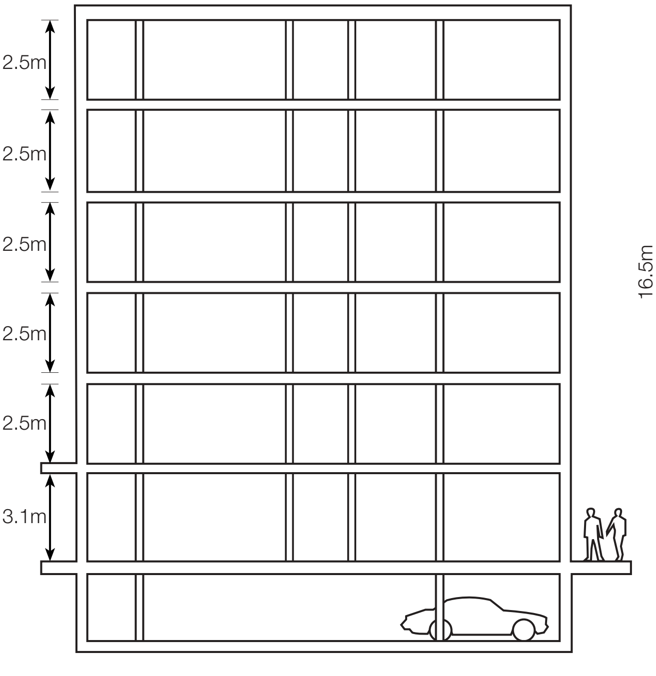
= 70mm raised floor
+ 250mm concrete slab
+ 88mm ceiling
= 408mm ≈ 410mm

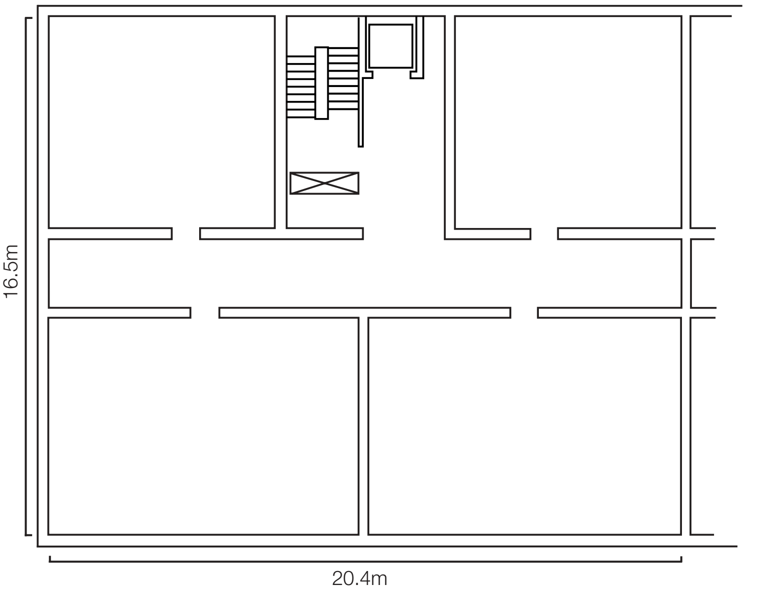
Reinforced concrete flat slab

= 70mm raised floor
+ 250mm concrete slab
+ 70mm ceiling
= 408mm ≈ 410mm



Building Figures (impression, plan, section, floor plan)





Study methods

The study considered four different structural forms.

These forms were chosen, as they typified the structural options currently in use in MSR buildings. The complete set of results appears in the new Steel Construction Institute publication SCI-P-338 'Cost Comparison of multi-storey residential buildings', but for the purpose of brevity only the highlights for each option have been detailed in this summary version.

Design assumptions

The design of the steel and composite options was carried out by the Steel Construction Institute, while the choice and design of the concrete option was by Arup. MACE detailed each construction programme and Davis Langdon priced the complete schemes.

A list of the main design parameters and assumptions are shown in Appendix One.

Fire protection

For effective fire protection, it is assumed that an intumescent coating is used for the beams, bracing and columns in the basement, while a board system is used (where required) for the columns and beams above ground level. Asymmetric Slimflor® Beams (ASBs) are partially encased in concrete and do not require any additional protection for 60 minutes fire resistance.

Construction programme assumptions

MACE undertook the programming for all options. It is assumed that the programming and plant resources for each option are consistent - so that they do not favour any form of construction. The key interfaces between preceding and following trades are assumed to be well maintained.

Construction of the steel options involves the use of a concrete pump to install insitu concrete, and the concrete option uses table forms. The steel columns in both buildings are a maximum of two storeys high during construction and all options use precast stairs.

Costing assumptions

Davis Langdon carried out the pricing of all options. In some cases, where a construction form had many possible arrangements, cost was used to determine the preferred layout. Price levels in the study are those prevailing in the last quarter (October to December) 2003.

The rates for steel fabrication include design, connections, transport and erection, but assume that the steel is not to be painted. Other steel-related components, such as fire protection, shear studs and steel decking, have also been accurately costed.

The itemised rates for the various concrete components, including upper floors and roof - as well as the associated work such as excavation, reinforcement and formwork - have similarly been compiled from recently tendered projects.

The composite unit rates used for other elements in the buildings have been compiled from Davis Langdon's costs database, and reflect a typical developer's standard specification.

The major element rates are detailed in Appendix 2.

A contingency and design reserve of 8 per cent has been added to reflect the typical cost for the MSR type development represented by the building. No allowance has been made for professional fees, sales and marketing and other non construction costs.

Regional variations

Construction prices can vary considerably around the country. The table below provides adjustment factors that may be applied to provide indicative costs for each of the building types, built in another region.

Region	Percentage adjustment to total building cost
East Anglia	-8
East Midlands	-15
Inner London	+6
North East	-12
North West	-12
Northern Ireland	-28
Outer London	0
Scotland	-14
South East	-4
South West	-10
Wales	-13
West Midlands	-11
Yorkshire and Humberside	-14

Cost-effective construction

The study showed that steel-based systems offer the fastest and lowest cost construction options available for MSR buildings.

Cost-effective steel
For the MSR building in the study, the results showed that the composite beam and slab system was the lowest cost option, followed by Slimdek® and ASB+PC construction systems. The concrete option proved to be the most expensive solution.

Rapid construction
The speed of construction of steel structures was highlighted by the study. For both steel and concrete, the erection of the structure is a relatively small proportion of the overall programme time – but steel was shown to be the faster option.

For MSR building, the steel structural systems could be erected in ten or eleven weeks, compared with the twelve weeks required for a reinforced concrete system. In addition, erection of concrete frame structures begins later than the steel alternatives, since a ground-bearing slab must be constructed prior to erection commencing.

Time-related savings
Faster construction has additional benefits. It results in savings in the cost of site management and on-site activities. It reduces the cost of finance, since a shorter construction period reduces the time during which interest has to be paid. This effect is an integral part of the cost comparison study.

Additionally the rapid completion of a building also brings an earlier return on investment as the building can be occupied sooner, helping to offset the cost of borrowing or allowing finance for the next phase of a development. These more intangible benefits are not calculated in the study

Time related savings

Structural form	Frame after completion of basement (weeks)	Completion of frame and floors (weeks)	Overall (weeks)
Composite beam and slab	10	22	69
Slimdek®	9	21	68
ASB+PC	10	22	68
Reinforced concrete flat slab	12	24	70

MSR Building gross floor area 6060m²
Elemental building cost per SQ M gross floor area for structural options

Code	Description	Composite beam and slab	Slimdek®	ASB+PC	Reinforced concrete flat slab
		£/m²	**£/m²**	**£/m²**	**£/m²**
1	Substructure	55	55	55	56
2	Frame and upper floors	104	119	116	122
3	Roof	17	17	17	17
4	Stairs	16	16	16	16
5	External walls	56	54	54	53
6	Windows and external doors	58	58	58	58
7	Internal walls, partitions and doors	84	83	83	83
8	Wall finishes	12	12	12	12
9	Floor finishes	38	38	43	38
10	Ceiling finishes	15	15	15	15
11	Fittings	63	63	63	63
12	Sanitary fittings and disposal	33	33	33	33
13	Mechanical services	67	67	67	67
14	Electrical services	35	35	35	35
15	Lift installation	26	26	26	26
16	Builders work in connection	7	7	7	7
17	External Works	8	8	8	8
	Subtotal	694	706	706	708
Preliminaries (approximately 15.00%)		105	104	104	106
	Subtotal	799	810	810	814
Contingency (8.0%)		64	65	65	65
Total building cost		**863**	**875**	**875**	**880**
Construction period (weeks)		69	68	68	70
Extra/(saving) in finance costs @ 6 % p.a.		0	-1	-1	0
Net building cost		**863**	**874**	**874**	**880**

Additional measurements

The tables below compare the finished structural dimensions and steel weights of each of the construction systems. These findings illustrate some of the merits of the different systems, but should not be considered in isolation.

For example, the weight of steel is only a crude measurement of efficiency - and does not take into account the reduced costs of fire protection and cladding and the ease of service installation.

Additional measurements

Structural form	**Beam and slab depth** (mm)	**Overall floor zone** (mm)	**Building height** (m)	**Area fire protection** (m²/m² floor area)	**Basic steel frame weight per floor area** (kg/m²)	**Total steel weight per floor area** (kg/m²)
Composite beam and slab	395	550	18.9	0.64	48.7	68.0
Slimdek®	300	460	18.3	0.24	46.3	73.4
ASB + PC	250	410	18.0	0.25	41.9	46.9
Reinforced concrete flat slab	300	410	18.0			

The value of steel

Steel offers considerable advantages over concrete, making it the first choice material for large building construction in any location.

Minimal disruption

Steel construction can dramatically reduce the impact of building activities on the surrounding area. This is particularly important in inner city locations or sites close to residential areas. Steel construction minimises noise and dust, shortens the construction period and reduces the amount of waste generated. Deliveries can even be timed to suit local traffic conditions and keep disruption in the area to a minimum.

Flexible solution

Steel construction generates an inherently flexible solution. All internal walls can be repositioned allowing buildings to be adapted repeatedly to suit the changing needs of their occupants.

Built-in quality

Off-site fabrication improves the quality of the building frame, since the majority of work is carried out under closely controlled factory conditions - unaffected by on-site trades or the weather. All steel frames are prefabricated, providing the potential for a "right-first-time" build, which minimises time and disruption on site.

Steel does not suffer from creep or shrinkage and, when properly protected, does not rot or decay.

Environmental benefits

Steel offers a clean, efficient and rapid construction method, which reduces the impact of building activities on the environment. The small amount of waste produced is generally recycled, and all steel is potentially reusable. Today, around 40 per cent of steel is produced from recycled material

Steel flooring solutions

Composite beam and slab

Composite beam and slab is the most popular form of multi-storey frame construction in the UK. This fast, efficient, lightweight solution utilises a shallow metal deck spanning, typically, 2.5m to 4.5m between supporting steel beams. The common span range of the beams is 5m to 12m. A shallow concrete slab is cast on the decking, and shear studs that have been welded through the decking on to the supporting beams generate composite action between the beam and slab.

The speed and structural performance makes composite construction the preferred option for offices and many other multi-storey building frames.

Slimdek®

Slimdek® is an engineered shallow depth flooring system for multi-storey buildings. The system utilises rolled asymmetric steel beams (ASB) supporting deep metal decking on an open grid (up to 9m x 9m) with no secondary steelwork. During construction, the ASB beam is encased within the concrete floor slab, and composite action is generated without shear studs. This results in a floor of between 300mm and 400mm depth with a flat soffit and no downstands.

Due to the encasement of the steel beam, the system has inherent fire resistance up to 60 minutes without the need for fire protection. Another key benefit of the system is the ease of service integration within the floor depth.

ASB+PC unit

This system (which is currently in development) is a logical extension to the Slimflor® concept in that it aims to utilize the inherent section properties of the ASB in conjunction with the spanning capabilities of the concrete pre-cast unit. The pre-cast units (which may be notched if required) are supported on the bottom flange of the ASB and the space around the beam at the end of the unit is filled with concrete to encase the beam. This creates a minimum structural floor zone. Reinforcement can be placed either over or through the ASB into the discrete open-ended voids in the pre-cast units for robustness. This can also enhance fire performance. Depending on the in-service conditions, the joints between the pre-cast units can either be grouted up, or a screed can be used to provide a flat floor.

Appendix one
Design parameters and assumptions

Structural design

The building is designed for an imposed load of 1.5kN/m^2 in the residential apartments, 2.5kN/m^2 in residential communal areas such as walkways and 4.0kN/m^2 in the retail ground floor area. Additional loads of 1 kN/m^2 for partitions and 0.7kN/m^2 for the ceiling, services and raised floor are common for all areas.

The deflection limits are taken as defined in BS 5950 Part 1. The total deflections of the beams or slabs of all options are limited to a maximum of span/200. Edge beam deflections are limited to a maximum of span/500 under imposed and cladding loads. In practice, deflections will be much less than these limits, owing to the stiffness of the connections.

S355 steel (to BS EN 10 025) is used for the columns whereas S275 steel is used for the UB and UC beams, which are generally controlled by serviceability criteria. ASB sections are always S355. Normal weight concrete is used throughout the building for all options.

The natural frequency limit is taken as 4Hz with a response factor in accordance with BS6472
The 2002 Building Regulations also require that all buildings possess `robustness' through provision of tying action. This necessitates the placement of additional reinforcement across the beams in the pre-cast concrete options.

The steel options for both buildings are designed as braced against wind load, with bracing accommodated within the core area. In the concrete option, reinforced concrete shear walls are used. These 'core' positions are selected to offer the required escape routes and zones for vertical services. Their size is sufficient to accommodate lifts, stairways and any vertical ducts and pipes.

The car park arrangement dictates the structural grid that is adopted in order to avoid the use of an expensive transfer structure. This is based on a 3-car bay (7.5m wide) along the facade, and columns at 4.8, 6.7 and 5.0m respectively across the building.

Fire protection

Fire protection is taken as board for columns, internal beams and bracing members above ground, but an intumescent coating protects the steelwork in the basement. In Slimdek® the ASB beams are partially encased in concrete, and do not require protection for this building.

Acoustic performance

The building is designed to meet the acoustic requirements of Part 'E' of the Building Regulations (2003) and uses robust details wherever possible. Post Completion Testing would be needed where no appropriate Robust Detail is available.

Separating walls

Separating walls are double layer light steel wall (250mm width and 8 kg/m^2 steel weight per unit wall area) with 2 layers of fire resisting plasterboard per side and 75mm mineral wool batts between the studs.

Partition walls

Partition walls are a single layer light steel wall (125mm width and 3 kg/m2 steel weight per unit wall area) comprising one layer of 12mm plasterboard on both sides.

External walls

External walls consist of an insulated render (on 100mm EPS insulation) attached to 10mm CPB , screw-fixed to single layer light steel wall (125mm width and 5 kg/m^2 steel weight per unit wall area) with two layers of 12mm fire resisting plasterboard on the inside, 100mm mineral wool batts and a 15mm cavity. Wall thickness is 250mm overall.

Floor zone
The floor zone in the accommodation areas comprises the structural floor, a battened floor (70mm overall) and suspended single layer plasterboard ceiling with 75mm void (88mm overall). The ground (retail) floor has a concrete finish without the acoustic floor and ceiling below.

Roof
The roof is a flat roof built as the floor construction but with a built-up layered roofing system laid to falls.

Car parking
The below-ground car parking is considered as being common to all schemes, the only variant being the use of steel or concrete columns.
A total of 38 car parking spaces are to be provided beneath the building.

Staircases
The staircases are generally precast concrete with powder coated balustrades and hardwood handrails.

Windows
Windows in the building are opening, aluminium, polyester powder-coated, double-glazed units.
The windows are to be 2100mm high. Double glazed doors are provided to access the balcony areas.

External doors
The type of external door specified changes with location but all are solid security doors.

Sanitary/kitchen fittings
The sanitary and kitchen fittings are proprietary products tailored to suit the type of accommodation.

Internal doors
The internal doors are veneered, solid core within a hardwood frame and have stainless steel ironmongery.

Internal finishes
The internal wall finishes are plaster/plasterboard with an emulsion paint finish. Ceramic tiles are detailed in the kitchens, bathrooms and en-suite areas.

Appendix two

The cost rates for some of the major elements used for the frame and floor costings in the study are included here for information but do not necessarily reflect current competitive pricing.

Structural steelwork	**Unit**	
280/300 ASB (S355)	Tonne	£1,080.00
Universal beams (S275)	Tonne	£950.00
Universal columns (S355)	Tonne	£980.00
Joists: channels: angles: tee section (S275)	Tonne	£1,000.00
Rolled hollow sections (S355)	Tonne	£1,550.00
Plates (S355)	Tonne	£1,250.00
Flats (S355)	Tonne	£1,050.00
Fire protection		
Mineral wool	m^2	£7.50
Plasterboard	m^2	£20.00
Infumescent paint	m^2	£12.00
Conlit 150	m^2	£9.50
Other structural items		
150 hollow core precast units	m^2	£37.00
250 hollow core precast units	m^2	£43.00
Concrete slab, pumped, g35	m^2	£111.00
Embedded beam encasement	m^2	£111.00
Reinforcement bars	Tonne	£685.00
Balcony support steel and decking	Each	£500.00
A193 reinforcement mesh	m^2	£4.00
A393 reinforcement mesh	m^2	£5.00
100 x 19 dia shear connectors	Each	£2.50
CF51 0.9 thick decking	m^2	£24.70
PMF CF70	m^2	£15.00
SD225 deep decking	m^2	£26.20
Insitu reinforced concrete frame		
Perimeter columns - 250x350, 280kg/m^3 reinforcement	m	£70.00
Internal columns (basement) - 450x450, 320kg/m^3 reinforcement	m	£123.00
Internal columns (ground - u/s second floor) - 450x300, 320kg/m^3 reinforcement	m	£99.00
Internal columns (second floor upwards) - 300x300, 320kg/m^3 reinforcement	m	£73.00
250mm thick shear walls	m^2	£120.00
Perimeter column head-slab interface	Each	£10.00
Internal column head-slab interface	Each	£10.00
Reinforced suspended concrete floors 250mm thick	m^2	£95.00

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Corus provides free advice to the construction industry covering all aspects of the design, specification and use of its range of construction products.

Corus Construction and Industrial manufactures structural sections and plates for building and civil engineering applications. Advice is provided by our team of qualified engineers with extensive experience in the design and construction of buildings and bridges. Specialist advice on fire engineering, durability and sustainability is also available. Our regional network of engineers covers the whole of the UK and Ireland and is supported by a dedicated design team based at our manufacturing centre in Scunthorpe.

General enquiries on other products and systems manufactured by Corus will be routed to our Construction Centre who will direct you to the appropriate source of market and product expertise.

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