STEEL INSIGHT #07

HEALTHCARE

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The healthcare sector can have exacting requirements for flexibility, specialist space, programme and vibration performance – it's just a matter of choosing the right steel frame

01 | Introduction

Previous Steel Insights have provided general guidance for quantity surveyors when cost planning structural steel-framed buildings, as well as a detailed study of two typical commercial buildings to explore not only the cost but also the programme and sustainability benefits of structural steel solutions.

Recent articles have focused on particular market sectors and this article considers the healthcare sector, specifically hospitals and smaller healthcare centres. However, many of the characteristics examined are also relevant to other healthcare buildings and can be considered during cost planning across the sector in general.

This article identifies the typical design requirements and construction and project specific cost drivers of hospital and health centres and will review how they impact on frame selection and design. The main types of structural steel frame in the sector will be reviewed to show how the typical requirements of both hospitals and health centres can efficiently be met through the utilisation of a structural steel frame.

This is demonstrated by the Construction Markets survey commissioned by the BCSA and Tata Steel, which shows that in 2012 steel frames accounted for 56.3% of all healthcare construction in the UK compared with 21.8% for insitu and precast concrete.

The article also examines the specialist design consideration of vibration performance in the context of structural frame material and design, and explores how this requirement can be addressed while still capturing the cost and programme advantages of a structural steel solution.

The article will conclude with the updated cost models for all building types, including updated location indices and a forward view of the market into 2013.

02 | Healthcare buildings: Typical characteristics

The healthcare sector includes numerous building types and uses. However, the key typical requirements of the sector can be identified through a consideration of hospital buildings and smaller health centres.

Even within the narrower focus of hospital buildings, there are variations in design requirements and characteristics between hospitals, which can range in size and function, such as general hospitals, specialist centres and teaching hospitals. However, functions such as consultation rooms, ancillary space and bed space are common across the sector, so a number of typical requirements can be identified.

Flexibility is important as hospitals need to accommodate a range of functions and spaces and, as the lifespans of the built assets are long, there may be changes in the functions and locations provided. Adaptability is also important to enable efficient future reconfiguration to maximise value over the life of the building.

Hospitals also have particularly high servicing requirements compared with other building types, so the efficient integration and distribution of services is important to maintain maximum flexibility and avoid significant impacts on floor-to-floor heights.

Acoustic performance is also a significant consideration, as privacy and the patient experience are key success factors. Unlike some sectors where early design and cost studies can focus on the benefits of insitu or precast concrete soffits inherently providing a "finish", such as for education buildings, this is less relevant for hospital buildings as, due to both infection control and acoustic performance requirements, exposed soffits are less common.

Where hospital buildings accommodate specialist functions, such as operating theatre space, they also have stringent vibration performance standards, which require close examination during the design stages to ensure that the architectural design allows this to be achieved as efficiently as possible.

Speed of delivery of the building is also a common requirement for hospital buildings and the healthcare sector in general, not only to bring new facilities on line as soon as possible, but also, where construction is proposed on occupied hospital sites, to minimise disruption to existing facilities.

As outlined above, since the majority of hospital buildings are long-term assets, whole-life cost and value are also considerations, with not only cost of construction but also costs in use being a key part of the decision making process.

Smaller health centres, which are typically staffed by GPs and nurses and offer family practice and dental care services, can also provide services such as pharmacy, laboratory and, in larger faciities, minor medical procedures.

These buildings share a number of design requirements with hospital buildings, particularly flexibility and adaptability, programme requirements and whole-life cost considerations. While vibration performance is less important as they do not typically contain specialised functions, acoustic performance and control of transfer of noise to maintain privacy is still an important consideration.

03 | Healthcare buildings: Structural steel frames

There are a number of structural steel frame solutions that can be adopted to address the typical design drivers of buildings in the healthcare sector outlined above.

For most healthcare functions, including offices, consulting rooms and wards, a 7-9m standard grid is adequate and will provide a good level of flexibility. Standard steel construction provides quicker erection time than other frame types and potential benefits in substructure construction due to typically lighter frame weights. Floor

systems such as a composite metal deck with concrete topping or precast concrete planks are supported on downstand beams and services can be suspended from the soffit of the floor slab and distributed with flexibility within each structural bay.

For buildings where future flexibility is particularly important, or where design features such as atria require it, a long span structural steel frame can be used to provide column free internal space and maximum floor plate flexibility.

Structural steelwork provides solutions for the efficient distribution and integration of services. Slimdek provides a flat soffit with the slabs and beams within the same zone at a minimised floor depth (typically 300-350mm), which gives maximum flexibility in services distribution routes. Where a long span structural solution is considered, the use of cellular beams with multiple regular web openings can provide flexibility in the initial installation and for future reconfigurations as well as reducing the total depth of structural floor plus service zone.

For healthcare buildings adopting a standard 7-9m repetitive grid, such as small health centres, the steel frame cost range is typically between £75 and £100 per m^2 GIFA (BCIS location index 100) assuming a frame weight of around 50-55kg/m^2 GIFA, which is similar to Frame Type 1 in Figure 5 (low rise, short span, repetitive frame type). However, where the proposed building is higher rise, such as is typical for hospital buildings, or where a long span or cellular beam solution is adopted, the frame cost will increase as the steel frame weight per m^2 GIFA will be higher and reference should be made to the cost range for Frame Type 2 of £125 to £150 per m^2 GIFA (BCIS location index 100) for a frame weight of around 70-75kg/m^2. It should however be noted that some specialist functions and facilities with particular design requirements will sit outside this range.

As with all building types, along with a consideration of standard cost ranges, there are a number of cost drivers that must be examined individually during cost planning to determine project specific frame costs.

04 | Key frame cost drivers for healthcare buildings

While the typical requirements for healthcare buildings influence frame solutions and make the standard cost ranges for structural steel frames a useful tool, it is also important to consider some of the elements that do vary from project to project throughout the cost planning process.

In particular, **location and site constraints** are key cost drivers for all types of building, influencing both the achievable design and the costs of construction. This is particularly relevant to the healthcare sector as construction often occurs on **existing, occupied sites** which, as well as impacting on design, can also impact on construction methodology and programme with limitations on noise, deliveries, working hours and restrictions on storage and craneage. Standard cost ranges based on relatively unconstrained sites will not include for the additional logistics and cost for preliminaries associated with constrained or city-centre sites with reduced access so this needs to be allowed for.

Site configuration will also have an impact on the building design in a number of areas, including floor plate configuration, grid, storey height and overall building height. Where the structural grid has to change across the building to account for site factors or adjacent buildings, the efficiencies of repetition across the frame may not be realised. A less constrained site can enable a more regular grid to be set, and more repetitive structures provide both material cost and on-site erection efficiencies. The extent to which a proposed building is influenced by factors that reduce the level of repetition should be assessed during cost planning to determine if these restrictions can be overcome as they may result in additional costs above those captured in the standard frame cost ranges.

Site constraints and configuration can also impact on **overall building height**, and therefore also on total frame cost. The frame cost for space provided on small floor plates across multiple storeys will differ from the same area provided on larger floor plates in a low rise building as the steel frame weight per kg/m^2 GIFA will differ, with a higher weight required for multi-storey construction. An understanding of the likely building form and height is important even at the earliest cost planning stages.

The **facilities** to be provided should also be reviewed during cost planning; the proportion of each type of space provided in the proposed building should be considered, as this will often directly impact the developing structural frame design. The inclusion of a number of different functions can reduce the regularity and repetition of the structure throughout the building, with hospital buildings tending to contain a greater variety of functions than smaller health centres.

As well as a consideration of the proposed mix of facilities, the proportion of **specialist space** with particular requirements will also need to be reviewed. In the healthcare sector, specialist functions, such as operating theatres, have strict **vibration control** requirements, and this will have an impact on the frame design and cost (see Section 5) that is not considered as part of the standard cost ranges. Similarly, the requirements for and method of acoustic attenuation must be assessed and included in early cost estimates as this can vary depending on the frame adopted. An exposed soffit solution is unusual in this sector, with suspended ceilings typically specified for infection control purposes as well as contributing to the economic achievement of acoustic requirements, so allowances for suspended ceilings should typically be included for all frame types in early frame material cost comparisons.

Influenced by all the above factors, a structural grid of 7-9m spans is typical for both multi-storey hospitals and smaller health centres. Therefore, where a long span grid or cellular beam solution is considered as a response to flexibility, services integration, site configuration or function requirements, there may be a cost premium as the weight of the steel frame may have to increase to achieve the spans. However, it should be noted that while long spans and cellular beams will tend to have higher cost per tonne than a standard steel frame, the frame cost overall is competitive compared with other frame solutions to achieve the same span and can also offer lower foundation costs due to fewer columns being required.

It should also be noted that partnering and framework arrangements are common in healthcare, with projects procured under ProCure 21+, Private Finance Initiatives and LIFT, so costs or solutions may already be set out with contractors. The procurement route will impact on the form of contract and supply chain, and benchmarked or cost ranges based on projects tendered in competition may not apply.

As with all projects, pressures on the design team during the development phase may tend towards only reviewing the comparative costs of different frame materials, but this is an overly simplistic approach as the frame design itself will also impact on the cost of associated elements.

For example, varying structural zones of different solutions and configurations will result in different floor-to-floor heights, which will impact on cladding costs, and different frame weights will also impact on the design and cost of the substructure, programme and cost of preliminaries.

05 | Structural steel frames and vibration

The prevalence of sensitive functions in the healthcare sector makes vibration performance a particularly important factor.

For most multi-storey buildings, standard steel construction will meet the requirements without additional modifications. However, some specialist functions in the healthcare sector have more onerous performance criteria as occupants can perceive very low amplitudes of vibration and where the building contains motion-sensitive activities, such as surgery, it is important to minimise vibration frequency and magnitude.

When the last wave of new hospital construction began a decade or so ago, there was a perception that composite floors in steel structures provide a lower level of vibration damping than concrete. However, testing was carried out to demonstrate the ability of steel-framed composite floors to meet the strict requirements (see Figure 1) and as a result, the use of steel frames for hospital buildings significantly increased, as designers and contractors were able to more readily use structural steelwork and take advantage of the other benefits, such as speed of construction, long span and column free layouts and flexible services integration.

The vibration criteria for each function must be established early in the design process to ensure all considerations are captured in the developing architectural and structural design and cost estimates.

Vibration performance is measured in terms of the response factor of the floor and this will be assessed during the design stages by the structural engineer through the use of design software or by following the design guidance and assessment methodologies set out in the Steel Construction Institute publication P354, Design of Floors for Vibration: A New Approach. Specialist guidance on the permitted level of vibration exists for the healthcare sector, and the Department of Health Acoustics: Technical design manual V0.6 (2012) sets out the continuous vibration limits for different healthcare functions.

There is a clear difference in the vibration limits across the types of spaces commonly found within hospital buildings and the resulting structural design will need to accommodate these requirements. To maximise efficiencies, thought should be given to the locations of different functions at the early design stages, with functions of similar vibration requirements located together as far as is possible.

The architectural design can also aid the structural design through consideration of the location of circulation routes. Areas close to beams and columns are typically less responsive than the middle of slabs, so by locating routes closer to beams and columns some vibration issues can be eliminated. Shortening circulation corridors or breaking them up into smaller lengths will reduce walking durations and can prevent a resonant

response building up in the floor structure.

A number of aspects of the structural design also need to be considered to ensure the floor performs as required, including floor construction, damping, floor loading and continuity and isolation of critical areas.

Metal deck composite floors and precast concrete units with a structural topping behave similarly when connected to the beams with shear connections or situated between beam flanges. However, when using precast units, it is important that they are fixed with shear studs or a structural topping is included to ensure the floor performs as a whole rather than as separate units, which may vibrate independently of each other.

When assessing the predicted vibration response of a structural frame it is important to establish the likely damping ratio, which is affected by the type of connectors and the degree of building fit out and furniture, as the level of damping will affect the duration of vibration response as well as its amplitude.

It is also important that the distributed mass assumed is representative of the mass when the building is in use as this affects the response factor of a floor at a given frequency. The higher the mass, the lower the response, so the weight of the structure and permanent loads such as ceilings and services should be considered to improve accuracy.

The vibration response of the floor can also be influenced by controlling the extent of floor plate participation. Where a greater mass is required to minimise vibration, greater floor plate continuity can be designed in. Alternatively, where specific areas are very sensitive to vibration, these areas can be isolated from the rest of the floor through construction joints at the edges or increasing the stiffness of the floor locally.

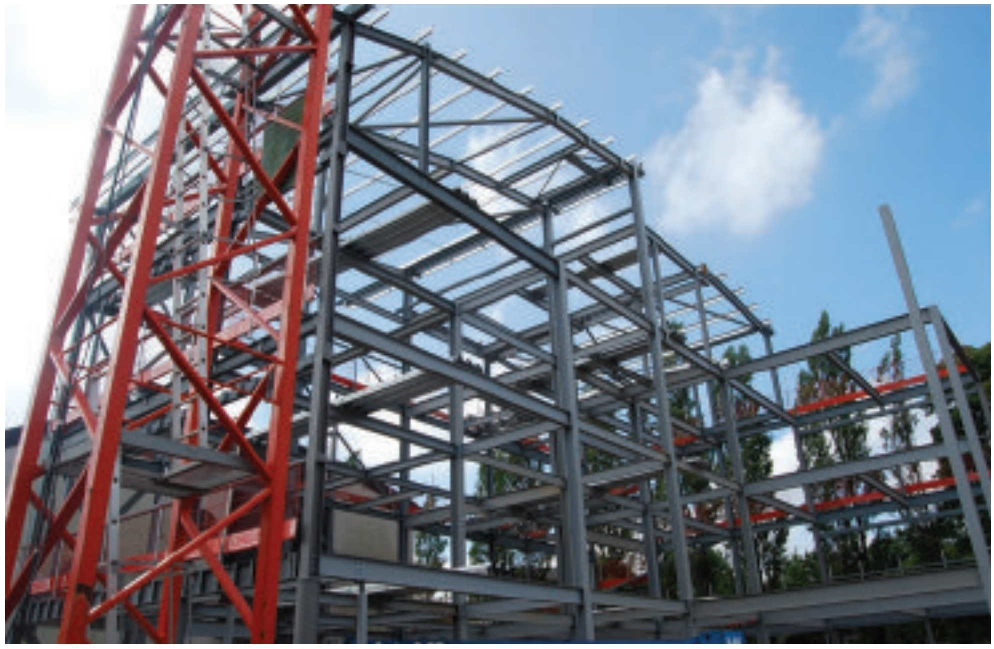

FIGURE 1: SUMMARY DATA FOR VIBRATION PERFORMANCE OF COMPOSITE FLOORS FROM TESTS IN OPERATING THEATRE AREAS (STEELCONSTRUCTION.INFO)

Form of construction	Fundamental frequency (Hz)	Response factor
Medium span composite beams, 8.1m span, 140mm deep composite slab	8Hz	0.21
Long span composite beams, 11.3m span, 300mm deep composite slab	6.4Hz	0.25
Long span composite beams, 15m span, 175mm deep composite slab	7.6Hz	0.49

Tests have been carried out on both long and medium span structures with floor build ups varying from 140mm to 300mm deep and have demonstrated that composite floor construction can satisfy the NHS Acoustic design manual limits for vibration, as well as showing that for long span steel structures, the mass of the long span sections reduces the magnitude of the vibration response rather than creating additional vibration. All measured response factors were significantly below the limiting value of 1.

06 | Summary and conclusion

Structural steelwork provides a number of frame solutions that respond to the key requirements of the healthcare and hospital sectors, including standard steel construction, Slimdek, long span construction and cellular beams.

A steel frame can provide a number of advantages, including programme benefits where rapid delivery is often a critical project success factor, flexible layouts and efficient services integration as well as the provision of a range of different functions, loadings and spans in an efficient and economic manner.

It is therefore important that the key cost drivers for the sector are understood to enable realistic cost plans to be produced. Comparisons should include not only the relative frame cost of each option, but also a consideration of related impacts on the cost of elements such as substructure, cladding and services installations to ensure that costs are assessed holistically.

Testing of steel-framed hospital buildings has also demonstrated that structural steelwork and composite floor construction can cope with the stringent design and construction requirements of specialist healthcare functions in relation to vibration control, while still providing the programme and other benefits of structural steel frames.

07 | Cost model update

Steel Insight Article 3 analysed two typical commercial buildings to provide cost and programme guidance when considering the options available during the design and selection of a structural frame.

Building 1 considered a typical out-of-town, speculative, three-storey business park office with a gross internal area of 3,200m² and a rectangular, open-plan floor space. Cost models were developed for four frame types: steel composite, steel and precast concrete slab, reinforced concrete flat slab and post-tensioned concrete flat slab.

Building 2 considered an L-shaped, eight-storey, speculative city-centre office building with a gross internal area of 16,500m² and a 7.5m x 15m grid. Cost models were developed for two frame types: steel cellular composite and post-tensioned concrete band beam and slab.

Steel Insight Article 6 reviewed the November 2012 Business Innovation and Skills (BIS) material price indices, which showed largely constant prices for cement, concrete and precast concrete between August and October 2012 and small falls in the material price of fabricated structural steel (1.2%) and concrete reinforcing bar (2%). This price stability was also reflected in tender returns and consequently, the Building 1 and 2 cost models remained constant across the period.

As Figure 2 shows, the indices for concrete, precast concrete and concrete reinforcing bar in January 2013 were at the same level as in October 2012, while cement prices have increased by 1% and fabricated structural steel material prices have marginally decreased (by 0.65%). The slight fall in fabricated structural steel prices across the period continues the reduction in the material price of fabricated structural steel since May 2012, with steel prices in December 2012 2.7% lower than December 2011.

Despite the fall in construction output across 2012 and predictions from market commentators for further falls in 2013, the small reduction in the material price of fabricated structural steelwork across 2012 has not generally been reflected in tender prices. Consequently, the cost model tables for both Building 1 and 2 below (Figures 3 and 4) have remained constant.

As Figure 3 shows, the steel composite beam and slab option remains the most competitive for Building 1, with both the lowest frame and upper floors cost and lowest total building cost. For Building 2, as shown in Figure 4, the cellular steel composite option has both a lower frame and floor cost and lower total building cost than the post-tensioned concrete band beam option, with lower substructure and roof costs and a lower floor-to-floor height resulting in a lower external envelope cost.

The lack of movement in the tender pricing levels of structural steelwork across the last quarter is also reflected in the structural steel frame cost table, where the cost ranges for each of the building types have also remained constant (Figure 5).

Looking forward, there may be a slight upward movement for both steel and concrete framed buildings in early 2013. For fabricated structural steel prices, this is due to price rises in raw materials such as iron ore, as reflected by the Tata Steel £30/tonne price increase of early December and for concrete where

FIGURE 2: DEPARTMENT FOR BUSINESS, INNOVATION AND SKILLS CONSTRUCTION COST INDICES (FEB 2013)

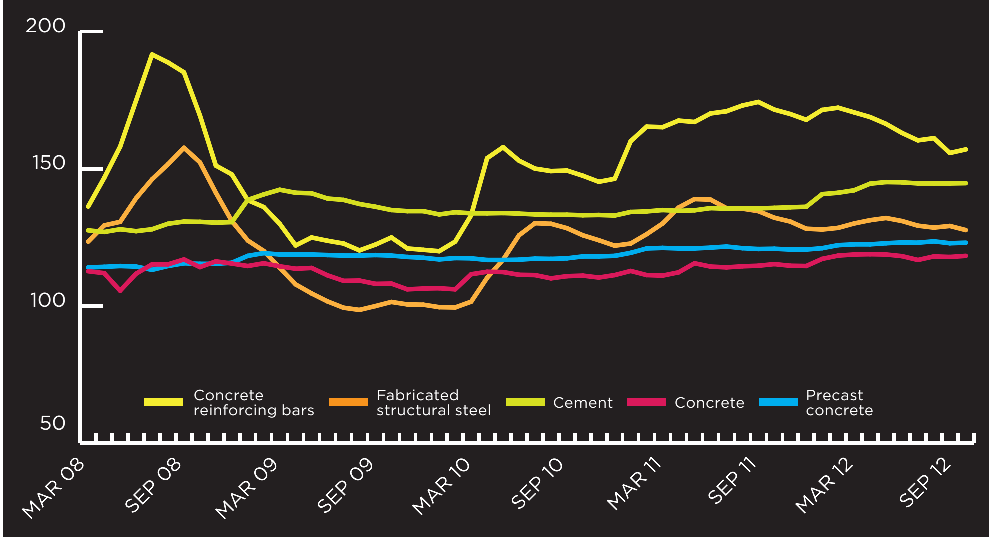

FIGURE 3: BUILDING 1 COST MODEL (KEY COSTS PER M² GIFA, CITY OF LONDON LOCATION)

	Steel composite	**Steel and precast concrete slabs**	**Reinforced concrete flat slab**	**Post-tensioned concrete flat slab**
Substructure	£52	£55	£67	£62
Frame and upper floors	£140	£151	£153	£150
Total building	£1,535	£1,561	£1,628	£1,610

FIGURE 4: BUILDING 2 COST MODEL (KEY COSTS PER M² GIFA, CITY OF LONDON LOCATION)

	Steel cellular composite	**Post-tensioned concrete band beam and slab**
Substructure	£56	£60
Frame and upper floors	£194	£210
Total building	£1,861	£1,922

reinforcing bar prices are expected to follow scrap metal price increases, although it is not expected that prices across 2013 will be higher than the 2012 average.

The further fall in construction output across 2013 is expected to maintain pressure on tender returns across the UK with competition for work high. It is therefore unlikely that upwards pressure on steel prices will be reflected in tender returns as tender pricing strategy will remain key to securing work.

To use the table: a) identify which frame type most closely relates to the proposed project; b) select and add the preferred floor type; c) add fire protection if required.

As highlighted in previous Steel Insights, before using such "standard ranges" it is important to confirm the anticipated frame weight and variables such as the floor-to-floor heights with the design team to determine whether they are above or below the average and to adjust the rate used accordingly.

Similarly, all of the other key cost drivers of complexity, site conditions, location, function, logistics, programme and procurement strategy should be considered in turn.

FIGURE 5: INDICATIVE COST RANGES BASED ON GROSS INTERNAL FLOOR AREA

TYPE	GIFA rate (£) BCIS index 100	GIFA rate (£) City of London
Frame – low rise, short spans, repetitive grid / sections, easy access (Building 1)	75 - 100/m^2	90 - 120/m^2
Frame – high rise, long spans, easy access, repetitive grid (Building 2)	125 - 150/m^2	140 - 170/m^2
Frame – high rise, long spans, complex access, irregular grid, complex elements	145 - 170/m^2	165 - 190/m^2
Floor – metal decking and lightweight concrete topping	40 - 58/m^2	45 - 65/m^2
Floor – precast concrete composite floor and topping	45 - 60/m^2	50 - 70/m^2
Fire protection (60-min resistance)	7 - 14/m^2	8 - 16/m^2
Portal frames – low eaves (6-8m)	45 - 65/m^2	55 - 75/m^2
Portal frames – high eaves (10-13m)	55 - 75/m^2	65 - 90/m^2

FIGURE 6: BCIS LOCATION FACTORS, AS AT 27 JULY 2012

Location	BCIS Index	Location	BCIS Index
City of London	114	Leeds	100
Nottingham	95	Newcastle	91
Birmingham	99	Glasgow	102
Manchester	94	Belfast	61
Liverpool	90	Cardiff	96

Steel website has all the facts

www.steelconstruction.info, developed by the BCSA, Tata Steel and the SCI, brings together guidance on all aspects of steel construction in one place. It contains over 100 interlinked, freely downloadable articles written by industry experts, covering best practice in design and construction with steel, including topics such as cost, sustainability and health and safety. To find other articles such as the Steel Insight series, case studies in healthcare and other sectors, video case studies and online CPDs including vibration and acoustics, please visit **www.steelconstruction.info**.

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THE STEEL INSIGHT SERIES

This article was produced by Rachel Oldham (associate) and Alastair Wolstenholme (partner) of Gardiner & Theobald. **It is the seventh in a series that will provide guidance on the realistic costing of structural steelwork. If you are considering using structural steelwork for your building, bridge or structure, we recommend an early dialogue with a specialist steelwork contractor. They can offer a range of support and advice, including budget estimates and value engineering. Steelwork contractors can be sourced according to project size and technical competency. This searchable function along with comprehensive design information on structural steelwork and the previous Steel Insight articles are available at**

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