

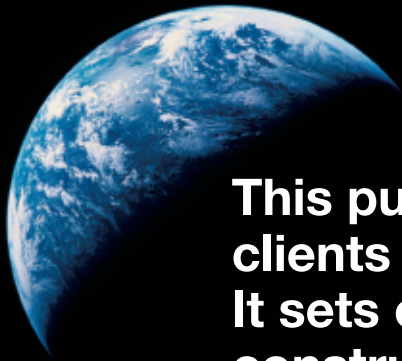
Corus

Sustainable steel construction

The design and construction of sustainable buildings



About this publication



This publication is aimed at construction clients and their professional advisers. It sets out key themes for the design and construction of sustainable buildings. Recent built examples are presented to illustrate how this is being achieved in steel construction.

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Executive summary

Society recognises the need to move towards sustainable development. Construction has an important role to play within the sustainable development agenda, not only because of its contribution to the national economy, but also because the built environment has a major impact on the quality of all of our lives, our comfort and security, our health and wellbeing and our productivity.

Constructing, maintaining and upgrading our built environment has a potentially significant environmental impact. Construction is a major consumer of non-renewable resources and a massive producer of waste, and the operation of buildings is responsible for around half of the UK's total CO₂ emissions. The challenge for the construction industry, therefore, is to deliver economic buildings that maintain or enhance our quality of life, while at the same time reducing the impact of the social, economic and environmental burdens which it places on us.

The purpose of this document is to describe the background to sustainable construction, the benefits it can bring to society as a whole and the obligations that it places on the construction sector. Examples are provided both of how to meet these obligations and of excellence in sustainable construction using steel.

It is intended that this be used as a reference document. Appendices at the back contain information which can be extracted and placed in tender documents to support the choice of steel in construction.

Sustainable construction defined

The Government set out the UK's sustainable construction strategy in a document entitled 'Building a better quality of life' [1]. This makes it clear that sustainability is not just about environmental issues but also encompasses what has become known as the triple bottom line; that is, that sustainability includes social, economic and environmental priorities.

So, for example, a development which addresses environmental issues only will not be considered as sustainable if, by doing so, it increases social and economic burdens.

'Building a better quality of life' identifies the following key themes for delivery of sustainable construction:

- Design for change.
- Design for minimum waste.
- Aim for lean construction.
- Minimise energy in construction and in use.
- Do not pollute.
- Preserve and enhance biodiversity.
- Conserve water resources.
- Respect people and their local environment.
- Monitor and report.

These themes form a framework within which the construction industry can contribute to a better quality of life in the UK. The challenge for designers is to use construction materials, products and systems to create buildings that meet these criteria. This document outlines key practical actions by which this can be achieved.

There have been a number of recent advances to support government policy in the broad area of sustainable construction. Examples aiming to address one or more of the above key themes include the

Sustainable Communities Plan; revisions to the Building Regulations; the Barker Review of Housing Supply; Sir John Egan's Review of Construction Skills; the Aggregates Levy; the Landfill Tax; various national and regional planning initiatives and the Secure and Sustainable Buildings Act.

One of most important initiatives has been the formation of the Sustainable Buildings Task Group. Set up by the Government in 2003, the group was given the job of delivering practical and cost-effective measures to improve the sustainability of buildings.

The task group's principal recommendations have been wholeheartedly supported by the Government and work is underway to establish a single national Code for Sustainable Homes. Due to be rolled out in 2006, the Code is likely to include clearly specified minimum standards in key resource efficiency criteria such as:

- energy efficiency
- water efficiency
- waste
- use of materials.

The Code will initially apply solely to social housing schemes and developments on government land and land owned by English Partnerships. Later amendments will expand its terms of reference to include other building types.

Project: Devonshire Building, University of Newcastle upon Tyne
Client: University of Newcastle upon Tyne
Architect: The DEWJOC Partnership
Structural engineer: WSP
Mechanical and electrical engineer: White Young Green
Management contractor: hbg Construction
Steelwork contractor: Elland Steel Structures Ltd

Devonshire Building, University of Newcastle upon Tyne

The Devonshire Building is a new, six-storey building in the heart of Newcastle University's campus. Home to the Environmental and E-science Research Centre, the design of the building incorporates many sustainable design features and has achieved a BREEAM 'Excellent' rating.

Design

The main structure of the building comprises a braced structural steel frame, which supports concrete hollow core floor units.

The southern elevation has a glazed façade that extends to a lightweight barrel vault roof over the building. The façade and roof are supported on a continuous tubular steel support frame.

Key sustainability features

Structural efficiency

- A structurally efficient steel frame which incorporates design features such as the south facing louvred façade, clear atrium volume and barrel roof lights.

Low operational energy

- This laboratory building places a heavy demand on electrical and mechanical services. It has been designed to be a low energy building with energy consumption around 30 per cent lower than UK best practice targets.

Energy efficient features include:

- Fabric energy storage is provided by the steel frame and concrete hollow core floor units.
 - The atrium space acts as a climate buffer between the laboratory and office areas providing natural lighting and night cooling.
 - The orientation and form of the building have been optimised for natural ventilation and daylight.
 - Passive displacement ventilation.
 - Shading to the glazed façade is provided by automatic controlled banks of louvres, which are fixed to the main steelwork supports in prefabricated panels. This climate responsive façade system optimises the levels of daylight and solar penetration, according to time of day and season.
 - Photovoltaic panels installed on the roof with the capacity to generate 30kW of electricity.
- #### Other sustainability credentials
- Grey water recycling and waste strategies.
 - Cooling by chilled beams served by a thermal water storage tank and heat exchangers.
 - Natural daylight from above with the atrium lit by barrel rooflights.
 - Daylight sensors adjust the level of artificial lighting.



The importance of construction to sustainable development

Sustainable construction is an important subset of sustainable development because of its contribution to the UK economy and the significant environmental and social impacts that buildings and other structures play in all our lives.

Economic importance

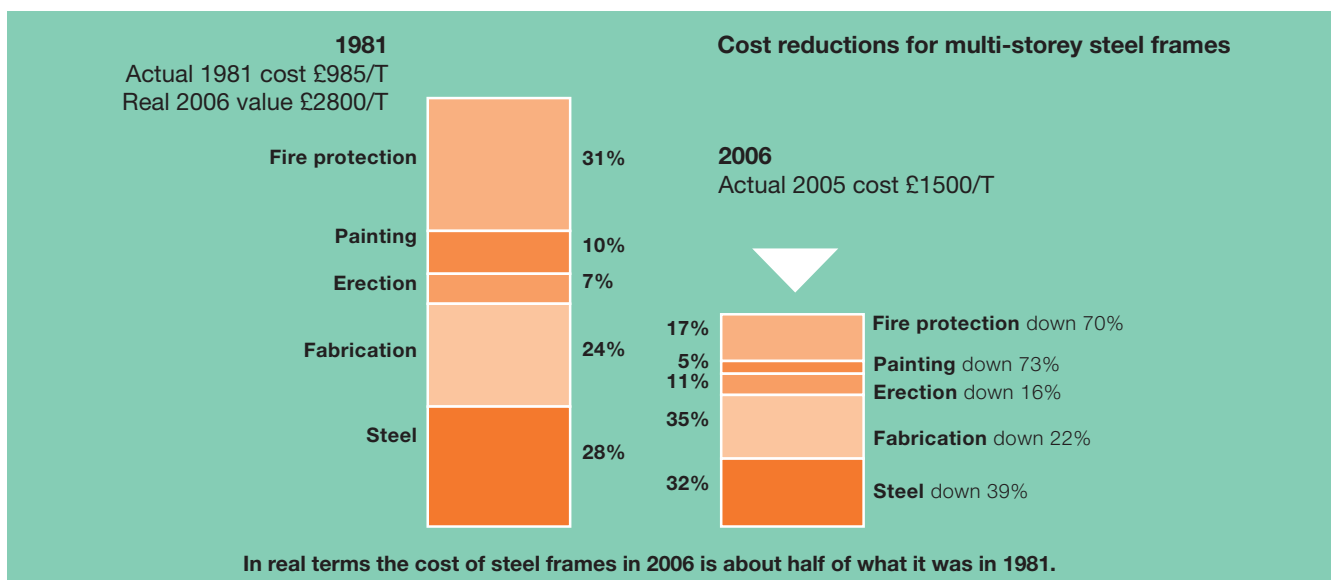
- The UK construction industry has an annual value of approximately £80 billion or 10 per cent of GDP.
- The industry employs around 1.4 million people.
- Construction activity is predicted to grow at around five per cent per year over the next 10 years.

Environmental importance

- The construction industry consumes around 420 million tonnes of materials annually.
- Buildings consume nearly one half of all the energy generated in the UK, primarily as operational energy.
- Construction and demolition activities generate around 94 million tonnes of waste every year.

Social importance:

- On average, people spend 90 per cent of their lives in buildings.
- Whether at work, at home, in education or at leisure, quality of life is a function of the built environment in which people live (their homes, schools, hospitals, offices, factories, roads, etc.).
- In commercial buildings, performance and productivity are strongly linked to the quality of the built environment.
- Construction is an important delivery for many aspects of government policy including transport, housing, education and health.



Project: Beaufort Court, Lillie Road, Fulham
Client: Peabody Trust
Architect: Feilden Clegg Bradley
Structural engineer: Michael Barclay Partnership
Main contractor: Llewelyn Rok
Steelwork contractor: Littlehampton Welding

Beaufort Court, Lillie Road, Fulham

Beaufort Court is a new, high-density housing development for the Peabody Trust comprising 65 flats, maisonettes and houses around a large, landscaped community space on a restricted site in central London. The development consists of three blocks, the tallest being six storeys.

Design

The structure is a combination of light-steel framing and modular construction incorporating light gauge steel panels for floors and walls, fully fitted-out modules for the bathrooms and hot rolled steel for balconies and other 'visually expressed' steel components. All accommodation blocks have a semi-basement car park in Slimflor® construction.

The external façade of the buildings consists of a pattern of full height glazing, stack bonded terracotta blocks, terracotta rainscreen cladding and coloured render.

The success of Beaufort Court has been acknowledged by a number of awards, notably from the Housing Corporation, National Homebuilders and CABE.

Key sustainability features

Structural efficiency

- In order to maximise structural and material efficiency, load paths are made as direct as possible by avoiding transfer structures and by ensuring that wall studs and floor joists are aligned at every junction.



Design and manufacturing flexibility

- The hybrid arrangement allows bespoke construction giving considerable flexibility in architectural form. This is important because of the mix of accommodation types needed and the planning constraints. This form of construction also permits efficient integration of services within the structure.
- The largest accommodation block at Beaufort Court comprises some 1,000 framing panels of 400 different types. Such a high degree of non-standard panels is only viable because of the extensive use of computer-aided design.

Speed of construction

- Off-site manufacture is faster than other forms of construction. The construction period gave a saving of 16 weeks on blockwork or concrete construction. The project was delivered on budget and within a week of the planned programme.

Energy efficiency

- Thermal insulation values were achieved in the external walls by placing mineral wool insulation between the steel studs and as an outer skin forming a warm wall construction.

Safety

- Pre-decked floor cassettes provide safe working platforms during erection; off-site construction in a controlled environment reduces risk.
- The site work minimises wet trades, with dry floor construction; dry lining to the walls, clip-fixed cladding and factory-made bathrooms. The result is safe and high quality construction.

Off-site manufacture

- Off-site construction is inherently more efficient than site construction. Products are of a higher quality with fewer defects and there is less waste. The use of panels, floor cassettes and bathroom pods reduces transport to and from site and eases site access and storage in congested, inner city locations.

Assessing sustainable construction

No robust methodologies currently exist that can objectively quantify and assess all three dimensions of sustainable construction, i.e. all the environmental, economic and social aspects.

By contrast the science of assessing the environmental impacts of construction and buildings is relatively advanced and decision-support tools are available to quantify and manage the environmental impacts of construction activities and buildings.

The most widely used decision-support tool for assessing the environmental performance of both new and existing buildings is BREEAM, the Building Research Establishment's Environmental Assessment Method [2]. BREEAM assesses the performance of buildings in the following areas:

- **management:** overall management policy, commissioning site management and procedural issue
- **energy use:** operational energy and carbon dioxide (CO₂) issues

- **health and wellbeing:** indoor and external issues affecting health and wellbeing
- **pollution:** air and water pollution issues
- **transport:** transport-related CO₂ and location-related factors
- **land use:** greenfield and brownfield sites
- **ecology:** ecological value conservation and enhancement of the site
- **materials:** environmental implication of building materials, including life-cycle impacts
- **water:** consumption and water efficiency.

Different factors have different weightings, some as high as 25 per cent, some as low as 10 per cent. Choice of framing materials can affect about 15 per cent of the outcome. To maximise a BREEAM rating, these weightings must be understood.

Project: South Cambridge District Council Building, Cambourne
Developer: Cambourne Business Park
Architect: AukettFitzroyRobinson
Structural engineer: Whitby Bird
Steelwork contractor: Frank H. Dale Ltd

South Cambridge District Council Building, Cambourne

The District Council moved into its new 6,000m² headquarters on a business park on the outskirts of Cambridge in May 2004.

Design

The four-storey office building is framed in steel with exposed, hollow core precast concrete planks. In addition to open plan offices for around 300 staff, the accommodation includes a council chamber, meeting rooms, library and staff restaurant. The plan form of the building comprises a central street flanked by parallel open plan offices. The lightweight steel structure and exposed concrete floor and roof slabs, give the open plan areas an expansive appearance. The building has a BREEAM 'Excellent' rating.

Key sustainability features

Built-in flexibility

Building flexibility was a key requirement of the council. They wanted to avoid a bespoke building that, should circumstances change, they could not partially sub-let or sell. Retaining commercial viability long into the future is a key facet of sustainable buildings.

Flexibility features include:

- Long-span, column-free 16m wide floorplates of open plan offices, providing flexibility for future office reconfiguration.
- Servicing flexibility that allows for subsequent conversion to either a fully air-conditioned or fully naturally ventilated building.
- The roof of the building has been designed to accommodate photovoltaics should this be required in the future.

Low operational energy

- The plan form of the building with a central street allows the offices to be naturally ventilated. The stack effect of the street causes the rising hot air to draw in fresh air across the working areas. Hot air is expelled in summer or mechanically extracted with heat recovery in the winter.
- Exposed soffits increase the fabric energy storage potential of the floor slabs.
- Passive cooling to the building occurs both during the day and at night, and is achieved through carefully positioned thermal mass, good use of natural daylighting and effective solar control.
- Solar louvres on the façades automatically track the sun to reduce excessive solar gains.
- Low energy lighting and appliances.

Other sustainability features

- The building has a rain water harvesting system, solar water heating for domestic hot water and low NOx emission gas-fired boilers.



Design for change

The pace of change in all walks of life has never been greater. Changing work patterns, new technologies, changing demographics and new legislation are all putting ever-changing demands on buildings.

Difficulty in adapting buildings to change often leads to their premature redundancy and subsequent demolition. Even before redundancy, failure or inability to adapt and upgrade buildings can compromise occupant comfort, energy efficiency and, in commercial buildings, reduce the productivity of workers.

To be more sustainable, it is important that buildings can accommodate future changes. By doing so, they will last longer and greater value will be extracted from the resources (materials) invested.

There are four principal areas in which buildings can be made more flexible and/or adaptable:

- Structural extension and strengthening.
- Internal flexibility.
- Flexible building services.
- Flexibility to integrate future technologies.

Project: Millennium Point, Birmingham
Client: Millennium Point Property Limited
Architect: Nicholas Grimshaw and Partners
Structural engineer: Buro Happold
Building services engineer: Ove Arup & Partners
Project managers: MACE

Millennium Point, Birmingham

This centre for technology and learning was built as a catalyst for urban regeneration in the heart of Birmingham. The 37,000m² complex houses a science museum, a university, shops, a leisure centre and an IMAX cinema, together with limited commercial and serviced office space.

Design

The various activities are accommodated within a building designed to offer the maximum flexibility. The composite structure of steel frame and precast concrete floors is fully expressed with exposed principal services. This allows the building to adapt to the changing needs of users. It also enables the construction and operation of the building to be easily understood, becoming part of the educational experience.

Key sustainability features

Prefabrication and fast track construction

- The structural frame was designed to be adaptable, durable and quick to build. All elements of the steel frame were designed to be manufactured into distinct modular sections with simple bolted connections to ensure rapid, easy assembly on site. This reduced the disruption on, and adjacent to, the congested and busy building site.

Flexibility and adaptability

- The structural system offered the fit-out and servicing advantages of traditional flat slabs. It enhanced the longevity of the structure by adding the ability for floors areas to be altered without costly and intrusive strengthening or demolition works.
- The hybrid structure has steel beams embedded within the concrete floor slabs, dealing effectively with the fire rating requirements.
- The floor beams were set out on a standard 3m by 6m grid, allowing flexibility in the configuration of the building.

Urban regeneration

- Millennium Point aims to bring together facilities for learning, leisure, and applications of technology, to meet the needs of individuals, business and the community. The building complex also incorporates office tenants from the government and private sectors. This diverse mix is all under one roof, a hub of activity attracting visitors to the area.



Structural extension and strengthening

The ability to extend buildings can be important in responding to the changing needs of the building owner or occupier. For example, it is frequently necessary to extend retail and factory buildings by adding mezzanine floors. It is important, therefore, to ensure that buildings can be simply and easily adapted and that additional structural members can be connected to the existing frame with minimal disturbance and cost. Providing more lettable floor area by extending buildings vertically can also increase their economic viability and longevity.

Architect: Wilkinson Eyre Architects

Empress State Building, London

Re-opened in 2003, after an £80 million refurbishment, the building now provides 45,000m² of flexible, modern, serviced office accommodation. Steel was used to extend this 1960s concrete-framed building built on a Y-shaped footprint. The southern façade of the building was extended horizontally over 27 floors using a braced steel frame supporting precast, pre-stressed concrete planks.

A three-storey vertical extension was constructed on top of the existing building using a braced steel frame supporting a bespoke, composite Slimflor[®] solution. Cold-formed steel purlins and lightweight roofing top the vertical extension.



Flexible internal space

It is estimated that British businesses currently spend more than £2 billion per year on moving people or departments around office buildings in response to organisational change. Changes in technology and working practice also places strain on existing structures. It is no surprise then, to learn that inefficient floor layout of offices is cited as the main reason for depreciation of commercial property.

Column-free, uninterrupted floor plates are the optimum answer to allowing users to optimally reconfigure internal areas and this generally means long-span solutions. In modern commercial buildings spans of 16m and more are practical and effective. In industrial buildings, sports halls and exhibition venues. Spans of 25m to over 100m are commonly used.

Flexible building services

In practice, space planning elements may have to be adapted and upgraded on a much more frequent basis than the building structure. Information technology is typically obsolescent within three years owing to the accelerating pace of change.

Therefore, long-life building features, such as the structure and floor plate, should allow as many servicing and layout options as possible to accommodate changes in the building services strategy.

Long-span solutions can also provide flexibility for services within the structural zone by providing openings in the webs of beams.

Flexibility to integrate future technologies

The shape and form of future technologies is an unknown for any designer. However, design for service flexibility and use of long clear spans will minimise the risk of premature building redundancy.



Structurally efficient cellular beams used to create flexible, column-free space at this motorway service station.



Service integration within cellular beams.

Design for deconstruction, re-use and recycling

When it is undesirable or uneconomic to extend the life of buildings and deconstruction becomes unavoidable, it is important that the end-of-life impacts of buildings are minimised. Principally this involves ensuring that materials are recovered, re-used or recycled.

Re-using and recycling construction products and materials has a significant contribution to make towards achieving sustainable development; by reducing waste and saving primary resources. To optimise re-use and recycling, it is important that consideration is given to designing buildings to facilitate their future deconstruction. This includes both the design of demountable buildings and the use of re-usable and recyclable products.

Steps the designer can take to maximise the potential for re-using steel buildings include:

- Using bolted connections in preference to welded joints

- Use of standard connection details, bolt sizes and the spacing of holes
- Ensuring easy access to connections
- Using long-span construction as this offers the maximum flexibility of use and maximises the possibility of re-use by cutting the beam to a new length.

Research carried out by the Steel Construction Institute [3] has estimated that there is around 100 million tonnes of steel in buildings and infrastructure in the UK. This 'stock' of steel is an important and valuable material resource that will be reclaimed and either re-used or recycled in the future.

Architect: Building Design Partnership

Hampden Gurney School, London

Hampden Gurney School stands out as a bold statement of what can be achieved in urban settings where space is at a premium. The building has a steel frame providing open, column-free space within the school.

The project was funded by developing the school's old playground. Replacing the playground are six open-air play decks providing safe, weatherproof play areas for each of the different playgroups. The architect 'designed in' demountability of the structure. The central atrium was designed to provide cross ventilation to the naturally ventilated classrooms.



Project: Arup Campus, Blythe Valley Park, West Midlands, UK
Client: BVP Developments Ltd
Architect: Arup Associates (London)
Structural and services engineer: Arup Associates (Solihull)
Main contractor: Tilbury Douglas Construction
Steelwork contractor: D.A. Green & Sons

Arup Campus, Blythe Valley Park, Solihull

This campus is Arup's third largest office. Comprising 3,200m² of office space in two-storey pavilions, the campus is designed to house 350 staff.

Design

The naturally ventilated buildings have exposed transverse steel frames supporting precast concrete floors and ceiling panels. The buildings are clad in timber. The concrete roof is covered with self-supporting, standing seam steel panels.

Key sustainability features

Resource efficiency

- The steel frame together with the precast hollow core floor units, is structurally resource efficient. This construction minimises structural costs, depth and weight. On-site activities are kept to a minimum.

Operational energy efficiency

- The lightweight steel structure with exposed precast concrete floor and roof planks provides the required fabric energy storage.
- Transverse steel frames optimise the penetration of natural light and assist natural ventilation. Artificial lighting is rarely needed during the summer. The natural ventilation system is a combination of cross ventilation and stack effect. Six roof pods (combined light scoops/chimneys) along the spine of each pavilion provide both ventilation and day lighting.
- Ventilation is controlled using casement louvred vents operated by the building management system. Users can also manually operate the windows and shutters.
- The cladding and glazing are variously arranged to suit the building orientation and minimise solar gain and glare.

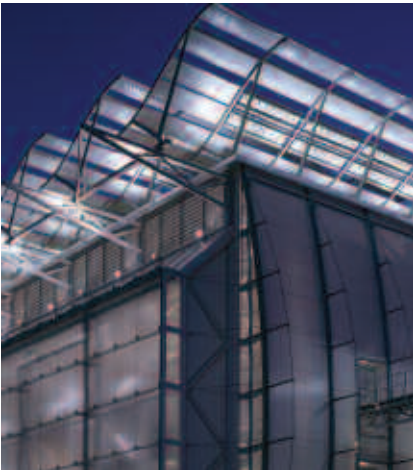
Design for deconstruction and re-use

- Standard structural steelwork components with site-bolted connections are used with proprietary, precast concrete units. This enables the buildings to be deconstructed in the future and the structural components to be re-used.

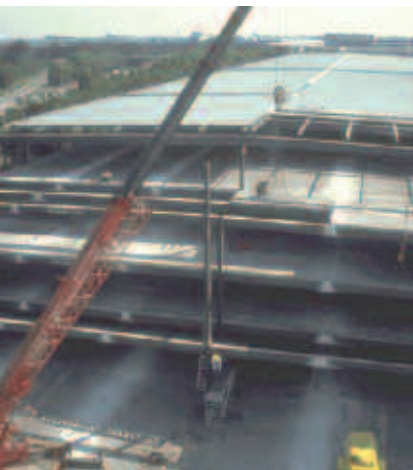


Re-use

Where possible the re-use of existing steel construction products and systems should be considered. Re-use can occur at both product and whole-building level. Future re-usability is enhanced by the standardisation of components and connections.



British Pavilion Expo 92 in Seville



A steel-framed car park building in Munich being dismantled for re-use

Architect: Bill Dunster Architects

Bedzed Project, London

Around 100 tonnes of reclaimed structural steel from Brighton railway station were used in the BedZed development in South London. The process is very straight forward. The reclaimed sections are inspected to verify their dimensional and strength properties. The member is then shot or sand blasted to remove any coatings and re-fabricated. It is then cut to the required length and new connections are created. Offcuts are recycled with no waste produced.



Re-using existing built assets

The resources required to renovate and refurbish an existing building are generally much less than those required to construct a new one. Re-using buildings increases resource efficiency and limits the amount of demolition waste. In addition, re-using old buildings can preserve their cultural and historic value.

Modern renovation and refurbishment techniques and systems enable many older buildings to be improved and brought up to today's high standards of building performance in areas such as energy efficiency and acoustics. They also allow designers to erect new structures behind existing façades to achieve long-span, column-free spaces.

New floors and mezzanines can be designed to level with existing walls and windows and appear unobtrusive externally.

Re-use sometimes demands that buildings be extended vertically to create more usable space and hence make them economically viable. This can be achieved by roof-top extensions, generally using lightweight construction to ensure that the existing structure is not overloaded. In this instance, prefabricated or modular construction is used so that most of the work can be done off-site or at ground level and the prefabricated elements simply craned into place.

Often the external appearance of buildings can lead to their premature redundancy and demolition. In many instances, the structure of the building is sound and all that is required is to upgrade the envelope. Available options include over-cladding and over-roofing or stripping the building back to its frame and installing a new envelope.

Architect: Trehearne Architects

Kinnaird House, London

Kinnaird House was constructed in the early 1920s using Portland stone held in place by an integral steel frame. The client for the refurbishment required this existing façade character be retained while maximising the net lettable floor area.

This was achieved using a Slimflor® beam system, tied to the original steel stanchions, with metal floor decking and lightweight concrete topping. The consequential reduction in load carried by the foundations enabled an additional floor to be inserted into the old banking hall area and an extra floor to be added for plant at roof level. The Slimflor® construction also allowed an unhindered services zone across each floor plate. The redevelopment achieved an excellent BREEAM rating.



Recycling

Recycling contributes to more sustainable development by diverting materials from the waste stream and by substituting primary resources.

There are different levels of recycling. Some products are recycled into new products that have exactly the same properties as the original product – this is the most environmentally beneficial form of recycling.

Other products are ‘down-cycled’ into new products that are only suitable for lower grade applications because the recycled product has different, usually lower, material

properties. Although waste is diverted from landfill by down-cycling, only lower grade primary resources are saved (rather than functionally equivalent resources). For example, crushing used bricks and concrete for hardcore or sub-base saves primary aggregates but doesn’t save the resources required to make new bricks or concrete.

Re-use and recycling of steel used in construction [4]

	Structural sections	Purlins and rails	Cladding	Composite floor decking	Rebar	Internal non-structural steel
Recycling (%)	86	89	79	79	91	85
Re-use (%)	13	10	15	6	1	2
Total %	99	99	94	85	92	87

Recycling in action

The Lackenby open hearth steelmaking building at Teesside was built in 1953. It had been used to produce steel until the 1970s, when a new BOS steel plant was built as a replacement. The building was then re-used as a store, but by 2004 had come to the end of its useful life. Following demolition, the scrap was recovered for steel production on site. The building contained over 15,000 tonnes of structural steel and cladding. This was recycled at a rate of about 1,000 tonnes each week over a four-month period. In order to show how old steel can be recycled into new products and into higher

quality applications, the steel made during this period was tracked through to end use.

This study has shown that the recycled steel has gone into many applications, including automotive, construction, shipbuilding, wind turbines, rail track and earthmoving equipment. Specific projects included the new Oval Cricket Ground and Heathrow Terminal 5.

This case study is also the subject of a separate publication from Corus [5].



The Lackenby open hearth steelmaking plant being demolished



Heathrow Terminal 5

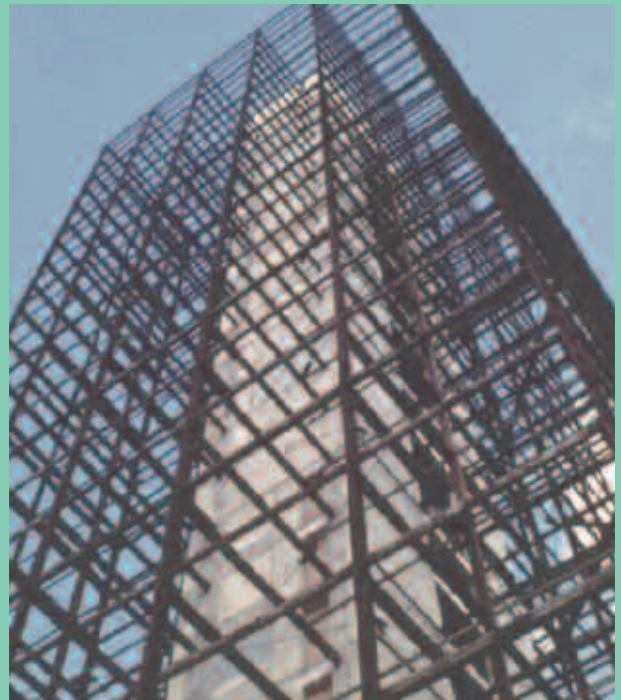


The Oval Cricket Ground

Architect: Hunt Thompson Associates

Winterton House, London

The building was remodelled completely using the existing steel structure. It was stripped down to the bare frame and rebuilt.



External refurbishment

External refurbishment occurs when the external envelope needs to be renewed to improve its performance, appearance or to incorporate a new design. With offices it may involve stripping back to the primary structure, extending the floor plate and re-cladding. For factories and warehouses it may be possible to re-use the existing purlin structure. Blocks of flats have been completely over-clad. There are many system solutions promoted by specialist contractors. The renewal process often occurs with minimal disturbance to occupants and users, with significant savings over demolition and construction.

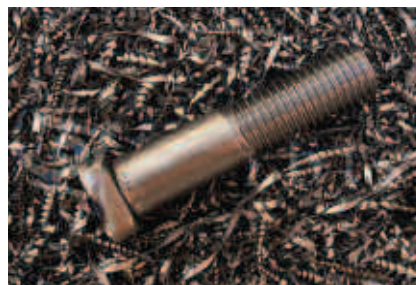
Design for minimum waste

Each year, construction and demolition activities in the UK generate around 90 million tonnes of waste [6]. Wastage occurs in the production of construction products, during the construction process, throughout the life of the building and at its end-of-life. In the past, little thought was given to the disposal of construction waste and frequently it was simply landfilled.

Today, landfilling of building waste is no longer acceptable or affordable and, in some cases, legal. Measures such as the Landfill and Hazardous Waste Directives, the European Waste Catalogue and the Landfill Tax control its disposal.

The challenge for designers is to minimise wastage through all construction stages.

Waste is not however just about what is visible on a building site. It is also lost time and effort and lack of efficiency. Conversely, reducing waste is often about doing things the best way and getting it right the first time. The following pages address this in more detail.



Steel swarf from manufacturing operations is recovered and recycled into new steel

Lean construction

Moves towards leaner construction have been added to the political and construction industry agenda in recent years.

The emphasis of lean construction on value for money, efficient supply chains, quality and continuous improvement, is consistent with the governing principles of sustainable construction. One of the key issues in lean construction is the move towards off-site manufacture. This is more efficient, faster, leaner and safer than site construction. Off-site manufacture is not delayed by inclement weather and factory working facilitates accurate, quality workmanship that results in

high quality, reliable products with fewer defects than site working. Products manufactured in the factory can more easily be standardised, tested and certified. Off-site working also has social benefits over site working. It is conducive to a permanent and stable factory workforce, which benefits the local economy and encourages local community relationships. Furthermore, staff development and training is encouraged and staff retention improved.

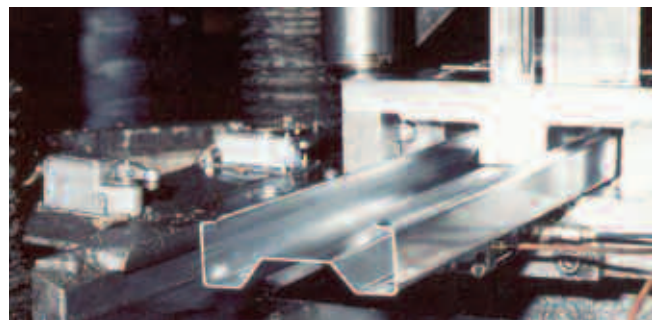
Architect: Kohn Pedersen Fox & Associates

MID City Place, London

The building occupies a large and prominent island site in Central London. The 30,000m² office/retail development was designed and fast-track constructed in just 15 months. The building comprises a steel frame and composite floors. A large proportion of pre-assembled and standardised components were incorporated within the design. Extensive use of 3D computer modelling during both the design and construction of the building had a major impact on the success and speed of the project. The large rectangular floor plates provide regular and uninterrupted office space that can accommodate change in use over time, maximising tenant flexibility.



Factory assembly of steel construction components. Off-site manufacture is more efficient, faster, leaner and safer than site construction.



Cold-forming light gauge steel components

Off-site manufacturing is characterised by a number of consistent features.

Computer-aided design: Construction products are efficiently manufactured using hi-tech, computerised equipment. Computer-aided design (CAD) systems are integrated with manufacturing software to produce quality products with very little waste. Many processes are fully or semi-automated.

No waste: Any waste produced during manufacture, such as off-cuts or turnings, are 100 per cent recycled. Construction products are pre-engineered to the correct dimensions, and there is very little, if any, wastage on the construction site.

Coatings: These are applied in the factory in preference to on the construction site. This enables greater quality control, reduces wastage through overspray and reduces the time taken on site to apply coatings. Importantly, factory-applied coatings reduce the risk of delay to following trades, reducing the overall site construction programme.

Just-in-time: Manufacturers of construction products operate on a just-in-time basis. Semi-finished products are delivered to the factory, promptly processed and the finished goods despatched to meet the on-site construction programme.

Improved site logistics: Just-in-time deliveries of construction materials reduce or even eliminate the

need for on-site storage. This improves site logistics and safety. It also reduces the risk of damage to products stored on site.

Predictable construction programmes: Fast, reliable and predictable construction programmes save money and reduce local environmental impacts and nuisance associated with construction work. Surveys of construction clients have confirmed that programme predictability is a key issue on large construction projects. 'Time is money' and predictable construction programmes mean that clients can plan and finance more accurately.

Safer construction: Construction products are manufactured under factory-controlled conditions that are inherently safer than working conditions on the construction site. On the construction site, products are quickly and simply erected reducing the overall construction programme. This limits the time that construction workers are exposed to the most common accident risks from trips and falls, falling objects and vehicle accidents.

Negligible site waste: Over-specification, damage to products, off-cuts and defects all cause significant wastage of materials on construction sites. Construction products delivered to the site pre-engineered to the correct dimensions produce very little waste.

Rapid construction: All of the features listed above reduce construction time.

Architect: Cartwright Pickard Architects

Murray Grove Apartments, London

Steel modules being erected at Murray Grove, the UK's first multi-storey modular housing development. 8 x 3.2m steel modules were used to construct this five-storey block of 30 flats in central London. Flats were delivered to site in two modular units that were fully fitted-out, plumbed and decorated prior to erection on site.



Architect: Chetwood Associates Ltd

TNT FastTrack, Magna Park, Lutterworth

This distribution centre was fully operational in just 12 weeks. The 1,600 tonnes of structural steel were erected and handed over to the main contractor in 20 days.



Efficient design and construction

Good design is fundamental to building and operating more sustainable buildings. Decisions made at the design stage have a significant impact on sustainability of a building through its life.

Buildings and their structures are more sustainable where they save resources by using materials sparingly and therefore efficiently. This is achieved by a combination of good design and engineered materials and products. The onus is on manufacturers and suppliers to develop systems and methods for using their products that will conserve resources and reduce impacts. There is a further onus on specifiers to use these correctly.

The following section outlines some design features that may be considered by the design team to deliver sustainable buildings for their clients.

Architect: REID Architecture

TAG Farnborough Airport

Making efficient use of materials and resources is a key sustainability attribute. The solution developed for the TAG aircraft hangars at Farnborough was an arch designed to follow the natural profile of the plane geometry. By reducing the area of the envelope, the cost of the cladding was minimised and the wind loading on the structure reduced. The structure comprises 90m steel trusses, formed from hollow sections, at 9m centres.



Architect: Austin Smith Lord

Portishead Marina, Somerset

A value engineering exercise was used to evaluate various alternative schemes for this six-storey apartment block, originally designed in reinforced concrete. Slimdek® construction was chosen as the preferred construction system, yielding significant cost savings by eliminating the expensive transfer structure at ground floor and reducing foundation loads by 30 per cent.



Project: Leeds Nuffield Hospital
Client: Nuffield Hospital
Architect: Carey Jones Partnership
Client's consultant: Waterman Partnership
Design and build contractor: Shepherd Construction

Leeds Nuffield Hospital

Leeds Nuffield Hospital is one of the most technically advanced independent hospitals in Europe. The 11-storey, 20,000m² floor area hospital has six operating theatres, eight intensive care beds, a 10-bed day case unit and 80 private in-patient beds.

Design

Tight planning restrictions on the overall height of the building necessitated integration of the ceiling services zone within the structure. This was only possible by using long-spanning cellular steel beams.

Steel was used for the structural frame, for the composite floor decking, for the infill walls and for many of the internal walls. Pre-fabricated toilet and bathroom pods, with integrated plumbing and electrical fittings, were used to shorten the construction programme.

Key sustainability features

Structural efficiency

- 'Lightweight' with a high strength to weight ratio, steel has been used structurally throughout this hospital. Using cellular beams has added to this efficiency.

Fire engineering

- The project was fire engineered which led to large reductions in the amount of fire protection required, saving material resources and site activities and costs.

Service integration

- Hospitals, and in particular operating theatres, are highly serviced buildings. The use of cellular beams with up to 625mm diameter cells, in the theatres and wards, enabled integration of the services with the structure. At certain locations in the span, elongated openings were created to provide for larger service ducting.

Fast construction

- Erecting the frame in advance of the lift and static cores resulted in the servicing plant being rapidly installed on the upper floors. By installing the plant early, an estimated 20 weeks (of the overall 18-month programme) was saved compared with more traditional construction methods.

Flexible/adaptable buildings

- The use of long-span, cellular beams created large, open-plan areas that are flexible for current needs and adaptable to the future requirements. Lightweight steel internal walls can be easily moved and reconfigured to accommodate change in the internal layout.

Off-site manufacture

- Off-site manufacture yields many sustainability benefits over site construction. These include high quality engineered products, predictable delivery and low wastage. In this project modular construction provided the toilet and bathroom pods. Manufactured under factory conditions, in parallel with the site works, they were simply craned into position and connected up to the building's service ducting. The pods have the advantage of being easily deconstructed and reconditioned or replaced at some point in the future.



Design features of sustainable buildings

Use materials with high strength-to-weight ratios:

This will allow designers to create 'light' structures that have low overall environmental impacts with few and lighter foundations.



Long-span structural frames.

Design for long spans:

Building designers invariably strive to create flexible, column-free spaces that can facilitate changes in use during the life of the building, and which will also increase the lettable area, reduce refit costs and extend the life of the building.



Long-span cellular beams.

Use forms of construction which provide safe working platforms:

The use of decking and permanent formwork helps here. Also, designers should consider the importance of using contractors who have signed up to high quality industry codes of practice and standards.



Installing 'deep' steel decking on the lower flanges of asymmetric Slimflor® beams.

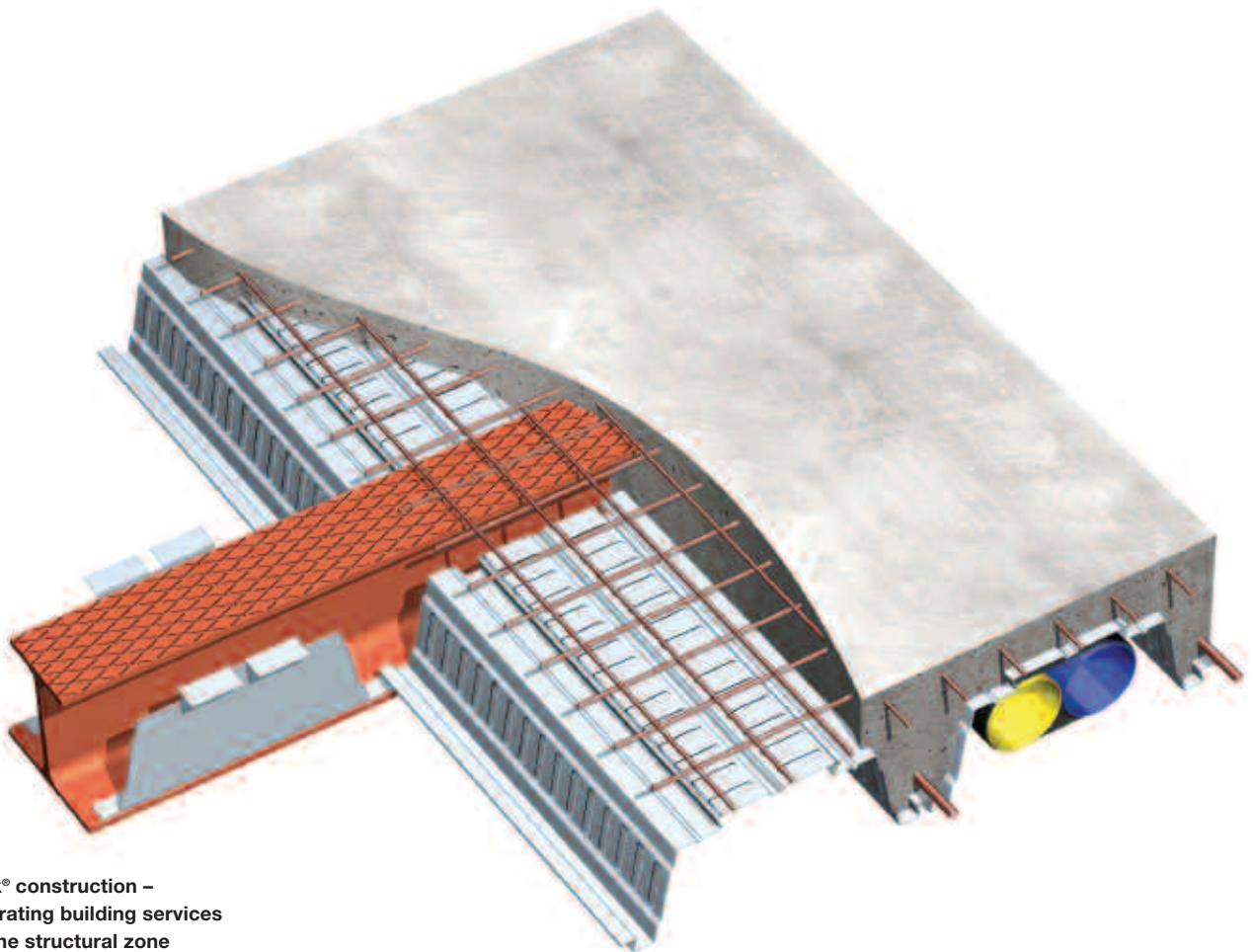
Design features of sustainable buildings

Utilise service integration:

The integration of services within the structural elements of buildings saves resources by reducing the storey height. This has a double benefit of reducing the external cladding required and reducing heat loss through the envelope. In multi-storey buildings, service integration can allow extra floors to be provided within the same building height and, in some situations, enable compliance with planning restrictions on the overall height of the building.



Service integration within cellular beams.



Slimdek® construction – incorporating building services within the structural zone building services within the structural zone.

Minimising energy in construction and in use

Energy consumption in buildings accounts for nearly half of that used in the UK. The link between fossil fuel use and climate change makes reduction in energy consumption one of the most important aspects of sustainable construction.

The Government's Energy White Paper [7] has set a target to reduce CO₂ emissions by 60 per cent by 2050, with half of these savings to come from greater energy efficiency. Building design will clearly have an important role to play in meeting these targets.

Improving energy efficiency in buildings can reduce:

- whole-life costs
- depletion of non-renewable fuels, e.g. oil, gas and coal
- global warming from the burning of carbon-based fossil fuels.

To understand how the impacts of buildings in construction and use can be reduced, it is important to distinguish between embodied and operational energy.

Embodied energy is the energy required to manufacture and transport the materials and for the means of construction and to carry out the building process.

Operational energy is the energy required to operate the building over its lifetime.

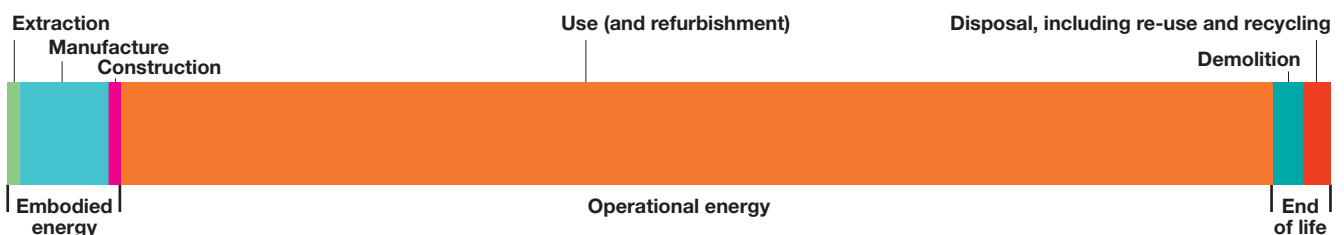
It is widely acknowledged that operational energy

consumption in intensively used and heavily populated buildings far outweighs the embodied energy. For example, research undertaken by the Steel Construction Institute [8] found that for an air-conditioned office building over a 60-year design life, the ratio of embodied to operational energy is around 1:10.

The message is clear – in such buildings, designers can make the greatest contribution to sustainable construction by concentrating their efforts on reducing operational energy.

Greater energy efficiency in buildings is generally achieved by a combination of the following measures:

- reducing primary heat losses through the building envelope
- reducing cooling loads
- introducing energy saving measures in the operation of the building, e.g. energy efficient electrical appliances
- installing energy creation systems, such as photovoltaic panels and combined heat and power plants
- improving natural lighting.



Energy life cycle for an office building over 60 years

Whole-life costing

Whole-life costing (WLC) is a tool for assisting decision making between different options with different cash flows over a period of time. In effect, therefore, it is a form of investment analysis.

It is a treasury requirement that major capital projects should be procured by taking account of whole life costs. This applies to Design & Build, PFI or one of the newer procurement initiatives such as NHS Estates Procure 21. Local authorities also often adopt WLC as part of their response to their duty to deliver Best Value.

Decision making in the construction industry has traditionally focussed on capital costs. Whole-life costing is used as an approach to balancing capital and revenue costs to achieve an optimum, and hence more sustainable, solution over a building's whole life.

WLC can be used to compare alternative investment scenarios such as:

- Retain and refurbish or sell.
- Alternative designs (such as between framed and load-bearing structures).
- Alternative specifications (such as window frames).

What costs are taken into account?

Operational costs that are commonly taken into account include:

- Rent and rates.
- Energy and utilities.
- Maintenance.
- Repair and refurbishment.
- Demolition and disposal.

All these activities have social, economic and/or environmental impacts and therefore like life cycle assessment, whole life costing can be a valuable tool for optimising the sustainability of buildings.

Why does whole-life costing matter?

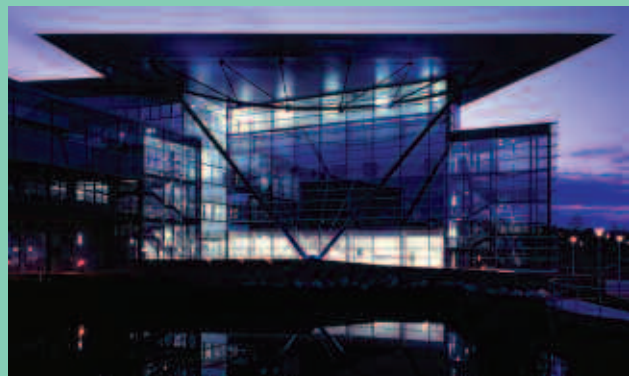
Whole-life costs can be substantially greater than capital or initial costs. It is estimated that the operational expenditure of offices is typically 5-10 times as much as the capital costs over a 30-year period. Studies have also shown that business costs are 100-200 times greater than initial costs over the same period. These ratios indicate that a one per cent improvement in productivity would pay for the entire capital costs of the building! It is estimated that operational productivity can, in fact, be increased by up to 17 per cent by improving internal conditions within commercial buildings.

Architect: Broadway Malyan

Met Office headquarters, Exeter

The structure of the main blocks is formed by steel frames supporting precast concrete floor planks. The design incorporates special steel beams which allow circulation of cold and warm air through the hollow cores of the planks. This exploits the thermal capacity of the building fabric, and with exposed concrete soffits, means that heat is transferred easily with the office surroundings. This reduces the demand on air conditioning. It also reduces the floor zone, thereby lowering the overall building height.

The building is highly insulated with an airtight building envelope, giving a high degree of energy efficiency. The development achieved a BREEAM 'Excellent' rating.



Project: City Hall, London

Client: GLA, CIT Markborough Properties, London Bridge Development

Architect: Foster and Partners

Structural and services engineer: Arup & Partners

Construction managers: MACE

City Hall, London

This 45m high, 10-storey headquarters for the Greater London Authorities (GLA), accommodates an assembly chamber, gallery, public library, committee rooms, offices, and restaurants. The building was constructed in 30 months and formally opened in July 2002.

Design

The 18,000m² GLA building has a steel frame. Structurally, the building demanded precise engineering to solve the three-dimensional jigsaw. Its shape and inclination meant the structural engineers had to design the building to counteract its tendency to fall over.

The architects took a sphere for the conceptual design of the building. A sphere has 25 per cent less surface areas than a cube of the same volume and therefore suffers less heat loss through the envelope during cold days and less heat gain on sunny days. The sphere has been modified so that it leans back from the river. At this angle the building presents a minimal surface area to the sun, reducing its solar gain. The tilt also means that the building does not cast a large shadow over the riverside walkway, allowing the sun to reach down to open public spaces.

The GLA building was awarded a BREEAM 'Excellent' rating in 2002.



Key sustainability features

Structural efficiency

- The form and shape of the building, together with the cladding and other design features, was made possible using structural steel. Its slender members, strength and ductility, have been fully exploited to create a unique building.

Low operational energy

- The steel diagrid structure supports the north side façade, and acts as a giant radiator. The majority of the horizontal tubular steel elements, measuring 300mm in diameter, have hot water coursing through them to act as a discreet heater for the atrium space.
- For cooling the building, naturally chilled borehole water is brought up 125m from the aquifer below. The boreholes use less energy than conventional chillers and cooling towers.
- The building has chilled beams to provide air conditioning. The beams are multi-functional units and incorporate passive chilled-water cooling coils, standard and emergency lighting fittings, smoke sensors, sprinkler heads and light detectors.
- The façade is made up of insulated panels that reduce the solar gain as well as heat loss to half that of a normal office building.
- The façade incorporates locally controlled natural ventilation. When the natural air vents are opened, 'smart' air conditioning and heating systems deactivate themselves in the adjacent area to prevent energy waste.
- The building is naturally ventilated, with windows that open in all office spaces. The deep-plan floors allow for the collection of heat at the building's core, which can then be redirected to its periphery. The combination of all these energy saving systems means that there is no need for chillers in the building.

Thermally efficient steel envelopes

Reducing primary heat losses through the building envelope can be achieved by insulating the external envelope and increasing its airtightness.

Insulating the external envelope

There are two main cladding types available to achieve U-values that exceed the current Building Regulations: twin skin built-up systems and composite (or sandwich) panels.

Twin skin systems: These comprise a weathering sheet, insulation and liner sheet. The sheets are held apart by spacer systems which also transfer the external loads to the supporting structure. The outer steel sheet is typically 0.7mm thick with a variety of durable organic coatings applied to a corrosion-resistant galvanised substrate. The sheets are supplied in a variety of colours and coating types suited to the intended application. Insulation thicknesses vary according to the insulation material and designed U-value.

Sandwich panels: Sandwich panels are also formed from two steel sheets but are separated by rigid insulation, usually polyurethane or mineral fibre, which is bonded to both sheets and contributes to the structural performance of the panel. The rigid panel acts compositely and there is no need for either of the sheets to be profiled other than for aesthetic reasons. The same range of coatings is available as for built-up systems.

Light steel-framed external walls: 'Warm frame' construction, in which the light steel frame is placed inside the insulation, is normally adopted to provide a system which is largely independent of the insulation thickness. The insulation is generally a rigid foam board which is applied as part of the frame erection process to give rapid weather protection. This enables construction to proceed independently of progress with the brick outer skin. Performance in excess of the requirements for energy conservation in the Building Regulations can comfortably be achieved with light steel-framed external walls.

Airtightness: As the thermal efficiency of building envelopes has improved, air leakage is an increasingly significant factor in energy wastage. Buildings over 1000m² now have to be tested for airtightness and must achieve a maximum loss of 10m³/m²/hr at 50 Pascals to comply with the current Building Regulations. More stringent rules are likely in the future. Good airtightness is achievable using steel cladding systems.

Reducing cooling loads

In a typical modern commercial building, the energy use within the building means that consumption for cooling generally exceeds that for heating. The challenge is to provide adequate cooling to achieve optimal working conditions throughout much of the year while at the same time minimising energy use.

Fabric energy storage (FES), often called thermal capacity, can be used to absorb excess heat inside buildings during the day which can then be removed by night-time ventilation or purging. Used effectively, it can mean that mechanical cooling can be reduced or even eliminated.

Control is achieved by providing sufficient building fabric (or mass) to absorb the energy and by designing the building to enable heat to be easily transferred into (and out of) the fabric. The simplest way of doing this is to expose the maximum area of those building elements that have the greatest thermal capacity. This is usually the underside of the floor slabs.

By allowing the fabric of the building to absorb heat energy during the hottest part of the day and then releasing it by cooling the fabric down, usually overnight, daytime peak internal temperatures can be reduced by 3-5°C and the 'midday peak' shifted to later in the day, after the building occupants have left.

Project: Oxstalls Campus, University of Gloucestershire
Client: University of Gloucestershire
Architect: Feilden Clegg Bradley Architects
Structural engineer: Whitby Bird & Partners
Steelwork contractor: Billington Structures Ltd

Oxstalls Campus, University of Gloucestershire

From its inception, the campus was designed with sustainability as a key component. Oxstalls Campus was the winner of the Civic Trust's 2003 Sustainability Award.

Design

The scheme comprises two linear blocks. The first block contains the Learning Centre and the Sports Science Faculty. The Learning Centre provides spaces for 300 computer workstations and study areas. The Sports Science building contains a large sports hall, research laboratories and teaching spaces, together with staff offices. Many of the sports facilities are shared with the community. The second block is student housing divided into a series of four-storey, linked villas.

Key sustainability features

Low operational energy

- The Learning Centre's energy consumption is approximately one-third of the current best practice figures in the UK for buildings with a high degree of environmental control.
- The buildings are steel framed with precast concrete, Termodec floors and roofs. The Termodec system utilises the fabric energy storage of the concrete floor slabs, providing cooling in summer and reducing heating loads in winter.
- A top-lit atrium, containing the vertical circulation that links the open plan study areas, introduces excellent daylight across all three levels.
- The Sports Science building has a waveform roof letting in northern light. This reduces the artificial lighting loads. Roof level photovoltaics are installed on the south-facing slopes of the roof, designed to generate 30 per cent of the electrical use in the building.



How much fabric energy storage is required?

The parameter used to measure the ability of a building element to store and release heat is admittance. The higher the admittance value, the greater the ability of the element to store and release heat energy. The graph below shows the variation of admittance of concrete slabs with depth.

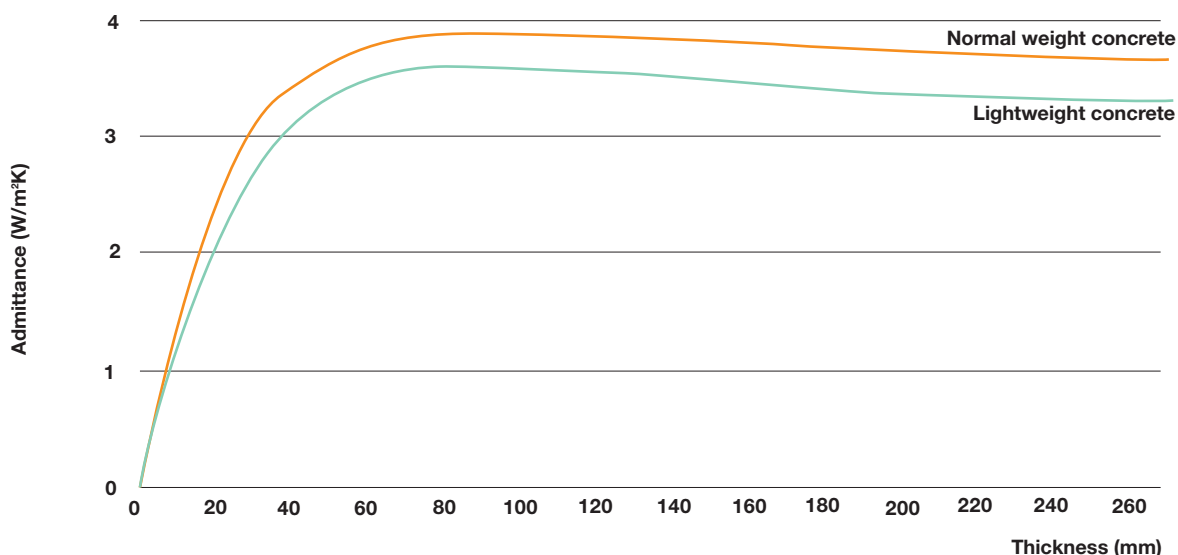
The graph shows that, in a naturally ventilated building, the maximum value of admittance for a concrete slab is achieved with only 75-100mm of concrete over a daily cycle [9]. Furthermore, beyond the maximum value, admittance progressively decreases with increasing slab thickness because of the relative difficulty in extracting heat from deep within the slab. There is therefore little point in designing large mass buildings solely to take advantage of FES.

There are two basic design strategies for utilising fabric energy storage in buildings. They are:

Passive systems: in which the building fabric, usually the floor slab soffit, is exposed to allow heat exchange to take place between the floor slab and the air. Thermally permeable suspended ceilings can be used where it is impossible or unacceptable to expose the soffit.

Active systems: in which heat removal from the building fabric is enhanced through the mechanical supply of air or water through, or over, the floor slab. Options include:

- Raised floor voids through which air is passed either via natural or forced ventilation.
- Air core systems, in which air is passed through voids in the slab.
- Water-cooled slabs, in which water is passed through plastic pipes cast within the concrete slab.



Project: Endeavour House, Ipswich
Client: Suffolk County Council
Architect: ttsp Limited
Structural/civil engineer: S&R Associates
Mechanical and electrical engineer: Haywards Property Services
Construction managers: Bovis Lend Lease
Steelwork contractor: The Wall Engineering Co. Ltd

Endeavour House, Ipswich

Endeavour House was built on a brownfield site following the demolition of an existing building. The building was purchased by Suffolk County Council in April 2003. They added a brief for the council chamber to be integrated with the existing project.

Design

The building comprises three office blocks (45m x 16.5m), providing 15,000m² gross floor area. These rectilinear blocks are connected by a large atrium.

The structure comprises a steel frame with composite metal deck floor slabs. Perimeter columns are at 9m centres with an internal spine beam and columns splitting the building into 9m and 7.5m bays.

The main structures are encased by fire protection and the building fabric. The atrium structure is a spectacular frame fabricated from circular hollow section steels. The structural glass envelope is suspended from stainless steel castings, which are connected back to vertical tension trusses.

Key sustainability features

Social/economic

- Built on a brownfield site, this project became the key development in bringing regeneration to this area of Ipswich. The proximity to the town centre facilitates good local transport, infrastructure and connections whilst maintaining strong employment opportunities.

Built environment

- The building itself addresses sustainability both in the use of materials and the way it is serviced. Waste from the demolition of the existing building on the site was broken down and graded for re-use as hardcore on site. Sub-contractors and suppliers were required to provide company Environmental Statements as part of their tenders.

Structural efficiency

- The major challenge when the county council acquired the building was how to accommodate a council chamber with a public gallery into the original building. The versatility and lightness of the structural frame made this possible.
- The general façades and particularly the atrium were designed to maximise transparency. The atrium is fabricated in a contemporary structural glass wall supported on a slender steel structure.



Energy efficiency

- Maximum energy efficiency has been met by adopting both active and passive energy saving measures.
- The fabric of the building was selected to be thermally very efficient.
- The type of glazing used was selected to minimise the solar heat gains within the building.
- Brise Soleil shading was implemented to further reduce heat gains within the office areas. The Brise Soleil consists of three solid shades set at a height to provide maximum shading efficiency.
- Five per cent of the building's peak electrical demand is met by photovoltaic cells. It is the largest commercial installation of integrated photovoltaic cells in Europe. The cells are laminated into standard curtain walling and structural glass units, an energy saving measure integral to the construction of the building.
- Heating and cooling is provided via an energy efficient water-loop and inverter driven system. This aims to keep the building in a balanced state. When simultaneous heating and cooling is required the waste heat from areas being cooled can provide the energy for areas which require heating.

- The carbon dioxide emissions for the HVAC system work out at almost half that of a standard Four Pipe Fan Coil System.

Natural lighting

- The building has a high level of natural lighting and this has been utilised in the fully programmable lighting management system to restrict the use of artificial lighting if daylight levels are sufficient.

Water efficiency

- The water wastage is kept to a minimum with PIR controlled appliances. Rainwater is collected from the building's roof areas, and drained into underground storage tanks. Rainwater is then pumped to serve all the toilet areas.

Healthy building

- The central atrium of the building is naturally ventilated, and although the office areas are mechanically ventilated, the system is designed to minimise energy wastage. Air quality is maintained by the use of carbon dioxide monitoring so that at times of low occupancy the recirculation of air is minimalised, but as occupational levels rise the level of fresh air is increased to maintain good air quality.



Project: Wessex Water Operations Centre, Bath
Client: Wessex Water
Architect: Bennetts Associates
Structural and services engineer: Buro Happold
Construction manager: MACE

Wessex Water Operations Centre, Bath

Winner of the 2001 RICS Building of the Year Award, this 10,000m², two-storey headquarters building utilises sustainable design and construction techniques.

Design

The building is E-shaped, the three parallel legs being open-plan, naturally ventilated offices, the long spine providing the main circulation route. A 'light' steel frame with exposed precast concrete floor units provides an open, spacious feel to the buildings. The southern façade comprises a double-glazed curtain wall system.

Key sustainability features

Brownfield land redevelopment

- The building and grounds occupy a three hectare, previously developed site.

Building orientation

- The building is designed and oriented to 'blend' into the natural landscape to minimise its visual impact and to promote natural ventilation.

Resource efficiency

- The environmental credentials of the materials used to construct the building were assessed and chosen by

BRE to minimise impacts. Issues addressed included emissions, waste, resource depletion and recyclability.

Structural efficiency

- The lightweight steel structure is used with precast coffer slabs to provide a resource efficient building. Large spans allow for flexibility with planning work areas.

Operational energy efficiency

- The structure is used for fabric energy storage with exposed surface areas to aid the thermal transfer. The precast hollow core concrete planks benefit from night cooling.
- Offices are naturally ventilated to minimise the use of mechanical ventilation and cooling.
- The building is heated by a combination of solar water heating and condensing boilers. The target energy consumption is 33 per cent below current best practice.
- External solar shading is used to minimise internal thermal gains while providing natural lighting deep into the buildings.

Other sustainability credentials

- Rainwater from the roofs is collected to provide toilet flushing.



Reducing pollution

Pollution can occur during the extraction of raw materials, the manufacture of products or during the construction process itself.

Major potential sources of pollution from construction processes are:

- Waste.
- Vehicle emissions.
- Noise.
- Releases of contaminants to atmosphere, ground and water.

Off-site manufacture, rapid site construction, flexible long-life buildings and high levels of recycling all contribute to low environmental impact during all life cycle phases of buildings.

The preferred process for assessing the environmental impacts of construction products is life cycle assessment (LCA). LCA is a complex methodology that involves quantification of all the resources requirements for the manufacture of products and all the resulting emissions, i.e. waste and emissions to air and water. Comprehensive LCA studies include all impacts from the mining of

resources, transportation, manufacture, construction, maintenance and end-of-life issues including recycling and disposal.

In the UK, the Building Research Establishment (BRE) has led the development of Environmental Profiles of construction materials and products using LCA. Environmental Profiles data are used by BRE to derive the ratings included in The green guide to specification [10] which, in turn, are used to assess the environmental impacts of materials within BREEAM and EcoHomes assessments [2]. Under these assessment schemes, buildings are awarded material credits depending upon the proportion of Green Guide A-rated specifications within the building. Many steel construction specifications in the Green Guide are A-rated.



strip steel

Respect people and their local environment

Construction projects can have significant social and environmental impacts on neighbours to the construction site, particularly in congested urban areas. These 'local impacts' include noise, dust, surface and ground water pollution and traffic congestion associated with both deliveries to the construction site and the construction works themselves.

The severity of these impacts is a function of both the type and form of construction and the duration of the project. The impact of construction activities, and indeed the finished development itself, on local ecosystems should also be considered and minimised.

Consideration of the following attributes can reduce the impact on local communities:

Look for rapid construction: minimise the duration of construction activities.

Specify clean construction: wherever possible choose dry and dust-free means of construction.

Try to ensure that the amount of manufacturing off-site is maximised: this reduces the duration of construction and 'snagging' activities.

Minimise noise: choose the quietest form of construction possible.

Minimise disruption: try to reduce the number of deliveries to site and maximise the number of deliveries made outside normal working and/or rush hours – lessening disturbance and the impact on local traffic.

Chose lightweight construction: this minimises the amount of earth moving, spoil and foundation works required.

Design for flexibility and adaptability: this maximises the potential for extension and refurbishment of existing buildings, with savings on demolition and full-scale redevelopment.

Architect: Nicholas Grimshaw & Partners

25 Gresham Street, London

The building is Lloyds TSB UK headquarters. Steel A-frames within the basement level were used to straddle, and hence preserve, archaeological remains found beneath the site. The braced steel-frame structure with simply supported floor beams, achieves clear spans of 12m, providing flexibility within the building. The building services are integrated within the steel beams minimising floor-to-floor heights. The building achieved the Corporation of London's Considerate Contractor Scheme Gold Award during construction.



Appendix I: The steel construction sector's commitment to sustainability

Corus

Corus is an international company that manufactures, processes and distributes metal products and provides related services in design, technology and consultancy. Corus has manufacturing operations in many countries with major plants located in the UK, The Netherlands, Germany, France, Norway and Belgium.

Corus is committed to sustainable manufacturing and to the sustainable use of its products and systems. It is a key member of the steel construction sector, which has been at the forefront of sustainable design and construction.

Guidance and support on how steel products and systems ensure sustainable buildings throughout their lifecycle can be found on www.corusconstruction.com or through the Technical Hotline on +44 (0)1724 405060.

Within the UK

The UK steel construction sector takes its responsibility to sustainability seriously and, over recent years, has worked closely with the Government to develop and implement a sector sustainability strategy. 'Building a better future' was launched in 2002.

'Building a better future' sets out a number of targets that include specific initiatives under the following themes:

- Supply chain engagement.
- Provision of accurate information to inform construction decision making.
- Developing sustainable market solutions.
- Benchmarking and measuring progress.

Responsibility for delivery of the strategy rests with the Sector Sustainability Committee, which meets regularly to review progress in its implementation. Regular reports on progress achieved in the delivery of the strategy are published annually on www.sustainablesteelconstruction.com.

Demonstrating the sector's ongoing commitment to its sustainability strategy, the Steel Construction Sustainability Charter was launched in 2005 to engage the steel supply chain in adopting more sustainable behaviour.

The initiative offers steelwork contractors a way of demonstrating that they are addressing sustainability, monitoring their progress and making improvements. Charter companies have undertaken to run their businesses on sustainable lines, demonstrate social responsibility and share their knowledge of sustainability with others.

After signing the charter, companies have to complete a sustainability application form and undergo an audit, carried out by RQSC auditors. Ongoing compliance with the charter objectives is demonstrated by annual audits.

The charter is available to members of the British Constructional Steelwork Association and the Register of Qualified Steelwork Contractors.

Internationally

Globally, the steel sector is committed to sustainable steel construction. The International Iron and Steel Institute (www.worldsteel.org) is coordinating activity

The Member Companies of IISI are committed to sustainable development. In a Policy Statement released during the United Nations World Summit on Sustainable Development in 2002, sustainable development was identified as development aimed at improving the quality of life for everyone, now and for generations to come. The statement commits the steel industry to a vision where steel is valued as a major foundation of a sustainable world, achieved by a financially sound industry, taking leadership in economic, social and environmental sustainability and seeking continuous improvement. IISI is charged to provide leadership for steel in addressing sustainability issues.

In 2005 IISI published the first sustainability report for the world steel industry. The report marked another milestone on the road to sustainability for the industry. The second sustainability report will be released in early 2006.

The international steel production industry has collectively developed and published a series of 11 sustainability indicators of the economic, environmental and social performance of the world steel industry [11].

Appendix II: Steel's sustainable construction credentials

Steel is a versatile product. Applications in construction include:

- **the structure, including the frame and metal floor decking**
- **the envelope, including roofing and wall cladding**
- **substructures, including foundations and sheet piling**
- **internal fit-out, including wall partitions and service ducting**
- **modular and panelised systems**
- **furnishings, fittings and finishes.**

High strength-to-weight ratio: Steel's inherent strength-to-weight ratio is exploited in resource efficient structures and buildings. Long-span steel solutions create open, column-free space that is flexible to changes in building use. Service integration within the structural depth of steel frames not only reduces cladding cost and heat loss through the envelope, but can also enable additional floors to be constructed in multi-storey buildings.

Inherently flexible and adaptable: Steel buildings are inherently flexible and adaptable, and can be easily extended. Steel's 'lightness' enables new steel structures to be built on existing buildings without overloading their foundations. Long-span solutions create flexible internal space. Openings within the webs of beams enable flexibility in routing building services.

Re-use of existing structures: The flexibility of steel construction systems makes them ideal for renovating and refurbishing buildings. Existing façades can be retained and new steel structures used to 'open up' the interior of buildings. Modern steel roofing and cladding systems can be used to bring old buildings up to today's high standards of performance by re-cladding or over-cladding the existing building.

Demountability: Steel construction systems are highly and inherently demountable.

By 'building-in' demountability at the design stage, steel structures can be easily disassembled and re-used in new applications.

Low waste: Steel construction generates very little waste. The by-products of steel production are widely used by the construction industry. Any waste generated during manufacture is recycled. There is virtually no waste from steel products on the construction site.

Recyclability: Steel is 100 per cent recyclable and can be recycled, again and again, without any degradation of its properties or performance. The current recycling and re-use rate for steel construction products in the UK is 94 per cent.

Manufactured off-site: The steel construction supply chain is very efficient. All construction products are manufactured off-site under factory-controlled conditions that ensure their high quality. Factory working is safer, faster and more efficient than site working. Most processes are fully or semi-automated with advanced computer design and manufacturing software used to further improve material and production efficiencies. Just-in-time deliveries to the construction site improve site logistics.

Rapid site erection: On site, steel construction is fast and of high quality. Steel construction reduces the risk of weather-related delays and there is less 'snagging' time and cost. These factors lead to greater predictability in the construction programme.

Thermally efficient: Steel cladding systems produce thermally efficient building envelopes. Twin skin (built-up) and composite steel systems are durable and they achieve high levels of thermal insulation and airtightness.

Minimal impact: Steel construction minimises the impact on communities neighbouring the construction site. Construction is dry, dust-free, relatively quiet and requires fewer deliveries to site than other forms of construction.

Appendix III: Steel's waste credentials

Steel construction has excellent, low waste credentials during all phases of the building life cycle:

Iron and steel making by-products such as blast furnace slag are those beneficially used by the construction industry for a range of products including roadstone, lightweight aggregate and as cementitious material used as a substitute for Portland cement.

During component manufacture, computer-controlled, automated production lines ensure that wastage of steel is minimised. Any off-cuts or trimmings from the production process are 100 per cent recycled into new steel.

Steel products are delivered to the construction site pre-engineered to the correct dimensions; consequently there is very little (if any) wastage. Furthermore, the quality of factory-produced steel construction products means that there are fewer defects and hence lower site waste.

When a building is deconstructed, the ease with which steel construction products can be reclaimed, coupled with the economic value of scrap steel, means that virtually all steel is recovered and either re-used or recycled. Currently, 94 per cent of steel from deconstructed buildings in the UK is re-used or recycled [3].

Appendix IV: Recycling steel

Globally, over 80 per cent of all scrap steel is captured and is either re-used or recycled. Steel can be recycled without any deleterious effects on properties.

Total global steel production is currently just over one billion tonnes per year. Approximately two-thirds of this is produced from iron ore and scrap via the basic oxygen steel-making route. The remaining one-third is produced entirely in electric arc furnaces, mainly from scrap steel. Overall, steel recycling makes up just over 40 per cent of global steel production [12].

Although one should not be complacent about non-renewable resources and should use them sparingly and efficiently, with estimated global reserves of around 800 billion tonnes, supplies of iron ore are secure for many years to come.

All new steel has a recycled content. The actual proportion of scrap in new steel is dependent upon a number of factors that include the availability and price of scrap, the production route and the specification or quality of the steel being made. In addition to saving iron ore, the scrap is an important part of the steel-making process; used to regulate the temperature of the steel in the furnace.

Global consumption of steel continues to rise, mainly as a consequence of industrialisation in the developing world. Global demand for new steel exceeds the supply of scrap steel by a factor of around two and therefore it is not currently possible for all new steel to be produced entirely from scrap. While this remains the case, there is no net environmental benefit in specifying recycled steel in preference to primary steel with a lower recycled content.

Instead, designers can be confident that by specifying steel products which are over 94 per cent recoverable and 100 per cent recyclable, they are constructing buildings that are a valuable resource for future steel products.

Appendix V: The advantages of steel in lean construction

Supply chain

The steel construction supply chain is highly efficient. All steel construction products, from standard structural sections to fully fitted-out steel modules, are manufactured off-site and delivered to site pre-engineered to facilitate fast and easy assembly and erection.

Off-site manufacture

Almost all steel construction relies on off-site manufacture, which is more efficient, faster and safer than site construction. Off-site manufacture is not delayed by inclement weather, unlike site construction work. Also by reducing the duration of site working, the risk of weather-related delays is minimised.

Factory working

Off-site manufacture means factory working facilitates accurate workmanship that results in high quality, reliable products with fewer defects than site working. Products manufactured in the factory can more easily be standardised, tested and certified.

Social benefits

Off-site working also has social benefits over site working. A permanent, and stable, factory workforce benefits the local economy and encourages local community relationships. Furthermore, staff development and training is encouraged and staff retention improved. Steel construction products are efficiently manufactured using hi-tech, computerised equipment.

Computer-aided design (CAD)

Computer-aided design (CAD) systems are integrated with manufacturing software to produce quality products with very little waste. Many processes are fully or semi-automated.

No waste

Any steel waste produced during manufacture, such as off-cuts or turnings, are 100 per cent recycled into new steel. Furthermore because construction products are pre-engineered to the correct dimensions, there is very little, if any, wastage on the construction site.

Corrosion and fire protection

Coatings for steelwork are increasingly being applied in the factory in preference to on the construction site. This enables improved quality control, reduced wastage through overspray and reduced time taken on site to apply coatings. Importantly, factory-applied coatings limit the risk of delay to following trades, reducing the overall site construction programme.

Just-in-time

Manufacturers of steel construction products generally operate on a just-in-time basis. Semi-finished steel products such as hot-rolled sections and steel coil are delivered to the factory, promptly processed and the finished goods despatched to meet the site construction programme.

Just-in-time delivery of steel construction products reduces or even eliminates the need for site storage of products and materials.

Improved site logistics

This leads to better safety; it also reduces the risk of damage to products stored on site.

Predictable construction programmes

Steel construction is fast, reliable, saves money and reduces local environmental impacts and nuisance associated with construction work. Surveys of construction clients have confirmed that programme predictability is a key issue on large construction projects. 'Time is money' and predictable construction programmes mean that clients can plan and finance more accurately.

Speed

Recent data from Davis Langdon [13] has confirmed that using steel as the structural frame in commercial buildings results in a 7-15 per cent shorter on-site construction programme compared to equivalent concrete options.

Safe

Steel construction is inherently safe. Construction products are manufactured under factory-controlled conditions that are inherently safer than working conditions on the construction site. Furthermore, products are manufactured using automated or semi-automated processes that are far safer than manual site operations. On the construction site, steel is quickly and simply erected, reducing the overall construction programme. This limits the time that construction workers are exposed to the most common accident risks from trips and falls, falling objects and vehicle accidents. Composite steel construction, in which the steel decking acts as permanent formwork to the concrete, improves safety. The floor decking provides a safe working platform for workers on that floor and protects workers below from falling objects.

Appendix VI: The contribution of steel to efficient design and construction

High strength-to-weight ratio

Steel's dual properties of strength and ductility make it the material of choice for structural applications. Its high strength-to-weight ratio can also be exploited in structures requiring fewer and lighter foundations.

Long-span capabilities

Building designers invariably strive to create flexible, column-free spaces that can facilitate changes in use during the life of the building, and which will also increase the lettable area, reduce refit costs and extend the life of the building. This can be achieved by taking advantage of steel's long-span capabilities. For floors, hot-rolled or fabricated steel beams with web openings can achieve spans of over 20m and provide regular openings for services. Cellular beams minimise the use of materials and are therefore structurally very efficient. By integrating building services within the structural floor depth, savings can be made in cladding and service distribution costs. Other long-span solutions, such as trusses and portal frames, can be used for larger applications such as stadia, airport terminals, factories and warehouses.

Composite floor systems

Modern composite floor systems are structurally, and therefore resource, efficient. In addition, composite floors can deliver long-span solutions (up to 15m), are erected rapidly and are cost effective.

Steel decking

Acts as a safe working platform and permanent formwork for the in-situ concrete. Shear connectors can be through-deck welded, which speeds up the construction process.

Service integration

- **Benefits:** The integration of services within the structural elements of buildings saves resources by reducing storey height. This has a double benefit of reducing the external cladding required and reducing heat loss through the envelope. In multi-storey buildings, service integration can allow extra floors to be provided within the same building height and, in some situations, enable compliance with planning restrictions on the overall height of the building. Steel-framed buildings offer the design team a number of options in terms of taking advantage of service integration.

- **Web openings:** Reserve capacity exists over much of the length of a standard beam section. This allows openings to be cut in the web, provided that these openings are away from the supports. Relatively large openings can usually be provided without the need for strengthening by stiffeners.
- **Cellular beams:** These are widely used to provide efficient, long-span solutions by cutting and re-welding I-section beams. Structurally efficient cellular beams provide numerous, circular openings in the web that provide excellent flexibility for future re-servicing. Asymmetric sections are very efficient in composite floor design.
- **Partial integration:** Pass major services below the slab and beams and use the space between the ribs for small pipes and fitments, such as lighting units.
- **Full integration:** Form circular or elongated openings in the webs of ASB beams so that ducts and pipes located between and within the depth of the ribs can pass through the beams.
- **Slab penetrations:** Services can pass vertically through openings (up to 400mm wide by 1m long) in the concrete topping between the ribs.

Cores

These provide vertical zones for stairs, lift shafts, service ducts, etc. They usually act as a key structural element, offering lateral stability to the main structural frame. Vertical steel bracings in steel frames are easy and quick to erect. These braced cores enable vertical services to be incorporated and provide flexibility for routing and re-routing of services.

Slimdek® flooring

The Slimdek® system has been specifically developed to achieve minimum structural depth and therefore provide maximum flexibility for the distribution of services beneath the floor. Service ducts can be located between the ribs in the deep decking and passed through holes in the beam web. There are three opportunities for service integration using Slimdek®:

Off-site construction

All steel components and systems are manufactured off site. This ensures accurate workmanship that results in high quality, reliable products with fewer defects than site working. It therefore facilitates rapid construction on site.

Economic solutions

Steel solutions are economic solutions. Commitment by the sector over the last 30 years has resulted in improved productivity in steel manufacture, the introduction of new fabrication technologies and the development of new forms of construction and new products to meet Client needs. The economic benefits of this collective commitment are demonstrated by steel's healthy market shares of 70 per cent of multi-storey buildings and 95 per cent of single storey industrial structures.

Appendix VII: The role of steel in respecting people and their local environment

Steel construction has many attributes that minimise the impact of construction on local communities:

- **Rapid construction:** Steel construction is fast – minimising the duration of construction activities
- **Clean construction:** Steel construction is dry and dust-free.
- **Manufactured off-site:** Steel construction products are manufactured off-site – reducing the duration of construction and ‘snagging’ activities.
- **Minimal disturbance:** Steel construction is relatively quiet.
- **Minimal disruption:** Steel construction materials can be brought to site quickly, efficiently and in relatively few journeys – lessening disturbance and the impact on local traffic.
- **Lightweight:** Steel structures are comparatively lightweight – reducing earth moving and foundation works.
- **Flexible and adaptable:** Steel structures are flexible and adaptable, allowing the extension and refurbishment of existing buildings, with savings on demolition and full-scale redevelopment.

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