Single Storey Buildings

Best Practice Guidance For Developers, Owners, Designers & Constructors

The Steel Construction Institute

The Steel Construction Institute (SCI) develops and promotes the effective use of steel in construction. It is an independent, membership based organisation.

SCI's research and development activities cover many aspects of steel construction including multi-storey structures, industrial buildings, bridges, civil engineering and offshore engineering. Forms of construction addressed include steel and composite frames, light steel framing systems and modular construction. Activities encompass guidance on structural design in carbon and stainless steels, dynamic performance, fire engineering, sustainable construction, architectural design, building physics (including design for acoustic and thermal performance), value engineering, and information technology.

It is also involved in the sponsorship of research and development, the provision of education, advisory and information services, the preparation of publications (currently over 200 titles) and participation in the writing of standards and codes of practice, and the activities of relevant national and international bodies.

Membership is open to all organisations and individuals that are concerned with the use of steel in construction. Members include designers, contractors, suppliers, steelwork contractors, academics and government departments in the United Kingdom, elsewhere in Europe and in countries around the world. The SCI's income is derived from subscriptions from its members, revenue from research contracts and consultancy services, publication sales and course fees.

The benefits of corporate membership include access to an independent specialist advisory service, free issue of SCI publications as soon as they are produced and free access to Steelbiz, an online technical information system.

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Picture on page 15: Astral Court, Baglan using Colorcoat Celestia®
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Foreword

The construction of large single storey buildings, widely known as 'sheds', is a significant part of the UK steel construction sector. Sheds are used in many aspects of modern life, such as retail stores, distribution warehouses, manufacturing facilities and leisure centres. Rising client expectations, Health & Safety regulations and Sustainability initiatives are impacting on shed construction. In turn the technologies used to meet these requirements demonstrate a willingness to embrace innovation in design, manufacturing and detailing. Examples are the use of plastic design, IT systems for design and manufacture, advanced cold formed components and highly efficient cladding systems.

A successful shed combines these technologies in an optimum way, but this demands high levels of understanding of the interdependencies. To improve this understanding, the SCI floated the idea of a Super Shed Group, and although the name officially changed to the Single Storey Building Group, the nickname stuck and best describes the intent of the group's discussions. The group consists of invited personalities from various design and supply organisations in the shed supply chain. This work is based on the individuals' collective wisdom and on discussions with associates intimately involved with shed construction.

The SCI has been responsible for the facilitation of the group and authorship of this publication.

The members of the group are:

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Roy Burns	Metsec plc
Mike Fewster	Billington Structures Ltd.
Grenville Griffiths	Caunton Engineering Ltd.
Kevin Hall	Hathaway Roofing
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Roger Peel	Cameron Taylor
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Alan Todd	Corus Construction & Industrial
John Verity	Yorkshire Sheeting & Insulation Services Ltd.
Brian Watson	C A Group
Tony White	Michael Sparks Associates
Graham Raven	SCI
Martin Heywood	SCI

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I am pleased to be the Chairman of the group which has been notable for the robust and progressive discussions held.

Richard Barrett

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1 Introduction

Steel framed long span single storey buildings, widely known as 'sheds', are a common sight across the UK, fulfilling a variety of roles from large functional distribution warehouses to modern, attractive leisure facilities. This publication examines the procurement of such buildings and offers best practice guidance to clients, designers and constructors, based on the experiences of some of the leading players in this sector of the UK construction industry. The contributors, who are acknowledged as leading players in the sector, are listed in the foreword.

Gazeley G-Park, Bedford
Courtesy of Corus

Sheds

The word 'shed' in the context of steel framed building is widely accepted shorthand for steel framed and clad long span single storey buildings that often contain a significant area of office accommodation. This form of construction is, in fact, far removed from the connotations usually associated with a garden shed and has very successfully grown from its beginnings in industrial buildings into a construction form that can enhance most aspects of modern life: retail, leisure, transport, distribution and manufacturing. The shed sector is now one of the most efficient and successful in UK construction with an annual value of approximately £1 billion for frames and £1.5 billion for associated envelope systems.

"The use of sheds is no longer

A history of change

During the 1970s and 1980s the focus of shed design was on the steel frame and compliance with the structural requirements of the Building Regulations. Basic profiled steel cladding systems, the forerunners of today's more sophisticated envelope systems, were emerging into the market at this time, but these were simply fixed to the frame along with minimal insulation. Today, there are many more demands on envelope systems, in particular relating to the energy conservation demands of Part L of the Building Regulations and the high-value activities for which these buildings are employed. Obtaining approval for the structure is now routine and the focus of Building Regulation compliance has shifted to the envelope system. This emphasis will increase further with the introduction of a revised Part L, with its more onerous requirements, and the European *Energy Performance of Buildings Directive* in April 2006.

Since their introduction, sheds have become larger and more complex in terms of their requirements. At the same time, clients have come to expect faster construction programmes, greater economy and improved quality. Individual disciplines within the supply chain have responded to these increased demands with a series of developments in construction technology. However, the leading players in the sector recognise that the necessary improvements in shed construction also require significant changes to the procurement process, with all parties working more closely together to produce a better shed. This publication is intended to encourage others to follow the new best practice.

Aerial view of DIRFT Logistics Complex
Courtesy of Caunton Engineering Limited

Target audience

This publication is aimed at helping clients, developers, funders, occupiers, specifiers, designers, contractors and specialist contractors, i.e. anyone who is involved in the procurement of sheds. It aims to provide a more sympathetic understanding of the performance drivers for each of the players and examine the effect that these drivers can have on the others in the supply chain. It assumes that the reader is aware of the technologies and systems involved.

Supply chain integration

This publication is about the interdependence of the various parties in the supply chain and perhaps more significantly of the individuals involved, rather than the technical detail of steel building design. Readers are assumed to be competent in their particular areas, but may not be aware of the interactions with others that can aid or, if not understood, prevent the best outcome for all concerned.

Client values

All clients commissioning buildings have a business case for doing so. For instance, they may be building it for their own use, to rent out, as an investment or to sell on. Although sheds are one of the least complicated building forms, there are several criteria which can affect the value that the building brings to the clients and users alike:

- **Speed of Construction**
  Logistics or similar businesses may need the building urgently to service a new contract and therefore speed of construction is vital. This can affect the design in many ways that are perhaps not immediately apparent. For example:
  - The layout and components can be designed so that parallel rather than sequential construction can take place.
  - Interfaces between trades should be minimised.
  - Collaborative discussion between trades will be needed to ensure that, whatever is decided, all aspects of construction can proceed safely.

- **Flexibility in use**
  The client may at some point wish to sell the building to an investment organisation. To facilitate this option, institutional criteria such as minimum height and more onerous imposed loads can be specified to maintain the asset value and provide flexibility for unknown future uses.

- **Maintenance**
  Full-repairing twenty five year leases, where the tenant is responsible for maintenance, are being replaced by shorter ones, where the owner carries the responsibility. This encourages the choice of better quality materials with a longer life expectancy in order to reduce maintenance costs. Increasingly, suppliers are providing guarantees and advice on necessary maintenance.

- **Sustainability**
  Energy costs and the reduction of CO_2 emissions are becoming increasingly important and sustainability is now a key issue within the planning process. In future, it is likely that planning permission will be easier to obtain with sustainable, environmentally friendly solutions. This is especially true in London. Many clients, potential clients and occupiers have sustainability policies against which their performance is monitored by shareholders and the public.

Note:

The energy conservation regulations differ in the various nations of the UK. However, for convenience Part L, which is the relevant regulation for "The conservation of fuel and power" in England and Wales, is used to cover the similar regulations across the UK. Dates for the revisions also vary.

In today's competitive environment, all members of the supply chain are under pressure in terms of the increased complexity of their own specific tasks and the reductions in time available to carry them out. In addition, with the increasing complexity there is also an increased interdependency between the various elements. A high degree of co-operation and coordination is needed in order to achieve an economic and high quality outcome. A key feature of any successful supply chain team is that it collectively understands how the whole building works and recognises the interdependencies between the various elements.

Supply chain contribution

The criteria for the selection of the various companies in the supply chain should take into account the potential supplier's and individual's understanding of how they can ensure the outcome that best meets the client's business aspirations. This publication is intended to assist the process.

The advice has been gleaned from those with a history of working for knowledgeable and experienced clients, who are experts in their fields and are anxious to share their knowledge to help others avoid unnecessary difficulties and raise the general standards of the sector to those of the best.

The success of any construction project depends not only on the quality of the companies and individuals involved but also on the procurement route. Sheds differ from other forms of building in terms of their architectural design approach, since they involve the integration of a few well-developed systems. The details within each system are in the control of that system's supplier rather than the overall architect. By comparison, other buildings are constructed from many individual components and often assembled in a form that is unique to that particular building, with the architect having more control over all aspects of the design.

It is essential that clients recognise this important difference between sheds and traditional building construction, by selecting a contractor who has a history of bringing the system suppliers together early in the procurement process. This will enable their interdependence to be recognised and exploited to provide the overall best solution for the client. Successful clients recognise this and ensure that they select the procurement route and suppliers to suit their needs.

Distribution warehouse for Argos Direct, Bedford
Courtesy of Barrett Steel Buildings Ltd.

2 Procurement Process

Although there is a proliferation of procurement processes in general construction, there are only two processes in common use for sheds: 'Design and Build' and 'Traditional'. Of these, 'Design and Build' has by far the largest share of the market. This situation has evolved because:

- The product is relatively simple when compared to other types of buildings.
- There are well-developed systems for all parts of the construction.
- The client brief can be set out in a relatively straightforward manner.
- The size of the market has attracted many competent companies to develop systems and offer their services.

B & Q, Ashford
Courtesy of C A Roofing

Design and Build contracts

The prime attraction for the client of the Design and Build process is that the risks are passed to a contractor, who is responsible for all the design and construction aspects. The contractor's role is to manage all of the activities and ensure the quality of the completed building. This situation works well, because there are sufficient companies within the sector, who have the relevant competence and financial strength from which clients can select their team. Many large clients with significant repeat business have developed good relationships with a relatively small number of organisations, who have become accustomed to working with each other in informal and trusting partnership arrangements. This has proved extremely beneficial to all parties involved.

"Manufactured and constructed

An important ingredient in Design and Build relationships that tends to develop over a considerable period is that of trust between the parties. This may be difficult to achieve in new situations, but it should be a major objective. The working arrangements and form of contract selected should be such that they encourage and reward helpful behaviour. This generally requires communications of all kinds to be as transparent as possible.

Despite passing much of the risk and responsibility to the contractor, the client retains overall responsibility for Health & Safety. The appointment of experienced, responsible contractors and specialist contractors is an essential part of this duty.

Early involvement of supply chain

In most cases, an architect is commissioned to produce the concept designs and obtain the necessary planning permissions together with sufficient information to obtain tenders from contractors and select the successful bid. The pre-contract period should be used to sort out the design responsibilities, the key roles which will be played by the project participants and their employees and the skills required to perform these roles. These factors may influence the choice of contractors.

Retail Park, Beckton
Courtesy of Hathaway Roofing

Once a main contractor has been appointed, he becomes responsible for all design and construction activities in the project, although it is common to employ specialist subcontractors to carry out the actual construction work. The architect who produces the concept design is often subsequently novated to the selected main contractor, together with the engineer who initially appraises the ground conditions and drainage if this has not been done already.

The main contractor has to manage all the interfaces between the various elements of the work. This coordination role is very important and can be undertaken in-house, although in many cases he will pay an architect to act on his behalf.

It is noteworthy that with experienced and knowledgeable clients, the specifications tend to be thinner documents that make use of trusted manufacturers' recommendations. Less experienced clients and their advisors tend to produce thick specifications that aim to defend against failure rather than encouraging energy to be spent in ensuring that all goes well. This may be a reflection on the earlier state of the construction industry, but there is a growing body of successful firms which can testify to the benefits of encouraging success. The progressive approach does require greater engagement by all concerned rather than the attitude of "go away and sort it out amongst yourselves". As in all aspects of life, caring attitudes are infectious.

Distribution warehouse
Courtesy of Michael Sparks Associates

Selection of supply chain

It is important therefore to work with people who have demonstrated that they can deliver predictably in terms of cost, time and quality. This is a familiar list of attributes, but the will to work collaboratively and not cynically is an important addition.

The selection of the supply team is critical but not always easy. Clients should select an architect and, where necessary, an engineer who are familiar with their business needs and the type of work envisaged. The appointment of the main contractor and specialist sub-contractors should be discussed between the client and his advisors who are already in place. Help is available from reputable trade associations such as the Metal Cladding and Roofing Manufacturers Association (MCRMA) the British Constructional Steelwork Association (BCSA). The latter maintains a Register of Steelwork Contractors with guidance on the type and size of contracts for which they have the skills and financial stability.

Achieving collaborative working

The preferred key players should be brought together by the contractor as soon as practicable. Initially, these players will be the architect, engineer and the steelwork and building envelope contractors. The design topics to be discussed are covered in the next chapter, but in terms of stages in the contract there are two important factors. Firstly, the participants have to be certain they will be carrying out the work, even though, secondly, they will not be fully committed financially at this stage. This is important, because they must be free to bring ideas to the project, safe in the knowledge that the information will not benefit their competitors. However, the joint discussions with fellow suppliers might affect the detail and costs of their work package. Cost reduction exercises are frequently part of the process, but the interdependence of the systems must be remembered by all and the knock on effects taken into account.

There will obviously be a more cooperative approach if the appropriate mechanisms are in place, rather than having to defend a fixed contract sum in which it may have been necessary to include some guesstimates of what to include at a detailed level. To achieve this end there are two possible approaches:

- A partial order to cover the work in stages.
- A letter of intent, but with recognition of the risks of cancellation incorporated.

Forward commitments need to include a recognition that suppliers have to manage the efficient use of their resources and, while they will undoubtedly be as cooperative as possible, it may be difficult to accommodate short term postponements in a busy schedule.

- Design and Build contracts predominate
- Knowledgeable designers, main contractors and specialists need to be selected
- Client retains overall responsibility for Health & Safety aspects of design, construction and use
- Main contractor is responsible for design and coordination
- Early involvement of all parties in design process is essential
- Financial commitments should reflect this
- Contracts and specifications should encourage and reward helpful behaviour
- Minimising problems is achieved through improving relationships between people

"Highly efficient designs to

Achieving commitment

Through early design orientated meetings, financial commitment can be finalised on the basis of information which is consistent across the supply chain, knowing that all pertinent issues and opportunities for improving performance have been explored. The contract should provide a framework for resolving disagreements if something does go wrong rather than attempting and, probably failing, to ensure that problems do not occur.

Minimising the occurrence of problems is achieved through improving relationships between people. This is extremely difficult to achieve through the use of complex documents. People perform best when they are incentivised and want to perform well, not because a piece of paper says they ought to. Time spent defending a contract would be better spent improving the job. However, protection for all is needed as things can go wrong. Construction is not exempt from the law of unintentional consequences.

If trust is to be developed, it is important to ensure that agreements made by senior people in meetings are followed by actions in practice. Care is needed to ensure that those working at the detail level are fully conversant with the agreements reached and understand why they will improve the performance of the overall project.

The actions and attitudes of the people involved are most important and these will be determined by the company culture as much as by instruction. Partnership based procurement has been extolled by some and in time, it may be the situation to which industry should aspire. However, well run Design & Build is currently best practice and a good foundation on which to move forward.

Traditional contract arrangements

Although Design and Build is easily the most common contractual arrangement for the procurement of sheds, 'traditional' construction contracts are also employed and may offer advantages to clients in certain circumstances. In this type of contract, the architect and design team are appointed by the client and are responsible for all aspects of the design work. The design team includes a consultant structural engineer to design the steel frame and specify the secondary steel components. The main contractor, who is selected through a competitive tendering process, is responsible for constructing the works according to the information provided by the design team. Much of the construction work, including the erection of the steel frame and installation of the cladding, is likely to be carried out by specialist subcontractors.

The traditional approach tends to be used for specialised buildings, since the architect, and hence the client, retains more control. Some elements of the building, notably the frame, may be procured through a limited design and build process.

Selection of contract arrangement

The decision as to which process to employ depends on the relative importance of maintaining control of the design process and the competitive edge offered by Design and Build. Of particular note are the different responsibilities of the various parties in the different contract arrangements.

Reflections

The construction industry has been characterised as being adversarial in its relationships between the parties in the supply chain. It would therefore be surprising if there was not a certain amount of cynicism and scepticism about the practicality of the ways of working extolled in this publication. However, members of the Single Storey Building Group, which include key players in the UK supply chain, have shown that the concepts do work in practice and have many successful projects and satisfied clients to justify the guidance.

The following chapters demonstrate how the Design and Build procurement route can be used to provide the best outcome for shed clients and occupiers. The early involvement of the supply chain to resolve the design and interface issues saves cost and increases value.

River Road, Barking East London
Courtesy of Michael Sparks Associates

3 Overall Design

Steel construction is one of the most efficient sectors in the construction industry. Leading suppliers manufacture the components offsite, using computer controlled equipment driven directly by information contained in 3D computer models used for detailing. In addition to driving the manufacturing process, the information in the model is also used for ordering, scheduling, dispatch and erection. Shed construction at its best, with its highly integrated design and manufacture, represents levels of efficiency to which other sectors aspire. The key to realising the highest level of efficiency is to work in a way that enables the optimum use of this infrastructure.

Kingswood Lakeside Business Park, Cannock
Courtesy of Barrett Steel Buildings Ltd.

Interdependence of frames and envelopes

The most popular choice of structural form for sheds with spans of 20 to 60 m is the portal frame because of its excellent structural efficiency and ease of fabrication and erection. Portal frames may be designed using elastic or plastic techniques, but plastic design tends to be favoured by steelwork contractors, because it results in a more efficient and lighter structure. It is therefore employed almost exclusively in 'Design and Build' projects in the UK. Elastically designed portal frames are usually heavier, as they do not fully utilise the capacity of the sections, but are simpler to design and detail using non-specialist design software. Elastic methods are sometimes used by consulting engineers working on smaller contracts. For longer spans, lattice trusses may be used to advantage instead of portal frames. Trusses are likely to be more efficient for spans over 60 m and in buildings of shorter spans where there is a significant amount of mechanical plant.

"Focus of attention has

B&Q, Belvedere
Courtesy of C A Roofing

The structural efficiency of portal frames is partly due to the provision of restraint to the rafters and columns by the purlins and side rails respectively. Similarly, the efficiency of the purlins is dependent on restraint provided by the cladding. The cladding sheets are profiled to provide the necessary strength to span between the purlins and provide the required restraint. The profile has also to accommodate storm water run-off. Designers and contractors should note that good interaction between the components is essential for structural efficiency and, for this reason, the cladding must be fixed to all purlins and rails in accordance with the manufacturer's recommendations.

The design methods for the steel structure are now well understood and accepted by all parties and the focus of attention has shifted to the envelope and how this is to be supported. There are two major reasons for this:

- The use of sheds is no longer restricted to industrial buildings and they are now used in a wide range of commercial applications. Examples include multifunctional headquarters, call centres, retail and leisure premises.

- The need to promote client image and public access has meant more attention has been given to planning and aesthetics.

Important too has been the focus on the energy saving qualities of the envelope and the increased significance of the "Conservation of Fuel and Power" as set out in Part L of the Building Regulations. A revision to these regulations is due for implementation in April 2006 and further changes are expected in 2010 and beyond.

The new regulations will also implement the EU Energy Performance of Buildings Directive (EPBD) with its requirement for energy labelling. Guidance on the application of the regulations to envelope construction can be found in publications by SCI and MCRMA.

The cladding has become the most significant element in the building and the emphasis and culture have to reflect this by designing the building from the outside in, rather than the earlier approach of the structure first with basic cladding systems fixed to it. The choice of building envelope contractor has also become more significant if economic compliance with regulations is to be reliably achieved.

Energy efficiency

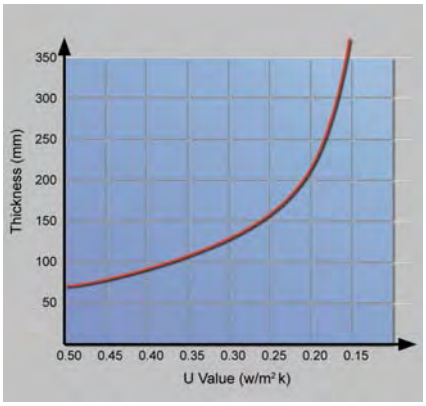
Reductions in U-values over recent years have led to a considerable increase in insulation thickness, with implications for stability (of built-up systems), cladding weight and consequential handling requirements. There is a common perception that this trend will continue indefinitely as future regulatory changes increase the demands on the building envelope. However, in reality, the relationship between insulation thickness and energy efficiency is subject to a law of diminishing returns and the point has now been reached where further increases in insulation thickness are unlikely to yield significant improvements in energy performance.

For many applications, the inclusion of roof lights is important because they reduce the amount of artificial lighting that is needed and, consequently, the energy demands of the building. However, they also increase solar gain, which can lead to overheating in summer and increase cooling demand. Heat loss through thermal bridging also becomes more significant as the insulation thickness increases, requiring the use of enhanced details and specialised components in order to meet with the regulatory requirements.

A balance of all the factors is necessary to optimise the reduction of emissions in the building operations.

Airtightness

The introduction of airtightness testing in the 2002 revision to Part L highlighted the importance of designing and delivering a building that is not 'draughty'. Recent studies have demonstrated that controlling airtightness is a very effective way of improving energy conservation.
As an example, while the current minimum standard for airtightness of buildings is 10m^3/m^2/hr at 50 Pascals, levels of airtightness down to a tested value of 2m^3/m^2/hr are possible with standard shed construction. However, achieving this level depends on assured construction quality and detailing. For buildings with floor areas less than 5,000 m^2, achieving good levels of airtightness becomes difficult to achieve due to the higher proportion of openings relative to the clad area. While a common view is that airtightness is the responsibility of the cladding contractor, in reality the necessary quality of construction can only be achieved if all contributors to the supply chain understand the requirements and the building design is well coordinated.



Note:

Recent studies have shown that controlling airtightness is a very effective way of improving energy conservation.

Levels of airtightness down to a tested value of 2m^3/m^2/hr are achievable.

Pressure testing at the B&Q Distribution Centre, Worksop
Courtesy of BSRIA

"Set appropriate criteria

Design coordination

As has been emphasised in the section on procurement, a significant part of the design process of the actual building is the coordination of the interfaces between the various specialist systems. This task, traditionally undertaken by the architect, is not easy because "how do you tell people what they do not know, if they do not know that they don't know". In a Design and Build contract, the main contractor is responsible for the design. To assist with the coordination, it is beneficial for the contractor to prepare a list of drawings that the architect is expected to produce, with the help of appropriate participants.

Over the past twenty years, there have been changes in the overall size and usage of sheds and many of the assumptions on which early shed design and detailing were based are no longer valid. This is because sheds are used for a wide variety of building types. Buildings are larger, higher and more highly serviced than they used to be. Under the predominant Design and Build form of procurement, the contractor is responsible for the design, and it is important to select one who knows what constitutes a good design for the intended use, what they expect to see from the suppliers and how it can be achieved.

Magnum 25, Waltham Cross
Courtesy of Michael Sparks Associates

Mainly architecture

The focus for the design should be to provide clients and building users with solutions that improve their business performance. While this document concentrates on the influences relating to the building-specific design, in the pre-contract phase the architect has a significant role in dealing with site-specific issues such as obtaining planning permission and dealing with abnormal situations such as wayleaves and flood risk.

A prime task for the architect is the sizing of the building and the determination of how the elements are set out relative to grid lines. There are institutional standards for measuring lettable area, minimum height to underside of structure, floor loadings, durability of cladding etc. The advent of the EU Energy Performance of Buildings Directive in 2006, where buildings will have to have their energy rating declared on change of ownership or usage etc. will encourage standards to be set for this attribute too.

Developers and funders are clearly anxious that any investment is future proofed in terms of its asset value and this generally means that flexibility for potential future tenants or owners is a significant criterion. Nobody wants to pay more than they need, but it is important to set appropriate quality and technical criteria (and see that these are maintained throughout the design and construction process) before going out to competitive tender.

Astral Court, Baglan
Courtesy of Corus

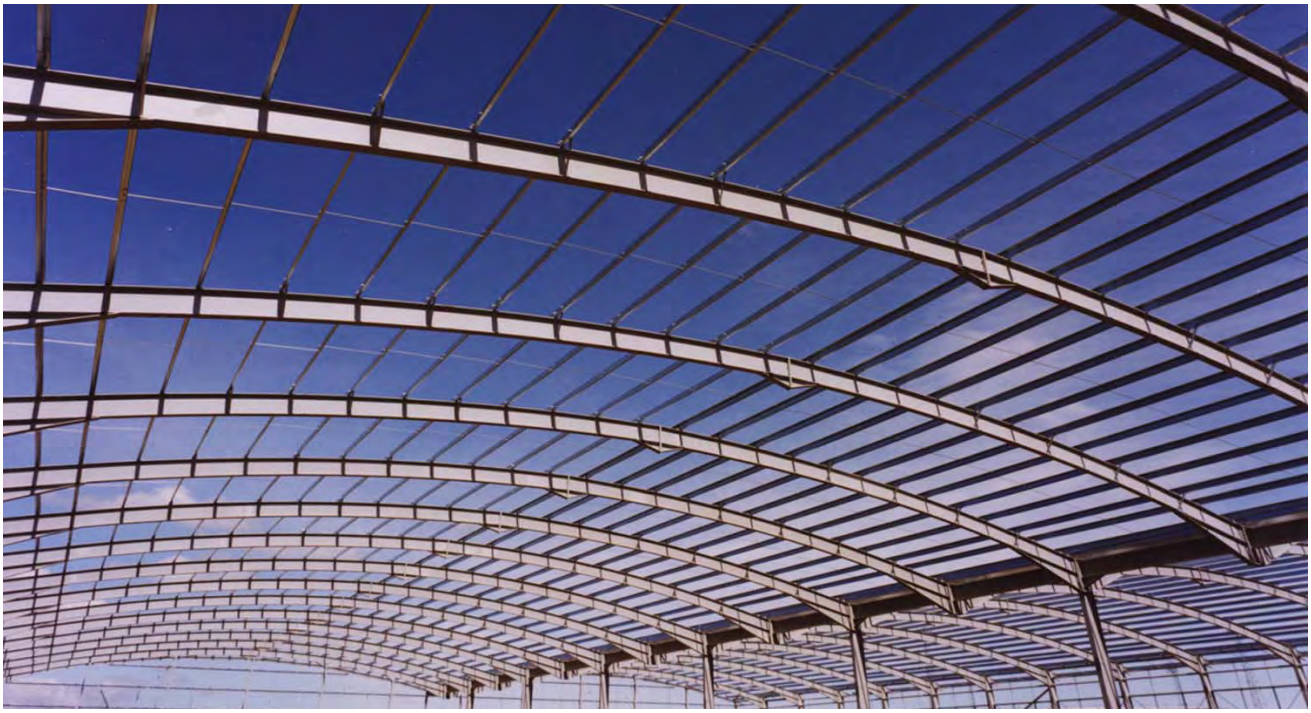
Attributes that should be considered, in addition to those required by regulations include:

- Overall geometry
  - Minimum height (clearance for crane beams, depth of haunch etc)
  - Achieving maximum lettable area according to the conventions for measurement
  - Column layouts to give appropriate future flexibility of use
- Loading
  - Service loads on purlins
  - Service loads on frame
  - Imposed floor loads
- Cladding system and available guarantees
- Adequate access for possible future vehicle needs
- Tolerances of floor slab
- Potential for re-use / recycling of materials
- End of useful life liability
- Energy consumption and reduction of CO_2 emissions

"Ensure clarity in

Mainly engineering

The effects of the site conditions on the structural solution, together with the engineering design of external works, will normally require the appointment of a consulting engineer to work alongside the architect prior to letting the Design and Build contract. The duties will include the selection and design of a suitable foundation system. In the majority of buildings, the structural frame will be pin-based, with some fixity assumed when assessing serviceability conditions and stability. Economies in the frame design in terms of weight of steel can be made where nominally fixed bases are used, but this approach will have implications for the cost of the foundations. It is, therefore, important that this decision is made by the consulting engineer rather than the steelwork contractor, as the former will be in a better position to assess the overall effect on the cost of the building and suitability with regard to the ground conditions.



The Pompey Centre, Portsmouth
Courtesy of Metsec plc

Influences on structural design and costs

When obtaining prices, it is important to ensure that there is clarity as to what is expected in each work package and that submissions are reviewed for any ambiguity and omissions. Particular attention should be given to ensuring that:

- The cladding system and frame design are based on the same wind loading criteria. A set of calculations should be requested from the envelope contractor showing the fixings required. It is recommended that the steelwork contractor issues the relevant sections of his design information to the envelope contractor.
- All necessary secondary support members and fixings are included.
- The tolerances of the frame and chosen cladding system are compatible. This issue has become more important as aesthetics have assumed greater importance, leading to the selection of cladding systems with tighter tolerance requirements.

- Provisions have been set out for sprinkler systems and that these can be sustained in terms of both load capacity and space required with pipes of 150 – 200 mm. The sprinkler system is itself generally carried by the purlin system and the layout can affect bracing locations and arrangements. Larger pipes may need special provision.

- Loads on secondary members are adequate. Cladding systems and services have increased in weight over the years and assumptions may be lagging behind current practice.

- An adequate allowance has been made for the weight of the gutters. Insulated gutters weigh around 140 kg for a 3 m length and require specific design of the supporting steelwork. Gutters are often designed on the assumption that they will fill with snow, but it should not be forgotten that they can also fill with water, which is considerably heavier than snow. The supporting steelwork design should recognise these loads, but experience suggests that many designers have not updated their assumptions in line with changes in the construction. The location of overflow pipes affects the layout of the steel framing and the advent of syphonic drainage systems means that the tolerances and deflections of the support system can be critical for effective operation. The weight of the gutters is such that cranage is necessary and this may need to be provided by the steelwork contractor.

While some of these issues might not appear to be significant, readers should note that it is not unknown for the steelwork contractor to be asked to tender (and sometimes even supply) without knowledge of the cladding system. Similarly, the envelope contractor is sometimes given little knowledge of the supporting structure.

The above list is not exhaustive and due care should be taken in each individual project. If this is not recognised, the likely outcome will be a poor building and a procurement process marked by a series of contractual disputes.

- Building Regulations impact on structure and envelope
- Structural design methods are now well understood by designers and Building Control
- Focus of attention has shifted to design and construction of envelope
- Envelope quality depends on interaction with structure and its details
- Asset value of the building is affected by design criteria
- Services and ancilliary loading have increased since traditional assumptions were made

"Sustainable construction

Sustainable construction

The need to consider sustainability is now recognised in all walks of life and the importance of the role played by construction is now widely acknowledged. The requirement for sustainable construction is being encouraged in many ways, ranging from regulations such as Part L to the societal pressures expressed through the increasing adoption of Corporate Social Responsibility policies by companies. The ability to demonstrate a sustainable approach is becoming an essential part of obtaining planning permission.

The concept of sustainability is underpinned by the need to balance the triple bottom line of economic, social and environmental viability. Good construction should meet all three criteria and good shed construction certainly does.

Economic considerations

As has been described earlier, steel construction systems have been refined over the past three decades and the various elements of the building are brought together in a highly integrated design, which is then manufactured and constructed using efficient production processes. The use of material is highly optimised and waste virtually eliminated. The buildings themselves are used for most aspects of modern life including logistics, retail, leisure, commercial and manufacturing and so provide economically the efficient infrastructure on which we all depend.

Social aspects

Sustainable construction should also help improve the quality of life of all involved in its production. The high proportion of offsite fabrication in steel buildings means that working conditions are safer, better controlled and protected from the weather. Additionally, by providing a fixed location for employees, it is easier to develop communities and family life than with an itinerant labour force associated with site-based construction. A stable workforce is also beneficial for the development of skills, since employers will be more likely to invest in their employees by facilitating training and encouraging career development activities.

Modern efficient manufacturing facility
Courtesy of Metsec Plc.

Environmental considerations

The environmental aspects of sustainability are well developed and there are powerful arguments in favour of the use of steel sheds over alternative forms of construction. Steel is among the most recovered and recycled materials available. Research has shown that 84% of steel frames and cladding from demolition sites is recycled and a further 10% reused. Although the materials are recovered after demolition, extending the building's life is generally more beneficial. This is often possible with steel construction, since the large open spaces designed to appropriate standards give flexibility for potential changes in use. The concept of extending a building's life also applies to the building envelope: for example by specifying the latest organically coated steel cladding, which is designed to give a guaranteed design life of up to 30 years.

In service, energy consumption and carbon emissions are regulated by Part L of the Building Regulations. This aspect of sustainability has possibly the greatest impact on the environment, since the CO_2 emissions associated with the operation of any building far exceed those resulting from its construction. In this respect, modern steel sheds perform well, easily meeting if not exceeding the requirements of the latest regulations.

The steel construction sector was one of the first to introduce a sustainability strategy with the publication of *Sustainable Steel Construction – Building a Better Future* in 2002. The BCSA launched a Sustainability Charter for its members in the autumn of 2005. *Achieving Sustainable Construction – a Client's Guide* was published by SCI and BCSA in 2003 and the SCI is developing further guidance, to be published in early 2006.

The Steel Construction Sector's Sustainability Strategy

- Design and manufacture is resource efficient
- Sheds provide infrastructure for modern living
- Offsite manufacture contributes to safe working, skills and community development
- Sheds provide flexibility to clients
- 84% of components are recycled and 10% re-used
- Sheds are energy efficient buildings
- Sector has developed a sustainability strategy

Reflections

This chapter has highlighted the need to coordinate the overall design of the individual work packages such that the specialist contractors are able to interact and jointly provide the optimum solution.

As with any design, improvements and changes should be introduced at the earliest possible stage, when the cost of change is at a minimum and the potential for saving at a maximum. It is possible that the savings in one area will result in increased costs in allied disciplines and careful judgement is needed to weigh up the overall benefit to the client. This can be achieved effectively with procurement through the Design and Build route. Unfortunately, in a competitive situation, where the difference between financial success and failure can be measured in a few pounds at the tender stage of a project, there is little inclination to increase spending for the sake of someone else's benefit. There is a need for clients to recognise this fact and to seek the best overall value (not necessarily lowest construction cost) by encouraging interdisciplinary design development and providing a framework that enables mutual benefits to be shared between the project partners.

Steel is among the most recovered and recycled material available

4 Detail Design Issues

The importance of the building envelope has been stressed throughout this publication, particularly in relation to the drive to improve the energy efficiency of buildings through a combination of well-insulated components, reduced thermal bridging and reduced air leakage. This section expands on the key detailed design issues that need to be considered in order to achieve a successful outcome in terms of Part L compliance, lower fuel bills for the building owner or occupier and a favourable energy label.

Construction of the steel frame
Courtesy of Billington Structures Ltd.

Emissions reduction

The increasing importance in the Government's agenda of reducing carbon dioxide emissions is being delivered through revisions to the Building Regulations *Conservation of Fuel and Power*. The new regulations, which are to be implemented in April 2006, will demand that new construction achieves a reduction in emissions of 28% for mechanically ventilated and air conditioned buildings and 23.5% for naturally ventilated buildings when compared to the equivalent notional building that would comply with the 2002 regulations. Compliance will need to be demonstrated through the Simple Building Energy Model (SBEM), which takes into account whole building performance including the efficiency of the heating, ventilation lighting and control systems. There will be no prescribed elemental insulation values in the regulations but to ensure good practice is adopted, there will be a maximum allowable U-value set for each type of component. It will be the designer's role to determine the most economic and beneficial way to achieve the required performance. Up to 10% of the savings may be derived from the use of renewable energy devices such as photovoltaic panels or wind generation. In the past, this technology has made little impact because of its poor financial viability, but there is now strong evidence of a growing interest in these solutions which are becoming more economic.

- Emissions reduction
- Impact on envelope design and details
- Compliance strategy
- Strength considerations for the envelope and supporting members
- Roof drainage systems
- Structural frame
- Selection of systems and components
- Design parameters
- Detailed design

"Part L compliance depends

Impact on envelope design and details

The detailed design of the envelope is crucial to achieving compliance with Part L. The use of whole building modelling techniques to demonstrate compliance, rather than the previously popular elemental methods, will give designers more flexibility in how they achieve the target emissions levels. Under the new regulations, no single element can be claimed to be Part L compliant, since compliance with Part L 2006 depends on the performance of the combination of elements that make up the building.

With the diminishing returns available from increasing insulation, reliance on improved airtightness, reduced thermal bridging and optimised use of other components such as roof lights will be paramount. Due to the interaction between elements, early involvement of envelope suppliers is imperative, if failure and expensive remedial action is to be avoided. It is vital that all the interfaces between the cladding, dado walls, doors, windows, ventilators etc. are robustly detailed and the responsibility for producing these details clarified. Gaps in information lead to gaps in the envelope and consequently a poor performance under airtightness testing. Delivery of reliable levels of airtightness and thermal bridging depends on the quality of the construction, making the choice of subcontractor a key issue.

The 2002 Part L regulations required pre-completion testing for airtightness with a maximum permitted value of 10 $m^3/m^2/hr$ at a pressure of 50 Pascals. In future, it will be possible to include improvements in this value as part of the emissions saving target. This means that Building Regulations approval can be sought based on a design value chosen by the designers and the pre-completion test will have to confirm that this value has in fact been achieved. This could be significant, as an improvement of 3 $m^3/m^2/hr$ is equivalent to a saving of 10% of the energy losses through the envelope. As has been mentioned previously, it is possible to achieve test values as low as 2 $m^3/m^2/hr$. However, some caution is needed before proceeding with designs which rely on very low figures, as these may be difficult to achieve in practice.

Office adjoining a large distribution warehouse
Courtesy of Hathaway Roofing

The superficially attractive option of eliminating roof lights, which have considerably poorer U-values than opaque cladding, has to be tempered by the energy used in the provision of artificial light. The SBEM will include calculations to take account of this, although it will be necessary to ensure that lights are only switched on when required. The design of the roof lights must be such that they can be installed safely as well as providing adequate seals for airtightness. Designs are emerging with improved insulation values.

- Compliance with Part L focuses on envelope design and quality of construction
- Compliance is based on whole building performance
- Emissions savings are calculated using the Simple Building Energy Model (SBEM)
- Airtightness of the total envelope is a significant factor and must be proven by pre-completion testing

Typical rooflight pattern in an industrial shed
Courtesy of Caunton Engineering Ltd.

"Structural aspects of the

Compliance strategy

The compliance strategy should have been determined during the overall design process. It is important that all contractors and suppliers ensure that the detail design and quality of construction are appropriate to the performance requirements. It is likely that the submission for Building Regulations approval and the specification of requirements for the various elements will be more complicated than before. This situation emphasises the need to have appointed the delivery team at the earliest possible time.

The interface with the supporting framework has many facets. One of the most important is the tolerances with which the purlins and side rails need to be specified in order for the envelope contractor to be able to fix the cladding to the required construction quality. This is hard to define in absolute terms and is dependent on the type of cladding being installed. It is vitally important that end laps can be well secured in twin skin cladding and adequate bearing is achieved with composite panels. These issues are explored in more detail in a forthcoming SCI publication SCI-P346 *Good practice guidance for cladding of industrial buildings*. The related issues of the cleat position and orientation, which can naturally have a significant influence on the erected location of the purlins and side rails, are due to be addressed in the next edition of the *National Structural Steelwork Specification,* which is expected to be published in the summer of 2006.

Strength considerations for the envelope and supporting members

It is important not to forget the structural aspects of the envelope. The issues that need consideration are:

- Restraint to the purlins and rails.
- Adequacy of spacer systems.
- The strength of the profile to resist applied loading in the form of foot traffic and plant for installation and maintenance.
- Imposed loads from snow and wind.
- The number of fasteners needed, in particular for wind suction.

Accurate secondary steelwork is essential if the building envelope is to achieve its functional requirements
Courtesy of Kingspan Ltd.

The loadings should be consistent with those used for the frame design and the frame designer is best placed to provide them. The design of the supporting structure must take into account the need to support realistic cladding loads during construction, as these can be significant, especially as component weights increase with insulation requirements. The positioning of packs of cladding panels on the roof prior to the fixing operations is crucial both from the viewpoint of structural safety and of preventing damage to the purlins. It is important that the construction loads do not cause permanent deformation of the purlins, as this could hinder or even prevent the installation of the cladding.

With this in mind, the cladding packs and other materials should only be placed over the rafter backs.

Roof drainage systems

Although mentioned in the overall design section, it bears repeating that the design, detailing and erection of gutters is often neglected. Those involved in the design of the supporting steelwork are often not aware of the impacts arising from the introduction of insulated gutters and syphonic drainage systems. The weight of the gutter, both in terms of the handling difficulties during installation and the strength and serviceability of the supporting structure, is such that it requires specific attention. Attention is necessary to the fixing details so that they can readily be attached to and restrain the supporting members. It is also good practice to include a secondary drainage system to avoid flooding into the building if the system clogs and fails. The gutter design should take account of the potential for flash floods and the fact gutters have to be maintainable with access for removal of anything likely to cause clogging.

- Structural aspects of envelope are important
- Overall strength is dependent on the profile, fasteners and spacer system
- Introduction of insulated gutters and syphonic drainage systems impose more stringent requirements on the supporting structure

Structural frame

The overall structural design of the main frame is usually not a contentious issue as regards obtaining Building Regulations approval. The main detail design considerations are the provision of robust support for the envelope and ancillary elements, such as gutters, roof lights, doors, door surrounds, services, and the accommodation of the construction sequence needed to satisfy the required construction programme. It is also important to ensure that there are no clashes with services, doors, windows, racking systems etc. Demands for faster construction have encouraged more work to be carried out off site in the form of precast foundations, door surrounds and the use of parallel rather than sequential working between trades. This may well affect the erection sequence. Where necessary, the design should take cognisance of all the temporary conditions.

Selection of systems and components

Finally, it should be noted that some envelope contractors market systems which coordinate the sheeting and secondary elements and are able to offer guarantees on their overall performance. Others purchase components separately from a variety of manufacturers. Clearly, in the absence of coordinated systems, more effort is needed to ensure the required levels of completeness and coordination of details and construction are achieved on paper and on site.

The use of roof cladding, rooflights and any other accessories, which have been tested for fragility to the appropriate standards, is essential. This applies during the construction and perhaps more importantly during maintenance or inspection. These latter activities may be performed by less well informed people. Some of the larger main contractors have seen the benefit in employing cladding supervisors to ensure the appropriate care is taken and a reliable outcome delivered.

Precast loading docks, Prologis Park, Coventry
Courtesy of Barrett Steel Buildings Ltd

Design parameters

Under a Design and Build contract the structural frame design is carried out by the steelwork contractor. Even under traditional contracts, this is often the case. The designer will need information on:

- Geometry
- Location
- Any local site influences affecting access, programme, ground conditions, wind and snow loading and the type of foundations on which the structure will be built
- The cladding system to be supported, including ancillaries
- Positions of openings and sub framework needed
- Positions and loads for major services
- Construction schedules
- Any constraints on layouts
- Architectural requirements.

All of this information should ideally have been set out at the tender stage but they will have to be confirmed following the award of sub-contracts. There should still be the opportunity for the steelwork contractor to use his experience and ingenuity to add value. This means that the specifications should be performance-based rather than prescriptive. Open discussion with all specialists has to continue as the design and details are finalised. Bearing in mind the perception of an adversarial industry, it comes as a surprise to some that transparency produces the best results, since everyone's energy can be directed to positive outcomes rather than looking for hidden catches and trying to exploit them. In addition to being transparent, the design information has to be of the highest standard.

Steel erection in progress at TNT FastTrack, Lutterworth
Courtesy of Barrett Steel Buildings Ltd

- Coordinated guaranteed envelope systems are available
- Obtaining structural Building Regulations approval is not a contentious issue
- Details must provide robust support for envelope and ancilliary elements
- Specifications should be performance based rather than prescriptive
- Transparent open discussion between specialists should continue until details are all resolved
- Use of off-site components should be considered

"Collaborative way of

Detailed design

As the design becomes more detailed, the items of information required by the steelwork contractor will include:

- Sufficient detail on the services to be accommodated to allow specific provision in the structure and the design loadings to be used to allow for sensible future flexibility; services loads in the range 0.15 and 0.35 kN/m^2 are common. Consideration should be given to the adoption of different global values for purlins and the main frame.
- Information on whether ceilings are to be supported from purlins.
- The cladding system to be finalised with agreement on all secondary items. This must include items such as gutters, cleader angles and any special tolerances.
- The required construction sequence, so that the effects on the final and temporary structure can be accomodated.
- Any influence of other components on frame erection, e.g. areas that have to be omitted initially and completed during future visits or erected in a particular sequence.
- Whether for large multi-span buildings, some areas of structure may have to be omitted to allow access for the envelope contractor's crane or collaborative use of the crane agreed.
- Access and site storage provision.

Health & Safey issues include:

- The provision and maintenance of a safe working surface.
- Use of non-fragile components.
- Mechanical and manual handling of components.
- Safe construction handover certificates.

Agreement must be reached on temporary and permanent requirements for the stability of purlins, rails and other secondary components. This will include working practices for the envelope construction. The purlin manufacturer should supply the fixing methods that have been assumed in calculating their safe loads.

All parties should produce method statements for their works as part of the Health & Safety regime. These documents should be made available to other members of the project team to ensure that assumptions made at the design stage are realised during the construction process and to allow safe collaboration between the various disciplines on site.

Special consideration should be given to the office accommodation since, from the construction point of view, it is the most complicated part of the structure, with some fifty trades involved compared to six in the main shed area. This may well have an effect on the overall programme and sequence of working. It is also the area on which potential tenants, owners and users will judge the appeal of the building.

Reflections

Clearly, the detail design stage is when the concepts developed at the start of the design process have to be brought to the point of fruition. The practicality of the ideas will be tested and the collaborative way of working continues to be important. This is significant because the individuals involved will not be the policy making directors but detail designers and draughtsmen working under pressure to meet the required timelines. They are more likely to take a self-interested position and inadvertently change decisions made at higher level unless the information is well communicated. The effects of this may not become apparent until the construction is taking place unless there is a strong coordination role.

Post completion testing for airtightness inherently happens at a critical time towards the end of the construction process and is likely to reveal any inadequacies in the integrity of the envelope. It would be a shame to provide another way to line lawyers' pockets. This is a waste of resources and energy that could be better spent on continuous improvement within the supply chain.

5 Client, Contractor and Professional Team Issues

While most of the superstructure design and construction is carried out by specialist frame and building envelope subcontractors, there are many key items that are not part of their work package but nevertheless have considerable impact on the overall performance.

- Health & Safety
- Ground slabs and foundations
- Office areas
- Other considerations

Health & Safety

Of prime importance is the responsibility for Health & Safety as it affects design for construction, in use, during maintenance and at end of useful life. It is not always realised that the client has overriding responsibility for Health & Safety and is required to ensure that sufficient resources are available for the works. Although there may be perceptions that Health & Safety is a site problem, Health & Safety considerations should permeate all aspects of the design. The overall design has to be such that erection can be easily carried out using safe procedures and in a sequence acceptable to all trades that is consistent with the desired programme. This extends to maintenance provisions.

The detailed design must allow for adequate handling, storage and working surfaces. Present working practices mean that the frame and envelope are erected prior to laying the ground floor slab. For safe and efficient working, it is imperative that the surface is prepared with appropriately sized hardcore to provide a level and well-compacted base for the plant.

The BCSA has introduced 'Safe Site Handover Certificates', whereby the main contractor issues a certificate to confirm that the site preparation conforms to all the necessary standards for the steelwork contractor to work. Although not designed specifically for envelope contractors, the same standards will be required. It is advisable for the envelope contractor to visit the site perhaps a week before he is due to commence work to ensure that the frame and secondary members are sufficiently accurate and robust for work to reliably commence.

Similarly, the incorporation of services and drainage has to be considered in detail both in terms of location and the timing of their construction. Open trenches will restrict access, may disrupt erection progress and are hazardous. Badly filled trenches are also hazardous and in some instances plant can damage previously installed underground or overhead services. It should not be forgotten that the access for plant extends beyond the boundaries of the building and so these comments will apply to much of the external works, in particular to the provision of retaining walls and where there are significant changes in level.

Use of mobile access platforms
Courtesy of Billington Structures Ltd

Ground slabs and foundations

The structural engineer will normally be responsible for the design details of the foundations. The ground slab is normally designed and built by a specialist subcontractor working to a performance specification prepared by the consulting engineer. The design and construction details should be approved by the engineer prior to construction. The details must be coordinated with all adjacent trades.

In order to assist in increasing the speed of construction, the potential for increasing the volume of offsite component manufacture is being explored by specialist subcontractors.

There are innovations in the use of precast concrete bases, ground beams and such items as dock leveller surrounds and retaining walls, which are helping to increase the overall speed of construction. The detail design of these items and the adjacent elements of structure and cladding has to be consistent with both the construction sequence and the need for access and handling.

The structural engineer has to determine whether nominally pinned or nominally fixed bases are appropriate for the steel frame. A site investigation should be commissioned and information obtained on the anticipated ground conditions. The decision on appropriate foundations will be based on this information and should be passed to the steelwork contractor as the basis for his design.

With regard to the ground floor slab, a recent Concrete Society technical report TR34 *Concrete Industrial Ground Floors* (currently in its third edition) sets out good practice for design and construction, including advice on tolerances, loadings, finishes, joints, sub base, a variety of alternative construction methods and necessary maintenance measures. Note as TR34 recognises, clients may have particular requirements beyond the report which need careful specification for compliance.

The slab is generally laid after the cladding has been erected, which means that it should not be affected by weather and dust. If acceptable methods can be developed, construction could be speeded up by casting the slab prior to erection of the envelope. However, for clients, the quality of the finished slab is high on their list of priorities when judging the finished product.

Concrete slab in a typical distribution warehouse
Courtesy of Michael Sparks Associates

Office areas

Most of the offices incorporated into sheds are designed to conform to normal commercial standards and the envelope may be curtain walling rather than a steel sheet based system.

In multi-storey office areas, suspended floors are commonly composite profiled decking with in-situ topping or precast units. The choice will depend on the programme and construction process selected by the main contractor. Design guidance for office structures is available from SCI guide SCI-P334 *Design of multi-storey braced frames*.

Although the office areas are usually very much smaller than the remainder of the building, the construction involves many more trades and is often the most critical area to sort out in good time, requiring innovative design and construction to meet the programme.

Other considerations

Dado walls up to the height of personnel doors have commonly been constructed from brick and blockwork. The reason was the apparently flexible location of doors and windows and a more robust construction against accidental knocks. However, masonry walls are slower to construct than steel cladding and it can be more difficult to achieve the required levels of air-tightness.

In addition to the detailing of the brickwork, there is the detailing of the long junction between the cladding and the brickwork to consider. Consequently, the current trend in UK shed construction is to extend the steel cladding to the ground level. However, there is a need to protect it from accidental damage, for example by forklift trucks or ongoing construction activities.

Oldfield Foods, Prologis Park, East London
Courtesy of Michael Sparks Associates

- The consulting structural engineer is normally responsible for the specification of the foundations and ground slab
- The engineer should determine whether fixed or pinned bases are most appropriate
- The Concrete Society's technical report TR34 "Concrete Industrial Floors" gives advice on floors
- Office areas are often on the critical path for design and construction due to number of trades

6 Final Reflections

The compilation of this publication has been an interesting experience in itself and provided a platform for all contributors to expound their personal views.

It is the result of candid discussions between experts with practical experience and the scars that accompany many years in construction.

The hope is that the process has led to the best practice guidance that is achievable. The implementation will demand changes to both the culture of large parts of the sector and to the processes employed.

Some may regard the recommendations as too idealistic and not therefore achievable but the success of the contributors suggests otherwise.

A common feature of the success stories is the involvement of strong and knowledgeable clients who have been able to provide a clear brief as to their requirements and encourage a way of working that has enabled expert supply chains to produce better buildings and be rewarded for doing so.

Although the procurement of sheds provided the focus for the publication, many of the lessons have wider application.

Barrett Steel Buildings
www.barrettonline.co.uk

Billington Structures
www.billington-structures.co.uk

C A Group
www.cagroup.ltd.uk

Cameron Taylor
www.camerontaylor.co.uk

Caunton Engineering
www.caunton.co.uk

Corus Colors
www.colorcoat-online.com

Corus Construction & Industrial
www.corusgroup.com

Hathaway Roofing
www.hathaway-roofing.co.uk

Kingspan Insulated Panels
www.kingspanpanels.com

Kingspan Metl-Con
www.kingspanmetlcon.com

Metsec
www.metsec.co.uk

Michael Sparks Associates
www.msa-architects.co.uk

Yorkshire Sheeting & Insulation Services