The case for CDM: better safer design-a pilot study

Prepared by Greenstreet Berman Ltd for the Health and Safety Executive 2003
The construction sector remains one of the highest risk sectors in the UK. Previous research has concluded that there is concern in the construction industry that there has been limited success in securing safer designs. It is reported that “The opportunities to design out hazards are not being exploited to the full”. Surveys have also reported that designers are not always fully aware of how they can reduce construction hazards by changing the design of structures. This project identified simple examples of how designers have significantly improved construction safety and reduced costs / programme time. These examples are illustrated, and hence can be used to raise awareness of how designers can achieve better, safer and cheaper construction. The case studies show that the main factor in achieving safer design is forethought and an appreciation of buildability issues. The examples do not entail specialist technology.

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1 INTRODUCTION

1.1 Background

The construction sector remains one of the highest risk sectors in the UK. A study\(^1\) conducted on behalf of the HSE (Construction health and safety for the new millennium) calculated the fatal and major injury rates for a selection of trades, as shown in Table 1. Taking a few examples it can be seen that;

- In a forty year career in scaffolding, you stand a 1 in 3 chance of a major injury and 1 in 130 chance of death!
- A steel erector has a 1 in 75 chance of death and a 1 in 6 chance of a major injury over a 40 year career!

In both cases the main risk is of falls. The latter study also found that the trades with the lower risk of fatal accidents, such as carpentry, tend to have a higher risk of serious ill-health, such as respiratory diseases, skin disease and hearing loss. The high incidence of musculoskeletal disorders associated with manual handling is well known.

Injury rate data for the period following this study gives no reason to suppose the position has changed significantly.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Scaffolders</td>
<td>1 in 5,357</td>
<td>1 in 115</td>
</tr>
<tr>
<td>Roofers</td>
<td>1 in 3,764</td>
<td>1 in 300</td>
</tr>
<tr>
<td>Steel erectors</td>
<td>1 in 3,016</td>
<td>1 in 232</td>
</tr>
<tr>
<td>Glaziers</td>
<td>1 in 11,956</td>
<td>1 in 360</td>
</tr>
<tr>
<td>Painters &amp; floorers</td>
<td>1 in 19,000</td>
<td>1 in 522</td>
</tr>
<tr>
<td>Maintenance workers</td>
<td>1 in 23,000</td>
<td>1 in 300</td>
</tr>
<tr>
<td>General operatives</td>
<td>1 in 28,000</td>
<td>1 in 600</td>
</tr>
<tr>
<td>Electrical trades</td>
<td>1 in 52,000</td>
<td>1 in 600</td>
</tr>
<tr>
<td>Bricklayers</td>
<td>1 in 76,500</td>
<td>1 in 600</td>
</tr>
<tr>
<td>Carpenters</td>
<td>1 in 78,000</td>
<td>1 in 512</td>
</tr>
<tr>
<td>Plumbers</td>
<td>1 in 80,500</td>
<td>1 in 990</td>
</tr>
<tr>
<td>All construction industry</td>
<td>1 in 13,000</td>
<td>1 in 250</td>
</tr>
</tbody>
</table>

The latter research also explored the role of designers in construction health and safety and the factors that influence uptake of health and safety by employers. The research found that:

- The vast majority (~70%) of respondents believe it is possible to foresee and remove health and safety problems during the design stage;
- Only a minority (~25%) reporting that the division of tasks between designers and contractors make it difficult to manage health and safety (p31);
- Respondents believe designers have a large scope to improve health and safety (p 34) but that they do not necessarily give a high priority to health and safety;
- About 30% of respondents (taking contractors, designers and client together) did not believe there had been any improvement in designed safety, although 50% of designers tend to believe there has greater improvement in designed safety.

The study concluded that there is concern in the construction industry that there has been limited success in securing safer designs. “The opportunities to design out hazards are not being exploited to the full.” (p70).

It is also reported that there has only been some improvement in designers’ understanding of health and safety risks, which, whilst ahead of clients, lags behind other parties such as project managers. It is also feared that professional qualifications for designers do not prepare them for real health and safety issues. This concern is expressed by designers more so than contractors and clients. Indeed, respondents indicted that designers are not always aware of how they can help to reduce construction hazards by changing the design of structures. In particular:

- Designers have limited experience and understanding of buildability;
- The differences in risk levels experienced by different trades and work methods is not well understood;
- The relationship of health and safety issues to lifetime costs is not well understood;
- Risk assessment are often insufficient, and;
- Risk assessments are undertaken too late to bring about design changes, therefore the opportunity to consult with other members of the construction team at this point is often not taken.

Respondents indicated that a partnering approach, where the site team is brought in at earlier stage of design, should provide opportunities for discussion, hazard identification and problem solving.
1.2 Designers’ duties under CDM

The Construction (Design and Management) Regulations 1994 clearly define the designer’s duties in respect of reducing health and safety risks during construction to avoid hazards, combat risks and provide information, as transcribed in Box 1. Indeed, according to the CDM regulations, the best form of protection against a hazard is to eliminate the hazard at source. Where elimination of the hazard is not possible, the next strategy is to reduce either the likelihood, or the potential impact of the hazard. Where elimination and/or reduction of the hazard are not possible, information about the hazard should be provided so that it can be dealt with as safely as possible. The hierarchy of control for designers, therefore is as follows:

- Eliminate
- Reduce
- Provide information
Box 1: Designers duties

Regulation 13 of Construction, Design and Management Regulations

Every designer shall –

(a) Ensure that any design he prepares and which he is aware will be used for the purposes of construction work includes among the design considerations adequate regard to the need –

(i) To avoid foreseeable risks to the health and safety of any person at work carrying out construction work or cleaning work in or on the structure at any time, or any person who may be affected by the work of such a person at work,

(ii) To combat at source risks to the health and safety of any person at work carrying out construction work or cleaning work in or on the structure at any time, or any person who may be affected by the work of such a person at work, and

(iii) To give priority to measures which will protect all persons at work who may carry out construction work or cleaning work at any time and all persons who may be affected by the work of such persons at work over measures which only protect each person carrying out such work;

(b) Ensure that the design includes adequate information about any aspect of the project or structure or materials (including articles or substances) which might affect the health and safety of any person at work carrying out construction work or cleaning work in or on the structure at any time or of any person who may be affected by the work of such a person at work; and

(c) Co-operate with the planning supervisor and with any other designer who is preparing any design in connection with the same project or structure so far as is necessary to enable each of them to comply with the requirements and prohibitions placed on him in relation to the project by or under the relevant statutory provisions.

1.3 Examples of the impact of design

Some examples of safer design have been highlighted. A few well-known examples of “safer design” include:

- The use of smaller blocks that reduce the likelihood of manual handling injuries;
• The use of trenchless technology which eliminates the hazards associated with excavations, and;

• The substitution of hazardous materials for less hazardous materials.

In addition, the impact of poor design has been highlighted. In particular, Avijit Maitra² gives examples of incidents influenced by design practice. The examples document accidents which the designers could have prevented by elimination, combating or providing information about the hazard, as follows:

• **Elimination:** A timber roof overturned when a slater mounted a ladder leant against the barge board. This hazard could have been eliminated by tying the roof to the building.

• **Combating:** Decayed lateral joists were being replaced in a four storey building. A wall collapsed due to the removal of lateral restraints, after the end of all the joints were cut off at once. The designer could have specified that one in three joints be cut off at anyone time.

• **Providing information:** During replacement of windows whilst converting a barn into an office, a wall collapsed. The window frames had been holding up the brick wall, especially where the lintels had cracked. The designer could have informed the contractor of the structural integrity of the lintels had been compromised by the cracks, and hence required temporary support.

Maitra also documented examples of where hazards were eliminated during design by simple measures. For example, retaining walls for a road in a cut were formed as pre-bored contiguous concrete piles. This eliminated the need to work at height to construct the retaining walls, sling shutters in by crane or work under an unsupported slope. This and other examples demonstrated how designers can eliminate or reduce hazards by simple measures.

However, there are few well documented examples of safer design and their benefits. This project aims to help fill this gap.

### 1.4 Aims of this project

In response to the findings from previous research, this project identified simple examples of how designers have significantly improved construction safety and reduced costs / programme time. These examples are documented and illustrated, and hence can be used to raise awareness of how designers can achieve better, safer and cheaper construction.

Other research³ on the promotion of health and safety has shown that publicity material generally needs to be educational in nature as well as promotional – showing people

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² Avijit Maitra. Designers under CDM – a discussion with case studies. Civil Engineering, p77- 84, 1999 May/August.

³ Evaluation of the Good Health is Good Business Campaign. Wright et al. HSE contract research report 272/2000
examples of what comprises good practice, as well as providing a convincing business case. It is also clear from previous research that many duty holders want industry-specific information and that the business case can be best illustrated by using specific examples of the costs and benefits. We have developed our case studies according to these findings.

This report provides a portfolio of material for use in promoting application of CDM by designers. As per the findings of previous research, the portfolio is specific to the construction industry, and demonstrates both the business case for safer design and illustrates practical examples of its application – thereby addressing the main motivational factors identified in the research discussed above. This is achieved by presenting the costs and benefits of design features for the construction process.

1.5 Structure of this report

The remainder of the report structure is:

- Section 2 provides a summary of the method
- Section 3 provides a collation of case study material
2 METHOD

2.1 Overview

The method is illustrated in Figure 1.

![Figure 1: Overview of method]

- Define selection criteria
- Identify and screen examples
- Collate material
- Draft promotional materials
- Pilot promotional materials
- Finalise promotional materials

2.2 Method description

2.2.1 Case study selection criteria

For any promotional material to be effective it should address the concerns and needs of the intended audience. Therefore, we will review conclusions of past research and hold discussions with HSE representative(s) to:

- Agree types of case studies that are likely to be effective in motivating designers / clients, such as “common” projects that everyone can recognise as being relevant to them, and;
• Agree a set of criteria for selecting case studies, such as demonstrable cost savings and safety benefits during construction process, application of techniques that can be managed by “common” designers etc, completeness of information available to researchers etc.;

Given the motivational aims of this study, the criteria for selection included:

• The case studies should be constructed to address clients’ and designers’ motivational factors, highlighting points such as cost and construction time;

• The examples would be clearly practical and manageable by the “common” designer;

• Illustrate good examples of designers adapting their designs to improve construction safety;

• Demonstrate the commercial benefits, such as schedule and cost savings, including any life time cost savings;

• Demonstrate the safety benefits, and;

• Have sufficient text, data and graphical / pictorial information to enable a body of material to be developed for use by the HSE.

2.2.2 Identify and screen examples

This entailed contacting designers and applying the screening tool to identify case studies. Upon identifying appropriate examples a request was be made for more detailed information.

Case studies were identified by contacting:

• Trade associations (such as Federation of Master Builders, RIBA, Engineering Construction Industry Association, Royal Institute of Chartered Surveyors, Construction Federation, Institute of Civil Engineers);

• Large firms, such as Carillion Plc, Taylor Woodrow etc;

• Health and Safety Executive contacts and;

• Asking trade associations/clients to nominate candidate projects.

2.2.3 Collate materials

Information was collated by:

• Desk top retrospective review of projects (face to face with designers / construction managers) - logging costs and benefits during the project, and;
Site visits to observe and photograph new construction techniques.

**Proforma**

A case study proforma was used to ensure a consistent approach to acquiring and documenting case studies. This was used during face to face and telephone based interviews to secure requisite information. Graphical information to illustrate examples was also acquired.

Information was acquired on:

- Description of the design / construction technique;
- Description of the project / building etc;
- Why the particular design / construction method was adopted;
- How safety concerns influenced the adoption of this technique;
- Construction time / productivity, such as rate of cladding per person hour;
- Qualitative examples of how design “eased” or complicated the construction process;
- Construction costs / savings;
- Safety benefits, such as less working at height, elimination of a hazard, less exposure to dusts, less manual handling etc;
- Any health and safety incidents or problems, and;
- Miscellaneous issues such as avoidance of project delays / disruption / risks etc.

An abbreviated version of the proforma is shown in Box 2.
Box 2: Abbreviated Proforma

**Case study summary**

1. Summary of the design / construction technique.

2. In what way is this design technique different from past practices or other practice in the construction industry?

3. What prompted this change in design?

4. In what way does this design technique reduce the risk of falls from height during the construction of the building?

5. What are the other health and safety benefits of this design technique?

6. What are the cost, schedule and maintenance benefits of this design technique?

7. Any other comments or points of information.

2.2.4 Drafting and piloting of materials

A draft version of the “promotional version” of the case studies was circulated for review by a sample of designers and the firms from whom the case studies were drawn.

After receipt of comments the case studies were finalised.

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4 Avijit Maitra. Designers under CDM – a discussion with case studies. Civil Engineering, p77- 84, 1999 May/August.
3 CASE STUDIES

3.1 Introduction

The examples have been selected to cover the key areas of concern in the construction sector, namely:

- Falls from height, and;
- Occupational health hazards such as Vibration White Finger (VWF), noise induced deafness and manual handling injuries.

The use of power tools, working at height, manual handling, operating plant, dust, noise, holes, falling tools, slippery surfaces, cold weather, unsafe scaffolding are all considered to be factors posing risks to health and safety on projects.

The examples also demonstrate that solutions generated at the design stage usually bring about easier, quicker, and better QA, in addition to eliminating some hazardous aspect of the construction task. None of the examples reduced aesthetics, buildability, environmental impact or end use. Also, none of the examples in the case studies involve the use of either specialist technology or techniques, and so do not represent a significant investment to achieve. Indeed, the examples demonstrate that safer design may only need a bit of forethought.

Some common themes are that safer design is achieved by:

- Eliminating the need to work at height by designing out the need to erect or use scaffolding/ladders, and;
- Pre-fabricating structures in factory conditions at ground level, and thence lifting them into position.
3.2 Case study 1: Pre-installed windows and glazing within precast concrete cladding panels

3.2.1 Summary

Carillion Building are one of the UK’s largest construction companies and are involved in some of the UK’s largest and prestigious projects, one of these being St Margaret’s Hospital Regeneration, Swindon. Carillion work closely with their specialist sub contractors to enable improved and innovative designs, coupled with improved health and safety. Two of these subcontractors are Trent Concrete and Broderick Structures, both cladding contractors.

At St Margaret’s Hospital it was decided in early design team meetings that the windows (Broderick Structures) would be pre-installed into the precast concrete panels (Trent Concrete) off-site. It was agreed this would be carried out at Trent’s manufacturing premises (shown in Figure 2). The main benefits for this were:

- Reduced construction programme;
- Improved quality of the window installation;
- Avoids working at height, and;
- Eliminates the need for site scaffolding.

Figure 2: Off site assembly of the windows into the pre-cast panels

(Project courtesy of Trent Concrete)

Project Team

- Architect - Whicheloe Macfarlane;
- Principle Contractor - Carillon Building Special Projects;
- Client - The Hospital Company;
- Specialist contractors - Trent Concrete;
- - Broderick Structures.
3.2.2 Traditional method

Traditionally precast concrete cladding consists of large prefabricated reinforced concrete panels fixed to site located brackets. The fabrication process involves the manufacture of timber, steel or GRP moulds into which the concrete is then cast.

The panels are fixed back to the main structure in a variety of ways, the choice of which is dependent on the panel size, thickness, point of connection and structure type. The joints between the panels are - commonly - a double, wet, face-applied silicone seal.

Typically with industrial or commercial buildings, window frames will be made from aluminium or steel. The windows are usually installed as the building work proceeds and must be protected from damage. However, windows with factory-applied finishes are best installed into previously prepared openings (see Figure 3). Once the window frames have been installed they are then always site glazed (McEvoy, 1994).

Figure 3: The traditional method of installing pre-cast concrete cladding panels

Traditionally the precast cladding panels are installed on site first. Figure 3 shows a typical precast concrete cladding panel being installed on site including a ‘punched’ window opening. Once the precast panels are in place the windows are then installed. The most common method of window installation is from a standing scaffold. However, they can also be installed from mast climbers or scissor lifts, but this still involves working at height.

3.2.3 Alternative method

St Margaret’s hospital relocation, Swindon, was built using a PFI method of procurement, lead by Carillion Building. During pre-design meetings, Carillion and the
specialist contractors identified that potential programme savings and reduced site health and safety risks could be achieved by pre-installing the windows and glazing into the precast concrete panels off-site at ground level, before delivery to site. All the sealant works around the windows are also completed at this stage. The cladding panel was then transported to site as one complete unit.

“The idea or philosophy was based around not using a standing scaffold at all, we identified this as a potential problem, and we wanted to cut accident rates. Therefore install the window at factory ground level, then bring them straight to site and install them with a crane and cherry picker” (Carillion design manager).

Using precast concrete cladding in this way as opposed to insitu-fixed store or brickwork improves programme, quality and health and safety benefits. These techniques are well understood and have been used for many years.

3.2.4 Health and safety benefits

Table 2 shows the operations affected and the Health and Safety risks removed or reduced using this method of window and glazing installation.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Delivery of window units and associated components</td>
<td>• Slips trips and falls&lt;br&gt;• Manual handling</td>
<td>Secondary benefit</td>
</tr>
<tr>
<td>2 Installation of windows</td>
<td>• Working at height&lt;br&gt;• Falling objects&lt;br&gt;• Manual handling&lt;br&gt;• Work in exposed areas</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>3 Sealing joint between windows and cladding</td>
<td>• Working at height&lt;br&gt;• Falling objects&lt;br&gt;• Use of scissor lifts&lt;br&gt;• Work in exposed areas&lt;br&gt;• COSHH risks&lt;br&gt;• Slips, trips &amp; falls on empty silicone tubes</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>4 Inspection/snagging of windows</td>
<td>• Working at height&lt;br&gt;• Use of scissor lifts</td>
<td>Primary benefit</td>
</tr>
</tbody>
</table>

A Delivery of window material

- Reduced slip and trip hazard for delivery drivers as they are delivering to a factory, which is less hazardous than a construction site;
- Reduced congestion-related hazards at construction site as fewer lorry deliveries;
• Reduced slip and trip hazard for workers off-loading materials because they are working in a safer factory environment (due to less materials being present on site);
• Reduced musculo-skeletal risk as more likely to have mechanical off-loading and less manual handling in factory environment, and;
• Reducing glazing and manual handling risks, as no site storage.

B Installation of windows

• Avoided the risk to window installers working at height as the glazing and associated works were carried out at ground level;
• Avoided the hazards associated with erection and dismantling of scaffold, including scaffolders working at height, manual handling of scaffold tubes, boards and fittings and the possibility of dropped objects;
• Reducing glazing manual handling risks, as there is less movement of glazing materials in a controlled factory environment than a construction site;
• Reduced risk of dropped objects during the construction of the windows, as the installers are not working at height from scaffold, and;
• Reduced slip and trip risk for window installers as they are working in a safer factory environment rather than a construction site.

C Sealing windows

• Reduced risk of dropped objects during the sealing of the windows, as the installers are not working at height from scissor lifts, cherry pickers or scaffolds, and;
• Avoided the risk to sealant contractor working at height (See Figure 4).

Figure 4 Pre-cast cladding and window interface being sealed

(Photograph courtesy of Trent Concrete)
D Inspection/snagging of windows

- Reduced risk from working at height for principle contractor/ architect inspecting completed panels and interfaces from a cherry picker/scissor lifts as most of the inspection is carried out at ground level during installation. The only site inspection was the joints between the precast concrete cladding panels, which were carried out off a cherry picker.

3.2.5 Commercial benefits

In addition to the health and safety gains there were a number of commercial benefits. These have been separated in three main sections; cost time and quality.

1 Cost

- Eliminated scaffold/scissor lift/ mast climber’s cost, approx saving £50,000 (Contractor estimate);
- Potential reduced cost due to more efficient delivery and working methods in factories – may not be passed on to the client, and;
- Potential ‘extra’ up front costs associated with pre-assembly should be balanced out by savings in site work-packages related to the reduced on-site labour.

2 Time/programming

- Building weathered (water tightness) quicker – less programming time – equivalent to time taken to install the windows, approx 8 weeks (Contractors estimate);
- Windows were easier and faster to install, as the operation was done at ground level and not from a scaffold. Also the panels were positioned back to back in the manufacturing yard, thus speeding up the operation (see Figure 2);
- As the panels were prepared in advance, there was less programming risk ‘on–site’;
- Easier co-ordination between glaziers and panel manufacturers as they work together in the factory, rather than sequentially on a construction site, and;
- The task of co-ordinating glazing delivery and installation timing is transferred to factory instead of ad hoc site activities.

3 Quality

- Better quality achieved by manufacturing in factory controlled conditions;
- Reduced problems at the critical precast panel to window interface– due to closer supervision in factory and more efficient working conditions;
- Less site damage to precast panels as no external scaffold required, and;
- Cleaner/safer working environment.
3.3 Case study 2: Pre-cast concrete guide-wall moulds

3.3.1 Summary

Carillion Building are one of the UK’s largest construction companies and are involved in some of the UK’s largest and prestigious projects, one of these being Five Ways Entertainment Centre, Birmingham. As part of their procurement process Carillion work closely with their specialist sub contractors to enable improved and innovative designs, coupled with improved health and safety. One of these subcontractors was Cementation, Foundations Skansa Construction, who are piling and ground engineering specialists.

Cementation Foundations Skansa has developed a precast concrete mould (Figure 5) that acts as a guide for contiguous piling. Carillion and Cementation Foundations implemented the precast concrete guide wall system into the Five Ways project, its main benefits were:

- Reduced construction programme for the sub-structure work;
- Improved quality for the piles, and;
- Improved health and safety for the piling operation due to reduced site operations

Figure 5: The pre-cast mould

(Picture courtesy of Cementation)
3.3.2 Traditional method

Five-ways Entertainment Centre (phases 1 & 2), Birmingham, was built using the design and build method of procurement, lead by Carillion Building. The centre incorporated a casino and nightclub in the basement. There are numerous methods of basement construction depending upon ground conditions. A detailed explanation is outside the scope of this report. For this project the contiguous pile method was chosen.

Contiguous piles

This method forms a permanent structural wall formed by augured piles. As the name suggests the bored piles are constructed from ground level, as close together as possible to form the perimeter wall before any excavation takes place (Figure 5). The accuracy of placing the piles depends upon the type of pile and the method of placement.

Figure 6 Contiguous pile formation (Harrison & Trotman, 2002)

Contiguous piles are normally restricted to conditions where the soil is dry or where there is likely to be very little water penetration through the basement wall. However there are methods of sealing the gaps between the piles. Their major benefits are their capability to be formed close to existing foundations and installed with the minimum of vibration and noise (Figure 6).
With all such pile walls the piles are drilled to the requisite depth, the shaft filled with concrete up to ground level and then reinforcement placed into the shaft. The top section of concrete is then removed by hydraulic breakers (usually hand held) such that the final level matches the level required for permanent works design. Typically, an insitu concrete capping beam is then constructed to tie together the tops of the piles and provide a clean start for works above ground (Figure 7).

Figure 7 Cementation Foundations Skansa drilling through the pre-cast concrete moulds (the brickwork is an existing structure)
Figure 8 shows the production sequence for continuous augured piles, there are 7 steps. (Most literature only acknowledges steps 1-4, 5 and 6 are generally overlooked)

Step 1: The auger is fitted with the desired head.

Step 2: The augured is drilled into the ground to the required depth of the pile.

Step 3: Concrete is pumped through the hollow stem in the auger to the shaft as the auger is removed.

Step 4: Once the auger is removed the reinforcement is introduced to the pile shaft.
Step 5: Shows the excess concrete at ground level from the piling operation – the amount will vary from project to project.

Step 6: The ground is excavated exposing the pile, and this is then broken down to the required level of the capping beam. Figure 9 shows a typical site operation of this process. It should be noted this is a live site and very typical of the activity, the ramifications of health and safety is very significant here.

Step 7: The capping beam is cast in-situ.

![Figure 9 Operatives manually breaking down pile tops](image)

(Sibb, Loughborough University)

**Sacrificial Guide Wall**

Contiguous piled walls used in basement construction, where a more accurate alignment is required (as was the case at Five Ways), need a temporary, sacrificial concrete guide wall to be cast in advance of the piling operations and through which the piling auger passes. This acts as a control for the piles final cast position and is eventually replaced by the permanent capping beam later in the construction process.

**3.3.3 Alternative method**

In order to prevent the abortive work of the early guide wall, which in the final permanent state is usually replaced by a concrete capping beam of similar dimensional proportions, a system has been developed that combines the temporary guide wall and permanent capping beam.
The combined system utilizes pre-cast concrete moulds (see Figure 7) placed into position and retained in that position by non-structural concrete at the outside of the mould. Circular voids in the mould allow the piling auger to pass through the mould and the position of the pile to be predetermined and achieved. Adjacent voids are protected with circular ‘lids’ to prevent them being filled with concrete or piling arising.

Figure 10 shows the guide blocks being placed along the line of the wall. Figure 11 shows the blocks removed after the piling operation, it also shows the mould left by the blocks acts as the formwork for the capping beam, eliminating the site operation.

**Figure 10 Precast blocks being positioned onto the sacrificial wall**
This solution was prompted by Carillion’s desire to reduce on site labour time and material use for the preparation of the capping beam. Cementation Foundations Skansa provided the design solution.
3.3.4 Health and safety benefits

Table 3 shows the operations affected and the Health and Safety risks removed or reduced using this method.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
</table>
| 1 Breaking the pile down | • Avoids vibration and noise hazards posed by scabbling and thus avoids vibration related disorders associated with scabbling such as Vibration White Finger (VWF)  
• Avoids manual hazards associated with shovelling waste concrete  
• Avoids moving vehicle hazards posed by dump truck movement                                                                                                         | Primary benefit      |
| 2 Shuttering             | • Avoids the use of power tools for electric saws - therefore reduced power related accidents  
• Reduced working in a muddy uneven trenches - therefore reduced slip and trip risk                                                                                       | Secondary benefit    |
| 3 Setting out            | • Less working in a muddy uneven trenches - therefore reduced slip and trip risk                                                                                                                                                    | Secondary benefit    |
| 4 Pile drilling          | • Reduced concrete burn risk – as less concrete work on site                                                                                                                                                                       | Secondary benefit    |

Table 3: H&S risks removed or reduced

1 Breaking down the pile
- Avoids vibration and noise hazards posed by breaking down the pile caps and thus avoids vibration related disorders such as Vibration White Finger (VWF), the symptoms of this disorder can vary from slight numbness and tingling in the fingers to very severe loss of grip strength and dexterity. HSE statistics state that there were 3,155 cases of VWF in 1998/1999; figures for the past four years have been similar with an average of 3,100 cases annually. The Safety and Health Practitioner regards the construction industry as one of the high-risk industries for employees suffering VWF;
- Avoids manual handling hazards associated with “normal” practice i.e. shovelling waste concrete after it has been broken out, and;
- Avoids moving vehicle hazards posed by dump truck movement employed to remove broken concrete from pile cap.

2 Shuttering
- Reduced working in a muddy uneven trench as there is not formwork required for the capping beam - therefore reduced slip and trip risk, and;
- Avoids hazardous conditions for formworkers working with power tools (saws etc.) as this operation has been eliminated.
3 Setting out

- Reduced working for setting out engineers in muddy uneven trenches as the precast moulds are set out at the start, and then the auger passes straight through them, acting as a guide.

4 Pile drilling

- Reduced cement related skin disease risk due to workers not having to “scoop” away excess concrete when the auger is removed from drilling the pile.

3.3.5 Commercial benefits

In addition to the health and safety benefits there are several commercial gains, and in fact these were the initial drivers to consider the technique. The commercial benefits have been separated in three main sections; cost, time and quality.

A Cost

- Less wasted concrete- saving on redundant in-situ pile concrete by not filling up the guide wall 170 cubic metres on 226 piles of 750mm diameter (estimate by Carillon Building);
- No cost for disposal of formwork- (based upon polystyrene block method, Figure 12 shows Cementation Foundations Skansa site prior to the guide wall method, highlighting the problems caused using this method) polystyrene moulds for an insitu guide wall are not required - polystyrene disposal cost alone is £25 per cubic metre (estimate by Carillon Building);
- Less manpower scabbling the piles- (estimate by Carillon Building) for 226 No. 750mm diameter piles, the man normal working hours saved is 904, which equates to 113 man days if HAVS Maximum Trigger Times are applied (i.e. 46 minutes per day per man maximum trigger duration), and;
- Blocks are reusable (unless used as the permanent capping ring beam- not done at five-ways)

B Time/programming

- For the 226 piles of 750mm diameter, a construction programme period saving of three weeks was achieved, in a combination of the foundation piling and capping beam construction.

C Quality

- It is more likely that the piles will be vertical as the guides improves installation, and;
- It is easier to set out the pile position which leads to greater accuracy.
Figure 12: Polystyrene debris being blown around site prior to precast guide wall method

(Photo courtesy of Cementation Foundations Skanska)
3.4 Case Study 3: pre-cast concrete beams

3.3.6 Summary

Taylor Woodrow is one of the UK’s largest construction companies and is involved in some of the UK’s largest and prestigious projects. One of their major repeat order clients is Tesco Superstore. As part of their procurement process Taylor Woodrow work closely with Tesco, their specialist sub contractors to enable improved and innovative designs, coupled with improved health and safety to reduce the site construction period.

Taylor Woodrow and their design process have developed numerous designs methods and processes, which enables reduced site operations. One of these examples is their method of installing concrete ground beams. They use precast concrete beams and a “T” section (Figure 13) as part of the steel column fabrication; this aids quicker installation. Its main benefits are:

- Reduced construction programme for the sub-structure work, and;
- Improved health and safety for the substructure work due to reduced site operations.

Figure 13: The “T” connection

Project Team
- Architect - Smith Smalley Architects Ltd;
- Principle Contractor - Taylor Woodrow;
- Client - Tesco Superstore.

Note; (This example is taken from the Scunthorpe project, on other stores the design team, floor area and layout may change)
3.3.7 Background

Tesco Superstore, Scunthorpe, was built using the design and build method of procurement, lead by Taylor Woodrow. The Superstore was built in a typical supermarket location, on a brown field site on the periphery of the town. The store has a gross floor area of 80,000 sq/ft with a 60,000 sq/ft sales area. The client is a large national retailer who requires their buildings built as fast as possible to gain maximum revenue. Therefore, when constructing a building for a retail client the contractor must:

- Procure the building as fast as possible, and;
- Procure the building with no delays.

Taylor Woodrow is continually reviewing their designs with Tesco to enable a reduced construction period. As part of this initiative design process they have introduced precast concrete ground beams connected to a “T” on the steel columns.

3.3.8 Traditional method

**Concrete ground beams**

The ground beam is the interface that connects the foundations to the superstructure. The ground beam is sometimes called the ring beam, in which the beams circle the base of the building enabling the exterior of the structure to be built upon. Ground beams usually consist of reinforced concrete sections, there main purpose is to provide lateral rigidity to the pile foundations and must be able to resist any bending (Foster and Harrington, 1994). The ground beam then supports the building envelope, (cladding in the case of Scunthorpe). There are two methods of construction;

- Cast-in-situ into excavated trenches, and;
- Precast with reinforced loops at the ends for connecting to other beams in the foundation, if required (Harrison and Trotman, 2002).

**Typically, the ground beam is cast-in-situ: this is where the beam is formed on site in its final location. This method is very intensive for skilled site operatives requiring two or three differing trades for the formation of the beam. Figure 14 shows the formwork preparation for the ground beam and**

Figure 15 shows the beam preparation prior to the concrete pour following the construction of the steel reinforcement.
Figure 14: Beam formwork (Brett, 1988)

Figure 15: Steelwork prior to the concrete pour

(Gibb- Loughborough University)
3.3.9 Alternative method

*Precast concrete beams*

In this method, prefabricated concrete beams are transported to site, where they are then lifted into the correct position. Highly skilled operatives are therefore not required to manufacture forms, as with the cast-in-situ method, or in the installation of the beams. Also, as the method is less dependent on weather conditions than cast-in-situ to achieve an accurate result, it is possible for work to be undertaken in wider range of weather conditions. Figure 16 shows a precast beam being installed at Scunthorpe.

**Figure 16: Precast concrete ground beam being installed**
3.3.10 Health and safety benefits

Table 4 shows the operations affected and the Health and Safety risks removed or reduced using this method.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
</table>
| 1  Reinforcement         | • Reduced working in muddy uneven trenches - therefore reduced slip and trip risk.  
                            | • Avoids adverse bending - therefore less musculoskeletal problems                                                                                                                                                        | Primary benefit  |
| 2  Shuttering            | • Avoids the use of power tools for sawing - therefore reduced power related accidents  
                            | • Reduced working in muddy uneven trenches - therefore reduced slip and trip risk.  
                            | • Avoids adverse bending - therefore less musculoskeletal problems                                                                                                                                                        | Primary benefit  |
| 3  Concrete pour         | • Less working in a muddy uneven trench - therefore reduced slip and trip risk  
                            | • Avoids concrete burn risk – as less concrete work on site                                                                                                                                                             | Primary benefit  |
| 4  Material movement     | • Reduces manual handling of materials used for beam formation - therefore less musculoskeletal problems                                                                                                                                                  | Secondary benefit|

Table 4: H&S risks removed or reduced

1  Reinforcement
   • Reduced working in a muddy uneven trench as there is no formwork required for the beam - therefore reduced slip and trip risk. European agency for safety and health at work statistics state that each year, one third of all workplace major injuries (reported to enforcing authorities) are caused by slips and trips, and;  
   • Avoids hazardous conditions for steel-fixers working continually bent over (musculoskeletal problems, this is common for operation A-C) and using power tools (angle grinders) as this operation has been eliminated.

2  Shuttering
   • Reduced working in a muddy uneven trench as there is no formwork required for the beam- therefore reduced slip and trip risk, and;  
   • Avoids hazardous conditions for form workers working with power tools (saws etc) as this operation has been eliminated.
3 **Concrete pour**
- Reduces cement related skin disease risk due to workers not having to shovel concrete in uneven trenches, and;
- Avoids concrete burn risk- as the site operation of concrete pouring has been eliminated.

4 **Material handling**
- Reduced slip and trip hazard for workers off-loading materials as they are working in a safer environment due to less site materials, and;
- Reduced musculoskeletal risk as more likely to have mechanical off-loading and less manual handling in factory environment.

**Note:** Using this method has increased some risks e.g. cranage of the precast beams and the potential for trapped fingers under the beams. However, overall health and safety will improve using this method.

**“T” Connection**

As part of the primary structure, Taylor Woodrow has added the “T” connection to the columns (Shown in Figure 17). This forms the connection between the beam and structure. The precast beams are slotted over the “T” onto pre-levelled shims; finally they are grouted into position.
The benefits of using this method over the standard method of installing precast beams are:

- Fast installation, the beams can be installed, using a digger and lifting chains with only two operatives in 10 minutes (timed by the author);
- The operation of drilling the fixing rod into the foundation pile has been eliminated (only when the column base is a pile head is there a requirement for drilling into the base), and;
- The operation can be carried out in virtually any weather condition, as there is no need for power tools.

3.3.11 Commercial benefits

In addition to the health and safety benefits there are several commercial gains, and in fact these were the initial drivers to consider the technique. The commercial benefits have been separated in three main sections; cost, time and quality.

A Cost

- No cost for disposal of formwork (if applicable), and;
- Taylor Woodrow’s cost evaluation for precast beams against cast-in-situ beams (for Scunthorpe) equated to the same price.

B Time/programming

- Using the precast beams, over the cast-in-situ beams, saved approx 7 days on the construction programme. Using the “T” connection reduced the construction programme by approx 1 day (Taylor Woodrow estimate). Taylor Woodrow built Scunthorpe store in 16 weeks (Steelwork upwards) it is unlikely this could have been achieved using conventional construction methods.

C Quality

- The beams are produced to a higher quality with fewer deviations - aiding the interface connection between beam and superstructure.
3.4 Case study 4: Structural steel columns- pre drilled web hole

3.4.1 Summary

Vauxhall Motors are a major client in the construction industry turning over in excess of £30 million per year. They have taken many of their car manufacturing techniques and strategies into their building works. Part of this is their design guides where they have standardised processes for the construction works. Their philosophy is that much more responsibility should be placed on the client and designers for buildability and safety. This then enables a cost effective and efficient construction project.

One example of their design guides relates to structural steel columns. Here they have designed in a hole at the head of the column as part of the frame fabrication. This enables the column to be erected faster and in a safer method (shown in Figure 18). This case study also demonstrates the benefits to be gained from close liaison between designers and construction experts as the technique could only be used if appropriate lifting equipment were available. The benefits of the technique include:

- Avoids undue manual handling, and;
- Avoids working at height

Figure 18: Pre-drilled hole in the column web
(column laid horizontally prior to installation)

(Pavitt – Loughborough University)

Project Team
- Designer        - Convoy Structural Services;
- Client        - Vauxhall Cars;
- Specialist contractor        - Convoy Structural Services.
3.4.2 Background

Vauxhall Motors is one of the longest established motor manufacturers in the world, and is part of the world’s largest corporation - General Motors. Founded in 1903, the company now employs 7,000 people directly, and supports an estimated 30,000 further jobs in the UK. During almost 100 years of motor manufacturing in the United Kingdom, Vauxhall has produced many classic vehicles.

A great proportion of this achievement can be attributed to its successful building and maintenance philosophy, where early pre-planning and design of the works prevents any shut down to the car manufacturing process. It is estimated that in one calendar year Vauxhall’s building projects can amount to 30 million pounds. This includes all civil and building works on the properties of Vauxhall – new build, extensions and refurbishment. Currently, a high proportion of the buildings incorporate steel framed structures.

**Steel frame construction**

Traditionally, steel framed structures are designed with the connections between the separate members treated as either non-rigid or fully rigid joints. The frame consists of horizontal beams in both directions and vertical columns. The connections are either shop or site assembled according to where the fabrication takes place. Most site connections are bolted whereas shop connections are often welded. The design of structural steelwork members and their associated connections is generally the responsibility of the structural engineer. Figure 19 shows a typical bolted column to beam assembly.
BS 5950 Part 2 gives tolerances for steel construction, which are designed to ensure that the steel work complies with the standard. These tolerances do not consider the wider requirements of the fit of components and architectural considerations. The National Structural Steelwork Specification for Building Construction (NSSS) gives tolerances, which are intended to reflect these issues.

At Vauxhall Motors, steel frame construction is generally chosen over the in-situ concrete method when the erection speed of the frame is critical. Generally, a steel frame will be erected quicker than an insitu concrete frame.

3.4.3 Traditional method

The erection of a steel frame will be carried out using a crane, which can be either a mobile or tower crane. There are two generic lifting systems from a crane - strops or chains. Figure 20 shows how a column is traditionally lowered into its assembly position. The illustration is demonstrating that generally the column is lowered into position at an angle, and not perpendicular to its final position because of the lifting method.
3.4.4 Alternative method

In order to allow the column to be installed vertically Vauxhall have designed pre-drilled hole at the head of the column. The hole is drilled as part of the steel contractor’s fabrication process, therefore should not incur added cost.

Figure 21 shows a column being lowered into its resting position, demonstrating that the column being installed is effectively vertical.
Figure 21: Column being lowered vertically

(Pavitt- Loughborough University)
3.4.5 Health and safety benefits

Table 5 shows the operations affected and the Health and Safety risks removed or reduced using this method.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
</table>
| 1 Lifting and installing steel columns | • Avoids manual handling of column wrapping the choke sling around the columns  
• Reduces manual handling of column whilst installing the column | Primary benefit  |
| 2 Removing lifting device  | • Avoids working at height removing choke sling.                                              | Primary benefit  |
| 3 Paint damage           | • Avoids working at height “touching up” damaged paint caused by choke sling.  
• Avoids on-site application of paint systems.                                              | Secondary benefit|

Table 5: H&S risks removed or reduced

1 Lifting and installing the column
   • Avoids manual handling of the columns wrapping chains or strops around the column, this is achieved by using a piling shackle - shown in Figure 22, and;
   • Reduces manual handling of the column whilst being installed, as the column is vertical and so can be moved into place much more easily.

2 Removing the lifting device
   • Avoids an operative working at height to remove sling or chain from the top of column after it has been installed. The operative would normally have to use a ladder or cherry picker to reach the top of the column. With the piling shackle it is released using a rope attachment from ground level - shown in Figure 22. 16.7% of accidents in the construction industry involve ladders, therefore use of this method will reduce this accident rate.

3 Paint damage
   • Reduced working at height risk because of not having to “touch up” damaged paint on the column caused by the lifting chains (if already pre-painted), and;
   • Reduced health risks associated with on-site application of paint systems.

This design solution will help reduce the high rate of fatalities when working from height; HSE statistics state that falls from height accounted for 44% of fatalities in the construction industry for 2000/2001.
3.4.6 Commercial benefits

The commercial benefits have been separated into three main sections; time quality and cost.

A  Time/programming
- Reduced erection time - approximately 5-10 minutes per column (Vauxhall Motors estimate). This saving will increase for larger, heavier columns, and;
- Reduced risk of erection interruption due to falls from height, or complaints about unsafe working practices.

B  Cost
- The piling shackle is not bespoke and the cost of drilling the hole would be part of the steel contractor’s tonnage rate if incorporated at the appropriate design stage.

C  Quality
- The case study did not identify any quality implications from using this technique.
3.5 Case study 5: Gutter/handrail support

3.5.1 Summary
Taylor Woodrow is one of the UK’s largest construction companies and is involved in some of the UK’s largest and prestigious projects. One of their major repeat order clients is Tesco Superstore. As part of their procurement process Taylor Woodrow work closely with Tesco and their specialist sub contractors to enable improved and innovative designs, coupled with improved health and safety to reduce the site construction period.

Taylor Woodrow and their design team have developed numerous design methods and processes, which enable reduced site operations. One of these examples is their method of constructing the roof to cladding interface. Here they have developed a permanent support (Figure 23) that allows the temporary roof handrail to be erected without interfering with the cladding erection. The support then acts as the primary support for the guttering (Figure 24 shows the construction drawing). The brackets enable:

- Reduced construction programme for the building envelope;
- Improved health and safety for the superstructure work due to reduced site operations, and;
- Reduced temporary works.

Figure 23: The handrail/gutter support

(K.Photo courtesy of Taylor Woodrow)

Project Team
- Architect - Smith Smalley Architects Ltd
- Principle Contractor - Taylor Woodrow
- Client - Tesco Superstore

Note; (This example is taken from the Scunthorpe project, on other stores the design team, floor size and layout may change)
3.5.2 Background

Tesco Superstore, Scunthorpe, was built using the design and build method of procurement, lead by Taylor Woodrow. The Superstore was built in a typical supermarket location, on a brown field site on the periphery of the town. The store has a gross floor area of 80,000 sq/ft with a 60,000 sq/ft sales area. The client is a large national retailer who requires their buildings are built as fast as possible to gain maximum revenue. Therefore, when constructing a building for a retail client the contractor must:

- Procure the building as fast as possible; and;
- Procure the building with no delays.

Taylor Woodrow is continually reviewing their designs with Tesco to enable a reduced construction period. Part of this initiative design process they have introduced a method of reducing the erection time of the building envelope.

3.5.3 Traditional method

The problem

When constructing an industrial building the roof to cladding interface is always problematic. In order to ‘weather’ the building in as fast as possible, both the roof and
cladding contractors will work concurrently. Many of these large retail or industrial buildings are designed without a permanent handrail at the roof edge, therefore requiring the installation of a temporary handrail to protect construction workers during installation. Generally, what happens is that the safety handrail, which surrounds the perimeter of the roof, has to be moved at some juncture, (see Figure 25 and Figure 26) to enable the cladding panels that meet the roof to be installed. This operation leads to certain criteria being added to the project:

- Added cost for the handrail being moved;
- Difficult programming issues for the main contractor, and;
- Often revisits for the subcontractors (roof and cladding).

**Figure 25** Typical temporary handrail programme for roof protection

The temporary perimeter handrail has to be removed to allow the wall cladding to start: However, because the roof cladding is incomplete the handrail has to be reinstated at some distance from the edge to maintain edge protection for roof

Note: Permanent handrails
The research team acknowledges that many projects are now incorporating a permanent handrail system to buildings that ensures the safety of maintenance workers and others who require long-term access to the completed roof.

Figure 26 and Figure 27 shows how the brackets for the handrail are typically installed. (Rossway Dowd Ltd has supplied the photographs.)
Figure 26 The handrail moved and re-erected on the roof

(Photo courtesy of Rossway Dowd Ltd)

Figure 27 Typical handrail detail, supported off the primary structure (this would puncture the wall cladding)

(Photo courtesy of Rossway Dowd Ltd)
3.5.4 Alternative method

Taylor Woodrow has devised a solution to the above problem for the retail stores they are commissioned to build. This includes a bracket welded to the structural steel frame, which has two main purposes:

- Support constraint for the handrail bracket, and;
- The support bracketry for the guttering.

Figure 28 shows a close up of the bracket where there is no guttering required.

Figure 30 shows a close up of the bracket with the cladding installed and Figure 30 shows the completed project with the gutter resting on the support.

**Figure 28: The handrail support without the need for gutter support**

(Photo courtesy of Taylor Woodrow)
Figure 29: The support with the cladding being installed

Figure 30: The completed project showing the gutter support

Advantages
The advantages for this method are:

- During the construction the handrail is constructed only once;
- The roof and cladding contractor can work independently of each other, thus easy to programme, and;
- The brackets are then used for the gutter support, thus there is also a cost saving.

3.5.5 Health and safety benefits

Table 6 shows the operations effected and the Health and Safety risks removed or reduced using this method.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Scaffolders moving the handrail</td>
<td>• Reduces the risk of the scaffolders/handrail assemblers working at height</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>2  Contractors revisits (roof and cladding)</td>
<td>• Reduces the risk of working at height</td>
<td>Primary benefit</td>
</tr>
</tbody>
</table>

Table 6: H&S risks removed or reduced

A Scaffolders moving the handrail
- Reduced working at height for the scaffolders as the handrail is erected only once and no remedial is work required. The ‘Working Well Together’ initiative has shown that between 1999 and 2001 there were 67 fatal falls in the construction industry, of these 28 were falls from roofs. The use of the new handrail will reduce this rate of falls.

B Contractors revisits to complete work
- Reduced working at height for the roofing and cladding contractors, as there are either none, or a much reduced number of revisits required for their installation.
3.5.6 Commercial benefits

In addition to the health and safety benefits there are several commercial gains, and these were the initial drivers to consider the technique. Commercial benefits have been separated in three main sections; cost, time and quality.

A Cost Break Down

The added cost of the bracket - £3000 approx
Saving on handrail movement by scaffolders +£8000 approx
Total saving +£5000

(Figures supplied by Taylor Woodrow)

B Time/programming

- Using this method the building envelope will be completed faster, thus the building is enclosed/‘weathered in’ quicker – and therefore the construction programme time is reduced.

C Quality

- As no subcontractor revisits are required and the installation can be completed in one operation, the quality of the installation will be higher than for work were revisits are required.
3.6 Case study 6: Unitised curtain walling

3.6.1 Summary

Bovis Lend Lease is one of the UK’s largest construction companies and is involved in some of the UK’s most prestigious projects. Many of these are inner city projects, which bring with them numerous site problems such as site storage, access and safety for the general public. Bovis work closely with their clients and specialist subcontractors to reduce these problems.

Reducing site operations is one of the key aspects of reducing accidents and also of improving productivity as off-site operations are deemed to be both safer and more efficient. The design team have developed numerous designs, methods and processes to facilitate a reduction in site operations. One of these examples is their method of installing curtain-walling systems. Typically these are erected using a ‘stick’ system, which is heavily reliant on site installation, however, wherever possible Bovis lend Lease, install their curtain walling using unitised systems, which is predominantly dependent on off site assembly. Figure 31 shows a typical unitised panel being lifted on site. Its main benefits are:

- Reduced construction programme for the curtain walling work;
- Improved health and safety for the facade work due to reduced site operations, and;
- No site scaffolding.

Figure 31: Panelised unit being lifted on site prior to installation

(Photo courtesy of Bovis-Lendlease)
3.6.2 Background

Bovis Lend Lease procures the majority of their inner city cladding packages using the unitised method. For the purpose of this case study a project in Paddington, London has been used as the frame of reference. The site is part of the Paddington Regeneration Scheme, where the client is developing an old car park and waste management area. There are numerous buildings being constructed as part of the overall project. Terry Farrell architects are the master planners for the redevelopment, and other signature architects are being used for the individual buildings.

The case study building is pre-let to a nationwide telecommunications company whose desire for a non-corporate building (not easily recognisable as an office building) was identified as part of the initial brief. Bovis Lend Lease has been commissioned to construct the building to shell and core stage, which is due to be completed by January 2003. Subsequent penalties apply for late completion, thus there is a need for construction methods that reduce site operations and aid health and safety.

3.6.3 Traditional method

**Curtain walling**

This is a form of lightweight non-load bearing cladding which forms a complete envelope around a building or structural frame (Chudley, 1994). It is often said that this is the most used cladding type within the UK construction industry at present.

The curtain wall generally consists of a grid system, either horizontally or vertically, complete with infill panels, an aluminium alloy is normally employed for the grid material. There are three methods of constructing a curtain wall system. They are as follows:

- Stick System;
- Unitised, and;
- Panellised.

With all three methods of erection the infill panels are usually made from glass or aluminium.

**Stick curtain walling**

The *stick system* consists of a prominent site erection process. With the frame (the stick) being constructed from the exterior of the building, generally off scaffolding. The
frames are normally extruded aluminium protected by anodising or powder coating, but maybe cold-rolled steel or aluminium clad with PVC-U (CWCT, 2000).

The infill panels are then secured to the grid. To make the structure ‘weathertight’ against the elements, the final structure is sealed using silicone-based mastic, with access made possible from a cradle or a mobile access platform, such as a cherry picker. Figure 32 shows the general arrangements of a typical stick system assembly.

**Figure 32: Curtain walling stick system (CWCT, 2000)**
3.6.4 Alternative method

**Unitised curtain walling**

The *unitised system* comprises narrow storey height units of steel or aluminium framework, glazing and panels pre-assembled off site in a factory environment. At site, assembly mechanical handling is required to position, align and fix the units onto site fixed brackets which are attached to the floor slabs or the structural frame (CWCT, 2000). Figure 33 shows the general arrangements of a unitised system assembly.

**Figure 33: Unitised curtain walling (CWCT, 2000)**
3.6.5 Health and safety benefits

Table 7 shows the operations affected and the Health and Safety risks removed or reduced using this method.

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>H&amp;S risk removed or reduced</th>
<th>Likely benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Panel installation</td>
<td>• Avoids need to work at height&lt;br&gt;• Reduces likelihood of accidents arising from falling objects&lt;br&gt;• Reduces need to work in exposed areas</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>2 Manual handling</td>
<td>• Reduces material manual handling</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>3 Glass handling</td>
<td>• Avoids site handling of glass</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>4 Scaffolding</td>
<td>• Avoids use of scaffolding</td>
<td>Primary benefit</td>
</tr>
<tr>
<td>5 Site storage and housekeeping</td>
<td>• Reduces need for manual handling of materials used for curtain walling system</td>
<td>Secondary benefit</td>
</tr>
</tbody>
</table>

1 Unit installation
- Avoids need for working at height when installing the panels as all the installation work is carried out internally, from behind the edge protection handrail and not off a scaffold. Figure 34 and Figure 35 (below) shows the panels being installed at Paddington (Note the safety of the installers behind the handrail);
- Reduces the likelihood of accidents resulting from falling objects dropped by site installers as the panels have been assembled in a factory environment and are not reliant on site assembly, and;
- Reduces the hazard of site operatives working under or gaining site access from cladding installers working overhead, on scaffolding or associated mechanical access equipment.
Figure 34: Unitised panel being installed
(Note: A safety back up system is always used in case the manipulator fails, this is not clear from the two examples)

(Photo courtesy of Bovis-Lendlease)

Figure 35: Unitised panel being installed
2 **Manual handling**
- Reduced manual handling of the materials that form the panels. The panels are delivered to site on mobile pallets (see Figure 31) and are lifted straight to a designated point ready for installation. Figure 36 shows the panels being craned to the loading platform on the floor where they will be stored.

*Figure 36 Panels being delivered to site*

3 **Glass handling**
- Typically, with a stick system, the glass is installed to the curtain walling after the frame has been erected. Therefore, there is a considerable amount of glass handling on site. Using the unitised method the glass is installed as part of the factory assembly process therefore reducing the amount of glass handling.

4 **Scaffolding**
- Eliminating the need for the site scaffolding has eliminated the risk from falling objects and scaffolders working at height.

5 **Site storage**
- As the panels are delivered to site preassembled and lifted directly to the site location, less site storage is required - only a sufficient area at the ‘slab’ level is required. This method is often employed when using the stick method, but extra storage area is needed for the boxed lengths of aluminium that form the frame.
Typically, discarded boxes can become a site housekeeping issue, unless managed correctly.

3.6.6 Commercial benefits

In addition to the health and safety benefits there are several commercial gains, and these were the initial drivers to consider the technique. The commercial benefits have been separated into three main sections; cost, time and quality.

A  Cost

- Unitised curtain walling is more expensive compared with a stick system. Generic basic system prices for the two systems compare as follows;
  - Stick: £300-350/metre square;
  - Unitised: £400-450/meter square;

(A major international curtain walling systems supplier has supplied these generic figures; specific figures will vary from project to project).

- A stick system is typically erected off scaffolding or mast climbers; the cost of this has to be factored into the overall cost. If scaffolding is used, then this generally will be included in the principal contractor’s preliminaries, and;

- The cost of the unitised system will vary according to the size of the project. The supplier has identified a project where the cost of the unitised was comparable to a stick system due to large quantities of unitised panels supplied to the project.

B  Time/programming

- One of the major decisions for using unitised over a stick system was the speed of site erection. At Paddington the cladding contractors were installing 12-20 panels a day depending upon locations and site implications, which equates to approx 60-100 m² a day. The system supplier quoted projects where they were installing 200 m² per day, but this was an exceptional case. As a ‘rule of thumb’ the same company estimated that unitised can be installed three times the speed of a stick system. This allows the building to be ‘weathered in’ much faster and allows the following trades early site access and, hence, enables their work to commence earlier. Figure 37 shows the cladding during installation.
The quality of unitised system will be improved because of 3 reasons (information supplied by Bovis Lend Lease cladding project manager);

- The units are factory assembled allowing for better quality assurance assessment and workmanship;
- Stick systems predominantly have problems with ‘creep’ and movement, with a unitised system this anomaly is accounted for within the gasketry between panels, and;
- Often stick systems require an Ethylene Propylene Diene Monomer (EDPM) to be site bonded for waterproofing, whereas a unitised system removes this operation.
3.7  Case study 7: Built up/ composite roofs

3.7.1  Summary

Health and safety is an increasingly important issue in the construction industry. Figures from the Health and Safety Executive (HSE) state that site construction workers face a 1 in 300 chance of being killed at work. Construction operatives are over 5 times more likely to be killed or injured at work than a typical factory worker. Figures for the year 1993/94 show that 77 construction operatives were killed on sites and of this total 43 (56%) were killed due to falling from a height whilst undertaking high level works. 53% of those were through roof lights and 17% through metal liner panels. Figure 38 shows HSE statistics for 400 deaths in construction and their related trade disciplines.

![Figure 38: HSE statistics for number of deaths per 400](image)

These statistics demonstrate that the installation of roofing systems is a difficult and high-risk operation. Roof workers are also often severely affected by the weather. Designers and contractors must carefully consider the type of system they specify, and the health and safety implications of that system during both the initial construction phase and future maintenance and cleaning.

Industrial buildings constitute one of the largest sectors for roofing works and most have profiled metal roofing systems. The two most common methods of installing profiled metal roofing systems are:

- Composite panels, and;
- Built up roofing systems.

This case study looks at the two systems and compares their health and safety implications for both design and installation.

The following companies have provided technical information for this report:

- CA Building Products Ltd;
- Reid Architecture;
- Rossway Dowd Ltd;
- Vauxhall Motors, and;
- Keyclad Ltd.
3.7.2 Background

Up to the end of the nineteenth century the majority of single storey buildings were of traditional construction, with timber on brick walls supporting timber-framed roofs covered with slate or tile. The introduction of continuous hot-rolled steel sections in 1873 led to the single storey shed frame form of construction for most new factories and warehouses. The building still consisted of brick walls with steel columns supporting trusses and purlins at a pitch of 20 degrees. Natural lighting was provided by means of windows in the sidewalls.

As technology advanced through to the mid twentieth century a range of deep profile steels sheets was developed that allowed the roof pitch to be reduced to 6 degrees. With this came the development of the portal frame, which is still common practice in construction today. Figure 39 portrays a typical portal frame used on single storey lightweight construction buildings (Barry, 1993).

![Figure 39: A typical portal frame with the roofing purlins (Barry, 1993)](image)

Generically there are two types of roofing used on portal frames: built up roofs, and composite panel roofs.

3.7.3 Built up roof system

Built up metal sheeting is referred to as hybrid construction in BS 5427 although some roofing contractors do provide a built up roof as a system. A built up roof system consists of three major parts: the liner panel, which spans across the roof purlins; insulation; and the outer skin. Both the liner panel and the outer skin are made from steel. For the roof to comply with building regulations, the U value or thermal resistance must deal with the cold bridging caused by the liner panel sitting on the steel purlins. Therefore, within the three core elements are specific thermal breaks and thermal bars.
These will vary from system to system, but discussion about variations that are possible is beyond the scope of this report. Therefore, this report will only concentrate on the liner panel, insulation and the outer panel. Figure 40 shows a cut away example of the construction of a metal built up roof system. These systems involve a considerable amount of site work during installation with each of these components being delivered, moved to the roof area and installed in a piecemeal fashion.

3.7.4 Composite Roof system

A composite panel is any laminated panel that is manufactured from different materials, permanently bonded together so that they act as a single structural element. The panel has metal facings to both sides, with an insulation core completely filling the space between the two facings and is continuously and permanently bonded to both surfaces (Spon, 1999).
The metal facings may be boldly profiled, as for external roof sheets or slightly profiled so as to be minimally flat. Almost flat facings are used for the liner panel face. As with the built up roof system the liner panel face spans directly across the roof purlins, but the panels are installed in their fully-finished form in contrast to the built up systems. Figure 41 shows a typical composite panel.

Figure 41: A typical composite panel
3.7.5 Health and safety comparison between methods

Table 8 shows the operations affected and compares the Health and Safety risks removed or reduced on both systems.

**Table 8: H&S risks removed or reduced**

<table>
<thead>
<tr>
<th>Main operations affected</th>
<th>Composite</th>
<th>Built-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Site operations</td>
<td>Reduced site operations through pre-assembly</td>
<td>Insitu installation</td>
</tr>
<tr>
<td>2 Work at height</td>
<td>Less time spent at height</td>
<td>More installation time required at height</td>
</tr>
<tr>
<td>3 Manual handling of large items</td>
<td>Panels are always heavier than the equivalent ‘built up’ components</td>
<td>Generally components will be smaller and lighter than composite</td>
</tr>
<tr>
<td>4 Reduced need for netting</td>
<td>Certain methods eliminate the need for safety netting</td>
<td>Safety netting will always be required.</td>
</tr>
<tr>
<td>5 Reduced falls risk during or replacement of damaged sections during maintenance</td>
<td>Removing a composite panel for maintenance leaves an opening in the roof.</td>
<td>The outer sheet (which is more likely to be damaged) can be removed with the inner sheet still intact.</td>
</tr>
<tr>
<td>6 Site storage and housekeeping</td>
<td>Reduces housekeeping problems as fewer materials are used</td>
<td>More individually delivered and stored materials.</td>
</tr>
</tbody>
</table>

1 Site Operations

The main difference between the two systems is that the built up system is assembled on site compared with the composite system, which is pre-assembled off site, thus reducing site hazards.

2 Working Height

As the built up system is assembled on site, as compared to the offsite pre-assembled composite system, the use of composite systems reduces working at height.

3 Manual handling of large items

Composite panels are generally very large (it may be a requirement written in the specification that they span from eaves to ridge as end laps are required on all composite panels) and when they are being installed or moved around on the roof they
can potentially cause problems, especially on windy days due to their size and weight. However this will also cause problems with the built up liner and outer panels. References should be made to the document “Roofing and cladding in windy conditions” produced by The National Federation of Roofing Contractors for further information.

4 Reduced need for netting

The common practice for installing a roof is to use safety nets. Once the structural frame has been erected nets are slung under the roof beams forming a fall prevention system (see Figure 42) thus allowing the roof installers a safe method of work (air bags are now being deployed on some projects but this is outside the scope of this report). However, when using a composite method a roof protection system developed by Rossway Dowd, the need to use nets is eliminated. The author is not advocating this as necessarily best practice, but it does offer a safe method of work without the need for nets.

Figure 42 Safety nets slung under roof trusses

(Photo courtesy of Taylor Woodrow)

5 Maintenance

If maintenance or replacement of sections of the completed roof is required problems may occur with composite roofs. This is because replacement requires the whole panel to be removed. Thus, in removing the panel there is an opening in the roof and the presence of this opening increases the risk of falling from height. To defend against this risk, safety barriers may have to be erected and a safe system of work introduced. However, with the built up system, if the top layer or the insulation has to be removed
this problem may not arise, as the inner liner sheet remains in place, provided that the liner panel is non fragile as outlined in ACR(CP)001:2002 “Recommended Practice for Working on Profiled Sheeted Roofs”.

6 Storage and Housekeeping

Composite panels are delivered to site pre-assembled and are generally lifted directly to the roof location. Therefore, less site storage is required, and only a sufficient area on the roof is required. However, when using the built up roof, extra storage area is needed for the different materials used in the roof formation. Typically, these come in boxes and can become a site housekeeping issue unless managed correctly.

3.7.6 Commercial benefits

In addition to the health and safety benefits there are several commercial considerations to be taken when comparing the two approaches. The commercial benefits have been separated into three main sections: cost; time; and quality.

A Cost

The unit rate comparison between the two systems is difficult. This is because the built up system can have different thickness for the liner panels. Generally, these are in three thicknesses: 0.4mm; 0.5mm; and 0.7mm. Generic prices have been established as (these are not finite costs and are used for demonstration purposes only):

- £25/ m2 for a composite roof;
- £23/ m2 for a built up system with 0.35mm liner panel, and;
- £25 / m2 for a built up system with a 0.7mm liner.

Therefore, either system can be ‘the cheapest’, depending upon sheet thickness used.

B Time/programming

As composite panels come pre-assembled, their installation speed will generally be faster than a built-up roof, therefore providing potential timesavings to a project. However, if the roof requires a lot of roof lights, then this may not be the case (see researchers recommendations below).

C Quality

It appears that there is no significant quality variation between the two systems, except that it appears that built up systems offer a greater range in design.
3.7.7 Researcher’s recommendations

The research into which system is the safest method has proved inconclusive. However it does appear that each system has its benefits and dis-benefits in terms of site health and safety. A consideration of both systems should be made in the design stage to establish which system would benefit the project under consideration. Listed below are observations and considerations derived from the research. These points should be carefully considered prior to deciding the type of system to be utilized.

- The choice of system appears to be strongly manufacturer driven.

- When consulting a roofing contractor for advice they will maintain one method is safer than the other depending upon the method they use the most.

- The thickness of the liner panel appears to be a deciding factor on price.

- The thickness of the liner panel can be a determining factor on whether the system is a safe working platform. It appears that a 0.7mm liner panel is safe to walk on during installation, whereas a 0.4mm is not. However, some roofing contractors advocate that 0.4mm can constitute a safe system as long as they are adequately secured with the correct fixings. Only a liner panel tested in accordance with ACR can be deemed a safe working platform, which identifies a 17mm deep 0.7 liner is an unsafe working platform. Also a 32mm deep 0.7 liner utilising a 300mm pitch is an unsafe working platform (information supplied by CA Roofing).

- The construction industry generally believes that the thickness of the liner panel can be the determining factor on whether the system is a safe working platform, often this is not true.

- In certain circumstances the liner panel (on a built up system) finish can be reduced in the specification, enabling a 0.7mm liner panel to be used this achieved by saving money on the finish and spending the money on the gauge/thickness, therefore making it more competitive.

- Roof lights seem to be a major hazard area rather than the roof system itself. However, roof lights installed as a component within a tested roof assembly are no more of a hazard than the metal roof.

- Problems can occur with fixings to a composite roof and with built up systems. Some contractors tend to lay the panels out on the roof first to gain a larger working platform, then return and fix the panels. However, the tolerances on the steel purlins are often very high, making them crooked. Therefore, some of the fixings miss the purlins, thus making the roof unsafe due to insufficient fixings. A safe method of installation is to lay and fix in one continuous operation, this then should be written in the method statement. Therefore, only trained roofers should be used otherwise baldly installed roofs can become a major hazard.
- Specialist contractors provide a high proportion of the design to the system, including the fixing types. They should be consulted as early as possible because the type of fixing can be the difference between a safe and an unsafe system of installation.

- Specialists must consider the type of insulation used in composite panels, specifically for potential fire hazards.

- Wherever possible it should be stipulated never walk on roof lights.

- If the principal contractor requires the building to be “weathered in” quicker then a built up system could be used as the liner panel section is installed faster than a composite roof.
4 CONCLUSION

These case studies demonstrate that it is possible to make buildings inherently safer to construct without necessarily incurring additional costs or programme time. Indeed, the design solution for construction health and safety often saves time and money, whilst also improving quality. The main factor in achieving safer design is forethought and an appreciation of buildability issues. Liaison between the whole design team clearly helps the buildability problem thus improving site health and safety issues.

These case studies offer a number of key learning points for the design process, namely:

- Think about designing out health and safety hazards early in the design process;
- Consult with construction personnel to identify potential hazards that can be designed out;
- Factor in the whole life costs and hazards of alternative designs, and;
- Check for opportunities to eliminate working at height hazards by prefabrication and standardisation.
REFERENCES


Evaluation of the Good Health is Good Business Campaign. Wright et al. HSE contract research report 272/2000


Avijit Maitra. Designers under CDM – a discussion with case studies. Civil Engineering, p77- 84, 1999 May/August.

