BCSA

BCSA Guide to the Erection of Steel Bridges

BCSA Publication No 38/05

BCSA Guide to the Erection of Steel Bridges

BCSA Limited is the national organisation for the steel construction industry: its Member companies undertake the design, fabrication and erection of steelwork for all forms of construction in building and civil engineering. Associate Members are those principal companies involved in the purchase, design or supply of components, materials, services etc related to the industry. The principal objectives of the Association are to promote the use of structural steelwork; to assist specifiers and clients; to ensure that the capabilities and activities of the industry are widely understood and to provide members with professional services in technical, commercial, contractual, quality assurance and health & safety matters.

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SUMMARY

This Guide covers all aspects of steel bridge projects from concept to erection which bear on the quality, economy, best value, and health & safety of the erection works on site. It aims to provide guidance on best practice to all members of the project team – from Client to Steelwork Contractor – particularly for participants who have little personal experience of steel construction. It applies to most common forms of composite and steel-decked construction for short and medium span road bridges, rail bridges and footbridges.

ENDORSEMENT

The Health & Safety Executive welcomes this BCSA Guide to the Erection of Steel Bridges and considers it as an important document which includes clear advice on the effective management of health and safety during bridge work. It is a good example of industry "self regulation", as the direct involvement of experienced and professional practitioners ensures that such guidance will be both relevant and authoritative.

The British Constructional Steelwork Association understands the importance of self regulation and over the years has been proactive and not simply reactive in reducing risks and accidents. The HSE welcomes working in partnership with BCSA because its positive approach has enabled steelwork erection to be undertaken both imaginatively and with increased safety.

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PREFACE

Bridges are built for Clients by construction industry teams of Designers, Contractors and Subcontractors with representatives of the Client. For a bridge constructed of steel, with or without a concrete deck, the Steelwork Contractor is either the major subcontractor or, on occasions, the Principal Contractor. The Steelwork Contractor is often, but not always, responsible for the erection of the steelwork on site as well as for fabrication. Whatever the contractual relationships within the team, success is achieved only through communication, cooperation, coordination and leadership. Effective teamwork depends on mutual understanding of roles and responsibilities and the effects on and consequences for others of team members' choices and decisions: performance depends on following best practice.

For most participants other than the Steelwork Contractor's construction specialists, bridge erection can seem like the tip of an iceberg; what is seen to happen on site appears relatively straightforward, if sometimes spectacular, but little is known of what goes into achieving an efficient, safe process. Erection is the culmination of a sequence of activities, every one of which is significant, from selecting the site and conceptual design right through to how the components are delivered. Indeed the plans for erection may influence design and will certainly define the fabrication process.

It is in the interests of better teamwork for the steel bridge industry to explain the whole process; there is a cultural gap to be overcome between civil engineering and engineering construction. The aim of this guide is to give new participants in bridge construction involving major steelwork – whether working for Client, Designer, Principal Contractor, or Steelwork Contractor – an understanding of the process leading up to what happens on site, and not just what is done there. As in all construction, safety is a fundamental driver of decision-making and planning: the aim is to describe best practice in today's construction market and thereby help all participants to fulfil their responsibility for health & safety.

This is neither a bridge construction manual nor a safety handbook; rather, it is an introductory guide and reference is made to other industry sources of expert guidance and information. It is complementary to the BCSA publication *Steel Bridges: A Practical Approach to Design for Efficient Fabrication and Construction*, published in 2002.

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1 INTRODUCTION

1.1 THE CHALLENGE OF BRIDGE BUILDING

Each new bridge challenges the people who have to design and build it. For a steel or steel and concrete composite bridge the Steelwork Contractor takes the lead in constructing the superstructure, but every other organisation forming the project team contributes in some way to what is to be built and how it can be built. Each one is also charged with the responsibility for health & safety in construction.

Most of the other work done on the site is planned and managed there; but the planning and preparation for the steelwork is done elsewhere – maybe hundreds of miles away and many months before components arrive at site. When they do, they come with a detailed plan for erection – the die has been cast. Many participants, whether for Client, Designer or Contractors, are unfamiliar with steel bridge construction before the project; at best their experience is limited and intermittent, yet to do their jobs they need to understand what is involved in it, just as the Steelwork Contractor has to understand their roles and responsibilities.

Bridge-building is a continuous learning process for everybody involved in determining how to build the bridge. They face challenges and opportunities of new techniques, innovations in plant and equipment, all in the context of evolving regulations for health & safety and the environment.

This guide follows the steel bridging process through from concept to completion, outlining what has to be achieved at each stage by the Steelwork Contractor, working with the other team members to ensure safe and efficient erection. It describes the features common to most bridge projects which affect how the work is done, and the hazards and techniques peculiar to steel bridge erection.

Manchester Metro

1.2 STEEL BRIDGE ERECTION

Steel bridge erection is an engineering service to carry through a process involving:

- design and planning,
- specialised procurement,
- construction management,
- expert supervision,
- mobilisation of specialist tradesmen, including erectors, platers and welders, and
- mobilisation of specialist plant and services.

The service is provided by bridgework contractors who must have a thorough understanding of what the project requires and be able to assemble an experienced competent team to undertake it. For most short and medium span bridges the service is provided with the fabrication of the steelwork as a subcontract to a civil engineering Principal Contractor.

Steel is used for bridges, small and large, simple and complex, utilitarian and landmark, in a variety of form, static and moving. Old bridges have to be replaced, modified and refurbished. The range of steel bridge erection projects is wide and very varied; and each project requires a different balance between the elements of service. Thus bridgework contractors offer an erection service based on their size, experience, resources and the expertise of their key personnel. Almost all British bridgework contractors fabricate bridge steelwork and their erection capability reflects the nature and size of what their factories produce. The Bridgework section of the Register of Qualified Steelwork Contractors (see Appendix 1) categorises contractors by their size and by the classes of bridgework they can undertake.

Bridgework is quite a different discipline for the steelwork engineers, managers, supervisors and erectors involved – transferring from building steelwork is a quantum leap for any of them. Although bridgework skills are necessary to erect some major "engineered" building structures, erecting bridgework is generally quite different from the erection of structural steelwork for buildings:

- typically the bridge has a 120 year design life and is fatigue sensitive,
- it is usually fully designed by a specialist consultant bridge Designer,
- the main components are longer, larger and heavier,
- site connections are made rigid by welding or using HSFG bolts,
- specialist cranes are needed and are operated up to their loading limits for economy,
- significant construction engineering and temporary works are generally required, and
- often during erection the partial structure sustains high stress levels to economise on temporary works.

1.3 THE PROCESS

This guide covers the work of the bridge project team relating to erection – from concept to completion; that is for the more common forms of short and medium span bridges for road bridges (which generally have composite-acting concrete decks), rail bridges and footbridges.

Sections 2 and 3 cover the management and design tasks which the project team has to complete before erection begins, based on the typical team of Client, Designer, Principal Contractor and Steelwork Contractor. Section 2 discusses the need for cooperation and coordination between the Principal Contractor and the Steelwork Contractor. Section 3 examines the technical management of the process by the Designer and by the Steelwork Contractor who often has a significant design role in how the bridge is to be built – involving construction engineering and temporary works design.

The Steelwork Contractor's planning for erection follows on directly from tendering and award, before fabrication can start; Section 4 identifies key decisions and risks in carrying the planning through to the Erection Method Statement – the master plan to carry out the erection as specified in the agreed manner safely. Section 5 examines some typical features which define the nature of the site as a workplace and have to be taken into account in planning. Section 6 demonstrates the influence of erection planning on manufacturing, delivery and the choices to be made about the work to be done in the factory.

Sections 7 and 8 cover the actual erection process at site. Bridge erection is carried out in a common sequence from handover of the site through to completion of the steel bridgework. Section 7 outlines each main activity and recommended good practice for it. In designing and planning bridgework, Designers are obliged to consider health & safety in the construction (and maintenance) of the bridge; they need to visualise the hazards involved in the tasks their work defines and how competent site personnel will carry them out. Section 8 describes some of the common tasks and health or safety hazards in bridge erection, and the personal protection of the individual worker.

1.4 REGULATIONS

Steel erection, as for all construction activity, is subject to extensive regulation within the framework of the *Health and Safety at Work etc Act, the Construction (Health, Safety and Welfare) Regulations and the Construction (Design and Management) Regulations.* The regulations particularly relevant to erection are listed in Appendix 3, and are referred to throughout this guide in abbreviated form, e.g. "CDM Regulations".

All managers, engineers and supervisors on site are required to be familiar with the relevant regulations and ensure that their requirements are observed. This is achieved by training, instruction and guidance provided under the auspices of each participating organisation's Health & Safety Policy.

1.5 FURTHER INFORMATION

This guide is intended as an introduction to steel bridge erection. Recent publications by the UK steel bridge industry provide engineers with information and expert advice. In particular the BCSA's *Steel Bridges: A Practical Approach to Design for Fabrication and Construction* and the SCI's *Steel Bridge Group: Guidance Notes on Best Practice in Steel Bridge Construction.* These are referred to in the text as "*Steel Bridges*" and "*Guidance Notes*" respectively, where appropriate. Other sources of information are listed in the References.

2 MANAGEMENT

2.1 THE PROJECT TEAM

Producing a new bridge requires a project team with all the necessary skills and resources: how that team is formed and how the constituent organisations relate to each other depend on the procurement method and form of contract – it may for example be traditional or by Private Finance Initiative. For most short and medium span steel bridges in the UK the steelwork is provided by a subcontractor and there are four key roles in the project team, however they relate contractually:

The Client – who will own the bridge, decides what is wanted, supervises and checks the works, and pays for the bridge.

The Designer – who designs the bridge and is the technical authority for the implementation of the design.

The Principal Contractor – who is responsible for delivery of the completed bridge to meet the project criteria, and has overall responsibility for health & safety on the construction site.

The Steelwork Contractor – who fabricates and erects the steel bridgework undertaking the required construction engineering.

Each of these is a corporate role fulfilled by an organisation which is represented by key personnel given specific responsibilities for the new bridge project; in most cases the organisations will fulfil the role using consultants, subcontractors and other specialists to support them.

This model of the project team is used throughout this guide for convenience and consistent terminology: the guidance should be applied to a specific project assigning the responsibilities of the four key roles to its particular organisation and titles.

The four key roles correspond directly to management defined in the CDM Regulations. The role of Planning Supervisor as a facilitator and monitor is currently a regulatory requirement, but it falls outside the scope of this guide, which deals with the Designer's and Contractor's decision-making and good practice for them to follow.

The objective of the project team is to deliver the bridge within criteria of quality, time, cost and safety. That requires effective organisation and leadership with focus on communication, coordination and programming.

2.2 WHAT IS TO BE MANAGED?

The pre-construction phase of the project has traditionally involved just the Client and the Designer but that is changing. The most significant aspect of this phase for erection is the buildability of the bridge design, and this is discussed in the Section 2 of this guide. Where the design and construct approach or early contractor involvement is used, then design for function and construction can and should be managed in the team as an integrated process.

Once construction starts on site, the Principal Contractor takes the overall lead until the new bridge is handed over to the Client. Management by the team then has to take account of the following factors which usually prevail:

- The Principal Contractor is based on site and manages the project from there. The Principal Contractor has to manage all the construction including the civil engineering and the steel erection.
- The Designer has an ongoing role for the steelwork until it is complete on site, but is generally not based there.

- The Steelwork Contractor manages his scope of work from his head office, and may be represented at site only for the duration of the steel erection activity.
- There is a cultural difference to be bridged between civil engineering construction and steel construction – in approach, experience, processes and trades.
- Erection of the steelwork has a major impact on the site but is often of relatively short duration, and is heavily dependent on site conditions and facilities.
- The erection method affects the fabrication process and conversely the quality of fabrication affects erection.
- Erection involves transport of large heavy components, major lifting operations, and working at height which present particular hazards to health & safety.
- Problems will occur on and off site, changes will have to be made – they have to be communicated and resolved by the team quickly.

The steelwork subcontract has to be managed actively from the start. The key representatives of the Client, the Principal Contractor, the Steelwork Contractor and the Designer have to work together continuously through the whole period of fabrication, preparation and planning for the erection operation to be successful.

2.3 MANAGEMENT FOR ERECTION

2.3.1 Key personnel

Effective management of the process requires the appointment of competent key personnel within each organisation, with clearly defined roles which are mutually understood. Different Steelwork Contractors may use different job titles for these roles: and depending on the particular project and personnel the roles may be combined. Each role is essential and the person responsible must be identified and have the demonstrable competence to fulfil it.

To be based generally in the Steelwork Contractor's main office from the outset, the Steelwork Contractor will appoint or should nominate the following:

- a contract manager with relevant bridge experience to be responsible for delivery of the complete scope of work for the bridge project;
- an engineer with the competence, qualifications and experience to take technical responsibility for the job and undertake the construction engineering;
- an erection manager with appropriate experience to organise the planning and resourcing of the erection.

At an appropriate time, dependent on the timing of erection, the Steelwork Contractor will appoint a site manager to be the representative at site during the execution of the whole scope of work there. The site manager reports to the contract manager, is responsible for the management and safe conduct of the works and is the Steelwork Contractor's line manager in direct charge of the erection personnel and any subcontractors on site.

In managing the steelwork subcontract, it is good practice for the Principal Contractor to appoint a competent engineer from his site organisation to maintain a continuous link with the Steelwork Contractor for communication and coordination. The implementation of the design in fabrication and development of the erection scheme requires technical dialogue with the Designer for clarification, review, approval and discussion of procedures and methods: part of the role of the Principal Contractor's engineer is to establish and facilitate that channel of communication, based on mutual trust and respect – the probability that he is not a specialist in steel bridgework is less significant. This approach also ensures the cooperation between designers for the permanent works, temporary works and construction engineering required under the regulations.

2.3.2 Pre-fabrication meeting

Erection of the bridge depends on timely delivery of the steelwork from the factory in the right sequence and in assured condition. Commonly fabrication lies on the critical path of the project programme so it is imperative to hold a pre-fabrication meeting at a very early stage in the contract. It should be attended by representatives of the Client, the Designer, the Principal Contractor, any inspection authority, and the Steelwork Contractor's team for the project. The purpose of the meeting is to confirm the clarity of the subcontract provisions for all the relevant technical issues, arrangements for carrying out the work, and procedures. A widely accepted agenda for such meetings is presented in *Guidance Note 5.09.*

It can be helpful to team-building for this meeting to be held at the factory where the steelwork is to be fabricated. This allows the whole team to be familiarised with the works and the production process and meet the people involved – who may be remote from the bridge site but whose performance is no less essential to the project.

2.3.3 Initial construction meeting

Similarly, representatives of the whole team should attend a meeting at site at an early stage to review construction. This meeting should be coupled with a joint inspection of the site and immediate access routes by the Principal Contractor and the Steelwork Contractor. The agenda for this meeting should include

- Clarification of Principal Contractor's requirements
- Agreement of facilities to be provided by each party
- Assessment of the site
- Erection sequence and outline method
- Temporary works
- Access for personnel, plant and material
- Traffic management
- Programme
- Quality plans
- Health & safety management
- Environmental management
- Arrangements for communication and coordination.

2.3.4 Programming

Erection of steel bridgework is a critical intermediate stage of the Principal Contractor's construction programme: it cannot commence until the site and the substructures are ready to receive the steelwork and construction cannot continue until the steelwork is, perhaps in stages, completed and handed over. The Principal Contractor and the Steelwork Contractor are dependent on each other's performance and progress to achieve their objectives. Thus programming the works has to be realistic and there has to be a mutual understanding of what each has to achieve and the areas of risk to the programme on site, in the factory, and for erection.

Safe construction requires not only competent contractors and workforce with sufficient resources, but also an adequate time allowance that takes account of constraints outside the Contractor's control and risk. The overall programme must allow for a safe approach to be adopted on site. Within the given construction period the time constraints may well dictate the sequence and method of erection. These are issues which should be considered during tendering by the Principal Contractor so that he is well aware of the time that needs to be allowed for fabrication and erection to achieve his construction proposals.

The Steelwork Contractor's programming for erection will be linked to the programming of the bridgework fabrication as part of the overall planning system for the factory.

2.3.5 Progress

As part of the normal contractual process of monitoring progress from the outset, the representatives of the team should meet regularly at the Steelwork Contractor's factory to review the progress of supplies and manufacture, as well as the progress of erection planning and preparation. This provides a forum for resolution of problems and management of change.

Is the site ready?

2.3.6 Site handover for erection

In effect the stage has to be set on site by the Principal Contractor before any of the steelwork is delivered, and before erection can begin: as soon as the staff, manpower, and plant needed for erection, are mobilised they need to be productive and proceed to the agreed plan.

Having agreed at the start of the contract what the Principal Contractor is to provide, the Steelwork Contractor is responsible for supplying the necessary information in good time to enable the site to be prepared systematically. This should be achieved through regular communication between the nominated representatives to coordinate the planning. The process culminates with the acceptance of the Erection Method Statement for construction; it defines the interfaces between erection and other activities and the attached sketches and drawings define the agreed arrangements. The Principal Contractor is responsible similarly for advising the Steelwork Contractor in good time of changes at site which might affect planning and carrying out the erection.

At least seven days prior to the confirmed start date for handover of the site to the Steelwork Contractor, his site manager should inspect the site with the Principal Contractor and check that the site will be safe and ready as agreed for erection. It is expedient for most sites to work through a pre-prepared check list, and the relevant part of the Erection Method Statement. The BCSA's *Bridge Safe Site Handover Certificate* (see Appendix 4) provides a comprehensive pro forma list for this essential check.

2.3.7 Management on site

The Steelwork Contractor's site manager, having accepted the site for erection, is responsible for the safe erection of the bridgeworks in the planned manner. There must be a detailed plan probably contained in an overall management plan that sets out the roles and responsibilities for the work on site, supported by the Erection Method Statement which relates them to all operations. The site manager will have the support of company services from head office as necessary including quality management, safety advice, engineering, welding engineering, procurement and personnel.

The Steelwork Contractor is responsible for handing over the completed bridgework in agreed phases on time: that requires close cooperation at site, so that problems and delays can be avoided, and a mutual understanding of the erection process, so that there are no surprises. When appropriate, the site manager should brief the Principal Contractor's site staff as well as his own about critical erection activities, in the interests of site safety and coordinated working.

2.4 MANAGEMENT OF HEALTH & SAFETY

The Principal Contractor has overall responsibility for health & safety during construction, and this responsibility is effected through the *Construction Health & Safety Plan* he develops for the overall construction of the bridge. Cooperation between the Steelwork Contractor and the Principal Contractor is essential in the planning and the implementation stages; it is also required by law. The Steelwork Contractor's health & safety plans prepared for the project will be complementary to the *Construction Health & Safety Plan.*

The principal safety objectives when erecting steel bridgeworks are

- safe access and working positions,
- safe lifting and placing of steel components,
- stability and structural adequacy of the part-erected bridge.

The most serious accidents during bridge erection are generally caused by falls from height, either from working positions or while gaining access to them. Other serious accidents occur because of structural instability or failure during erection and while transporting, handling and lifting heavy components. The Steelwork Contractor's health & safety management system must address the particular hazards and risks in steel construction as well as the normal range of issues in working on construction sites (e.g. slips, trips and falls). The planning for health & safety is systemic to all the preparation for erection through risk assessment, devising safe systems of work and working up the Erection Method Statement.

2.5 MANAGING QUALITY

Finished bridge steelwork is a manufactured product using materials and processes which have to meet precise complex specifications and be validated by testing. Steelwork correctly made goes together readily, whereas even minor manufacturing errors have quite disproportionate effects at site. Quality management is essential in the manufacturing and erection process: all competent bridge Steelwork Contractors in the UK operate quality management systems third party accredited to BS EN ISO 9001: 2000.

The Steelwork Contractor produces quality plans, including inspection and test plans, for each bridge project which will cover design, manufacture and construction as necessary.

It is common for Clients to require the appointment of an independent third party inspection authority to deal with the specialist aspects of approving the quality of workmanship. This is particularly important for work such as welding that will be incorporated into the works and will not subsequently be available for inspection (see item 19.0 in *Guidance Note 5.09*).

2.6 ENVIRONMENTAL MANAGEMENT

The Principal Contractor prepares and operates a Construction Environmental Management Plan with which the Steelwork Contractor has to comply in planning and carrying out the work. Each Steelwork Contractor has an environmental policy for the manufacturing and site activity which he undertakes, as part of his management system, and this is implemented on site in cooperation and coordination with the Principal Contractor. Civil construction has a direct impact on the environment and the particular site environment constrains construction, so the Steelwork Contractor has, for the erection work, to:

- assess the particular environmental requirements of the project;
- use formal risk assessments to identify environmental risks and appropriate associated risk reduction and mitigation measures;
- plan the erection within the environmental constraints;
- cooperate with the Principal Contractor in "customer care" measures;

- control the generation of noise, waste, dust and pollutants from each erection activity;
- manage waste systematically in accordance with the relevant regulations;
- communicate environmental issues, and their role in good management of the site to all site personnel.

2.7 COMPETENCE

It is in the Client's interest and is his legal obligation, through the procurement process, to appoint a project team which is competent to produce the bridge – competent in design, in management, and in the particular construction activities required. Each of the key roles in the project influences the erection process directly or indirectly, particularly the management of health & safety; so it is important that the key personnel with responsibility for the project have the necessary experience and expertise in steel bridge construction.

The current practice of requiring bidders to submit quality statements as well as financial bids gives Clients a surer basis for satisfying themselves of the bidders' competence. The quality statement should demonstrate the approach to the specific project, its challenges and opportunities, as well as historical experience; it should nominate a competent team of key personnel. This process enables the Client to assess more objectively which bidder can give the best value.

Selection of a competent Steelwork Contractor is a necessary precondition to ensure that competent personnel are mobilised to undertake erection. All Steelwork Contractors operating in the UK for steel bridge construction, who have demonstrated their capability satisfactorily to independent expert auditors, are included in the Register of Qualified Steelwork Contractors. Registered contractors are qualified to a limiting value of project, based on their resources and financial standing, and in specified types of bridge construction. The details of the Bridgeworks Register are given in Appendix 1.

The Steelwork Contractor must be satisfied that the personnel employed on bridge erection – in the workforce, supervision, and management – are physically fit to carry out the work, have the necessary experience and qualifications, and have the training necessary to carry out the work competently, safely and without risk to health. All persons employed on site need to produce evidence of having passed an appropriate health & safety test, and their training and qualifications should meet those required by the Principal Contractor (e.g. those of the Major Contractors Group – MCG).

3 DESIGN FOR STEEL BRIDGE CONSTRUCTION

3.1 THE DESIGN PROCESS

Design is a continuous activity throughout a steel bridge project even though notionally the design of the bridge may be complete before the construction contract is let. Design in the widest sense covers construction engineering, temporary works design, and technical management to ensure that the design intent is fulfilled, as well as the design of the permanent works. How the bridge is to be built and how it is designed are linked inextricably; safety in construction and the quality of the end product depend on how well that linkage is recognised and managed by the project team.

The Designer conceives a design solution for the Client and completes the design in every detail to meet a given set of criteria – for quality, value, performance, aesthetics and also for health & safety in building and maintaining the bridge. The solution has to perform its prescribed function and it has to be buildable on the given site. At each stage of design – in concept, development, detailing and specification – the Designer defines the construction tasks to be done on site and, wittingly or not, he heavily influences how that work is to be done by the contractors.

The Steelwork Contractor has design responsibility too in planning and detailing the erection of the steel bridgeworks and the associated sitework. His scope of design may be small, or it may be large, depending on the chosen bridge design and the accepted construction method. Other contractors will have design responsibility in their complementary works for the bridge project. Thus the Designer has to satisfy himself that his design intent will be fulfilled properly during construction by effective communication and cooperation: similarly he has to be prepared to respond to technical problems and change as construction progresses.

Best practice in bridge-building has always recognised the linkage between design for purpose and design for construction and the need for good communication and cooperation between designers and engineers. In the UK this is underscored by the legal obligation placed on all the designers for a project by the CDM Regulations. Present day procurement practices such as design-and-construct, partnering and early contractor involvement provide much greater opportunities for an integrated approach to bridge design and a better service for clients and stakeholders; however the Client, the Designer and the Technical Approval Authority need to respond positively to the opportunities to achieve potential benefits, for example from innovation or departure from standards.

3.2 DESIGN ISSUES FOR ERECTION

3.2.1 Structural form

The bridge design has to be buildable: the issues in Section 3.2 are particularly relevant to the erection of the range of steel bridges covered by this guide. The aim is to draw attention of the reader to them and where appropriate refer to sources where they are discussed more fully.

Any site for a new or replacement bridge presents an obstacle to be bridged: the site in its environment and associated infrastructure present constraints and opportunities for the Designer to consider before defining the structural form. Similarly the site presents constraints and opportunities to the bridge builder, for example:

- available access routes dictate the size of component or heavy plant which can be used,
- water may provide particular challenges and opportunities,
- site configuration will dictate how cranes can be deployed,
- rapid installation may be essential – perhaps during restricted "possession" periods.

Different structural forms can meet the constraints and exploit the opportunities to a greater or lesser extent. Which form gives the best fit and the best value solution for erection, as well as for function? Which structural form for that site best avoids hazards and diminishes the risks to health & safety? It is for the Steelwork Contractor to meet the challenge of erection, but the Designer should anticipate the challenge to ensure the best outcome – early interaction between Designer and Steelwork Contractor can help this to happen. So before selecting the structural form, it is important to test each option against the basic construction issues and compare practicable methods of delivering and erecting each one. The chosen structural form is only acceptable if its erection is practicable and economic within the project criteria.

Structural layouts for conventional bridges are covered in *Steel Bridges 1.2* to 1*.5, Guidance Notes 1.05* and *1.08*, and for rail bridges in chapter 4 of the *Design Guide for Steel Railway Bridges.*

3.2.2 Pre-assembly

Bridge erection consists of installing large and heavy fabricated components and connecting them together; the size and weight of the primary members are limited by the available routes from the fabrication works and the location of each member on site. Erection almost always requires work at height, especially on connections, yet there is an obligation to minimise work at height in the interests of safety. Many bridges have to be installed in the short time of a railway possession or a road closure, so piece-small erection in situ is not feasible for them.

Present day plant and equipment enable steelwork contractors to lift or move large and heavy bridge assemblies with relative ease: the expensive plant may be required for only a short time so its cost can be outweighed by the savings of working at low level. Pre-assembly can be done in the works, on site, or some distance from installation site given a suitable haulage route. The cost needs to be compared with the savings for the project as a whole, not just for the steelwork scope.

Development of the bridge design should consider the practical arrangement of primary and secondary members, and positioning of connections to facilitate pre-assembly – especially when it will be essential or obviously economical and safer e.g. with braced pairs of plate girders of more than span length.

Pre-assembly of steelwork for composite construction can also be exploited to fit critical falsework and formwork, temporary and permanent walkways, access arrangements and edge protection before lifting the bridge section into place.

3.2.3 Plate girder stability

Elastic buckling of slender plate girders is an issue particular to steel bridge construction, a beam which is stable in the finished bridge may be potentially unstable during erection: this is a risk the Steelwork Contractor has to understand and the Designer has to anticipate.

Many new short and medium span bridges use composite construction with a reinforced concrete deck slab on a number of parallel steel plate girders, usually continuous for multi-span bridges and viaducts. Efficient design of the plate girders tends to produce relatively small top flanges: this exposes the girder to the risk of flexural-torsional buckling at relatively low overall stress levels. This risk exists at each stage from completion of fabrication in the works, handling for protective treatment, delivery, storage, primary erection, exposure to high winds after erection, and loading during concreting.

Thus in designing plate girders the Designers should look critically at slenderness and anticipate the need to use temporary bracing:

- for steelwork stability, to brace adjacent girders into pairs, using an even number of girders in the cross-section; and
- for wet concrete stability, to maintain steelwork stability under the full weight of formwork, reinforcing steel, and wet concrete in the non-composite state.

It is best practice to include the bracing in the original design, to make it permanent and use it to make the structure more efficient under live load. In general terms it should be noted that making the bracing permanent is more economic and avoids the hazards of its removal from below the deck (see *Guidance Note 1.03*).

3.2.4 Box girders

Box girders offer an attractive solution, with distinct advantages over plate girders, for footbridges and landmark bridges; but they present practical problems for the fabricator, in erection and for internal maintenance. For long span bridges, with boxes deep enough for a man to walk through upright, the problems are manageable; for shallower girders, the Designer should take great care in detailing to ensure that construction is practicable and to avoid unacceptable risks to health & safety on site and in service. In particular:

- for final assembly of a small box girder, detail the closing plate of a box so that all welding for it can be done from outside the box, after final fit up – thus reducing the full enclosure risks;
- for butt welding of site splices in box girders, detail access hatches local to each joint to minimise access routes for welding, supervision and inspection;
- use externally welded butt joints with backing strips for site joints, when it is structurally acceptable, to avoid welding in the confined space inside the box; and
- the need for internal protective treatment, initial and maintenance, can be avoided by using weather resistant steel where blast cleaning and painting are impractical (this does not preclude external painting if desired). Such work in confined spaces is extremely hazardous and Steelwork Contractors could well refuse to undertake it (see *Guidance Note 1.07*).

3.2.5 Connections

In general, for short and medium span bridges, welding is used for connections in the fabrication works and bolting is the preferred option for site joints. At site, bolted connections can be completed more readily; erection can proceed more quickly; and the requirements for access, support facilities, weather protection and working at height are less onerous. Although welding at site to a high standard is perfectly practicable, it is relatively expensive unless on a large scale: where it is chosen for aesthetic reasons, say on fascia girders, it comes at a premium. The options are compared in S*teel Bridges 4*, and *Guidance Note 1.09* gives a detailed tabulated comparison of bolted and welded splices.

Buildability issues for detailing site bolted connections, which for bridgework use high strength friction grip (HSFG) bolts to BS 4395, include:

- locating splices to suit transport limits and a viable erection method, as well as for structural efficiency;
- ensuring ready access and space for installation and tightening of bolts using power tools;
- using the industry preferred standard general grade M24 bolt assemblies to BS 4395-1 wherever practicable;
- considering the use of alternative forms of bolt (equivalent to general grade bolts) which can offer installation and service advantages); and

Parallel primary beams

Primary beams with secondary beams

Braced pair being lifted

Pre-positioned scaffolding

Continuous box girders

Box girders curved in plan and elevation

- considering manual handling problems with splice cover plates which are relatively small but can still be heavy.

If welded joints are required at site for pre-assembly or in situ:

- permit weld reinforcement to remain wherever possible to avoid the risk of exposing operatives to unnecessary grinding activities;
- maximise the use of downhand position welding for plate girder flanges; and
- avoid welding infill plates in cope holes or in webs at flange splices, to avoid repeat visits for welders and inspectors (consider modern metal fillers and mastics as alternatives).

3.2.6 Substructure details

The layout and details of the bridge piers and abutments can help or hinder erection of the steel superstructure, so the Designer should anticipate the tasks which have to be undertaken there and provide:

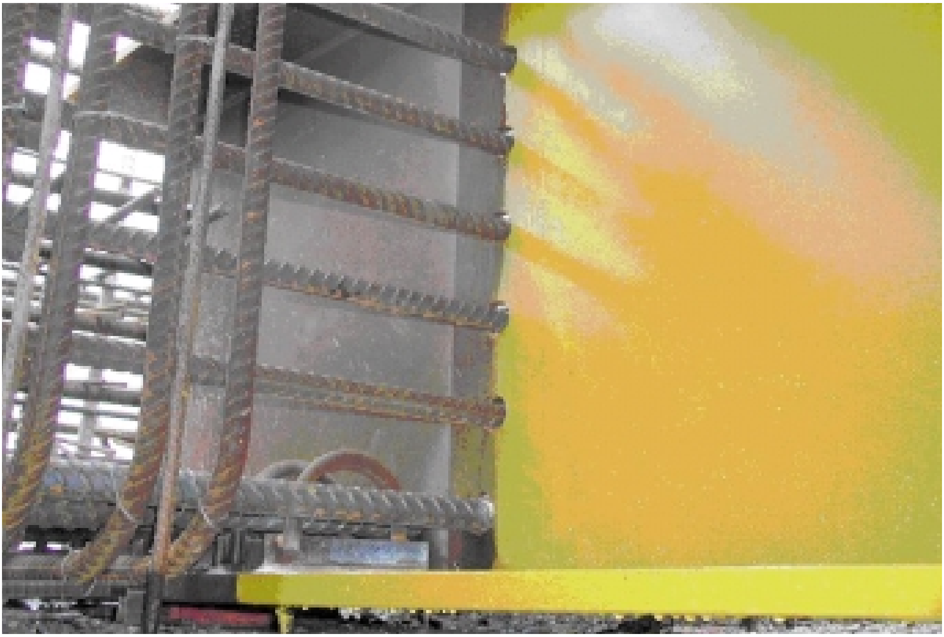
- access for safe and precise installation of bearings and grouting;
- access for maintenance and replacement of bearings during service;
- space and adequate bearing areas for vertical jacking operations during erection and bearing replacement in service; and
- the facility to prop bridge sections off the substructures if required for stability during erection, to avoid temporary supports off the ground involving extra resources and potential hazards to manage.

3.2.7 Interface details for integral bridges

Integral construction is common practice now for highway bridges up to 60m span: bearings and movement joints are eliminated and in composite construction the steel girders are cast in to the piers and abutments. In general, experience has shown that erection on to integral supports gives fewer problems than on to pot bearings (see the SCI's *Integral Steel Bridges: Design Guidance*).

Problems do arise, as always, if the detailing does not take account of the erection process – of placing the steel members on the incomplete reinforced concrete substructures. In particular:

- rebars need to be positioned and fixed accurately to be clear of steel members as they are placed; they should take account of skew where the abutment is not square to the girder;
- for girders to be erected with bracing between pairs, there should be no L bars and U bars which would foul the bracing;
- rebar details need to permit access within the cage to fit bracings between erected girders;
- longitudinal and lateral restraints are required for girders during concreting and should be cast in: they are best detailed by the Designer as they may require modification of the landing plate or cast-in anchors; and
- where girders are not directly above the piers, the problem of temporary support must be considered by the Designer and the designer of temporary falsework has to resolve it with the Steelwork Contractor.



Integral bridge abutment interface

3.2.8 Camber

The bridge Designer will specify a profile for the completed bridge but the steel girders in each span will deflect as they are loaded progressively during construction, so the fabricated profile has to be cambered to offset the deflection. Apart from the allowances for fabrication effects, the Designer can calculate the required nominal camber for an assumed construction sequence. For composite construction it is good practice for the Designer to specify the profile of the erected steelwork before deck construction starts – that is when the Principal Contractor takes over the steelwork from the Steelwork Contractor – so that the profile is verified at a meaningful time.

Camber and the various issues in allowing for permanent deformations are discussed fully in *Steel Bridges 1.6* and *Guidance Note 4.03.*

3.2.9 Essential information

In designing the bridge, the Designer will acquire information and make assumptions which are all relevant to how the bridge is to be built but may not be obvious even to an experienced Steelwork Contractor. This information needs to be made explicit in the design documentation and drawings at tender stage: if it is needed then the requirement is reinforced by the CDM Regulations. It needs to include:

- the sequence and method of construction, e.g. for concreting of a composite deck, assumed as the basis for design;
- information about the site acquired in preparing the bridge design, e.g. physical conditions, hidden services, geotechnical data, environmental data and operational constraints to meet third party requirements; and

- risks to construction which are not obvious, although the experienced contractor will be more sensitive than the Designer to all the obvious issues, e.g. falls from height, and confined space working.

3.3 CONSTRUCTION ENGINEERING

3.3.1 General

The Steelwork Contractor is responsible for the design of the erection process – of how to get the manufactured components from the works to the site and safely into their designed configuration. This work goes well beyond "design of temporary works" and is better described as construction engineering which includes:

Launching nose

- method development from conceptual design through planning of methods to preparation of method statements,
- stage by stage analysis of effects on the structure and its behaviour,
- design of temporary works,
- specification of plant and equipment,
- alternative methods and value engineering, and
- verification of the Steelwork Contractor's design.

Temporary propping

For many bridges the scope of this work can be relatively modest; for some, depending on the design and the required method, it can be comparable with the scale of the permanent works design. The Steelwork Contractor has to have the technically competent resource in-house to undertake the construction engineering for each bridge contract he undertakes, or at least the technical competence to procure and manage the competent specialist resources to carry it out.

Temporary propping

Stabilisation for movement

3.3.2 Methods

The Steelwork Contractor brings the bridge-building expertise to the project team for a new bridge. He is responsible for carrying out the erection to meet criteria of health & safety, quality, time and cost; that is within constraints set by the Client, the Designer and the Principal Contractor.

Typically, conceptual development of the method forms the basis of the tender for erection because the entire steelwork programme and costing depends on the chosen sequence and method of erection – in principle, change of method will change the programme and the costs. The input to the conceptual stage includes the Designer's envisaged method, as portrayed in the tender documents, and the Principal Contractor's requirements together with information about

- the site, its location, configuration, hazards and operational constraints,
- the location and facilities of the fabrication and protective treatment works,
- delivery routes to site by road, rail or water,
- availability on the site of relevant plant and equipment, owned or hired,
- specialist subcontractors for craneage, jacking etc,
- environmental considerations at site, for the works and impact of the works,
- availability of competent labour and supervision, and
- the relevant risk.

Definition of the resultant method is driven by technical decision-making based on the evaluation of risk to health & safety, cost, time, and commercial factors: it comprises a construction sequence, an erection scheme, a resourced plan and procedure, and an outline method statement for the erection. During negotiation and award of the steelwork contract, the method may well be revised and developed but it is important that it is confirmed as the basis for the provision of the steel bridgework. Detailed development of the method starts immediately after contract award as design outputs are required for procurement of material, preparation of fabrication data, and planning.

In the same way that the bridge design starts from the concept, is developed and fully detailed, the construction method is developed through the manufacturing period with design outputs for construction planning and procurement, and culminates with the Erection Method Statement – the detailed instructions for carrying out the work on site.

3.3.3 Analysis of the structure

The Steelwork Contractor has to satisfy himself, and the Designer, that each stage of carrying out the accepted method is structurally safe and has no detrimental effect on the permanent works. Checks on movement, transport, storage on site, and lifting of major components is generally straightforward covering overall stability, e.g. that stored girders cannot topple due to poor supports or storm winds, and overstressing or buckling during lifting as described above.

Similarly for many erection schemes structural safety at most stages can be verified by inspection subject to checks, for example of stability of girders when landed before bracing and the susceptibility of incomplete structures to wind or thermal effects before connections are complete. Some techniques however require extensive structural analysis to verify them, quantify the temporary works, and establish control parameters. Launching, in particular, requires global analysis of the structure at each critical stage for strength, stability and deflection, and local checking of girders subject to the high rolling support reactions and bending as they pass over the launching gear at each pier or trestle:

this work is best done by the Designer at the original design stage – he can utilise the same analytical model and the erection loadings may well govern some plate thicknesses and local detailing.

Output from the analysis is required for the design of temporary works, modification by stiffening or strengthening the permanent works, and for establishing limiting conditions for "weather windows".

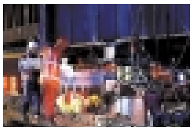
3.3.4 Design of temporary works

The Steelwork Contractor uses his experience and expertise to minimise the extent and scale of temporary works required for erection within the overall economy of the project: in themselves they represent a non-productive cost and require resource and work on site to provide and remove them. The need for them has to be justified; but every new bridge requires some temporary works to carry out erection safely to the performance criteria.

It is helpful to identify three categories of temporary works – having established the need, they have to be provided or procured in a timely and economic manner:

- Items which are integral with the steel bridge components such as lifting lugs, temporary bracing, and local stiffening – these are best provided in the normal course of fabrication so information is required during the lead-in periods before preparation starts in the works.
- Items which affect the substructures or require temporary foundations – these require liaison with the civil works contractor and information in time to meet his construction programme.
- Items to be procured or specially fabricated e.g. trestles or launching gear – sufficient time is required from release of design information for economic procurement.

Thus the Steelwork Contractor's designer has to develop the method quickly after award, and he requires most of the necessary design input data straight away and confirmed. Delay at this stage, or subsequent change, will affect not only the steel erection but all the activities which go before it; that is from preparation of fabrication data and material ordering onwards as well as civil site works which may need ground preparation or even piling for temporary works.



Use of hydraulic jacks

3.3.5 Specification of equipment

The erection will require the use of cranes and probably other plant or specialist equipment e.g. transporter units, jacking systems, or strand-jacking equipment, possibly with the support of specialist technicians. The Steelwork Contractor's designer has to identify the need, quantify the requirements, and prepare precise specifications – commonly in consultation with specialist suppliers or subcontractors. The items and services have to be procured: the Steelwork Contractor's designer has to ensure that all the drawings, sketches, and special methods are properly documented so that the site manager has the information necessary to manage the erection safely as planned.

3.3.6 Alternative methods

The Designer identifies a viable erection method in the course of completing the design of the bridge, and this is commonly described in the contract documents: for composite construction, it will be the basis of some design assumptions.

Tendering contractors may well identify an alternative method which offers the Client tangible benefits in time or cost. Indeed Steelwork Contractors will use their ingenuity and knowledge in this way to establish a competitive edge. Although such a proposal may require adjustment of the design, if the potential benefits are significant, the Designer, with the Client's support, needs to be able to respond positively. This is discussed more fully in *Guidance Note 4.04*. After contract award, this value engineering approach can be used to compare alternative solutions developed during the construction engineering process.

When a project is undertaken on a design and construct basis or with Early Contractor Involvement, the Steelwork Contractor's expertise can contribute to the design process: he can and should enable the project team to optimise the construction method with the bridge design. In such arrangements he can contribute to formal value engineering too.

3.3.7 Verification of design

The design scope of work undertaken by the Steelwork Contractor, directly or by his sub-consultant, need to be verified in compliance with his BS EN ISO 9001 quality management system and the requirements of the contract. The verification processes require time and may be critical to the programme, especially when changes are required during the course of construction.

When an independent third party check of the erection scheme is required, it is good practice to allow the Steelwork Contractor to nominate the checkers, subject to the approval of the Client or Designer: he will know from experience who is the most appropriate for the task and that they can provide a good service in the timescale of the particular project.

3.4 COOPERATION AND COMMUNICATION

Given the strong link between the design of a bridge and how it is to be built, it is imperative, to ensure the best service to the Client, that there is proactive and timely communication and cooperation in design and engineering between the members of the project team. The team is usually set up over time, dependent on the Client's procurement method, so an integrated approach to design may not be possible. To achieve the best outcome:

- The permanent works design team (the Designer) should include engineers with steel bridge experience in construction as well as design. The Designer should consult steelwork contractors with demonstrable expertise and knowledge relevant to the scale and nature of the proposed design.
- At tender stage the Steelwork Contractors need to be provided with sufficient information about the design and the site to provide them with an adequate design brief to make competitive and enterprising proposals.
- From award of the steelwork contract, clear and unfettered channels of communication for design and engineering should be established between all the designers in the project team to encourage a team approach and mutual trust and respect between them – an essential component in partnering, but just as necessary in more traditional contract relationships.

4 PLANNING FOR ERECTION

4.1 DEVELOPMENT OF THE PLAN

In tendering, the Steelwork Contractor has a plan of how to build the bridge: from the award of contract, he develops that plan in consultation until at the start of erection an agreed comprehensive plan is implemented for which everything has been prepared to suit. The previous Section focussed on the design aspects of the planning process, this Section examines aspects of erection which require choices and decisions.

Method statements are used to communicate, at different stages of the project, how the bridge is to be built. The definitive form of the Steelwork Contractor's plan is the Erection Method Statement: a general model for an Erection Method Statement is given in Appendix 2 to illustrate what it should contain and what is expected of it.

4.2 CHOICE OF METHOD

4.2.1 Making the choice

Often the choice of method in principle for bridge erection is self evident – the input to the conceptual stage of planning, described in 3.3.2, may permit the most straightforward of schemes, it may dictate the choice of the more difficult and costly. For bridges and viaducts of short and medium span, the methods fall into three categories:

- direct erection in place,
- launching, or
- movement into place of complete spans.

The options have to be evaluated and the choice made at the start of the contract.

Direct erection

4.2.2 Direct erection

Direct erection uses a crane to lift components into place, so development of the method is determined by the capacity of the available crane and the duties it can perform on the particular layout of the site. Historically, with the cranes of the day, most schemes would require temporary trestle supports and other works to provide stability for the incomplete structure. This "piece-small" erection is sometimes essential today at remote locations, inaccessible for heavy plant and components (e.g. in undeveloped countries) or on very constricted sites. It can be used economically where a new bridge is built on a greenfield site before highway construction.

The availability of larger and larger mobile cranes has diminished the need for any form of falsework or, by pre-assembling long pairs of girders at ground level, for significant stabilising works. Using the costly crane in a short visit avoids the time, cost and greater exposure at height required for smaller components; typically it is safer and more economic.

Wherever practically possible, direct erection should be the first choice.

4.2.3 Launching

Launching involves the assembly of the steel bridgeworks, typically behind the abutment, on the bridge alignment and moving the assembly bodily across the abutment and piers. It is suited to multi-span continuous plate girder or box girder superstructures where most of the spans are inaccessible to cranes, such as over wide railways, roads or rivers. The technique requires:

- low resistance roller or sliding systems at each pier or temporary support, to carry high reactions;
- distribution of the rolling reaction into girder webs coupled with coincident high shears and bending moments;

Launching

- haulage and restraint systems;
- a purpose-made launching nose and/or tail (sometimes) to reduce cantilever bending and to take out tip deflection;
- adequate resistance of piers to launching forces;
- intermediate support trestles (sometimes);
- lateral rolling or sliding guide systems at each support;
- lateral bracing to sustain code wind forces in the event of launching breakdown; and
- an assembly area behind the abutment.

Launching, as referred to in 3.3.3, requires a lot of construction engineering and should be anticipated in the original design, otherwise there has to be sufficient time in the project programme for all the engineering, including global analysis, to be done and verified. The technique can be used on bridges with vertical curvature, and horizontal curvature of constant radius provided the mechanisms are detailed to match.

The main advantages of launching, other than overcoming an otherwise insuperable obstacle, are:

- assembly near ground level,
- smaller cranes for erection as assembly takes place at smaller radius,
- minimising work at height,
- the facility to add access systems, and possibly shuttering and concrete before launching, and
- avoidance of interference with traffic on roads, railways or navigable waters below the bridge, except during final superstructure movement.

Movement of spans by transporter units

Movement of complete spans by floating crane

4.2.4 Movement of complete spans

For many situations it would be most advantageous to install the complete span of a bridge in a single short operation; this can be done sometimes. Historically this was the classic solution to replacing a railway bridge over a weekend to avoid disruption to the service; a "rolling-in" technique was used where the new bridge was built alongside the old, virtually completed, and moved laterally into place as soon as the old bridge was demolished.

The availability of larger cranes and heavy equipment, developed for the offshore construction industry, gives the bridge-builder a range of options whereby he can construct a complete span at a convenient location and move it into place for installation quickly by:

- sliding in with heavy duty sliding and traction systems,
- a single "big lift" with a very large crane,
- movement by steerable heavy multi-axle transporter units,
- floating in on navigable water, or
- transport and erection by marine sheerlegs in estuarial and river sites.

Depending on the chosen option, the technique requires:

- civil and structural temporary works e.g. a suitable load-bearing haulage route for heavy transportation,
- specialised equipment and subcontractors,
- the expertise to devise and manage implementation of the method, and
- the availability of the specialist equipment when required, by everybody meeting the planned installation date.

The advantages of this technique are:

- rapid installation, which is vital for possession work on live railways and motorways,
- optimum conditions for erection of the span, and
- avoidance of conflict with other site works.

4.3 CHOICE OF ERECTION SEQUENCE

The main steel bridge components are large heavy objects requiring specialised transport and equipment to move them about and manoeuvre them – every movement carries a significant cost. So for efficient fabrication, delivery and construction, the Steelwork Contractor has to decide the erection sequence in consultation with the Principal Contractor, even before steel is ordered for fabrication. What is the start point at site for erection and in what sequence are the main members to be erected or pre-assembled? Even on the smallest of bridges the choices need to be verified by visualising each operation of the proposed sequence – to check that no practical problems or hazards are incurred which could be avoided otherwise.

The best point to start is at the fixed bearing in the bridge articulation; starting elsewhere requires temporary restraint systems at piers and probably the jacking facility to move the erected steelwork longitudinally when erection reaches the location of the fixed bearing. In erecting long viaducts, where it may be expedient to erect on more than one front, such a jacking facility will be necessary to adjust the gap between fronts for erecting the closing members.

Choosing the sequence is about finding the best solution to the logistical problem of:

- receiving large (long) heavy components on site and placing them for lifting,
- manoeuvring them into place in a structurally viable sequence,
- access and good ground for large and very heavy cranes,
- space to manage each lift safely,

- safe access to working positions during installation,
- working around the erected steelwork which can be an obstacle, and
- getting the crane off site.

Thus, for example, it may be essential to choose the sequence for erecting a span of multiple plate girders to work the crane out of the span and not trap it beyond the span, with nowhere to go.

As well as influencing the fabrication sequence, the erection sequence may influence detailing such as site splice positions and lifting attachment positions.

4.4 CHOICE OF CRANES

Modern cranes come in a great variety of type and size. Most types have found a use in steel bridge construction, but for small and medium span bridges the most commonly used are road mobile cranes with telescopic jibs and, in some circumstances, heavy crawler cranes with fixed lattice booms. It should be noted that only crawler cranes and some smaller specialist rough-terrain mobile cranes are able to traverse the site with a load.

In mainland Britain mobile cranes are freely available up to quite large nominal capacities, they can be mobilised and demobilised quickly and it is practicable to use them for short duration erection schemes. On more remote sites the availability of cranes will be more limited, especially if access requires the crane to be transported by ferry. For work over navigable waters it is occasionally economic to mobilise a specialist floating crane. Purpose-made floating cranes are generally very large and expensive, but it can be feasible to fix a mobile or crawler crane on to a moored dumb barge quite economically.

Tandem lift

Lift by floating crane

For a chosen method the Steelwork Contractor will aim to choose the smallest crane which can erect the steel safely within the limits of its capacity. In considering the logistical problem the key factors are:

- the operating position for each major lift determined by the weight of the component with the necessary lifting gear, and the lift radii to the erected position and to the pick-up point from delivery;
- the need for the crane body and the jib to have clearance to slew and move at each operating position;
- at each operating position, the need for the crane to stand level on its outriggers placed on adequate bearing points which will often require crane mats to bring the ground bearing load within the assured capacity of the ground;
- the crane must be able to travel safely on a hard surface from the site access to each operating position, which may require the construction of temporary roadways;
- for a given lift weight, the larger the radius the larger the crane has to be – and there is a significant load penalty with increasing radius (e.g. a "100 tonne" crane will only lift 100t at a minimum 6m radius with its capacity dropping to 10t at a maximum 50m radius);
- mobile cranes cannot move with a heavy load; and
- crane movements are inhibited by underground and overhead services.

It is permissible in certain circumstances to use two cranes working together – that is in tandem – to lift and move a large or cumbersome load. This is, however, a potentially very hazardous procedure because either crane can be overloaded inadvertently. The preparation and use of cranes for tandem lifting are set out in BS 7121. Tandem lifting must be planned by experienced engineers and carried out under strict supervision to a detailed procedure. In considering it as the solution for a lifting problem, it should be noted that:

- the two cranes should be similar and similarly rigged,
- the crane capacities have to be down-rated, and
- the centre of gravity of the load has to be known and be clearly marked.

Before confirming the method, the sequence and the choice of crane, it is prudent to check that each lift in the sequence is viable, working from accurate general arrangement drawings and assured site information. A site visit and inspection is essential. For bridges on new road construction the planned configuration and conditions at the site at the time of erection have to be defined and agreed with the Principal Contractor at the start of the steelwork contract.

4.5 WORKING UP THE METHOD

The decisions about method, sequence and craneage provide the basis for detailed planning of the work, programming and resourcing. Each stage of the method is considered in detail, working through in sequence from start to finish.

The execution of each operation is visualised with the aid of the relevant drawings, specifications and site information to identify precisely what is required and that it can be carried out safely. This process identifies as necessary:

- preparations before starting the operation,
- access for plant and components,
- temporary works,

- special measures,
- structural works,
- control information,
- hold points,
- weather criteria,
- actions to complete the operation, and
- required sketches, drawings and data.

Every detail needs to be thought out in advance, so that the erection can proceed safely and efficiently following a detailed plan with every operation well prepared for. The consequent construction engineering, described in 3.3, has to be carried out, verified and approved by the project team in time for everything to be prepared and the plan to proceed smoothly.

Erection is subject to hazards and risk which must be anticipated in working up the method for any bridge:

- hazards to health & safety which require risk assessment, and a safe system of work;
- effects of weather on health & safety, productivity and structural safety;
- construction problems to be anticipated, planned out, or to have contingency arrangements.

The final stage of the process is the preparation and approval of the Erection Method Statement, which documents the plan comprehensively.

4.6 WEATHER CONDITIONS

Like most civil engineering activities on site, steel erection is subject to the vagaries of the weather. In developing the erection method different aspects of weather conditions can affect productivity, detail planning, and the behaviour of the structure, and cause hazards for health & safety. The character of the weather at the particular bridge site during the period of the year when erection is to take place has to be appreciated, as does its significance for each operation.

Wherever practicable, bridge erection should be during clear daylight hours of a normal working week. Bridge installation in possessions will, though, require continuous working with dayshifts and nightshifts.

Adverse weather effects on health & safety in bridge erection are:

- rain or dew that leaves steel surfaces wet and slippery,
- frost, ice or snow resulting in slippery surfaces,
- fog, mist, glare and bad light which impair visibility,
- wind on the components and plant as noted below, and
- high winds disturbing loose material and equipment, especially from height.

In working through each stage of erection, the construction engineering must take account of the possible wind effects on the operation and on the partially completed structure. In particular:

- all crane operations and use of access plant are subject to limiting wind speed; lower speeds would apply to lifting of large components;

- as each component is erected, connections and temporary bracing must be installed to make the steelwork safe before the end of the shift to sustain safely any wind forces which may be imposed before work is resumed;
- where operations, e.g. launching, can only be carried out safely at low wind speeds then weather conditions must be specified and monitored with contingency arrangements being made for protecting the bridgeworks if the weather deteriorates before completion of the operation.

Temperature and differential temperature effects can be significant as the temperature of steel members in direct sunlight can be well in excess of the shade temperature. Steel members can expand and contract quite quickly causing movement and generating forces against restraints – movements of 20mm or more are possible on longer spans. These changes can affect the fit up of members as they are being assembled and change the shape of box girders. Accurate surveying of steel members, when necessary at site, can only be carried out when the steelwork temperatures can be steady and fairly uniform – on very critical surveys in the early hours of the morning before sunrise (*see Guidance Note 7.02).*

4.7 EVALUATION OF RISK

4.7.1 Risk to health and safety

Bridge sites and the activities carried out to build them present many hazards to the health & safety of everybody on or near to the site. Each site and each bridge presents its own unique combination of hazards engendering risks which must be eliminated or, if that is not possible, minimised. Some of the hazards presented by new steel bridge sites are explored in Section 5, and some of the hazards of steel erection activities are covered in Section 8.

Risk assessment has to be carried out by law under the MHSW Regulations and applies to all work activities: other regulations dealing with specific hazards, such as COSHH, require risk assessments which meet part of the general requirement. All significant hazards for the particular scope of work have to be covered.

Risk assessment for health & safety has therefore to be systematic; so for the erection of a bridge:

- consider each activity in sequence,
- identify the hazards and plan to avoid them where possible,
- assess risks of the remaining hazards,
- apply precautions required by regulations or approved codes of practice,
- identify precautions not dealt with in regulations, and
- document planned precautions in a safety method statement.

4.7.2 Risk to construction

Successful construction depends on effective management of risk; just as hazards to health & safety must be managed, so must potential problems in the erection process which could affect quality, progress, structural stability and performance, as well as safety.

In working up the method, the "what if" question needs to be asked at every point. To avoid problems and diminish their significance should they occur requires:

- operation of an effective and appropriate quality management system,
- thorough and timely planning and preparation for the work on site,
- preventative measures e.g. trial erection if lack of fit will have disproportionate consequences, and
- contingency measures, e.g. to cover weather change or equipment failure.

4.8 METHOD STATEMENTS

4.8.1 The Erection Method Statement

Method statements should be used throughout the procurement process for a bridge to communicate how it might or should be constructed:

- by the Designer to demonstrate his assumed method,
- by the Principal Contractor to fit the erection into his overall plan,
- by the Steelwork Contractors to demonstrate the basis of their tenders, and
- by the project team in developing the scheme.

These are usually relatively brief, often in the form of sketches or a stage by stage drawing; they are essential for the team to reach an agreed solution.

It is expedient to distinguish the final version for the bridge as the Erection Method Statement; it is the working document used by the Steelwork Contractor's line manager on site to carry out the erection as planned, safely and efficiently, in accordance with the Designer's intentions as part of the whole construction process managed by the Principal Contractor. Its scale and scope will reflect the scale and relative complexity of the work to be done.

4.8.2 Preparation of the Erection Method Statement

Large or small, simple or complex, the production of any Erection Method Statement follows the same basic principles and has to meet the same acceptance criteria. The basic principles are:

- preparation by the Steelwork Contractor with technical and project management input, internal independent safety review, and involvement of the nominated site manager where practicable;
- preparation at the end of the planning process drawing together the output of the construction engineering, the final information, and the discussions and agreements of the project team – in time for final approval by the Principal Contractor, the Designer and the Client;

Preparation of the Erection Method Statement

- presentation, like any other technical document, in a clear systematic format, properly identified, and setting out the objectives and direct instructions for each stage of the plan clearly and unambiguously;
- control, like any other technical document, by a quality management system which ensures proper review, approval, change and issue procedures;
- comprehensive content, with the necessary and sufficient information to complete defined works, including sketches, drawings, crane duties, and special requirements;
- setting out a complete safe system of work for the defined scope using generic task specific method statements, e.g. for making bolted connections, where appropriate;
- defined interfaces and dependencies with other contractors and for inspections;
- defined management and specific responsibilities;
- setting out the essential logic and allowing for flexibility and planned options e.g. if actions A, B and C have to be completed before D, but their order is not essential, say so, do not instruct A then B then C; and
- support by written risk assessments.

The acceptance criteria for an Erection Method Statement can be summed up by two questions:

1. Is the Erection Method Statement, with its reference documents, complete and sufficient for a competent site manager, with no previous information, to implement it as a safe system of work for erection as planned by the project team?

2. If challenged, can the originators and the reviewers demonstrate from the Erection Method Statement how it satisfies all the technical, safety and management requirements?

4.8.3 Authorisation of the Erection Method Statement

All the principal parties have responsibilities for how the bridge is built, particularly of course for health & safety; so they must be satisfied that the plan for erection fulfils their responsibilities. Thus the Erection Method Statement must be reviewed by the team and thereby authorised for use; it requires the whole project team's contribution to ensure its validity. *Guidance Note 7.08* provides guidance on best practice for review and control of Erection Method Statements. A model format for an Erection Method Statement is given in Appendix 2.

To the uninitiated, the preparation and approval of method statements can seem to be yet another bureaucratic paper exercise. A little experience of the process is most instructive as the discipline of preparing written instruction often throws up gaps and inconsistencies in detailed plans which have to be addressed. A large part of the value of preparing and reviewing the method statement is acquired during the process itself.

5 SITE PRACTICE

5.1 THE BRIDGE SITE AS A WORKPLACE

Bridges are built to carry traffic over obstacles: they are not designed to be workplaces and their sites present many obstacles and hazards to efficient and safe construction. How is a bridge site to be a safe workplace?

This Section outlines good practice to be adopted in dealing with common issues to make the bridge site safe for the people working there and the other people on or close to the site. All these issues, depending on the particular site, have to be considered by the bridge Designer, and by the Principal Contractor and Steelwork Contractor in planning the work and construction engineering. They have to be anticipated, assessed, and dealt with before work starts on site: they may involve consultation with third parties and complying with their requirements.

5.2 ACCESS AND WORKING PLATFORMS

5.2.1 General

Bridge structures are generally large, at height and inaccessible: erecting them requires access for personnel from ground level to each point in the structure where work has to be done – and the risk of anyone falling from height must be managed and controlled. For each activity at height – whether, for example, it is erecting a girder, bolting up or welding a connection, erecting secondary members, or painting – a safe working method has to be provided with a safe means of getting to it and back to ground level. The working platform must be suitable for the specific task providing an efficient workplace to enable the erector, the welder, the painter or the inspector to do his job properly with the equipment and facilities he needs, as well as to protect him and protect others from his activity – and their needs differ.

5.2.2 Working at height

The Working at Height Regulations (WAHR) have recently been introduced. They are intended to consolidate all the requirements to control the risks from working at height in one place. The new regulations are "goal setting" rather than prescriptive and they will require the duty holders, for example the employers who are party to a construction project, to consider carefully the work at height in which they are involved. They will require employees to "take positive steps to understand the hazards in the workplace".

The proposed definition of "work at height" is "work in any place…from which, if measures required by [the] Regulations were not taken, a person could fall a distance liable to cause personal injury…"; this includes therefore, on a steel construction site, work at height of less than 2m and activities involved in loading or unloading steelwork from a vehicle, as well as erection activities at greater heights. This means that the work must be properly planned, supervised and carried out in a safe manner; and risk assessment must be the basis of the process. The proposed regulations follow the hierarchy of risk control:

- Avoid work at height – if you don’t have to go up there, then don't;
- Prevent falls – work safely if it is possible to do so from an existing safe place of work at height; adopt the most suitable method of working and select the most suitable equipment for work at height; and then
- Mitigate the consequences of a fall – have measures in place to arrest a fall should one occur.

Working at height

Collective measures are given priority over personal protection measures so, for example, reasonably practicable guard rails are preferred to personal fall protection systems. The provisions must also allow for safe escape or rescue from the work place at height.

5.2.3 Access during construction

Given that some work at height is unavoidable during bridge construction, and certainly during maintenance, the options for access in planning the work in order of priority are:

Permanent access: In designing the bridge, the Designer has to anticipate bridge inspection and maintenance activities during service. Thus abutments and piers will be detailed to permit access to bearings, expansion joints, drains and steelwork: these arrangements can provide a basis for safe work platforms at the substructures for erection. Where permanent walkways are provided, say for access below deck in spans over water, they can offer part of the solution for erection. Cast-in sockets in the deck soffit can provide scaffolding supports for painting after erection as well as in service.

Erected deck: A steel deck, completed formwork or a concrete slab can be used as a workplace, provided it has suitable barrier edge protection to the perimeter edge and round any openings. To fix, remove and replace the edge protection will require a fall prevention/arrest solution.

Fixed scaffolds: Often these are provided at piers or abutments with platforms at working height below bearing level for erection of girders and higher for subsequent activities. There are also suspended scaffolds from girders or deck soffit, and prefabricated scaffolds fitted to girders before lifting into place, or after erection, for work at connections. All such scaffolds require regular inspections.

Mobile elevating work platforms: MEWPs come in a variety of forms: the most useful for bridge erection is the self-propelled boom rough terrain type, developed specially for construction site work. Modern machines come with a reach of 30m or more, but care is needed that they work over sound ground and are not used beyond their safe wind limits. Scissor lifts, which have vertical lift only, may be useful but they require hard level ground to work over.

Mobile access towers: MATs require level ground, proper installation at each work point, and are limited in height.

Work restraint systems: These prevent the worker approaching fall hazards such as leading edges: usually in the form of a full body harness with a lanyard attached to an anchor point, or on a slide that allows sideways but not forward movement.

Work positioning systems: These allow the worker to be suspended in a work position. As the worker is suspended at height, specialist training is required to select and use the equipment to provide a safe effective system. An additional safety back up and rescue system is required.

Fall arrest systems: These are the only systems where a fall is permissible. The fall arrest system reacts by arresting the fall in a controlled manner. Careful consideration must be given to ensure that the selected system is suitable in the intended orientation and that there is adequate clearance below the user to prevent contact with obstacles during a fall. A procedure, with the necessary equipment, is required for recovery of personnel in the event of a fall. Usually this dictates that a man-riding basket should be on site for this purpose as it is the most likely method to be able to reach all rescue positions.

Fixed scaffold

Mobile elevating work platforms

Man-riding baskets: These, when slung from a crane hook, are used primarily for one-off short duration tasks or for rescue from height. As with all personal access equipment, even a purpose-made basket needs proof testing before use. When used, the crane lowering must be under power to eliminate the risk of free fall: there are special requirements too for crane testing and operation – see BS 7121.

Fall arrest system

Ladders: These are intended primarily for vertical access, although stairs are preferred for extended duration access. In certain circumstances after risk assessment, they may be used for very short duration tasks that can be undertaken single-handed, or two-handed with fall arrest protection. Currently it is rare for ladders to be supplied with proprietary fall arrest systems already installed, although these are available from specialist suppliers for work on masts and tall towers.

In some circumstances the only reasonably practicable method of access, with careful planning and control, may be by climbing off a MEWP platform or a basket, standing on the rail of a basket or cradle, or over the bridge steelwork. When such access is justified, then the Steelwork Contractor must:

- develop a task specific method statement based on assessment of the risks in the particular circumstances,
- establish the controls and briefing to reduce the risk as far as possible, e.g. instruction on the need for double lanyards to provide fall arrest at all times and how they should be attached and relocated,
- address the training and experience of the personnel undertaking the task, and
- plan and prepare for recovery of persons, should a fall occur.

5.2.4 Fall arrest equipment

Steel bridge erection can require activities where protection by fall arrest is the only solution because scaffold or MEWP access is not reasonably practicable, for example in making first connection of a girder in a span over water, or for access along a single girder to a connection.

There is continuous development of equipment for fall arrest, both collective and individual, by the steel construction industry and its suppliers. For most new bridgeworks erection, compared with steelwork for buildings, the available collective protection equipment is unsuitable or inappropriate: nets have their use on some refurbishment work but otherwise the risks inherent in installing them, their restriction of crane and plant movement, and the nature of the tasks generally rule them out.

Various proprietary systems for individual fall protection are available, based on safety harnesses with lanyards clipped on, but they are only effective when there is adequate clearance. Wires or running lines have to be properly designed and installed to be effective; some systems incorporate a rescue system to recover a suspended man to a safe place quickly. The safety harness for fall arrest protection must incorporate shock absorbing devices.

5.2.5 Material falls from height

Lifting operations and work on the erected steelwork make the area underneath and around the activities hazardous; so work at height has to be safe for the personnel doing the work, but it must not put the safety of others at risk.

Safe management of a lifting operation requires a temporary exclusion zone around the crane and the locus of the component being lifted – an area within which only the personnel directly involved are present – and the zone has to be marked out clearly and controlled by the Steelwork Contractor. On most bridge sites this will affect other site activity and may interfere with site routes for plant and personnel; so an exclusion zone has to be planned and operated in coordination with the Principal Contractor who is responsible for safe management of the site as well as managing it for efficiency.

The hazards created by work at height must first be tackled at source by:

- providing the work platform constructed so that it contains any material produced or any item which may be dropped, e.g. a tool or connector in bolting, hot slag or welding rods from welding, grit or paint from protective treatment,
- good housekeeping to keep the platform clean and tidy, and
- ensuring that nothing can be displaced and fall in strong wind, e.g. scaffold boards.

Exclusion zones should be set out and maintained immediately below erection activities: where movement of personnel or traffic through the affected area has to be maintained then, through risk assessment, further protective measures must be implemented e.g. traffic management of site vehicles, and crash decks over pedestrian routes. Additional attention to the operation of exclusion zones should be given if general public access is allowed in close proximity to steel erection operations.

5.3 MATERIAL HANDLING

Apart from a relatively small number of large heavy components, a lot of small components, tools and equipment are required to assemble the complete bridge structure. These all have to be received, stored appropriately, and moved about the site to wherever they are required – at ground level or at height – and only a relatively small proportion of these can be carried by hand to their appointed place. So material handling is a significant issue in making the site a safe workplace: it requires planning, safe storage areas, and suitable equipment such as forklift trucks or tele-handlers to minimise the amount of manual handling in building the bridge.

The Steelwork Contractor must set out planned safe systems of work for material handling using task specific method statements – which may well be generic, as many of the tasks are not project specific. Considerations need to include:

- palletising, or placing in metal stillages, bulk items such as bolts or small loose items,
- matching the lifting and transport method to the type of pallet or stillage used,
- mounting bottled gases on a purpose-made trolley with hangers for the hoses,
- lifting jacks, welding equipment, power tools and other large or heavy items into position by mechanical means,
- using hoists on scaffolds, within the capacity of the hoist,

- using roller tracks for movement of heavy objects in confined spaces,
- not carrying tools, equipment or material up or down ladders, and
- good access and housekeeping to prevent manual handling.

Telehandler

Manual handling of any item of significant weight or bulk, certainly of any item weighing more than 25kg, must be planned (Manual Handling Regulations), following specific risk assessment, and all personnel involved must be trained to carry out the planned method, as for any other task, by a suitably trained and competent person.

5.4 WORKING IN CONFINED SPACES

A confined space, for the purposes of safety in construction, is any enclosed space where a hazard may exist due to lack of oxygen, the presence of a suffocating, toxic or flammable atmosphere, or an actually or potentially hostile environment. In steel bridge construction the interior of a box girder is obviously a confined space, but other less obvious spaces can be hazardous too – heavier than air gases can collect in the bottom of open top box girders, lighter than air gases can collect below deck level at an abutment, plant can be positioned so that exhaust fumes are trapped in such spaces. A lack of awareness of these potential dangers has led to construction fatalities, including to would-be rescuers.

The main risk in steel bridgework is box girder bridge refurbishment or strengthening which are outside the scope of this guide; but where the confined space hazard is present in new bridgework it must be given particular attention by the Designer and by the Steelwork Contractor in planning and undertaking the work on site. That also applies to everyone else who has to go into the confined space for inspection or other works.

As with all work activities, when work within a confined space cannot be avoided, the hazards and risk must be assessed and controls introduced. That requires consideration of the work to be done, the characteristics of the confined space, risks from hazardous substances or lack of oxygen, the method of working and the work equipment involved. If the assessment indicates a risk of death, serious injury, or ill health, then the Confined Spaces Regulations will apply.

Confined space working

Having designed and planned to minimise the risk the Steelwork Contractor has to establish a safe system of work, for all activity within the confined space, which is controlled by a permit-to-work procedure. The steelwork activities may include bolting, welding, painting or inspection with all that goes with them. The system of work must cover:

- sufficient competent supervision,
- training, with certification, of all personnel required to enter the confined space,

- isolation and physical disconnection of sources of energy and hazardous substances,
- thorough ventilation of the space before first entry,
- testing of the atmosphere,
- access for personnel, services, equipment and material given the size of entrance,
- access for escape and rescue – at least two routes should be available at all times,
- ventilation and removal of fumes from work equipment,
- use of non-spark tools and protected low voltage lighting in inflammable atmospheres (e.g. from dust or painting),
- use of breathing apparatus, unless forced ventilation is provided and the atmosphere is tested safe,
- emergency arrangements including rescue equipment,
- communications, including someone outside keeping watch, and
- control of personnel entering and leaving.

The emergency procedures must be planned and tested in liaison with the local Emergency Services before the work begins. They should cover communication systems; rescue, resuscitation and first-aid equipment; properly trained and equipped rescuers; emergency plant shut-down arrangements; and call-out of Emergency Services. This needs to be agreed within the context of the overall site emergency procedures for the bridge organised by the Principal Contractor and the Steelwork Contractor.

Apart from the overriding safety considerations, confined space work presents very real practical problems in carrying out the appointed task to the specified standards of workmanship, especially within smaller box girders, for example with the manual handling of components and equipment, or positional welding or drilling. These require particular attention to detail by the Designer and preparation of task specific method statements by the Steelwork Contractor.

5.5 WORKING NEAR OVERHEAD POWER LINES

The presence of overhead power lines (11 to 400kV) over or close to a bridge site has a significant effect on planning how the bridge is to be built and on doing the work. They will be evident from the project drawings and the initial site visit so the erection scheme should take account of the hazard from the start. It is good practice to consult with the Electricity Authority as early as possible to clarify their requirements and take advice: if possible, the power line should be isolated or diverted during the critical stage of construction.

If power lines remain live during construction, then all practical steps must be taken to prevent danger to any person from any live cable, and adequate and suitable barriers must be placed where cables are liable to be a cause of danger. The danger zone is defined as at least 6m horizontally from the nearest conductor for overhead cables on wooden posts and 15m for steel pylons and it must be delineated by physical barriers, on both sides if the site requires it, to ensure that plant cannot enter the danger zone. No work should be done within the zone and nothing should be stored there. Personnel, plant and vehicles may pass below overhead power lines using defined passageways protected by barriers and goalposts.

Overhead power lines pose particular hazards to the use of cranes and MEWPs. They must work outside the danger zone so that no part of a crane, its load or an operating MEWP can enter it: they should be at least jib or boom length away from the barrier, alternatively mechanical or electronic limiting devices should be fitted to restrict the reach of the appliance. Similarly, work on and from the erected bridge structure must be outside the danger zone.

Work on or near electrified rail tracks or tramways with overhead catenary cables, or conductor rails, must comply with the procedures of Network Rail or the relevant authority.

5.6 WORKING NEAR WATER

5.6.1 General

Steel bridges are built over rivers and canals, in ports and harbours. The presence of water is always a hazard in construction but there are environmental issues too; and if the water is navigable, the contractors have obligations to traffic on the water and, possibly, opportunities to work on the water to expedite construction.

5.6.2 Protecting the water

Construction activities have plenty of potential to pollute the water: the Environment Agency and river and harbour authorities have an interest and obligation to avoid pollution and improve water quality. They require contractors to take positive action to prevent their activities polluting the water and to have emergency plans to cope with any environmental accidents. Fishing authorities and owners of fishing rights put strict seasonal limits on construction which may affect them – especially on salmon rivers.

These issues are very relevant to the Steelwork Contractor as well as the Principal Contractor and have to be taken into account in devising the erection scheme, working it up, and carrying it out within the requirements of the interested parties.

5.6.3 Working safely

Every effort has to be made to prevent people working near or over water from falling into the water – drowning is fatal; so it is essential to ensure that anyone who does fall in can float, and be recovered as quickly as possible. In some locations there are risks of infection, after wetting, with leptospyrosis or Weil's disease.

Working near the edge of water can be as hazardous as working over it, so where there is a risk of falling into water from the edge of adjoining land, then guardrails or fencing must be provided. If there is any risk of drowning, suitable rescue equipment must be provided nearby and persons instructed in the use of it.

Work over water

All personnel required to work over water, where there is a risk of falling into the water, must have completed appropriate induction and training in procedures based on the specific risks. Except where the access and work platforms are detailed and provided to eliminate the risk of falls, all such personnel must wear suitable life-preserving personal protective equipment. This ensures that in the event of a fall, the individual will float face upwards even if unconscious. When necessary, this must be compatible with any fall protection harness worn at the same time.

A rescue boat, exclusive to the task, must be on station downstream if the water is navigable all the time work is proceeding over the water: it must be manned by two trained operators. In tidal waters, mud rescue provision may be necessary. If it is not possible to use a rescue boat, then special measures may be required. Normally this would be provided by the Principal Contractor to cover all activities over or closely adjacent to the water.

5.6.4 Navigable waters

If the water being bridged is navigable then, although it is an obstacle to the landsman, it is a route used by others for trade, sport and recreation. The water is subject to the rules and regulations of a harbourmaster or river authority which are designed to protect the interests of all users; these will act as constraints on construction planning, so early consultation with the relevant authority and the establishment of a good working relationship with the responsible officer are most desirable.

That is particularly so when the contractors plan to use the water as a construction facility, for example to use a marine sheerlegs to install a complete bridge in a single operation, or to operate workboats to ferry personnel across the river. The water provides opportunities to the bridge-builder with which, with watermanship skills and expertise, he can achieve construction economy, a safer better quality solution, and even influence the overall design of the bridge.

Working near a highway

5.7 WORKING NEAR HIGHWAYS

Construction of new bridges generally has to be carried out whilst maintaining traffic flow on associated roads or motorways: it may be possible to close a minor road for several weeks whereas complete closure of a busy motorway may be unacceptable except for a short possession overnight. This interaction has to be recognised at the conceptual design stage, in overall construction programming, and in planning the erection method.

Some such bridges are very easy to erect: bridges for a new motorway or a new bypass may be on a greenfield site away from public roads. They can, though, present access problems for heavy cranes and long delivery vehicles especially when the new road formation has not yet been constructed: the bridge may be required early in the project but there is no good way of getting to it. Planning for the erection by the Principal Contractor and the Steelwork Contractor has to recognise the weather and seasonal risks to unmetalled access routes, and hard standing for cranes and steelwork – mud and steel construction do not go well together.

Where construction and busy traffic have to coexist, consideration has to be given to:

- protecting the road users from construction activities,
- protecting the workforce and construction from road users,
- minimising disruption to the traffic, particularly at peak periods, and
- delivering major steelwork to time and without delay.

The risks of interaction are controlled by planned systematic traffic management carried out to specified procedures in cooperation with the police and the highway authority. This is usually done by a specialist subcontractor, employed by the Principal Contractor, with a Traffic Management and Control Officer on site at all key times. Traffic management arrangements for installation, change and removal have to be programmed and approved well in advance so they provide a time framework within which the bridge has to be erected: changes can be made, subject to approval, but they introduce more risk to be controlled and cost to the project.

Work close to moving traffic must be managed so that, in the event of a construction accident there is no risk of a crane, equipment or steelwork falling on to the roadway. When there is a risk of an operation distracting passing drivers, then it should be carried out when traffic is light or be screened from view. Activities producing dust, grit, grease or paint overspray must be controlled and shielded for safety – drivers may well recognise or suffer from weaknesses in the system, and claim for damage.

Constructing a new overbridge for an existing motorway is very similar to working over a mainline railway. Disruption of the traffic is costly and can be politically sensitive, so clear-span bridges which can be installed in a single possession are an attractive solution. Then the bridge is constructed complete off site and launched or transported into position, involving substantial construction engineering and contingency planning.

5.8 WORKING NEAR RAILWAYS

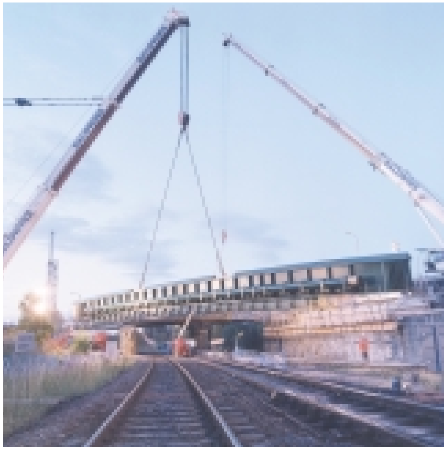
5.8.1 Disrupting the railway

Any construction work close to a railway creates hazards to the safety of railway traffic and can disrupt the operation of the railway. The railway authority will generally be the Client for a new railway bridge (an underbridge) and otherwise an interested party whose requirements will influence how the project is carried out and the timescale in which it can be done. The fundamental principle is that disruption to the railway must be minimised.

No access or work is permitted during normal railway working within a horizontal distance of 3m from the nearest operational rail, and any plant operating nearby must not be able to infringe that zone, should it overturn or fall. Even then speed restrictions may be placed on the line during some construction activities, and these are clearly disruptive.

Work over or within the zone is only permitted during possessions when a section of the railway is closed to normal rail traffic. If anything is done which could affect the stability of the track, e.g. relaying track over a new underbridge, then a Temporary Speed Restriction (TSR) has to be imposed for such time as is necessary for the track to be bedded down. The amount of disruption at any time on a section of railway is strictly limited, and this may well control when a TSR may be available to do the work.

5.8.2 Possessions



Working over a railway

On most of the British railway system, possessions are available for maintenance of the railway between 4 and 29 hours long, depending on the line affected: these are known as Rules of Route possessions and are normally booked three months in advance. Longer possessions can be arranged, Outside Rules of Route or abnormal possessions, up to 2 days long or sometimes longer if over a public holiday: these may have to be booked up to two years in advance and obviously present critical and immutable dates in the project programme. The duration of the construction activity in a possession is somewhat less than the overall permitted duration, which includes the time to make the track safe for construction and to return it to good order: that time is greater where the line is electrified. The disruption to the railway and the consequential costs of overrunning a possession are great, so the time limits are strictly enforced. A new policy has been introduced of applying rail blockades of extended duration where the rail authority considers it to be cost effective.

The railway authority has overall responsibility for safety of the railway so every person required to work within the railway envelope at any time has to have received specific training and be registered: that applies to all personnel on the track in a possession – management, supervision and operatives.

Thus building bridges over or under a railway is subject to a set of strict time constraints which affect the design and detailing of the bridge, the fabrication and construction; and it requires short bursts of working day and night, at weekends, and public holidays. The construction has to be planned for completion safely within a strict timetable.

5.8.3 Overbridges

The outline construction programme for a new overbridge, carrying a road or motorway over a railway, is generally planned jointly with the railway authority well in advance so that when the construction phase starts the Principal

Contractor and the Steelwork Contractor are committed to a schedule of rail possessions within which all their work over the track has to be done. Work on the substructures and superstructure outside the rail envelope without possessions is limited to what can be done safely. The risks to the programme if work is not carried out or completed in designated possessions has to be controlled, and minor problems can have disproportionate effects.

Successful use of possession time requires teamwork, involving the Principal Contractor, the Steelwork Contractor and railway staff, so possessions require timely thorough preparation, including:

- use of substantial trackside barriers to allow normal working as close to the 3m limit as possible (minimising possession work);
- coordinating all the lead-in activities to ensure that everything required is ready;
- risk assessment and safety planning to cover possession hazards, including work at night and on the track;
- detailed planning of what is to be done, with an hour by hour schedule for the planned work;
- resourcing the work to maximise the output from the possession;
- providing facilities (lighting, access, services and welfare) to maximise productivity;
- contingency arrangements for failure of plant and equipment;
- team rehearsal and briefing; and
- team debriefing after the possession for improvement.

Where practicable and cost effective, protective measures can be used to allow work on the superstructure to proceed over the operational railway, for example on bolting, welding or painting by installing solid work platforms, fully screened to eliminate the risk of falling personnel or material, and complying with railway requirements.

5.8.4 Underbridges

The design and construction of underbridges, which carry a railway over an obstacle, are complicated by the presence of trackside signalling and communications systems and in many instances by overhead or rail conductors – particularly where an existing bridge is being replaced. The design and the erection method have to be considered together, as the bridge has to be installed and operational within one possession, a much more onerous regime than for an overbridge. Construction of underbridges is covered in some detail in the *Design Guide for Steel Railway Bridges.*

Railway underbridge being lifted in

5.9 WORKING AT NIGHT

As a general rule steel erection on bridgework should be carried out in clear daylight; working in poor light and after dark introduces further hazards so it should be avoided whenever practicable. It can, however, be necessary for continuous working round the clock on road or rail possession; for carrying out tidal operations on marine sites; and for critical operations which overrun daylight hours and have to be completed for reasons of structural stability or health & safety.

In planning and making risk assessments for night work, as a required or contingency arrangement, the additional hazards include:

- carrying out erection activities and related tasks in artificial light,
- safe access for plant and personnel around a darkened construction site,
- working over water in hours of darkness,
- reduced availability of support and back-up services,
- physiological effects of night and shift working, and
- low or freezing temperatures overnight on UK sites in winter.

Thus night work requires the provision of additional resources and facilities to carry it out with due regard for quality, efficiency and health & safety:

- comprehensive lighting of the working area and for tasks at levels appropriate to the task;
- lighting of all access routes on the structure and site, with emergency lighting provided to cover for main power failure;
- planned deployment of labour and supervision to maintain continuity of work, without working excessive hours;
- welfare facilities for rest, meal breaks and transport to and from the site; and
- back-up facilities and services to cover breakdown and emergencies.

6 MANUFACTURE AND DELIVERY

6.1 MANUFACTURING OBJECTIVES

The two main objectives for the Steelwork Contractor in manufacturing the bridge steelwork for erection are:

- To maximise the work done at the factory and minimise the work on site; and
- To deliver the steel components to site in assured condition, on time and in the sequence to suit the erection method.

Work done in the fabrication shop

Bridge steelwork is a manufactured product from a factory equipped to carry out all the processes safely and economically to the specified standard. Carrying our these processes on site to the same standard of workmanship requires more resources using temporary facilities subject to weather and environmental risks. The scope for maximising work in the factory for a specific project differs between fabricators; it depends on:

- the limits on component size and weight in the factory, though most bridge fabricators in the UK can fabricate components over 30m long and weighing up to 60 or 70t,
- the location and capacity of facilities for protective treatment of completed large components,
- the available delivery route from the factory to the particular site, which will limit size and weight of components, and
- specification requirements.

More work in the factory with less work on site offers benefits to the Client and to the Principal Contractor in managing the overall construction: today it is quite feasible to bring some bridges to site and install the steelwork complete in just a few days.

Delivering the steelwork to the site in the right condition, the right order and at the right time economically and efficiently depends on:

- working from the outset to a manufacturing programme which matches the agreed erection sequence and method,
- receipt of firm data in the planning phase from the other members of the project team,
- avoiding change after manufacture has started,
- management of material and fabrication risks by the fabricator, and
- effective operation of the fabricator's quality management system and rapid resolution of problems.

The fabrication process and the issues to be managed in the factory are outside the scope of this guide, they are described in *Steel Bridges* Chapters 3, 5 and 7. The important point here is that, shortly after award of the steelwork contract, the project team should confirm the plans for erection and provide final design information, for permanent and temporary works, to the fabrication planners.

6.2 INCORPORATION OF TEMPORARY WORKS

As described in 3.3.4 some items of the temporary works will be integral to the permanent steelwork as minor modifications or additions. In the interests of quality and economy it is best to incorporate such items during manufacture of the permanent components. They can include:

- bracing members and connections required for stability during erection or deck concreting;
- lifting attachments for individual members, or assemblies – welded or bolted lifting lugs, drilled holes for eyebolts or cleats;
- drilled holes for structural restraint prior to fixing bearings;
- steel guides and cleats to aid alignment, fairing and securing of connections for welding;
- drilled holes or welded attachments for securing personnel access, edge protection, and fall arrest systems; or
- bolted or welded brackets for subsequent works including falsework.

Many of these minor items can be detailed, in consultation with the Designer, so that they need not be removed after use, which will avoid the risk of damage and the requirement for remedial works and additional inspection. Where lifting lugs, for example, cannot be detailed to clear deck reinforcement they can be removed using approved cutting procedures, say 25mm above the flange.

Temporary cleats in position

6.3 MARKING OF STEELWORK

All steel components, large and small, must be readily identifiable through manufacture and on site; that is essential for traceability, quality management, and for efficiency and safety in erection. It is standard practice for all material to be marked at the steel mills before delivery to the factory, and the marking is carried through the manufacturing process. The marking system for component identification should be designed in a logical sequence which is easy to follow.

At site it is difficult to identify painted components and their correct orientation without unique marking located where it can easily be seen. Hard stamping is the industry recommended method which is indelible and unlikely to be obscured by paint. The Steelwork Contractor will provide a written statement of the marking method with locations for marks on each component: it is usually not difficult to locate the marks away from fatigue sensitive areas. Guidance Note 5.05 covers this subject in some detail.

The weight of all substantial components and the centre of gravity of asymmetric or irregularly shaped items need to be identified clearly: this is essential for safe handling and lifting at each stage from the factory to final placement.

6.4 TRIAL ERECTION

The accuracy of modern automated fabrication equipment and improved three-dimensional survey techniques has reduced the need for trial erection at the fabrication works to prove the geometry of the steel components. Partial trial assembly of complex or close fitting connections can be very useful to verify fit-up especially when access is difficult or the implications of carrying out rectification work on site for safety, resources, and delay would be unacceptable.

Trial erection is a time consuming and costly process which inevitably falls on the critical path of production, it extends the programme too because all components in a full trial assembly are on hold until the assembly is inspected and passed. The main purpose of trial erection is to eliminate the risk of delay and disruption of erection on site because components are incorrect or connections do not fit. What are the consequences should that occur? For construction in possession the risk will be unacceptable, otherwise the costs of remedial works and some delay may be small compared with the cost and time required with trial erection. It is in a sense a matter of insurance, is the cover worth paying for? (See *Steel Bridges 5.9 and Guidance Notes 7.04.*)

If trial erection is undertaken, it requires the necessary area of suitable load-bearing ground at or near the factory. Generally the members can be assembled close to ground level on low stillages to the unstressed profile: connections should be assembled but not normally fully bolted. The Steelwork Contractor will prepare a method statement for the trial erection including the acceptance criteria and a safe system of work for assembly and dismantling.

6.5 PROTECTIVE TREATMENT

Good practice is to take the protective treatment system as far as is practical in the factory. Generally most of the steelwork can be taken to final coat and, with correct lifting and support provisions, damage to the system can be minimised.

The primary purpose of protective treatment is precisely that, cosmetic considerations are of secondary importance. The effectiveness of the treatment depends on proper preparation of the steelwork in a dry clean environment and application of an appropriate paint system in accordance with the manufacturer's instructions. Conditions on a civil construction site, the weather risk and seasonal constraints are good reason for painting on site to be minimised. As well as the potential environmental impact of the process, it inevitably involves painters working at height and all that that entails. Of course the final appearance matters, particularly of more visible components such as fascia girders: the extent of site painting needs to take account of all the risks and work involved.

Treatment of bolted and welded joints has to be completed at site but action can be taken to minimise the work required in the air by masking off the joint areas at the factory, and careful use of appropriate specifications for cleaning, assembly, sealing and treatment of the completed joints.

Bridges in weather resistant steel require blast cleaning, even though they are not painted, to produce a surface which will weather to give a uniform appearance. This can be completed at the factory, except at site-welded connections which will require local treatment; usually this can be carried out from the temporary access provided for welding.

6.6 PRE-ASSEMBLY AT THE FACTORY

The merits of pre-assembling bridge steelwork before erection are outlined in 3.2.2. It may be possible to pre-assemble some members into final configuration at the factory. Small rail bridges, single lane overbridges and footbridges may be fully assembled at the factory and delivered complete to site. Pairs of girders for larger structures may be pre-assembled with bracing or in longer lengths. To maximise the benefit all connections in the pre-assembly should be cleaned and painting finished.

The size of assembly which can be delivered depends on the delivery route to site – every part of the route has to be checked for dimensional and load clearances – and the views of the police and highway authorities. The Steelwork Contractor has to consider the options available in consultation with the haulage contractor and the authorities.

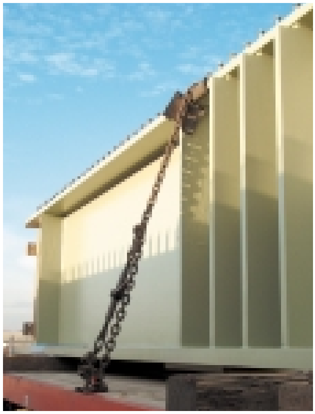
Pre-assembly at the factory is of particular merit when site constraints preclude pre-assembly on the ground at site and the bridge is to be erected in a short possession, which is common for motorway overbridges and railway bridges.

6.7 DELIVERY TO SITE

Delivery of large loads by road is subject to dimensional limits and regulations which are described and discussed in *Steel Bridges 1.7* and *Guidance Note 7.06.* The largest loads are subject to planned movement orders and police escort. The Highways Agency has recently modifying its policy with the aim of transferring the responsibility for escorting loads from the police to the haulage contractor.

Pre-assembled units

Delivery to site



Secured for transportation

Each load has to be transported safely without risk to other road users and without damage to the steelwork. The haulier is responsible for checking that the load is stable and properly secured. Normally steel members are supported on timber baulks with packs between members: the load is restrained in position by chains or nylon webbing straps. Protection is essential between the restraints and corners of the steelwork to prevent damage to the steelwork, the protective treatment, or the straps or chains.

The Steelwork Contractor is responsible for providing suitable lifting facilities for loading and unloading the transport vehicle with cranes, lifting equipment such as shackles, chains and strops, together with lifting lugs or attachments to the components. Large and heavy components require the Steelwork Contractor to plan safe systems of work for loading at the factory and off-loading on site. Recent changes to the regulations require more careful consideration of loading and unloading vehicles to avoid the risks of falling in handling and securing the steelwork on the vehicle – it is not acceptable for personnel to climb on high loads or stacked components unprotected.

7 IMPLEMENTING THE ERECTION SCHEME

7.1 INTRODUCTION

For most steel bridges covered by this guide the Steelwork Contractor will, as subcontractor, come to a prepared site and carry out the erection in a sequence of common activities – from taking over the site for erection to completion. The main activities are outlined below.

7.2 HANDOVER OF THE SITE

When the Steelwork Contractor arrives on the bridge site he brings on personnel, equipment and plant followed shortly by major steel components. His arrival is the culmination of a process over several months or more of preparation for erection and fabrication of the steelwork – it is the beginning of the end of his work and it is vital that he is ready, the Principal Contractor is ready, and the bridge site is ready for erection to start without delay. Any lack of preparedness at this point can be disruptive and costly.

Therefore it is good practice, as discussed in 2.3.6, for the Principal Contractor and the Steelwork Contractor's site manager to make a thorough joint check on site in good time before the start date – at least seven days before. Provided the project team has worked together through the pre-construction phase, the joint check should verify that everything which has been agreed is in place and there are no surprises. A prepared check list of everything required before starting erection acts as an aide memoire, expedites the process, and the formality of signing off the completed list injects some discipline for both parties' representatives at this key point. If any items are outstanding and cannot be completed in time before the programmed start, then a delayed start or default arrangements need to be agreed. The checklist should cover, as relevant for the particular bridge:

- **Access** – for plant, personnel and materiel into and across the site, details of obstructions to access, provision of working access at substructures;
- **Working areas** – hardstandings for cranes and plant, offloading and storage areas for steelwork, bases for trestles; details of hazards and protective measures;
- **Temporary works** – agreed civil temporary works for erection;
- **Personnel** – welfare facilities, space for cabins and stores, details of emergency services and induction requirements for the site;
- **Exclusion and protection** – measures to separate other activities, other construction personnel and the public from erection working areas;
- **Particular site hazards** – such as overhead power lines; and
- **Documentation** – to confirm acceptance of the Erection Method Statement, and the Steelwork Contractor's site management plans for health & safety, quality and the environment.

A *Bridge Safe Site Handover Certificate* (see Appendix 4) published by the BCSA provides a convenient pro forma for this purpose.

Safe site conditions

It is prudent as part of the joint check at site to "walk through" the Erection Method Statement on the ground from receipt of steelwork and cranes, offloading, storage, lifting operations and stage by stage erection to verify that there will be no potential obstructions or hitches to implementing the agreed method. For larger structures the check should cover the first few weeks of work. For erection in a possession e.g. of an overbridge in a motorway closure, the check should cover all preparations and contingency arrangements in detail.

Once the area for erection has been taken over by the Steelwork Contractor's site manager, he is responsible for the safe conduct of work within that area of the site until the steelwork is complete, inspected and handed over to the Principal Contractor. He is responsible for cooperating with the Principal Contractor in managing safety overall.

7.3 SITE MANAGEMENT

The size and make up of the Steelwork Contractor's team on site depends on the scale and duration of the work and the detailed work content. The site manager is responsible, with the support of an experienced bridge foreman erector, for the erection of the kit of parts supplied in programmed sequence and following the agreed method statement. The support staff and mix of trades depends on the work scope. The site manager reports to his line manager at head office who has overall responsibility for the bridgework contract, and receives support services from there including engineering, procurement, personnel, quality management and health & safety.

Responsible also for the safety of the structure and for quality, the site manager has to have the knowledge and experience to understand and respond to:

- the Designer's intentions for the bridge;
- the characteristics of fabricated bridge steelwork;
- the behaviour of the bridgeworks, as they are erected, under their own weight and the effects of wind and temperature change;
- the vulnerability of the partially erected structure at each stage; and
- the requirements to achieve the specified performance of bolted or welded connections, bridge bearings, and protective treatment.

This is essential for him (or her, obviously) to be able to focus attention on the critical aspects of workmanship, to foresee potential problems and head them off, and to deal with problems in consultation with the project team efficiently and with the minimum of delay.

Bridge erection is sensitive to weather, particularly the effects of wind on lifting operations, and of damp or rainy conditions on working at height and workmanship. Good planning and control of operations depends on a keen awareness of the weather and how it is changing, so habitual observation of current conditions and comparison with regular forecasts applicable to the site are essential daily input to managing the site safely and efficiently.

7.4 USE OF THE ERECTION METHOD STATEMENT

The Erection Method Statement and the erection programme set out the plan for the work to be done and define the overall safe system of work. They provide the framework for planning the site work day by day and to apply the Steelwork Contractor's management procedures for health & safety, and quality – with supporting generic procedures, for example for common tasks such as tightening bolts, and inspection and test plans.

The planning of site work has to take account of the actual site conditions, the anticipated weather, and any changes in plant, equipment or site circumstances. Implementing the method statement day by day requires on site risk assessment before briefing the personnel for each activity; that is not to justify departure from the agreed plan but to ensure that nothing is overlooked. Some aspects may require task specific method statements which are within the competence of the site manager to prepare – these should be reviewed and signed off by the appointed representatives of the Steelwork Contractor and the Principal Contractor as defined in the agreed management system.

Development of method statements for generic or site-specific tasks appropriate to a Steelwork Contractor's business should follow his quality management procedures. The BCSA has provided an industry model *Task Specific Method Statement* which may be used as a guide to procedure, content and format.

When circumstances require a change of sequence or method, not allowed for in the method statement, any proposed revision should be referred to the originator to amend as practicable and reissue the revised Erection Method Statement – which requires the same authorisation as the original. This need not be a time-consuming operation or cause significant delay provided that the personnel responsible are prepared for such eventuality and can cooperate. If substantial construction engineering is required, then it is often expedient, as described in 2.3.1, for the Steelwork Contractor's engineer to attend the site to deal with this.

On projects with a number of separate bridges, or with a long continuous viaduct, it may be appropriate and can be more convenient to use separate Erection Method Statements for each bridge or section of viaduct.

7.5 INDUCTION AND BRIEFING

Communication through preparation, information and involvement is essential to counter the risks and get the best out of people in doing the job: the principal means are induction, briefing and tool-box talks.

Briefing the team

All personnel starting work on a construction site need to be made familiar with the site, the hazards and restrictions, the planned works, the facilities and emergency arrangements: the Principal Contractor usually organises formal induction for everybody, carried out by trained staff members. The Steelwork Contractor's team of experienced staff and tradesmen also need induction for their scope of work and its particular hazards and characteristics; this should be organised by the Steelwork Contractor in coordination with the Principal Contractor. These personnel are also required to have had training for any special hazards, such as confined space working. Thus the personnel are properly prepared to use the site as a workplace.

Erection is carried out by personnel working as a team – for example a supervisor, crane driver, banksman and erectors carry out a major lift to erect a main girder – and the team must be briefed before the activity starts. The supervisor briefs the team beforehand on the planned procedure, the preparations, potential problems or hazards, and safety measures; he ensures that everyone knows and understands what to do and he encourages feedback. In some circumstances, a general briefing at the start of the day's work is good practice.

Tool box talks – short training or information sessions with the workforce – are used regularly to:

- familiarise personnel with the development of the work following through the Erection Method Statement,
- brief them on changes to methods,
- explain task specific method statements,
- focus on problems identified from "walk round" risk assessments,
- ensure the proper use of equipment, and training in its use, and
- update and remind the workforce about health & safety matters in general.

The talks are conducted by trained personnel, sometimes with prepared training material, and personnel are encouraged to raise and discuss relevant points. Those participating should countersign an attendance list to confirm that they have received and understood the training. Although drawings are very useful, reliance should not be placed on the use of written documents (particularly lengthy documents) as the sole means of communicating important matters to the workforce.

All employees are responsible for their own safety and that of others and are required to report hazards, problems, and potential for improvement; so feedback through briefings and tool box talks is an important part of consultation with employees about health & safety. It is also important to encourage a culture of looking out for the safety of workmates and others on site whilst work is progress. All employees must have a basic training in health & safety evidenced, for example, by the CSCS card for operatives and tradespersons.

7.6 DELIVERING AND OFFLOADING STEELWORK

Delivery of the principal components, commonly long and heavy plate girders, to the point of pre-assembly or erection needs careful planning and preparation. The objective is to deliver each of them on the delivery vehicle to an offloading point within reach of the erection crane wherever practicable; that is, to avoid extra handling and crane movements which take extra time and space, add unnecessary risks and represent cost with no value. To achieve that requires

Ready for off-loading

- a haul road from the highway to the offloading point suitable for the delivery vehicle to arrive and depart; the vehicle may be carrying girders up to 50m long, and the haul road, which is often vulnerable to adverse weather, must be maintained in a safe condition for use by road vehicles;
- if not for immediate erection, an area of hardstanding where components can be placed on level timber baulks on stable ground; components must be braced if there is a risk of being blown over whilst in store;
- control of the unloading area to exclude the public and other personnel during offloading;
- factory fitted lifting attachments for each component or sub-assembly for safety and speed; and
- a task specific method statement for any offloading which entails working at height.

Whenever possible the delivery vehicles should arrive on site with sufficient time, weather permitting, to offload the steelwork in the normal working shift. If delivery time is critical for erection and traffic conditions in the area, or traffic management arrangements, present a real risk of delay it is prudent to arrange for delivery vehicles to arrive in good time at a marshalling area a short distance from the site.

7.7 LIFTING OPERATIONS

7.7.1 General

Lifting operations are an important constituent of most bridge erection schemes with a small number of major lifts and many small routine lifts of material and equipment to complete the bridge structure. They are carried out in the main using mobile cranes with a range of equipment to support the load safely on the hook of the crane. Cranes and equipment are mechanical devices which can deteriorate and they can be abused, so they must be used properly by competent, suitably qualified personnel and be maintained in compliance with detailed regulations which place obligations on the site manager and the erection team.

7.7.2 Use of cranes and equipment

All equipment provided for use at work, from small hand tools to large mechanically operated plant, must comply with the Provision and Use of Work Equipment Regulations (PUWER) and the Lifting Operations and Lifting Equipment Regulations (LOLER) which cover any equipment used at work for lifting or lowering loads including attachments for anchoring, fixing or supporting. Thus the regulations cover equipment which includes cranes, lifts, hoists, forklift trucks and MEWPs, as well as lifting equipment or accessories such as chains, slings, strops, shackles, eye bolts and the like. PUWER and LOLER also extend to temporary lifting accessories such as lifting beams, spreader beams, cradles and devices designed especially for the particular operation. As explained below, all equipment must be tested to prove it suitable for the particular task and be marked to indicate the safe working load.

The regulations require that all crane operations must be under the control of a "competent person" who has the training, knowledge and experience to ensure that the choice and use of all cranes is appropriate and safe. The appointed person (as termed in BS 7121) participates in the planning for erection described in Section 4 as well as being responsible for the lifting work at site. Generally the appointed person will delegate site control of specified lifting operations to a suitably experience and qualified "crane supervisor". These roles must be determined in advance and should be notified to the Principal Contractor.

After arrival of a crane at site and before any lifts take place, the crane supervisor must ensure that the crane has up-to-date certification in accordance with LOLER and BS 7121. A valid test certificate for the crane must be available, and kept available at all times: every crane is subject to thorough examination every twelve months and weekly inspection by a competent person. The supervisor must check that the crane operator and banksman have the appropriate certification and experience for the particular type of crane to be used.

For lifting equipment, the regulations require that:

- all chains, slings, shackles and other lifting tackle must be tested and certificated before being put to use;
- all such equipment must be examined by a competent person every six months and records must be kept;

- temporary lifting cleats attached to the steelwork, designed and verified by suitably qualified persons, are not subject to test; and
- other temporary designed equipment may be verified by a certified design check by a qualified person; if validated by testing, the test load must not damage the equipment by overload beyond the safe working load given by the design certificate plus an appropriate margin.

It is good practice to use a colour coding for each six monthly period, to mark lifting equipment; then it is easy to verify that equipment in use is in test. The crane supervisor must ensure that damaged lifting equipment is quarantined or destroyed to prevent it from being used again.

7.7.3 Control of lifts

In planning each major lift, the appointed person needs to carry out a risk assessment and identify the quantity, sizes and arrangement of all the lifting equipment required. The crane positions must be clearly set out on dimensioned lifting scheme drawings which identify the particular crane and the loadings. The conduct of each lift, including the sequence of motions, is set out in the Erection Method Statement with reference to the scheme drawing.

Controlling the lift

A carefully supervised lifting plan

The appointed person is responsible for supervision of lifting operations. He may, in accordance with guidance given in LOLER and BS 7121 delegate the role of crane supervisor but not the responsibility to a suitably experienced person – suitable that is for the operations to be undertaken. It is normal practice in steel bridge construction for routine lifting operations to be under the control of qualified steel erectors working as banksmen/slingers in cooperation with a trained crane operator. Such routine lifting operations can be planned under site operating procedures and risk assessments.

Before each major lift, including any lift which requires the crane to operate close to its safe working load limits, the crane supervisor must:

- check that the crane has been assembled correctly from the separate components travelled to site,
- check that the crane is correctly rigged for the lift,
- check that the crane is positioned and supported safely as planned on sound ground, if necessary with a Permission-to-Load certificate issued by the Principal Contractor,
- check the load, the steelwork to be erected, is positioned as planned within safe reach of the crane, and that handlines are attached as necessary for control,
- check that the lifting equipment is rigged and fitted correctly as planned between load and crane hook,
- ensure that arrangements are complete at the erection position to receive the load,
- confirm the system of signals to be used and brief the lift team including the crane operator, banksmen and erectors on the plan for the operation, and
- organise an exclusion zone for the area below and around the lifting locus and erection position.

The crane supervisor can then make the final decision to proceed, taking into account the current and forecast weather conditions, the expected duration of the task and any necessary contingency measures. The anticipated weather conditions must be within the limits recommended by the crane manufacturer, or hirer, or within lower limits if set in the Erection Method Statement for the particular lift. The crane supervisor must assess the weather conditions in consultation with the crane operator who is responsible for the safety of the crane, as discussed further below. Once the lift is commenced it must be completed as a continuous operation – that is until the steelwork is in place and secured so that the load can be released from the crane. Alternatively, the operation must be reversed and the load landed on safe supports and made secure. The crane supervisor must ensure that the erected steelwork and the crane are made safe before the team stands down.

The crane supervisor must ensure that:

- the crane is checked every time it is moved or set up for a lift,
- the crane is checked daily when it remains in position overnight,
- the crane operator makes the regulation inspection each week, and records the inspection.

7.8 MANAGEMENT OF WIND EFFECTS

7.8.1 Wind effects

Disregard of the potential effects of wind can have disastrous consequences in bridge-building: the possibility of high wind speeds during construction in the UK is ever present so it has to be catered for in the construction engineering, planned for (see Section 4) and taken account of in each day's work.

The effects to be considered are:

On the structure

- on stored girders on the ground, which could blow over,
- on the stability of erected members before connection,
- on the complete structure at each stage of erection,
- on the temporary works, large or small, required to support, brace and stabilise the structure at each stage, and
- on bridge launching or transport.

On operations

- on the stability of cranes themselves,
- on the stability of access equipment including mobile elevating work platforms (MEWPs) and towers, and
- on large components when lifted which affect control and add to crane loads.

On tasks

- on exposed work at height,
- on the quality of welding,
- on the quality of painting, including wind-borne dust, and
- consequential environmental effects.

Storm damage

- displacing loose material from height,
- damage to protective sheeting, and
- damage and overloading caused to work platforms or the bridge by protective sheeting with large sail areas.

The characteristics of wind are complex but the salient features to remember are that:

- peak wind loads are determined by gust speed, conventionally the 3-second gust speed,
- the gust factor on the mean hourly wind speed varies with the height above ground, the surrounding topography and loaded length,
- wind loads are proportional to the square of the wind speed.

The effects of wind in erection are dealt with either by design for a suitable return period, by protection or by working to strict operational "weather window" limits.

7.8.2 Designing for wind

Wind loading for bridge erection is specified by the Composite Version of BS 5400-2 incorporated in Highways Agency Specification BD 37/01. Whereas the bridge design uses wind speed for a 120 year return period, a 10 year return period is specified for erection giving 85% of the full design speed. It is permissible to use a predicted wind speed when an erection activity can be completed, and made safe within two days or less, for which reliable wind speed forecasts are available – a "weather window". This means that in benign conditions some temporary works can appear overly substantial: nevertheless they must be erected and fitted in strict compliance with the construction engineer's requirements and the Erection Method Statement and be verified by specified inspection and testing.

To enable the site manager to work within a planned weather window, the Erection Method Statement needs to define the limiting wind speed and highlight the need for reliable weather forecasts for conditions at site together with monitoring using measurements taken on site.

7.8.3 Working to defined limiting wind speeds

Before any lifting or erection starts on site, the site manager must ascertain and confirm the limiting wind speeds which will govern the planned operations; he must brief all site supervision and inform the Principal Contractor what the limits are. These will include for:

- cranes – manufacturer's maximum wind speed for lifting,
- wind sensitive operations – wind speeds defined in Erection Method Statement e.g. for temporarily propped girders until connections are made,
- weather windows for critical operations, and
- manufacturer's maximum wind speeds for MEWP operations, which may be reduced if shielding is fitted to the basket.

In planning for each day's work and deciding whether an operation or task can proceed safely within the particular governing limit, the site manager needs to:

- know the current wind speed on site and the 24-hour forecast,
- know the probable duration of each task,
- assess the safe handling of components with large surface areas,
- assess from reliable weather forecasts the likelihood of the wind speed increasing and, if so, how quickly it might reach the governing limit,
- have contingency plans to ensure safety of construction and personnel if wind speed increases more quickly than anticipated, and
- enable site supervisors and crane supervisors to be able to monitor wind speed reliably.

Wherever the location, duration or nature of a new bridge project render erection susceptible to the risk of high wind, it is essential when planning erection to identify the character of the weather at the site and how it can vary during the relevant season. Local weather stations and the Meteorological Office are able to provide reliable information, as well as regular weather forecasts during critical phases. Public broadcast forecasts provide a reliable guide to trends in the weather pattern, but shipping or coastal waters forecasts will not provide a good guide except on insular or exposed coastal sites.

The site manager has to be able to interpret wind speed data and relate the Beaufort Scale to mean hourly and 3-second gust speeds. Some general guidance is given on this in the BCSA's *Guide to Steel Erection in Windy Conditions.*

Checking the local wind conditions

Wind speed at site is best measured with an anemometer located at an appropriate point or with a hand held instrument where a reliable observation can be made: some cranes are fitted with an anemometer, but if it is at the jibhead at height it will record a higher speed than at the erection front.

On many days on most bridges on inland sites, the risk of high wind will be insignificant, but it remains an issue which the site manager must ensure can be controlled. That requires a constant awareness of the weather during erection, information, and reliable measurement when necessary to keep within safe operational limits.

If, despite all precautions and contingency planning, the wind increases in strength more quickly than anticipated and it is no longer possible to operate safely but components are in a dangerous condition, the demarcation and maintenance of an exclusion zone are imperative. Work must not be restarted until the stability of the erected components has been assessed by a suitably qualified person.

7.8.4 Protection from wind

Wind, wind-blown rain or spray, and wind-blown dust can be detrimental to the process in welding and in all protective treatment activities. Wind can also reduce the productivity or affect the health & safety of personnel, for example from windchill when they are carrying out work in a stationary position. Thus some work at height requires the working platform to be screened to protect the work and the worker.

The same tasks produce waste continuously during the process which can be a hazard to other people on the site and can damage property and the environment. The hazard from such waste is aggravated by the wind. Then the screening is essential to protect the surrounding area from the activity.

In implementing the erection method, these particular risks have to be assessed too and, when and where necessary, protective measures put in place. The screening material and method have to be suitable for the process and provide for adequate ventilation and escape in the case of emergency. It must be secure. The effects of extra wind load on the stability of the access systems must be considered, and in the case of large screened areas on the stability of the structure itself.

When erection is suspended for any period of more than two days - for a long weekend, a site holiday shutdown, or between phases – then the erection works must be made safe to sustain the erection design wind speed. The site manager must be satisfied through a thorough physical inspection that:

- the partial structure and all temporary works are in place, properly supported, and secure as planned;
- stored steelwork is stable;
- crane jibs and MEWPs are lowered or rigged for storm conditions;
- working platforms are cleared of loose material and equipment; and
- screens are taken down and lashed in position.

7.9 ALIGNMENT AND BEARINGS

Bearings ready for the steelwork

7.9.1 Management of an interface

The bridge bearings are at the physical interface between the steelwork and the substructures; and usually they are at the contractual interface between Principal Contractor and Steelwork Contractor. They are precise mechanical devices fitted between steelwork made to fabrication tolerances and reinforced concrete built to civil engineering tolerances. The objective is to complete the bridge to correct line and level with the bearings able to perform throughout their life as the Designer intended. Installation of the bearings is not a straightforward procedure but, given a clear understanding of the responsibilities of the Designer, the Principal Contractor and the Steelwork Contractor and knowledgeable management of the whole process, potential problems can be avoided without difficulty.

Usually the Principal Contractor takes responsibility for the supply and installation of the bearings and the Steelwork Contractor fixes them to the underside of the steelwork as it is erected on to them. The process has to be anticipated by the Designer and requires actions from the two contractors to complete it correctly.

7.9.2 Setting out and dimensional control

In these circumstances, the Principal Contractor is responsible for setting out the bridgeworks and completing the substructures with the bearings ready to receive the steelwork; that is with centrelines clearly marked and benchmarks for reference at each set of bearings.

The Steelwork Contractor requires accurate agreed data to erect steelwork in the correct position and maintain dimensional control. Some of this data should be provided by the Designer, some as output from production of fabrication data or drawings, and some by agreement with the Principal Contractor. All this information should be checked and verified before handover of the bridge to the Steelwork Contractor.

Best practice for dimensional control comprises:

- Agreement beforehand between the Steelwork Contractor and the Principal Contractor on the survey methods and equipment to be used and the responsibility for collating and using the data to monitor and control progress. BS 5964 provides a basis for this.
- An independent survey of the physical interface between substructure and steelwork by the Steelwork Contractor's site engineer using survey instruments and steel tapes as appropriate (for possession work, this survey should allow sufficient time before the possession for any adjustments).
- Systematic checking of the position, line and level of members as they are erected in situ or pre-assembly before completion of bolting up or welding connections, generally using simple techniques with spirit levels, plumb-lines, laser devices and string lines.
- Surveys to control build-up of length in continuous structures before connections are completed.
- Survey of steel and bearing positions in uniform temperature conditions, if necessary in the early morning

before dawn, by measurement of relative positions to verify the final setting of bearings.

- A joint survey of the finished steelwork on completion of a bridge structure, or section of structure, carried out with the Principal Contractor using levels to check the profile against the Designer's predicted shape, and to measure critical steelwork dimensions e.g. gaps between flanges for shuttering.

Note that once the steelwork is erected and fully connected little can be done to change profiles, other than perhaps adjusting levels at bearings which would redistribute self weight stresses within members.

7.9.3 Function and details of bearings

The function of the set of bridge bearings is to:

- transfer the weight of the superstructure and traffic to the substructure,
- transfer transverse and longitudinal forces from wind, traction and braking, and thermal effects to the substructures, and
- allow the superstructure to articulate freely under live load and thermal effects, by longitudinal and transverse rotation and translation.

Thus bearings are designed to permit the full design range of translation and rotation. Usually translation is arranged so that:

- one bearing at one substructure is not free to slide and transmits most of the longitudinal forces,
- one bearing at each substructure is fixed laterally to transmit transverse loads to the substructure, and
- all other bearings are free to slide in both directions.

Rotation may be needed to accommodate changes of shape under working load or due to thermal effects. Translation and to a lesser extent rotation will also require the installation of expansion joints, the installation of which will generally be undertaken by the Principal Contractor after the steel bridgework is complete.

Bearings come in a range of types and sizes. Although they are designed to carry large loads, they contain components and materials which can easily be damaged – seals can be displaced and sliding interfaces do not tolerate dirt or grit. Manufacturers supply bearings as complete units held together by transit straps which are not to be removed until absolutely necessary during erection. *Guidance Note 3.03* and the *Steel Designer's Manual*, chapter 28 are useful background reading, as well as bearing manufacturers' technical data sheets.

Typically the lower bearing plate is bedded on a layer of strong grout (at least 25mm thick) and fixed in plan by vertical dowels in pockets in the concrete: the dowels are recessed into counter-bored holes in the base plate and each is retained by a single screw from the top. The upper bearing plate is fixed to a tapered plate on the soffit of the steelwork so that it is nominally horizontal and secured either by through bolts or screws into tapped holes in the tapered plate – see *Guidance Note 2.08* for discussion of this detail and the advantages and disadvantages of each method.

7.9.4 Design and planning for bearing installation

To achieve the desired accuracy of construction and correct installation requires resolution of some design points at an early stage of the contract:

- **Levels:** The design drawings do not always define the bearing levels at the interface with the steelwork; they may have to be deduced from the highway geometry data so it is important that the Principal Contractor and the Steelwork Contractor agree on the intended levels before fabrication commences.
- **Transverse rotations and movements:** At bearings these should be carefully assessed by the Designer. This is not normally an issue on square multi-girder bridges, but on highly skewed bridges and on ladderbeam decks it is. Elastic movement of main girders and crossgirders under self weight and wet concrete can cause significant transverse rotations and kick-out which must be anticipated in determining the rotational and translational capacity of the bearings. If they are not allowed for, the effects may not be noticed until the deck slab is complete when remedial measures – to replace tapered plates or inspect bearings – will be time-consuming and expensive.
- **Tapered bearing plates:** The Designer should specify clearly on the design drawings at what stage the top plate of the bearing is to be horizontal, and whether transverse taper is required in the tapered bearing plate.
- **Fixing to the steelwork:** As referred to in above and discussed in *Guidance Note 2.08*, the Designer must consider the practical and design issues in deciding how the bearings are to be fixed to the steelwork.

In planning for the bearing installation, the contractors have to consider:

- **Plan tolerance:** Given the accuracy of measurement, the inherent deviations in the steelwork (within tolerance) and the restricted access to compare girder positions with setting out marks, it is not possible to achieve positional accuracy consistently better than $\pm$15mm. Substructures are not normally sensitive to bearing eccentricity, so it should be acceptable to move the whole bearing bodily to line up with the steelwork without inhibiting or using up the translational capacity of the bearing.
- **Clearance in pockets:** These should be a nominal 25mm all round each bearing dowel, horizontally and vertically, which is usually sufficient to allow for deviations in the position of the steelwork and the pockets.
- **Shimming of bearings:** This is usually carried out by the Principal Contractor, requires shimming drawings of the position and area of shims to the underside of the bearing base plate for each bearing. The shims must support the steelwork loading evenly with a grout gap of not less than 25mm. Base shims are grouted in level and all subsequent shims are taped together to maintain the set level securely.
- **Erection restraints:** These are designed and installed by the Steelwork Contractor, and are required to provide longitudinal and transverse support to the erected bridgework until the bearings have been grouted: that is to sustain wind loads on the steel and prevent it drifting off line due to thermal movements. The anchorages for the restraints require fixings to the substructures of adequate strength.
- **Damage avoidance:** Care has to be taken at each stage, from delivery of the bearings to site to completion of the grouting, to ensure that the bearings are not damaged. This is best achieved by following through an overall bearing installation method statement and an associated inspection and test plan: this can be a task specific method statement forming part of the Erection Method Statement.

7.9.5 Installation method

It is most expedient to start erection of the superstructure from the fixed bearing; and, if practicable, that bearing alone is best grouted before erection so that it provides a fixed start point. If erection starts from another bearing, temporary restraints are required to hold the steelwork in place at that point. For a typical proprietary bridge bearing, installation is carried out in three stages, and the best practice procedure would be:

Preparation (Principal Contractor)

- complete bearing plinth with pockets with top level to ensure not less than 25mm of grout;
- mark setting out lines clearly for bearing for reference as local position points during erection;
- check condition of bearing and transit bolts after delivery to site;
- set level and grout base shims in planned positions;
- set remaining shims to required level and tape them together;
- assemble and fix dowels to bearing baseplate, and position bearing on shims to line and level with dowels in pockets; then
- carry out joint survey with Steelwork Contractor to verify position, level, clearances for grouting, transit bolts, and shim arrangement.

Checking the bearing for level

Erection of Steelwork (Steelwork Contractor)

- lift member into place over a bearing (the other end of the member will be over a second bearing or supported otherwise);
- position over bearing and line up with upper plate bolt holes, lower member on to bearing;
- fit all bolts, and transfer all weight to bearing;
- tighten all upper bolts and check that the bearing and shims have remained in a satisfactory condition;
- ensure the steelwork is restrained as planned and stable, then release the load from the crane;
- repeat the joint survey with the Principal Contractor, ensuring base plate is horizontal and record inclination of top plate in both directions; then
- release the transit bolts to permit thermal movement without disturbing bearing.

Grouting (Principal Contractor)

- before further load is placed on the bearing, and in accordance with the bearing manufacturer's instructions, clean out plinth pockets and recheck bearing setting;
- grout dowels in pockets and allow to cure; then
- complete grouting and allow to cure before increasing bearing load and removing temporary restraining works.

During this process it is vital to ensure that the final setting of each sliding bearing is at the right point of the range of translation: a large difference in steel temperature from the design datum during erection can be significant particularly for long continuous decks.

7.10 MAKING CONNECTIONS

7.10.1 General

In service the connections transmit the full design forces between members; as erection advances they hold the bridgeworks in place to the correct shape. The aim of the manufacturing process is to provide accurate components which can be assembled and connected together without further preparation, fitting, or remedial work: the quality procedures are designed to ensure that.

To make bolted or welded connections, as erection proceeds, requires:

- the adjoining members to be correctly aligned,
- the mating ends to fit as drawn,
- sufficient initial connection at the joint to maintain alignment and transfer dead load before the crane is detached, and
- temporary connection to transfer wind loads and restrain thermal movement until the joint is made.

Further progression of erection depends on how quickly sufficient strength is provided by the connection. Welded main joints require temporary bolted connections anyhow to transfer load and to permit alignment of joints to be welded to the close tolerances required of root gaps. They also take longer to complete, and require more clean-up and remedial work.

7.10.2 Bolted connections

Bolted connection

Virtually all bolted connection in UK bridgeworks today are made with high strength friction grip (HSFG) bolts, generally to BS 4395-1 or using equivalent proprietary fasteners. These enable the loads to be transferred from member to member by friction generated between lapping parts of the joint – the performance of the connection depends on the surface quality of the interfaces, the faying surfaces, to produce the designed level of friction and the tension induced in each and every bolt by tightening. The surface preparation and treatment of the faying surfaces is usually specified with the overall protective treatment; they are protected by masking off at the works before the overall application of paint. It has been shown that generally weathering of faying surfaces improves the slip factor of the joints so it is not necessary to maintain the specified blast clean finish until assembly. However, the untreated edges immediately around the faying surfaces will require careful protective paint treatment on site.

Each bolted connection made in the course of erection is prepared, assembled, aligned, bolted and fully tightened:

- shortly before erection, all faying surfaces must be cleaned of masking material and any contaminant including oil or grease, and inspected to verify their condition;
- for main girder splices, the several large and heavy cover plates are fitted before erection to the end of one girder (it is "dressed") in position and secured with a few bolts (possibly service bolts) so that the mating girder can enter the projecting plates;

- when the mating component is lifted into place, it is positioned on the correct alignment, usually remaining suspended on the crane hook;
- an initial connection is established by lining up corresponding bolt holes using drifts and podger spanners (a long drift of bolt diameter) and sufficient bolt assemblies (nut, bolt and washers) are fitted and hand tightened to draw the components together (the "sufficient" number of bolts should be stated in the Erection Method Statement);
- when the mating component is secure, the remaining load on the crane is lowered off, the alignment verified, and the hook released;
- the remaining bolt assemblies are fitted systematically and drawn up spanner tight;
- before starting to tension the bolts, the whole joint is inspected to ensure that all interfaces are in full contact, and overall member alignment is rechecked; bolt threads are checked to ensure they have not been damaged by insertion or corrosion; then
- all bolts are fully tensioned using the chosen method, and the joint checked for compliance with the permitted deviations for fit-up given in the specification.

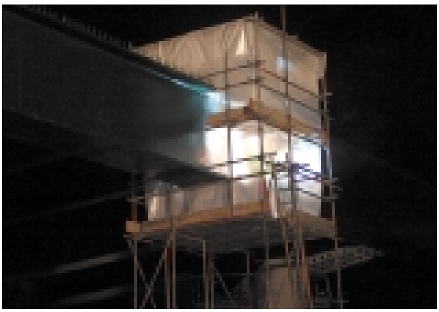
In terms of the method for tensioning, the specifications may allow the torque-control and/or part-turn methods, or the use of load-indicating washers or proprietary tension control bolts (TCBs).

In fitting and connecting bracing members, it may be necessary to use hand operated devices (*Pul-lifts* or *Tirfors*) to align the steelwork and to ensure, for example, that girder webs are vertical.

Once the connection is complete and has passed its final inspection, it is good practice if practicable to clean the whole joint thoroughly straightaway, seal it as specified and carry through the painting. Bolts and plate edges are the most vulnerable areas of the steelwork for breakdown of protective treatment in service, so thorough cleaning and priming as soon as possible is highly desirable. Depending on the specified protective treatment system and the degree of damage to it at the connection, local blast-cleaning may be required. If adverse weather prevents this being done, a holding coat of suitable moisture-tolerant paint should be applied in order to avoid the need for blasting later on. For pre-assembled steelwork near ground level it is clearly safer to clean and paint the connections there, rather than at height.

7.10.3 Welded connections

Most major welded connections on bridgeworks at site are full strength butt welded splices in girders. The end of each flange and web plate at the mating ends of girders are prepared at the works so that, when the girders are erected and correctly aligned, the plates are ready for butt welding; the alignment devices, brackets and cleats are often fixed in the fabrication shop during trial assembly. The works protective treatment is stepped back from bare steel at least 150mm from the butt weld.



Night welding

The process to make a main girder splice is:

- erect the mating girders on permanent and temporary supports using a common trestle to support both ends or a temporary bracket at the splice;
- ensure that the girders are secured in place, stable and correctly aligned before releasing the crane; straightaway complete temporary restraints to resist the design erection wind speed;
- with approved welded attachments fair the flange and webplate to line up the weld gap correctly. With modern fabrication techniques, the joint set up should then be correct, but if necessary the root gaps can be adjusted by grinding or weld build-up to approved procedures;
- run on/run off plates are attached to the flanges, some are extended to provide coupons as destructive test specimens;
- the welds are made in a planned sequence to control distortion, normally flanges first and then webs;
- all the welds are subject to inspection and testing as specified in BS 5400-6 and the project specification, often requiring a 48 hour long hold period before testing;
- when welding is complete, all the temporary attachments are removed carefully, the local surfaces of the girder being ground if necessary and tested.

Again, it is best practice to carry out protective treatment straightaway, starting with blast cleaning, and bring the joint painting up to the surrounding paintwork. Blast cleaning is a noisy and dirty process carried out by others than erectors; its aim is to produce a chemically clean profiled surface to which paint must be applied within a few hours. Preparing for and carrying out blast-cleaning, even for small areas, has to be thorough to avoid contamination of the shop-painted surfaces, nuisance or hazard to other workers. The sooner it is done after welding and testing, or bolting up, the better.

7.11 DECK CONSTRUCTION

In composite construction, after erection is finished, the Principal Contractor takes over the spans to complete the superstructure with the reinforced concrete deck slab. Some points of detail can cause problems at this stage; if not anticipated by the project team, they can affect progress, productivity and quality.

As formwork, reinforcement and wet concrete are loaded on to the steelwork it will deflect and rotate: these displacements are anticipated by building in calculated camber but they cannot be ignored:

- if deck slab construction starts before main girder joints are complete and too close to the erection front, consequent displacements can cause difficulty with making joints and lock unwanted deflections into the deck. The start of deck construction in relation to erection should be specified on the drawings;
- significant but unpredictable transverse rotations can occur at skewed supports. The Designer should specify webs vertical on completion of erection (to make control of modelling and erection easier) and check the design for webs being out-of-plumb at supports by the full theoretical amount (see *Guidance Note 7.03*);
- wet concrete deflections can vary from 50% to 100% of the calculated values, so edge beam and cantilever details must be able to cope with such variation to achieve an acceptable finished alignment.

Problems can occur at the interface between the formwork and the steelwork:

- where permanent formwork is to be used, the paint return on the top flange of the girder should be dimensioned on the design drawings from the edge of the flange not from the uncertain "in situ concrete-steel interface". The return should not go past the face of the shear studs as painting has then to be done by brush and incurs extra cost and time;

- permissible deviations of the top flanges (L/1000) can cause large variations in the width of unbraced bays: permanent formwork cannot normally tolerate that degree of variation – a single transverse steel angle, connected to cleats above or below the top flanges is sufficient to maintain the spacing;
- welded attachments using the drawn-arc process, such as threaded studs for fixing formwork systems, should be load-tested before use;
- the positions of formwork attachments should be specified by reference to the fabrication dimensions, because gradient and camber make the top flange longer than the nominal plan dimensions – otherwise the risk of clashes is high.

Inefficient working and cost can be avoided by anticipation of clashes between reinforcement and the steelwork:

- shear studs are normally set out manually in the factory so the spacing should be in multiples of 10mm. On a curved deck where transverse reinforcement is radial it is better to displace the bars slightly, if possible, than to specify odd stud spacings;
- if works fitted erection and assembly cleats on top flanges do not interfere with deck construction, they are best left in place;
- site erection lifting cleats can clash with reinforcement or compromise concrete cover: it is better to flame cut them off within 25mm of the flange, and leave the stub, than to remove them entirely and then grind and non-destructively test the flange.

Deck construction carries a substantial risk of damage to the protective treatment of the steelwork (or to the uniform finish of weathering grade steel), from mechanical damage in constructing and removing formwork, and from contamination by grout leaks. Much of the risk can be eliminated by the Principal Contractor by careful planning and detailing and control of the construction process. When grout leaks do occur, the affected surfaces should be washed down and cleaned straightaway; if this is not done, the remedial works are time-consuming, the service life of the treatment is put at risk, and painting personnel are required to work many more hours at height.

7.12 PROTECTIVE TREATMENT

A bridge site in the UK is not the best place to paint steelwork, especially between October and March, so management of the completion of protective treatment on site requires a careful approach and a sound understanding of the specified system to ensure proper application and the planned performance. Premature failure of paint systems is not uncommon, and leads to lengthy argument and costly remedial works: failure is often due to inadequate preparation or not complying with specified application criteria. The project team needs to consider, as outlined in Section 6.5, how much work should be left to be done at site in the light of the proposed paint system, the nature of the structure, how it is to be built, and at what season of the year.

Damage to paintwork applied at the works can be caused:

- in transport to the site,
- accidentally during erection,
- in erection and stripping of formwork,
- by grout leaks during concreting, especially when not cleaned off before drying,
- by silane overspray, dust, or spray from nearby traffic, or
- by particles of metal removed by grinding operations on steelwork or reinforcement.

Some paint systems are more vulnerable than others but the risk of damage can be diminished by detailed planning and supervision of each stage of the process by the site manager and the Principal Contractor. Even if the whole paint system is applied at the works, the areas of connections remain to be cleaned and fully painted at site.

Site applied protective treatment

Shop applied protective treatment

The key aspects to consider with site painting are:

- the provision of protected access to all areas of steelwork to be painted which must be clean, well lit and ventilated,
- good preparation in going back to bare metal or sound paint in damaged areas, in blasting and cleaning of connections, or in full wash down of works paintwork for overcoating,
- application of paint only to dry surfaces at ambient temperatures and relative humidities specified by the paint manufacturer,
- choice of application by brush or roller or by airless spray depending on the paint system and the risk of environmental pollution or damage to vehicles,
- intercoat times need to comply with the manufacturer's specification otherwise the correct chemical bond will not be achieved: painting over undercoats which have been cured for several months may require special preparation,
- operating a quality management regime for paint, paint storage, the process, workmanship, and daily records of application conditions, paint usage, and film thickness checks,
- health & safety management with COSHH assessment, method statements and requirements for PPE, and
- safe disposal of waste and unused paint.

Whenever practicable, protective treatment should be carried out near ground level e.g. for damage repairs, site made connections, and pre-assemblies. Opportunities to avoid work at height, work over water and work over moving traffic should be sought and exploited.

In some circumstances it may be essential to carry out some painting during the winter months, though it will be more costly. It is probable that the specified paint systems cannot be applied and an alternative e.g. moisture cured system may have to be used. Alternatively a holding coat for the winter period can be applied.

7.13 COMPLETION

The structural steelwork, and its protective treatment, are but part of the whole bridge and just as the Steelwork Contractor needs the site to be fully prepared for erection, so the Principal Contractor requires the erected steelwork to be in the specified condition for the ensuing construction works. There will be pressure to anticipate the completion of erection which can cause problems, so there is a need for planned handover of the superstructure as a whole, or in stages. This should be a formal action by the site manager and the Principal Contractor's representative, accompanied by a handover certificate, so that there is no room for misunderstanding about the preparedness of the steelwork. The inspection should include:

- condition and setting of the bearings,
- alignment and cambered shape of the structure,
- critical dimensions,
- location and nature of any damage to steelwork or protective treatment, and
- removal of temporary works.

For composite construction, it is unlikely that protective treatment is finished when the structure is handed over, so the joint inspection of that must be made when the Steelwork Contractor has completed his works.

The site manager is responsible for clearing the temporary works, his plant and equipment from site in cooperation with the Principal Contractor. Where necessary this may require risk assessment and coverage by the Erection Method Statement.

8 ERECTION TASKS

8.1 CARRYING OUT ERECTION TASKS

There is a lot more to bridge erection than the obvious action of the team lifting large components into place: much of the time skilled tradesmen are carrying out individual tasks which make up the whole scheme of work. They need special tools and equipment; the equipment needs to be safe; they need to be safe in what they are doing. The work has to be carried out to specified standards of workmanship, and is subject to quality control.

The Steelwork Contractor has to plan for these tasks too; the company's Health & Safety Policy and supporting procedures cover all these tasks as they are common to the company's business activity. The site manager works to the Steelwork Contractor's project specific Health & Safety Plan which covers the erection scope of work within the framework of the *Construction Health & Safety Plan* developed by the Principal Contractor. He has to select techniques and sufficient appropriate equipment for them, and ensure that it is maintained. This Section focuses on the most common tasks peculiar to steel bridge erection, the main hazards in carrying them out, and what to do should accidents occur. Often it will be appropriate to develop a task specific method statement for such activities whether they are general from project to project (such as drilling and reaming) or specific to one project (such as rigging special lifting tackle developed for a single lift).

8.2 PERSONAL PROTECTION

8.2.1 General

The individual requires protection in carrying out his assigned tasks – from hazards of the place of work, of the work of others, and of his own task. Risk assessment of all these hazards determines what personal protective equipment (PPE) is necessary to ensure that protection, when all other methods of removing the hazard or reducing the risk have been exhausted. Similarly, the visitor to site has to be protected too.

8.2.2 Selection

Blue signs give mandatory instructions

When selecting PPE it must:

- comply with the relevant statutory provisions for design and manufacture,
- be appropriate for the risks involved without itself leading to increased risk,
- take into account ergonomic requirements and the person's state of health,
- fit correctly after any necessary readjustment,
- be compatible with other items of PPE and remain effective when it is necessary for the person to wear several items at the same time,
- not create health or hygiene problems for different users when it is to be worn by more than one person,
- be used only for the specified purposes, and
- be used in accordance with instructions which have been communicated clearly to the employee.

On a typical steel bridge site the PPE required includes:

- safety helmets to BS EN 397 for all personnel on site in compliance with the Construction (Head Protection) Regulations;
- high visibility vests or jackets to BS EN 471 for all personnel on site;
- suitable safety boots or shoes to BS EN 344 and 345, and gloves to BS EN 388;
- full body safety harnesses to BS EN 361 with restraint or arrest lanyards as appropriate to BS EN 355 worn and used for at all places of work where there is a danger of falling a distance liable to cause a personal injury and no other method of preventing falls is available – including suitably clipped on when working from a mobile elevating work platform;
- shock absorbing devices to BS EN 355 fitted to safety harness lanyards when used for fall arrest and retractable fall arrestors to BS EN 360 when used for restraint;
- appropriate eye protection to BS EN 166, which must be worn, when work involving a risk of eye injury is being carried out;
- appropriate ear defenders to BS EN 352 where noise above permitted levels is likely to be produced; as well as
- specialised PPE for welders, painters and those working in confined spaces.

8.2.3 Use

The site manager is responsible for managing the provision and proper use of PPE by ensuring that:

- information, instructions and training on correct use are provided to all personnel, including visitors to the site;
- records of the issue of equipment and training are kept;
- users check the adequacy and condition of their equipment daily and bring any possible deficiencies of their equipment to the attention of their supervisor;
- a competent person regularly inspects safety harnesses for suitability or damage;
- an effective system of maintenance is used to ensure equipment continues to provide the degree of protection for which it was selected;
- equipment is worn and used properly, with enforcement when necessary;
- site safety inspections systematically audit the use of equipment; and
- equipment is stored properly.

The site manager should ensure that clothing is worn safely and is suitable for the weather conditions:

- warm waterproof outer garments are generally needed in winter,
- when necessary foul weather clothing should be issued and used e.g. in possession work, and
- shirts should be worn in sunny weather,

8.3 SAFETY OF EQUIPMENT

All equipment required for a task must be safe – in a safe condition and, with proper instruction and regular maintenance, be safe to use. As described in Section 7, all equipment must comply with PUWER: the regulations cover the selection, use, maintenance and regular inspection of equipment.

Selection, inspection and maintenance of equipment must be controlled by a competent person; a register must be kept of all plant and equipment on site with the relevant test certificates and inspection records, whether the equipment is owned by the Steelwork Contractor or hired.

The risks associated with the use of equipment must be considered before selecting the item: it must be appropriate for the job to be done, and the location and conditions in which it will be used. Risks will be associated with different power sources – petrol or diesel engined, compressed air, hydraulic power, or electricity – all are different, all are subject to their own limitations and regulations. What is suitable for working at ground level may not be suitable for work at height or in a confined space.

Equipment must be used and operated by personnel who are trained to use it. Under the regulations equipment is manufactured and supplied with guards, protective devices, markings and warning devices: as the first line of protection these must not be interfered with and must be maintained to function as intended. PPE is the last option for protection and physical protection systems must be employed if practicable.

Inspection and maintenance must be carried out only by competent personnel with appropriate training.

8.4 COMMON TASKS

8.4.1 Bolting

Most bolted joints on bridges in the UK are friction grip connections which require each bolt to be tensioned to achieve a specified minimum shank tension. Joints are put together as described in Section 7; when all the bolt assemblies are in place and spanner tight, the bolts are tensioned systematically in a pattern to suit the layout of the splice using power tools.

The most commonly used fastener is the general grade high strength friction grip (HSFG) bolt to BS 4395-1 used in accordance with BS 4604-1. The higher grade HSFG bolt to BS 4395-2 is little used in bridgework as it offers little benefit to the Designer working to BS 5400-3. HSFG bolts are "high strength" (similar to grades 8.8 or 10.9) and used in "friction grip" connections. The term "preloaded" is now also becoming a common term for the bolts in use. HSFG bolts are tightened by:

- rotating the nut a specified amount relative to the bolt after achieving a set bedding torque – the part-turn method, or
- using a proprietary load indicating device – usually a washer with nibs which are compressed in tightening to leave a small gap, or
- applying a specified torque to the nut, torque-control, but this is least favoured as daily, or more frequent, calibration of the equipment is required and the applied torque/bolt tension relationship is affected by a number of factors that are difficult to control under site conditions.

Pneumatic torque equipment

In assembling the connection erectors use hand tools carried in a tool belt, with pockets for a few bolt assemblies. Best practice to run the nuts down is to use a low torque power tool, either electric or compressed air driven. To achieve the bedding torque, for the part-turn method, a manual torque wrench or preset hydraulic torque device is used: then the threaded end of the bolt and the nut are permanently marked with a chisel or punch.

The bolts are fully tensioned almost exclusively using a socket fitting over the nut, driven by a power tool with the capacity to tension the particular size of bolt – the larger the bolt diameter, the larger and heavier the tool, and particularly so for bolts larger than M24. Current practice is being driven by legislative, environmental and insurance considerations – of risk and cost – so equipment manufacturers are bringing new or improved products to the market to meet these requirements. Tools can be powered electrically, hydraulically or by compressed air.

For many years the favoured tool was the compressed air driven impact wrench – and it still is favoured by erectors as it is quicker than current replacements. The loud hammering noise it emits is hazardous and an environmental nuisance, and the tool should only be used for very short periods because of the risk of causing HAVS (see below). Best practice is to use a slow running pneumatic torque wrenches that require compressed air at the workplace, or hydraulic torque converters driven from hydraulic pumps with 110V electricity supply.

Two other forms of friction grip fasteners are used in bridge construction:

- Tension Control Bolt (TCB) which has a round head – a special electrically powered tool turns the nut against the restraint of a splined shank at the end of the bolt; the shank is designed to shear off when the specified bolt tension is achieved. Most manufacturers of torque-control twist-off bolts do not galvanize them, as this makes the torque-tension relationship under which these devices operate much more difficult to control; and
- Huck Bolt – a special device, hydraulically or electrically driven, tensions the bolt and then swages a collar on to the shank; at the specified tension the reduced diameter shank breaks off. These bolts have been used for railway bridges.

The use of heavy power tools in bolt tensioning requires the following to be considered in design and planning:

- the steelwork must be detailed so that it is easy to install the fasteners and there is room for the power tool in line when tensioning – it is easy to overlook this at bracing or diaphragm connections,
- fastener arrangements should enable tensioning to be done horizontally or downhand,
- work platform layout should enable tensioning to be done without crouching or stretching, and
- risk assessment based on vibration testing must be carried out in selecting the tools.

Bolt tensioning has to be carried out systematically using planned procedures, with hold points for inspection, to ensure that the connection is completed as the Designer intended. Given that the connection has been assembled as described in Section 7 with washers fitted correctly:

- after all bolts are installed and are spanner tight, all plies in the connection must be in close enough contact to meet the specified fit-up requirements;
- for the part-turn method, the bedding torque is then applied to each bolt in turn, working outwards from the centre of the group; the torque on each bolt is checked again after the whole group has been addressed. Only then should the witness marks be made on each nut and bolt;
- final tensioning of any form of bolt may then proceed, following a similar pattern;

- tensioning of HSFG bolts must be verified by inspection of the witness marks, or the final gaps under load indicating washers; and
- if any bolt has to be slackened off, then the whole fastener assembly must be scrapped, and a new assembly used to replace it.

Bolted connections and bolting are also covered in *Steel Bridges 4* and *Guidance Note 7.05*.

8.4.2 Welding

After a joint to be welded is assembled and held securely in position, the making of the site welded connections requires plating work, which completes the necessary fairing up of the components and alignment of the prepared plate edges before welding can start; then the welding process itself can be undertaken. On large bridge sites, these tasks will be carried out by separate trades, platers and welders, but commonly a skilled welder/plater can do the whole job. Welding on any scale requires management by experienced qualified supervision.

As for every other activity, site welding has to be planned and prepared for. As well as the previously described good access to the work with shelter from the environment and protection for others, the process of making a connection requires:

Welding equipment

- qualified welding procedures for each type and position of weld, which set out all the welding parameters including the sequence of weld runs, the process, and the consumables to be used;
- welders who are qualified by certificated testing to make each type and position of weld;
- qualified and independently accredited inspectors and test house facilities to carry out the required non-destructive testing and destructive testing;
- welding equipment including mobile welding sets or welding transformers operating off site generated or mains supply;
- dry storage for equipment and consumables, ovens and electrically heated quivers to store welding rods at the workplace;
- equipment for preheating joints where necessary;
- flame retardant protective sheeting and/or fire blankets, suitable types of extinguisher, and often a fire watcher appointed to meet "hot work" permit procedures;
- an inspection and test plan, and quality records; and
- specialist personal protective equipment.

The welding procedures to be used for an actual weld must be based on welding procedure specifications (WPSs) that cover a defined scope in terms of a range of material types, thicknesses, welding consumables etc. The WPS is supported by a welding procedure qualification record (WPQR), previously termed a welding procedure approval record (WPAR). The change of terminology is because "approval" implies acceptance under the contract by the Client, the Designer or a delegated independent inspection authority, whereas "qualification" is neutral as far as the contractual arrangements between the parties. This allows Steelwork Contractors to build a portfolio of WPSs and WPQRs that are available for use on any project – although permission to use them may still require approval under the contract.

The use of welding in steel bridge construction is described in some detail in *Steel Bridges 6*, and the measures to achieve satisfactory performance of site welding operations are set out in *Guidance Note 7.01*. Inspection of welds is described in *Guidance Notes 6.01, 6.02, 6.03, 6.04* and *6.05*. It is common for a specialist inspection authority to be appointed under the contract to deal with welding (both in the shop and on site), as independent approval of the qualification, inspection and testing arrangements requires detailed knowledge of welding that is not otherwise generally available to the Designer, Client or Principal Contractor. The RQSC requires Steelwork Contractors undertaking bridgework to employ a suitably competent welding specialist.

8.4.3 Drilling and reaming

Usually all holes for principal structural connections are completed in the fabrication works: occasionally site drilling may be necessary where particular precision is required or where parapets or other bridge furniture are to be attached to the structure. Site drilling is carried out with:

- a compressed air or electric drill stand clamped to the steelwork using Morse taper drills, or
- a portable electric magnet based drill using core drills, such as the *Rotobroach* system: in use the drill needs to be secured against falling any distance should the power supply to the magnet fail.

Care needs to be taken when drilling holes for HSFG bolted connections that the faying surfaces are not contaminated with grease, lubricant, or swarf; if necessary the surfaces must be cleaned afterwards to ensure the design slip factor is maintained. This may require dis-assembly and re-assembly of the joint.

Reaming of holes is rarely performed on site. It is allowable under some circumstances and, subject to the Designer's approval, may be the most practicable method to rectify limited amount of hole misalignment in bolted connections. (Note that an oversize hole used with a bolt of the original size can reduce the effective friction generated by the tensioned bolt through the hole.) Reaming is also used where the design requires connection by close tolerance fitted bolts or dowels. Electric or compressed air drills in stands can be used for reaming; or a tapered reamer can be driven by a pneumatic impact wrench. Use of such equipment should be accompanied by clear instructions in the form of a task specific method statement.

8.4.4 Cutting and grinding

Flame cutting is closely associated with structural steelwork but at site, as a matter of principle, it should not be used on permanent bridge steelwork: its main use is with the temporary works and particularly for removing them. If, with approval of the Designer, flame cutting of the permanent works is required in particular circumstances, then it should be carried out to an approved procedure followed by grinding and dressing of the cut edge.

Angle grinders are used with abrasive wheels and cutting discs, particularly for repair work after removal of temporary works fittings and for the dressing of edge preparations for welding. As with all equipment the users must be trained and competent to use them in accordance with PUWER, and the wheels or discs must be fitted by a competent person.

These processes may result in hazards to other personnel in their vicinity, particularly when used at height, so protective screens should be used or an exclusion zone operated. Paintwork in the proximity of grinding operations needs to be protected also to avoid contamination by metallic particles.

8.4.5 Jacking

Jacking is used in bridge erection for work with the bridge bearings, transferring loads to and from temporary works, adjusting the level or position of assembled steelwork and sometimes for lifting or lowering significant distances. It is a powerful technique for moving very large loads short distances, and larger distances by using strand jacks and suitably engineered temporary works.

For small tasks, portable jacks with an integral pump are used with stroke of around 150mm and up to 100t capacity. For major movement and high loads, a wide range of jacks is available for purchase or hire; these operate at pressures up to 700 bar and are:

- of 100t to 1000t capacity,
- with 25mm to 300mm stroke, and
- single-acting or double-acting.

They can be connected individually or in groups to an electrically powered hydraulic pump with high pressure hoses and valves arranged to suit the task. This enables jacks to be operated in parallel to lift a high load locally, or an assembly with jacks under each member. Jacks can be provided with screw collars so that the load can be safely supported when the oil pressure is released or if it fails. For special tasks jacks and equipment operating at 1500 bar are available.

Hydraulic jacking is potentially very hazardous, so when it is to be used it is planned into the erection scheme with associated temporary works for support and safety. The scheme requires:

- adequate strong points on the steelwork with bearing stiffeners if necessary,
- suitable load paths to take the load on each jack safely into the substructure,
- a system of safety packs each side of a jack, which is capable of sustaining the load in the event of jack failure and is adjusted continuously during jacking to maintain a gap of no greater than 25mm,
- the same system when vertical movement greater than the jack stroke is required,
- lateral protection for each jack from side loading which will damage it, and
- swivel bearings when the jack is between surfaces which are not parallel.

Hydraulic oil at high pressure can cause serious injury so all the equipment must be maintained properly and tested. Good hygiene is essential as hydraulic systems are vulnerable to dirt.

8.5 HEALTH HAZARDS

8.5.1 Manual handling

Handling and inexpert lifting of heavy weights and bulky objects can easily cause strain and injury: in most situations the need for this can be avoided by some forethought and adequate preparation. Section 5.3 on material handling sets out the overall approach that needs to be applied to comply with the *Manual Handling Operations Regulations.* Care over tool selection, which can be heavy, and design of the work platform can make work easier or more difficult to carry out.

As with all erection activity, the site manager should ensure that in detailed planning and procurement of equipment the risk of onerous manual handling is anticipated and dealt with. If onerous duties are unavoidable, then a risk assessment is needed to develop a task specific method statement which is then implemented through instruction by trained supervisors.

8.5.2 Hand-arm vibration

Workers whose hands are regularly exposed to high levels of vibration, e.g. from power operated tools, may suffer several kinds of injury to the hands and arms, including impaired blood circulation and damage to nerves and muscles. The injuries are known collectively as 'Hand-Arm Vibration Syndrome' (HAVS) and amongst the main symptoms is 'Vibration White Finger' (VWF). The effects of HAVS are cumulative and, with the exception of mild cases of VWF, seem to be irreversible; it is a notifiable disease under RIDDOR. Having cold or wet hands while working increases the likelihood of VWF, as does smoking, because both cause constriction of the small blood vessels.

It is important, therefore, to minimise exposure to vibrating equipment and to use alternative methods where possible. Steelwork erection involves some use of hand-held tools, for example in cutting, grinding and bolt tensioning. Equipment should be selected with care, particularly for long duration tasks, and be well maintained to reduce vibration transmitted to the operator. During cold weather, operators using vibrating equipment should wear gloves to keep their hands warm. They should rotate their work with others to break up and limit the exposure time for each individual.

All operatives must be given instruction and training and know how to recognise the early symptoms of the injury: they should have routine medical check-ups.

8.5.3 Noise

Noise generated on site should be kept as low as reasonably practicable: it can damage the environment, be a nuisance to the surrounding area and harm the health & safety of the individual worker and those around him. Careful selection of power tools and plant can minimise the problem, but consideration must be given to the location of the tasks and the openness of the site: the effects can vary, for example, with buildings nearby or the prevailing weather.

The Noise at Work Regulations specify action levels at which employers must make adequate hearing protection available to employees (first action level) and when it is obligatory for employees to wear it (second action level). They apply to all personnel working in a noisy vicinity, whether they are directly involved or not.

8.5.4 Hazardous substances

Under the COSHH Regulations all substances affected by or used in carrying out a task are potentially hazardous so an appropriate assessment of the risk has to be made, as prescribed by the regulations, and actions taken to eliminate or minimise the risk before work starts. In steel bridgework, the common substances to be assessed are:

- fuel oils and grease,
- lubricants for sliding operations,
- hydraulic oil in jacking systems,
- gases for cutting and welding,
- fumes from welding,
- combustion products from plant,
- the presence of lead-based paints or plating (particularly cadmium) in existing structures which can be affected by heat – with lethal effect, and
- paints, and the residues from painting.

All hazardous substances have to be controlled by an "appointed person" who is responsible for ensuring that data sheets and information are provided on site; records of use must be kept, and be available on site. The site manager must cooperate with the Principal Contractor who is responsible for overall control of substances on the site; they must clarify the role of the appointed person in relation to the Steelwork Contractor's scope of work on the site, bearing in mind that some aspects of this scope may go beyond the conventional understanding of steelwork (e.g. grouting, use of adhesives or even radiography).

8.5.5 Housekeeping and waste

The presence of unwanted material, equipment and waste where work is to be done prejudices efficiency of working, productivity, quality and safety, so good housekeeping on a daily basis is essential. This is particularly important on access platforms and suspended stagings, where as well as hampering work there is a risk of such material overloading the access platform or falling from height to cause accidents or pollution.

Waste materials should be disposed of promptly and not be allowed to accumulate on the ground: hazardous wastes must be segregated and all wastes should be removed from site by a licensed waste carrier, preferably coordinated and managed by the Principal Contractor.

Equipment, components and material not required for immediate use should be placed where they are safe and not where they can restrict movement of personnel or the work to be done.

8.5.6 Fire

Fire precautions associated with steel bridgework concern "hot work", electric power and flammable materials, as follows:

- the "hot work" processes of welding, flame-cutting and grinding,
- the use of electricity, (see the *Electricity at Work Regulations*),
- electric pre-heating for welding,
- the use and storage of gases,
- dust and paints, particularly in confined spaces,
- inflammable waste material,
- the proximity of recognised hazards such as gas mains,
- use and storage of inflammable liquids, (see the *Highly Flammable Liquids* and *Liquefied Petroleum Gas Regulations*).

Control measures may include permit to work procedures for confined space working and for hot work, with monitoring of the work area by a fire watcher including for a suitable period after work ceases.

The site manager needs to liaise with the Principal Contractor in managing the risk of fire, and he should ensure that the relevant recommendations of HS(G) 168 "Fire Safety in Construction Work" published by the HSE are followed. They include storage and control of gases, flammable liquids, paint and fuel, and the disposition of appropriate fire extinguishers.

8.6 ACCIDENTS AND EMERGENCIES

8.6.1 General

When and where people are working, the risk of accident or illness occurring cannot be ignored, so arrangements have to be in place on the bridge construction site in case an accident should occur. The Principal Contractor is responsible for coordinating the arrangements and ensuring they are in place and the Steelwork Contractor's site manager must ensure that they cover any situation which may occur in the erection works.

8.6.2 Site Diary

The site manager should maintain a personal daily diary to provide a contemporaneous record for technical, commercial, contractual and administrative purposes. It should include information relevant to any accident or emergency which may occur, including:

- weather and site conditions,
- plant and manpower on site,
- deliveries received,
- erection progress and handovers,
- problems encountered,
- toolbox briefings given,
- health & safety issues, and
- liaison with the Principal Contractor.

8.6.3 Rescue and recovery

Rescue and emergency procedures must be in place to cover any eventuality at site: hazards such as working at height, over water or in confined spaces need to be identified in the planning process well before the start of erection. The emergency procedures include control procedures and equipment to limit the damage caused to people and property by an incident. Local emergency services should be briefed through the Principal Contractor on any particular hazards and may be involved in the preparation and rehearsal of procedures.

8.6.4 First aid

Under the Health and Safety *(First Aid)* Regulations, first aid facilities must be provided on site with a number of identified and designated first-aiders. Personnel must know where the first aid facilities are located. A person must be appointed to be in charge of the facilities and to call an ambulance if required.

A first-aider is someone who has undergone an HSE approved course in first aid at work and holds a current certificate. The number of first-aiders required on site depends on the size of the workforce and the category of risk. For bridge erection, the scale and accessibility of the construction must be considered to ensure that

Green and white signs indicate safe conditions immediate first aid attention is available at each work place: it is quite possible that an incident might occur several hundred metres from the first aid facility.

8.6.5 Accident reporting

The *Reporting of Injuries, Diseases and Dangerous Occurrence Regulations* (RIDDOR) require the reporting of specified accidents, ill-health, and dangerous occurrences to the enforcing authorities – events that arise out of or in connection with work activities and include three-day lost-time accidents, major injury, and death. Cases of ill-health and dangerous occurrences are detailed in schedules to the regulations.

The site manager must ensure that all accidents on his site are recorded in the accident book kept on site. Anyone who is injured is required to inform his employer and record information on the accident, and how it happened, in the accident book. The site manager must report any accidents to the Principal Contractor and to his own company's safety officer so that the appropriate investigations and reporting are undertaken.

The steelwork nears completion

REFERENCES

PUBLICATIONS PRODUCED BY THE BCSA:

Steel Bridges: *A Practical Approach to Design for Efficient Fabrication and Construction*

Guide to Steel Erection in Windy Conditions

Health and Safety Guide for Managers and Supervisors

Task Specific Method Statement

OTHER PUBLICATIONS:

SCI Publication P163 *Integral Steel Bridges: Design Guidance*

SCI Publication P185 Steel Bridge Group: ***Guidance Notes*** *on Best Practice in Steel Bridge Construction* (a series of 60 guidance notes on separate topics – identified in text as a numbered Guidance Note)

SCI Publication P318 *Design Guide for Steel Railway Bridges*

Steel Designers' Manual. Blackwell, Editors B Davison & G W Owens

BS 4395 *Specification for high strength friction grip bolts and associated nuts and washers for structural engineering*
- BS 4395 - 1 *General grade*
- BS 4395 - 2 *Higher grade bolts and nuts and general grade washers*

BS 4604 *Specification for the use of high strength friction grip bolts in structural steelwork. Metric series*
- BS4604 - 1 *General grade*
- BS4604 - 2 *Higher grade (parallel shank)*

BS 5400 *Steel concrete and composite bridges*
- BS 5400 - 2 *Specification for loads*
- BS 5400 - 3 *Code of practice for design of steel bridges*
- BS 5400 - 6 *Specification for materials and workmanship, steel*

BS 5964 *Building setting out and measurement*

BS 7121 *Code of practice for safe use of cranes*
- BS 7121 - 3 *Mobile cranes*

BS EN ISO 9001:2000 *Quality management systems. Requirements*

Highways Agency *Design Manual for Roads and Bridges.* Vol 1 *Highway Structures: Approval Procedures and General Design.* Section 3 *General Design.* BD 37/01 *Loads for Highway Bridges* (incorporating the Composite Version of BS 5400-2)

APPENDIX 1:

THE REGISTER OF QUALIFIED STEELWORK CONTRACTORS

1. Introduction

For design solutions to be constructed successfully, the client requires a robust supply chain for procurement of his project: each party has to be competent and have the resources to fulfill its role.

Successful construction is also safe construction and competence for the task is absolutely essential for a safe outcome as well as a technically and commercially successful project. Evolving UK health & safety legislation was rationalised by the *Health and Safety at Work etc. Act* in 1974 but it was the *Construction (Design and Management) Regulations* of 1994 which made explicit the indisputable requirement for competence in design and construction. The regulations place obligations on the parties down the supply chain to assess competence and satisfy themselves of the competence of parties before placing work with them. In brief, responsibility for ensuring safe practice cannot be escaped by subcontracting. How do Clients, or Designers or Principal Contractors, ensure that subcontracted work is done safely?

The problem of assessing competence in steel construction, let alone for bridgework, may often be aggravated because the Client, the Designer and the Principal Contractor are not expert in the intricacies of working with steel. This is a problem for the industry too, because it can increase the risk of a client accepting an unsustainably low price from an inexperienced steel firm obviating fair competition. How can a competent contractor be selected?

2. The Register of Qualified Steelwork Contractors

The government sponsored research into procurement in the construction industry included the issues of procuring competence and quality performance. This research, undertaken by the BCSA, led to the formation of the Register of Qualified Steelwork Contractors Scheme to provide procurement agencies with a reliable listing of steelwork contractors which identifies their capabilities for categories of steel construction, and a classification in terms of the recommended maximum contract value that they should be able to resource.

A fundamental principle of the Register is that companies may apply to join it and are subject to independent expert audit before admission: the Register is administered by the BCSA but it is open to any capable steelwork contractor to join, member or non-member, British or foreign.

On receipt of an application to join the Register, the experienced professional auditors visit the company at its premises to assess its capabilities in eleven categories of building steelwork and/or six sub-categories of bridge construction. The auditors also take up relevant project references before the application is accepted. Registered companies make annual returns and the auditors re-assess each company at the works triennially and when there are significant changes. Entry in the Bridgework section of the Register involves a more extensive audit with a wider range of acceptance criteria as explained below.

There are over 65 companies currently on the Register with several listed for Bridgeworks, including all the principal UK steel bridgework contractors (see www.steelconstruction.org).

3. Bridgework Scheme

All companies on the Register have to satisfy the auditor of their financial standing and resources: to be registered in the Bridgework Category, a company must have a minimum turnover in steelwork for bridges of £1 million in the most recent year or alternatively per annum if averaged over the last three years.

The company must present references for completed supply and erect contracts that include at least six bridgework contracts undertaken over the last five years, of which two must each exceed £100,000 contract value completed within the last three years.

The company's track record and the company's systems, existing facilities and employed personnel will be used to establish its capability, as follows:

- The track record will be based principally on the two £100,000 contracts. If necessary in addition other contract references of comparable complexity (but not necessarily of £100,000 value or as recent) can be used.
- The contracts can have been undertaken with sublet erection, but must have been either for bridges exceeding 20m span, or for mechanically operated moving bridges. One contract must involve the application of multi-coat treatment, which may have been sublet.
- The end-user clients, who must be different for the two contracts, will be contacted to establish their satisfaction with the work on the contracts.
- The company must have manufactured in-house at least 75% of the steelwork for each of the two contracts. Both contracts must have required materials and workmanship to BS 5400-6. One of the contracts must have required thick plate welding such as the butt welding of S355J2 plate in a thickness of at least 40mm.
- The company will need to demonstrate that it has erected a bridge of at least 30m span over water, and a bridge that involved the use of a railway possession.
- The company's quality system must be independently certified to meet the requirements of BS EN ISO 9001 2000 with a scope of registration that includes steel bridges.
- The company must have the ability undercover in its own works to lift a single piece of 20 tonnes using EOT cranes singly or in tandem. The company must be able to demonstrate that it has the ability to undertake trial assembly of large pieces post-fabrication and prior to dispatch.
- The company must employ at least one suitably competent person with clearly designated tasks and responsibility in each of three key management disciplines: technical/design, welding and erection methods.

The technical/design manager should have appropriate specialised technical knowledge relevant to the assigned tasks, and at least five year's steel bridge construction engineering experience. In terms of knowledge, an individual with Chartered/Incorporated membership of one of the ICE, IStructE or IMechE would be appropriate.

The manager of welding coordination should have appropriate specialised technical knowledge relevant to the assigned tasks, and at least five year's experience in the execution of steelwork. In terms of knowledge, a welding specialist with specific knowledge to BS EN 719, or with the qualification of European Welding Technologist, or with individual Chartered/Incorporated membership of the Welding Institute would be appropriate.

The manager in charge of erection methods should have a knowledge of the CDM and CHSW Regulations, and be able to produce a copy of the Erection Method Statement that he/she has authored for use on a complex contract.

The company must employ welders with suitable approvals.

Based on evidence from the company's resources and portfolio of experience, the Subcategories that can be awarded are as follows:

FG	Footbridges and Sign Gantries;
PT	Plate girders [>900mm deep], trusswork [>20m long];
BA	Stiffened complex platework in decks, box girders, arch boxes;
CM	Cable-stayed bridges, suspension bridges, other major structures [>100m];
MB	Moving bridges;
RF	Bridge refurbishment; or
X	Unclassified (for competent companies without extensive recent bridgework experience).

Companies wishing to be registered in the Bridgework Category but which do not possess suitably complete bridgework experience may be registered as unclassified companies. For acceptance in this sub-category such companies need to fulfil all the requirements set out above, possibly using reference to contracts of comparable complexity for steelwork other than bridgework. Unclassified companies cannot be awarded other sub-categories in the Bridgework Category. This enables companies with the relevant technical and managerial competence to enter the Bridgework Category and reflects the auditor's professional opinion of that competence.

4. Use of the Bridgework Register

The Bridgework Register provides an effective pre-qualification mechanism to match Steelwork Contractors to the needs of particular bridge tenders. Although the Register itself is not a quality assurance scheme, listing in the Bridgeworks Category verifies that the company's quality management systems are third party accredited by an appropriate body.

Particular projects may present requirements or challenges to prospective tenderers which go beyond the range of criteria of the Bridgework Category: that is for the procurement organisation to identify but it can be assured that a Registered Bridgework Contractor meets the essential basic requirements for bridgework. The use of a registered company matched to the demands of the project is a prima facie defence to any allegation that insufficient care was taken in selecting a competent steelwork contractor.

The Highways Agency has given a lead to prospective bridge owners by requiring that only firms listed on the Register of Qualified Steelwork Contractors for the type and value of work to be undertaken will be employed for the fabrication and erection of bridgeworks. This places an obligation on Clients and Principal Contractors to observe this requirement and bid and order stages; and, indeed, it assists them in fulfilling their duties under the CDM Regulations.

APPENDIX 2:

MODEL ERECTION METHOD STATEMENT

1. General

The Erection Method Statement (EMS) is the Steelwork Contractor's document to be used on site by his site manager, under site conditions, to carry through the planned erection of the steel bridgework using a safe system of work which meets the engineering, quality and environmental criteria of the project. It is important that the EMS is:

- prepared systematically so that it is clear and comprehensive in use,
- based on assessment of construction and health & safety risks,
- reviewed to verify it meets technical, safety and project requirements before issue, and
- controlled in a way that manages changes and ensures that only the correct issue is used to undertake the work.

As with any engineering document it is best to adhere to an ordered structure, approach and style in preparing the EMS. This helps the originator in drafting, the reviewers in reviewing the draft, and gives the site manager confidence in using it. *Guidance Note 7.08* gives further guidance on the generation, review and control of the EMS.

The following recommended format and structure and notes for guidance are based on many years of use for bridgework large and small, complex and simple, and with adaptation to meet the evolving health & safety legislation.

2. Format, structure and authorisation

Format – use a common header on each page of the EMS which includes:

- company name or logo,
- project title,
- document title,
- document number and revision status,
- date of issue of current revision, and
- page number out of total e.g. 17/75.

The front page should contain the list of contents, and the authorising signatures (see below). Note that when the EMS is revised and reissued, the actual revisions must be identified clearly by either a detailed revision history after the front page or highlighting the text or both. It is expedient to state the reason for each revision.

Structure – set out the content of the EMS in these sections:

1. Purpose
2. Scope
3. References
4. Definitions
5. Safety
6. Method
7. Appendices

Use this as the contents list with subheadings as appropriate. Notes for guidance on each of these sections are given below.

Authorisation – the front page must show that, before issue for implementation, the EMS has been checked and verified in sequence:

- by the originator,
- for engineering content, independently from the originator,
- for compliance with health & safety requirements, independently by a health & safety specialist,
- for compliance with project requirements by Steelwork Contractor's line manager with overall responsibility for the steelwork contract,
- as required otherwise by the contract (e.g. by the authorised representatives from the Principal Contractor, Designer, Client and/or inspection authority).

Verification needs to identify the signatory's name, job title, and date of review for the current revision.

3. Notes for guidance

Section 1 Purpose

The purpose of the EMS may well be self-evident but it should be defined. Typically the form of words can be "To set out the safe system of work for … in compliance with the contract requirements".

Section 2 Scope

It must be clear to any one referring to the document what it covers and what it does not cover. Where it covers only part of a bridge structure, then reference should be made to the method statements for associated sections.

Section 3 References

3.1 In implementing the EMS, the site manager has to refer to a range of drawings, documents, and information; he will have been briefed but normally he will not have been party to the planning phase of the work so it cannot be assumed that he is familiar with all the contract documentation. The References section is there to list all of that range which is necessary for him to do the work as planned and specified; that is, all the project specific documentation, but not, for example, regulations and specifications of general application. Documents including drawings must be individually and clearly identified with the applicable revision status.

3.2 Only necessary documents should be included: it is easy, but most unhelpful to the user, to refer to items which are not needed. Thus the originator needs to select the required documents carefully as the EMS is developed.

3.3 The references should include:

- contract drawings of the bridge site, substructures, and steelwork,
- fabrication drawings,
- layout drawings and rigging sketches for lifting operations,
- drawings of temporary works,

- parts of contract specification relating to steel construction,
- specialist subcontractors' method statements and data (e.g. on winches, skids etc to be used during a controlled slide), and/or
- task specific method statements selected from the company's portfolio of generic instructions (e.g. site welding) or developed for ancillary project-specific tasks (e.g. use of adhesives).

Section 4 Definitions

4.1 It is necessary to assign defined meanings to terms and expressions used in the EMS, particularly for roles and responsibilities – corporate or individual, e.g. for the Principal Contractor, the Project Supervisor, an independent inspector, the site manager, an Appointed Person, or a specialist subcontractor. This avoids repetitive use of corporate names, but more importantly, makes clear what roles the parties are playing in the erection of the bridgeworks, and who they are.

4.2 Note that roles or job titles should be used in the text, not names of individuals.

4.3 It is also expedient to define the meaning of any uncommon technical terms or expressions which have to be used so that any user will have no doubt what is meant. The finished text must be clear and unambiguous to a technically competent person who is not familiar with steel construction.

Section 5 Safety

The EMS is implemented within a framework of health & safety planning procedures. This section is used to identify that framework. Typically it should include reference to:

- the site manager's overall responsibility for health & safety in the bridgeworks,
- the *Construction Health & Safety Plan*, emergency arrangements and contacts,
- the Steelwork Contractor's Health & Safety Policy and associated procedures,
- the risk assessments prepared in planning the erection method,
- special hazards and measures to deal with them, e.g. overhead lines,
- special safety requirements, e.g. lineside working for a Network Rail railway bridge,
- change of methods and EMS to be referred back to originator of EMS,
- activities which require the site manager to prepare task specific method statements based on on-site risk assessment, e.g. unloading vehicles.

Section 6 Method

6.1 **Structure** – This is the longest section of the EMS and for all but the smallest of bridges needs to be structured in phases which are worked through in sequence. Usually each phase is best dealt with in three stages:

- a narrative which describes in summary form the sequence and method for the phase: this is best written in the present tense. This narrative should make reference to relevant drawings and identify the craneage needed to lift and place the steelwork and where the cranes will need to be located;
- a list of all preparatory actions which have to be completed before erection of the phase can start, by the Principal Contractor, the Steelwork Contractor and possibly others, e.g. for access, setting bearings;
- the method or series of actions to carry out the phase of work given in the form of direct instructions following the essential construction and engineering logic. The instructions for each action must be complete and specific, and identify the components, their orientation and position uniquely.

6.2 **Drafting the method** – the most straightforward way of drafting this section of the EMS is to work from the contract drawings, lifting arrangements, and temporary works drawings; begin at the start of the erection process and think through each action in the proposed sequence. As each action is dealt with – including how everything is accessed and done – write it up and move on in sequence. This process commonly reveals problems which have to be resolved, e.g. how to get to an attachment point to release the lifting gear from a girder. Writing the EMS is the culmination of all the planning and discussion of method. It should be supported by a matching itemised delivery sequence and identifying mark numbers for all items of fabricated steelwork and bolt assemblies, together with a list of the necessary plant and equipment (and their planned source, e.g. company plant yard, hired or bought).

6.3 **Risk assessment** – the planned method must be based on assessment of all risks to health & safety, which must be recorded. In following the drafting sequence, ensure that risks are recognised and addressed systematically. Reliance can be placed on generic risk assessments used to develop the company’s standard health & safety procedures as applicable.

6.4 **Drawings** – clear sketches, erection drawings, and temporary works drawings are essential to the method. The narrative and instructions must refer explicitly to the relevant data, point by point.

6.5 **Construction logic** – engineering, logistical and safety considerations impose an essential construction logic on the erection. It is important not to put in any artificial logic, e.g. if actions A,B and C can be done in any order, say so and do not say do A, then B, then C, so that the site manager has the option when planning his day's work. Starting or carrying out some actions can be conditional, e.g. subject to a weather window or grout having cured, so the conditions must be specified with the relevant action. All the engineering requirements must be explicit.

6.6 **Hold points** – which are required to assure quality or for safety must be identified together with the involvement of others, say, in inspection or acceptance.

6.7 **Contingency arrangements** – erection does not always progress as planned, e.g. due to a change in the weather, or plant breakdown. Such risks (including foreseeable emergencies) have to be assessed and contingency arrangements or actions set out wherever necessary in the instructions.

Section 7 Appendices

These should contain copies of all the reference material which is specific to erection, but not necessarily all the accompanying documents listed in section 3, which must be available on site for the site manager to manage the works, e.g. the contract drawings and specification. Thus the Appendices should include in separate sections the following, which are essential to the method:

- risk assessments,
- rigging and lifting arrangement drawings,
- crane duties for designated cranes,
- erection sketches,
- temporary works drawings,
- bearing drawings, and
- specialist subcontractors' method statements and supporting data.

APPENDIX 3:

REGULATIONS AND DOCUMENTATION

Steelwork Contractors have to be familiar with the many regulations which apply to erection of steel bridgeworks and to ensure that all applicable requirements are observed. The most practical way of doing this is to follow the approved codes of practice and guidance notes prepared for this purpose by the Health & Safety Executive (HSE). The person named in the company's Health & Safety Policy as having primary responsibility for Health & Safety is responsible for ensuring that line managers have copies of the latest issues of the relevant HSE documents.

Copies of relevant documents (such as the HSE's Construction Information Sheets (CISs)) should be issued to those directly responsible for the supervision of site operations. Site supervisors can use the codes and guidance to brief their site personnel as necessary. Supervisors should not rely solely on issuing paperwork; instead they should use abstracts to brief the site team.

The regulations valid currently that are of most importance to steel bridge erection are:

- *Confined Spaces Regulations*
- *Construction (Design & Management) Regulations* [CDM Regulations] (currently under review)
- *Construction (Head Protection) Regulations*
- *Construction (Health, Safety & Welfare) Regulations* [CHSW Regulations]
- *Control of Substances Hazardous to Health Regulations* [COSHH]
- *Electricity at Work Regulations*
- *Fire Precautions(Workplace) Regulations* (currently under review)
- *Health and Safety at Work, etc Act* [HSW Act]
- *Health and Safety Information for Employees Regulations*
- *Health and Safety (Consultation with Employees) Regulations*
- *Health and Safety (First Aid) Regulations*
- *Health and Safety (Safety Signs and Signals) Regulations*
- *Highly Flammable Liquids and Liquefied Petroleum Gases Regulations*
- *Lifting Operations and Lifting Equipment Regulations* [LOLER]
- *Management of Health & Safety at Work Regulations* [MHSW Regulations]
- *Manual Handling Operations Regulations*
- *Noise at Work Regulations* (currently under review)
- *Personal Protective Equipment at Work Regulations* [PPE Regulations]
- *Provision and Use of Work Equipment Regulations* [PUWER]
- *Reporting of Injuries, Diseases and Dangerous Occurrences Regulations* [RIDDOR]
- *Safety Representatives and Safety Committees Regulations*
- *Work at Height Regulations* [WAHR]
- *Workplace (Health, Safety & Welfare) Regulations*

APPENDIX 4:

BRIDGE SAFE SITE HANDOVER CERTIFICATE

Introduction

Safety during steelwork erection is a key focus of BCSA and its member companies; issues such as safety when working at height, personal protective equipment, preventing and arresting falls are, quite rightly, afforded high priority. Equally, the provision of proper site conditions, access and hardstandings is of fundamental importance to the efficient and safe erection of constructional steelwork; yet often, in practice, this does not receive the same priority and attention.

Objectives

This "Safe Site Handover Certificate" (SSHC) has been developed specifically for bridge construction:

- to facilitate the safe erection of bridge steelwork, with the risks arising from poor site conditions removed, avoided or reduced,
- to provide a mutual basis for improved productivity, efficient working and reduced delay and, hence, reduced overall total cost,
- to establish criteria for safe site conditions as an inherent part of the bridge steelwork tender offer, and as a mutually agreed basis for the commencement of delivery to site and of bridge steelwork erection,
- to provide consistency of approach to safe site conditions, and
- to assist Clients, Principal Contractors and Steelwork Contractors alike to meet their respective responsibilities under health and safety regulations such as the Construction (Design and Management) Regulations.

Operation

The Bridge SSHC provides a checklist approach to key areas of safety related to site conditions, and is to be used as the basis of discussion between the Principal Contractor and the Steelwork Contractor. Commencement of site deliveries and/or steelwork erection will be contingent upon the provision of a safe site environment and this can be facilitated by the completion of this certificate, typically ***seven days*** prior to the agreed date(s). This period will allow the Steelwork Contractor to ascertain that adequate conditions appear to have been provided and to return a copy of the Bridge SSHC to the Principal Contractor signifying that the steelwork delivery and/or erection can commence on the agreed date(s).

It is assumed that the site conditions will be maintained at a proper level, and the Bridge SSHC checklist provides the means for monitoring conditions throughout the programme of steel erection. Similarly, where the contract involves phasing, the Bridge SSHC can be used as a means of monitoring conditions for each phase.

HSE Reaction

The development of the Bridge SSHC has been communicated to HSE, and HSE has responded: *“We support BCSA in its development of guidance on health and safety issues, and welcome this initiative to establish common criteria for the provision of site conditions that are suitable and adequate for the erection of steelwork”.*

THIS CERTIFICATE SIGNIFIES THAT APPROPRIATE MEASURES HAVE BEEN TAKEN TO PROVIDE SAFE SITE CONDITIONS, IN ACCORDANCE WITH THE ATTACHED CHECKLIST, FOR:

a) bridge steelwork delivery, and
b) bridge steelwork erection,

and that these conditions will be maintained to a similar standard throughout the duration of the bridge steelwork contract period.

Contract Name: Project Title and Reference and/or Phase: Principal Contractor: Steelwork Contractor:	Site Address:
Programmed commencement of bridge steelwork delivery to site:	Date of confirmation of Bridge SSHC to Steelwork Contractor: (minimum of **7 days** before bridge steelwork delivery date)
Confirmed on behalf of the Principal Contractor: Name: Position: Signature: Date :	**Accepted on behalf of the Steelwork Contractor:** Name: Position: Signature: Date :

DESCRIPTION			YES, NO OR N/A	DETAILS / NOTES
ENVIRONMENT	Details of any special site operating requirements or restrictions have been provided (e.g. restricted hours, noise restrictions, local area contamination restrictions)			
	Details of any watercourses on or adjacent to the site have been provided including any knowledge of hazardous pollutants (e.g. Weil's disease)			
	Details of any S.S.S.I. or protected habitats on or adjacent to the site have been provided			
	Details of any other special site conditions have been provided (e.g. contaminated land, unexploded bombs, buried chambers, archaeological remains)			
ACCESS	To (from) site boundary from (to) public highway	Proper/adequate access route has been provided for:		
		Materials delivered by notified vehicles and lorries		
		Cranes/Plant (e.g. mobile access platforms)		
		Personnel		
	Within site boundary to (from) erection working area and other designated work areas (e.g. assembly area)	Proper/adequate access route has been provided for:		
		Materials delivered by articulated lorries		
		Cranes/Plant (e.g. transporter units)		
		Personnel		
	Obstructions	Details of all overhead and underground "obstructions", services, manholes etc affecting access routes have been provided		
		Suitable access to abutments and piers for personnel has been provided		

HARDSTANDING Within the erection working area and other designated work areas	Firm hardstandings capable of resisting loads applied from axles, tracks, and outrigger pads and bases for:		
	delivery, off-loading, storage and assembly of bridge steelwork		
	trestles		
	craneage and lifting operations		
	MEWPs		
	(Note: This assumes that Steelwork Contractor provides a list of craneage, max. lifting loads and MEWPs and identifies areas for MEWP operations within the Erection Method Statement)		
	Adequate measures have been taken to control or drain ponding water to prevent deterioration of hardstandings		
	Details and locations of all site excavations have been provided and such excavations have been adequately backfilled and consolidated		
	Details of all overhead and underground "obstructions", services, manholes etc. affecting hardstandings have been provided		
	Adequate protection to and marking of such overhead and underground obstructions, manholes etc (pegging/bunting)		
PREPARATORY WORKS	Provision of temporary works in accordance with the erection scheme as detailed in the erection method statement:		
	foundations and crane supports		
	suitable anchor holes for restraints		
	cast-in sockets for lateral restraints		
	Bearings and suitable packs set to line and level with clearly defined centrelines		
	Provision of suitable flood barriers to trestles		
	Provision of a ballast wall with anchor holes/sockets for longitudinal restraint		
PERSONNEL	Adequate welfare facilities (in accordance with regulatory requirements)		
	Proper, clean and adequately drained access to the "workfront" (at-grade and other common-use access provided by PC)		
	Details of emergency services and assurance that emergency procedures are in place and have been properly communicated		
	Detail and protection measures to other hazards to personnel (e.g. foundations, projecting rebar etc.) have been provided		

EXCLUSION / PROTECTION	Adequate means of exclusion from areas affected by bridge steelwork erection and protection have been provided for:		
	other tradesmen/activity within the "project frame"		
	other site personnel using site access routes		
	members of the public		
	(Note: Such exclusion can comprise physical distance, provision of protective measures to ensure separation, or programming to separate adjacent activity in "time")		

OTHER SITE HAZARDS Details of other identified specific site hazards – *list from Health & Safety Plan to be appended to this Checklist*		

EXCEPTIONS All agreed "exceptions" to the requirements – *to be listed and appended to this Checklist*		

Notes:

Erection Working Area = Area shown on temporary works scheme drawing or if none are required then the structure footprint plus 20m.

Vehicles = 40ft & 60ft in length / 22 tonne load / Gross Vehicle Weight 38 tonne / Axle Load 11.5 tonne (unless noted otherwise).

Craneage & MEWPS - Outrigger pad loads to be identified on temporary works scheme drawings or indicated in erection method statements after selection of plant.

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BCSA Guide to the
Erection of Steel Bridges

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