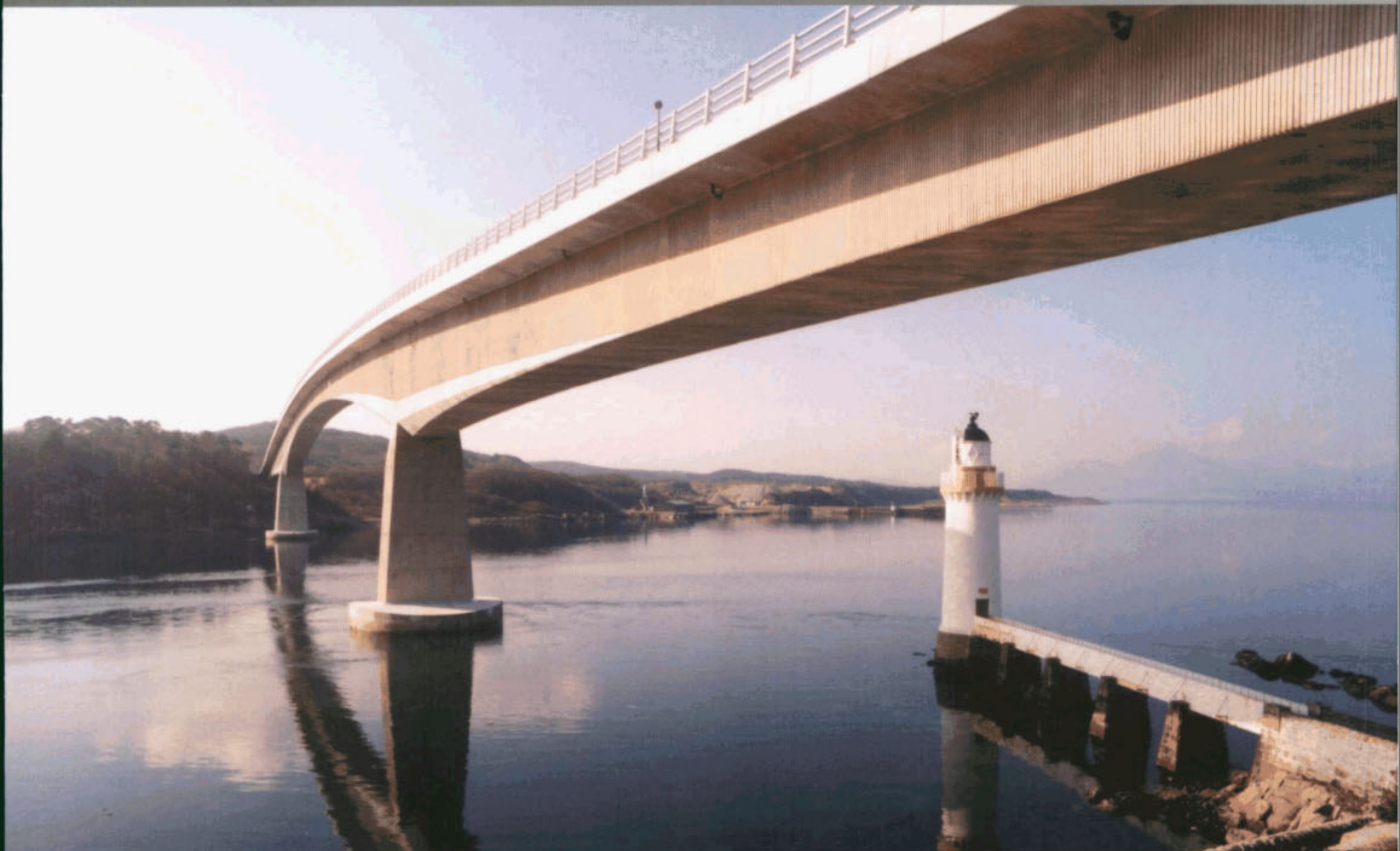
Fast Construction of Concrete Bridges

A state-of-the-art report

Technical Guide No. 5



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1. Introduction

1.1 Background to this report

Society and the construction industry are continually setting targets where speed is of the essence. It is necessary for concrete construction to remain innovative and competitive in this environment. Adequate pre-planning, precasting of elements and the use of appropriate technology in design and construction can make concrete the cheapest and fastest material for bridge construction, without sacrificing quality and durability.

This report has been produced by a task group set up by the Concrete Bridge Development Group, to bring together construction methods and details that are recognised as contributing to speeding up the construction of concrete bridges. It sets out to help clients, developers, designers and contractors to understand better the factors that contribute to fast construction and to appreciate some essential requirements and consequences of achieving a short delivery period.

Fast bridge construction in this context means any bridgework that improves upon traditional performance, whether this is a faster overall construction period or a speedy installation process. However, *it is essential that quality should not be sacrificed for the sake of speed*; any decision regarding the construction process must not compromise the long-term performance of the structure.

Speed of installation on site is particularly relevant where the cost of traffic management, road congestion or possession of a railway is found to be significant. Efficiency in construction that results in a reduced overall time for fabrication and installation almost invariably results in reduced costs. The effects of construction work on other facilities and services can often result in very significant additional cost elements. Reduced disruption, whether to a motorway or to a railway, often becomes a major objective. However, there will be times when a shorter period of major disruption will be more acceptable and get a job done quicker than a longer period of continual controlled interruption.

1.2 Scope

There is no unique approach to achieving fast construction. This report reviews and considers the main elements of a wide range of bridge types by identifying appropriate substructures and a variety of superstructures. Consideration is given not only to the construction and erection methods but also to the planning and procurement processes that will complement the design and construction details. Simple and radical designs can supplant a client's more traditional or preliminary expectations. The use of major items of plant can revolutionise both design and construction, making prefabrication of larger and heavier items acceptable and reducing on-site time to a minimum. Prefabrication in a protected factory environment can increase production by improving working conditions while enhancing quality and assuring delivery on time.

Figures

Standardisation of design details and material specification will contribute to ease and speed of construction. Small changes in site practices can lead to significant improvements in programme time. The integration of the design process with the construction methods and availability of plant and equipment will also be major issues. Minimising the variation in elements, such as the choice of a single size of pile or a single type and strength of concrete for different elements, will all contribute to speed of construction. Simplification of the erection and installation process can be greatly assisted by the choice of tolerances; sometimes a realistic approach to tolerances that are fit for purpose can meet the requirements and even produce a superior product.

The report includes chapters on:

- general issues affecting speed of construction
- identification of appropriate substructures
- review of superstructure alternatives
- consideration of design details and suitable products.

The points discussed are illustrated by a variety of case studies.

1.3 Objectives

It is hoped that the report will encourage early participation between contractors/designers and clients/developers intending to construct bridges within a limited time frame. A range of options will be available for the construction of a given bridge; there will not be a unique solution. The report is intended to provide general guidance and advice, while including specific examples and wider references. It should become a handbook that summarises the processes and provides good ideas for fast construction in concrete and thus promotes the use of concrete in bridges. It should prove to be a reminder of good practice to those experienced in bridge engineering, taking into account durability, maintainability and aesthetics while at the same time, providing less experienced professionals with details and illustrations from successful schemes which can be used directly or developed further.

1.4 Summary

Concrete can continue to be recommended for construction because it is durable and both a renewable and a re-useable material. When carefully specified and used concrete provides a high quality and aesthetically pleasing natural appearance. With proper planning none of these attributes need reduce the speed of erection or construction. Although precasting is often the preferred method of achieving in advance the structural strength and precise physical appearance required by even the most testing of specifications, in situ concrete can be simplified in design and be constructed quickly. Appropriate plant and equipment can install and erect major elements or whole structures in very limited windows of time and in a wide range of environmental conditions.

2. General issues relating to the project

2.1 Introduction

Fast construction may be demanded for many different reasons and the approach to speeding the construction process will be influenced by those requirements.

Quicker construction can lead to cost savings simply through reduction in the duration of overheads associated with the construction process; thus any steps to improve efficiency may realise far greater cost saving than the immediate operational benefit. On the other hand, the main driver for fast construction may be an external demand, for instance minimisation of disruption, and in this instance the benefits of a short on-site construction period may dictate the adoption of a more expensive construction method.

Subsequent sections of this document will consider in detail the various techniques that can reduce overall bridge construction time or facilitate construction with minimum disruption.

Where a structure is replacing an existing structure, if site constraints and/or alignment allow, off-line construction for the new work is generally a speedier way to proceed than on-line replacement with its attendant difficulties of accommodating existing use.

2.2 Initial considerations

If the time it takes to construct concrete bridges is to be reduced, a rigorous approach to design, construction planning and management must be taken.

Design decisions must be made with buildability in mind and with recognition of the constraints on construction imposed by the site. The involvement of members of the construction team during the design process can yield significant benefits in improving understanding. The resulting design details will reflect the constructor's requirements, construction safety issues can be better recognised and the cost implication of decisions can be readily assessed.

This is not to imply that a design-and-build approach is necessarily the best means of project delivery. The recent move towards working in partnership offers the opportunity to involve all the team members at an early stage while still maintaining the traditional separation of design and construction functions. The key factor in achieving success is the involvement of the whole team so that decisions are made with a clear understanding of all the issues. It is therefore equally important that the client's priorities are fully understood.

Subcontractors and suppliers, through their knowledge and expertise, can also make an important contribution to the early design and planning process in order to speed up construction.

Finally, whatever decisions are made on the use of methods and strategies to speed up the construction process, their adoption must not compromise safety.

2.3 Planning

Planning of any construction project is of paramount importance. Issues regarding purpose, style, magnitude, environment and programme all need careful consideration, as choices to suit one purpose may not be appropriate to others.

Programme issues are of major importance for fast construction. Detailed planning and careful management will be needed to make the most appropriate use of resources and to minimise the effects of construction on others around the site, e.g. rail or road users.

Programming must be given priority, for lack of it could negate any endeavours to complete a project quickly. Fast construction may involve off-site fabrication which can take place over a relatively long period while a very short period, sometimes hours, is required for erection on site.

Sufficient time must be allowed for designers and contractors to adequately plan the construction sequence with due regard to any imposed restrictions. The client must be consulted and have an active part in the discussions to resolve any difficulties with other parties. Indeed it may not be others, but the client who imposes the restrictions.

2.4 Risk management

The decision to adopt fast construction techniques can increase risks; this refers to all project risks and not simply safety issues. The adoption of a formalised approach to risk assessment and management is a valuable tool in the management of any construction project and especially if speed is the prime consideration. For example, the commercial risks involved in the overrun of a possession on a rail bridge construction project are such that risk management techniques are essential.

Guidance on risk management has been produced by a number of organisations over the past few years and it is not intended to deal further with this topic here.

2.5 Land acquisition

Availability of sufficient working access and space can help to simplify and speed up construction. Speed may be achieved through the use of large lifting equipment located alongside a bridge or perhaps by allowing a traffic diversion while construction proceeds. Often, once a construction contract is awarded, there is insufficient time to acquire additional land or the configuration of the bridge precludes this approach. Consideration of these issues at the design stage can often eliminate the restrictions that slow down construction. Here again close co-operation between the client, designer and contractor is often a key factor.

2.6 Utilities

The presence of utilities will usually have a significant influence on the construction programme, but their impact can be minimised by avoiding the need for diversion. Therefore, it is worth considering whether diversions can be avoided by redesign, for example by changing bridge spans to move piers away from existing apparatus or whether a less intrusive piling method such as Continuous Flight Auger (CFA) might allow apparatus to remain unaffected. Where diversions are unavoidable, they should, wherever possible, be undertaken as advance works prior to the start of the main construction programme.

The following issues need to be addressed from the outset to avoid time-consuming problems arising during the design and construction phases:

- Appropriate provision must be made for apparatus crossing the bridge, e.g. a trough within the structural deck, ducts in the verge above the deck, hangers below the deck.
- Establish whether cable chambers will be required within the deck span; the maximum acceptable spacing between characters for cable pulling is typically 250 m.
- Consider any additional loadings that need to be taken account of in the design.
- Consider any special measures necessary where apparatus crosses expansion joints or the effects of expansion of the apparatus itself (e.g. pipe loops).
- Make provision for installation of future apparatus.
- Consider the effects of ancillary apparatus; for example, water main air valve could obstruct the footpath.
- Consider the need for future maintenance of the apparatus and space requirements for access.
- Do the foundations need to accommodate additional apparatus in the future?

2.7 Traffic management

Road closures, lane closures, rail or waterway possessions can affect the speed of bridge construction. Rail and waterway are usually cases where closure occurs for a period of time to complete phases of the works. In the case of highway bridges, if sufficient room is available it is often preferable to divert traffic around the construction site. Closures or possessions have to be arranged many weeks in advance. Typical periods are 36 weeks for rail and 8 weeks for roads, although they can often be far longer; disruptive rail possessions require a minimum of 52 weeks' notice and may need far in excess of this.

Traffic management often plays a major part in planning for the construction of concrete bridges. The phasing of works will be dependent upon restrictions on the number of lanes required to cope with peak traffic flows. Certain traffic management layouts can be carried out with a restriction in the number of traffic lanes that can be occupied or by using lanes that are narrower than standard. Motorway works can have extremely tight schedules for traffic management with lane occupation changing within a few hours.

2.8 Health and Safety

When devising methods of fast construction speed must not compromise safety. The requirements of Health and Safety planning and management are of even greater significance when speed of construction is paramount. In addition to the normal Health and Safety considerations associated with concrete construction, other factors often arise when working next to live traffic or adjacent to a railway. These might include heavy lifting operations, working at night or in adverse weather conditions; a possession does not normally stop for the weather.

Multiple shift working poses further problems. It is important that each new shift is briefed on Health and Safety issues and that a formal handover system is established.

It should be noted that prefabrication and the use of precast units can reduce significantly the need for working at height.

Frequently, quick-setting adhesives (see Section 3.9) and chemical agents are used to speed construction. It is essential that operatives using these materials are adequately trained, are aware of the appropriate COSHH Regulations[1] and are provided with the correct personal protective equipment.

2.9 Off-site fabrication

Erection time on site can often be reduced through the prefabrication of elements in a workshop or alongside the bridge. Examples of this include precasting of structural elements or prefabrication of reinforcement cages (see Section 3.8). Over or under rail lines where possession times are very restricted, complete deck elements can be prefabricated and slid, lifted or rolled into place (see Chapter 5). An example is the Hawkes Road Bridge replacement where a 17 m span 1,700-tonne unit was constructed off-line and slid into position during a single possession. The designer will play an important role in the development of such methods.

The use of more off-site fabrication is being encouraged by various government initiatives, such as the Egan Report[2] and the general move towards 'modern methods of construction'. The improved working conditions will remove the risk of time being lost due to bad weather and should improve the overall quality of the work.

3. General issues relating to the structure

3.1 Repetition

Standardisation of details and dimensions within and between different bridges will reduce construction time. Where multiple uses of formwork can be achieved, time for making and reconfiguration is saved. In addition, the more uses that can be made of formwork and reinforcement designs, the more efficient production will become through familiarisation. A secondary benefit is that other structures on the same project will appear as part of the same family. For example, on the Channel Tunnel Rail Link (CTRL) project, while divided into several different contracts, all bridge parapets were designed to look similar when viewed from the outside (see Figure 1). This applied to both road and footbridges.

While striving to achieve economy and efficiency through multiple uses of formwork, it should also be remembered that additional counting moulds can provide a greater production rate, thus achieving a shorter programme.

Figure 1
Parapet on Channel Tunnel Rail Link

3.2 Simplicity

This is a key element for efficiency. The more complex a component is, the more time will be needed for production or fixing. A careful balance is needed to achieve efficiency without creating a bland or boring structure.

Methods of handling precast units should be engineered to be simple while safe. There are several patented systems available that will speed up the operation.

Supports that are inclined invariably complicate construction as they may need to be supported until the propping action of the deck is introduced. Consequently they should be avoided if possible.

Slip-forming, particularly for barriers, is a fast construction process and there are many organisations offering well-tried and tested systems. Some offer systems that will accommodate varying sections.

3.3 Top-down construction

Top-down construction is the process by which the abutments of a bridge are formed by piling (see Section 4.2). The superstructure is constructed in its finished position at ground level, and the soil beneath the deck excavated and the road below constructed. Clearly this technique is appropriate to situations in which the new road will pass under the existing one. Examples include the Top Lane Underpass on the A64 [see Case Study 1] where the existing road was on an embankment and the construction of a new road under an existing canal [see Case Study 2]. For the M8/M9 Newbridge Interchange, top-down construction was used to build two motorway overbridges. Contiguous bored piles formed the abutments and wing walls, with the bridge superstructures being cast in situ. Top-down construction was also used for reconstruction of the A34/M4 interchange[3].

One of the major advantages of top-down construction is that it greatly simplifies traffic management. One disadvantage is that piling adjacent to live carriageway requires careful planning to satisfy the Health and Safety regulations. In addition, ground conditions for piling can be more critical than with conventional excavation, depending on the method used. If steel sheet piles are used the bridge span may be limited by the bending capacity of the sheet piles and the moment connection between the pile top and bridge deck.

3.4 Permanent formwork

General

Permanent formwork[4] is used to speed construction by removing the need for extensive formwork and falsework. Economies can be achieved where the formwork becomes an integral part of the completed structure. Permanent formwork is used in localities where it would be difficult or impossible to remove conventional formwork. It may be particularly beneficial in situations where additional possession time would be required to remove formwork, such as when working close to live roads or over railways.

Precast concrete

Precast concrete sections are often used as permanent formwork. A common application is the use of lattice girder units forming the soffits of composite slabs, in which the precast units will contain a proportion of the reinforcement required for the finished deck slab. Figure 2 shows a purpose-made lifting frame used to speed up the placing of precast lattice girder units on a bridge deck and Figure 3 shows the units in place prior to the casting of the in situ concrete topping.

The Doncaster North Bridge, South Yorkshire [see also Case Study 3], made extensive use of lattice girder units.

Figure 2
Purpose-made lifting frame for lattice girder units

Figure 3
Lattice girder units in place

An alternative approach is to use a precast unit to form the exposed face of a wall or column. In this instance, high quality concrete (for example using white cement or pigments in the mix) can be used to give the required appearance with lower quality concrete for the infill material. An example of this approach was the white concrete shell units for the tower of the Flintshire Bridge[5].

Glass fibre reinforced cement

GRC (glass fibre reinforced cement) is widely used as permanent soffit formwork for bridge decks, spanning between closely-spaced precast concrete beams. The GRC is non-participating, providing no strength to the finished structure. Various flat or corrugated profiles are available, suitable for a range of spans. However, it should be noted that not all are currently permitted by BA 36/90[6]. GRC panels were used for the Junction 8 West Overbridge on the M62 [see Case Study 4] to enable deck construction to continue while the motorway was running below, hence minimising the number of lane closures required.

Glass fibre reinforced plastics

GRP (glass fibre reinforced plastics) are widely used in a range of construction applications. For bridges, a variety of GRP panels are available that can be used as permanent formwork, for the decks of bridges, spanning between the main precast concrete beams. However, it is essential that the material is correctly specified as many of the commonly used resins are attacked by the alkalis in concrete. Generally GRP permanent formwork will be non-participating and not contribute anything to the load-carrying capacity of the concrete. Figure 4 shows GRP panels, spanning between steel members, prior to the concrete being cast.

Figure 4
GRP panels used with steel beams

Expanded metal

Expanded metal can be used as permanent formwork, generally in vertical applications. The expanded metal retains the concrete, though there will be some grout loss. If the surface is to be exposed in the completed structure it will require rendering or the application of some other surface layer. An additional benefit is that some water passes through the mesh, lowering the pressure on the formwork and hence reducing the support needed. Expanded metal can be a very effective method of forming a stop end for a construction joint as the rough surface requires no further preparation prior to the subsequent phase of casting. Continuity reinforcement can be easily installed through the expanded metal. Figure 5 shows the application of expanded metal to form a stop end at the junction of a slab with an edge beam. Figure 6 shows a stop end with a large pipe passing through it.

Figure 5
Use of expanded metal to form stop end at edge beam

Figure 6
Use of expanded metal to form stop end with large pipe passing through

Mesh with larger openings, covered with a layer of polyethylene sheeting on both faces, can be used in foundation works such as ground beams. The material is rather flexible and is generally supported by the backfill. The reinforcement cage must be sufficiently robust to support the pressures from the backfill until the concrete has gained sufficient strength.

Expanded polystyrene

Expanded polystyrene can be used as permanent formwork to form voids in concrete members where the stripping of formwork would be difficult. The material can easily be cut or trimmed to the required shape. One practical consideration is that ties are required to prevent void formers from floating in the wet concrete. (WARNING: Expanded polystyrene is combustible and care should be taken in its storage and use, particularly if welding or burning operations are taking place in close proximity.)

3.5 Maintenance and durability

When fast construction is to be achieved, the design and construction sequence must not compromise the durability or quality of the finished structure. Adequate and appropriate supervision must be provided at all times, particularly when novel techniques and/or materials are being used. The finished structure should not require additional or earlier maintenance, nor should its design be such that it is more difficult to maintain than one constructed conventionally.

Some of the off-site techniques described later are likely to improve durability, e.g. the control of the cover and concrete quality for precast concrete beams, which will generally be better than for in situ construction. Other techniques have the potential to adversely affect durability. Consideration should be given to concrete cracking due to early-age thermal effects; some admixtures can offer advantages in this area. In addition, the construction process may mean that high loads are applied at an early age, with the resultant risk of cracking. The expression 'get it right first time' is very relevant to fast construction, as remedial work may seriously disrupt the construction programme.

3.6 Quality and aesthetics

Achievement of an acceptable quality standard depends largely upon the abilities and attitude of the workforce. A degree of involvement will help if targets are explained. However, supervision will always be needed, particularly for fast construction.

The aesthetics of the overall structural appearance should not be compromised by fast construction but, depending upon use, certain finishes may be required which create either longer finishing times or a delay in striking formwork. It is important that the selected finishes are appropriate. For example, a bridge only seen by train passengers need not have special finishes, but a footbridge, where the users will be in contact, will require generally a very high quality or textured finish.

3.7 Concrete

Concrete specification

Various options are available when specifying concrete in accordance with BS 8500[7] and BS EN 206[8] to meet a given environmental condition. These will include different types of cement and different concrete strengths. The selection of the cement type will have an impact on the speed of construction, because of the early temperature rise and the associated rate of gain of strength. Various parts of the structure will be subjected to different environments, each requiring a different concrete specification. Similarly different concrete strengths may be specified. It may be possible to select one concrete that will be satisfactory for a number of locations, thus simplifying the supply. This may speed the construction by allowing for greater flexibility, with the option to switch delivery from one part of the structure to another.

Self-compacting concrete

Self-compacting concrete can improve the speed of placing in situ concrete, particularly when the reinforcement is congested[9]. As the material will flow from one end of a pour to the other, the need for temporary access for operatives and plant will be significantly reduced. Because compaction is not required, the rate of placing can be increased. However, this may lead to increased formwork pressures, particularly for high lifts. Research has recently been carried out at Dundee University.

When construction is being carried out in an urban area there may be restrictions on the hours of working because of the level of noise. It has been found that the use of self-compacting concrete, because of the absence of vibrators, can overcome this restriction. A further Health and Safety benefit is the avoidance of 'white finger' and other vibration-induced injuries to operatives.

Figure 7 shows the formwork in position for the replacement of an integral bridge pier 9 m high. Because of the difficulty of placing the concrete at the top of the shutter and subsequent compaction of the concrete, self-compacting concrete was used. The concrete was pumped through ports in the side of the formwork. This method required an allowance to be made for an increase of concrete pressure on the formwork.

Figure 7
Self-compacting concrete being used for the reconstruction of a bridge pier

High strength concrete

High strength concrete can offer advantages for bridges[10]. The achievement of high early age strengths can obviously speed the construction process, for example by allowing earlier removal of formwork or application of prestressing. However, high early strength may result in a high temperature rise due to the heat of hydration. This needs to be taken into account and sufficient reinforcement provided to control any cracking that may occur.

Concrete surface impregnation

Hydrophobic pore lining impregnants are required to be applied to specified areas of concrete structures to help prevent and control chloride-induced reinforcement corrosion from de-icing salts. Currently monomeric alkyl (isobutyl) trialkoxy silane is recommended in BD 43/03[11] but there is the opportunity to use alternative products.

Although silane is very effective its application is slow and consequently several new products, which will speed up the process, are being trialled. It is also claimed that these new materials have improved health, safety and environmental benefits.

Corrosion inhibitors

Another method of providing protection to the concrete is the use of corrosion inhibitors which are included in the concrete mix. These inhibitors are expensive and are only required in the surface area of the structure; therefore, in thick sections most of the additive is unnecessary. There is, however, the opportunity to use them in thin precast sections, e.g. precast concrete permanent formwork for bridge decks. This type of application is also being trialled.

3.8 Reinforcement

Rationalisation

Rationalisation may be defined as the process of eliminating unnecessary variation by simplifying, reducing complexity and taking advantage of opportunities provided by manufacturing and prefabrication approaches. For a complex structure, rather than designing each element separately, the designer/detailer should try to identify typical reinforcement arrangements that will be suitable for the majority of elements. Though this may result in some elements being 'over-designed', there will be subsequent economies in terms of the time taken to fix the reinforcement on site, with resulting savings. In slabs and other flat structures welded fabrics can replace loose bars. This may increase the weight of reinforcement required but will significantly reduce the time for fixing. Similarly loose shear reinforcement may be replaced by proprietary systems[12].

Prefabrication

Prefabricated reinforcement is available from some suppliers or can be assembled adjacent to the construction site. This may be standard cages, for example for columns or bases, or may be made to order. Alternatively, reinforcement cages can be prefabricated on the ground on site and lifted into position. Figure 8 shows the reinforcement for a pier crosshead, which was fabricated on site. Some additional reinforcement will generally be required to avoid distortion of the cages during transportation, lifting etc.

Figure 8
Prefabricated reinforcement for pier crosshead

As an alternative to welded steel fabric reinforcement, which is available in sheets of limited size, some suppliers offer reinforcing bars in the form of a 'carpet'. The system is suitable for large areas of deck. The required arrangement of reinforcing bars is rationalised to reduce variation in bar sizes and spacing. Bars of the required diameter are welded at the necessary pitch to flexible strips in a special machine, the output being a roll of reinforcement. This is transported to the site and lifted into position by crane, being placed at one end of the required area. It is then rolled out like a carpet; generally only two operatives are required for a 10-tonne roll. Obviously this approach provides reinforcement in only one direction; a second roll of reinforcement is required for the orthogonal steel. One limitation with this method is the high local loads imposed on the formwork and falsework by the roll before it is spread out.

Couplers

Connecting precast units to in situ concrete, or consecutive in situ pours, may require relatively long lengths of reinforcing bar projecting from the elements, which will be lapped. Connections can be simplified, and the construction process speeded up, by using couplers, which provide a direct connection between the ends of the bars. This is particularly economic for large bar diameters. Various types of coupler are available; some carry both compression and tension while others are designed to work in compression only. The most common type are threaded, requiring the ends of both bars to be prepared. Others are swaged or clamped over the bars.

3.9 Adhesive connections

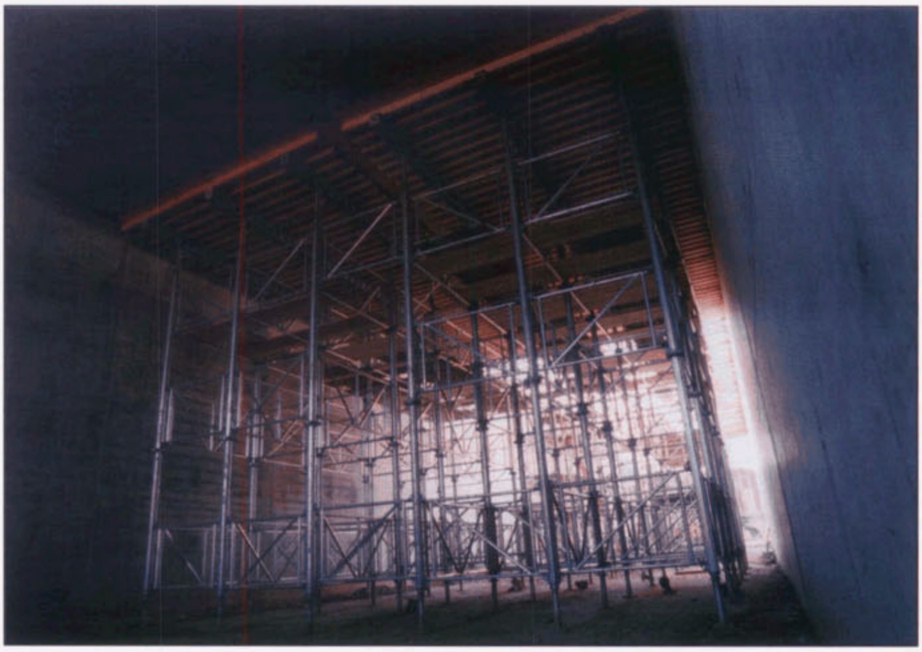
The major advantage of using adhesives (such as epoxies) is their rapid gain in strength. Suitably formulated epoxy adhesives gain their full strength in a matter of hours while cementitious materials will take several days or weeks. The main use of adhesives in concrete bridges is in glued segmental construction. However, the epoxy mortar placed between the match-cast units is primarily to seal the joint and to provide a uniform bearing area. Adhesives have been used in a number of building applications to form the connections between precast units. For the roof of the Sydney Opera House adhesives were chosen in preference to conventional mortar because of the very thin, watertight bond lines that could be obtained and the improved rate of erection because of the rapid gain in strength. It was estimated that about 6 months of construction time was saved in all[13]. There may be opportunities to benefit from the technology in bridge construction.

3.10 Travelling falsework

Travelling falsework can be used to speed up the construction where significant repetition is required. The units can be built from proprietary equipment or purpose-made steel frames. Figure 9 shows a traveller being used for the construction of a deck cantilever and stringcourse. Figure 10 shows the use of a heavy-duty scaffold traveller to support the soffit of a large underpass. The traveller was constructed in two sections across the width to allow clearance during moving; this was carried out by removing the central bracing frames between the sections and attaching wheels to the base of the support legs.

Figure 9
Traveller being used for the construction of a deck cantilever and stringcourse

Figure 10
Traveller being used for construction of soffit of underpass



4. Substructures

4.1 General

Foundations and substructures are invariably concrete and a wide range of options can be adopted to achieve speed:

- The use of fewer larger or longer piles might rule out the need for the testing normally required.
- An increase in site investigation can not only reduce the risk of unforeseen conditions but suggest or confirm a quicker option.
- Concrete can be placed directly into excavations and onto the ground, removing the need for formwork, which saves time as well as expense.
- Special constituents can contribute to the workability, density, durability and stability of a concrete rendering it easy and quick to place in large quantities and in a minimum of time.

For the sake of clarity and simplicity this section on substructures has been split between foundations and abutments/walls/piers.

Location

The location of substructures can significantly affect their speed of construction. Foundations should be kept out of water wherever possible to avoid the need for cofferdams and the restrictive effects of navigation, floods or tidal variations. Substructures should be kept back from riverbanks and railways so that they can be built and maintained without the need for costly access arrangements and avoid the need for track possessions, which inevitably have a delaying and cost effect on a job. It is best to avoid situations that necessitate piling through existing abutments especially if there is a possibility that they may themselves be piled and there is uncertainty about the location of the piles. Also, avoid services unless diversions can be achieved in advance of and without hindrance to the progress of the work.

It should be noted that columns adjacent to highways have to be designed to resist high impact forces if they are within 4.5 m of the carriageway. Avoiding this demanding requirement can achieve columns of significantly smaller section, which are easier to construct and offer less complicated connections to foundation and superstructure.

Several of the above may result in longer-span bridges. This may not, however, have a detrimental effect on cost or speed of construction as the initial savings may cover the investment in the extra span length.

Access

Access for construction plant is an important issue for both the buildability of foundations and the speed with which they can be constructed. Foundations inevitably take up more ground space than is required for the next stage of construction and this must be taken into account early in the planning of the job.

Kickers

While there are differing views on the use of kickers they do speed up the construction of the wall by affording a good line and secure support for the temporary formwork. It is important to note that they must be formed in the same quality concrete as the main wall stem and this will affect either the quality of concrete in the whole of the foundation or the strength of concrete used in the design of the abutment/wall/pier.

Secondary finishes

There are three types of finish to concrete substructures, namely plain, featured or faced with a cladding. For fast construction a plain finish is best but with the attendant lack of aesthetic appeal. If a featured finish is required reuse of what will be more expensive formwork is desirable and should be detailed to avoid remake between pours. Such formwork can of course be prepared in advance of the job and so its fabrication should not be critical to the programme.

Cladding allows the main concrete work to be done more quickly as there is not the attendant concern with quality of finish. The cladding itself, at least in bridge works, can be done outside of the more critical works window and without delaying the operational use of the structure.

4.2 Foundations

There are two broad types of foundation, spread footing or piled. The former will generally be used unless ground conditions or other issues dictate otherwise. There are situations where deeper excavations and replacement fill under a spread footing will offer a cheaper, quicker solution than piling. Mass concrete offers the simplest, speediest form of foundation wherever there is the space to use the solution. This is probably a much-underrated form of construction.

Spread footings

Time spent in getting the blinding concrete layer right will improve both the speed of construction and economy of spread footings. Where possible self-levelling concrete should be used for the blinding layer. The concrete of the footing should be placed to the edges of excavation rather than using side formwork. The extent of over-dig will determine this. (It should be noted that concreting directly against the ground offers better passive resistance than compacted fill.) The excavation must be kept free of water; a suitable drainage sump should be provided.

Simplicity of detailing is of paramount importance. Examples include making bases deep enough to avoid the need for shear links, though some links will be necessary to support the top reinforcement mat. Where possible prefabricate the reinforcement cage; additional reinforcement may be required to make the cage sufficiently rigid for it to be transported.

Piled foundations

The conventional type of piled foundation uses piles with a foundation slab on top. To speed up and simplify construction, consider the use of driven precast concrete piles, although these will be of limited capacity due to size availability. For augered or bored piles use the largest size that access for plant and ground conditions will allow, to reduce the number required. If acceptable, avoid the need for a pile test by designing empirically and adopting a more conservative factor of safety.

With regard to the different types of piling available some offer a faster rate of build than others, particularly in poor ground conditions. For example, current developments in CFA piling offer significant benefits especially where precasting or the driving of piles is unsuitable.

For the foundation slab similar points as for spread footings apply.

Spread footings have been eliminated by the use of single large diameter piles (1.5–2.5 m), for example on the Doncaster North Bridge in South Yorkshire [see Case Study 3]. This method has been used to support both road and railway bridges and is particularly suitable for twin beam/girder decks.

Intermediate supports

Where columns are designed to resist impact forces they are often detailed so that a thicker upstand projects from the foundation to reduce the effective length. This complicates the construction of the foundation and for speed and simplicity could be avoided. A bigger but single section of column may also provide aesthetic and cost benefits.

To speed construction, temporary works should wherever possible be designed as integral with the permanent work or sacrificial. In the latter case they should offer minimal obstruction to the permanent works.

Hinged connections to columns, piles or abutments should be avoided for fast construction.

4.3 End supports

Introduction

'End supports' is the general term covering all forms of construction used to support the ends of a bridge deck, and includes the following:

- full-height abutments
- integral abutments
- bank seats abutments
- cantilever walls
- reinforced earth walls
- anchor-tied walls.

The use of precast units wherever possible will generally speed up construction and this is highlighted where appropriate in the following sections.

Reinforced earth techniques also offer the benefit of speed but there are some limitations on their use, which are highlighted.

Full-height abutments

A full-height abutment is a solid wall of concrete or masonry emanating from road or original ground level and supported on a foundation. Splayed or in-line wing walls retaining fill beyond the approach to the deck are either free-standing or attached to the abutment. It is a robust element of the bridge where, with few exceptions, aesthetics are secondary to overall function. Unless there are over-riding issues, the sheer size of an abutment for a standard road bridge makes precasting impractical and therefore in situ reinforced concrete construction is standard. Access is required for inspection and maintenance unless the structure is integral.

The following measures may be taken to speed the construction of a free-standing abutment:

- The overall shape of the wall and reinforcement detailing should be made as simple as possible.
- Rectangular sections should be used wherever possible, which simplifies construction.
- Use preformed reinforcement cages.
- Design to avoid shear reinforcement wherever possible, which again aids fixing.
- Consider using precast bearing plinths.
- Where separate access chambers to galleries are needed, consider the use of precast units.

Integral abutments

BA 42/96[14] requires that bridges up to 60 m in length and not exceeding 30° skew should normally be continuous over intermediate supports and the decks should be integral with the abutments. By definition, integral abutments do not have bearings and hence do not require galleries and bearing shelves. This will considerably speed up the construction process.

The detail at the connection between the deck and the abutment requires a considerable quantity of reinforcement. To simplify the erection of precast deck beams it is preferable to fix this afterwards. To assist with this a box-out can be formed at the rear of the abutment wall using a permanent mesh. An example is shown in Figure 11.

Bank seat abutments

Bank seat abutments are small height abutments generally used as end supports in situations where existing ground is at or slightly below the finished level of the road carried by the new structure. Their design is usually simple with the wall thickness being dictated by the need to accommodate bearing plinths and drainage channel. As with full height abutments, access for maintenance is required. Wing walls are generally short and share the same foundation as the wall. Ballast walls to allow deck movement and retain the fill immediately behind the deck complete the structure.

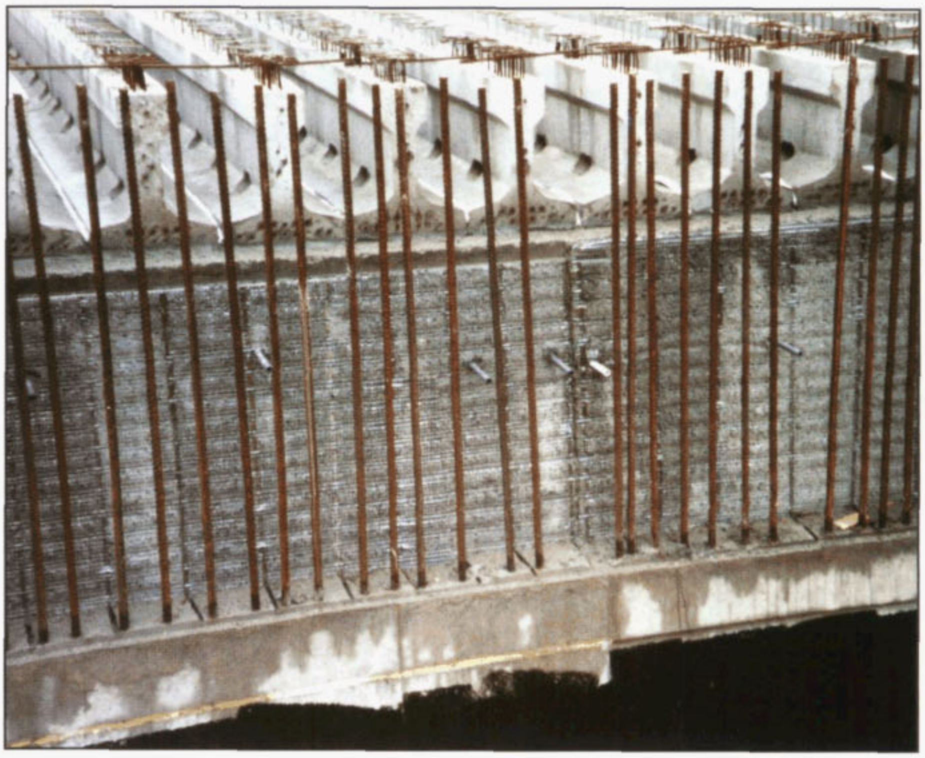


Figure 11
Example of permanent mesh used to form box-out at abutment

Although much smaller than a full-height abutment their size would still be too great to make precast construction economic unless other over-riding circumstances prevail.

Bank seat abutments can also be used in integral bridges, but the connection is effectively rigid with limited rotation capacity. On longer bridges, where temperature movement must be considered, the foundations will need to be detailed to accommodate the longitudinal movement range. This may involve the use of flexible piles, typically in steel, or a sliding interface with the blinding concrete if the footing is a pad foundation.

The aids to fast construction will be the same as those outlined above for full-height abutments. In addition, the reinforcement will be light and uncomplicated. Consideration should be given to the use of unreinforced concrete and to pre-consolidation techniques for embankment construction.

Cantilever walls

Used in top-down construction, these are formed either in contiguous/secant pile construction or diaphragm walling of various configurations. They are expensive when compared with conventional construction but become economic when the use of open excavation is limited by site constraints, e.g. the proximity of existing property. The appearance of the ensuing wall when excavated is generally unacceptable as a long-term finish and requires treatment either by facing with in situ concrete or cladding.

For a simply supported design, the wall would be topped with an in situ concrete capping beam and would require all of the features for maintenance associated with a conventional abutment. For integral designs the capping beam becomes the end diaphragm for the deck.

These factors will contribute to the fast construction of piled walls:

- Provide adequate access and working area; piling plant requires a lot of room and there will be an attendant crane for the reinforcement.
- Avoid pile tests; obtain sufficient soils data to establish a safe pile length.
- Prefabricate reinforcement cages; avoid lapping reinforcement and use couplers if necessary.
- Avoid a sophisticated drainage system.
- Avoid box-outs for secondary fixings for cladding.

For diaphragm walls, in addition to the above points:

- Avoid curves or sudden changes in direction.

Points to consider for the capping beam include the following:

- The overall shape of the wall and reinforcement detailing should be made as simple as possible.
- Use rectangular sections wherever possible; this simplifies construction.
- Use simple reinforcement details to aid fixing and allow the use of preformed cages.
- Design to avoid shear reinforcement wherever possible; again this aids fixing.
- Consider using precast bearing plinths.
- Where separate access chambers to galleries are needed, consider the use of precast units.

Anchor-tied walls

Anchor-tied walls are used in top-down construction in conjunction with a piled or diaphragm wall to limit the size and depth of wall construction. They should be considered only if circumstances rule out the use of other more simple methods of construction. They are not suited to integral bridge design.

As an aid to fast construction:

- Install fewer, large-capacity anchors.
- Avoid where possible multiple rows of anchors.
- Use precast walling beams.

Reinforced earth walls (hard faced)

Reinforced earth offers a quick solution to constructing retaining walls. An example is the widening between Junctions 8 and 9 of the M62, where the embankments could be built entirely from the rear, thereby eliminating the need for adjacent lane closures [see Case Study 4]. The system comes in many guises but the ones of interest here are those that use reinforced concrete panels to support and protect the soil fill. Steel or geotextile straps anchor the panels to the fill material and provide the frictional strength of the wall. Facing panels are typically of cruciform shape but may be the full height rectangular type. Because these walls rely upon friction being developed between the fill material and the straps, water mains should not be allowed in embankments formed this way. If they are unavoidable, extra precautionary measures must be taken such as through ducting. Also vehicular parapets must be mounted on an independent ground beam.

Reinforced earth has been used to support bank seat abutments, generally for simply supported structures with short-span, low-skew decks, where differential settlement is not an issue. However, there is still some concern among practitioners about using reinforced earth in such applications.

It is important to highlight some limitations and concerns relating to use of the system to ensure maximum serviceability:

- Reinforcing straps must extend well back from the face and under the carriageway, railway etc.
- Top layers could be disturbed by the installation of utilities so must be suitably protected.
- In the event of a soil failure, problems arise, especially at an abutment, as to how to deal with the support of the deck and how to carry out repairs.
- The standard parapet anchor slab does not meet static design criteria. It may also extend under the running carriageway.
- For reasons of aesthetics, preformed facing panels should be used. Special attention should be paid to the long-term serviceability of the connecting anchorages.

Reinforced earth is a fast construction technique. It does not require a foundation but the existing ground must meet limiting settlement criteria. However, a small base is required for the facing panels. Various decorative finishes are available for the panels, which will avoid the need for secondary treatments.

4.4 Other buried structures

Subways and culverts

Subways are short-span structures intended for use by pedestrians and/or cyclists. They are designed to provide a safe passage beneath a highway or railway and must be attractive and safe to the user. Surface finishes, lighting, good alignment and the disposal of surface and ground water are essential requirements for a good design. Culverts, however, are used to carry waterways under highways and railways. Subways and culverts can be constructed using in situ concrete or precast concrete factory-produced units, which are transported to the site and installed on prepared footings.

Precast concrete box sections

Ranges of sizes are available, with spans from 1.2 m to 6 m and internal heights varying between 600 mm and 3 m. Usually spigot and socket joints are formed at the ends of the units. Although the joints between abutting units can be rebated and left open within culvert construction, it is common practice to fill the joints with a hydrophilic sealant and/or a compression seal. The face of joints can be finished using polysulphide sealant.

Figure 12
Underpass formed from open cell units

Precast concrete open cell portal sections

Using a configuration of two inverted 'T' wall units and a roof unit comprising an inverted 'U' section, spans from 4 m to 12 m with clearance heights of up to 6 m can be manufactured. The horizontal and longitudinal joints formed by abutting units can be treated similarly to those between box sections. Figure 12 shows an underpass formed from open cell units.

Precast concrete closed cell portal sections

An inverted 'U' may be mounted on another 'U' to form a box, with a horizontal ball and socket joint in the walls. Spans up to 12 m can be factory produced and internal clearance heights of 6 m can be achieved.

General

The above precast options offer a rapid means of construction and can be designed to accommodate the range of highway and railway loadings, in addition to the dead loads from embankments and the pavement or track construction. The larger sections are suitable for the construction of vehicle underpasses. Specially designed box sections can also be made available for installation by thrust bore methods.

To simplify construction, wing walls perpendicular to the structure can be avoided by allowing the structure to project beyond the embankment side slope. Alternatively, special splay-end units can be used.

Considerations for fast construction include the following:

- Precast concrete box or portal frame units are quick to install but the joints have to be adequately sealed. In situ construction, while slower, does not have this attendant problem.
- Precast concrete retaining wall units should be considered for the wing walls **but avoid wing walls if possible**.

For in situ construction:

- The overall shape of the wall and reinforcement detailing should be made as simple as possible.
- Use rectangular sections wherever possible, this simplifies construction.
- Simple details aid fixing and allow the use of preformed cages.
- Design to avoid shear reinforcement wherever possible, also to aid fixing reinforcement.

Precast concrete arches

Arches offer an alternative profile to the more conventional slab deck designs. Structural efficiency can be achieved while providing a smooth, pleasing, aesthetic profile. Figure 13 shows a pedestrian and cycle underpass in the Netherlands. Due to the arrangement of the structural elements a wide range of geometric configurations can be achieved to provide a varied selection of clearance envelopes using a limited stock of casting moulds.

Figure 13
Pedestrian and cycle underpass

Depending on location, use, ground conditions and depth of cover, a structure comprising two, three or four elements can be used to provide economically viable spans of between 2.5 m and about 20 m, with internal heights up to 8 m. The simple structural form means that structures can be installed in a comparatively short time. Quality can be maintained and easily controlled, thus ensuring the long-term durability of the structure.

Units will usually be 2 m to 4 m long, between 180 mm and 300 mm thick and weigh up to 34 tonnes. In the arrangement in which two units are used with the joint at the crown of the arch, the units can be erected in a staggered fashion, thus avoiding temporary propping. In the case where three units form the arch, the wall units are free standing and support the curved roof units, again avoiding the need for temporary works [see Case Study 5]. Using these installation techniques, 30–40 units can be installed during a working day.

This form of construction is typically suited to a project where cut-and-cover tunnel, bridge or subway construction is to be used, or for bridging over highways, railways [see Case Study 6] or watercourses[15]. Most commonly the single-span arch is used. However multi-arch designs are available, and have been installed widely in Spain, Portugal and Japan.

Because of the speed of erection, the route below can be returned to use quickly with the minimum of disruption. An example is the New Cowdens Railway Bridge on the M74 in Scotland [see Case Study 7], where the precast arch units to form the 190 m tunnel were erected in a single weekend possession of the railway. Spandrel or wing walls can be in situ or reinforced earth panels tied back to the arch fill. Fill depths over the crown of the arch can be as little as 400–500 mm.

Considerations for fast construction include the following:

- Precast units are quick to erect and can accommodate medium length spans.
- Effective long-term waterproofing and joint sealing is required.
- Although curves in the horizontal alignment can be accommodated, sharp changes in direction should be avoided.
- A limited amount of skew can be accommodated.
- Spandrel walls can be avoided by extending the walls of the structure using adapted tapering wall units to suit the slope of the approach embankments.
- Steep gradients in the vertical alignment should be avoided.

An alternative approach is to use a number of arched ribs to form the bridge, such as the three-span Sir Thomas Fairfax bridge recently constructed across the River Weaver in Cheshire[16]. A total of 17 arch units with a span of 16 m were used for the main span across the river; this form of construction was selected so that the river would not be obstructed at any time. The brick-faced precast spandrel units incorporated mock sandstone voussoirs. Foamed lightweight concrete was used for the fill over the arches.

5. Superstructures

5.1 Precast concrete units

Precast concrete beams

Precast pre-tensioned concrete beams are a form of construction that has been used for many years. Various shapes and depths of cross-section are produced, suitable for a range of spans and applications. This form of construction is economic for a wide range of spans, but the span may be limited by the length of beam that is permissible for transport. In the UK this is normally 27.4 m, though lengths up to 40 m may be transported via the motorways with special permits. Figure 14 shows the installation of a precast beam during a night-time possession.

Inverted Tee beams are placed adjacent to each other, transverse reinforcement passed through preformed holes and the space between the units filled to form a solid slab. Typical spans, depending on the depth of the unit, vary from about 6 m to 18 m. Wide box beams are used in the same way as inverted Tee beams, but require significantly less in-fill concrete, giving a lighter cross-section.

M beams, U beams, Y beams and super-Y beams are spaced apart, permanent formwork is placed between the top flanges and an in situ deck slab cast over the top. Special units are used for the edge beams, which are considerably heavier and more expensive. Consequently, on some structures, internal beams have been used for the edge beams. The top surface of the beams is suitably prepared and has projecting reinforcement so that the slab and beams act compositely. Typical spans, depending on the type and depth of the unit, vary from about 16 m to 40 m, the longest spans being with super-Y beams.

Figure 14
Installation of precast concrete beam

Figure 15
Parapet clad with masonry

Figure 15 shows a P6 parapet prior to erection on a river bridge, which has been clad with masonry in the precasting yard to eliminate the need for access over the river for the masons.

Precast concrete deck panels

An alternative to longitudinal precast units is precast concrete deck panels that span transversely. These can be the full width of the carriageway, including the edge beam. An example is the A828 Creagan Bridge [see Case Study 8] where the units were installed on twin steel plate girders, with which they were made composite with in situ concrete stitches. Although steel main beams were used here, and in other applications, the approach would be equally suitable for concrete main beams if sufficient span could be achieved.

5.2 Precast segmental bridges

The first use of precast segmental construction was over the River Seine at Choisy-le-Roi in 1962. A further example was on the Water Orton section of the M42 where the contractor changed the in situ post-tensioned concrete box interchange bridges to precast segmental. Because they were able to construct the segments in advance in the winter months they were able to save several months of construction time. The technique is now commonly used in Europe, South East Asia and America. Examples in the UK include the Roundhill Viaduct, Folkestone [see Case Study 9], the Cross Harbour Road and Rail Links, Belfast[17] [see Case Study 10] and the 1.75 km long A13 Viaduct for the Channel Tunnel Rail Link[18].

Segmental construction requires a considerable capital outlay for moulds, casting sheds and erection equipment. Thus economics dictate that the project should be of a sufficient scale to warrant these costs; typically the total deck area should be more than 10,000 m^2. The methods particularly lend themselves to construction over difficult or obstructed ground, roads, railways or rivers – all locations where the cost of conventional falsework can become prohibitive. The minimum span length of 25–30 m is determined by the need to keep box depths above a practical minimum of around 1.4 m, whereas maximum spans can be up to 200 m.

The easiest form to create is that of a single-cell box which can be poured as a complete unit on a daily cycle. Lengths can vary between 2 m and 5 m, though a 3 m length is usual. Typical weights can be between 25 and 50 tonnes, with units closer to the piers possibly being up to 100 tonnes. The casting area should generally be located on the site in a purpose-built shed. The whole factory process is then akin to that of a production line, with as much as possible being taken off the critical path.

It is the programme advantages of segmental construction that generate significant benefits, in that the deck casting can start at the same time as the substructure works. Erection of the superstructure can start as soon as a sufficient stockpile of units has been cast. The erection methods depend on the available access to areas of the site. The two main types of construction most widely used are balanced cantilever and span-by-span.

In balanced cantilever construction, units should be erected sequentially either side of a pier unit so that the overall cantilever is never more than one unit out of balance. Temporary props should be used at the pier to provide stability until further continuity is achieved and the props should sit on the permanent works foundations. If the ground conditions permit, then the simplest solution should be to erect all the units using a mobile crane. Sophisticated gantries should become economical for larger structures having a total deck area of 20,000 m^2 or more. In span-by-span construction, the units of one span should all be erected onto a gantry beam spanning between pier locations.

5.3 In situ balanced cantilever bridges

Balanced cantilever construction is an economical method when access from below is expensive or practically impossible. An example was the A483 River Dee Viaduct in Clwyd[19] [see Case Study 11], which was constructed on piers up to 50 m high over a steeply-sided valley.

This type of construction is generally used for spans over 50 m, typically 70–100 m, and worldwide up to the biggest beam span of 301 m. The methods are particularly suited to construction high over difficult ground, such as valleys, rivers or estuaries, which are locations where the cost of conventional falsework is prohibitive. Spans up to about 60 m should be built with a constant depth, but a variable depth is required for longer spans, using either linear or parabolic haunches.

The cross-section is best developed as a single-cell box, poured in one operation. Unit lengths can vary between 3 m and 5 m, typically cast as a balanced pair on a weekly cycle. The unit formwork is generally supported from an overhead travelling frame that is attached to the end of the last segment cast. Under-slung frames, which keep the top of the deck clear, are becoming more popular as they allow the segment reinforcement cage to be prefabricated and lifted in as a whole piece. This allows the casting cycle to be reduced to less than a week. The new segments are cast and once the concrete has reached its required minimum strength, the section is post-tensioned to its balanced pair.

Construction starts from the top of a pier with a hammerhead unit that forms the initial platform for the travelling forms. Temporary props, sat on the permanent foundations or supported off the piers, should be used at the pier to provide stability to the balanced cantilever until further continuity of the spans is achieved. Alternatively, the hammerhead units are often cast monolithically with the piers.

The main programming and economic advantages of in situ balanced cantilever construction are the use of a bespoke travelling formwork system that is used many times on a regular production-line cycle, obviating the need for falsework from the ground to support the deck. Construction at several piers can also be started at the same time, thus reducing the programme further.

5.4 Incrementally launched bridges

Examples of incrementally launched bridges in the UK include the seven-span Ceiriog Viaduct on the A5 Chirk Bypass [see Case Study 12], the 1,025 m long Thurrock Viaduct for the CTRL (Channel Tunnel Rail Link), the Brides Glen Bridge in Ireland[20] and the twin 320 m long footbridges attached to Hungerford Bridge, London[21].

The economics of incremental launching, with the capital outlay for moulds, casting areas, launching noses and jacking equipment, dictate that the project should be of a sufficient scale to justify these costs. Typically the total deck length should be more than about 200 m. The methods again particularly lend themselves to construction that is high and over difficult or obstructed ground, such as roads, railways or rivers. These are all locations where the cost of conventional falsework would be prohibitive. The typical span for launching should be around 40–50 m, with a minimum span of 25–30 m for a box structure. Maximum spans can be around 70–80 m, but such spans will invariably need temporary intermediate props during the launch. The main series of spans should, wherever possible, be of equal, or very similar, length. Bridges must always be of constant depth, and must have an alignment that is of constant curvature, in both plan and elevation. Smaller span to depth ratios of around 15:1 tend to be used to control the amount of prestressing needed. The methods are therefore particularly suited to long, straight bridges.

Single-cell boxes are preferred with units varying in length between 15 m and 25 m, which are cast on a typical weekly cycle. Generally, the bottom slab and webs are cast first followed by the top slab. The length should be chosen to suit the particular span arrangement, i.e. by using either half-span or third-span lengths.

In order to limit the stresses in the deck as it progresses out over the piers, a launching nose is attached to the front of the bridge. This generally consists of a braced twin-plate girder with a length equal to about 2/3 of a typical construction span. The total weight being launched can vary from 5,000 tonnes up to 30,000 tonnes, which should then be pulled forward using prestressing strands or pushed forward with jacks.

The programme advantages of incremental launching are significant, in that the deck casting and launching can be completed efficiently and quickly on a regular cycle. Ideally, the whole bridge should be cast from a single area located behind one of the abutments. The factory process for casting and launching is then comparable to that of a production line.

5.5 Transversely slid or rolled bridges

Where an existing bridge needs to be replaced, it is increasingly desirable to limit the disruption to the existing road or railway by building the new structure alongside. A short but large disruption can often be more preferable than a long series of minor disruptions. The traffic management in the area can be greatly improved by avoiding the phased or piecemeal construction of traditional replacement operations. The temporary support of services during the sliding operation also becomes more feasible, with a potential reduction in the need to divert or move services. Though these options may appear to more expensive, the greater degree of programme certainty and the reduced level of risk, as well as the unhindered deck construction, will often make these solutions faster, and therefore more economic. They may be the only possible solutions in the railway environment.

The new bridge deck can be built on an adjacent temporary platform. Runway beams and temporary supports should be installed below the existing bridge to carry the transverse slide tracks. In a single road or rail closure, over a weekend for example, the existing bridge can be demolished, or disconnected and slid away on to a further temporary platform. Demolition of the existing bridge can then occur off the critical path. The new deck should then be slid across and connected to its piers and abutments. Existing piers can be re-used or new piers can be installed, under, or adjacent to the existing locations.

The new deck can be either pulled into place using strand jacks, or pushed into its final position with ram jacks. These techniques are frequently used in the railway environment where possession time management is vital to the feasibility of the project. Railway underbridges within embankments can also be built alongside the track and slid into position. Concrete portal structures can be built in an adjacent casting area and slid in during a long possession on pre-bored slide tracks, with the embankment having been partially removed.

An example is the new underline bridge at Bridgend, where the 4,000-tonne reinforced concrete two-span railway bridge was constructed off-line and slid into its permanent position during a 171-hr possession. This method reduced the project duration from 123 weeks to 85 weeks. Figure 16 gives a view of part of the structure.

Another example is Hawkes Road Bridge, which replaced an underbridge beneath the Newcastle–Sunderland railway line. New foundations were constructed in small diameter tunnels bored through the embankment during normal railway operations. The 17 m span 1,700-tonne portal was constructed in its entirety on slide tracks adjacent to the tunnels and slid into position, complete with ballast and railway tracks during a single closure of the railway.

Complete structures can be lifted using heavy-duty jacks and moved using multi-axle rubber-tyred transporters. Redundant bridge spans can be lifted off their supports and transported to a remote site for demolition. Replacement spans, or complete portal-type structures, can be constructed off-site and moved into position. In the case of rail bridges, they can be complete with ballast and track.

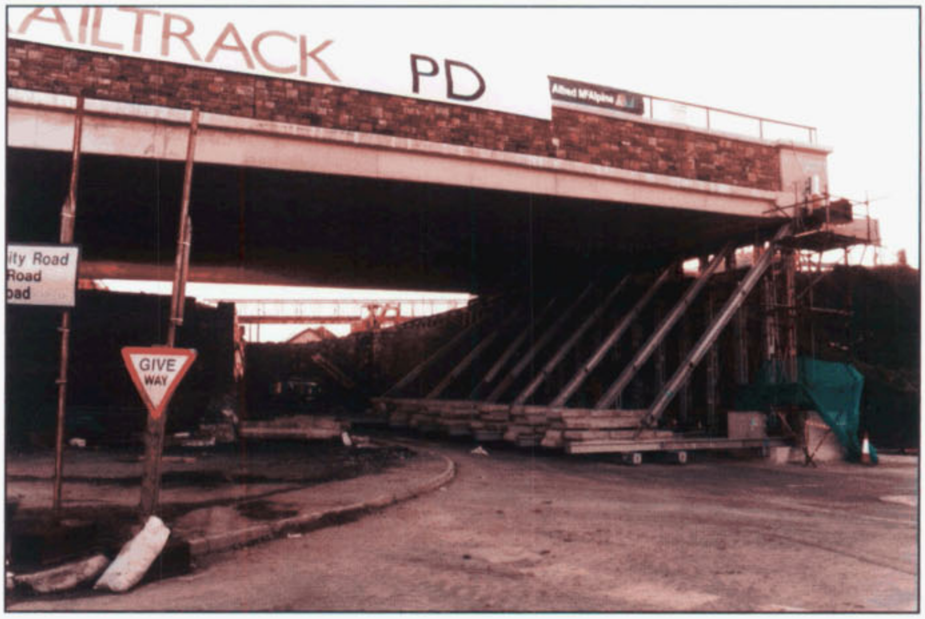


Figure 16
End of two-span railway bridge constructed off-line and slid into position

Examples include the dualling of the A90 Brechin Bypass, where a precast concrete portal overbridge was moved into place using a heavy lifting vehicle. In addition a steel–concrete composite bridge was constructed adjacent to the main road, turned through 90º and landed on reinforced earth abutments, using two heavy lifting vehicles.

For replacing small-span bridges, it may be possible to construct the complete deck in one location and lift it into place using a crane. Clearly this approach will be limited by the economics of providing a crane of sufficient size and reach.

Rapid construction can also be achieved by the casting and erection of full-span units, or full-bridge length units. Heavy spans or decks, weighing up to several thousand tonnes, can be cast away from the site, transported and then installed in very large pieces. Typical examples would include the use of massive prefabricated pieces being slid onto marine barges, for transport by water to river crossing locations. Tidal or ballasting actions can then lower the units down onto prepared pier and abutment locations. Other examples would be the similar use on land of large-wheeled transporters, to move complete spans or complete bridges from adjacent casting areas to prepared substructure locations. All these techniques use the advantage of unhindered deck casting away from the critical locations, followed by a concentrated burst of erection activity. These solutions would all be developed to speed erection and to minimise disruption at the bridge site.

5.6 Jacked boxes

Precast concrete box culverts (see Section 4.4) and pipes can be jacked beneath existing embankments, obviating the need to close the road or railway above. Larger concrete box structures, suitable for vehicular traffic, can also be jacked through embankments. These boxes are formed in adjacent casting areas and then pushed into the embankment using suitable jacking points in the casting area. A steel or concrete shield is used to support the advancing front face beneath the embankment. The frictional load on top of the box can be limited by either the use of anti-drag systems, or by the prior installation of a steelwork grillage that supports the road or railway. Major projects include the tunnels of the Central Artery in Boston[22].

The first application of the technique in the UK for a major road was on the tunnel under the M1 in Northamptonshire to provide a second carriageway for the A43 between Towcester and Northampton[23]. The 3,500-tonne, 45 m long box was fitted with a tunnelling shield and jacked under the motorway in a continuous process lasting three weeks, with no disruption to the live motorway, see Figure 17.

Figure 17
Concrete box jacked under the M1

6. Other structures

6.1 Gantries

Sign gantries, consisting of prestressed beams and reinforced columns, are being used on motorways and major roads. Depending on the cross-section of the beam used, spans up to 40 m can be achieved. Generally they are designed to span one carriageway though they can be used to span both carriageways, thus eliminating the support in the central reservation [see Case Study 13]. The units offer fast, economic erection, which is a particular advantage when they are being installed on a 'live' road. The columns are placed in preformed sockets in the foundations; if required these can be designed to be demountable so that the complete gantry can be removed and reused elsewhere. The beams are provided with the necessary fixings for the signage already cast in.

6.2 Footbridges

A number of manufacturers offer precast footbridge deck units, usually prestressed beams with pre-tensioned strands. The deck beams usually take the form of box, Tee or double-Tee sections. Fixings for handrails are cast in or the units can be supplied with precast concrete parapets where additional protection is required, e.g. over railway lines. The beams are best suited to rectangular, straight layouts. The dimensions and weight of units are limited by transport and the available size of crane for erection. Typical spans are 10–40 m.

7. Case Studies

Some of the following Case Studies are referred to in the text of the Report as examples of the specific topics being discussed. Others are intended to illustrate the range of approaches that have been adopted on various projects to achieve fast construction.

1. A64 Top Lane Underpass
2. A350 Semington to Melksham Diversion, Canal Aqueduct
3. Doncaster North Bridge, South Yorkshire
4. M62 New Junction 8 and widening Junction 8 to 9, new Junction 8 West Overbridge
5. Foundry Brook Bridge, Bolnore Village, Haywards Heath
6. M1 Dublin to Belfast – Northern Motorway, Lagavooren Rail Bridge
7. M74 New Cowdens Railway Bridge, Scotland
8. A828 Creagan Bridge
9. A20 Roundhill Viaduct, Folkestone, Kent
10. Cross Harbour Road and Rail Links, Belfast
11. A483 River Dee Viaduct, Clwyd
12. Ceiriog Viaduct, A5 Chirk Bypass, North Wales
13. Motorway Incident Detection and Automatic Signalling (MIDAS), Manchester Motorways Stage 4

Case Study 1
A64 Top Lane Underpass

Description
This underpass is an example of 'top-down' construction. Initially the walls are constructed by using sheet piles driven into the ground. The bankseat/pile cap is then cast onto the top of the piles followed by an integral bridge deck which consists of precast concrete beams with a concrete deck slab on top. Once the bridge deck has been completed the soil underneath the bridge deck is removed, the invert slab is cast and the carriageway is then constructed through the underpass.

Owner Highways Agency
Designer Mouchel
Contractor RMC/Dew
Value £4.1M (for complete road and structures works)
Completed 2002

Advantages of approach adopted
- The excavation works required to construct the bankseat / pile cap are kept to a minimum thus reducing the amount of space required for construction.
- The works can be carried out in distinctly separate phases thus reducing the disruption to adjacent properties / travelling public.
- There are less high-level temporary works being used to construct the bridge and as such the risks to site personnel are therefore reduced, though piling adjacent to live carriageway requires careful planning to satisfy the Health and Safety regulations.
- When the works to the bridge deck are completed traffic can immediately start trafficking the bridge deck while works to the carriageway beneath are ongoing.
- The time required to construct the bridge can be generally reduced compared with traditional cut and cover construction techniques.

Figure 18
Construction of Top Lane Underpass

Case Study 2

A350 Semington to Melksham Diversion, Canal Aqueduct

Description

Top-down construction was the contractor's alternative for this structure. It allowed early access to the bridge while keeping the diverted canal, at high level, fully operational. Piles for the abutments were installed at existing ground level prior to the deck and cantilevers being cast. The canal was diverted onto the aqueduct before removal of the 7 m deep plug. This method of construction reduced the programme by 22 weeks.

Owner Wiltshire County Council
Designer Arup
Contractor Alfred McAlpine Capital Projects
Completion March 2004

Advantages of approach adopted

- Early commencement of the Aqueduct reduced the overall programme time.
- Disruption to canal use was avoided.
- Temporary works were eliminated therefore reducing costs and improving Health and Safety.
- Easier access and egress to the structure.
- Improved timing of earthworks balance – the plug was removed when fill areas were available.
- Constructed within a better weather window.

Figure 19
Top-down construction of aqueduct

Figure 20
Completed canal aqueduct

Case Study 3
Doncaster North Bridge, South Yorkshire

Description
The ladder-beam, steel-composite deck with thin precast planks was the contractor's preferred design in this Design & Construct project. The scheme was developed to speed construction, to minimise disruption to the adjacent areas, and to increase value for the client. The 625 m long bridge has typical spans of 45 m. Each pier consists of just two circular columns, each resting on a single 2 m diameter pile. The parapet units were also precast and were then cast into the main in situ deck pours. The bridge carries the road over the electrified East Coast Main Line, the River Don and the South Yorkshire canal. The steelwork and the precast concrete planks were all erected by crane.

Owner Doncaster Metropolitan Borough Council
Designer Mott MacDonald and Robert Benaim & Associates
Contractor Amec Civil Engineering
Value £9M
Completed 2001

Advantages of approach adopted
- Precasting of soffit formwork planks ensured greater speed and quality.
- Fabrication of steelwork and casting of planks concurrent with the substructure works.
- Ladder beam layout allows use of single piles, with no pile caps.
- Fast, simple erection of steelwork and planks using crawler cranes.
- Rapid erection over railway to minimise possessions.
- Reduced risk and disruption to the railway.
- Amount of in situ works minimised.
- Ability to work on several fronts at once to speed erection.
- Completion works all took place in a safe environment.
- Parapets precast for speed and to minimise falsework.

Below left: **Figure 21**
Construction of Doncaster North Bridge

Below right: **Figure 22**
Impression of completed Doncaster North Bridge

Case Study 4

M62 New Junction 8 and widening Junction 8 to 9, new Junction 8 West overbridge

Description

The two-span semi-integral bridge was designed in concrete for ease of maintenance and construction and to aesthetically match with the existing concrete bridges along the adjacent stretch of M62 motorway. The new structure, in conjunction with an existing overbridge, will form the new Junction 8 Interchange in Warrington, Cheshire. The bridge is founded on bored and cast in situ piles and a reinforced concrete leaf pier. At the abutments the plies are sleeved through reinforced soil embankments with an in situ concrete slab. The deck is 17.5 m wide and 42.15 m in length.

Owner Highways Agency
Designer WS Atkins Consultants Limited
Contractor Costain Ltd
Value £0.75M
Completed 2002

Advantages of approach adopted

- Reinforced soil embankments could be built entirely from the rear, thereby eliminating the need for adjacent lane closures.
- The prestressed YE5 edge beams were constructed with an integral stringcourse, which negates the need for extensive in situ temporary works.
- GRP permanent formwork panels were used to enable deck construction to continue while the motorway was running below, hence minimising the number of lane closures required.

Figure 23
Construction of new overbridge

Case Study 5
Foundry Brook Bridge, Bolnore Village, Haywards Heath

Description
This 10m span underbridge selected from the Matière range of CM4 open single-cell arches forms a vital link for wildlife beneath a perimeter road around a newly built prestigious housing estate. The structure crosses a small ancient stream the banks of which were to remain undisturbed to maintain the habitat of badgers and otters. Due to the speed of construction disturbance of the area was kept to a minimum. The structure is 25 m in length and was installed in two days; this included rigging and de-rigging the 300-tonne crane.

Owner Crest Nicholson South Ltd/West Sussex County Council
Consultants Bettridge, Turner and Partners
Designer ABM Design and Build/Matière
Contractor Anderson Construction
Value £200K
Completion 2003

Advantages of approach adopted
- Precast factory production allowed valuable site resources to be deployed on other critical activities such that the developers could achieve an early return on investment.
- Due to the availability of a ready-made stock of castings moulds the exact requirements of the client were achieved avoiding a lengthy lead-in period.
- Speed of installation reduced the disturbance of wildlife in a sensitive area of conservation.
- Spandrels were constructed using reinforced earth retaining wall panels.
- The complete structure, including the highway bridge parapets is a one-stop precast concrete package.

Below left: **Figure 24**
Construction of Foundry Brook Bridge

Below right: **Figure 25**
Completed Foundry Brook Bridge

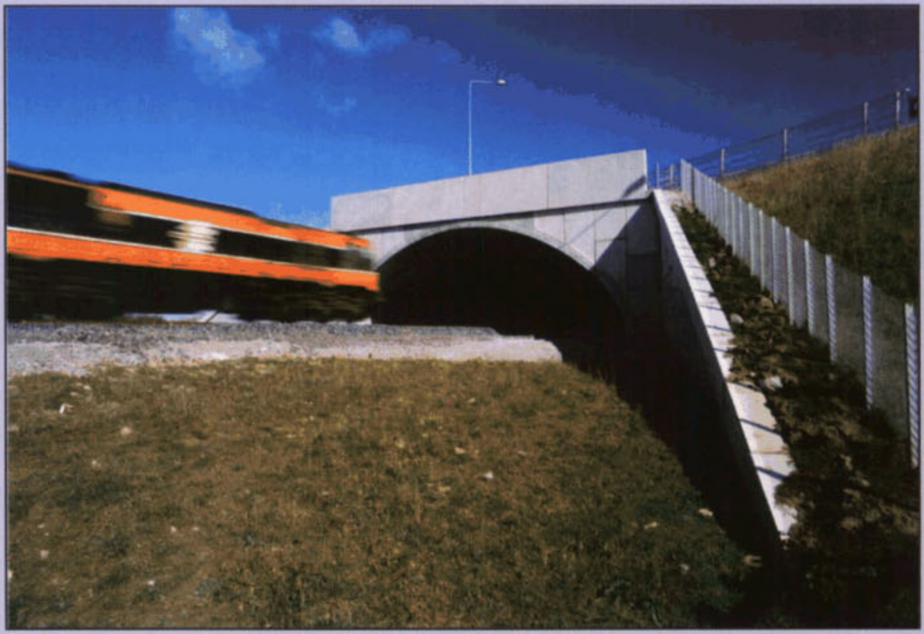
Case Study 6
M1 Dublin to Belfast–Northern Motorway, Lagavooren Rail Bridge

Description
For the section of the M1 from Balbriggan to the Boyne Bridge crossing the contractors opted for an alternative design for the Lagavooren rail bridge. A precast concrete arch with reinforced earth spandrels and wing walls was selected. Although a larger span than that originally proposed, the construction of the 17.5 m span structure enabled the contractor to dispense with major temporary works involving sheet piling close to the rail tracks. As the bridge is 105 m in length extensive use of rail possessions was avoided. The bridge structure comprising 82 'L' wall units and 41 curved roof units was installed during four days. By the use of off-site factory manufacture a structurally efficient, cost-effective and high-quality product was produced which led to ease and speed of installation on site. The travelling public reaped the benefit of the consequent early commissioning of the project.

Owner Meath County Council, Eire
Designer ABM Design and Build/Matière S.A.
Contractor Siac Construction/Laing O'Rourke
Value £1.1M
Completion 2003

Advantages of approach adopted
- Structurally efficient design.
- Major temporary works avoided close to railway.
- Speed of installation.
- Saving in costly rail possessions.
- Factory-produced high-quality products.
- Site resources available to concentrate on other operations made critical by early completion of bridge.
- Opportunity for Rail Authority to increase track capacity.
- Early commissioning of motorway.
- Reduction in overall costs.

Figure 26
Lagavooren Bridge over railway



Case Study 7

M74 New Cowdens Railway Bridge, Scotland

Description

The precast, two-pinned arch was a contractor's alternative design that was developed to speed construction, to minimise disruption to the railway and to increase value for the client. The 190 m long, precast reinforced concrete arch has a clear span of 21 m. The arch carries the M74 over the electrified West Coast Main Line with a rise of over 8 m to clear the catenaries. The arch units were precast on site and erected by tandem crane lifts in two halves. They were stitched together circumferentially and at the crown with reinforced concrete. All the 3.2 m long, precast units were erected within a single weekend possession. The structure won a Saltire Design Commendation in 1995.

Owner Scottish Development Department
Designer Robert Benaim & Associates
Contractor Balfour Beatty Construction (Scotland)
Value £4M
Completed 1994

Advantages of approach adopted

- Precast arches replaced in situ retaining walls and precast beams.
- A more efficient structure.
- Casting in standard units in factory conditions ensured greater speed and quality.
- Casting of arches was concurrent with the substructure works.
- Faster to erect.
- Erected in a single weekend possession.
- Reduced risk and disruption to the railway.
- No in situ works requiring craneage next to the railway.
- Minimal completion works all took place in a safe environment.

Below left: **Figure 27**
Construction of New Cowdens Railway Bridge

Below right: **Figure 28**
Overview of New Cowdens Railway Bridge

Case Study 8
A828 Creagan Bridge

Description

The A828 Trunk Road links the towns of Connell and Ballachulish on the west coast of Scotland. The contract eliminated a 9 km long journey round the shores of Loch Creran by constructing a 1.2 km long diversion on the line of the abandoned West Highland Railway. New twin steel plate girders were installed on the existing granite piers of the old 150 m long Creagan railway bridge, which were strengthened to meet modern standards. A total of 43 full-width precast concrete deck units, complete with side parapet upstands, were installed using a crane on the bank. In situ concrete stitches and a 100 mm thick upper layer were used to make the units act compositely with the girders.

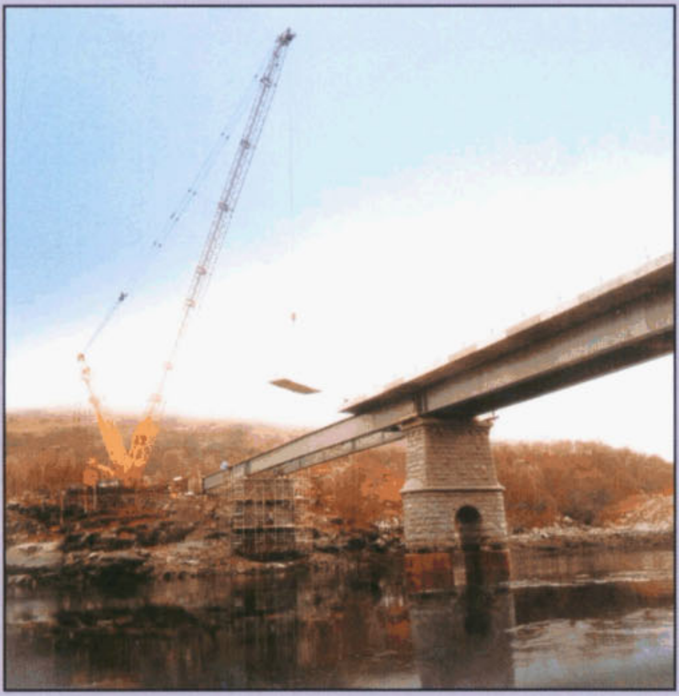
Owner The Scottish Office
Designer Carl Bro
Contractor Balfour Beatty
Value £3.4M
Completed 1999

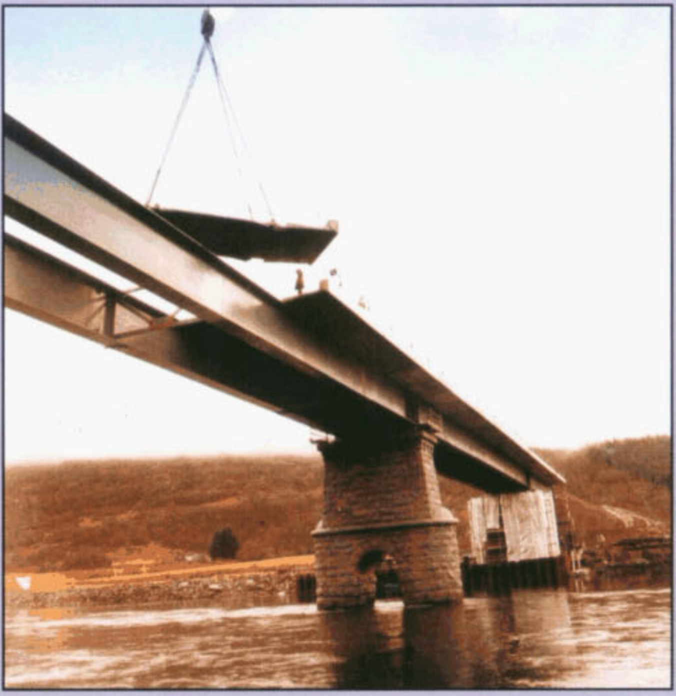
Advantages of approach adopted

- Prefabrication of deck units in controlled environment.
- Rapid erection of precast units over the fast-flowing tidal loch.
- Use of full-width deck units, complete with side parapet upstands, eliminated the need for falsework.
- Significant reduction in contract period.

Below left: **Figure 29**
General view of construction of Creagan Bridge

Below right: **Figure 30**
Installing precast units on Creagan Bridge





Case Study 9
A20 Roundhill Viaduct
Folkestone, Kent

Description
An alternative design of two viaducts built using the glued segmental balanced cantilever system. Individual viaduct lengths of 340 m and 384 m are made up of spans typically of 60 m and 63 m. The viaducts form part of the road improvements for the A20 Folkestone to Dover route. A complete redesign of the supporting columns and foundation was also undertaken taking into consideration the Channel Tunnel, which crossed the site within 1 m of the finished ground level.

Owner Department of Transport
Designer Tony Gee and Partners
Contractor Birse Construction Ltd
Value £9M
Completed 1993

Advantages of approach adopted
- Precast segmental deck construction shortened construction time.
- Repetition in construction saved time and costs.
- Factory conditions for casting of segments improved quality.
- Erection by crane provided flexibility in construction programme.
- Minimised falsework.
- Efficient and economic design achieved.
- Aesthetically pleasing appearance.

Below left: **Figure 31**
Overview of Roundhill Viaduct

Below right: **Figure 32**
Construction of Roundhill Viaduct

Case Study 10
Cross Harbour Road and Rail Links, Belfast

Description
The precast segmental decks, erected in balanced cantilever, were the contractor's preferred design in this Design & Construct project. The scheme was developed to speed construction, to minimise disruption to the adjacent areas and to increase value for the client. The 2.5 km long, prestressed concrete viaducts have spans between 28 m and 83 m. The bridges carry both motorway and railway over the River Lagan. The 1,060 segments, weighing from 55 to 95 tonnes, were precast close to the site and were all erected by crane. The structure won a Concrete Society Commendation in 1995.

Owner Department of the Environment, Northern Ireland
Designer Acer and Robert Benaim & Associates
Contractor Graham- Farrans JV
Value £36M
Completed 1994

Advantages of approach adopted
- Casting in similar segments in factory conditions ensured greater speed and quality.
- Casting of segments on a daily cycle was concurrent with the substructure works.
- Fast, simple erection using crawler cranes and temporary bars.
- Up to six segments erected on temporary bars alone, to take permanent stressing off the critical path.
- Simple falsework prop off (and ties to) the pile caps provided stability.
- Reduced risk and disruption to adjacent traffic.
- Minimal in situ works to complete the structure.
- Ability to work on several fronts at once to speed erection.

Below left: **Figure 33**
Overview of Cross Harbour Link

Below right: **Figure 34**
Construction of Cross Harbour Link

Case Study 11
A483 River Dee Viaduct, Clwyd

Description
The in situ concrete deck, erected in balanced cantilever, was a contractor's alternative design that was developed to speed construction and to increase value for the client. The 350 m long, prestressed concrete viaduct has spans between 55 m and 83 m. The bridge carries the road over the steep-sided valley of the River Dee, on piers up to 50 m high. Pairs of cantilevering deck segments, each 3.6 m long, were cast on a weekly cycle. This alternative was promoted particularly to reduce the overall construction period by a complete winter season. The structure won the Concrete Society Award in 1991.

Owner The Welsh Office
Designer Travers Morgan and Robert Benaim & Associates
Contractor Edmund Nuttall
Value £4M
Completed 1990

Advantages of approach adopted
- Fully prestressed structure replaced part-prestressed, part-reinforced structure.
- A more efficient structure.
- Casting similar segments in controlled conditions ensured greater speed and quality.
- Repetitive weekly casting cycle ensured delivery to programme.
- Faster to cast, saving a complete season.
- No need for any falsework to the ground.
- Permanent piers used to provide stability, avoiding temporary towers.
- All concrete cast in the travelling shutters on the deck.
- Ability to work on several cantilevers at once to speed casting.
- No completion works necessary.

Below left: **Figure 35**
Completed River Dee Viaduct

Below right: **Figure 36**
Construction of River Dee Viaduct

Case Study 12
Ceiriog Viaduct, A5 Chirk Bypass, North Wales

Description
A high level, incrementally launched, concrete, box girder, seven-span viaduct. Situated in an area of scenic beauty, the design was subject to the approval of the Royal Fine Art Commission. The method of construction, while requiring the contractor to work to very close tolerances, resulted in many benefits including ease of supervision, all-weather construction and the ability to incorporate safety rails and finishes in the concrete casting area.

Owner Welsh Office Department
Designer Tony Gee and Partners
Contractor Christiani & Neilsen
Value £5.25M
Completed 1991

Advantages of approach adopted
- Minimised falsework needed.
- Minimised disruption to valley and surroundings.
- Factory conditions for casting concrete.
- Repetition in construction saved time and costs.
- Aesthetically pleasing appearance.

Below left: **Figure 37**
Construction of Ceiriog Viaduct

Below right: **Figure 38**
Overview of Ceiriog Viaduct

Case Study 13

Motorway Incident Detection and Automatic Signalling (MIDAS), Manchester Motorways Stage 4

Description

Conventional motorway sign gantries span one carriageway. The design and nature of this contract enabled Alfred McAlpine to develop an alternative concrete beam design to span both carriageways, thus eliminating the need for support legs in the central reservation. The beams were 40.4 m long prestressed concrete, weighing 120 tonnes each and were lifted into position with a 650-tonne mobile crane (one of only two in the UK). The erection of each beam was carried out at night using extensive traffic management and a police rolling block to close the motorway for up to 20 minutes. A total of 34 gantries were erected over a period of three months.

Client Highways Agency
Project Manager W.S. Atkins
Main Contractor (Design & Build) Alfred McAlpine Capital Projects
Contractor's Designer Parkman
Completion November 2001

Advantages of approach adopted

- Elimination of central reserve gantry support legs.
- Improved safety and reduced public disruption during construction due to elimination of central reserve works.
- Improved long-term public safety due to elimination of central reserve safety fence.
- Cost savings in comparison with two conventional gantries.
- Reduced environmental impact.
- Enhanced long-term maintenance due to improved accessibility via verge gantry support legs.

Below left: **Figure 39**
Installation of gantry

Below right: **Figure 40**
Completed gantry

8. References

1 *Control of Substances Hazardous to Health Regulations*, SI 437, 1999. The Stationery Office.
2 EGAN, J. *Rethinking construction*, Department of Trade and Industry, London, 1998.
3 PLACE, D. Relief for the A34/M4 bottleneck, *Concrete*, October 2004, pp. 23–24.
4 CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION, *Permanent formwork in construction*, (Prepared by Wrigley, R G), Report C558, The Construction Industry Research and Information Association, London, 2001.
5 ANON, The Flintshire Bridge, *Concrete*, October 1999, pp. 12–14.
6 HIGHWAYS AGENCY, BA 36/90, *The use of permanent formwork*.1990.
7 BRITISH STANDARDS INSTITUTION, BS 8500, *Complementary British Standard to BS EN 206-1 Concrete*, BSI, London 2002.
8 BRITISH STANDARDS INSTITUTION, BS EN 206, *Concrete*, Part 1, *Specification, performance, production and conformity*, BSI, London 2000.
9 CONCRETE BRIDGE DEVELOPMENT GROUP, *Self-compacting concrete in bridge construction*, 2005.
10 CONCRETE BRIDGE DEVELOPMENT GROUP, *High strength concrete in bridge construction*, 2005.
11 HIGHWAYS AGENCY, BD43/03, *The impregnation of reinforced and prestressed concrete highway structures using hydrophobic pore-lining impregnation* 2003.
12 CONCRETE SOCIETY, *Towards rationalising reinforcement for concrete structures*, Technical Report 53, The Concrete Society, Camberley, 1999, p. 40.
13 INSTITUTION OF STRUCTURAL ENGINEERS, *Guide to the structural use of adhesives*, The Institution of Structural Engineers, London, 1999.
14 HIGHWAYS AGENCY, BA 42/96 (including Amendment 1, May 2003), *The design of integral bridges*.1996.
15 WEINMANN, P. The Matière system evolution, *Concrete Engineering International*, Vol. 7, No. 4, Winter 2003, pp. 31–32.
16 DRAYCOTT, I. Sir Thomas Fairfax Bridge spans the Weaver, *Concrete*, October 2004, pp. 33–34.
17 DONALD, P T, KNIGHT, R G W & BOURNE, S D. The design and construction of the cross-harbour road and rail bridges, *Proceedings of the Institution of Civil Engineers, Transport*, Vol. 117, February 1996, pp. 28–39.
18 COLLINGS, D. The A13 Viaduct, *Concrete*, January 1999, pp. 30–33.
19 THOMAS, C G & BOURNE, S D. River Dee Viaduct: construction, *Proceedings of the Institution of Civil Engineers*, Part 1, Vol. 90, April 1991, pp. 259–280.
20 HEWSON, N & HODGKINSON, A. Incremental launch of Brides Glen Bridge, Ireland, *Concrete*, July/August 2004, pp. 29–31.
21 PARKER, J S, HARDWICK, G, CARROLL, M et al. Hungerford Bridge millennium project – London, *Proceedings of the Institution of Civil Engineers, Civil Engineering*, May 2003, pp. 70–77.
22 POWDERHAM, A, TAYLOR, S & WILSON, D. Moving structures – Jacked tunnels on the Central Artery, Boston, USA, *The Structural Engineer*, Vol. 81, No. 18, 2003.
23 DEANE, C. Box jacking on the M1 – first for UK, *Concrete*, October 2003, pp. 24–25.

CONCRETE BRIDGE DEVELOPMENT GROUP

The Concrete Bridge Development Group aims to promote excellence in the design, construction and management of concrete bridges.

With a membership that includes all sectors involved in the concrete bridge industry – bridge owners and managers, contractors, designers and suppliers – the Group acts as a forum for debate and the exchange of new ideas. A major programme of bridge assessment, strengthening and widening is already underway to accommodate European standards and the increasing pressures on the UK road network. The Group provides an excellent vehicle for the industry to co-ordinate an effective approach and to enhance the use of concrete.

Through an active programme of events and seminars, task groups, newsletters, study visits and publications, the Concrete Bridge Development Group aims to:

- Address the challenge of the national bridge programme.
- Provide a focus for all those involved in concrete bridge design, construction and management.
- Promote an integrated approach and encourage development of innovative ideas and concepts.
- Promote best practice in design and construction through education, training and information dissemination.
- Make representations on national and international codes and standards.
- Identify future research and development needs.
- Maximise opportunities to develop the wider and better use of concrete.

Membership of the Concrete Bridge Development Group is open to those who have an interest in promoting and enhancing the concrete bridge industry. Five main types of membership are available:

- Group membership for industry organisations and associations
- Corporate membership for contractors, consultants, suppliers and specialist service companies
- Associate membership for academic organisations
- Bridge owners for all organisations that commission, own, maintain and manage concrete bridges
- Individual consultants

By being representative of the whole industry, the Concrete Bridge Development Group acts as a catalyst for the best in concrete bridge design, construction, maintenance and management.

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UPC

Fast Construction of Concrete Bridges: A state-of-the-art report

Society and the construction industry are continually setting targets where speed is of the essence. It is necessary for concrete construction to remain innovative and competitive in this environment. Adequate pre-planning, precasting of elements and the use of appropriate technology in design and construction can make concrete the cheapest and fastest material for bridge construction, without sacrificing quality and durability.

This report has been produced by a task group set up by the Concrete Bridge Development Group, to bring together construction methods and details that are recognised as contributing to speeding up the construction of concrete bridges. It sets out to help clients, developers, designers and contractors to understand better the factors that contribute to fast construction and to appreciate some essential requirements and consequences of achieving a short delivery period.

Fast bridge construction in this context means any bridgework that improves upon traditional performance, whether this is a faster overall construction period or a speedy installation process. However, it is essential that quality should not be sacrificed for the sake of speed; any decision regarding the construction process must not compromise the long-term performance of the structure.

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