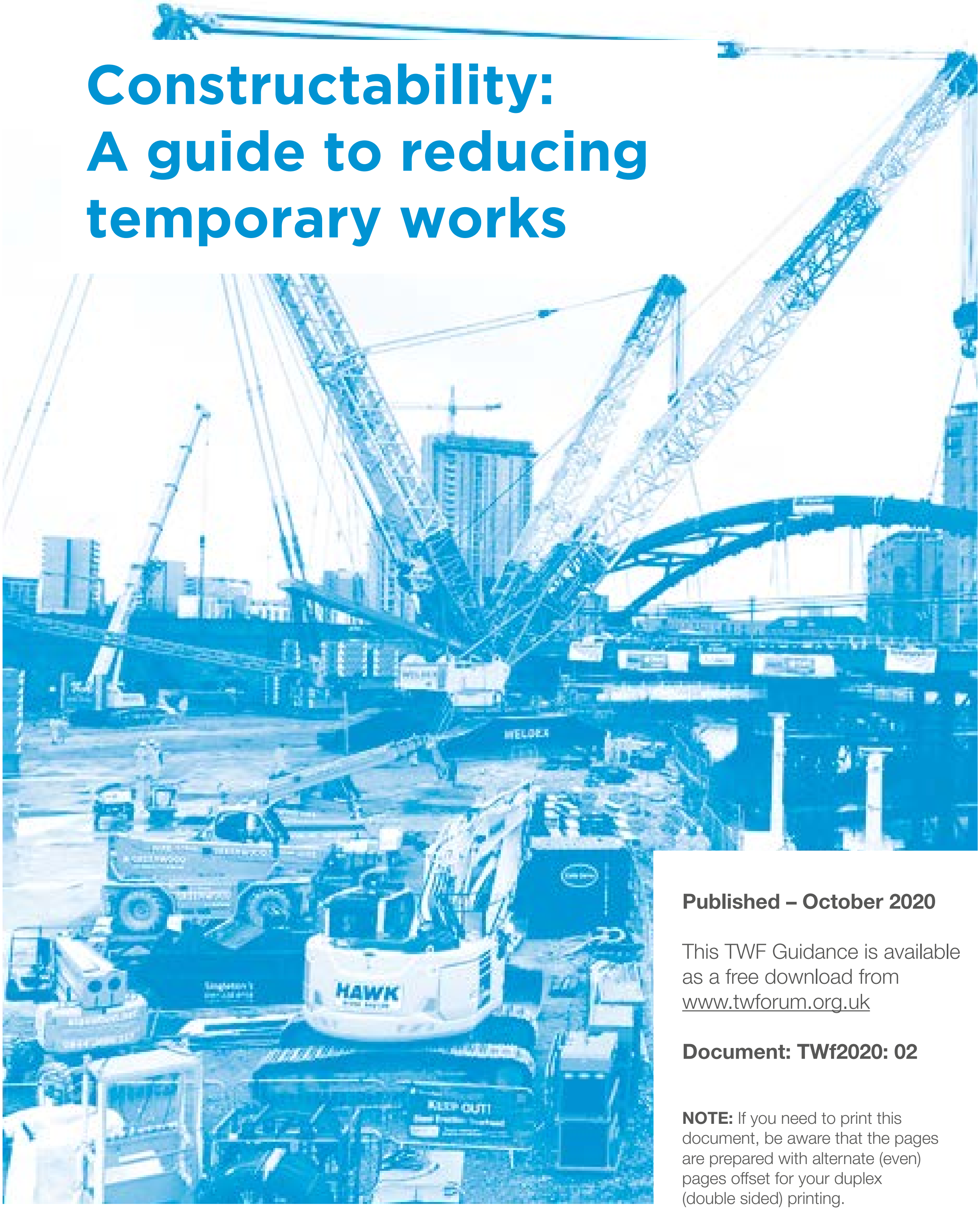
Constructability: A guide to reducing temporary works



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Temporary Works forum

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Editorial note

The information provided in Chapters 6 to 8 is available in 'Word' format on the Temporary Works Forum (TWf) website (www.twforum.org.uk . . . select . . . Resources/ Library Folders/TWfGuidance). These lists do not set out to be prescriptive and should be amended to suit individual company operations and preferences. They may be updated from time-to-time (and the Secretary invites contributions to them (secretary@twforum.org.uk).

Synopsis

This guide provides a definition of what is meant by "constructability"; guidance on the legal requirements on clients and designers; and suggests aspects of constructability that should be considered throughout the project lifecycle. The principles can be applied to any size or type of project, from conception to decommissioning. The guide also contains suggested further reading and examples where the principles have been applied successfully.

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Readers should note that the documents referenced in this TWf Guide are subject to revision from time to time and should therefore ensure that they are in possession of the latest version.

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1.0 Introduction

This document aims to provide guidance to all those in project teams on the consideration of constructability.

1.1 The constructability of a project results from decisions made by the client, architect, designer(s) and contractor(s) at the pre-project, options, development, construction and decommissioning/ demolition phases on aspects such as location, land-take, form, programme and cost.

1.2 For the purpose of this guidance the following definition is adopted[1]:

Constructability

> *"the extent to which the design of a building or construction project and its environment facilitates ease of construction, subject to the overall requirements of the building or construction project and its environment."*

Source: Network Rail Safe by Design, Guidance Note – Early Focus on Constructability and Temporary Works (2019) **[1.]**

1.3 This guidance makes recommendations for the stages when it is sensible to consider the constructability of the project. It also identifies some of the factors that affect constructability and which are common to many sites. Finally, it gives examples of projects where constructability has been considered early in the project development and incorporated into the design; and other projects where details of the design have left room for improvement.

1.4 The practical result of considering constructability during the development and design stages is that projects will be easier to build.

NOTE: A peer review may include some aspects of a constructability review.

2.0 Statutory legal aspects

2.1 Constructability should be considered by the client, the designer(s) and the contractor(s). The legal aspects of constructability are many and varied. The following extracts highlight key issues in the Construction (Design and Management) Regulations 2015 (CDM2015) **[2.]**[2] with which the reader should be familiar:

Regulation 4 - Client duties in relation to managing projects

4.—(1) A client must make suitable arrangements for managing a project, including the allocation of sufficient time and other resources.

(2) Arrangements are suitable if they ensure that—

(a) the construction work can be carried out, so far as is reasonably practicable, without risks to the health or safety of any person affected by the project; ….

2.2 In relation to designers:

Regulation 8 - General duties

8. - (1) A designer (including a principal designer) or contractor (including a principal contractor) appointed to work on a project must have the skills, knowledge and experience, and, if they are an organisation, the organisational capability, necessary to fulfil the role that they are appointed to undertake, in a manner that secures the health and safety of any person affected by the project.

Regulation 9 Duties of designers

9. - (2) When preparing or modifying a design the designer must take into account the general principles of prevention and any pre-construction information to eliminate, so far as is reasonably practicable, foreseeable risks to the health or safety of any person ….

2.3 The role of the designer is recognised in HSE Guidance:

> *"A designer has a strong influence during the concept and feasibility stage of a project. The earliest decisions can fundamentally affect the health and safety of those who will construct, maintain, repair, clean, refurbish and eventually demolish a building …"*

Source: HSE, L153, Para 75 **[3.]**

2.4 CIRIA has published Construction work sector guidance for designers (C755) **[4.]**. The document has been produced to assist designers in complying with CDM2015, Regulations 8, 9 and 10. It provides a description of the risks typically associated with various construction methods and how the designer can consider overcoming them.

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[1] *'Constructability' isn't new and other definitions and terms have been in use for many years. See Appendix 1.*

[2] *CDM came effect first on 31st March 1995 as the Construction (Design and Management) Regulations 1994, following the introduction of European Directive 92/57/EEC on the minimum safety and health standards for temporary or mobile construction sites. The Regulations were, and still are, aimed at improving the overall management and co-ordination of health, safety and welfare throughout all stages of a construction project. They place duties on all those who can contribute to the health and safety of a construction project: clients, designers and contractors.*

2.5 C755 states:

> *"Designers have to weigh many factors as they prepare their designs. H&S considerations have to be weighed alongside other considerations, including cost, fitness for purpose, aesthetics, buildability, maintainability and environmental impact. …"*

and provides a discourse[3] on the issues that should be taken into account.

2.6 It repeats the definition in L153 of what is meant by the term *reasonably practicable*[4] and contains some salutary advice 9 *[emphasis added]*:

> ***"There is a feeling that after an accident, in retrospect, it is always obvious what more could have been done to prevent it occurring. Any decision in which cost plays a major part will be likely to be (in retrospect) particularly criticised."***

2.7 BS 5975: 2019 **[5.]**, states:

> *8.1.2 Designers should address the buildability of permanent works, temporary works, their interfaces, their proposed methods of construction and any related design assumptions.*
>
> *8.3.1 Permanent works designers should address the buildability of the permanent works and identify, and make provision for, any temporary works and temporary conditions required by their design and their assumed method of construction …*

2.8 The Management of Health and Safety at Work Regulations 1999 **[6.]** were the first to set out the requirements for 'risk assessment' (Reg. 3) and introduced the 'general principles of prevention' (Reg. 4). The latter are summarised in CDM2015 **[3.]** as an hierarchy[5]:

a) avoid risks

b) evaluate the risks which cannot be avoided

c) combat the risks at source

d) adapt the work to the individual, especially regarding the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work, work at a predetermined work rate and to reducing their effect on health

e) adapt to technical progress

f) replace the dangerous by the non-dangerous or the less dangerous

g) develop a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment

h) give collective protective measures priority over individual protective measures

i) give appropriate instructions to employees

2.9 In summary[6], the legal context to the need to consider constructability has been around for many years. The concept is not new.

3.0 Construction process

3.1 The construction process is the delivery of the whole permanent works. The permanent works are usually an assembly of component parts. There is an interdependent relationship between the choice of component and method of assembly.

3.2 Components are defined by their material, size, shape, weight and structural properties. These may be dependent on the manufacturing process, any post-processing assembly, the weight that can be lifted, the position that they can be supported in during the temporary stage(s), the stability of the component(s) under their own self weight and environmental loads and the way in which they are incorporated into the other permanent works.

3.3 These are in turn affected by the availability of raw materials, skilled workforce, manufacturing facilities, transport, the type and size of plant and any limitations on access and egress arrangements. Where transport is problematic the smallest transported components are - for example - clay bricks, bagged cement, steel reinforcing bars, locally won sand and aggregate, locally sourced timber. It may also be feasible to set up on site pre-assembly manufacturing facilities (e.g. from concrete batching plants to production lines for match-cast segmental concrete bridges).

3.4 Constructability exists on a varying scale and every structure (or building) has overall requirements which may necessitate some degree of compromise.

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[3] *C755, Section 1.4.6*

[4] *The term 'reasonably practicable' has been defined as: "balancing the level of risk against the measures needed to control the real risk in terms of money, time and trouble. However, you do not need to take action if it would be grossly disproportionate to the level of risk. (See www.gov.uk/risk/faq.htm for the most up to date explanation of what 'reasonably practicable' means)" (Source: Glossary of acronyms and terms, L153 (HSE, 2015) [3.])*

[5] *This hierarchy is often referred to as 'ERIC' – **E**liminate, **R**educe, **I**nform and **C**ontrol*

[6] *There may be commercial and/or contractual aspects in the delivery of a project, not considered here*

3.5 In some instances, a design which increases the material content of the permanent works but reduces the need for temporary works may be safer, less disruptive, more cost-effective, more carbon-efficient and cheaper. For example, the overall combination of factors should be aggregated and where a more substantial permanent works solution might significantly reduce the temporary works required then this should be given due consideration as the preferred solution, particularly where it results in reduced construction time and risk exposure on site.

3.6 Decisions made about the design of the permanent works have a fundamental impact on the materials available, even at early stages.

3.7 The plant and techniques which are available to the constructor evolve constantly. For instance, in the 25 years since the drafting of CIRIA R155 **[7.]** and CIRIA C543 **[8.]** there has been an increase in the capacity of cranage, allowing larger parts of the construction to be prefabricated/pre-assembled and lifted into position (so minimising the need for insitu falsework and formwork and reducing the impact on the site) as well as self-propelled modular transporters (SPMTs).

4.0 Background

Constructability; temporary works; safety; construction methodology

4.1 For many years the typical form of procurement was for a Client to have separate contracts with the Engineer and Contractor. The Contractor built what the Engineer specified and there was little opportunity to suggest improvements in design which would increase buildability and reduce cost, risk and project duration. This contract arrangement was also thought to lead to poor project delivery, quality of finished construction, delays, cost overruns and claims[7].

4.2 These issues led to a general change in the typical forms of procurement to the Early Contractor Involvement (ECI) and Design and Build (D&B) contracts common today. The intention is that the constructor is allowed to input ideas at an earlier stage, enabling more effective communication, improving design empathy for production and simplifying construction techniques. In some cases the Client enters into a contract with a single administrative party who then delivers the whole project. In theory, the designer and constructor are an integrated team with the function of delivering the project (CIRIA C534 **[9.]**).

4.3 There remain some challenges in the UK of the resulting arrangements, which do not appear to have delivered all the improvements sought[8], but in respect of the consideration of temporary works these forms of procurements have advantages.

5.0 Procurement models (UK)

5.1 There are now several programme management models within the UK construction industry which define the progress of the project through the stages from initial briefing to final completion, including:

- Network Rail ‘Governance for Railway Investment Projects (GRIP)’ (2018) **[10.]**
- Highways England ‘Project Controls Framework’ v4 (2018) **[11.]**
- Royal Institute of British Architects (RIBA) ‘Plan of Work’ (2013) **[12.]**
- Office of Government Commerce ‘Gateway Review Process’ (2011) **[13.]**
- Institution of Structural Engineers ‘The Structural Plan of Work’ (2020) **[14.]**

5.2 All the procurement methods follow a similar pattern (see Figure 1):

- pre-project
- options phase
- development phase
- construction phase (to ‘completion’ or ‘hand back’)
- use phase (including operation and maintenance)
- decommissioning / demolition phase

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[7] *UK: Emerson 1962; Banwell 1964; EDC 1967; Wood 1975; CIRIA 1983; CIRIA 1989; Latham 1994; Egan 1998; USA: ASCE 1974; CII 1986; CII 1987; Australia: Gyles 1992*

[8] *NAO 2001; RCTF 2001; SFC 2002; NAO 2005; Wolstenholme 2009; Laidlaw 2012; May 2013; CO 2013; HMSO 2013; Public Accounts 2016*

Figure 1 - Summary of some programme management models (UK)

	Pre-project/ Initiation		**Options phase**		**Development phase**				**Construction phase**	**Use/operation**		**End of use and demolition**
HE Project Control Framework (PCF) 2008	**0** Strategy shaping and prioritisation		**1** Option identification	**2** Option selection	**3** Preliminary design	Decision point: **4** Statutory procedures and powers	**5** Construction preparation		**6** Construct, commission and handover		**7** Closeout	End of use, decommissioning and demolition may have such significant consequences that it is appropriate to use the full project/ programme management model for this stage (from pre-project to implementation)
Network Rail GRIP	**1** Output definition	**2** Feasibility		**3** Option selection	**4** Single option development	**5** Detailed design			**6** Construct, test and commission	**7** Scheme hand back	**8** Project closeout	
RIBA Plan of Work 2013	**0** Strategic definition	**1** Preparation and brief		**2** Concept design	**3** Developed design	**4** Technical design			**5** Construction	**6** Handover and closeout	**7** In use	
Construction Industry Council (CIC)	**Stage 1** (Preparation)			**Stage 2** (Concept)	**Stage 3** (Design development)	**Stage 4** (Production information)			**Stage 5** (Manufacture, installation and construction information)	**Stage 6** (Handover and closeout)	**Stage 7** (In use)	
The Structural Plan of Work 2020 (IStructE)	**0** Strategic definition			**2** Concept design	**3** Spacial coordination	**4** Technical design	**4.5** Production information		**5** Manufacturing and construction	**6** Handover	**7** In use	

5.3 The consequences of the end of use, i.e. the decommissioning and demolition phases, may in themselves be significant enough that it would be appropriate to consider all these stages in this approach, e.g. from pre-project through to use (including operation and maintenance).

5.4 Irrespective of the management model adopted, constructability reviews should be undertaken.

6.0 Constructability principles

There have been many works published recently on the subject of "Lean Construction". However, the application of science to manufacturing is not new. To help achieve a sense of perspective, the following are offered:

Charles Babbage (1791-1871)[9]

Charles Babbage was credited as the inventor of the digital (mechanical) computer and his ideas helped shape the "Industrial Revolution" as well as the Victorian expansion in manufacturing.

Fredrick Taylor (1856-1915)[10]

Fredrick Taylor was one of the first Management Consultants. His legacy to us is: knowledge management; quality assurance; operational research; and lean manufacturing.

6.1 Lean construction

6.1.1 'Lean' in its simplest form means eliminating waste from everything we do.

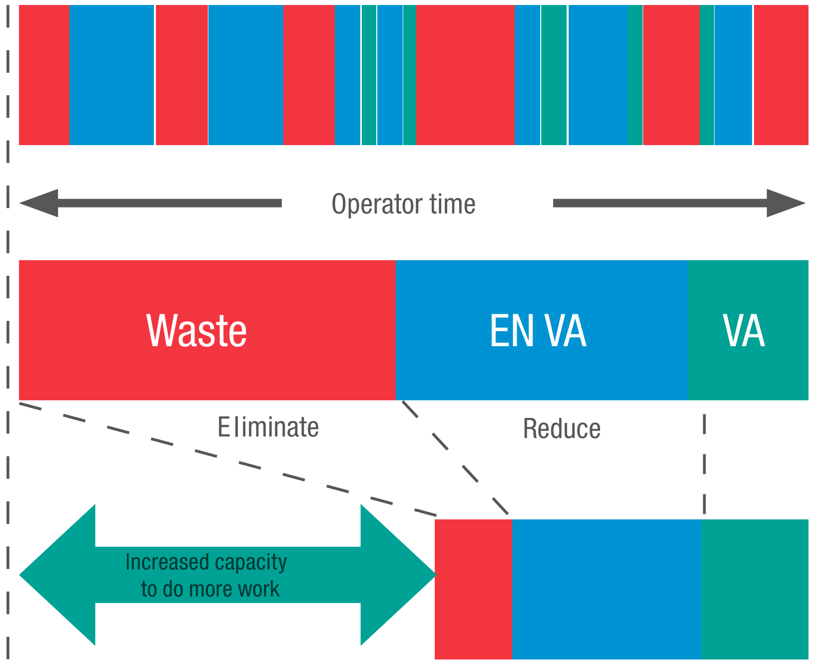
6.1.2 Essentially, 'lean' is a collection of 'Work Study and Operational Research' techniques some of which have been used for decades. These techniques have been used by contractors to gain a competitive edge. It has now been re-branded and is covered by a suite of CIRIA guides[11]. One of most valuable concepts is the definition of waste in CIRIA C730 **[15.]** (see Figure 2):

6.1.3 Applied simply to construction:

Value adding (VA) = permanent works

Essential non-value adding (enVA) = temporary works

Waste = waste and inefficiency



Any work activity will comprise all three elements of work. It **is usual to find that value-**adding (VA) content will be a lot less than other elements.

When improving the way work is carried out:

Step 1: aim to eliminate waste

Step 2: improve the way ENVA is carried out

Step 3: improve efficiency of VA

Lean improvement reduces the time taken to carry out a particular task, releasing more capacity: 'more for the same' or 'more for less'.

Figure 1.1 Eliminating waste

Figure 2 – Defining waste

Source: CIRIA C730, Lean tools and techniques – an introduction

[9] *Babbage wrote, "On the Economics of Machinery and Manufactures" (1832). This book described differentiating task with skills, bonus systems, "piece work" and profit sharing. His ideas are said to have influenced Marx.*

[10] *Taylor wrote the very influential book, "The Principles of Scientific Management" (1911). It is reported that his principles have been adopted by everyone from Henry Ford to Lenin, Trotsky and Stalin.*

[11] *CIRIA: Implementing Lean in Construction (RP978); Build Lean (C696); Lean construction and BIM (C725); Lean and the sustainability agenda (C726); Lean benefits realisation management (C727); A Lean guide for client organisations (C728); Selecting and working with a Lean consultant (C729); Lean tools and techniques – an introduction (C730); Health and Safety Synergies of Lean (C769)*

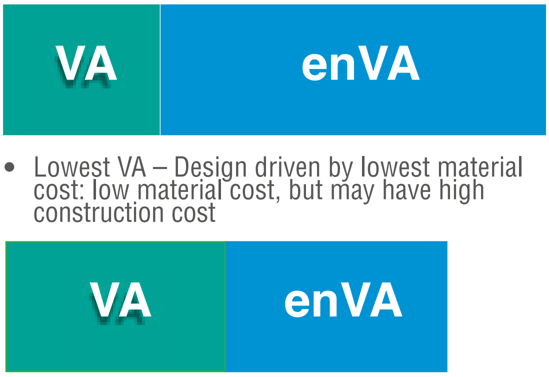
6.2 Low carbon design

6.2.1 The term embodied carbon is used to describe the greenhouse gas (GHG) emissions associated with the production of materials or products to the factory gate. Carbon dioxide equivalent (CO2e) is used as a proxy for the impact of different greenhouse gases included in carbon assessments. In line with PAS 2080: 2016, Carbon management in infrastructure **[16.]**, carbon assessments should consider the whole life of the asset from manufacture of materials, through construction, operation and end of life. To this end the trade-offs between more carbon intensive stages can be made with other lower carbon stages. However, often the scope is limited to embodied carbon assessments that are carried out without consideration of construction techniques or temporary works.

6.2.2 Cost is also subject to the some of the same drivers as carbon (In general terms more embodied carbon equals more cost **[17.]**). This can lead to designs which at first sight appear efficient because they have low "Value Adding" (VA) content but require more temporary works - "essential non-Value Adding" (enVA) - content to construct them.

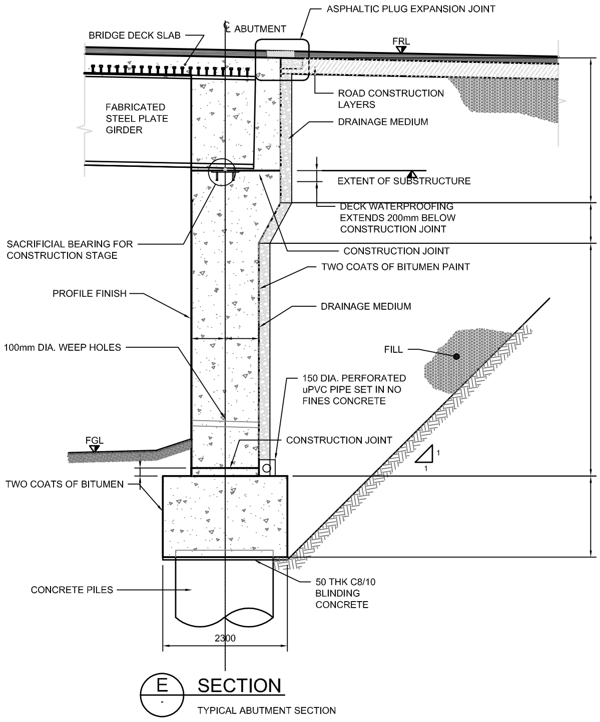
6.2.3 It may be cheaper overall - and therefore produce less embodied carbon - to construct permanent works with a higher material content and which requires less temporary works, i.e. is easier to build (see Figure 3 and Figure 4).

6.2.4 The permanent works designer (PWD) needs to engage with the temporary works designer (TWD) to ensure greater consideration of constructability, e.g. through constructability reviews.



- Lowest VA – Design driven by lowest material cost: low material cost, but may have high construction cost
- Lowest enVA - Design driven by lowest construction cost: material costs may be higher, but the construction costs are lower
- The overall cost of the project is a combination of material and construction costs. A project with greater material content may be sufficiently lower in construction cost for this to be the most economic solution

Figure 3 – Consequences of different approaches to constructability



In this instance the designer aimed to make savings by reducing the thickness of the abutment wall below the level of the bearing shelf.

While reducing the concrete content of the wall the complexity of the reinforcement detailing and the formwork costs were increased.

A straight wall would have resulted in simpler and cheaper reinforcement, reduced formwork costs, exposure to less risk and faster construction.

Figure 4 – Example of a design driven by material reduction rather than constructability

6.3 Off-site fabrication - aspects of construction that can influence the design

6.3.1 The plant available for construction is constantly evolving.

6.3.2 Developments in fabrication facilities, transportation and means of placing (e.g. larger cranes, SPMTs) allow structures to be constructed from components of greater size. This can reduce the need for in-situ falsework and formwork and so reduce the work on the site.

6.3.3 Sections 6.4 to 6.7 list some of the aspects of the construction process that can influence the design for off-site fabrication:

- Reasons to consider off-site construction (see 6.4)
- How the components get to and across site (see 6.5)
- The design of fabricated elements required to be lifted or moved (see 6.6)
- The handling and installation of pre-fabricated elements on site (see 6.7)

6.3.4 Similarly, some of the design choices will affect the construction. They should be adapted by the reader to suit their own project-specific needs.

6.3.5 Designers should be aware of the problems the Contractor will face. However, to obtain the best solution dialogue with the contractor (a construction method specialist) should be arranged.

6.4 Reasons to consider off-site construction

6.4.1 There are many reasons to consider off-site construction:

- Enhance safety - e.g. to avoid building at height or over water; avoid live transport routes.
- Less interfaces to manage on site.
- Potential reduction in the amount of temporary works required on site (and the associated reduction in risk exposure for site workers)
- Absence of foundations and working space available beneath the structure, e.g. in rivers, over valleys, on poor ground, or above roads, railways, sewers and tunnels.
- Potential disruption to adjacent sites, e.g. when working near or over railways and/or roads.
- Absence of or unsuitable working space adjacent to (or above) the structure, e.g. in a congested city centre site, near airports, under overhead lines.
- Limited period of access to the site, e.g. rail or road possession, tidal working.
- Presence of obstructions, e.g. something already on site, especially if an existing structure is being replaced.
- Potential for an improvement in programme delivery, e.g. working on several different parts of the project concurrently.
- Protection from the environment during fabrication.
- Potential reduction production costs.
- Improved quality control, e.g. concrete finishes, welding, etc.

6.5 How the components get to and across site

6.5.1 There are many issues to be considered when assessing any access route(s), i.e. how the components get to and across site:

- Components and/or plant being delivered to and across site:
  - weight
  - dimensions including protrusions
  - number of vehicles
- Restrictions on the existing route:
  - width; height restrictions under, through bridges and/or tunnels; between buildings
  - length restrictions, e.g. tight bends, street furniture
  - gradient of road route
  - weight restrictions, e.g. bridges, roads
  - availability of railway (viz. route availability (RA) rating)
  - whether permits are required to use the route (and how long they will take to obtain)
  - can bollards, etc. be removed temporarily to assist the movement of Abnormal Indivisible Loads, by agreement with the relevant highway authority
- Is the route affected by tides?
  - This will affect the timing of operations
- Is the route in the inter-tidal zone?
  - This significantly restricts the access by both land based and floating plant
- How exposed is the route to weather (and will it flood or become blocked by snow)?
- Resilience of the route
  - Will it deteriorate rapidly under adverse weather? Will it take the traffic?
- Speed
  - Can the route accommodate the number of vehicles in the required duration?

Example 1 – Bringing in material by rail

The Birmingham New Street Gateway programme was a £650m refurbishment of the old railway station into an iconic passenger Hub; completed whilst keeping the operational railway working at all times in a very congested city centre site.

In order to maximise project efficiency and minimise the effects on the neighbourhood an early decision was made to deliver most materials/small plant - and remove most waste products - by train. Only one of 12 platforms could be closed at any time, so the closed platform was utilised to receive materials at the start of each shift and remove waste at the end.

Materials and plant were delivered to and stored at the Bordesley sidings, just outside the city centre, minimising disruption throughout the project.

This was a good example of thinking strategically at an early stage in order to facilitate efficient construction, whilst minimising the impact on others.

- The proximity of being able to bring in material by rail (see Example 1)
- The need for haul roads and/or temporary bridges
- The impact on residents in the urban environment
- Splice positions:
    - Ensure that they are in the most appropriate and optimal area
- Contingency plans, e.g. redundancy; alternative delivery methods:
    - Ensuring that there is a robust approach to minimise failed manoeuvres

6.6 The design of fabricated elements required to be lifted or moved

6.6.1 There are considerations for the design of fabricated elements required to be lifted or moved[12]:

- What is the size, weight and position of the centre of gravity (CoG)?
    - The point of application of the lift must pass through the CoG, or movement will take place; the load will slew, twist or rotate (see Figure 5)

      NOTE: The position of the CofG varies during the assembly of component parts
    - Do precast concrete elements have protruding reinforcement?
- Does the load have to be tilted?
    - Can the element be transported in its permanent orientation such that it does not have to be adjusted when lifted into position (e.g. a bridge beam for placing on abutments at different levels can be transported on temporary supports that have the same level difference as the permanent supports)?
- What is the structural and material form of the load to be moved?
    - What is its strength and rigidity?
        - If considering prefabricating or lifting reinforcement cages, remember that reinforcement ties are poor structural connections
        - If the element is made from concrete, what strength should have been achieved before handling?
    - How is it supported before moving?
    - Where are the attachment points?
    - What is the maximum reaction at each attachment point?
    - Is relative movement between supports (temporary and permanent) important?
- Will load be transmitted through two, three or four points?
    - Can it rock on just two supports (e.g. when considering 4 lifting points theoretically equidistant from the centre of gravity, due to minor variations in setting out, all the load could be taken by only 2 lifting points)?
- Will the load need to be stored in a temporary position on site prior to be lifting into its permanent position?
    - What type of area is required for storage purposes?
- How will the load be supported after placing?
    - Will it be supported immediately, without the need for grout to set?
    - It must be lined and levelled accurately. Does the detailing allow for this? Temporary jacks can be used for fine adjustment
    - The temporary supports and any permanent works they are attached to, must have adequate strength and stability for all ongoing environmental and construction loads (e.g. accidental impact, wind and hydrostatic concrete loads), until incorporated into the permanent works.

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[12] *See also 'Precast concrete: Good practice and common issues in temporary works' (TWf2019: 01, TWf, 2019) (https://www.twforum.org.uk/viewdocument/precast-concrete-good-practice-and)*

    - Can it be adequately supported about its CoG? Is there any novelty in the design of the permanent works which makes the temporary support particularly difficult (e.g. inclined members, cantilever members)?
- How is the member required to connect with the existing structure?
    - Will protruding reinforcement clash with existing reinforcement?
- How will the component be lifted?
    - Are screw-in loops (eyes) required? Has the size and position been required, in order to accommodate later construction?
- Consider the stability of modules
    - Are braced beams required?

      NOTE: Beams in pairs are preferred to an odd number of beams
    - Have any splice positions been considered?
- Have lifting checks been made in all temporary states (i.e. at all stages and not just off-site)?
- Is off-line construction an option, e.g. bridge slides, transportation by SMPT or bridge launches (where the road is diverted/constructed afterwards)
    - Consider temporary states of the permanent works
- For multiple lifting operations, ensure the attachments are designed to suit
- For complex lifts load compensating devices may be required
    - Consider the possibility of redundancy in lifting equipment

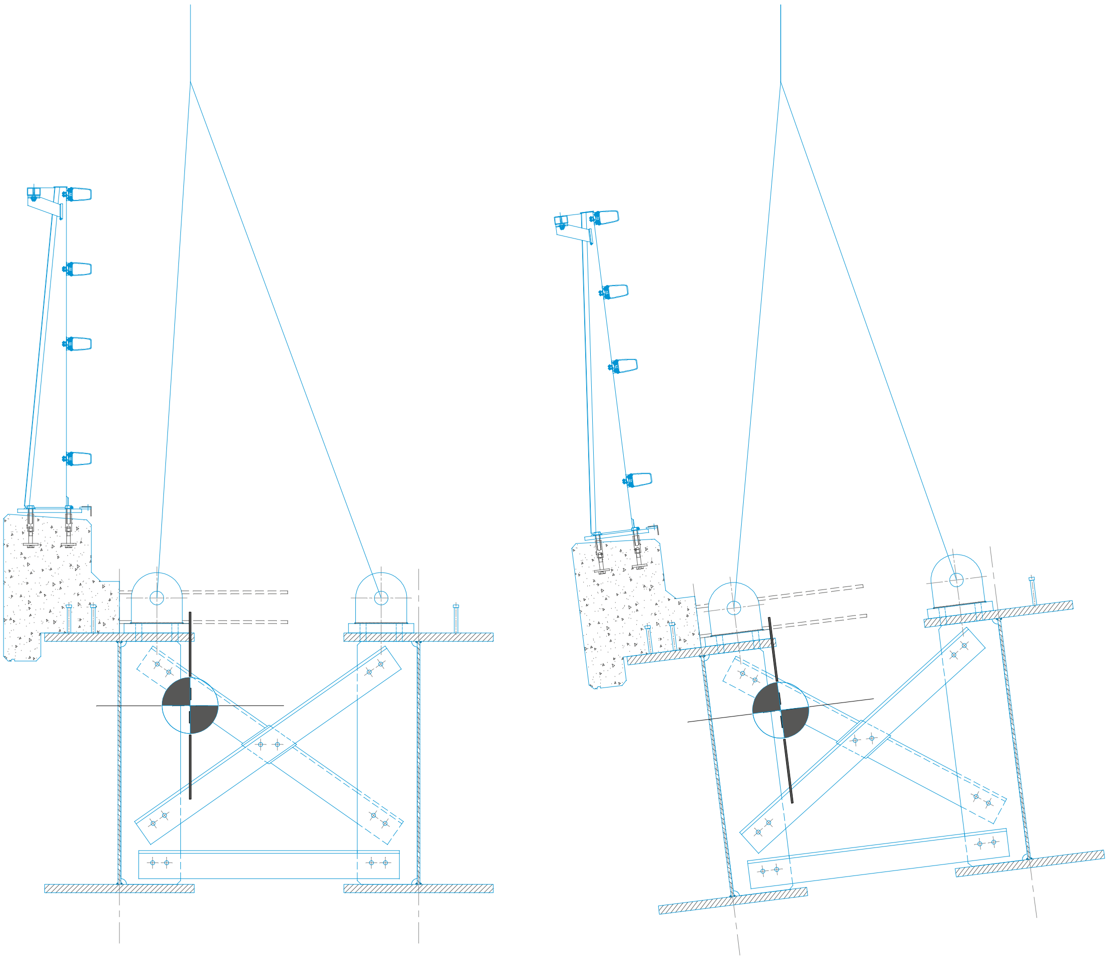

Figure 5 - Example of eccentric lift. Centre of gravity is very close to lifting eye

NOTE: If the hook is not directly above the centre-of-gravity the load will rotate (In this example, unequal chain lengths were used to achieve a level lift).

6.7 The handling and installation of pre-fabricated elements on site

6.7.1 The considerations for handling and installing fabricated elements on site include:

- Will pre-fabrication result in ‘locked-in’ stresses in the permanent works?
  - Consider the effect of the construction sequence on the final arrangement
- Have all the construction load cases been considered, e.g. prior to composite action being achieved
  - Include horizontal loads
- What is the availability of plant?
  - How does this affect the robustness of the programme to meet the installation date?
- What size vehicle is required?
- Consider:
  - Dimensions including protrusions
  - Weight
  - Applied ground bearing pressure
- What space and/or additional cranage requirements are necessary for rigging and de-rigging large cranes
  - Consider space for additional ballast, delivery vehicles and turning circles
- What is the direction, distance and height to be moved?
  - Are there changes in direction of travel and slope or fall?
- What are the site conditions?
  - What are the ground conditions, topography and foundation requirements?
  - Are there constraints from adjacent sites, such as headroom near airports, over railways or near nuclear facilities?
  - What is the route of transportation (e.g. road, rail, river or sea) and what limitations does this route impose?
  - Is on-site assembly of sub-assemblies constructed off site required?
- How many items need to be moved, e.g. one-off move or multiple items?
- Is speed critical (both programme duration and velocity)?
  - What site storage is required?
  - Is delivery ‘just in time’?
- Are there environmental constraints, e.g. weather, tide and season?
- What provides the fail-safe in case of malfunction?
- Is there any aspect in the design of the permanent works which makes its temporary support particularly difficult?
- Consider the stability of precast concrete beams[13] and steel girders
  - These may be separate or combined
- Are trial lift(s) and/or erection required?
- When lifting, consider the access required at any landing points to make connections and remove lifting chains
- Can cross-bracing of girders and similar features required during the temporary state be left permanently in place as sacrificial elements to reduce dismantling works?

7.0 When to consider constructability

It is suggested that there is benefit in carrying out a formal constructability review at each of the four phases of the procurement management model (see Figure 6):

- pre project/ initiation (see 8.1.1)
- options (see 8.1.2)
- development (see 8.2 and 8.3)
- construction (see 8.4)

These are considered in more detail in Sections 8.1 to 8.4. It may be appropriate to have a number of constructability reviews during the same phase. These can have the same goal (e.g. as an aid to the selection between alternatives during the initiation phase) or be different (e.g. as in the development phase when the design develops from preliminary design to a pre-construction cost estimate).

The design develops by a succession of choices between alternative solutions. As the alternatives are considered and preferences selected the design and detail become more defined. At each phase the choice of alternatives is limited by the preceding decisions. As the definition increases the range of possibilities for future choices reduce, until eventually the design is completely defined.

If, after considering constructability, a decision on which the design has been based needs to be changed, this may invalidate the design work that had been based on it. The earlier the original decision was made, or the later the change is made, the more chance there is that it would affect other parts of the design; and the more re-working necessary. The earlier that constructability is considered in design development, the more opportunity to influence the design and the less need for reworking.

It should be noted, there is evidence from past projects that constructability was undertaken well during some stages but was absent from others (e.g. considered well at the design options stage but undertaken poorly at the design stage).

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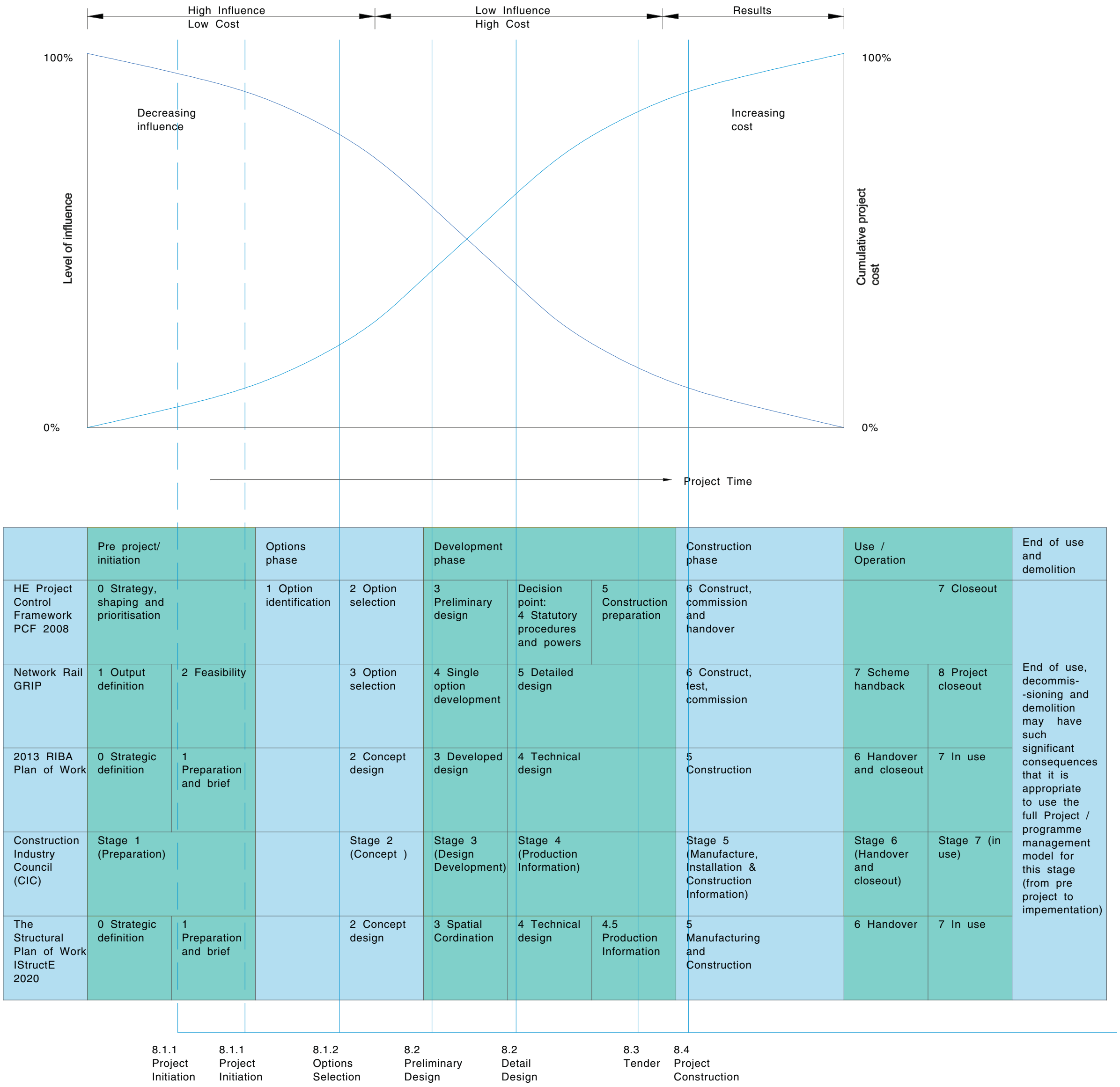
[13] *Technical Advice Note: Handling of Bridge Beams on Site (PCA) (Now available at: https://www.twforum.org.uk/viewdocument/technical-advice-note-handling-of)*



	Pre project/ initiation		Options phase		Development phase			Construction phase		Use / Operation		End of use and demolition
HE Project Control Framework PCF 2008	0 Strategy, shaping and prioritisation		1 Option identification	2 Option selection	3 Preliminary design	Decision point: 4 Statutory procedures and powers	5 Construction preparation	6 Construct, commission and handover			7 Closeout	End of use, decommis- -sioning and demolition may have such significant consequences that it is appropriate to use the full Project / programme management model for this stage (from pre project to impementation)
Network Rail GRIP	1 Output definition	2 Feasibility		3 Option selection	4 Single option development	5 Detailed design		6 Construct, test, commission		7 Scheme handback	8 Project closeout	
2013 RIBA Plan of Work	0 Strategic definition	1 Preparation and brief		2 Concept design	3 Developed design	4 Technical design		5 Construction		6 Handover and closeout	7 In use	
Construction Industry Council (CIC)	Stage 1 (Preparation)			Stage 2 (Concept)	Stage 3 (Design Development)	Stage 4 (Production Information)		Stage 5 (Manufacture, Installation & Construction Information)		Stage 6 (Handover and closeout)	Stage 7 (in use)	
The Structural Plan of Work IStructE 2020	0 Strategic definition	1 Preparation and brief		2 Concept design	3 Spatial Cordination	4 Technical design	4.5 Production Information	5 Manufacturing and Construction		6 Handover	7 In use	

Figure 6 - How a constructability review can improve the design of permanent works

NOTE: A diagram – based on figure 1 – showing the idealised change in the influence and cost of design and constructability decisions on the project cost with respect to project duration, overlaid with project procurement management model and suggested opportunities for formal constructability reviews

7.1 Notes on the practical aspects of carrying out constructability reviews

There are a number of issues to consider:

Positives:

7.1.1 Constructability reviews:

- should be polite and inclusive;
- can be a team-building exercise, when done well;
- will highlight issues which may affect safety, operations, temporary works requirements, etc. and may inform 'design change';
- should consider the likely impact on neighbours and test whether the proposals have the potential to disadvantage particular groups in the community;
- can enable efficiency for design and execution of the works, enable contingency plans to be developed and will troubleshoot issues before they get to site.

7.1.2 A constructability review can also:

- 'de-risk' a project by ensuring that it can be constructed and in what sequence (allowing a better focus on the most effective options);
- facilitate early identification of temporary works requirements, to enable early procurement;
- facilitate the production of temporary works solutions that suit chosen temporary conditions and sequencing;
- enable early decisions to be made on whether the permanent works design can be amended to improve constructability;
- improve constructability to facilitate improved safety, programme and cost.

Hazards/pitfalls:

7.1.3 It should be remembered that:

- There is more than one way to build something and different construction experts may have preferred techniques;
- The people best at constructing are most likely be on site constructing - the most experienced or best construction expert(s) may be not be available for the constructability review;
- The continuity of construction experts at subsequent constructability reviews may depend upon staff retention and the contractor's work commitments.

7.2 Who should undertake reviews

7.2.1 To be considered an effective way of ensuring constructability, at any stage, constructability reviews should be undertaken by all parties to a project, bringing together different expertise from all duty-holders:

- project manager;
- client;
- permanent works designer (consultant);
- construction expert (temporary works);
- principal designer;
- specialist construction experts (e.g. proprietary suppliers);
- stakeholder technical representative(s);
- facility operator;
- safety expert(s).

7.2.2 Sometimes, the best constructability advice comes from the site team, e.g. foreman.

7.3 Information

7.3.1 The project needs to be defined to a sufficient level of detail to be able to carry out a constructability review. This information may take the form of reports, surveys, archive information, calculations, drawings and models.

7.3.2 Building Information Modelling (BIM) - see Appendix 3 - can be an effective way of capturing, collating and presenting this information[14].

8.0 A methodological approach to constructability reviews

Sections 8.1 to 8.4 show a methodical approach to reviewing constructability. They identify the stages when a constructability review may be useful and list some of the pre-requisites, aims and outputs of the review process.

The items listed and the topics covered should be adapted and changed to suit the requirements of a particular project.

More than one constructability review may be required during each stage of the project delivery process. For example, it may be appropriate to have a constructability review at the preliminary design stage and another at detailed design.

It is expected that as the use of BIM develops within the industry it will become a key tool in carrying out and recording constructability reviews.

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[14] The TWf [September 2020] is preparing some advice, 'An open standardized approach to the management of temporary works design – digital collaboration'.

NOTE: Engineering assurance and constructability reviews

Large infrastructure organisations such as Network Rail and Highways England have engineering assurance processes that seek to de-risk designs against numerous criteria - such as maintaining open railways and open roads as far as is reasonably practicable – in order to minimise the effects of repairs and enhancements on rail and road users.

Undertaking constructability reviews will enable the project team to home in on the most appropriate, constructible solutions and ensure operations continue without undue disruption.

Such procedures call for schedules of temporary works to be developed, to include the following:

- location/description of temporary works
- design check category
- high- or low-risk check category for work package planning
- confirmation and consideration of coordination between all permanent and temporary works
- dates for submission and acceptance for deliverables
- details of temporary work design organisation
- details of interdisciplinary interfaces
- requirements for inspections and testing

A constructability review will enable early determination of the need for such works.

8.1 Constructability at project initiation, option development and selection

8.1.1 Constructability at project initiation

Grip 1, RIBA 0, HE 0

It is never too early to consider constructability; and as early as project initiation stage. A constructability review at this stage should be a swift process, as there will be many unknowns and many options to home in on. Such a review will enable appropriate conversations about how a proposal can be built; to test its feasibility for construction.

As early solutions are developed, the basics will then be better understood and key decisions can be made in principle, e.g. access arrangements, logistics, materials storage, cranage. This will enable key issues to be resolved, e.g. the need to buy or hire land owned by others to facilitate construction in good time.

It is important to identify early on any technical approval authorities, e.g. highways, rail. Large clients may have their own technical approval process and should be engaged.

8.1.2 Constructability at option development and selection

Design development and options selection GRIP 1/2/3; RIBA 0/1/2; HE 0/1/2

The brief (requirements) should be identified. Consider the variety of options (forms) developed, e.g. location, number of spans, concrete or steel, practicalities, sequence of construction, aesthetics, etc.

The **deliverability** – in addition to **constructability** - should also be assessed. A **project risk workshop** may, for example, be the way to do this. This process may repeat in later stages.

8.1.3 The importance of constructability at project initiation, option development and selection

If constructability and temporary works are not considered from the outset the structure may be very difficult (unsafe) and/or impossible (too risky) to build; as well as too expensive.

Decisions on land-take, programme and aesthetics taken at the project initiation and option development stages will have a fundamental impact on the delivery of the scheme, e.g. space for site access and cranage, key possession dates and length of programme.

The designer may introduce risks that could be avoided or increase exposure. CIRIA C755 **[4.]** advises:

- *"Designers would be wise to stray on the side of caution – especially when considering significant ('life or death') risks because after a death legal analysis of reasonableness will be tinged by the reality and emotion of what has actually happened …*

8.1.4 Actions to be complete before holding constructability review

The following actions should be completed:

- Functional requirements established
- Alternative geographical locations identified
- Stakeholders identified
- Value criteria established
- Outline solutions determined
- Options preliminary design and feasibility
- Site investigation(s) carried out
- Restrictions on timing and boundaries of site possession identified, e.g. rail interface, airport/flightpath, tidal working, nearby power transmission

8.1.5 Aim of the constructability review

The aim of the constructability review is to determine:

- whether the project can be built safely in the time allowed
- construction materials and methodology
- what specialist plant and contractors are required
- what geotechnical work has to be carried out
- the obstacles that must be overcome

For example, site access and egress (e.g. timings: tides/possessions; environmental, site of special scientific interest); weather and seasonal conditions (e.g. monsoon season, school term times)

- major items of temporary works; better still, what can be done to design them out (elimination)
- potential logistics problems

For example: can the materials and resources be made available; where will they be coming from; does a mine, quarry or borrow-pit need to be established; do people need to be trained

- potential transport problems

For example: can the materials and resources be delivered to site at the correct time

- any sources of uncertainty

8.1.6 Actions to be carried out after constructability review

The following actions should be completed:

- best (compromise) solution chosen from options
- safety case developed
- hazard identification carried out
- risks designed out or reduced
- risk register developed

8.2 Constructability at preliminary and detailed design

Development phase: GRIP 4/5; RIBA 3/4; HE 3/4/5

Consider the form to be chosen: For example, sequence of construction; bearing details (and temporary fixity/restraint); thermal movements; residual stresses; temporary support to follow on construction (e.g. temporary support to precast; precast acting as formwork resisting hydrostatic loads; precast acting as edge protection); unsupported reinforcement; correct poor buildability; eliminate unnecessary temporary works.

8.2.1 Actions to be complete before holding constructability review

The following actions should be completed:

- Form of structure established
- Geographical locations established
- Stakeholders engaged
- Check that value criteria are being met
- Determine outline solutions
- Advanced the options preliminary design
- Identify interfaces between functions of works
- Identify interfaces with other contracts
- Carry out further site investigation(s)
- Draw up a schedule of site possessions

8.2.2 Aim of the constructability review

The aim of the constructability review is to determine:

- Method for choosing the location of construction joints
- Determine the size of pre-assembled components to be delivered to site
- Method of handling (craning) pre-assembled components.

  NOTE: If reinforcement has to be pre-fabricated, how will the reinforcement cage temporary structure be designed?

- Method of connecting pre-assembled components
- Method of supporting pre-assembled components before they become incorporated into the works and are self-supporting

  NOTE: This includes reinforcement, steelwork and precast concrete

- Method of providing strength and stability during early maturity (e.g. concrete strength for slip-forming)
- Method of providing stability during early stages of construction

  For example: additional bracing in composite bridges where the steel beams would rely on the deck to restrain the top flange; longitudinal restraint of continuous span bridges that are constructed in incremental spans

- Assess the stability of any existing structures during the works, e.g. masonry walls upon removal of any adjacent walls, roof or floor support; the support of wet concrete on masonry walls; wind loading on previously protected walls and/or structures

- Identify parts of the permanent works that act as support for follow on construction works, e.g. precast units resisting horizontal hydrostatic loads, permanent formwork
- Construction (and access) loads that must be carried by permanent works in temporary condition

  For example, are decks strong enough for follow on work; access and egress; MEWPs, telehandlers; is extra steel required
- Identify access routes for transporting materials and plant to site
- Identify location of foundations required for any likely temporary works or plant loadings
- Consider methods of restricting water ingress into the permanent or temporary works
- Identify gaps in information that will be required to design temporary works

  For example, is the ground investigation (GI) sufficient (and was it in the correct location); have the upper layers been sufficiently categorised

  NOTE: GI is generally commissioned by permanent works designers, designing permanent works foundations, with little consideration for the associated temporary works. Often, there is no information on the uppermost layers in the locations where temporary works are required (e.g. cranes). For example, many boreholes have no information for the top 1 to 2 m.
- Review boundary of work package and which other packages and interfaces for possible constraints and interference

  For example: access and egress routes, cranes over-sailing, incompatible work being carried out during the same possession
- Allow access for the implementation of surveys and the setting up of monitoring equipment

8.2.3 Actions to be carried out after constructability review

The following actions should be completed:

- Design solution developed from concept to working drawings
- Develop any requirements for inspection and testing (including access)
- Safety case developed
- Hazards identified
- Risks designed out (or reduced)
- Risk register developed
- Preliminary temporary works register developed

  NOTE: Identify the implementation risk class and the design check category
- Confirm necessary site possessions with stakeholders

8.3 Constructability at pre-construction cost estimate build up (‘tender’)

Interface between Development and Construction phases: GRIP 5/6; RIBA 4/5; HE 5/6

Consider the form to be chosen and complete detailed design: For example: sequence of build (e.g. transport, eliminate storage and double handling); plant required; temporary works required (and plant required); improvements to buildability.

8.3.1 Actions to be complete before holding constructability review

The following actions should be completed:

- Design sufficiently mature to avoid major changes to form, material type and sizes

  NOTE: To achieve this it is recommended that the client and/or permanent works designer should have engaged already with contractor(s)
- General arrangement (GA) and reinforcement detailing drawings substantially complete
- Stakeholders engaged
- Schedule of possession dates determined
- Check value criteria are being met
- Likely timing of work established
- Key dates identified for constraints and deliverables (e.g. possessions, handovers, etc.)
- Interfaces between functions of works defined
- Interfaces with other contracts defined
- Identify work content and work packages
- Establish methods and routes for delivering materials to site
- Establish preferred methods for constructing works
- Source resources for constructing the works
- Preliminary programme construction of works
- Contact and engage with specialist contractors
- Sufficient GI carried out in correct locations for temporary works assessments

8.3.2 Aim of the constructability review

The aim of the constructability review is to determine:

- Ensure the methods for constructing works are practical
- Ensure the sourcing of materials is practical
- Ensure the sequence and programme for constructing the works is practical
- Check the availability of specialist plant and contractors
- Check that all geotechnical risks have been identified
- Identify solutions to obstacles that need to be overcome
- Identify solutions to potential logistics problems
- Identify sources of uncertainty

8.3.3 Actions to be carried out after constructability review

The following actions should be completed:

- Identify sources of materials for constructing the works
- Develop a safety case
- Develop the risk register
- Develop the temporary works register

  NOTE: Identify the implementation risk class and the design check category
- Preliminary temporary works design carried out
- Cost the temporary works
- Schedule movement orders
- Finalise programme construction of works based on actual timings and dates considering access to site, seasonal effects, tides and possessions, etc.
- Calculate target cost for constructing the works

8.4 Constructability at pre-construction stage (‘site work’)

Construction phases: GRIP 6; RIBA 5; HE 6

8.4.1 Actions to be complete before holding constructability review

The following actions should be completed:

- Design complete (for the whole or part, as appropriate; the work may be staged)
- General arrangement and reinforcement detailing drawings complete
- Necessary site possessions confirmed with stakeholders
- Budget established
- Materials for constructing the works sourced
- Resources for constructing the works engaged
- Construction team in place (including key temporary works staff)
- Divide site into work packages
- Develop programme for each work package so that each activity is identified
- Risk Assessment(s) and Method Statement(s) (RAMS) drafted for each of the work items
- Temporary works register in place for project delivery

8.4.2 Aim of the constructability review

The aim of the constructability review is to:

- Review each work package in turn
- Review the boundary of work packages and those of other packages it interfaces with for possible constraints and interference (e.g. access and egress routes, cranes over-sailing)
- Define each work package site

  For example (on a bridge construction site):
  - Define access and egress and any associated temporary works (e.g. access roads, bell-mouth, service crossing, temporary bridges)
  - Define site boundary fence, welfare, car parking and storage facilities, and any associated temporary works (e.g. fences, hoarding, cabins, foundations, drainage, outrigger foundations for cranes or HIAB)
  - Define hardstanding and laydown areas
  - Define plant movement route(s)
- Review each step in programme from first to last activity
- Consider any provision for carrying out inspections and tests (and the access required)
- Define extent of temporary excavation (e.g. vertical supported or battered, de-watering)
- Identify affected services (e.g. diversions, service crossings)
- Define limits on plant size and materials stockpiles next to temporary excavations
- Confirm the plant required for carrying out excavation
- Define access requirements in/out of excavations, including rescue provision
- Define likely cranage requirements and possible crane locations

- Formwork for foundations
- Cranage for handling foundation reinforcement and formwork
- Support for foundation reinforcement
- Delivery of concrete
- Access for fixing wall reinforcement
- Cranage for handling wall reinforcement and formwork
- Support for wall reinforcement
- Formwork for wall
- Concrete delivery

8.4.3 Actions to be carried out after constructability review

The following actions should be completed:

- Obtain certified temporary works designs
- Finalise risk assessment(s) and method statement(s) (RAMS) for each of the work items
- Finalise the Inspection and Test Plan (ITP) and any associated check lists
- Carry out the work

9. Summary and concluding remarks

9.1 The aim of the guide is to raise awareness of the importance of constructability to clients, architects, permanent works designers, temporary works designers and contractors and how improved constructability can be achieved through a consistent systematic approach involving all parties.

9.2 Constructability is an iterative process. It should not be considered just once during project development, but reviewed at stages throughout the design.

9.3 Good constructability exists already and Appendix 2 gives examples of projects where the benefits of this approach, and early contractor involvement, have been achieved. Examples of construction issues resulting from aspects of the design (Appendix 4) and site work (Appendix 5) are given.

9.4 This edition of the guide is seen as a first step and it is intended that it will be developed and expanded with subsequent editions.

9.5 It is hoped that part of this development will be further examples of good constructability practices provided by the industry. Indeed, readers are invited to submit cases studies for consideration.

References

[1.] Network Rail Safe by Design, Guidance Note – Early Focus on Constructability and Temporary Works (2019)

NOTE: Appendix A provides an example constructability review template

[2.] Construction (Design and Management) Regulations 2015 (CDM2015)

[3.] Managing health and safety in construction, Construction (Design and Management) Regulations 2015, Guidance on Regulations, HSE, L153 (2015)

[4.] CIRIA C755, Construction work sector guidance for designers (2015)

[5.] BS 5975: 2019, Code of practice for temporary works procedures and the permissible stress design of falsework, BSI (2019)

[6.] Management of Health and Safety at Work Regulations 1999 (as amended)

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[15.] CIRIA C730, Implementing Lean in construction: Lean tools and techniques – an introduction (2013)

[16.] PAS 2080: 2016, Carbon management in infrastructure (BSI)

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[23.] Clients' guide to temporary works: Recommendations for Clients, their representatives, programme managers and others on the design and coordination of temporary works, TWf2014:02, TWf (2014)

[24.] Capital Delivery Engineering Advice Note 203 (CD EAN 203), Guidance on Temporary Conditions (Multi-disciplinary), Network Rail (2020)

Further reading

There is an excellent text on constructability:

- Constructability in building and engineering projects (1995) **[18.]**

Also of note is:

- Network Rail Safe By Design - Early Focus Guidance on Constructability and Temporary Works **[1.]**

  NOTE:This is available on the Network Rail (NR) Safety Central Safe By Design (SbD) website, https://safety.networkrail.co.uk/safety/prevention-through-engineering-and-design/safe-by-design-groups/building-and-civils/

In the UK, CIRIA has - over the years - published a number of documents on buildability:

- SP26, Buildability: an assessment (1983) **[19.]**
- CIRIA/Butterworth, Practical Buildability (1989)
- CIRIA R155, Bridges design for improved buildability (1996) **[7.]**
- CIRIA PR27, Securing the contractor's contribution to buildability in design (1997)

  NOTE: This did not take CDM into account 1997
- CIRIA C534, Civil engineering design and construct - a guide to integrating design into the construction process (2000) **[9.]**
- CIRIA C543, Bridge detailing guide (2001) **[8.]**

  NOTE: Includes reference to CDM. Good general details. Falls short on stability of rebar, support and stability of PC units prior to integration into permanent works and construction loading on PC units

Of particular relevance is:

- CIRIA C755, CDM 2015 construction work sector guidance for designers, fourth edition **[4.]**

In some countries the quantitative measurement of buildability, in buildings rather than structures, has advanced to such a degree that Federal Codes of Practice are published specifying the measured buildability targets:

- Code of Practice for Buildability (Singapore) (2015)

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Precast Concrete Association:

Technical Advice Note: Handling of Bridge Beams on Site

NOTE: Now available at https://www.twforum.org.uk/viewdocument/technical-advice-note-handling-of

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Handbook of structural steelwork - 4th Edition, P201 (2002)

Steel Bridge Group: Guidance notes on best practice in steel bridge construction - Sixth issue, P185/6 (2015)

Offsite Modular Steelwork - Design Advice, P430

British Constructional Steelwork Association (BCSA):

https://www.steelconstruction.info/Health_and_safety

Allocation of Design Responsibilities in Constructional Steelwork, 2007 (Publication No. 45/07)

Safe Site Handover Certificate and Checklist, 2008

Normal scope of competence

Special scope of competence

Guide to Steel Erection in Windy Conditions, 2005 (Publication No. 39/05)

Code of Practice for Erection of Multi-Storey Buildings, 2006 (Publication No. 42/06)

Guide to the Erection of Steel Bridges, 2005 (Publication No. 38/05)

Guide to Work at Height during the Loading and Unloading of Steelwork, 2007 (Publication No. 43/07)

Code of Practice for Metal Decking and Stud Welding, 2014

Guide to the Management of Site Lifting Operations, 2009 (Publication No. 47/09)

Code of Practice for the Erection of Low Rise Buildings, 2004 (Publication No. 36/04)

Health & Safety on Steel Construction Sites: Guide for Employees, 2009 (Publication No. 48/09)

Steel Bridges: A practical approach to design for efficient fabrication and construction, 2010 (Publication No. 51/10)

Steel Buildings, 2003 (Publication No. 35/03)

Joints in Steel Construction: Simple Joints to Eurocode 3, 2014 (SCI P358)

Metal Decking Good Practice Guide - MDG 01 to MDG04, 2016

Concrete Society

http://www.concrete.org.uk/publications.asp

Composite concrete slabs using steel decking (TR75)

Guide to the design & construction of reinforced concrete flat slabs (TR64)

Guide to flat slab formwork and falsework (CS140)

Checklists for Formwork and Falsework (CS123 and CS144)

Formwork - a guide to good practice, 3rd edition (CS030)

Appendix 1: Other definitions and terms

A1.1

Notwithstanding the definition of constructability adopted in Section 1, definitions and terms do vary in meaning between countries. Other definitions, from various sources, illustrate breadth (and this document should be read in conjunction with any local guidance, as appropriate):

A1.2 – Constructability:

- *“the optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives”*

  Source: Construction Industry Institute, CII, Texas (1983) **[19.]**

- *“a system for achieving optimum integration of construction knowledge in the building process and balancing the various project and environmental constraints to achieve maximisation of project goals and building performance”*

  Source: Construction Industry Institute, CII, Australia (1991) **[20.]**

A1.3 – Buildability:

- *“the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building”*

  Source: CIRIA SP6 (1983) **[21.]**

A1.4 – Value Engineering:

‘Constructability’ and ‘Buildability’ should not be confused with ‘Value Engineering’. This term was first used in the 1940s to describe a systematic process developed by Lawrence Mills, of General Electric, to generate alternatives to existing manufacturing solutions to overcome material shortages while maintaining functionality and manufacturing output. Today, in the US, ‘Value Engineering’ is a term used by Federal Government:

- *“‘value engineering’ means an analysis of the functions of a program, project, system, product, item of equipment, building, facility, service, or supply of an executive agency, performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety, and life cycle costs”*

  Source: National Defense Authorization Act for Fiscal Year 1996, Section 4306 **[22.]**

A1.5 – Temporary works:

- *“Temporary works can be described as providing an “engineered solution” that is used to support or protect either an existing structure or the permanent works during construction, or to support an item of plant or equipment, or the vertical sides or side-slopes of an excavation during construction operations on site or to provide access”*

  Source: BS 5975: 2019 **[5.]**

- *“states of the permanent works which are temporary, loading conditions of the permanent works during construction or project execution which not envisaged in the permanent condition, structures in states of modification or demolition”*

  Source: TWf Client Guide (2014) **[23.]**

- *“those parts of the works that allow or enable construction of, protect, support or provide access to, the permanent works and which might or might not remain in place at the completion of the works, including states of the permanent works which are temporary, loading conditions of the permanent works not envisaged by the permanent works design and structures in states of modification or demolition”*

  Source: Network Rail Safe by Design, Guidance Note – Early Focus on Constructability and Temporary Works (2019) **[1.]**

A1.6 – Temporary conditions

- *“those parts of the works that allow or enable construction of, protect, support or provide access to, the permanent works, which may or may not remain in place at the completion of the works. This includes states of the permanent works which are temporary and temporary stages or phases of works put into operational use prior to completion of the works. …”*

  Source: Capital Delivery Engineering Advice Note 203 (CD EAN 203), Guidance on Temporary Conditions (Multi-disciplinary), Network Rail (2020) - (2020) **[24.]**

Appendix 2: Projects that benefited from early contractor involvement

1. Bar Hill bridge deck

Two bridge decks were installed eighteen hours ahead of programme, using self-propelled mobile transporters (SPMTs) (Figure A2.1). The many challenges were mitigated successfully through collaboration between the permanent works designers and the temporary works designers, including amending the design of the bridges to accommodate the temporary support configuration of the SPMT which differed from those of the permanent structure, and with the supply chain in the manufacture and delivery of the structures. Under a full closure, the team prepared the road surface throughout the night and into the early hours of the next morning, when the 44-metre bridge decks were guided into place using the huge remote-controlled platforms.

This time-lapse video shows the installation of two new 1,000 tonne bridge decks over the A14 at Bar Hill, during the weekend of 14th to 16th September 2018. These bridges now form part of a new junction on the A14 Cambridge to Huntingdon improvement scheme.

https://www.youtube.com/watch?v=nvBryO0O6xA

Figure A2.1 – Self-propelled mobile transporters

The weekend's success was a consequence of months of planning, thought and thorough preparation. The work finished so early because each member of the team did what they promised to do and, in many cases, exceeded expectations. There was excellent planning and execution.

Client: Highways England

Permanent works designer: Atkins/CH2M

Temporary works designer: IDT

2. Installation of bridge deck (A14)

This time-lapse video shows the installation of a bridge deck on the pedestrian and cycle bridge at Swavesey on the A14 Cambridge to Huntingdon improvement scheme.

https://www.youtube.com/watch?v=b2OPmE8qwiA

Figure A2.2 – Tandem lift

A pre-fabricated bridge deck was guided by remote control along 4.6 miles of carriageway using self-propelled mobile transporters (SPMTs). Tandem lifting (Figure A2.2) was used to erect the deck over multiple lanes below. The bridge was set on temporary piers ready for welding and, ultimately, was suspended from the pylons by steel cables. Landing the prefabricated main span deck of this landmark structure was completed within one day, resulting in reduced road closures and disruption to the travelling public as well as less temporary support requirements over a segmental insitu fabrication alternative.

Client: Highways England

Steel constructors: Viktor Buyck

3. Pre-cast slabs form viaduct deck

Over 500 pre-cast concrete slabs (Figure A2.3) were chosen to form the deck of a multi-span viaduct; comprising 17 spans (measuring 41 metres on the approaches and 59m over the water). The first panel weighed 22.5 tonnes and was fabricated at the contractor's near-by pre-cast yard. The total crossing length was 747m and will carry six lanes of traffic over a flood plain and river. The pre-cast deck solution will save £4 million and two months in construction time, compared to an in-situ build. It was considered a much safer process and will result in a higher quality finish. It was a great example of constructability, value engineering, innovation and safety in action.

This time-lapse video shows the building the River Great Ouse viaduct. This viaduct now forms part of the A14 Cambridge to Huntingdon improvement scheme.

https://www.youtube.com/watch?v=npi8Ct8eOGQ

Figure A2.3 – Pre-cast deck units being lifted into place

Appendix 2: Projects that benefited from early contractor involvement – *continued*

4. Dover Western Docks Revival – New Marina Pier

The 500m long pier (Figure A2.4) comprised of 90 No 1829mm dia. tubular piles supporting modular precast concrete wave wall and deck units forming a breakwater to protect the new marina and to provide a promenade for the public.

Figure A2.4 – New marina pier under construction

There were a number of examples of constructability built into the design, including:

- Opting for the pile size to be the same as the main quay walls provided considerable efficiencies with plant and piling equipment. Varying chalk levels were accommodated by using longer piles and a verification exercise based on dynamic testing.
- The modular precast concrete design meant that off-site construction and on-site assembly techniques were used, eliminating formwork and reinforcement placement in a tidal environment.
- The number of courses of precast units was reduced from thirteen to four compared to the reference design. These heavier blocks meant that no temporary works were required to prevent them from being dislodged by wave action prior to the insitu concrete stitch.
- Each precast concrete unit was optimised for transportation through collaborative working with the contractor and concrete supplier; with each unit no wider than 3m (to avoid the need for police escorts) and the weight limited to 45 Te (to suit the permitted lift capacity of the crane barge).
- Precast concrete corbels lowered over each tubular pile, accurately positioned and levelled prior to grouting into position provided a series of solid and level platforms over the length of the pier. These platforms enabled the wave wall and deck unit installation to be completed in only 17 weeks.
- The total number of precast units was reduced by 40% compared to the reference design, resulting in a significant programme reduction (with less transport movements, crane lifts and joints to seal).
- The precast and insitu concrete works were modelled fully in 3D using DFMA, facilitating the elimination of errors and reducing wasted time (e.g. by eliminating reinforcement clashes at the design stage).
- Stitching the units together was achieved by inserting a reinforcement cage into the top of each tubular pile and threading bars into couplers cast into each of the precast deck units. This arrangement meant that all the insitu reinforcement work was kept above Mean High Water Springs, eliminating the need for tidal working.

Client: Dover Harbour Board

Contractor: VolkerStevin Boskalis Westminster

Permanent and temporary works designer: Tony Gee and Partners LLP

5. Dover Western Docks Revival – Wellington Dock Navigational Access

The 120m long 12m deep cut channel is formed from reinforced concrete and connects the new marina to the existing Wellington Dock (Figure A2.5). The structure passes through an existing highway and was built within a steel sheet pile cofferdam.

Figure A2.5 – Dock navigational access under construction

There were a number of examples of constructability built into the design, including:

- The access channel was built in three separate phases, permitting the design of one phase to be completed whilst another was being constructed; reducing the overall construction programme of this design and build project.
- By phasing the construction, the multiple live critical services in the highway could remain whilst the new service chambers and ducts were built in Phase 1. These were then diverted before commencement of Phase 3. This decision expedited the construction whilst minimising the risk associated with obtaining approval to divert third parties' apparatus.
- Phasing of the works meant construction could continue even if one phases experienced disruption due to historical finds.

Appendix 2: Projects that benefited from early contractor involvement – *continued*

- 3D models of the sector gates, mitre gates and bascule lift bridge were used to identify and eliminate potential clashes between the moving structures and the concrete access channel at the design stage.
- Collaboration with the hydraulic struts supplier and dewatering equipment supplier enabled optimisation of the excavation, propping and concrete pour sequence (e.g. by detailing reinforcement laps to suit strut levels, allow sequential removal of dewatering following concrete pours and account for the influences of tidal groundwater).
- A 10% saving in the amount reinforcement was achieved by integrating the sheet piles needed for the temporary works into the permanent works concrete walls through the use of shear studs. These studs permitted the walls and sheet piles to act compositely, reducing the required reinforcement. Furthermore, by utilising the skin friction between the sheet piles and the ground below, 10% less concrete is needed to resist uplift forces during maintenance dewatering of the dock. Traditionally this would have been resisted solely by the structures concrete mass.

Client: Dover Harbour Board

Contractor: VolkerStevin Boskalis Westminster

Permanent and temporary works designers: Tony Gee and Partners LLP

6. Blackfriars Thameslink Project

A 115 m long steel track protection structure (TPS) was required to withstand any potential impact loading from demolition of the station concourse directly above and allow train operations to continue through the closed station completely unaffected by the major works (Figure A2.6).

Due to spatial constraints, the steel structure construction was achieved through an innovative stiffened plate design. From an early stage, the temporary works designer assisted the contractor in its interfaces with both Network Rail and London Underground by preparing the necessary documentation and making presentations on the proposals during scheme development.

Figure A2.6 – Steel track protection structure being tested

Client: Balfour Beatty Civil Engineering Ltd.

Temporary works designer: Hewson Consulting Engineers

7. Landmark, Manchester

A £100m project to redevelop a city centre brown field site into a multi-storey office block (Figure A2.7). The site had been occupied by a former theatre/cinema since the 1920s. The site was small, located in the city centre, and the existing structure was in a poor condition. Public roads lined the site perimeter. The site also shared a boundary with a multi-storey structure being retained for the permanent works. These tight and difficult site constraints made the task of creating a double storey basement, using the existing perimeter walls for support, very challenging.

From an early stage, the temporary works designer (TWD) worked closely with the permanent works designer (PWD) to enable a smooth integration of temporary works into the permanent works, achieving the aim to be efficient in using the permanent works where possible to reduce the amount of temporary works structures (that would become redundant upon completion). Important was the need to have efficient temporary works designs as well as a good working relationship between the TWD and the site team to ensure that any constraints were satisfied and the project delivered safely.

Figure A2.7 – Landmark, Manchester

Appendix 2: Projects that benefited from early contractor involvement – *continued*

Theatre demolition

Much of the former theatre was removed using a long reach excavator. However, some parts required innovative engineering to reduce the risk to the public. One such design was the pull down of the 20 tonne truss that spanned 25m and supported the roof and high ceiling of the former theatre. Pulling the truss down into an exclusion zone in a controlled manner not only eliminated the potential for structural collapse outside the site perimeter but also significantly reduced the number of man hours working at height.

Basement propping scheme

The basement propping scheme involved supporting the existing outer brickwork perimeter walls using fabricated steel raking props that were supported from a central reinforced concrete basement raft. Support to the corners of the structure was provided with horizontal flying shore braces. The point load that arose from the prop bases had to be distributed to ‘strong points’ in the elevated slab and this was the main driver for a triangular prop frame design.

A geogrid reinforced earth wall allowed the piling rig to operate at a raised level whilst only using a limited amount of space on site. 3D sequence drawings were prepared to cover the final stages of demolition, raft slab construction, installation of propping and underpinning to perimeter walls and the construction of the new basement structure.

Permanent works design (structural engineers): Curtins

Principal contractor: Bowmer + Kirkland

Demolition contactor: Forshaw Demolition

Temporary works designer: Andun

Appendix 3: Good practice in BIM

A3.1 – More projects are designed using the many advantages of Building Information Modelling (BIM) and numerous examples of good practice are available to demonstrate advantages in the consideration of constructability. In the context of this guide, BIM-enabled projects can be especially useful for the following:

a) Captures reality, i.e. ensures that surveys reflect existing infrastructure; hence new permanent and temporary works designs 'fit'.

b) Cuts down re-work by ensuring that clashes are detected, and interdisciplinary coordination takes place.

c) Intelligent planning (4-D) allows the sequencing of activities, which might influence both permanent works and temporary works designs.

d) Intelligent planning for unforeseen changes, such as the need to re-sequence work leading to alternative design solutions.

e) Promotes collaborative working using a 'common data environment'.

f) Resolves conflicts between designs within the design process, at greatly-reduced cost compared to re-design on site.

g) Reduces the potential for errors and omissions, leading to better project efficiency.

h) Improves safety.

i) Leads to better records of the as-built design to be used for future maintenance and refurbishment.

A3.2 – Projects should consider the advantages of BIM at early development stages to maximise the benefits throughout the project lifecycle.

A3.3 – Two examples of good practice follow:

Example 1 - Manchester Victoria Station

The Manchester Victoria Station Redevelopment was an early example of the development of a complex multi-discipline railway project in a Level 2 BIM environment (Figures A3.1 and A3.2).

Figure A3.1 – Manchester Victoria Station

Redevelopment: Visualisation from complete BIM model

Figure A3.2 – Manchester Victoria Station Redevelopment: Erection sequence, temporary works and lift planning within the BIM model

A major benefit of all disciplines working within the BIM environment from conception to fabrication enabled clarity and consistency of thought around Constructability and Temporary Works in a congested city centre site.

Example 2 - Birmingham New Street Station

A good example of the use of BIM was with the innovative temporary works used to provide access to clad the atrium structure at Birmingham New Street (Figure A3.3). Delays to steel erection due to adverse weather meant that the deconstruction sequencing of the structure below needed to continue to maintain overall programme, resulting in the need for new temporary works. The 4D BIM model used for the project allowed the swift identification of issues and the timely design of some innovative temporary works, making use of BIM to coordinate temporary and permanent works designs to identify suitable fixing points and confirm the overall sequencing.

Figure A3.3 – Birmingham New Street: Atrium temporary decking

Appendix 4: Construction issues resulting from aspects of the design

Some common issues that result from design choices and the changes in modern construction techniques include:

A4.1 – Stability of reinforcement

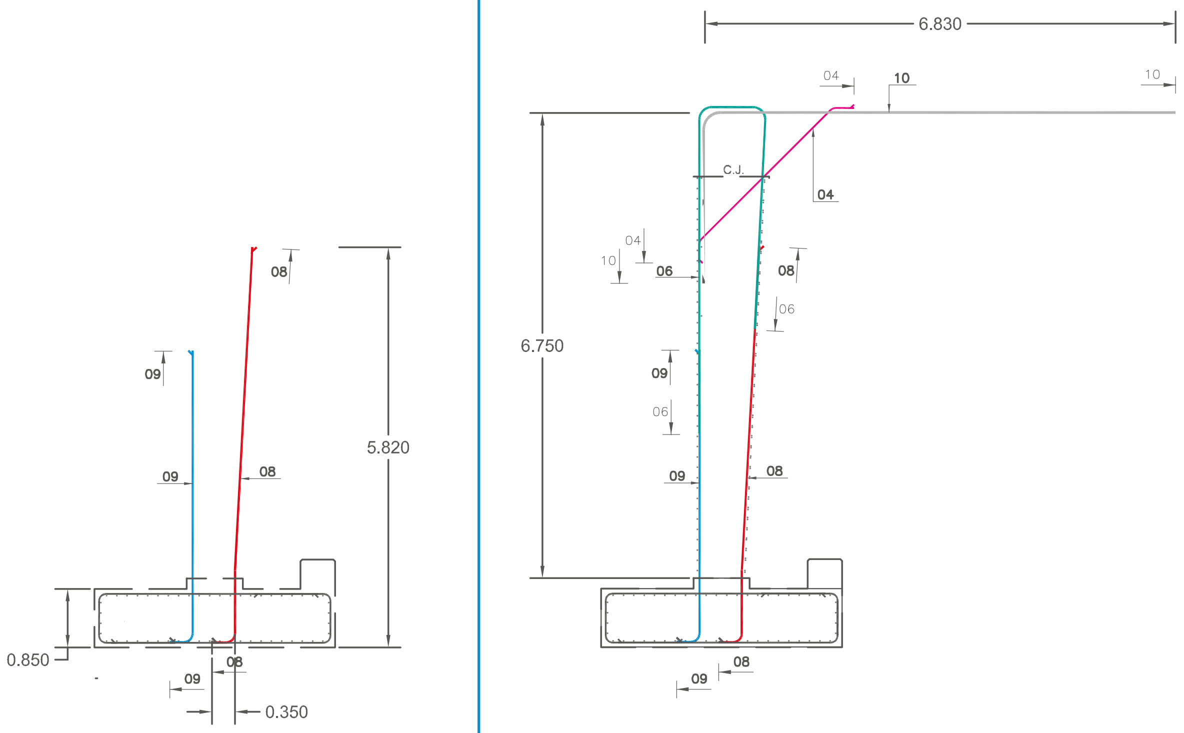
Integral bridges span from one abutment, over intermediate supports to the other abutment without any movement joint in the deck. The design of the bridge leads to a greater moment at the junction between the pier/abutment and deck. If the permanent works designer chooses to address this by having larger diameter reinforcement verticals at the top of the pier than those below - introducing projecting cantilever bars - this will be inherently unstable in the temporary condition (Figure 4.1). The permanent works designer should consider the buildability of typical integrally constructed bridge reinforcement details and the additional temporary works that may be required, in order to judge which permanent works detail is best. Consider detailing couplers.

A4.2 – Temporary piers

Bridge construction that uses in-situ piers with precast beams - where the precast beam cannot be temporarily placed on the pier - will, as a consequence, require an independent temporary pier to be constructed. This method of construction should be considered carefully. If the only reason it has been chosen is to minimise the material cost of the permanent works, the additional cost and safety issues of increased temporary works must be considered.

A4.3 – Stability of precast element

Designs that use precast elements which have to be temporarily supported, and have construction loads applied to them before they are incorporated into the permanent works (e.g. hydrostatic concrete pressure), should consider the overall stability and the position of the temporary horizontal and vertical bearing that will be needed (Figure A4.3). This can also happen with symmetrical loading.



(a) Example of reinforcement that would require significant temporary works

Plinth level

B32 inclined starter bar projecting 5m above kicker, weight 38kg per bar

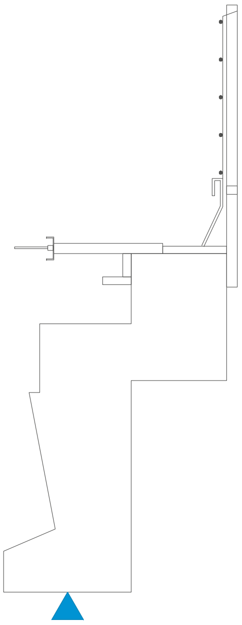
(b) Example of reinforcement that would require significant temporary works

Top of abutment

B40 bar 9.2m long projecting horizontally 6.9m, weight per bar 91kg

Figure A4.1 – Integrally-constructed bridge deck (with over-hanging reinforcement)

Appendix 4: Construction issues resulting from aspects of the design – *continued*



Example of a Y-E precast reinforced concrete "boot" beam fitted with a precast parapet and temporary edge protection before placement on elastomeric bearings.

As a minimum, wind loads will be applied to the arrangement. The resolution of the vertical and horizontal loads does not pass through centre of the elastomeric bearing.

An elastomeric bearing will not resist rotation.

Unless adequate temporary support is provided it is possible for the beam to fall off the bearing (and this is known to have happened in the past)

Figure A4.3 – Stability of a precast element

A4.4 – Precast concrete ceiling planks in a school

Significant cost associated with bespoke precast concrete planks, e.g. manufacture, transport, storage and cranage, could have been avoided at design stage (Figure A4.4). An architect specified a precast concrete finish to the ceiling of a single-story school classroom with a 'green' roof. The structural engineer specified thin 9-metre-long precast planks, simply-supported between steel edge girders, with a 400mm insitu concrete topping (with topsoil for planting, above). The temporary works required to eliminate excessive deflection in the PC planks was almost equivalent in cost to the entire roof being cast insitu.

Figure A4.4 - Precast concrete ceiling planks

A4.5 – Insitu cast earth retaining wall – concrete finish

An insitu cast earth retaining wall - up to 8m in height - was constructed adjacent to a main railway line. The base of the wall was below finished ground level. The Engineer specified an F3 concrete finish to the exposed face of the wall facing the railway (i.e. no formwork ties). Despite an alternative proposal from the Contractor, the Engineer insisted the works be constructed to the tender design.

The adopted solution was to use plywood form panels backed with horizontal proprietary aluminium beams and vertical steel soldiers. These were erected and stabilised using push-pull props to concrete kentledge blocks. The wall was tied using standard formwork ties at kicker level and over the top of the forms. Large universal beam sections (UBs) were then lifted into position between each soldier; clamped to the aluminium beams and tied just above kicker level using twin-rail sections as walers and twin, large diameter Macalloy bars.

Careful setting out was required to clear the wall starter bars and main reinforcement. Above the top of the wall, further twin large diameter bars were used at each UB.

A significantly cheaper option, with less risk, would have been to adopt an F4 concrete finish using evenly spaced form ties.

Appendix 4: Construction issues resulting from aspects of the design – *continued*

A4.6 – Suspended ground floor slabs

Suspended ground floor slabs are sometimes designed without taking the constructability of the floors above into account. If the permanent live loading that the suspended slab is designed for is less than the construction load of the floor above, the suspended slab will not be able to carry the weight of the temporary condition. The solution to this problem is to (in order of preference):

- increase the strength of the suspended slab; make the slab ground bearing (if possible);
- specify the construction of the floor above using structural steelwork, precast beams or permanent formwork that require no support from the slab below;
- use a temporary works solution to bridge the suspended slab.

A4.7 – Nearby buildings and party wall issues

Developments and construction next to existing buildings and structures should take into account the party wall boundaries and the risk of affecting or undermining existing foundations. The permanent works solution should be chosen with regard to the scale of temporary works that would be required to support adjacent structures, the risks involved and the benefits to the project. For example integrating the temporary works excavation support with the permanent works solution.

A4.8 – Composite decking

Long-span steel/concrete composite slabs had been specified. This required the decking sheets to be propped at mid-span (Figure A4.8) and impacted upon the concrete pouring sequence. Longer sheets result in manual handling issues and are more difficult to install (see Box, References (A4.8)). The temporary effects of the construction sequence on the permanent works had not been considered.

Figure A4.8 - Propping to metal decking

References (A4.8):

Metal decking good practice guide (BCSA):

Loading and positioning of packs, MDG 01, https://www.steelconstruction.info/images/e/e7/BCSA_MDG-01.pdf

Shallow metal deck flooring (BCSA):

Guidance on manual handling: introduction, SIG.00

https://www.steelconstruction.info/images/3/38/BCSA_SIG-00.pdf

Manual handling survey, SIG.01

https://www.steelconstruction.info/images/c/c9/BCSA_SIG-01.pdf

Off-site cutting procedures: case study, SIG.02

https://www.steelconstruction.info/images/4/40/BCSA_SIG-02.pdf

Material loading out and positioning guidelines for principal contactors, SIG.03

https://www.steelconstruction.info/images/b/ba/BCSA_SIG-03.pdf

Manual handling: advice to structural engineers, SIG.04

https://www.steelconstruction.info/images/8/85/BCSA_SIG-04.pdf

Manual handling of decking sheets: reducing the handling risk, SIG.05

https://www.steelconstruction.info/images/f/f1/BCSA_SIG-05.pdf

A4.9 – Reinforced concrete slab design/back propping

There is great pressure on a project's design team to reduce the building costs. Reinforced concrete slabs are being designed more efficiently and their limited live load capacity makes backpropping of formwork challenging. If small changes were made to increase the slab live load capacity it would reduce the back-propping requirement during construction and ease impact on follow-on trades. The temporary effects of the construction sequence on the PW had not been considered (see Box, References (A4.9).

References (A4.9):

The Structural Engineer (IStructE):

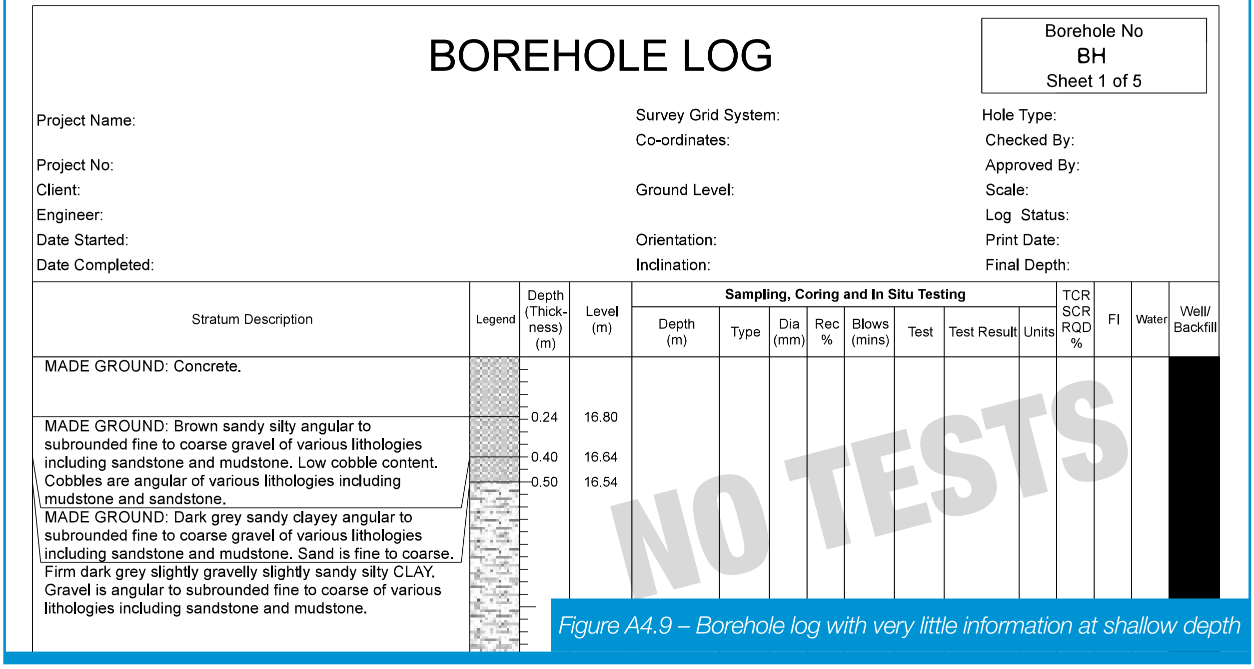
Temporary Works Toolkit. Part 4: An introduction to backpropping of flat slabs

https://www.istructe.org/journal/volumes/volume-94-(2016)/issue-12/temporary-works-toolkit-part-4-an-introduction-to/

Temporary Works Toolkit. Part 6: Backpropping of flat slabs – design issues and worked examples

https://www.istructe.org/journal/volumes/volume-95-(2017)/issue-1/temporary-works-toolkit-part-6-backpropping-of-fl/

Appendix 4: Construction issues resulting from aspects of the design – *continued*



BOREHOLE LOG

Borehole No
BH
Sheet 1 of 5

Project Name:	Survey Grid System:	Hole Type:
	Co-ordinates:	Checked By:
Project No:		Approved By:
Client:	Ground Level:	Scale:
Engineer:		Log Status:
Date Started:	Orientation:	Print Date:
Date Completed:	Inclination:	Final Depth:

Stratum Description	Legend	Depth (Thick-ness) (m)	Level (m)	Sampling, Coring and In Situ Testing: Depth (m)	Type	Dia (mm)	Rec %	Blows (mins)	Test	Test Result	Units	TCR SCR RQD %	FI	Water	Well/ Backfill
MADE GROUND: Concrete.		0.24	16.80												
MADE GROUND: Brown sandy silty angular to subrounded fine to coarse gravel of various lithologies including sandstone and mudstone. Low cobble content. Cobbles are angular of various lithologies including mudstone and sandstone.		0.40	16.64												
MADE GROUND: Dark grey sandy clayey angular to subrounded fine to coarse gravel of various lithologies including sandstone and mudstone. Sand is fine to coarse.		0.50	16.54												
Firm dark grey slightly gravelly slightly sandy silty CLAY. Gravel is angular to subrounded fine to coarse of various lithologies including sandstone and mudstone.															

Figure A4.9 – Borehole log with very little information at shallow depth

A4.10 – Limited soil investigations

On a project where the design team knew that there was likely to be a piled solution, the site investigation reflected this and focussed on the deep soil properties. To design the temporary works the properties of the soils at shallow depth are required (Figure A4.9). Additional site investigation should be undertaken by the permanent work designer so that the design of piling platforms, mobile crane outrigger pads, haul roads, excavation stability checks and temporary soil retention can be more efficient. The use of conservative soil property assumptions, in the absence of test data, leads to larger temporary works items than would have been required thus costing the contractor money.

A4.11 – Limited investigation of existing structures

The client should make an early investment to ensure longer-term savings. On a refurbishment or 'cut and carve' project, the more that is known about the existing structure the more can be done to get that structure to "work" in the temporary condition. Information such as dimensional surveys, rebar breakout reports (Figure A4.11), ferro-scanning, concrete testing, etc. is critical to saving money and whether there is even a requirement for temporary works.

A4.12 – Integrating permanent and temporary works design: needling and propping

It is very typical on a refurbishment project for walls to be removed or masonry openings to be extended. This requires the design of a needling/propping system in the temporary condition to install the new lintel/goalpost. The permanent works designer (PWD) has already designed the lintel element for a line load but doesn't always put this value on the drawing for the temporary works designer (TWD). Doing so saves time/costs as the TWD does not then need to complete a detailed load takedown for that temporary works design (although, typically, a 'sense check' would take place).

A4.13 – Integrating permanent and temporary works design: basements

Frequently, the constructability of basements is poorly addressed by PWDs and it may be they not are fulfilling their CDM requirements in this area. The PWD should consider whether they can:

- design the capping beam to act as a horizontal waler in the temporary condition
- design the basement perimeter wall to act as a cantilever in the temporary condition (to remove the requirement for large basement propping)
- use thrust blocks cast below slab formation level so that they don't need to be removed subsequently.

Figure A4.11 - Intrusive survey to locate rebar

Appendix 5 – Construction issues resulting from aspects of the site work

Figure A5.1 - Collapse of slender rebar cage being fixed from a MEWP

A5.1 – Stability of reinforcement

One of the developments in construction techniques has been the replacement of access scaffold with mobile elevating work platforms (MEWPs) for fixing reinforcement. This reduces the duration of the operation (with no scaffold to build then dismantle) but requires a separate temporary works system to provide stability for the reinforcement cage . This also requires intelligently detailed reinforcement (Figure A5.1).

A5.2 – Precast concrete bridge fascia panels

When considering precast concrete (PC) bridge fascia panels there are typically many design-related tasks. The potential for error at the interfaces is clear and demonstrates the need to ensure responsibility for the design and design checking. On one job responsibility was assigned as shown.

Figure A5.2 – Precast concrete bridge fascia panels: design tasks

Consulting Engineer	Concept and illustrative permanent works design (i.e. size and shape, reinforcement cover, material specifications, stability in permanent condition)
Contractor	Concept for the lifting of the PC panels; PC panel stability prior to casting the insitu stitch; provision of temporary edge protection during installation
Reinforcement detailer	PC panel reinforcement scheduled to accommodate permanent works design
Precast concrete supplier	Design and specification of lifting sockets in the PC panels for transportation purposes
On site lifting equipment supplier	Design and specification of proprietary lifting equipment for use on site
Structural Engineer (on-site lifting)	Design and specification of bespoke lifting equipment and lifting frame
Steelwork fabricator	Design of bespoke lifting frame connections
Edge protection supplier	Design and specification of proprietary edge protection panels
Structural Engineer (edge protection)	Design and specification of edge protection fixing anchors

Notes:

Temporary Works forum

Chairman: Tim Lohmann, CEng, FICE, FIStructE
Secretary: David Thomas, CEng, FICE, CFIOSH, MInstRE

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