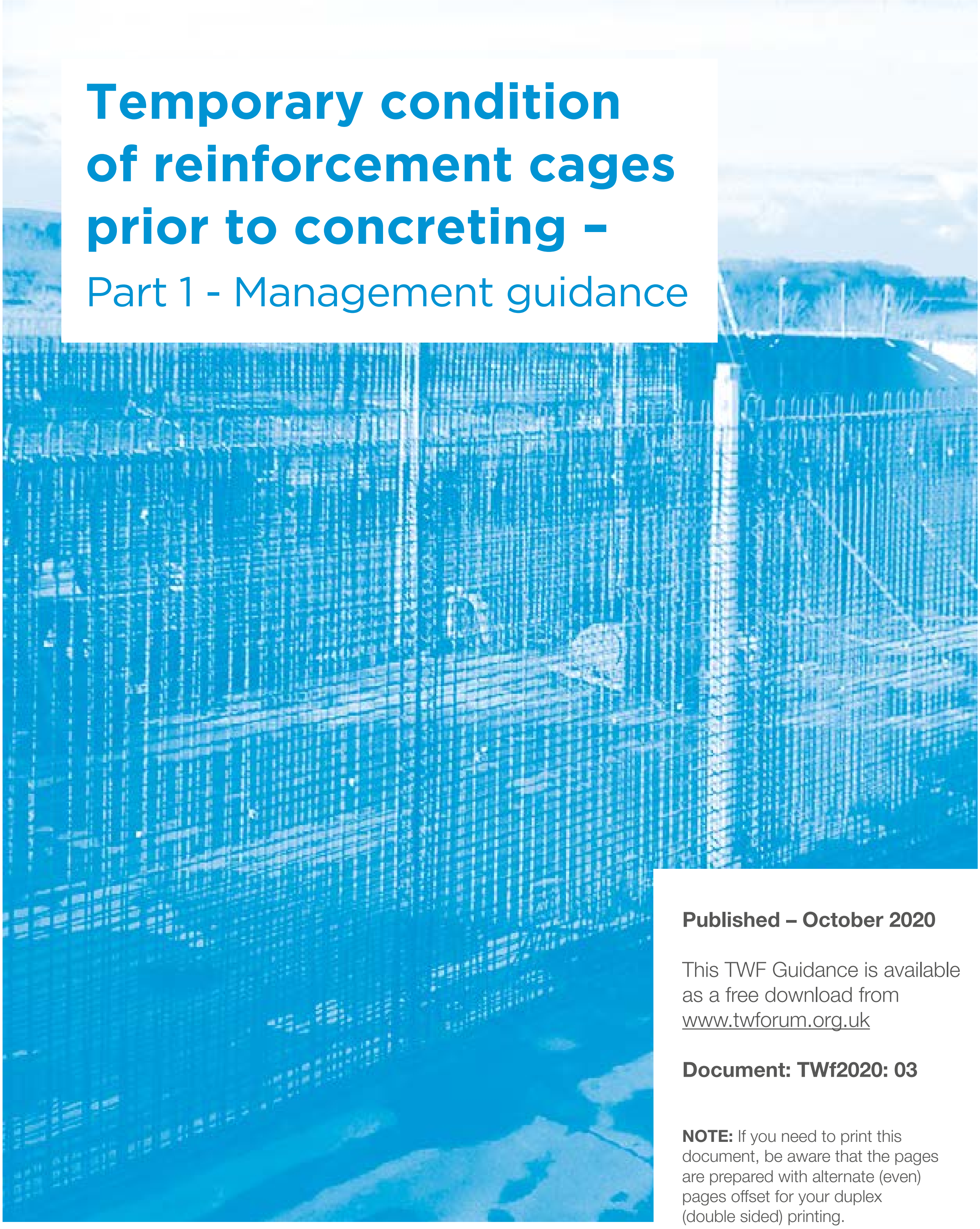
Temporary condition of reinforcement cages prior to concreting –

Part 1 - Management guidance



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Temporary Works forum

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Acknowledgement

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The original working group (Ref.: TWf2013: 01, October 2013) is listed in Appendix 2.

Synopsis

Prior to being encased in concrete a reinforcement cage should be considered as an item of 'temporary works'. This guide seeks to highlight the risks associated with the temporary condition of reinforcement cages; whether the cages is constructed in-situ or prefabricated. Consideration is given to assembling, transporting, lifting and rotating cages into their final position. Generalised guidance is provided on how to identify and manage the risks; the division of responsibility; and some practical measures to prevent problems and accidents.

Background

At a meeting on 23rd September 2015 the TWf, in discussing the issue of rebar instability, identified that industry 'custom and practice' in the measures taken to ensure the stability of reinforcement prior to concreting was changing. As an interim measure, pending the preparation of this guidance, a TWf Safety Bulletin was issued to highlight key issues for all parties to consider (Title: Stability of reinforcement prior to concreting, Ref: TW15.116, Date: 16th October 2015[1]).

Notes

The working group recognises that some photographs may show breaches of current safety regulations, but the photographs have been retained in the guide to illustrate particular items of interest.

This version of the guidance supersedes 'Stability of Reinforcement: Cages Prior to Concreting' (TWf2013: 01, October 2013) (which is to be withdrawn upon publication of Part 2 (Temporary condition of reinforcement cages prior to concreting: Part 2 – Technical guidance (TWf2021: 01)).

Disclaimer

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.

[1] https://www.twforum.org.uk/viewdocument/sustainability-of-reinforcement-pri

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Introduction

Reinforcement cages are a common feature on construction projects. However, the engineered assessment of their temporary condition during assembly, transportation and lifting, prior to concreting, is commonly dealt with by 'custom and practice', as limited definitive guidance on these issues has been available. Reinforcement cages have been known to periodically collapse and cause death and serious injury, along with programme and financial consequences. This guide highlights and explains the key issues to those specifying, managing, designing, assembling, transporting, moving and installing reinforcement cages.

Reinforcement cages for walls, columns, beams and slab elements, whether they are to be assembled in-situ or prefabricated and moved into the final position, are included within this guide. Guidance is given on stability in-situ prior to concreting and during assembly, transportation and lifting. General guidance for pile cages and diaphragm walls is also provided although specific guidance is beyond the scope of this document[2].

For simplicity, 'cage' is the descriptive term used throughout the text for 'reinforcement cage'.

1.0 Scope

This guide applies to organisations and individuals involved in specifying, managing, designing, detailing, assembling, transporting, lifting and stabilising cages. It seeks to draw attention to some key issues in ensuring stability and robustness and, thus, safety.

1.1 This guide highlights common potential challenges and hazards with cages, in the temporary condition and how to manage these to ensure safety. It is complementary to other existing guidance (see Bibliography).

1.2 This guide:

- highlights the need to understand the roles, responsibilities and procedures from concept, procurement, design and detailing, through to assembly, transport, lifting, inspection and finally to concreting.
- provides guidance on management procedures.
- emphasises the importance of competence, communication and the clear division of responsibilities.

1.3 Part 2 of this guidance provides specific technical guidance and example calculations.

1.4 Fundamentally, and prior to concreting, cages should be recorded in the temporary works register - whether potentially stable or not - and considered as 'temporary works', thus invoking the procedural controls recommended in BS 5975: 2019.

2.0 Understanding the challenges and issues with the temporary condition of reinforcement cages

There is a lack of awareness and understanding that assembling cages in-situ, or transporting and lifting prefabricated cages, has inherent risks and can be dangerous; or that buckling of bars can occur suddenly and without warning. Also, that cages assembled in-situ can become progressively less stable as work progresses; something that can be counter-intuitive. Ultimately the cage is encapsulated in concrete and generally forms part of the permanent works (unless specifically used for temporary works, e.g. some tower crane foundations). This can seem counter-intuitive, as the reinforcement gives concrete its strength in tension, but the reinforcement may be unable to support its own weight in the temporary condition. The responsibility for identifying and managing the hazards and resulting risks is often not clearly defined. Maintaining safety during the assembly, transportation and lifting of cages is a temporary works issue and needs to be managed appropriately.

2.1 The temporary condition of cages prior to concreting is an item of temporary works and needs to be managed appropriately to:

- comply with UK health and safety legislation, regulations and industry best practice standards.
- improve the assessment and understanding of the hazards (from identification, design, assembly, transporting and lifting of cages), to control and reduce the associated risks and accidents.
- ensure those involved understand their roles and responsibilities.
- ensure cages are cost-effective and can be assembled / positioned safely and perform as intended.
- reduce the chances that mistakes / omissions are made and improve the chances of mistakes/ omissions being spotted and dealt with effectively.

2.2 The Health and Safety Executive (HSE) can visit any project and may expect to see evidence of adequate and appropriate procedures for the management of temporary works. They have powers of enforcement and if evidence cannot be produced they may stop you working.

NOTE: Other organisations such as the Office for Nuclear Regulation (ONR) or the Office of Rail and Road (ORR) have similar powers for projects within their scope.

[2]Advice is available from the Federation of Piling Specialists (FPS): see Bibliography.

2.3 There has been significant advancement, refinement and optimisation in analysis and design principles in permanent works design, along with improved detailing methodologies. In some cases, this has led to smaller diameter reinforcement bars being specified (leading to less rigid cages). This has potential cost benefits but the individual bars within cages have become increasingly slender, thereby detrimentally affecting overall stability. Additionally, there is an increasing trend by permanent works designers to sub-contract the detailing of reinforcement elsewhere. Those responsible for the design and detailing of cages often have insufficient practical site experience to identify the challenges and hazards with fixing and moving cages. The tendency is to only consider the final completed construction (once the concrete has fully matured).

2.4 Research has shown it can be difficult to justify that adjacent vertical wall mats behave compositely. There is limited information on the strength of tie wire intersections (and further research is required). Double-face cages usually require spacer bars or chairs to connect the individual faces of reinforcement together. While these bars appear to improve rigidity, designers should consider if this can be relied upon; the evidence is that unless the spacer bars are specifically designed (and the ties specifically detailed) to create a 'truss action' they do not improve rigidity.

2.5 Site 'custom and practice' has evolved and changed. In particular:

- There appears to be a trend towards fixing taller in-situ cages with smaller diameter vertical bars and to prefabricated cages then lifted into position. Pre-fabrication can occur on-site or off-site whereby cages then need to be transported.
- Previously, reinforcement was mainly fixed in-situ and, if stability was considered an issue, it was often tied back to one side of a formwork system. The formwork was stabilised by props anchored to a slab or kentledge (known as "Kelly Blocks"). Once the formwork was aligned and stabilised it was used to provide support to the cage which was tied to the formwork. On the front side an access scaffold was provided for operatives. Once the cage was completed the front formwork was installed between the cage and scaffolding.
- Scaffolding was provided for access (which could also be used to provide stability). Now, many sites prefer to use mobile elevating working platforms (MEWPs) in lieu of access scaffolding. However, unlike a purpose-designed scaffold, MEWPs do not provide stability to the cage.
- There is a lack of awareness on site that bars should not be cut and bent to suit site constraints without approval from designers.
- On-site and off-site prefabrication has become commonplace, with completed cages being lifted into a freestanding position.
- Fixing reinforcement, erecting formwork and placing concrete are increasingly carried out by different gangs or different sub-contractors and coordinating these activities can be complex. As such, formwork may be erected increasingly after the cages are complete and in their final position and often this is not identified as a potential hazard.
- The 'hook'-shaped tying tools - and some proprietary automatic tying machines - do not usually provide the ability to lock tension into ties (unlike long-handled nips).
- Different types of tying wire and tie patterns (with more use of slash/hairpin type ties than traditional crown or double ties) and developments in the use of tying guns (which use multiple thickness of finer wire).
- A lack of awareness and understanding of the temporary works issues by all parties involved and that the hazards need to be identified, the principles of prevention applied and good management procedures to be followed.

2.6 Often, there is a reliance on the competence and experience of operatives; along with 'custom and practice'. However, this should not be relied upon to ensure safety. Many of the changes have led to an increase in accidents involving cages. Notwithstanding this, many of the measures required are straightforward and long-standing. A large reinforcement cage can represent a considerable danger to those working on, adjacent to, or within it, should it buckle, collapse or fail during lifting. Many collapses (see Figure 1) usually occur through lack of strength or lateral instability, or a lack of cage robustness prior to it being fully stabilised through containment within formwork and eventual encasement in concrete.

Figure 1: Examples of reinforcement cage collapses

2.7 The challenges and issues which need to be understood include:

(a) cages which are assembled in-situ prior to concreting;

(b) cages which are prefabricated (either on-site or off-site) and then transported / moved / lifted into position prior to concreting.

2.8 Prefabrication in factory-controlled conditions provides a reduction to the risks in safety and particularly health (e.g. chronic musculoskeletal problems in steel fixers caused by poor posture and acute wrist problems). Risks relating to haulage including lashing points and dynamics under hard braking should be considered. Off-site cage fabrication should be considered in balance with the environmental considerations of transporting.

2.9 Industry standard contracts are, for the most part, silent on the subject of temporary works. The Client or Contractor may choose to stipulate specific obligations with respect to temporary works, for example reference to industry good practice. These must be incorporated expressly into the contract. Contracts should be clear about who is responsible for the design and/or detailing of reinforcement. Traditionally, this was the Permanent Works Designer (PWD), but it is now frequently the contractor (or even sub-contractor).

2.10 Detailing of reinforcement is the specification of individual bar shapes, spacing, location and lengths to comply with design codes and detailing rules. The detailing output is presented in the form of a bar bending schedule and reinforcement drawings. These can be a significant cost for an organisation. Consequently, there has been a tendency to use relatively cheap resource sourced from overseas. Overseas detailers may not be aware of the provisions of UK legislation in this context. Regulation 10 of the Construction (Design and Management) Regulations 2015 (CDM2015) requires the person who commissions the overseas detailing - or the client (if the commissioning is also not in UK) - to ensure that Regulation 9 is also complied with. Even if the contractor is responsible for detailing, the personnel doing the detailing may not have practical, on-site experience. Designers and detailers should understand the hazards that cages can present in temporary conditions. Those commissioning detailing should be aware that detailers may not have this understanding and should adapt their brief, and their own checks and actions, accordingly.

2.11 CDM2015 requires the principal designer (PD), during the pre-construction phase of a project, to coordinate the work of others in the project team to ensure that significant and foreseeable risks are managed throughout the design process.

3.0 Overview of legislation, regulations and industry best practice with relevance to cages

The users of this guide should be familiar with all the relevant legal requirements, standards and industry best practice guidance.

3.1 There is much legislation, guidance and industry best practice. These include (but are not limited to):

- Health and Safety at Work Act etc. 1974 [1.]
- Construction (Design and Management) Regulations 2015 [2.]
- Management of Health and Safety at Work Regulations 1999 [3.]
- Work at Height Regulations 2005 [4.]
- Provision and Use of Work Equipment Regulations 1998 (PUWER) [5.]
- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) [6.]
- BS 5975: 2019, Code of practice for temporary works procedures and the permissible stress design of falsework [7.]

- BS 7121-1: 2016, Code of practice for safe use of cranes. General **[8.]**
- BS 8666: 2005, Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification **[9.]**
- Standard method of detailing structural concrete: A manual for best practice (4th Edition) (2020), IStructE **[10.]**

3.2 The legal requirement is that the party in control must ensure that work is allocated and carried out in a manner that does not create unacceptable risk of harm to workers or members of the public. CDM2015, and its associated guidance, is directly applicable to the design and management of both permanent and temporary works. Maintaining the stability of cages, as well as the transporting and lifting thereof, should follow the 'general principles of prevention and protection' as set out in the Management of Health and Safety at Work Regulations 1999 (and emphasised in CDM2015).

3.3 The legal requirements for lifting are given in LOLER and its associated Approved Code of Practice (ACoP), L113. These provisions need to be considered in parallel with the Management of Health and Safety at Work Regulations 1999 (MHSW) and PUWER. There are no parts of LOLER that are specific to the lifting of reinforcement. However, general advice on the safe use of cranes is given in BS 7121-1: 2016.

3.4 The British Constructional Steelwork Association (BCSA), Guide to the management of site lifting operations **[11.]**, contains additional guidance (although again not specific to lifting reinforcement). The Federation of Piling Specialists have also produced guidance on this subject **[12.]**.

3.5 Table 1 in 'Managing health and safety in construction, L153 (HSE) **[2.]** provides a useful summary of roles and duties under CDM2015.

4.0 Overview of organisational responsibilities for managing temporary works (including the temporary condition of cages)

All organisations are required to have appropriate policies and procedures in place to comply with the law and industry standards. They should be competent organisations, have adequate resources and be appropriately insured. Insurance should be kept up to date.

Prior to concreting, cages should be recorded in the temporary works register - whether potentially stable or not - and considered as 'temporary works', thus invoking the procedural controls recommended in BS 5975: 2019.

Any organisation employing another organisation to undertake temporary works, e.g. principal contractor employing sub-contractors and designers, should take reasonable steps to check these organisation(s) are competent (have the necessary skills, knowledge, experience and capability) to construct, manage and/or design the work.

4.1 General

4.1.1 Every organisation involved in temporary works (e.g. clients, contractors, designers, equipment suppliers) should have an auditable procedure for the management of temporary works. These should follow the recommendations made in BS 5975: 2019 and be relevant to the type of work the organisation is responsible for. The procedure should ensure that the hazards and risks associated with cages are identified, classified and controlled. It should cover the design, assembly, transportation and lifting and include all relevant forms and provide an audit trail. The procedure should also include the appointment of competent persons.

4.1.2 A summary of the overall sequence for managing cages is:

- **Planning**

  For commercial projects, the need for cages should be identified at planning / tender stage. If possible, identify whether the cages are likely to be assembled in-situ or prefabricated. If prefabricated on-site, then significant working / storage space is required and a means of lifting and providing stability. If assembled off-site, then transportation also needs to be considered.

- **Design, detailing and design checking**

  Cage designers, detailers and design checkers should ensure the principles of prevention have been followed. The manual handling of long heavy bars, access requirements, lifting points and stability should be considered and are likely to require a design. Bar splice positions should be chosen so that they are adjacent to construction joints. The requirement for bars to project beyond the construction joint should be minimised.

- **Assembly**

  Cages should be assembled by competent operatives. There must be a safe means to assemble the cage (e.g. sequence of fixing bars, access considerations, manual handling), with task-specific risk assessment(s) and method statement(s) (RAMS). Operatives need to be briefed in any limitations of use and any specific measures to ensure stability and safety.

- **Transportation and lifting**

  Consideration should be given to how prefabricated cages are loaded onto and transported by vehicles on public highways and how they are to be lifted safely into position. Lift plans and lifting points need to be provided. Once in place how stability needs to be achieved and maintained prior to concreting.

- **Inspection**

  The cage should be inspected at various stages, to ensure that it has been assembled, lifted, transported and stabilised correctly. Prior to moving a cage an inspection should be carried to ensure that loose bars or other items cannot fall from the cage. Inspections should also be carried out to ensure any means of providing temporary stability prior to concreting have been provided. Inspections are also required on items of access equipment (e.g. scaffolding, MEWPs).

4.2 Clients

4.2.1 CDM2015 requires that commercial clients ensure they select and appoint competent organisations (e.g. a principal designer and, on projects with more than one contractor, a principal contractor) and allocate sufficient time and resource to ensure the work can be carried out without risks to health or safety.

4.2.2 If commercial clients are directly involved in temporary works (including cages) they should have an auditable procedure for the management of temporary works that follows the recommendations of BS 5975: 2019.

4.2.3 Some clients (e.g. Network Rail) have their own procedures for temporary works. These are intended to protect their assets if construction work is carried out, on or near their property. They may impose additional requirements on contractors and designers relating to loads or safety measures and there is an extra level of approval by the client’s representative. These requirements need to be understood and allowed for in terms of programme, costs and supervision levels. It should be noted that their specific requirements are additional, not alternative, to the law.

4.2.4 Generally, domestic clients are not expected to carry out the same duties as those placed on commercial clients. Their duties are passed to the professionals they employ (e.g. architects, contractors). It is unlikely that large cages be required on domestic projects, hence the risks are deemed to be low.

4.2.5 Organisations that commonly require and commission cages for their projects, may include:

(i) Principal Contractors (PCs) and/or contractors for temporary reinforced concrete (e.g. foundations to temporary bridges).

(ii) Owners of commercial properties or infrastructure for permanent works reinforced concrete. The reinforced concrete may be for new structures or strengthening / repairs of existing structures. Also, reinforced concrete may be required for temporary works (e.g. foundations to props).

(iii) Consulting engineers or architects, e.g. for foundations to scaffolding or crane foundations on poor ground, to carry out inspections on structures.

4.3 Permanent works designer (PWD)

4.3.1 CDM2015 (Regulation 9) requires all designers (PWD or TWD) to take into account the general principles of prevention and eliminate risk wherever possible (e.g. eliminate the possibility that a cage becomes unstable or eliminate the need for work at height). Where this is not possible and significant risks remain, additional temporary works (e.g. propping or scaffolding for access) may be required and the principal designer and designer have a duty to ensure these temporary works items can be facilitated in a safe and efficient way without undue risk or complexity. Very little guidance exists for PWDs as to the challenges involved with the temporary condition of cages.

4.4 Principal Contractor (PC) and Contractors (C)

4.4.1 For commercial projects the PC/C has an overall duty for the safe execution of all works on site. This includes cages. They should have an auditable procedure for the management of temporary works that follows the recommendations made in BS 5975: 2019. However, some of the responsibility may be delegated to specialist sub-contractors who are deemed competent to coordinate their own temporary works, e.g. sub-contractors used to assemble and/or lift cages or cage designers.

4.4.2 In this case, the sub-contractor’s procedures should be reviewed and approved for use on the project by the PC. However, the PC should pro-actively monitor performance and manage the interfaces between different sub-contractors.

4.4.3 The PC is normally responsible for organising permits, road closures, etc. to allow cages to be transported, assembled, and/or lifted and for managing interfaces.

4.5 Sub-contractors (SC)

4.5.1 More than one sub-contractor may be involved in carrying out reinforced-concrete work; including formwork (traditionally built or hired proprietary systems), steel-fixing, placing concrete, craneage for lifting, providing / installing propping and providing access. Each of these activities has hazards and elements of temporary works that need to be identified and managed along with the interfaces.

4.5.2 Sub-contractors involved in temporary works should have an auditable procedure for the management of temporary works (specifically for managing cages) that follows the recommendations made in BS 5975: 2019 and provide evidence of their competency to carry out the work.

4.5.3 On larger projects their procedure may be approved by the PC for use on the project. If they do not have their own approved procedure, they should adopt the PC's procedure. The PC then manages the overall reinforced concrete package. However, the PC's procedure is unlikely to be bespoke to reinforced-concrete work so may require enhancement. Also, the PC's site team may not have the expertise to adequately manage the individual elements.

4.5.4 It is reasonable for any sub-contractors to be made aware of the requirements of the PC's procedure as part of the tender.

4.5.5 Sub-contractors should have a recorded training scheme. They should be able to demonstrate that they have competent supervision to manage the assembly and lifting of cages on site (e.g. CSCS skilled worker card specific to steel-fixing occupations) and are working within their capabilities.

4.5.6 Sub-contractors should:

- have appropriate employers' liability, public liability and professional indemnity (if designing) insurances in place.
- ensure management, supervision and operatives have received relevant training.
- have access to a competent designer if required (noting that design in relation to cages in the temporary condition is highly specialist).
- ensure all deliveries are undertaken in a safe manner with proof of operator competence, certification and lift plans as necessary.

4.6 Cage designer, detailer and design checker

4.6.1 Cage designers, detailers and design checkers (they may be separate entities to the PWD) could be from the same organisation, but it is not unusual for them to be from different organisations in different countries. They may be employed by clients or contractors. The cage designer, detailer and the design checker are likely to be PWDs. However, on occasion, a specialist temporary works designer (TWD) may become involved to offer expertise on specific temporary works issues or to design cages for temporary works purposes (e.g. tower crane foundations).

4.6.2 All these parties have duties under CDM2015 where the requirement is to follow the principles of prevention and eliminate risk wherever possible. Where the risk cannot be eliminated, they must highlight any significant residual risks. All designers need to be sufficiently competent in designing / checking cages (including temporary works issues associated with the cages) and have appropriate professional indemnity insurance.

4.6.3 There should be an auditable procedure for the management of temporary works (specifically for designing / checking the cage in the temporary condition) that follows the recommendations made in BS 5975: 2019 and be able to provide evidence of their competency to carry out the work.

4.6.4 The procedure can be approved by the PC for use on the project. If they do not have their own procedure, they should adopt the procedure of the PC and the PC should manage the overall temporary works design package.

4.6.5 It is reasonable for temporary works designers to be made aware of the requirements of the PC's procedure as part of the tender process.

4.6.6 Depending on the category of the design check required the checker may be part of the same organisation that carried out the cage design or external (see BS 5975: 2019, Table 2).

5.0 Overview of people involved in managing temporary works (including the temporary condition of cages)

5.1 General

5.1.1 Refer to BS 5975:2019 [7.] and TWf's Competencies of the TWC [13.] (under revision) for further information and guidance on roles and responsibilities.

5.2 Designated Individual (DI)

- Every organisation involved in temporary works (including those involved in the temporary condition of cages) should appoint a senior person (e.g. technical director) to be responsible for establishing and maintaining a suitable procedure for their work, which is periodically reviewed, updated, audited and that adequate resources are made available to control the procedure (i.e. appoint competent persons).
- The DI should ensure the procedure is approved by the board of directors or board director; and is distributed and audited periodically.

- If an organisation undertakes multiple roles (e.g. steel-fixing sub-contractor undertakes design), their DI should establish and maintain separate procedures for each role (BS 5975: 2019, Clause 6.1.1.8).
- A DI should ensure that any organisation they employ as a sub-contractor or supplier has adequate temporary works procedures and is competent. Where a contractor wishes to manage their own temporary works the PC's DI should approve these procedures for use on the project.

5.3 Principal Contractor's Temporary Works Coordinator (PC's TWC)

- The PC's TWC is a management role with ultimate responsibility (where there is more than one temporary works coordinator) for coordinating all temporary works on a project. They should ensure the PC's temporary works procedure is being implemented on the project.
- The PC's TWC should be an employee of the PC, be appointed by PC's DI and is responsible to the PC's DI for temporary works.
- They should be competent in the types of temporary works present on that project and have completed TWC training.
- The PC's TWC should be appointed formally, accept the responsibilities and have sufficient time / resource to carry out the role.
- They should be familiar with BS 5975: 2019 and their own company's procedure.
- The PC's TWC must have the authority to stop work if it is not satisfactory and the authority to sign permits (see BS 5975: 2019, Table 1).
- They need to ensure (e.g. by inspection and audit) that any temporary works coordinator / temporary works supervisor is operating to the agreed temporary works procedure.
- They should manage any "grey areas" of responsibility / interfaces between different contractors.

5.4 Temporary Works Coordinator (TWC)

- Every project involving temporary works should have a TWC (a PC's TWC where there is more than one contractor managing temporary works) and is a management role with responsibility for coordinating temporary works on a project. They should ensure their temporary works procedure is being implemented.
- The TWC should be an employee of the PC/C. On larger more complex projects they may be an employee of a sub-contractor (e.g. concrete-frame sub-contractor) whose procedures have been approved for use on the project. They are appointed by their organisation's DI and are responsible to their organisation's DI for temporary works. They should liaise closely with the PC's TWC if one is present.
- They should be competent in the types of temporary works they are being asked to coordinate (including the temporary condition of cages) and should have completed formal TWC training.
- The TWC should be formally appointed, accept the responsibilities and have sufficient time / resource to carry out the role.
- They should be familiar with BS 5975: 2019 and their company's temporary works procedure.
- A TWC must have authority to stop work if it is not satisfactory and the authority to sign permits (see BS 5975: 2019, Table 1).
- They need to ensure (e.g. by inspection and audit) that any TWS is operating to the agreed procedure.
- They should manage any "grey areas" of responsibility / interfaces between different contractors.
- In relation to the temporary condition of cages this role is generally carried out by site engineers or project managers.

5.5 Temporary Works Supervisor (TWS)

- Some projects choose to appoint TWSs to assist the PC's TWC / TWC with specific duties (e.g. ensuring temporary works are built correctly or inspections). This may be a "hands on" and "practical" site supervisory role. They should have technical and practical knowledge appropriate to the complexity of the work.
- TWSs are generally employed by sub-contractors (e.g. steel-fixing sub-contractor). They are appointed by their organisation's DI and are responsible to the PC's TWC / TWC.
- They should be competent in the types of temporary works they are being asked to supervise (including the temporary condition of cages) and should have completed formal TWS training. On higher risk / complex cages this may also need to be supplemented with significant technical as well as practical input.
- They should ensure that cages are being assembled and lifted correctly and any additional temporary works required to ensure stability are installed correctly; request or carry out inspections; check that the actual site

conditions reflect any design assumptions; inform the PC's TWC / TWC when the constructed works are ready to be inspected or loaded.

- TWSs should be formally appointed, accept the responsibilities and have sufficient time / resource to carry out the role.
- They should be familiar with BS 5975: 2019 and their company's temporary works procedure.
- They must have the authority to stop work if it is not satisfactory and where necessary (and within their capabilities) be given limited authority to sign permits (commonly known as permits to proceed / fix / lift / pour); generally for lower risk cages (see BS 5975: 2019, Table 1).
- In relation to cages the role is generally carried out by steel-fixing site supervisors. A degree of independence is required to ensure that the pressure of the delivery schedule and pour dates do not drive unsafe behaviour.

5.6 Others

5.6.1 The safe assembly, transportation and lifting of cages relies on good communication, co-operation and appropriate input of all parties carrying out the works. This includes the aforementioned as well as the Appointed Person for lifting (AP), Crane Operators, Slinger/Signaller, haulier and steel-fixers.

NOTE: The PC's TWC / TWC is the point of contact between all parties for issues relating to temporary works. It is preferable for the PC's TWC / TWC not to have day-to-day responsibility for site progress and they do not have to have any design experience. Deputies for all roles should be provided to cover for absence.

6.0 Procedures for managing temporary works (including the temporary condition of cages) to BS 5975: 2019

The temporary condition of cages prior to concreting should be considered as temporary works and the hazards should be assessed and eliminated where possible. Where this is not possible the risks need to be managed. Familiarity with legal requirements and the recommendations made in BS 5975: 2019 is essential to ensure the issues with cages are identified, planned, designed, checked, assembled, moved and inspected correctly.

BS 5975: 2019 is not a legal requirement and you don't have to follow its recommendations for controlling temporary works. However, you may need to justify that what you are doing is as least as good as it is the only detailed document on the management of temporary works.

6.1 General

6.1.1 This section highlights the procedures required to manage the temporary condition of cages. BS 5975: 2019 has three fundamental principles:

- All organisations have a duty to manage and control their work.
- The contractor is responsible for building the permanent works and all associated temporary works.
- One person should take overall responsibility for managing the temporary works; known as the PC's TWC or TWC and every project should have one.

6.2 Managing temporary works (including the temporary condition of cages)

The main items that should be included in any procedure for managing temporary works (including the temporary condition of cages) are:

6.2.1 Planning / pre-construction / design

- Every organisation involved in temporary works should appoint a senior person to act as DI to establish and maintain a temporary works management procedure.
- Often working space for assembly, storage and access - or space for lifting machinery - are a premium (especially in inner cities). The client and PD should address these issues and permission for additional space may be sought and permits for transportations may need to be applied for. Agreement and approvals from neighbours may also need to be sought especially from organisations such as Network Rail.
- Where possible, cages and any potential hazards related to the temporary condition of cages, should be identified (a temporary works register is a useful tool for this purpose) as early as possible by the client, PD, PWD, cage detailer and the hazards eliminated where possible. It should be noted that the detailer is also a 'designer' under CDM2015, irrespective of whether they are contracted to the PWD or the Contractor, and is duty bound to consider the manner and method by which the reinforcement is to be assembled and held stable.
- Many issues can be identified and addressed (eliminated where possible) by the PWD during the planning / design stage and they need to justify that their design can be assembled and used safely. Some issues, however, may only become apparent upon award of contract and may be specific to the method of work selected by the contractors, in which case the contractor needs to liaise with the PWD or specialist TWD to resolve these issues.

- Designers and detailers should consider how the cage is likely to be assembled: in-situ or prefabricated (Some cages are always prefabricated and lifted into position, e.g. for diaphragm walls). Where necessary, additional advice should be sought from experts in this subject (e.g. early contractor involvement or discussing with temporary works specialists). Items such as stability, lifting points, manual handling, sequencing, access. need to be addressed. The size of individual prefabricated cages may be restricted by limitations on working space on site, transport or anticipated crane sizes on site. Temporary works is often required to allow large complex cages to be assembled, moved or stabilised.
- Designers and detailers should communicate clearly any design assumptions (and how they are to be confirmed) and any significant residual risks (those that a competent contractors is not expected to be able to deal with) need to be highlighted so they can be addressed on site.
- Often there is a large amount of repetition with cages and designers may consider providing “standard solutions” or “typical details” to resolve some of the issues. These standard solutions or typical details may consider stability of vertical cages when being assembled in-situ, lifting points, support to heavy mats of horizontal reinforcement, etc. and need to be designed and checked and the limitations of use clearly stipulated.
- For large and complex cages a bespoke design is required - with an appropriate category of design check (in accordance with BS 5975: 2019, Table 2) - and a design check certificate issued. External approval may also be required, e.g. when adjacent to or on a Network Rail asset.
- Sub-contractors (such as steel-fixing sub-contractors) should be vetted and their policies and procedures reviewed and, if appropriate, approved for use on the project by the DI of the potential PC/C. Many PCs/Cs have lists of approved suppliers and sub-contractors.
- The steel-fixing sub-contractor may be asked to provide outline information, such as price, timescale, area required for storage or assembly, for tender purposes.
- Permissions may need to be sought (e.g. from neighbours or obtaining licences for additional working space or road closures for reinforcement deliveries or cranes).

6.2.2 Upon award of contract

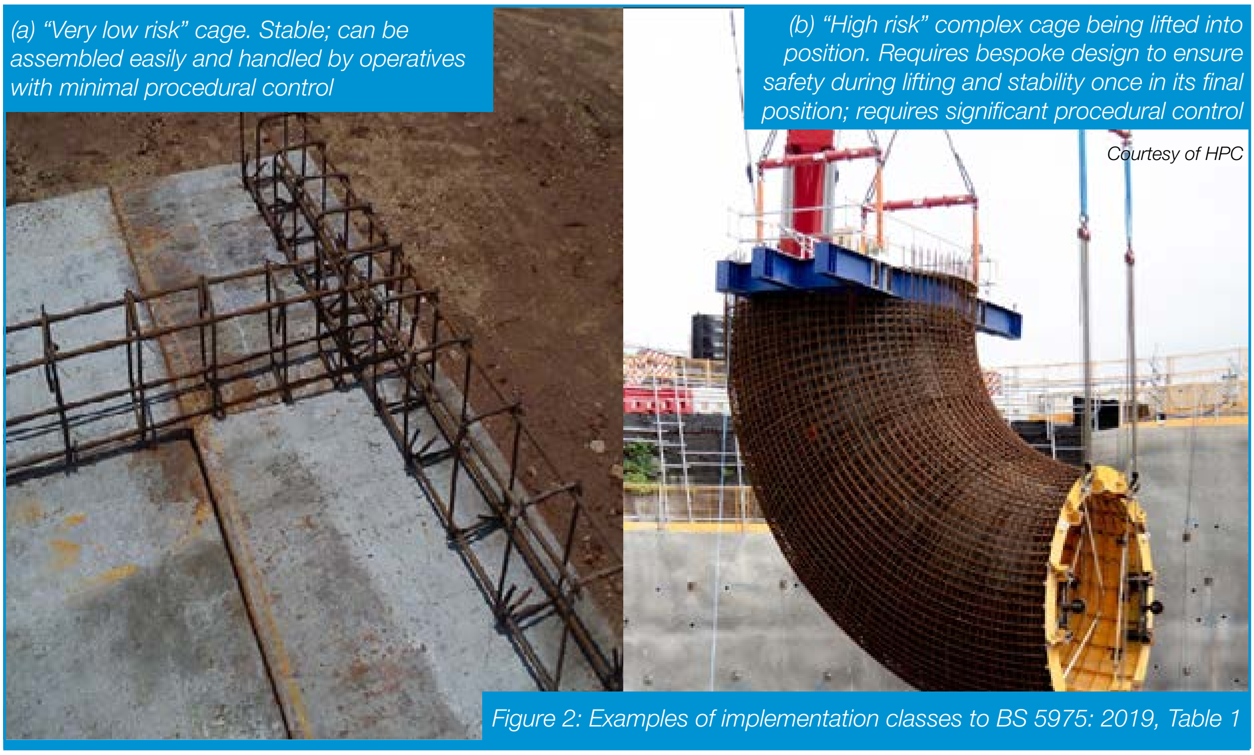
- The PC should be appointed formally. In turn, a steel-fixing sub-contractor and (if required) other sub-contractors (e.g. scaffolders, crane suppliers) should also be appointed formally.
- Determine which organisations’ procedures should be used for managing the temporary condition of cages. This should be determined by the scale and complexity of the cages. If the steel-fixing sub-contractor’s procedures have been approved they can be used; if not the PC’s procedures must be adopted by the steel-fixing sub-contractor for use on the project (although amendments may need to made to reflect the sub-contractor’s work).

6.2.3 Appointments

- Each organisation’s DI should - as required - appoint in writing competent individuals (e.g. PC’s TWC, TWC and/or TWS), with a list of responsibilities and duties. The individuals should accept the appointments.
- The PC’s TWC should be employed by the PC and is required if sub-contractors’ procedures have been approved for use on the project.
- A TWC should be employed by the contractor (on projects with a single contractor) or by a sub-contractor (e.g. steel-fixing sub-contractor) whose procedures have been approved for use on the project.
- A TWS, if required, is generally employed by sub-contractors (e.g. steel-fixing sub-contractor).

6.2.4 Temporary works register

- The PC’s TWC / TWC should maintain a master temporary works register with the various cages (and associated temporary propping, scaffolding, formwork or cranes, etc.) on a project being added as the work progresses. The register may be started pre-construction with significant items being identified and this register can be further developed on site.
- The hazards should be assessed and the risks for each different type of cage should be classified (known as ‘implementation risk’ in BS 5975: 2019, Table 1) as “very low, low, medium or high” (see Figure 2, for Examples). The class determines the level of procedure required to manage the risks. The hazards should be regularly reviewed, and measures provided to manage the risks.



(a) "Very low risk" cage. Stable; can be assembled easily and handled by operatives with minimal procedural control

(b) "High risk" complex cage being lifted into position. Requires bespoke design to ensure safety during lifting and stability once in its final position; requires significant procedural control

Courtesy of HPC

Figure 2: Examples of implementation classes to BS 5975: 2019, Table 1

6.2.5 Constructing the cage

The responsibility for ensuring that the temporary condition of the cage has been considered during the construction phase falls to the PC's TWC / TWC (as set out in BS 5975: 2019). Most small cages normally present no significant risk. However, specific location and consequences of failure need to be considered. Also, larger and more complex items need to be assessed and considered more closely which is likely to involve discussions with the PWD, cage designer and detailer:

- Method statements and risk assessments (RAMS) should be carried out and recorded for every significantly-different type of cage, considering the hazards associated with its assembly, transportation, lifting, positioning, stabilising, consequences of failure, location and interface with other items of temporary works or permanent works. Many cages and projects are similar, but it is not acceptable to use a risk assessment from a previous site. Each project is slightly different, and authors need to ask: "What's different about the hazards and risks for this location and job?"
- RAMS should be reviewed by the PC's TWC / TWC and a record kept, including any amendments.
- Measures should be provided on site to manage the designer's residual risks.
- A suitable working area should be provided for pre-fabrication and storage of cages prior to lifting into position. Safe access for transport vehicles needs to be provided when delivering prefabricated cages or loose bars for on-site fixing. Appropriate measures need to be in place to allow vehicles to be offloaded safely. Lifting machinery and lifting accessories should be certified and inspected and again a safe area with exclusion zones for lifting (where possible) provided.
- The PC's TWC / TWC should ensure that relevant licences, permissions, etc. are in place to allow the cage to be assembled, transported, and/or lifted. A 'permit to fix reinforcement' may be used.
- The PC should provide site induction, check the competence of steel-fixers, slinger / signaller and crane operator (for lifting), scaffolders (for access) and brief them in the methodology and risks.
- When assembling in-situ cages, stability and access are important considerations. Hold points may be required at intermediate points, to ensure temporary works measures have been provided. The PC's TWC / TWC should ensure hold points are provided and released (generally following an action that may require an inspection) by the provision of single or multiple 'permits to proceed'.
- If a cage is required on-site for temporary works purposes, then the PC's TWC / TWC should ensure an adequate design brief is provided to the designer.

- The TWS and other relevant members of the site team should be involved in developing the solutions and should be encouraged to raise any concerns about stability that they observe during routine inspections.
- If on-site changes / modifications are required to designed cages (or departures from standard details) this should be communicated via the PC's TWC / TWC to the designer for checking and approval. On-site changes may be necessary due to:
  - i) contractor's method of work differs from the designer's assumptions;
  - ii) on-site conditions differ from designer's assumptions;
  - iii) the cage or part of the cage is unable to "fit" into its final position;
  - iv) client instructs late changes to the permanent works.
- The PC's TWC / TWC - along with other members of the site team - should review the design proposals to ensure the design brief has been met and that it considers practical issues such as buildability and provides control measures for residual risks.
- If the cage is to be lifted using a crane, then the cage requires lifting points that have been adequately designed, tested and certified. The weight of the cage and centre of gravity (for complex shapes) need to be calculated. The crane and lifting attachments require thorough examination (see LOLER **[6.]**) with a competent crane operator. A lift plan should be provided by a competent person (known as an Appointed Person) with due consideration given to the crane foundations. All lifting equipment should be inspected for compliance and quality prior to use. A competent slinger / signaller is required to securely connect the cage to the lifting attachments and provide instructions to the crane operator.
- Prior to releasing the cage from the crane, consideration must be given to stability and additional temporary propping may be necessary. The design and RAMS should provide sufficient detail to ensure stability.

NOTE: It is not unusual that during the construction of a cage that part of the design doesn't quite 'fit' or 'work' and it's common for the site team to make changes to keep the works progressing. This should be avoided as those making the changes then take on design responsibility themselves (see CDM2015). The correct procedure is that the PC's TWC / TWC should be notified and they should communicate with the cage designer to seek approval for any changes that need to be made.

6.2.6 Inspection

- Any access provision such as scaffolding should be formally inspected prior to use and then at regular intervals, by a competent person (see 'Effective management of scaffolding to BS 5975: 2019' (TWf) **[14.]**). For very tall cages the access provision is a significant item of temporary works.
- Access machinery (e.g. MEWPs), lifting machinery and lifting accessories, should be suitable for purpose and comply with relevant legislation and regulations (e.g. LOLER and PUWER) and be inspected for compliance and damage prior to use.
- During the assembly of in-situ cages, periodic formal inspections (generally carried out by TWS) may be necessary (and should be recorded), to ensure that the correct methodology is being followed, stability is being achieved and that any temporary works measures have been correctly installed. Once the cage is completed it should be inspected formally for conformity with the design. The PC's TWC / TWC should liaise with the PWD / TWD to determine the extent and frequency of any inspections and it is often useful to provide checklists as an "aide memoire" for inspections.
- Prefabricated cages are generally assembled in the horizontal plane without the need for extensive or complex access requirements. However, temporary formers may be necessary to maintain the required shape. The inspection regime should be similar to that for in-situ cages, with additional attention being paid to how the cage is to be moved, lifted and/or transported.
- Prior to lifting or moving cages should be inspected to ensure they are safe to lift. This includes inspecting lifting points, checking for loose bars and other items that may fall and - once lifted and in place - the cage should be inspected again for any potential damage or deformation.
- A permit system should be adopted on site for more complex items of temporary works (generally not required for items classified as 'very low' risk). The temporary works procedure should stipulate who can sign permits (see BS 5975: 2019, Table 1). Generally, the permit is the culmination of the procedure to assemble the cage with any associated formwork and is required to

allow the formwork to be filled with concrete; thereby rendering the temporary condition of the cage obsolete.

6.3 Notes

6.3.1 For very large or very complex projects or schemes (e.g. Hinkley Point C or HS2) the management procedures and structures should be adapted to suit the site-specific hazards, risks, competencies and scale that are relevant to such a project. This may involve some departures from the recommendations made in BS 5975 and/or contractors having to adhere to the clients' specific procedures and standards.

6.3.2 Management and operatives may also require specific competencies to work on such projects. Similarly, it should be recognised that small and simple projects (e.g. housing) may choose to simplify the management procedures.

7.0 Loads applied to cages during construction

The principal loads (which may be static or dynamic) that designers need to consider are:

- self-weight of the bars (see BS 4449: 2005 **[15.]**), couplers and tying wire (generally 16-guage, 1.6mm diameter British Standard Wire Gauge, is used).
- self-weight of any temporary or permanent formers, spacers, proprietary splicing systems or restraint systems used to join or maintain the shape of the cage.
- self-weight of any "box outs" (often made from timber) which may be necessary for services or openings passing through the cage.
- self-weight of any instrumentation, cables, brackets, pipework (e.g. for base grouting of piles) or other cast in items inserted into the cage.
- wind loading and the possible accumulation of ice or snow (large cages can be affected by vortex shedding, suction and resonance).
- eccentric loading due to self-weight of vertical bars caused by a lack of as fixed verticality, construction tolerances splices and sway due to wind loading.
- eccentric loading due to self-weight horizontal bars being fixed to one side of the vertical bars and "L"-shaped bars on one side at the top of the cage.
- horizontal and vertical reactions from inclined ropes or cables used for stability or "plumbing" or from reactions when lifting chains or soft strops which are inclined.
- live loading.

NOTE: Operatives should not climb onto vertical cages. With horizontal mats, boards should be provided to prevent operatives having to walk directly on bars and spread the load.

- loads generated due to transportation, stacking, moving and positioning cages (dynamic loads).
- self-weight of any equipment used for placing or compacting concrete.
- falling concrete during placement and vibration during compaction.
- forces from pour "stop-ends" if tied to reinforcement.
- accidental impact, e.g. when formwork is being position.
- shutter tie forces can be transferred into cages (e.g. for wide slabs).
- buoyancy forces from void formers and uplift from top shutters if tied to reinforcement.

8.0 Challenges and hazards to be considered

The specific challenges and hazards are varied and can be specific to each cage and each location. Cage collapses can lead to injury or death and financial loss. If a cage deforms then structural performance of the reinforced concrete element may be compromised or concrete cover to the bars may be inadequate to provide adequate fire and corrosion protection.

The principal modes of failure are due to lack of strength, lateral instability, over-turning, sliding/ movement of bars, failure during lifting or moving. They are also likely to occur in combination. The likelihood of cage instability increases as the depth, weight of top mat and incline increase and as the length and weight of any eccentric projections increases.

There are a number of common challenges and hazards that should be identified and addressed to ensure the safety and stability during assembly, transportation and lifting. Often, failure of a cage can be attributed to a combination of issues:

8.1 Common to all parties

- Lack of awareness that a cage is an item of temporary works and that the hazards need to be managed.
- Inadequate management procedures.
- Lack of assessment of the competency of organisations and individuals.
- Lack of clear responsibility and communication between parties.

8.2 Designers (PWD, TWD, cage designer) and detailers

- Inadequate consideration given to how the cage is to be assembled, transported, lifted, moved and positioned. The sequence the bars are to be fixed in should be determined in order to ensure efficiency, operative safety and maintain stability.
- Lack of understanding of the applied loads, potential modes of failure and combinations (see Sections 7 and 9).
- Lack of understanding of the lateral loads that heavy top bars impose on vertical bars.
- Little consideration given to partially assembled cages (the focus tends to be on completed cages). For architectural or structural reasons some cages are may be inclined, splayed, have significant eccentric projections, or have large “L”-shaped starter bars at the top. These are often inherently unstable and temporary support is inevitable.
- Inadequate consideration as to how the vertical faces or horizontal mats of reinforcement are to be spaced apart and temporarily supported.
- Double-faced wall mats of reinforcement cannot be relied upon to act compositely unless specifically designed (e.g. trusses to stiffen the cage). Single-faced wall mats of reinforcement are vulnerable to instability and can overturn. Temporary measures may be necessary to support the reinforcement (depending on height above kicker level and the spacing and diameter of the vertical and horizontal bars).
- Consideration must be given to the manual handling of long and heavy bars. However, reducing the length of individual bars may introduce numerous joints and splices into the cage which can make it inherently unstable and increasing the amount of steel being used.
- How the concrete is to be placed to ensure adequate bond, especially for structures where there is a large amount of reinforcement (include laps, splices and formers). Cages should be sufficiently robust and adequately tied to prevent distortion from falling concrete and vibration during placement.

8.3 Contractors (PC, steel-fixing subcontractor) during assembly

- Poor workmanship and lack of supervision on site. Inadequate assembly plan and unapproved on-site changes.
- Inadequate working space for the assembly, lifting and storage. Inadequate access for operatives to work at height and, only if unavoidable, inside cages. Once the cage is assembled access is required for inspection and for attaching any lifting equipment (if necessary).
- Inadequate protection and/or exclusion to protect cages from accidental impact, which can cause sudden and catastrophic collapse.
- The primary purpose of MEWPs is to enable operatives to carry out work at height. The carrying of materials should be carefully controlled to prevent overloading. To reach a working area, MEWPs may have to negotiate props or other temporary measures to support the cage and protection measures may be necessary.

8.4 Contractors (PC, steel-fixing subcontractor) during transportation, lifting and moving

- The risk of falling objects, e.g. individual loose bars, tools, timber spacing blocks during assembly and lifting.
- Inadequate procedures for managing the lifting and moving of cages.
- Assessing whether there is a clear path for moving the cage to its required location and how the cage is to be released from the crane.
- Considering how the cage is connected to the starter bars and whether any other temporary measures have been provided.
- Allowing operatives to work within a large should be avoided. However, should it be the only reasonably practicable way of working an emergency escape / rescue plan should be developed.

9.0 Common modes of failure

Collapses can occur throughout all stages in the assembly process including at an early stage of assembly where there can be less restraint. Any form of physical sway movement or visible lean can be an early warning sign of instability.

- During assembly on-site or prefabrication off-site, large cages can become unstable due to significant wind loading (unless being assembled inside a workshop) and eccentric loading which can cause instability.
- The failure of vertical members tends to be by the failure of the spacers between the faces, leading to the mats separating and acting individually.
- **Bending failure** of a cage out-of-plane (see Figure 3) occurs due to an applied moment, e.g. wind, eccentric loading and impact. Tall, thin walls with small diameters bars are flexible and particularly prone to bending failure. Walls with larger diameter bars are not immune.

Figure 3: Example of bending failure leading to toppling of the cage

Once the cage starts to bend the situation worsens progressively and the cage is likely to collapse. When the cage collapses it may collapse on operatives or machinery causing injury and damage.

- **Buckling failure** of vertical bars is due to the bar diameter, spacing of bars, wall height, applied vertical load (e.g. horizontal bars and reactions from cables) and fixity at the base (see Figure 4 and Figure 5). As the height of the cage and the load increases the buckling instability increases and the wall is less able to resist its self-weight and any applied moments.
- In practice, a **combination** of bending and buckling failure is most likely. Lack of verticality (by design or accidental), eccentric loading (e.g. self-weight of bars, couplers) during construction and external loading (wind, accidental impact, reactions from guy ropes) exacerbate the issue. Each different vertical bar diameter has a limit to the height at which it will resist normal construction loads and wind without further measures. Above this height designed temporary works are required (see Part 2).

Figure 4: Elastic instability of a freestanding cantilever causes an initial lean from vertical buckling. Gravity then exacerbates the problem, causing progressive creeping deflection and failure in bending (known as P-delta). Cage is being assembled by operatives using a MEWP and clearly seen to be unstable and eventually collapsed leading to injuries.

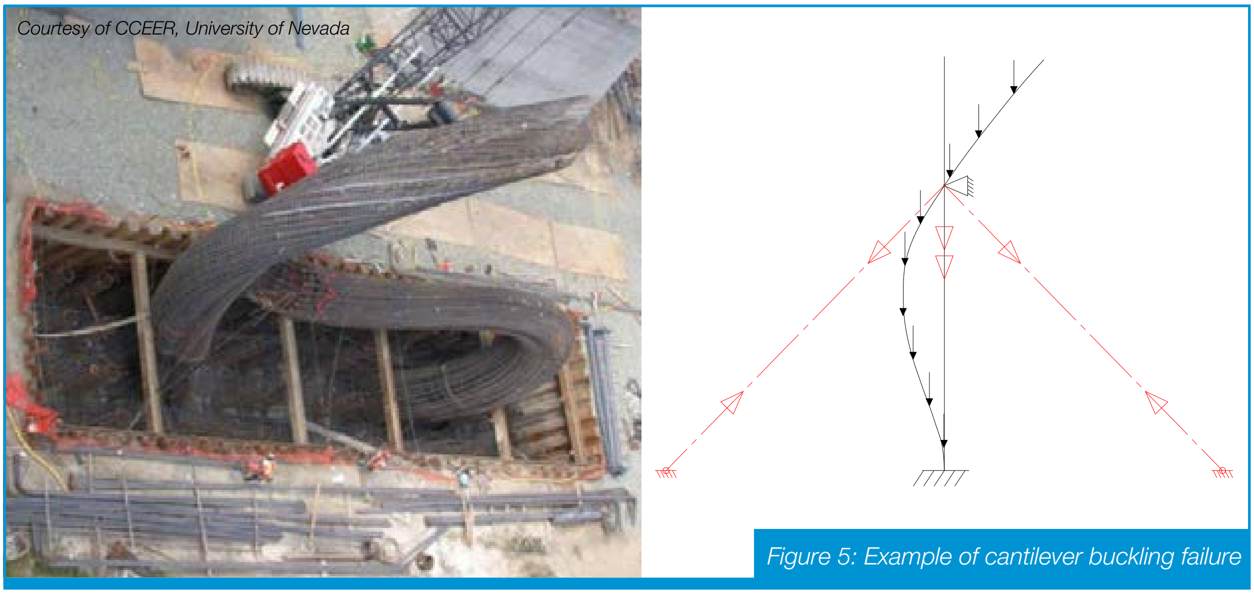


Figure 5: Example of cantilever buckling failure

- **Discontinuity failure** (due to wind loading, self-weight, eccentric loading of bars or corbels or cantilevers, impact, etc.) at joints and splices, e.g. cantilever bending can cause rotation of vertical bars at connection point with starter bars (see Figure 6). This may occur if starter bars are too short or insufficient ties have been provided. The connections at such discontinuities (generally ties) fail and the cage can separate. Sliding may also occur down the vertical bars as the cage weight is only supported by ties and the ties could slip (especially at starter bars where the vertical load is greatest). This can result in combined buckling and bending. Tie fixity and bend radii reduce the rotational and shear stiffness at the connections.
- **In-plane sway** ('side sway' or 'racking') as every bar intersection can act as a 'pin' with negligible moment capacity, i.e. there is no in-plane "diaphragm" resistance to sway and racking. The cage fails by collapsing in the long face. The cage behaves in a similar way to a scaffolding or falsework with no bracing (see Figure 7). This could occur in cages assembled in-situ or prefabricated cages, especially during transportation (see Figure 8).
- Once assembled, the cages (and mats) need to be lifted into position. Large, heavy cages require machinery and equipment for lifting. The requirements of LOLER and PUWER apply to all lifting operations and equipment in order to prevent failure of the lifting equipment, attachments, connections or cage. An area

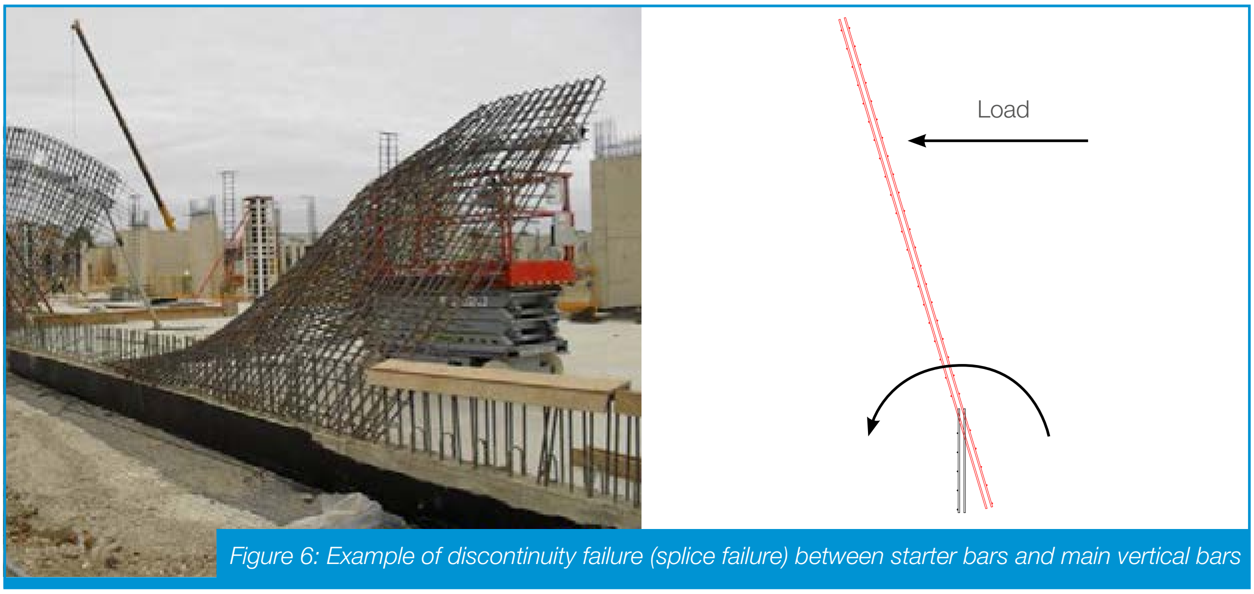


Figure 6: Example of discontinuity failure (splice failure) between starter bars and main vertical bars

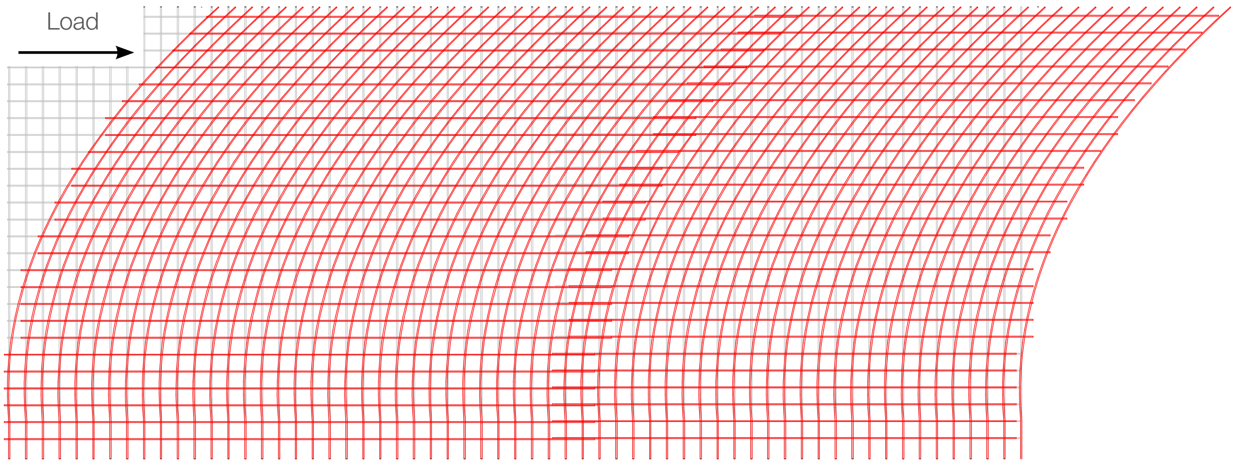


Figure 7: Example of sway (racking) failure

should be prepared for the lifting machinery to operate (particularly crane foundations) and a clear path identified for the cage to be moved into its required location.

- Cages are generally assembled in the horizontal plane, to eliminate work at height (apart from very wide cages). Once assembled cages need to be lifted and may need to be rotated from the horizontal plane to the vertical. Long and slender cages can distort (fold in half) and bend (see Figure 9). The position of the centre of gravity changes if the cage deforms excessively.
- If assembled off-site cages need to be lifted onto transport vehicles. Cages need to be adequately secured and may be stacked on top of each other so should be sufficiently robust so as not to deform. During transport cages are subject to vibration and consideration should be given to the possibility of additional longitudinal forces due to the sudden braking of the vehicle or lateral forces if the vehicles corners too quickly.
- Some prefabricated cages (e.g. for piles) are commonly mechanically pushed or vibrated into the wet concrete and need to be sufficiently robust to withstand this action without distortion.
- Extremely large or heavy cages (e.g. for diaphragm walling or piles) may have very highly stressed connections or are too large to lift in a single piece and need to be spliced together. Reliance solely on tying wire may be difficult to justify (and can fail), especially for splicing.

Courtesy of Balfour Beatty

Courtesy of Balfour Beatty

Figure 8: Example of transportation problem

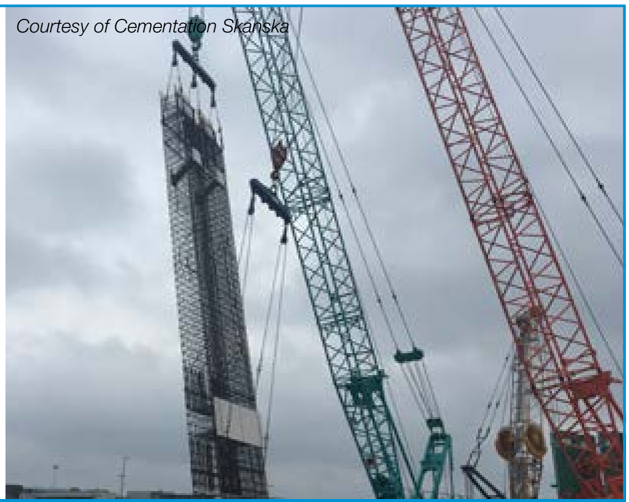


Figure 9: Example of a large prefabricated cage being rotated and lifted. Consideration is required to how to prevent deformation of the cage during this operation.

- Tensioned ropes or cables ('guy wires') can be used to aid the "plumbing" of cages and to provide stability. However, caution needs to be exercised and a robust design and methodology provided to ensure that equal support is be provided all round so the system is balanced and reactions need to be considered (see Figure 10). This is not something that should be improvised on site by operatives. The use of hydraulic 'tirfors' should be avoided as the high tension loading may pull the cage over and the vertical reactions are likely to cause the vertical bars to buckle. As with propping, the ropes or cables need to be removed to allow the formwork to be installed and a sequence should be determined and followed.
- Failure or damage to formers used to maintain shape, sacrificial stiffeners, instrumentation, pipework, 'box outs', etc. due to self-weight of items they are supporting, during lifting operations or when concrete is being placed.
- The faces of wall reinforcement may have different diameter bars and spacing, creating an asymmetric moment and the connections between the faces are effectively 'pins' and each face behaves independently.
- Failure modes can act in combination.

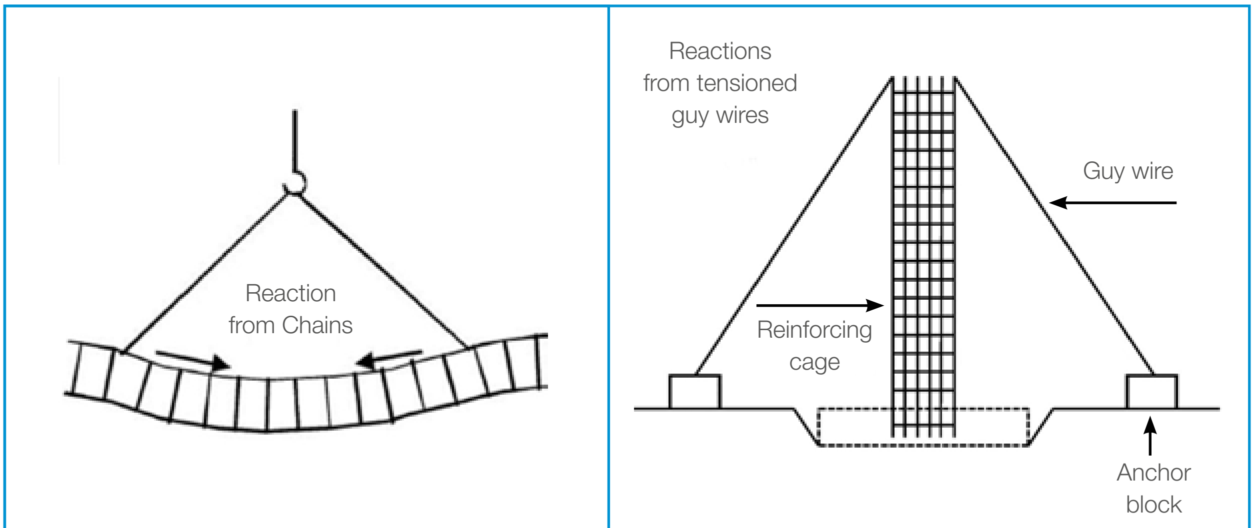


Figure 10: Example of reactions during lifting and stabilising operations that need to be addressed

10.0 Common solutions to the challenges and hazards with cages in the temporary condition

All significant cages should be checked to ensure they are stable and safe during assembly, transportation moving and lifting. If stability can be justified, additional temporary works measures may not be necessary.

Where contractual situations allow, the PWD should cooperate with the contractor so that 'constructability' is incorporated into the design, i.e. early contractor involvement (ECI). It is important that responsibilities and duties are clearly allocated, and actions that flow from them are recorded in writing and made known to the relevant parties. This guide recognises there are many different solutions to the challenges listed, depending on complexity and location. The project team should determine the most appropriate solution. Design guidance and example calculations are provided in Part 2 of this guidance.

10.1 Actions taken by designers (PWD, TWD, cage designer) and detailers

- Consider how the cage is to be assembled to ensure the general principles of prevention are followed. Provide relevant information on residual risks in a timely and clear manner. Provide all relevant and necessary information on how stability can be achieved throughout the assembly process (including partially assembled cages). Consider potential modes of failure and/or potential combinations.
- Be aware of the loads that can be applied to a cage, potential modes of failure (plus combinations) and construction tolerances.
- Design any measures required to maintain the shape of the cage and provide temporary stability (e.g. formers, propping). Ensure connection details are robust and able to resist rotation. For simple and repetitive operations, 'standard details' can be developed.
- Specify the maximum unsupported height of bars. If support or stiffening is required, the type of support, additional bars, connections and intervals should be specified.
- Consider longer starter bars with robust connections which can resist rotation, along with staggered joints, to prevent failure at the discontinuities. When fixing starter bars in the preceding pour, consideration should be given to the increased vertical and horizontal loads, eccentricity and positional support required.
- Free-standing heights of cages should be determined depending on the diameter of the bars being used and exposure conditions (consider using larger diameter bars to improve temporary stability) or positioning splices and construction joints to avoid instability issues.
- For cages to be lifted, the total weight should be calculated accurately and appropriate lifting points designed (including connections to the cage and how the weight of the entire cage is to be supported). The centre of gravity should be calculated. This can be difficult for a complex cage which may be asymmetrical in shape, with different size bars, splays, and overhangs at high level (a high centre of gravity for lifting could cause rotation). Large, long and heavy cages are likely to deform during lifting or possibly fail. Discontinuities such as laps and splices, need careful attention and a design to ensure safety during lifting operations.
- Consider reducing the height of individual wall pours or consider an alternative construction methodology, e.g. precast or twinwall[4].
- Check the structural strength of individual members (bars), including designated cage 'framing members'. The connections between load-carrying members should also be checked to ensure that they transmit the applied forces safely. Tied bar-to-bar connections of main load-carrying members need careful consideration.
- There is a need to 'balance' the manual handling considerations (e.g. for long heavy bars) against the need to limit joints and splices in cages. Where possible, discontinuities and splices should be staggered in a cage and a robust design required to prevent a discontinuity failure. Alternatives to tying wire for splicing are available, e.g. welding (see Section 11), 'wire rope' clips (commonly known as "Bulldog" grips), fish-plate systems and proprietary systems such as Superlatch®.

  NOTE: Bulldog grips are primarily designed for termination of steel wire rope (as stated in BS EN 13411-5: 2003 **[16.]***) but, providing they have been assessed by a competent person considering appropriate factors of safety, they can be used as a secondary system (see FPS; Bibliography). It is usual to carry out load tests on rebar splices formed with Bulldog grips to establish slip resistance for each type used (and for a given torque and combination of bar diameters).*

[4]*See https://www.concretecentre.com/Building-Solutions/Walls/Twinwall.aspx*

Figure 11: Example of a robust and stable cage ready for formwork to be installed

- Provide an assembly plan that considers the sequence of fixing bars, access, temporary formers, lifting (if required), stacking and support to mats. A thorough assembly plan may often be sufficient to ensure stability (see Figure 11). Where possible, eliminate the need for operatives to enter inside the cage or for arms and hands to be inserted into the cage
- For in-situ or prefabricated slab cages, any large 'chairs' (e.g. if over 1m deep) - that support the top mats and space the top and bottom mats apart - should be designed and checked (see Figure 12). The design should consider the self-weight of the top mat, environmental loads and potential live loads. Large chairs are slender elements and may buckle or sway. Spacing of wall mats should also be considered, the edges of slabs and walls need support close to the end of the wall and any stop-ends. As an alternative to large chairs, props can be used.
- Designers should consider, that when being lifted the cage behaves differently to its intended purpose. The weight of the cage is suspended and exerts a tensile force on the ties and any splices. The position of lifting points should be determined to ensure that the cage does not deform excessively and lifting beams can be used to ensure loads are distributed evenly and at an angle perpendicular to the bars being lifting. Even distribution of loading on the cage depends upon the lifting beam stiffness, spacing of attachments, sling stiffness and length.

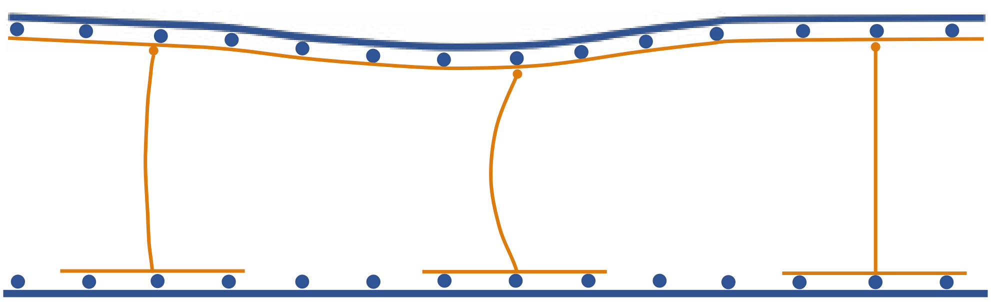


Figure 12: Example of failure of "chairs" leading to deformation of top mat (sway also needs consideration)

(a) Support frame to raise cage from horizontal to vertical position and lift

Courtesy of Friends 4 Expo Transit

(b) Complex multiple point lifting frame to a cage

Courtesy of Balfour Beatty

Figure 13: Example of complex and high risk lifting of prefabricated cages

- Some lifts are often carried out by a pair of cranes working in tandem and should be considered as high-risk, complex operations; with a specialist design required. When turning reinforcement cages from horizontal to vertical there is always a risk of damaging the cage at the point of contact between the ground and the cage unless tandem lifting, or a lifting frame is provided or additional stiffener bars are added. Lifting equipment is required that can accommodate the change in lifting angles (e.g. pulley to allow rotation). The cage should not be allowed to slide along the ground as it likely to distort. An alternative could be a lifting/support frame (see Figure 13).
- Additional stiffeners (e.g. bars, steel sections) which have been designed and checked may be added to the cage to prevent excessive deformation between the lifting points (viz. to give the cage a "backbone") or when rotating a cage from horizontal to vertical.
- Face bracing may be necessary to prevent in-plane sway and additional bracing bars may be necessary to prevent cages distorting or collapsing during lifting, transportation and placement.
- Specify any testing that may be required and any design assumptions that need to be confirmed.
- Tensioned guy-ropes and cables can be connected to the cage to aid stability and for plumbing purposes. They can be anchored into the ground or fixed to concrete blocks or slabs. This should be taken in account in the design; with great care exercised as the horizontal and vertical reactions from guys and cables should be considered. Horizontal reactions should be 'equal and opposite' to prevent toppling in one direction. Vertical bars should be checked for bucking from the induced vertical reaction.

WARNING: The risks associated with using tensioned guy-ropes and cables on reinforcement cages are out of balance horizontal loads, increased vertical load, concentrated load on induvial members at connections points. Many contractors deem these risks unacceptable.

- In heavily-reinforced slabs that require shear reinforcement consider using overlapping bars rather than closed links, to avoid the need to work in a closed cage.

10.2 Actions taken by Contractors (PC, contractors, steel-fixing subcontractor) during assembly

- The PC should ensure that competent operatives and adequate competent supervision is employed. Inspections should be carried out at regular intervals to ensure the work is being carried out correctly. Assembly workmanship is critical. Tie-wire needs to be twisted sufficiently tight so that bars do not slip or move, but not too tightly that the wire may snap. The type of wire, spacers and frequency should be specified in the permanent works specification or by the temporary works designer. The specification for reinforcement work (cutting, bending, storage) should be followed (see Concrete Society, Concrete on Site 2: Reinforcement **[17.]**).
- Working areas should be safe. Cages can be prone to accidental impact loading and a significant impact is likely to cause a catastrophic collapse. If possible, exclusion zones (from traffic and machinery) around cage assembly areas should be created and great care taken when placing formwork around cages.
- Ensure an assembly plan is in place and being adhered to, which considers the sequence of fixing bars, adequate access provided, temporary formers and support to mats (chairs should be designed for large cages). If possible, eliminate the need for operatives to enter the cage or for arms and hands to be inserted into the cage. Consider how the chains or soft slings can be released once the cage is in position (e.g. MEWP, scaffolding, remote release mechanism). The bars or cages should be placed on timber to allow the removal of chains or soft slings placed around them for lifting.
- If temporary works are provided to ensure stability, ensure that they have been installed correctly and consideration given to the sequence of removing temporary supports.
- Monitor and inspect the cage as work progresses.
- Large reinforcing bars and cages are heavy. Consider where and how they should be stacked to prevent the cage distorting. Incidents have occurred when reinforcing has been positioned on falsework systems or metal decking. This creates a significant point load which the falsework or metal decking may not have been designed for. Additional propping beneath may be a solution.

10.3 Actions taken by Contractors (PC, contractors, steel-fixing subcontractors) during lifting

- LOLER requires that all lifting operations shall be properly planned and supervised by competent persons, using certified machinery (this includes cranes, lorry loaders, excavators, forklifts) and certified lifting accessories. A ‘lift plan’ should be prepared by an ‘appointed person’ for all lifting operations. If the lifting operations are simple and repetitive a generic plan can be prepared.
- Ensure the correct machinery and accessories are being used and all certification is current. All equipment should be visually inspected for damage before every lift by the slinger/signaller.
- If operatives are capable of lifting and moving cages (and where it is safe to do so) without machine assistance, then manual handling issues should be considered.

  NOTE: Further guidance is available in ‘Manual Handling Operations Regulations 1992, Guidance on regulations’, L23 **[18.]**
- The weight of cages and position of centre of gravity should be known and indicated clearly on the cages. This is particularly important for asymmetric cages or where the centre of gravity is high up as the cage may rotate significantly during lifting. Lifting points should be positioned above the centre of gravity of the cage. For complex cages it may be advisable to carry out a “test lift” (i.e. lifting the cage so it is just clear of its supports or ground) to ensure the weight and centre of gravity have been assessed correctly and the cage manoeuvred safely.
- Lifting operations should not be carried out in high winds or poor visibility. If hand signals cannot be used the signaller and crane operator should be in contact with radios.
- Specialist lifting equipment (e.g. non-fixed load lifting attachments) should comply with BS EN 13155: 2003 + A2: 2009 **[19.]**.
- If possible, the cage should be fixed and moved / transported in the same orientation as that it is to be placed eventually placed so that tilting or turning is not necessary. This can involve creating the cage in a jig that is set at the correct angle with the bars securely fixed in place.
- Ensure appropriate lifting machinery and attachments are used, e.g. chains or soft slings, and their angles, to determine reactions. Timber packing may be used at corners to prevent rubbing, slipping and damage.

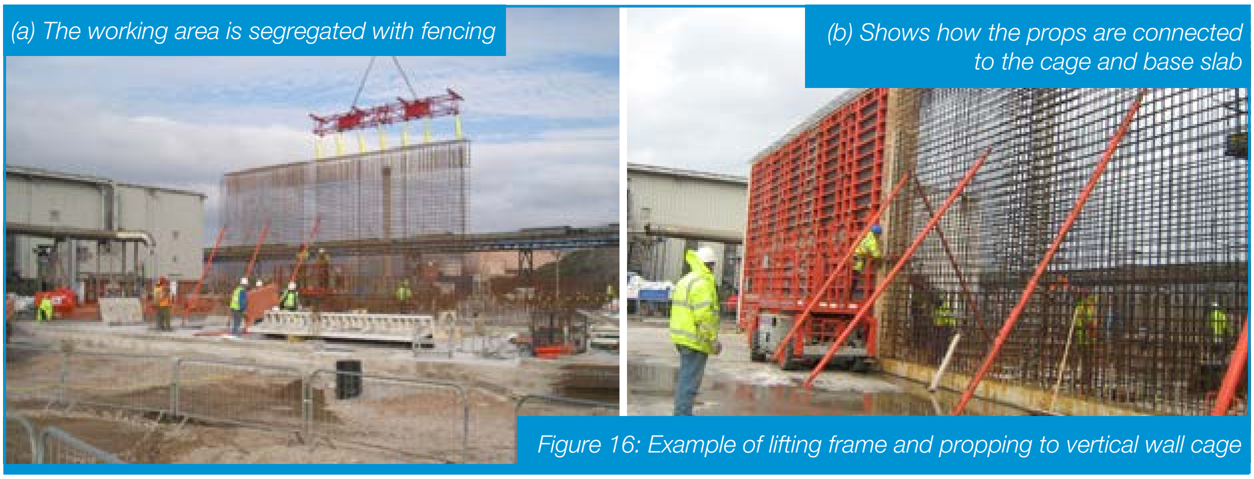
Figure 14: Example detail - lifting from underneath with soft slings NOTE: Slings should be positioned to account for the position of the centre of gravity to prevent rotation during the lift.

- The weight of a cage should be evenly distributed amongst the lifting points. However, cage stiffness determines the actual load on each lifting point. Very stiff cages may induce higher than expected loads in individual lifting points on a multi-point system. Common practice is that lifting points should be welded to cages (if the specification permits). The use of steel flats for this purpose is common practice. Double ties are required for cages that are to be lifted. For large and heavy cages, with multiple lifting points, load compensators can be used, which also help absorb shock and vibration. Ropes (‘tag lines’) are usually provided to control the cage during lifting and to ensure it does not snag on anything.
- Avoid lifting large cages by connecting the chains or soft sling to the top mat of reinforcement or to lifting bars connected to the top mat with tying wire (relying wholly on ties to support the weight of the cage). Where lifting points have been designed for large cages, during lifting the cage should generally hang from the lifting points. The type and number of ties should be designed, specified and inspected on site prior to lifting. Where possible, lifting points should be positioned on the lowest bars - or by lifting the cage from beneath (see Figure 14) - to limit the number of ties working in tension during the lift.
- Lifting large cages with inclined lifting chains or soft strops should be avoided as they impose a horizontal compressive reaction onto the cage which can cause distortion (see Figure 10). A lifting beam or purpose-designed internal stiffeners is the preferred option. The lifting beam may be proprietary equipment (which has previously been designed and checked and has the relevant testing and inspection certification) or bespoke. In both cases, LOLER and PUWER apply.
- Occasionally, bespoke beams may be necessary and these should be designed and certified as required by LOLER. Particular attention should be paid to the position of the spreader beams, so they provide sufficient support, prevent rotation and distortion of the cage. A design and certification for any lifting points is also necessary and these lifting points should be clearly marked (e.g. colour coding).
- Timber or steel “formers” (which may or may not be sacrificial) can be used to maintain the shape of a cage when it is being lifted.
- When lifting large cages, ‘tag lines’ and exclusion zones for operatives should be enforced.
- Prior to lifting, the TWS should ensure that there are no loose items that could fall from the cage (e.g. loose bars, blocks of timber, steel-fixers tools). Often, a “good shake” can identify issues. The TWS should also ensure the area around the lifting operation is safe; and the correct lifting machinery and accessories being used.
- The slinger/signaller (this may also be the TWS) should ensure the cage is correctly connected to the lifting machinery and should monitor the cage during the lift for excessive movement or deformation.

Figure 15: Stabilised rear face of formwork can be used to provide stability to the cage

10.4 Specific measures to provide stability

- One face of formwork may be used to provide stability to the cage (see Figure 15). The rear face of the formwork can be erected against a “kicker” and stabilised (and its verticality ensured) by using “push-pull” props. These props can be anchored to a slab beneath or to large concrete blocks (commonly known as “Kelly Blocks”). If the cage is prefabricated it can be lifted into position by crane and be connected to the formwork with ties. If the reinforcement is to be fixed in-situ then it may need to be detailed so the lacers are not the outside of the pour. The formwork should be designed for wind loading (see Formwork a Guide to Good Practice, Concrete Society **[20.]**) plus an allowance for eccentric loading from the cage (‘out-of-plumb’). An inclined prop causes a vertical reaction (uplift) and if there is insufficient self-weight in the formwork then anchorage will be necessary to resist the uplift.
- The cage itself could be propped (see Figure 16). The props should be designed to resist the wind loading on the cage plus an allowance for eccentric loading of the cage. Designers need to consider the effective length of the vertical reinforcement for lateral buckling the connections between the props and the cage (significant point loading), connections to the base slab and the sequence of progressive prop removal to allow the formwork to be installed. Access around the props may also be required for MEWPs (MEWPs require a level surface to operate).
- If an access scaffolding is required to assemble the cage, then it might also be used to provide support to the cage (see Figure 17(a)). Buttressing of the scaffolding may be



(a) The working area is segregated with fencing

(b) Shows how the props are connected to the cage and base slab

Figure 16: Example of lifting frame and propping to vertical wall cage

(a) Scaffolding can also be used to support the cage

(b) Example of internal braced mattress to provide stability (design required to justify that the cage can be freestanding)

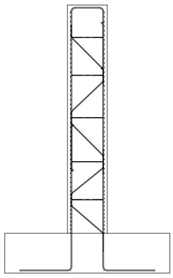


Figure 17: Examples of designed cage supports

required to provide sufficient resistance to collapse. Such scaffolding should be designed (and design checked) to prevent the cage from becoming unstable and consideration should be given to how the formwork is installed. Bespoke support frames might also be provided but, again, stability should be considered.

- Additional bars (generally "z"-bars) can be fixed to the faces as bracing/truss action, provided there are sufficient ties to achieve composite action. This can be sufficient to make the cage free-standing (see Figure 17(b)). Sizing of bars and specification of designed connections is critical. Considerations should include the practicality of the fixing sequence and access whilst ensuring the specified cover to the bars.
- Sacrificial 'king posts' (often UC sections) can be driven or concreted into the ground and the cage constructed around the post. They provide stability akin to wind posts or piers in brickwork. Vertical trusses assembled from reinforcing bars (usually welded) can be connected to starter bars and the cage constructed in-situ around them; or prefabricated sections can be lifted into position. The trusses are generally designed as a 'standard detail' and then cut to length with spacing to suit the stability required. A design (and design check) is required for the connection of the trusses to the starter bars; or they can be cast-in during the slab pour (see Figure 18).

  NOTE: Generally, these details are sacrificial. However, a support frame may be manufactured from proprietary components or from fabricated steelwork and re-used.
- Cables, ropes, guy wires can be used to provide stability and for 'plumbing'. These should be used with great care and under supervision. The reactions from inclined cables, ropes and wires should be accounted for by the designers (see Figure 10). It is important not to overestimate the strength and stiffness of the cage when using tensioned members. The precise stages of assembly and removal with rigorous checks, controls and hold points are pre-requisites. (See 10.1, WARNING.)
- For cages to deep base slabs, sacrificial braced scaffold tube frames may be assembled to support the top mat.

(a) King post support

(b) Truss support

(c) Support frame

Figure 18: Examples providing stability to cages NOTE: Generally, these details are sacrificial. However, a support frame may be manufactured from proprietary components or from fabricated steelwork and re-used.

10.5 Actions taken by various parties relating to transportation

- Confinement frames are commonly used for the transportation of cages and, generally, they are not suitable for lifting the cage from the vehicle. Such frames should be designed.
- Hauliers should ensure that vehicles are loaded correctly, with loads adequately secured (using restraint frames and/or straps/chains) and consideration given to off-loading.
- The PC should ensure that there is safe access onto site and sufficient space for off-loading and storage of the cages. Off-loading delivery vehicles may involve work at height and pre-slinging cages should be considered, so there is no need for operatives to climb onto vehicles.
- Designers and detailers should consider how cages are loaded onto and from delivery vehicles, with lifting points designed, as well as considering the effects of lifting on the cage itself. The stacking of cages on top of each other (on vehicles and also once off-loaded on site) should also be considered in the design of any “chairs”. The effects on the cage of sudden braking or sharp turns of the vehicle should be considered. Additional bracing bars can be provided to help ensure stability of cage (see Figure 8).
- Care is required when lifting and transporting epoxy-coated reinforcement, or cages with instrumentation, as protection is required to prevent damage.
- Though not specific to the transportation of reinforcement cages some useful further guidance is available in the following:

  a) Transport of steelwork by road, Guidance Note No. 7.06, Steel Bridge Group **[21.]**

     NOTE: This covers the transport of steelwork by road.

  b) Safety of Loads on Vehicles (Third Edition) Code of Practice Department of Transport (2002), **[22.]**

  c) Guide to work at height during the loading and unloading of steelwork, BCSA Publication No. 43/07 (2007) **[23.]**

     NOTE: This covers the loading and unloading of streel and steelwork prior to fabrication, after fabrication and at site locations.

  d) BS EN 12195, Load restraint on road vehicles. Safety. (Part 1: Calculation of securing forces. Web lashing made from man-made fibres. Part 3: Lashing chains.) **[24.]**

  e) European Best Practice Guidelines on Cargo Securing for Road Transport, European Commission **[25.]**

10.6 Actions taken by Contractors (PC, concrete sub-contractors) during concrete works

- During placement, concrete should not be permitted to free-fall any appreciable distance. Generally, 1.5m is considered a maximum. Placement aids, such as flexible hoses, should be used on tall structures (e.g. columns) to guide the concrete down to base of the formwork.
- Weather conditions can change quickly and it is advisable to concrete the cage as soon as possible after assembly, placement and inspection.

11.0 Welding of bars and cages

11.1 Welding of reinforcing bars is an alternative to tying for highly stressed connections and should be subject to client approval, designed by a suitably qualified engineer and carried out by competent welders. The purpose is to increase stiffness and strength by ensuring bars are adequately joined, for lifting, to aid stability or to rigidly fix components such as instrumentation,

(a) Weld not evenly distributed over both bars

(b) Weld splatter and porosity

Figure 19: Examples of weld defects

pipework and brackets. Welding should comply with BS EN ISO 17660-2: 2006 **[26.]**, which gives guidance on procedures, approvals and acceptable imperfections. The CARES Guide to Reinforcing Steels – Part 6, Welding of Reinforcing Steels **[27.]** also provides useful information.

11.2 A high degree of skill is required to weld rebar. There is a high risk of changing the metallurgy of the permanent works steel, rendering it useless, if the proper welding quality controls are not implemented effectively (brittle failure at minimal load). It is recommended that all welding of reinforcement is undertaken in workshop conditions to ensure quality and be subject to appropriate quality control measures.

11.3 Welds should be designed, specified and the work carried out by competent operatives (see Figure 19). A visual inspection for all welds should be carried out to ensure compliance, quality and that they are free from defects. Further non-destructive testing (NDT) may be deemed necessary for critical items. This should be specified by the designer. Full load-testing may also be necessary and again the designer should specify the requirements.

11.4 Welding produces extremely hot surfaces and splatter with potential for fire and injury from molten metals. High-intensity light waves can cause damage to the inside of unprotected eyes.

11.5 The British Association of Reinforcement (BAR) recommends "… a precautionary approach to the use of any welded steel that may potentially include boron by checking the full analysis back to the producing mill or have full sample tests taken …". Such rebar "… requires changes from the normal welding techniques …"[5].

11.6 The Health and Safety Executive provide information on safety with welding at https://www.hse.gov.uk/welding

12.0 Site checklist for workmanship

12.1 Physical checks should be carried out at all stages of the assembly, transportation, lifting and positioning process. However, there is a greater potential for problems to occur on site. It is, therefore, important that there is adequate and experienced supervision in place that is fully aware of the risks and has been briefed on the control measures that need to be put in place.

12.2 The key points include:

- Competency of operatives and whether an assembly plan has been provided and communicated.
- Latest revision of the design being used with a checked and signed off temporary works design in place.
- Correct materials employed and the fixing sequence followed correctly.
- Workmanship complies with the design

  NOTE: Particularly important when relying on tying wire ties for part or all the strength of a cage.
- Correct types and frequency of ties and spacing complies with the design.
- Ties are correctly tensioned with sufficient twist projecting from the tie.
- Whether any temporary bars are correctly fixed.
- Correct shape codes and correct orientation of bars, position, spacing and layering.
- Unauthorised cutting of bars or application of heat should not be permitted.
- Bars bent using correct formers in accordance with BS 8666.
- Splices have appropriate lap length and ties and laps have been staggered.
- Cage has retained the design shape (and not kinked or bent out of shape).
- Overall physical dimensions of the cage comply with the design to ensure adequate cover.
- Any mechanical couplers are fully engaged and tightened.
- Welding carried out by an appropriately skilled welder to an approved procedure.
- Welds comply with the design and are of appropriate length and size and have been inspected for quality.
- Mechanical grips or connectors installed in accordance with manufacturer's guidelines and tightened to the correct torque.
- Temporary works installed as per the design and a 'permit to load' provided.
- Modifications that are necessary to enable bars to be fixed have been approved by the PWD cage designer or TWD.
- Prefabricated cages need to tie to starter bars and a template should be provided.
- Any distress to the cages or failures of ties should be reported to the TWC.

[5] *https://www.theconstructionindex.co.uk/news/view/warning-issued-on-welding-rebar*

- When lifting, a lift plan is in place and complied with, appropriate lifting beams, shackles and slings are used in accordance with the lift plan and temporary works design.
- For heavy/complex cages an exclusion zone should be enforced and a test lift carried out.
- Check that there is nothing loose that could fall from the cage during lifting.
- All lifting equipment should have current certification and a visual inspection for damage should be carried out before every lift.
- The cage can be placed and secured in its final position after the lift and there is a safe means of releasing the cage from the crane.
- A post-lift inspection should be carried out, with any loose or failed tie wires replaced.

13.0 Recommendations

13.1 Readers are encouraged to improve the awareness of the issues involved, across the whole industry, by distributing this guide widely and encouraging all parties involved to understand and address them, including:

- All organisations (i.e. clients, designers, detailers, contractors, sub-contractors, equipment suppliers) involved in temporary works (including the temporary condition of cages) should have management procedures to BS 5975: 2019.
- The PD should ensure that there is a clear division of design responsibility, established as early as possible, and adequate coordination between the various different parties.
- The PWD, TWD, cage designers and detailers should fulfil their CDM2015 obligations by following the general principles of prevention and, specifically, by considering ‘buildability’. As a result, they should identify the challenges as early as possible (e.g. concept/planning stage) and consider the likely modes of failure (and combinations) at each location.
  A better understanding of site practice should be encouraged and sought (e.g. site visits, discussions with contractors who have experience and understanding of this subject).
- The PD should ensure that designers and detailers produce robust designs which consider the temporary condition of cages. Any significant residual risks (and not just slips, trips and falls) and design assumptions (and how these are to be confirmed) relating to the temporary condition of the cage should be clearly communicated
- The PD should ensure designers and detailers are providing clear information relating to the weights of cages, centre of gravity and lifting points (for lifting purposes) and how stability is to be achieved.
- The PWD and detailers should provide all necessary loading and positioning details for temporary supports, even though they may not be designing the propping themselves (which is often best left to the contractor as they select the equipment that best serves their purpose).
- Designers and detailers should balance the cost savings of “lean” cage design against stability and buildability issues. They should also consider carefully the positioning of discontinuities in cages, as these create inherent weakness.
- Finite element analysis can be used to model and analyse large/complex cages in the temporary condition. Virtual reality can be used to model and simulate the assembly plan and lifting of cage from the viewpoint of operatives. BIM can be used for clash detection and limit the amount of on-site modification.
- The PC should ensure that cages are treated as an item of ‘temporary works’ and the management procedures from BS 5975: 2019 should be followed on site. There should be a clear division of site responsibility, with adequate coordination between the different parties involved.
- The PC (along with other relevant parties on site) should review all significant cage designs for buildability and safety, especially where they need to be lifted. They should also ensure the designers/detailers’ assumptions are confirmed and residual risks are managed appropriately on site.
- The PC should ensure there is careful coordination of the various trades on site (e.g. steel-fixing, formwork, scaffolding, lifting cages, concrete placement) to ensure the temporary condition of cages is managed and that “grey areas” of responsibility and interfaces between the different trades are addressed.
- Well-established existing ‘custom and practice’ on site (i.e. “We have always done it like this”) may no longer be applicate to many cages and operatives should be made aware of the challenges. The PC should ensure there is adequate competent supervision on site, that operatives are competent and that they are briefed in the methodology and how risks are to be managed.

- The PC should ensure that any on-site departures from the design are communicated to the designer via a design brief or request for information. The designer should confirm the departures are acceptable.
- The PC should ensure appropriate 'hold points' are in place during the assembly or lifting of cages, to ensure safety measures and any additional temporary works items have been provided prior to proceeding to the next stage. If all appropriate measures have been taken, a permit system should be used to release these hold points. It should be clear who can sign these permits.
- The PC should ensure that cages are inspected for compliance with design, quality of workmanship and any temporary stability considerations. LOLER and PUWER should be followed for all cages to be lifted (i.e. lift plan, lifting points, certified equipment, etc.) and inspections carried out prior to and after lifting.
- 'If it doesn't look right, then it probably isn't' so, on-site, the area around a cage should be cleared and remedial action taken.
- For extremely heavy/complex cages, or where the consequences of failure could be catastrophic, an external peer review by industry experts should be undertaken.

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Spacers and visual concrete, CONCRETE ADVICE No. 43, March 2012

https://www.concretebookshop.com/spacers-and-visual-concrete-1523-p.asp

The changing face of diaphragm wall construction, CONCRETE, July/August 2013

Rebar cage construction and safety, Best practices, Michael J. Casey and Girum S. Urgessa, Construction Institute of the American Society of Civil Engineers (2012)

Useful websites

British Precast
https://www.britishprecast.org

British Construction Steelwork Association (BCSA)
https://www.steelconstruction.org

CARES
https://www.ukcares.com

Concrete Society
http://www.concrete.org.uk

Construction Industry Training Board (CITB)
https://www.citb.co.uk

Federation of Piling Specialists
https://www.fps.org.uk

Health and Safety Executive (HSE)
https://www.hse.gov.uk

National Access & Scaffolding Confederation (NASC)
https://nasc.org.uk

Temporary Works Forum (TWf)
https://www.twforum.org.uk

Appendix 1: Example procedure flow chart for managing the temporary condition of reinforcement cages prior to concreting Pre-construction

Figure A1: Example procedure flow chart for managing reinforcement cages

Pre-construction

Each organisation should appoint a senior person as DI to produce, implement and maintain a procedure suitable for the type, scale and complexity of the work you get involved with.

Separate procedures should be produced to cover each different role the organisation carries out e.g. construction and design

The potential hazards associated with the temporary condition of cages should be determined at tender / planning stage by the PD / PWD

PD / PWD to consider buildability and follow the principles of prevention and provide residual risk information (if a cage is required for a temporary works purpose such as a tower crane base then the TWD has this responsibility).

Determine which organisations procedure is to be used for managing the temporary condition of cages at pre-construction stage and during construction

PC procedure is to be used on site

PC to appoint their own competent TWC

PC may ask steel-fixing sub-contractor to appoint TWS to assist TWC

Specialist sub-contractor procedure has been approved for use on site by PC's DI

PC to appoint their own competent PC's TWC

Steel-fixing sub-contractor to appoint their own competent TWC and TWS (if required)

TWC to liaise closely with PC's TWC.

PC's TWC to audit TWC and manage interfaces between different sub-contractors

PC's TWC or TWC to add the various types of rebar cage onto the temporary works register and classify (implementation class) each cage according to BS 5975: 2019, Table 1.

Implementation class - High Risk

PWD has not ensured temporary stability and the cage requires temporary works. Which party has design responsibility?[6]

Steel-fixing sub-contractor

PC

Steel-fixing sub-contractor appoints competent designer(s) (could be in-house or external) and design checker for appropriate level of checking

TWC arranges a design brief

Designer carries out design and design is checked

Design check certificate is provided

TWC coordinates interfaces that fall within their scope of work and design may need approval by external parties

PC appoints competent designer(s) and design checker for appropriate level of checking

PC's TWC arranges a design brief

Designer carries out design and design is checked

Design check certificate is provided

PC's TWC coordinates all interfaces and design may need approval by external parties

PC may ask steel-fixing sub-contractor(s) to provide input and provisional comment on the design proposal

Implementation class – Very Low Risk

PWD has ensured the stability of the cage or a standard solution is to be used

Simple risk assessment carried out for assembly in situ or for pre-fabrication, moving and positioning

Competent person to select appropriate standard solution and another competent person should confirm the correct detail has been selected

Simple method statement required, if being lifted a simple lift plan also required

Cage built as per instructions by competent steel-fixers and formally inspected

Permit-to-load probably not necessary

Any alterations need to be checked for compliance with standard solutions

Continued on page 35

Appendix 1: Example procedure flow chart for managing the temporary condition of reinforcement cages prior to concreting Pre-construction – *Continued*

Figure A1: Example procedure flow chart for managing reinforcement cages – *Continued*

Continued from page 34

PC's TWC may need to provide additional design briefs to cover information from external designers and coordinates all interfaces with other sub-contractors

↓

Design should be formally reviewed for buildability and to ensure all relevant information has been provided

Comprehensive RAMS for assembly, lifting, stabilising of the rebar cage(s) should be produced by steel-fixing sub-contractor

Designer's significant residual risks to be addressed in the RAMS

PC and perhaps external parties review the RAMS

TWS needs to ensure all equipment is inspected prior to use for compliance and quality

PC's TWC may issue a permit to commence work

↓

Cage to be assembled (when in situ) and lifted and positioned (when prefabricated) by competent persons who have been briefed and are being supervised by TWS

PC may introduce 'hold points' during the assembly for installing additional temporary works measures to ensure stability. These are 'released' by the issuing of permits to continue

↓

During the assembly, any proposed on-site changes must be communicated to the PC's TWC or TWC who seeks approval from the designer

Additional checking and external approval may be required

↓

Cages and any associated temporary works need to be formally inspected by competent person

PC's TWC issues permit-to-load for whole scheme including interfaces

↓

Concrete is placed Operatives should be briefed on any limitations of use

Cage stability is no longer an issue

Any temporary works measures can be removed in a pre-determined sequence (unless sacrificial). PCsTWC or TWC may issue a permit to remove

↓

Once the concrete has gained sufficient strength the formwork, etc should be removed (in accordance with the RAMS)

PC's TWC issues a permit-to-dismantle

[6] *Where design responsibility remains with the PWD they should consult with the contractor to develop the most effective solution.*

Appendix 2: Original Working Group (2013)

Convenor:	P Wilson	Kier Construction – Engineering Ltd
Secretary:	J Carpenter	Temporary Works Forum
Members:	J Gregory	Carillion plc
	S Hall	Costain
	T Lohmann	Swanton Consulting Ltd
Corresponding Members:	C Bennion	Kier Construction – Engineering Ltd
	N Boyle	Balfour Beatty Construction Services UK
	M Davies	Barhale Construction plc
	J Gill	Hochtief (UK) Construction Ltd
	R Hare-Winton	BAM Construct UK Ltd
	W Hewlett	Costain
	M Holmes	Pascoe Ltd
	A Jones	RMD Kwikform Ltd
	R Kugananthan	Laing O'Rourke
	S Marchand	Wentworth House Partnership
	J Pratt	Pinsent Masons LLP
	A Rattray	HSE
	K Shivji	Miller Construction

Notes:

Temporary Works forum

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

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