



**Temporary Works
forum**

Promoting best practice in
the construction industry.

Ref.: TW15.116
Date: 16th October 2015

STABILITY OF REINFORCEMENT PRIOR TO CONCRETING

TWf SAFETY BULLETIN

Preamble

At its meeting on 23rd September 2015 the Temporary Works Forum (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 are changing. The TWf has undertaken to update its own guidance¹. In the meantime, as an interim measure, this Safety Bulletin aims to highlight key issues for all parties to consider. The ultimate aim is to save lives and reduce injuries.

Introduction

This Safety Bulletin is aimed at those specifying, managing, designing, detailing and installing reinforcement cages – whether this is permanent works designers or contractors – and seeks to draw attention to some key issues in ensuring stability and thus safety.

Many do not realise that rebar cages can be dangerous, or that buckling can occur suddenly. Also, that cages built in-situ can become progressively less stable as work progresses; something that can be counter-intuitive.

1. Background

The collapse of reinforcement ('rebar') cages before concreting has occurred periodically with serious consequences, including death and injury^{2 3 4}. There have been collapses of wall cages, column cages and deep slab cages. Despite these occurrences, there is only limited guidance on the assessment of cage temporary stability. To a great extent, temporary stability has been dealt with by custom and practice. However, practices change, e.g.:

¹ www.twforum.org.uk/media/41823/twf13_stabilityofreinforcement_v8_22_jan.pdf

² www.structural-safety.org/publications/view-report/?report=1439

³ www.structural-safety.org/publications/view-report/?report=1449

⁴ www.gov.uk/government/publications/highways-agency-safety-alerts/stability-of-reinforcement-cages-prior-to-concreting



- There appears to be a trend towards fixing taller cages with smaller diameter vertical bars;
- The use of mobile elevating work platforms (MEWPs) in lieu of scaffolding is more widespread;
- The use of long handled nips and automatic slash tie machines;
- Different types of tying wire, tie patterns, etc.

These changes invalidate a reliance on custom and practice as a means to ensure safety. It is unacceptable for incidents to occur as a means to allowing a new approach to evolve. Notwithstanding this, many of the measures required are straightforward and long-standing.

A key message in planning is to, 'Look, think, consider and decide'.

2. Management (and risk reduction)

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.

Reinforced concrete is a widely used material and history has demonstrated that it can be constructed safely. Despite this, there is a legal duty⁵ on designers to understand and be aware of significant risks that workers and users can be exposed to, and how these can arise from their design decisions. Designers should apply a hierarchy of risk reduction, i.e. Eliminate, Reduce, Inform, Control (ERIC).

It is recommended that a 'Temporary Works Schedule' be prepared by the Permanent Works Designer, listing any significant temporary works, and passed to the Principal Contractor as part of the Pre-Construction Information. The latter should contain information about significant design and construction hazards, including design assumptions and temporary instability conditions, and suggest work methods, sequences or other control measures.

Prior to concreting, it is recommended that rebar cages - whether considered stable or not - be considered 'temporary works', thus invoking the procedural controls given in BS 5975⁶.

It is recommended that potentially unstable rebar cages be listed in the Temporary Works Schedule and, whether or not listed in the Schedule, be listed in the Contractor's 'Temporary Works Register'. This should ensure that the 'Temporary

⁵ Construction (Design and Management) Regulations 2015

⁶ BS 5975:2008+A1:2011, Code of practice for temporary works procedures and the permissible stress design of falsework



Works Coordinator⁷ is able to coordinate all temporary works activities; giving particular attention to the design brief, design check⁸, on-site supervision and site checks.

Contractors may wish to consider the use of a 'Permit to fix reinforcement', i.e. the use of a 'Hold point' that should ensure that all the appropriate procedures have been followed and the required control measures put in place. Such a 'Hold point' is analogous to a 'Permit to dig'.

Contracts should be clear about who is responsible for the detailing of reinforcement. Traditionally, this was the Permanent Works Designer, but it is now frequently the contractor (or even sub-contractor). Even if the contractor is responsible for detailing, the personnel actually doing the detailing may not have practical, on site experience. Detailers should understand the hazards that rebar can present in temporary conditions, i.e. prior to concreting. 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.

3. Analysis and design of cages in temporary conditions

Failure modes

Any designer(s) of cages in the temporary condition - whether a permanent works designer or a temporary works designer - should consider the different failure modes. For example:

- Foundation, slab and beam elements - support of the top mat, racking, lateral instability;
- Column and wall elements - discontinuity at lap positions, bending failure of bars, axial buckling, in-plane racking (side sway);
- Cages that are lifted - individual bars may drop from the cage, or the cage may be unstable and/or break up as a consequence of the lifting forces imposed.

Actions

Cages are subject to external forces, e.g. wind loads, accidental impact, etc., in addition to their self-weight and the effect of any construction tolerances and imperfections.

Consideration should be given to accidental impact loading, e.g. cranes, vehicular impact, wind loading, people pushing a cage to right it, and other abnormal load conditions, e.g. from poor workmanship, such as being erected out-of-plumb. The assessment of axial buckling is not wholly straightforward, due to lap positions.

⁷ See Clause 7.2 in BS 5975

⁸ For advice on 'Categories of design check', see Table 1 in BS 5975



Any dynamic loading, e.g. people pushing a cage to right it, has a much greater effect on instability than the same force applied as a static load.

Considerations

Single face reinforcement is particularly vulnerable to instability and temporary measures may be necessary to support the reinforcement (depending on its height above kicker level and the spacing and diameter of the vertical rebar). Research has shown that the adjacent vertical bars do not behave compositely. There is limited information on the strength of tie wire intersections (and 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 trussing action, they do not improve rigidity. To brace cages in beam and slab elements, longitudinal bracing bars may be required.

Permanent Works Designers should give thought to:

- Cages that involve man-entry;
- Tall wall and column cages, particularly if above the heights in **Table 2** (see **Appendix**);
- Large or heavy elements at the top of cages, e.g. projecting slab starters or corbel reinforcement.

Changes to custom and practice, e.g. the use of taller and or more slender bars, will create a significant risk of failure which might not be spotted even by an experienced contractor.

Provision of information

Any designer should provide information on significant risks. Significant risks are not necessarily those that involve the greatest risks, but those that are:

- Not likely to be obvious to a competent contractor or other designers;
- Unusual; or
- Likely to be difficult to manage effectively.

Information should be brief, clear and concise. It should include, for example, the envisaged construction sequence, the location of construction joints, unusual details, etc. A useful way of drawing attention to significant hazards is to highlight them on the construction drawings.



4. Designing stability measures

If a rebar cage is considered unstable then stability should be provided by one or a number of measures:

Re-designing or amending the design of the permanent works and/or controlling the sequence of erection, e.g.:

- Additional longitudinal bracing bars, spacer bars, etc.;
- Using welding or bulldog grips to give robust composite action.

Providing independent stabilisation⁹, e.g.:

- Installing one face of the shutter ahead of the rebar fixing, to act as a support;
- Installing independent props;
- Installing guy ropes¹⁰;
- Casting support posts (which can be left in or be designed to be removed);
- Access scaffolding, designed to provide the necessary support.

In designing such measures, the designer must consider the cage at each stage of construction and ensure stability at every stage. This can be a time consuming process and may lead to a work sequence that needs close control.

5. Cage assembly

Consideration should be given to assembling cages either 'at grade', e.g. alongside the works; or 'off site'. However, whilst this reduces risk, e.g. work at height and manual handling, it results in the need for lifting.

6. Lifting of cages

The legal requirements for lifting are given in the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER). General advice on the safe use of cranes is given in BS 7121-1: 2006¹¹. Additional advice, relating to temporary works and rebar, is given in Section 2.0 of TWf2013:01.

⁹ See 3.3 in TWf 2013/01

¹⁰ It should be noted that many collapses have occurred where guying was used. Induced compression from guy wires leads to rebar buckling failure; lack of tensioning control causes out of balance forces; maintaining balanced forces during installation and removal can be very difficult to manage on site. Guy ropes may be removed during shutter installation, just at the moment the cage is most unstable. Guy ropes require extreme care and should be used only with very careful design and procedures in place.

¹¹ BS 7121-1:2006, Code of practice for safe use of cranes. General



Cages for lifting are a 'designed item'. There is a need to consider, as a minimum:

- The position of lifting points, to avoid cage deformation and axial buckling;
- The adequacy and security of attachment points;
- Determining the centre of gravity, to avoid rotation during lifting;
- Any limiting deflections;
- Lifting strop angles and the need for a lifting beam;
- The size of bars and bending failure;
- The position of laps and/or the use of couplers;
- The adequacy and frequency of tie-wire;
- The risk that a single bar might detach and fall during lifting;
- A means to ensure that the cage is soundly connected to the starter bars before it is released from the crane; and
- A means to ensure that the temporary condition as a whole (the newly fixed cage and starter bars) is stable before the crane is released¹².

Lifting plans for rebar cages should avoid lifting the cage above people.

When cages are to be lifted, subject to the specification and agreement with the permanent works designer, stiffness and strength can be added by welding laps and welding in bracing bars. It is recommended that all welding of rebar is undertaken in workshop conditions and subject to appropriate quality control measures.

7. Access and egress

MEWPs

The use of MEWPs should be considered with great care¹³. The primary purpose of a MEWP is to enable persons to carry out work at height, getting into the work platform at the ground and returning to the ground to exit¹⁴. The carrying of materials that are associated with the work is permitted provided that they and the persons are within the capacity of the machine. This includes the rated capacity, position of centre of gravity, wind area and any non-vertical forces due to the load. As MEWPs generally have low rated capacities by comparison with cranes and telehandlers, it is very easy to overload them. They are fitted with load sensing systems, but these take account only of vertical loads in the work platform.

In terms of work with rebar, they are ideal for getting a steel fixer to where they want to be, but not for handling materials. The use of a MEWP may also prevent, or

¹² There have been many failures of craned cages immediately after the crane is released

¹³ See: www.hse.gov.uk/pubns/geis6.pdf

¹⁴ See Scope, BS EN 280:2013+A1:2015, Mobile elevating work platforms. Design calculations. Stability criteria. Construction. Safety. Examinations and tests



interfere with the use of inclined props and other stabilisation measures. Should a rebar failure occur MEWPS generally offer less protection than scaffold,

Scaffolding

Where scaffolding is used to provide stability it must be 'designed'¹⁵. Account should be taken of:

- Vertical and lateral loads; and
- The ground conditions.

8. Workmanship

The specification for reinforcement work must be followed carefully and the cutting, bending and storage must all be carried out meticulously¹⁶. The fixing must be carried out accurately and firmly in order to keep each bar in position. Fixing requires a high degree of skill. Tie wire needs to be twisted sufficiently tight so bars do not slip or move. If too tight, the tying wire may be over-stressed and snap. If too loose, slippage of the joint will occur.

The type of tie wire, spacers, frequency of tying, etc. should be specified. Advice is available in BS 7973-2¹⁷ and TWf2013:01, Section 2.3.

9. Supervision

Work on site should be the subject of careful direction, supervision and inspection to ensure that the temporary works is constructed safely in accordance with the design, planned sequence and specified materials (BS 5975, Clause 10). All those involved should be competent, i.e. have the right knowledge, skills and experience.

'Hold points' should have been identified, along with suitable checks. Site changes, or queries, should be raised with the Temporary Works Coordinator, who will coordinate responses from the designer and design checker. Those on site should be aware of the stability measures required and be alert to the need to inspect the ties periodically. Checklists may be appropriate.

A 'Permit to fix reinforcement' hold point – analogous to the widely used 'Permit to dig' – would provide a good opportunity to engage site management and ensure that risk has been identified and any required checks implemented, before work commences.

¹⁵ TG20:13 Good Practice Guidance for Tube and Fitting Scaffolding, NASC, 2013

¹⁶ Concrete Society, Concrete on Site 2, Reinforcement (2015)

¹⁷ BS 7973-2:2001, Spacers and chairs for steel reinforcement and their specification – Part 2: Fixing and application of spacers and chairs and tying of reinforcement



10. Provision of information

The provision of information in a timely manner is central to good health and safety management. This may be:

- Technical, e.g. in specifications, on drawings, etc.
- Safety-related, e.g. in pre-construction information, on drawings, etc.

Information of sufficient quality will be specific to the work in hand, rather than being generic. The specific hazards must be identified so that the work can be planned with adequate resource, properly risk assessed and appropriate method statements, inspection and test plans, drawings, task briefings, toolbox talks, etc. prepared and communicated.

Further reading

- TWf, Stability of reinforcement cages prior to concreting, TWf2013:01, October 2013
- TWf, Stability of reinforcement cages prior to concreting, Addendum to TWf2013:01, October 2014
- BRC, The essential guide to reinforcing concrete, 2007
- CARES Information Sheet, Introduction of British Standard BS 8666:2005, Scheduling, Dimensioning, Bending and Cutting of Steel Reinforcement for Concrete
- CIRIA, Special Publication 118 (1995), Steel Reinforcement, A handbook for young construction professionals
- CONCRETE ADVICE No. 43 (March 2012), Spacers and visual concrete
- CONCRETE July/August 2013, The changing face of diaphragm wall construction Rebar Cage Construction and Safety, Best Practices, Michael J. Casey and Gium S. Urgessa, Construction Institute of the American Society of Civil Engineers (2012)

Note:

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



APPENDIX

The following points were tabled at the TWf Meeting on 23rd September 2015. Those involved in specifying, managing, designing, detailing and installing reinforcement cages may wish to consider them when considering measure to ensuring stability.

How high can wall and column reinforcement free stand?

Any assessment must consider the loads, deflections, buckling, consequences of failure, etc.

It was proposed that if rebar heights exceed those given in **Table 2** the risk of instability should be considered explicitly. While lesser heights would normally be stable given current 'custom and practice', it was obviously important to understand what this constituted. **Table 1** lists the characteristics of normal 'custom and practice' in the UK construction industry, as discussed at the meeting.

Departure from these characteristics would tend to invalidate a reliance on experience as to the safe freestanding height of wall and column rebar. So, if the criteria in **Table 1** are not met, temporary stability should be given specific, engineering, consideration notwithstanding the height.

Table 1: Characteristics of normal 'custom and practice' for wall and column cages in today's UK construction industry
The cage is vertical, with starter bars cast into a pile cap or robust slab.
The starter bars are not smaller in diameter than the vertical bars ('verts').
The starter bar laps are staggered.
Standard UK-type 'nips' are used by experienced steelfixers.
Tying conforms to BS 7973 Part 2; 1.6mm dia. black annealed soft tying wire is used, with a minimum ultimate strength of 280MPa. Specified ties and tying pattern.
The diameter of the lacers is not greater than the diameter of the verts.
The centre-to-centre spacing of the lacers is not less than the centre-to-centre-spacing of the verts.
The verts are single bars - and at least 50% are bearing onto the kicker.
There are no slab starters or other bars projecting horizontally, or other feature imposing an eccentric load or otherwise tending to weaken or destabilise the cage.
There is no abnormal high consequence should a failure occur.
A designed scaffold for access is provided, which can be used to laterally support the cage.



Table 2: Limiting heights for self-stability of wall and column cages given today's custom and practice in the UK construction industry.	
Bar size (verts) (mm)	Height of cage from slab level to highest point (m)
12	2.4
16	3
20	3.5
25	4.5
32 or bigger	5

Note:
This Table is for guidance only and individual circumstances should be assessed by the designer

Acknowledgements

The Temporary Works Forum gratefully acknowledges the contribution made by Members in the preparation of this bulletin.

Liability

Although the Temporary Works Forum does its best to ensure that any advice, recommendations and information it may give either in this publication or elsewhere are accurate, no liability or responsibility of any kind (including liability for negligence) howsoever and from whatsoever cause arising, is accepted in this respect by the Forum, its servants or agents.

Notes for Editors

Established in 2009, the intent of TWf is to encourage open discussion of any matter related to temporary works, for the good of the industry overall. The Forum is open to anyone, individual or corporate, working within the industry and sharing this intent. The TWf's objectives are:

- The advancement of education;
- The saving of lives;
- The advancement of science;
- Avoidance of disasters.

TWf welcomes new members, whether clients, main contractors, specialist contractors, temporary works designers, permanent works designers, proprietary equipment suppliers, academia or other interested companies and/or individuals. For details, please contact the TWf Secretary: secretary@twforum.org.uk

/End