Reinforcement Cage Stability

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Foreword

Reinforcement cage is one of the most common features on construction projects. However, the assessment of their temporary stability during lifting and prior to concreting has limited guidance and is most commonly dealt with by custom and practice. They have been known to collapse and cause both death and injury.

This guidance note is written to highlight the key issues, and to give specific assistance to those specifying, managing, designing and installing reinforcement cages.

This publication presents recommended procedures and good practice for ensuring rebar cage stability in Hong Kong construction projects. Contractors may consider making reference to this document as a basis for setting up a systematic control framework to manage risks in temporary works within construction projects. Clients may consider encouraging the use of this document as a standard of best practice on their projects.

At various points in this report, formal design processes are recommended. This recommendation is made despite the inexact nature of design in the subject area of this document. Experience is thus a pre-requisite. Any designer new to design for temporary stability of reinforcement is urged to seek expert advice.

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Practitioners are encouraged to provide comments to the TWf at any time on the contents of this Publication, so that future improvements can be made in future editions.

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1 Introduction

1.1 Target Audience

This guidance note is written to assist all parties involved in construction to understand the key issues, and to give specific assistance to those specifying, managing, designing and installing reinforcement cages.

1.2 Background

A large reinforcement assembly or cage can represent a considerable danger to those working on, adjacent to, or within it, should it collapse or fail during lifting. Collapses usually occur through lack of strength or lateral instability, or a lack of cage robustness prior to it being fully stabilised through containment within a shutter or similar. A number of cases had been reported where collapse had occurred. Some had involved fatalities.

The increase in frequency of reinforcement cage collapses may be connected to the use of Mobile Elevating Work Platforms (MEWPs) to fix reinforcement. Previously, scaffolds have been used to fix reinforcement and these probably acted as supports to the reinforcement cages where required. There also appears to be a trend towards fixing taller cages with smaller vertical bars.

1.3 Scope

Reinforcement cages for walls, columns, beams and slab elements are considered within this document both for stability in place prior to concreting and also during lifting. These cages are considered either fixed in-situ, or pre-fabricated. Pile cages and diaphragm walls are beyond the scope of this document.

Guidelines on fabrication of bored pile reinforcement cages was separately published by the HKCIC, which can be downloaded from this link: http://www.cic.hk/cic_data/pdf/about_cic/publications/eng/V10_6_e_V00_Guidelines_on_Fabrication_of_Reinforcement_Cages_of_BoredPiles.pdf

For simplicity ‘cage’ is the descriptive term used throughout this note.

In practice the cage will require specific measures to be undertaken to ensure that it remains rigid and stable at all stages of the erection. Typical situations occur:

1.3.1 Lifting

- Adequacy of lifting mechanism/lifting point
- Adequacy of tying (or other method) to secure cage as a whole
- Cages which are required to be lifted from the horizontal to the vertical
- Security of individual bars

1.3.2 In place, prior to concreting or stabilisation by the shutter

- Large foundation structures which often have substantial
reinforcement cages, made up of large diameter bars, to both top and bottom mats

- Retaining wall reinforcement where the front shutter has been omitted to allow access
- Vertical reinforcement cages e.g. for a wall, erected without any lateral support and which rely on the lap with foundation or other lower starter bars for stability

### 1.4 Responsibilities

Safe fabrication and erection of reinforcement cages relies on the cooperation and appropriate input of all parties including the Permanent Works Designer, Temporary Works Designer, Temporary Works Coordinator, Principal Contractor and the contractor carrying out the work. The Code of Practice for Temporary Works, BS 5975 sets out a recommended framework for managing this process by treating reinforcement cages as an item of temporary works (permanent works in an incomplete state). Further detail is provided in section 4.0.

### 1.5 Risk assessment method

On each individual location stability of reinforcement must be considered with the appropriate actions identified. During the risk assessment phase the permanent works drawings should be examined.

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Clear allocation of responsibility at all stages (on-site delivery to concreting)</th>
</tr>
</thead>
</table>
| Nature of the cage itself | • Bar size and density  
• Shape of cage  
• High or eccentric centroid |
| Delivery/Assembly        | • Lifting actions  
• Partial erection states  
• Lifting attachments  
• LOLER requirements  
• Access (suitable collision protection required from mobile plant) |
| Means of stability       | • Inherently stable  
• Relying on laps/tying/welds  
• Relying on sequence of assembly  
• External means of support e.g. shutter  
• Dependent upon actions by other trades e.g. erection of shutter or scaffolding |
| Personnel                | • Requires entry into or access onto cage.  
• Adjacent working to cage  
• Competency |
| Time: weather influences | • Short duration before concreting  
• Specific support is provided  
• May be left over longer periods of time before concreting |
| Tying guidance           | • See Appendix A |
| Welding guidance         | • See Appendix A |

### 2 Lifting of reinforcement

The underlying requirement to carry out site specific risk assessment and design for the lifting of prefabricated reinforcement cages must be observed and managed in accordance with current legislation.

![Possible buckling of cage](image)

![Suitably designed reinforcement arrangement around lifting points](image)

Fig 5. Buckling of cage due to axial forces and designed lifting points

#### 2.1 Regulations and standards

The Factories & Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations and relevant practice notes regulates the safe use of Lifting Equipment. However, there is no specific guidelines on the lifting of reinforcement. The British Constructional Steelwork Association (BCSA) ‘Guide to the Management of Site Lifting Operations’ contains additional guidance although not specific to lifting of reinforcement.

#### 2.2 Modes of failure when lifting

Potential modes of failure to be considered when planning lifts are:

- Instability of the crane (or lifting plant).
- Failure of lifting equipment (strops, chains, bars, shackles, lifting eyes etc.)
- Lifting points ripping off the cage
- Inadequate load path from the lifting points
- Axial buckling due to compression caused by inclined chains/strops
- Bending failure with scissor action at laps or excessive deflection of cages (requiring stiffening by inclined bars, links or U-bars)
- Laps and splices give way (tied laps frequently experience relative movement of around 25mm before failure).

#### 2.3 Requirements for tying reinforcement cages

Nodes where one rebar overlaps or crosses another in the same plane are commonly connected using single or multiple strands of tying wire that is twisted tight to hold the node in place.

If the tying wire is not twisted sufficiently tight then the bars may slip or move; but if the wire is twisted too tight it can be
Reinforcement Cage Stability

strained to leave little working margin leading to failure under little additional load. Wire ties can be easily overstressed if the twisting action is used to pull rebar together to close up gaps. Kinked, nicked or corroded tie wire will also result in weak ties.

Where design is used to determine the risk of the failure modes above, the strength of ties can be assessed numerically or established from testing. Ties are normally formed using 1.6mm diameter (16 SWG) wire or 1.2mm diameter (18SWG) stainless steel wire to one of the details below.

It should be noted that the strength of reinforcement ties can vary considerably. The fixing of reinforcement is mainly carried out using hand tools and there is inevitably a large variation in the techniques used by steel fixers.

Where there are multiple layers of reinforcement (3+), the ties should be wrapped around the adjacent bars, for example, layer 1 to layer 2 and layer 2 to layer 3. Wrapping ties around multiple layers increases the stretch in the wire and reduces the capacity of the ties.

![Fig 6. Tie patterns](image)

2.4 Lifting

When lifting prefabricated reinforcement cages the following should be considered:

- The weight of the cage should be established using published data (see Appendix B) and the reinforcement bending schedule.
- The position of the lifting points should be determined to ensure that the cage does not deform excessively with lifting beams used to ensure loads are distributed evenly and at an angle perpendicular to the bars to be lifted. Evenly distributed loading on the cage will depend on

lifting beam stiffness, spacing of attachments and sling stiffness and length.
- Where lifting points are used measures need to be taken to ensure that loads can be distributed into the cage. In general lifting points should be welded to cages (if the specification permits; by

competent welders and with due allowance for the reinforcement grade) and the use of steel flats for this purpose is common practice. Double ties are required for cages that are to be lifted or handled.
- Many reinforcement cages are unusual shapes and the centre of gravity becomes difficult to calculate. As with all lifts the cage will move or rotate as the load is taken up until the centre of gravity of the lift is directly below the point of suspension (the crane hook). It is important to establish a set of lifting points and lifting equipment that facilitates any required movement.
- Provided that a cage being lifted will not become unstable/over heavy during the lift, consideration should be given to positioning lifting points on the lowest bars so as to minimise the number of wire ties working in tension during the lift. However, in normal circumstances all lifting points should be fixed to the reinforcement cage above the level of the centre of gravity of the cage.
- Cages should be re-inspected after each lift if moving several times. Ties may have stretched if the cage has deflected significantly during the previous lift. It is advisable not to double or triple handle cages where practicable.
- Small pile-caps are often prefabricated, and these are often lifted by excavator travelling on rough ground. As such they are prone to failure by the spacing of the upper and lower mats not being maintained.
- Prefabricated lifting cages should not be lifted over the heads of personnel.

2.5 Rotation of cages (fabrication/lifting)

If possible the cage should be fixed in the same alignment as it will be eventually placed so that no tilting or turning is required. This can involve creating the cage in a jig that is set at the correct angle.

Some cages such as walls may need to be fixed on their side and then tilted through 90° when they are picked up. Tilting a cage will be critical both for the internal strength of the cage and for the lifting equipment (including the lifting points). Large wall cage lifts are often undertaken as tandem lifts so that the cage is not touching the ground when it is rotated but the rigging and execution of such lifts is complex and involves lifting equipment that accommodates the change in lifting angles (this can involve pulleys to allow rotation). Sliding of the cage along the ground as it is tilted should be avoided and prevented with ties if necessary.

The design of lifting points to facilitate rotation in reinforcement cages is very complex and best avoided if possible. A competent designer should carry out the design otherwise.

2.6 Example of good practice

The following sequence of photographs shows the key stages in the fixing, lifting transporting and placing of some large reinforcement cages weighing approximately 17t each.
Fig 7. Initial fixing in an offsite jig

Fig 8. Opposite end of jig showing alignment rails

Fig 9. Template welded to end of cage facilitates alignment of tensioning ducts (small lugs are not lifting eyes)

Fig 10. Fabricated support near rear of cage. The cage has been constructed rotated to allow the supports to be fixed

Fig 11. Detail of welding lugs fixing the template to the front of the cage.

Fig 12. Cage rotated using appropriate lifting equipment.
3 Stability of reinforcement

3.1 Modes of failure

Elements can fail in a variety of ways depending on the size and shape of the element and how it is moved or placed.

3.1.1 Foundation elements

Larger foundation elements, built in-situ, generally fail due to the insufficient support of the top mat on chairs or similar.

3.1.2 Column and wall elements

Column and wall elements can fail by the shape not being maintained, and also by overturning if the connection to the starter bars is insufficiently robust.

The failure mechanism for vertical members tends to be by the failure of the spacers between the mats leading to the mats separating and acting individually, causing a reduction in the section resisting overturning. An alternative mechanism is for the ties between the starters and the cage to fail.

The presence of L-bars as starters to the top of the column or wall, for slabs can introduce an eccentric load at the top of the member, decreasing the stability of the element.

3.1.3 Slab elements

Slab elements can fail due to the insufficient support of the top mat on chairs or similar.

3.1.4 Beam elements

Beam elements can fail by racking of links or buckling of upper bars. Deep beam elements can be laterally unstable.

3.2 Maintaining form and spacing of cages

3.2.1 Spacing of mats

In order to fix the final depth of the element the bars need to be spaced apart. With beam and column elements this is usually achieved with the links. For slab and wall elements specific chairs or spacers will be required.

Even with links providing the shape of the elements some bars may be supported only by the ties to the links rather than by the enclosure of links.

For slabs and foundation elements the chairs will need to be robust enough to allow the top mat to be accessed as a working platform. The size of chairs to support the upper mat will be a function of the chair spacing (which depends on the size and strength of the top mat) and the weight of the top mat combined with the access load.

Distribution steel running perpendicular to the lowest top mat bars should be provided as this prevents bars being suspended by tying wire and ensures all bars bear adequately onto the cover spacers. The standard chair (BS8666 shape code relies on the strut action of the vertical legs. These are bi-axially bent by the shape of the chair.

It is suggested that the effective length of the strut is considered as 1.5 times the distance between the mats. Tables 2 and 3 are based on using grade 500 reinforcing steel and a factor on load of 1.5.

For maintaining the separation of mats in walls and thinner slabs, continuous wire chairs are useful. The edges of slabs and walls will need support close to the end of the wall or
Table 2 Ultimate capacity of chair elements per leg - $P_{ult}$ (kN)
(Based on effective length equal to 1.5 times mat spacing)

<table>
<thead>
<tr>
<th>Depth between mats (mm)</th>
<th>250</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1250</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>H12 leg</td>
<td>12.7</td>
<td>3.4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H16 leg</td>
<td>36.8</td>
<td>10.6</td>
<td>4.9</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H20 leg</td>
<td>79.4</td>
<td>25.2</td>
<td>11.7</td>
<td>6.7</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H25 leg</td>
<td>Y</td>
<td>59.1</td>
<td>28.0</td>
<td>16.1</td>
<td>10.5</td>
<td>X</td>
</tr>
<tr>
<td>H32 leg</td>
<td>Y</td>
<td>Y</td>
<td>76.4</td>
<td>44.0</td>
<td>28.5</td>
<td>19.9</td>
</tr>
</tbody>
</table>

Notes: X indicates an element that is too slender, Y indicates a dimension that is too small to bend

Table 3 Working capacity of chair elements – 2 legs (kN)
(Based on Shape Code 98, A, C, D = 500mm, B to suit cage. Capacity is $2 \times P_{ult} / 1.5$)

<table>
<thead>
<tr>
<th>Depth between mats (mm)</th>
<th>250</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1250</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>H12 leg</td>
<td>16.9</td>
<td>4.6</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H16 leg</td>
<td>49.1</td>
<td>14.1</td>
<td>6.5</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H20 leg</td>
<td>105.8</td>
<td>33.6</td>
<td>15.6</td>
<td>8.9</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H25 leg</td>
<td>Y</td>
<td>78.8</td>
<td>37.3</td>
<td>21.5</td>
<td>14.0</td>
<td>X</td>
</tr>
<tr>
<td>H32 leg</td>
<td>Y</td>
<td>Y</td>
<td>101.9</td>
<td>58.7</td>
<td>38.0</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Notes: X indicates an element that is too slender, Y indicates a dimension that is too small to bend

3.2.2 Maintaining shape

For columns and beams the main issue is in keeping the shape of the element. The stiffness of the element comes entirely from the connections between the bars and the links. As such the tying of the reinforcement becomes critical, particularly if the element is to be lifted.

Although outside the scope of this document, prefabricated pile and diaphragm wall cages often have shaped templates within the cage and bars are welded to these to provide some additional integrity to the cage.

3.2.3 Improved fixity of bars within cage

The requirements of BS 7973-2:2001 - Spacers and chairs for steel reinforcement and their specification, provides for stable cages in most circumstances. However the use of additional ties at starter bars, lifting points and any other highly stressed areas is recommended. The use of welding or of 'bulldog' type clamps should be considered when the connection is highly stressed. Where slabs are heavily reinforced, very deep or have to support heavy construction loads then the vertical load capacity of the chairs should be checked.

3.2.4 Improved spacing of mats within cage

If chairs are provided within the requirements of BS 7973-2 the mats will be adequately spaced. Where there are large eccentricities or potentially high lateral loads providing larger/stronger chairs will stiffen the element.

3.3 Measures that can increase stability

Supporting reinforcement often presents a number of practical problems such as finding suitable support points and the support obstructing the formwork. Various options are available which have advantages and disadvantages.

- Install one face of the shutter ahead of reinforcement fixing to act as a support
- Install independent props
- Install guy ropes
- Cast support posts within the wall projecting from the kicker.
- Adapt the access scaffolding used to erect it to have sufficient capacity to support the reinforcement.
- Install additional longitudinal bars to prevent racking, or additional spacer bars tied to the horizontal lacers to prevent flexure.

3.4 Method of assessing stability requirements

Prefabricated reinforcement cages require special consideration to ensure that the cage remains stable during fixing.

Single face reinforcement mats are particularly vulnerable to instability and temporary measures may be necessary to support the mat depending upon its height above kicker level and the spacing and diameter of the vertical bars.

Double faced cages may also require the addition of spacer bars to connect the individual faces of reinforcement together thereby improving the rigidity of the cage. Double face reinforcement above a certain height may also require additional external temporary measures to support the cage depending upon the spacing and diameter of the bars.

The construction sequence and method of working should ensure that the formwork closely follows the fixing of reinforcement. Specific measures should be undertaken, to ensure that stability of reinforcement is maintained, in the section beyond a previously concreted wall or pier.

Wherever possible the fixing of reinforcement should generally commence or terminate at corners or return walls which will normally provide additional rigidity to the cage. If external temporary measures are considered necessary their form should take into account the method of supporting the formwork fixed at a later stage.

3.5 Example of good practice

The following sequence of photographs shows details of support posts cast in to the base slab providing lateral stability to the reinforcement. This solution required permission from the permanent works designer.
Reinforcement Cage Stability

4 Procedures and Responsibilities

4.1 Procedure

In principle, the procedures shall involve the key steps shown in the flow chart in Figure 20 below.
4.2 Responsibilities: General

Responsibilities may arise in a number of ways, as shown in Tables 4 and 5.

The Permanent Works Designer (including as appropriate, the detailer) must give consideration to the buildability of the design at the permanent works design stage and this should have included consideration of the detailing of, for example, any identified splices and construction joints to ensure so far as is reasonably practicable that the specified reinforcement cages are not inherently unstable.

Significant residual risks should be brought to the attention of the contractor. Although advice will not be expected on ‘normal cage situations’ e.g. wall or base reinforcement (the contractor may be assumed to be competent to deal with this), where the cage is significantly unusual in some way, the contractor should be alerted. For advice generally see ‘Guidance for Designers’ at:

http://www.cskills.org/supportbusiness/healthsafety/cdmregs/guidance/Copy_5_of_index.aspx

Where contractual situations allow, it would normally be advantageous for the Permanent Works Designer to cooperate with the Contractor so that specific constructability is incorporated into the design. This will ensure that splices and construction joints are detailed to avoid unnecessary instability issues.

Industry standard contracts are for the most part silent on the subject of temporary works. The Employer or the Contractor may choose to stipulate specific obligations with respect to temporary works, for example reference to industry best practice. These must be incorporated expressly into the contract.

With regard to all responsibilities it is important that allocation of duties, and actions that flow from them, are recorded in writing and made known to the relevant parties. Checks are an important element of risk management and should be built-in to the design and construction processes.

### Table 4 Responsibilities under Contract and Statute

<table>
<thead>
<tr>
<th><strong>Contract</strong></th>
<th>Responsibilities will vary depending upon the exact contract text but normally all site operations will be the responsibility of the contractor and sub-contractors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temporary Works Co-ordinator (TWC)</strong></td>
<td>It is important that the division of responsibility between contractors is clear in respect of the lifting and stability of reinforcement cages</td>
</tr>
<tr>
<td><strong>Statute</strong></td>
<td>Permanent Works Designers (PWD) (employed by clients or contractors) must give consideration to situations where significant risks might arise from their design e.g. the configuration, weight, stability, size etc. of reinforcement cages, and where the significant risk could be reduced by reasonable actions by the PWD. Where significant risk remains, this must be brought to the attention of the contractor. ‘Significant risk’ is where it is not likely to be obvious to a competent contractor; unusual; or likely to be difficult to manage effectively.</td>
</tr>
<tr>
<td><strong>Temporary Works Designers (TWD)</strong></td>
<td>TWD must give specific consideration to reinforcement cages and ensure the design is such that lifting and stability in place is achieved safely. Information on</td>
</tr>
</tbody>
</table>

The Construction Design and Management jointly published by the Occupational Safety & Health Council (OSHC), Environment, Transport and Works Bureau (ETWB) and Hong Kong Housing Authority (HKHA) also provides some guidance on the design and management of both permanent and temporary works. The document can be downloaded from:

significant residual risks should be passed onto the contractor.

<table>
<thead>
<tr>
<th>CDM Co-ordinator (CDM-C) (for notifiable projects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The CDM-C has the responsibility of ensuring that all designers are co-operating and co-ordinating their work, and working to eliminate hazards and reduce risk.</td>
</tr>
</tbody>
</table>

### 4.3 Responsibilities: Construction Phase

The responsibility of ensuring that the temporary conditions are properly considered during the construction phase falls to the Temporary Works Coordinator (TWC) as set out in the British Standard. Whilst the majority of small items of reinforcement will present no significant risks the larger and more complex items will need to be considered more closely. Supervisors should be involved in developing the solutions and should be encouraged to raise any concerns about stability that they observe during routine inspections.

The responsibility for safe working will always involve the contractor undertaking the task; it will frequently involve other contractors and the Principal Contractor. The TWC will have a role as a coordinator.

#### i) Identify significant items of risk
- Large and potentially unstable cages
- Items to be lifted

#### ii) Identify potential solutions
- Review the proposed construction method
- Introduce stability elements (additional reinforcement or bracing)

#### iii) Communicate
- Co-ordination and consultation meetings/Tool box talks
- Temporary works design drawings
- Method statement (safe system of work)

#### iv) Control Procedures
- Supervision
- Formal inspection/permission procedure (Permit to load / lift)
- Monitoring and feedback

### 4.4 Physical checks

All stages of the process are equally important 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. The check list below illustrates some of the key points to be considered.

- Ties
  - Correct types of ties used
  - Tie frequency and spacing complies with the design
  - Ties are correctly tensioned
  - Sufficient twist projects from the tie
- Bars
  - Temporary bars are correctly fixed
  - Correct shape codes have been used
  - Orientation of bars, position, spacing and layering are correct
  - No unauthorised cutting of bars has taken place
  - No unauthorised heat has been applied to the reinforcement
  - Bars are bent using correct formers in accordance with BS8666
- Splices
  - Splices have lap length and appropriate ties
  - Appropriate lap stagger has been employed
- Cages
  - Cage has retained the design shape
  - Reinforcement has not been kinked or bent out of shape
  - Physical dimensions of the cage comply with the design
- Mechanical fixings/Welding
  - Mechanical couplers are fully engaged and tightened
  - Welding is carried out by an appropriately skilled welder to an approved procedure
  - Welds comply with the design and are of appropriate length and size
  - Any mechanical grips or connectors are installed in accordance with manufactures guidelines and are tightened to the correct torque
- Any temporary works are installed in accordance with the temporary works design and a permit to load (put to use) is completed.
- Any modifications that are necessary to enable bars to be fixed have been approved by the Permanent Works Designer and Temporary Works Designer.
- Any distress to the cages or failures of ties should be reported to the TWC.
- 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. They should also have current certification.
- A post lift inspection should be carried out, with any loose or failed tie wires replaced.

It is particularly important that works supervisors are vigilant in checking that the method statement (and other relevant documentation) is, and remains, relevant to the actual work in hand. Any concerns raised must be actioned prior to works continuing.

### 5 Local Experience on Good Practice

Some good practice and pictorial diagram illustrating the
sequence of erection shared by the contractors are given in Appendix D for reference.

6 References

- BS 7973–2:2001 – Spacers and chairs for steel reinforcement and their specification. Fixing and application of spacers and chairs and tying of reinforcement
- Construction Industry Council – Guidelines on Fabrication of Reinforcement Cages of Bored Piles
- Occupational Safety & Health Council (OSHC), Environment, Transport and Works Bureau (ETWB) and Hong Kong Housing Authority (HKHA) – The Construction Design and Management
Appendix A

(i) Guidance on design for lifting and fixing

The design of reinforcement cages should only be carried out by a designer who is competent to do so.

When carrying out a design the performance of reinforcement cages under load can be difficult to predict using a straightforward structural analysis approach. There will inevitably be large variability in the construction due to differences between steel fixing techniques which needs to be considered. The secondary effects caused by large deflection can also redistribute forces making it difficult to accurately predict realistic stresses in joints and members. The resultant of pulling components and shearing components needs to be considered when assessing the overall load on the ties at the bar to bar connections. Anyone designing cages should therefore adopt a conservative approach with a high degree of redundancy. Robustness is the key.

(ii) Planning

Before carrying out a design it is important to get a clear brief so that all parties fully understand the responsibilities, requirements and the forces that are to be considered. Good planning is a key factor in this. As noted in Section 4, responsibility for design in the temporary condition must be assigned. A plan should identify the following:

- Proposed layout
  - Position of joints both length and height
  - Permanent works reinforcement drawing and schedule
- Construction method
  - Prefabricated or fixed in situ
  - Limitations on lifting
  - Preferred method of providing stability
- Site constraints
  - Environmental considerations including exposure to wind
  - Physical restrictions due to site layout or working space
  - Time of year the work is to take place

(iii) Loading

The loads on a reinforcement cage are derived from a number of different sources as listed below.

- Self-weight of reinforcement (including laps, additional bracing reinforcement, en-cast items and couplers)
- Wind loading. Typically based on the site wind pressure and the area of bar in each face multiplied by a force coefficient appropriate to a circular member $C_f = 1.2$. Consideration should be given on when the density of the cage becomes more critical than the individual bars.
- Ice loading (not common)
- Impact loading (value to be determined by the designer depending on the level of risk and the consequences of failure typically varies from 0 – 10 kN)
- Dynamic loading when being lifted (Typically 10% to 25% of dead load depending on the type of crane being used.)
- Nominal loading to take account of distortions (Typically 2.5% of dead load but should be determined by the designer)

It should be noted that not all these loads occur at the same time so the designer should make appropriate judgements to determine the most onerous combination that is likely to exist.

(iv) Different types of tie

The strength of ties can vary depending on the configuration of the wire and the tension in the wire when the tie is made. The length and number of twists will also affect the capacity of the tie. Most ties are still are still made by hand however there are machines available which are constantly being improved.

It is good practice to assume that half the ties are loose or broken in the design and ensure that there is sufficient redundancy to make sure that every bar is still secure. It is important to specify tie patterns, minimum numbers of ties and maximum tie centres.

The following photographs show some typical ties:
Appendix A

Plate 2. Double slash tie

Bars may be clamped together at laps to achieve a higher strength joint, however this is very expensive and time consuming.

Plate 3. Proprietary clamps

Bars may be clamped together at laps to achieve a higher strength joint, however this is very expensive and time consuming.

Plate 4. Welded reinforcement splice

Plate 5. Example of welded splice detail
### Reinforcement bar weight

Table 6. Reinforcing bar weights per metre (BS4449:2005 Table 7)

<table>
<thead>
<tr>
<th>Size</th>
<th>Kg/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.222</td>
</tr>
<tr>
<td>8</td>
<td>0.395</td>
</tr>
<tr>
<td>10</td>
<td>0.616</td>
</tr>
<tr>
<td>12</td>
<td>0.888</td>
</tr>
<tr>
<td>16</td>
<td>1.579</td>
</tr>
<tr>
<td>20</td>
<td>2.466</td>
</tr>
<tr>
<td>25</td>
<td>3.584</td>
</tr>
<tr>
<td>32</td>
<td>6.313</td>
</tr>
<tr>
<td>40</td>
<td>9.864</td>
</tr>
<tr>
<td>50</td>
<td>15.416</td>
</tr>
</tbody>
</table>
Appendix C – Forms

Appendix C1

Appointment Letter for Bar Fixing Foreman (Sample Only)

Construction Site: __________________________________________________________

Project Name: ______________________________________________________________

The Company appoints the following persons as the Bar fixing Foremen on the aforementioned
construction site from __________________ to ____________________. The personnel possesses 10
years' experience or above in bar fixing, in which 3 years' experience or above is in the fabrication of
similar reinforcement cages.

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Green Card</th>
<th>Relevant Experience</th>
<th>Certificates of Relevant Work</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Signature and Company Chop:

__________________________________________________________

Name:

__________________________________________________________

Title:

__________________________________________________________

Date:

__________________________________________________________
## Reinforcement Cage Fixing – Design Checklist (Sample Only)

Construction Site: 

Project Name: 

<table>
<thead>
<tr>
<th>Items</th>
<th>Completed (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Explore with designer for possible modification to achieve more safe rebar cage details</td>
<td></td>
</tr>
<tr>
<td>2 Calculate the weight and overturning force of rebar cage</td>
<td></td>
</tr>
<tr>
<td>3 Calculate the reaction force and FOS that can be provided by the supporting system to hold the rebar cage</td>
<td></td>
</tr>
<tr>
<td>4 Determine the maximum height / length of a rebar cage that is allowed to be fixed</td>
<td></td>
</tr>
<tr>
<td>5 Define rebar cage lifting and supporting procedures / requirements</td>
<td></td>
</tr>
<tr>
<td>6 Design temporary support to rebar cage (e.g. fixing to starter, shutter at one face with props, etc.)</td>
<td></td>
</tr>
<tr>
<td>7 Design details and spacing of supporting chairs</td>
<td></td>
</tr>
<tr>
<td>8 Design details and spacing of U-bolts</td>
<td></td>
</tr>
<tr>
<td>9 Design details of wire tie</td>
<td></td>
</tr>
<tr>
<td>10 Design details and spacing of rebar cage bracing</td>
<td></td>
</tr>
<tr>
<td>11 Design details and spacing of welding</td>
<td></td>
</tr>
<tr>
<td>12 Assess any impact on adjacent slope, retaining wall, temporary platform, scaffolding, etc.</td>
<td></td>
</tr>
<tr>
<td>13 Others (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

This checklist shall be signed off by the temporary works designer prior to commencement of rebar cage fixing.

Structural element: 

Name and Signature of Bar fixing Foreman: 

Date: 

Remarks:
Appendix C – Forms

Appendix C3

Safety Training Record (Sample Only)

<table>
<thead>
<tr>
<th>Construction Site:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name:</td>
<td></td>
</tr>
<tr>
<td>Training Date:</td>
<td></td>
</tr>
<tr>
<td>Training Venue:</td>
<td></td>
</tr>
<tr>
<td>Training Content:</td>
<td></td>
</tr>
<tr>
<td>Speaker:</td>
<td></td>
</tr>
<tr>
<td>Speaker's Qualification and Experience:</td>
<td></td>
</tr>
</tbody>
</table>

**Signature of Participants:**

I hereby clearly understand the aforementioned work procedures and safety rules, and shall strictly comply them to ensure other workers and I should work in a safe and healthy environment.

<table>
<thead>
<tr>
<th>Name</th>
<th>I.D. no.</th>
<th>Company</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Signature and Company Chop: ___________________________ -

Name: ___________________________ -

Title: ___________________________ -

Date: ___________________________ -
## Appendix C4

### Reinforcement Cage Fixing - On Site Checklist (Sample Only)

**Construction Site:** ______________________________________________________________________

**Project Name** __________________________________________________________________________

<table>
<thead>
<tr>
<th>Items</th>
<th>Comply (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ensure working condition is appropriate (e.g. even ground, firm ground, etc.), and necessary measures are implemented to ensure safe execution of rebar cage fixing.</td>
<td></td>
</tr>
<tr>
<td>2. Ensure stockpiling of rebar and rebar cage is in strict accordance with the loading key plan</td>
<td></td>
</tr>
<tr>
<td>3. Ensure all workers are fully briefed about all the abovementioned key requirements.</td>
<td></td>
</tr>
<tr>
<td>4. Check and ensure the rebar cage complies with the defined lifting and supporting requirements.</td>
<td></td>
</tr>
<tr>
<td>5. Check and ensure the rebar cage complies with the maximum height/length requirements.</td>
<td></td>
</tr>
<tr>
<td>6. Check and ensure the rebar cage complies with the lifting requirements.</td>
<td></td>
</tr>
<tr>
<td>7. Check and ensure the rebar cage complies with the supporting chairs requirements.</td>
<td></td>
</tr>
<tr>
<td>8. Check and ensure the rebar cage complies with the U-bolts requirements.</td>
<td></td>
</tr>
<tr>
<td>9. Check and ensure the rebar cage complies with the wire tie requirements.</td>
<td></td>
</tr>
<tr>
<td>10. Check and ensure the rebar cage complies with the bracing requirements.</td>
<td></td>
</tr>
<tr>
<td>11. Check and ensure the rebar cage complies with the welding requirements.</td>
<td></td>
</tr>
<tr>
<td>12. Check and ensure that measures are implemented to prevent any loose rebar from hitting people nearby during lifting, stockpiling and fixing</td>
<td></td>
</tr>
<tr>
<td>13. If the rebar cage is to be temporarily supported by starter bars, ensure that the starter bars are cast into a robust structure which is sufficient to hold the rebar cage.</td>
<td></td>
</tr>
<tr>
<td>14. Ensure the vertical bars of the rebar cage are firming bearing onto the existing slab / kicker.</td>
<td></td>
</tr>
<tr>
<td>15. Check if there is any slab starters or other bars (corbels, etc.) projecting horizontally resulting in eccentric loads, and ensure they are sufficient to take the load of the rebar cage and concreting.</td>
<td></td>
</tr>
<tr>
<td>16. Ensure additional measures are implemented if there is abnormal high consequence should a failure occur.</td>
<td></td>
</tr>
<tr>
<td>17. Others (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

This checklist shall be signed off by an approved Bar fixing Foreman prior to concreting

**Structural element:** _____________________________________________________________________

**Name and Signature of Bar fixing Foreman:** _____________________________________________________________________

**Date:** _____________________________________________________________________

**Remarks:** _____________________________________________________________________