BCSA Guide to Steel Erection in Windy Conditions

BCSA Publication No 39/05

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The British Constructional Steelwork Association Ltd.,

4, Whitehall Court, Westminster, London SW1A 2ES.

Telephone: (0) 20 7747 8121 Fax: (0) 20 7976 1634.

E-mail: postroom@steelconstruction.org

Website: www.steelconstruction.org

ISBN 0 85073 047 3

British Library Cataloguing-in-Publication Data.

A catalogue record for this book is available from the British Library

BCSA Publication No 39/05

SUMMARY

This document gives guidance to Steelwork Contractors on steel erection in windy conditions for structures being erected in the UK, and discusses the issues that should be considered when designing for the part-erected condition. Its general recommendations apply to steel-framed buildings up to ten storeys. It does not cover the erection of bridges, masts, towers or chimneys.

Additional consideration may be needed for specially-rigged complex lifts, tall structures (over 20m), and to sites where especially extreme wind conditions might be expected (eg islands off the north and west coasts of Scotland). For such cases, a lift-specific or project-specific study of the effect of wind on the erection tasks should be undertaken.

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ENDORSEMENT

The Health & Safety Executive welcomes this BCSA Guide and considers it as an important document in supporting the effective management of health and safety risk. It is a clear example of industry "self regulation", as the direct involvement of experienced and professional practitioners ensures that such guidance will be both relevant and authoritative.

The British Constructional Steelwork Association understands the importance of self regulation and over the years has been proactive and not simply reactive in reducing risks and accidents. The HSE welcomes working in partnership with the BCSA because its positive approach has enabled steelwork erection to be undertaken both imaginatively and with increased safety.

HSE

CONTENTS

1 INTRODUCTION

1.1 OBJECTIVES

In accordance with the requirements of the *Construction (Design & Management) Regulations,* this document identifies the issues to be considered by managers and designers when developing and implementing methods for steel erection in windy conditions for structures being erected in the UK. The guidance applies generally to steel-framed buildings up to ten storeys. It does not cover the erection of bridges, masts, towers or chimneys. The information given in this guide may be of value in the erection of bridges, but the BCSA *Guide to the Erection of Steel Bridges* provides more detail.

If the Steelwork Contractor appoints a specialist erection subcontractor, then some obligations defined in the guide may inevitably devolve to the erection subcontractor (eg where these relate to the direct employer of the erectors), but the Steelwork Contractor should still ensure that the guidance is being followed properly by agreeing the allocation of responsibilities in advance.

This document is principally addressed to those working on site on behalf of the Steelwork Contractor as they are responsible for the implementation of the chosen erection method. It also includes information and guidance for designers concerned with developing the design erection sequence. Development of a safe method requires liaison with the Principal Contractor and generally with the designers of the permanent works; hence, this document serves to brief them as well[1].

1.2 GUIDANCE

This document firstly presents practical guidance that has general application for those directly involved with steel erection on site.

This is followed by three Appendices that give more detailed information on wind conditions, management and design issues. Designers and managers involved with developing and managing safe design erection sequences need to read the relevant Appendices in detail.

[1] SCOSS, the Standing Committee on Structural Safety, has also prepared a topic paper for designers on *Erection of Steel Structures: Learning from experience* reference SC/T/04/01.

2 RECOMMENDED PRACTICE

2.1 RISK MANAGEMENT

- A risk assessment would identify windy site conditions as a hazard that can commonly arise during steel erection operations. It is also quite possible that a fatality might arise from collapse of a part-erected structure for example.
- Steps must therefore be taken to address this risk, either by eliminating it if reasonably practicable, or reducing it such that it becomes a very improbable occurrence. These steps commence in the design and planning stage. Risk reduction must be accompanied by management measures to ensure that suitable information is passed to those with responsibility for controlling the residual risk that remains during the site operations.
- Control of wind-induced risk needs to include briefing all those involved on site with undertaking steel erection on the following advice.

2.2 WIND CHARACTERISTICS

- Note that twice the wind speed means four times the pressure, ie four times the hazard and hence four times the risk unless risk control measures are taken.
- Weather forecasts should be taken to be <u>mean</u> wind speeds unless <u>gust</u> speeds are explicitly mentioned.
- When comparing speeds quoted in forecasts and documents, use 10m/s = 20 knots = 23 mph as a guide.
- It is gusts that matter, if only a mean speed is known, using gust speed = 2.0 x mean speed will give a safe prediction.
- Even for a steady wind, conditions will be windier higher off the ground and will not be the same throughout a large site. Surrounding obstructions can provide locally sheltered regions, and wind can be funnelled by sloping ground or surrounding obstructions.

2.3 LIMITING CONDITIONS

- This guide recommends that erection activity should be planned and managed on the basis of a general operating limit of 12.0 m/s (27 mph) as the "safe gust wind speed"[2]. This would mean the activities should be safe in locations where the Met Office forecasts mean winds up to 15 mph or Force 4.
- In addition, this guide recommends that all site activity should be planned and managed on the basis of a general operating limit of 18.0 m/s (40 mph) as the limiting gust wind speed associated with a working wind pressure of 200 Pa. This would mean steps should be taken to cease all external site activities if the Met Office forecasts mean winds of 25 mph or Force 6.
- For transient conditions outside of working hours and lasting up to three months, this guide recommends that designers should not derive wind pressures using lower site wind speeds (*Vs*) than 18 m/s inland and 20 m/s in coastal locations. This implies a typical minimum wind pressure of 550 Pa from a gust wind speed of 30 m/s inland.

[2] This is generally termed the effective wind speed *Ve* in design documents [see Appendices A and C for further details].

2.4 MANAGERS AND SUPERVISORS

- Windy conditions present a hazard that it is your responsibility to manage. A clear operating limit in terms of a safe gust wind speed needs to be established and managed for each site. Guidance on appropriate considerations is given in Appendix B.3. This may most easily be arranged in the form of a "default" basis for all company sites unless noted otherwise.
- Develop the erection method statement for each site such that it is consistent with this operating limit. Check with a suitably competent engineer that this limit will suffice for the planned erection sequence, or, if not, agree the special restrictions to be incorporated into the method statement and decide how these restrictions will be managed.
- Identify whose responsibility it is to monitor site conditions for wind hazards, and ensure that they are familiar with the contents of this document. If significant, the effect of local conditions should be reviewed with the Principal Contractor as the *Construction Health & Safety Plan* is developed.
- Keep an eye on how the weather is developing a day or two ahead using the weather forecasts on television, radio or in national newspapers. Use regional forecasts, such as those on the Met Office website http://www.meto.gov.uk, to get more detail on forecast wind speeds local to the site.
- Decide whether the erection methods themselves or the site circumstances dictate that specific local weather forecasts need to be obtained. If not, remember that conventional weather forecasts (given on the radio etc) generally quote wind speeds in mph and they do not mention gust speeds until the wind approaches gale Force 7, by which time all erection should have stopped. Take specific steps to monitor site wind conditions more closely when forecast speeds of 15mph (or more) are given as these indicate possible gusts of 27mph.
- Provide a method for monitoring site wind conditions. If an anemometer is provided, agree beforehand how its measurements will be interpreted. Generally anemometers mounted on cranes or held aloft in a mobile elevating work platform [MEWP] would give more representative readings than those hand-held at ground level. Additional guidance on monitoring is given in Appendix B.1.
- If an anemometer is not provided, agree what procedure will be followed to check the current wind Force by site observation and for the possibility of deteriorating conditions from forecasts. In the absence of anemometer readings, err on the safe side in assessing site wind conditions.
- If possible, ensure that the erection method is safe for implementation up to gust speeds of 27 mph. Ask a competent engineer familiar with the design to check this (eg for single un-tied columns and their foundations) and to identify any lower limiting conditions to be applied.
- If possible, ensure that manufacturers' recommendations allow all plant used for lifting or access to be used up to gust speeds of 27 mph. If this cannot be arranged, identify the critical item of plant and apply the limiting conditions in practice.
- In any case, the safety of any steel erection will not generally be affected by winds up to Force 3 (ie gusts up to 20 mph). These "safe" conditions would generally be associated with conventional weather forecasts of mean wind speed of no more than 10 mph. In general, wind Force 3 conditions would not deteriorate beyond Force 4 within a half-shift of four hours.
- In contrast, weather conditions can change significantly overnight, so check that the erection site is left in a safe condition before leaving site at the end of the day. Depending on the weather pattern and forecasts, this may mean that loose materials need to be secured or that cranes need to be lowered.

- There are some circumstances where winds of Force 3 or below might present a hazard. The possibility of such conditions should be reviewed on a project-specific basis. These include lifting components with high windage and erecting tall slender columns that might be susceptible to dynamic excitation at lower wind speeds.
- For columns taller than 10m with a height to minimum width ratio exceeding 50, or if the structure shows any tendency to wind-induced vibration, humming or whistling during erection, refer to a competent engineer for a safety check of dynamic excitation.
- Always check whether speeds are expressed in terms of gusts when relying on any other sources of wind data (eg manufacturer's recommendations for operating limits of site plant such as cranes).
- If it is necessary to undertake steel erection operations in wind conditions above Force 4, develop a *Task Specific Method Statement* for this work.
- Ensure that the importance of wind-critical activities are fully understood and observed by all the site erection team. These include:
  - Not deviating from the erection sequence specified in the method statement.
  - The need to tie newly-erected steelwork back in to a stable "box" as soon as possible.
  - The crucial importance of securing the bases of single columns before they are tied in by proper use of packing, bolt tightening and wedging.
  - The possibility that special circumstances may arise, for example the need to use resin anchors that take time to cure. If necessary, issue a *Task Specific Method Statement* for this work.

2.5 FOREMEN, CHARGEHANDS AND ERECTORS

- Make sure you know what the "safe gust wind speed" is for the operations you are asked to undertake, who will monitor the conditions and how you would be warned if conditions become hazardous.
- Do not deviate from the erection sequence given in the erection method statement or from any *Task Specific Method Statements* issued for the work. In particular:
  - Always tie newly-erected steelwork back in to a stable "box" as soon as possible.
  - Do not leave single columns untied for more than 1 hour. If necessary hold them in the crane whilst using another crane to place the other components.
  - Always secure the bases of single columns by proper use of packing, bolt tightening and wedging.
- If problems arise that make it difficult to follow the erection method statement, you must not use any different method until it has been authorised by a suitably competent person within the chain of command.
- Keep alert for the possibility that that site conditions might produce unexpected gusts of wind. If these occur, inform the responsible supervisor immediately.
- If wind conditions approach the operating limit, develop a plan of how operations will be safely stopped. It may be necessary to take down items that have been erected if these cannot be tied back securely to a stable part of the structure.
- As wind conditions approach the operating limit, be especially alert for unauthorised intrusions into the exclusion zone for non-erectors around the steelwork being erected.

2.6 DESIGNERS

- Designers who develop the scheme design should consider the stability of the part-erected structure and individual components in the context of their assumed outline design-basis method of erection.
- Scheme designers should ensure that sufficient information concerning the stability of the part-erected structure is provided to the engineer responsible for finalising the design erection sequence.
- The engineer responsible for finalising the design erection sequence should ensure that the manager responsible for erection is informed about:
  - The assumed "safe gust wind speed".
  - Requirements for stabilising part-erected components such as free-standing columns.
  - Identification of any components susceptible to dynamic excitation.

APPENDICES

APPENDIX A WIND CONDITIONS

A.1 WIND SPEED AND PRESSURE

In monitoring wind speeds and deciding what action is necessary, it should always be remembered that twice the wind speed means four times the pressure.

A.2 MEAN SPEEDS AND GUSTS

In assessing the risks that may arise during steel erection from windy conditions, it is the strength of gusts experienced on site that matter. It is important to understand the distinction between what is termed in BS 6399-2 *Loading for buildings: Code of practice for wind loads* the site wind speed (expressed as an hourly mean) and the effective wind speed (based on the strength of a 3-second gust). Other reference sources may use different measures, such as 10-minute mean wind speeds or area averages[3].

In this document ALL wind speeds are expressed in terms of GUSTS unless noted otherwise. When relying on any other sources of wind data (eg manufacturer's recommendations for operating limits of site plant such as cranes), these always need to be checked as to whether they are also expressed in terms of gusts. As the ratio between gust and mean speeds is a factor in the order of 1.5 to 2.0, the relationship **gust speed = 2.0 x hourly mean speed** may be used as a safe general guide for all heights up to 35m.

It is useful to be able to relate wind information given in weather forecasts to expected gust conditions on site. Wind speeds given in widely broadcast weather forecasts broadcast in the UK are generally based on Meteorological Office predictions of what the mean speed will be at a given moment in the future over an area such as a whole town. It may be assumed that these area mean wind speeds equate to the hourly means. When gale force winds are expected (Force 7 and above, see below), it is common also for forecasts to give expected gust speeds, which may be relied upon in the absence of other data.

Also, wind speeds are generally either expressed in mph for regional weather forecasts, or knots for shipping forecasts (which can be useful when working on exposed coastal sites). Forecasts issued for aviation are given in terms of m/s. The precise relationship between these is 11.18 m/s = 21.74 knots = 25.00 mph, however as a rule of thumb the following conversion factors may be used:

10m/s = 20 knots = 23 mph

In this document where speeds are quoted in terms of both m/s and mph, the values in m/s should be relied upon; the values in mph are generally rounded to the nearest 0.5 mph.

It is also convenient to be able to estimate the wind speed from the visible local conditions. This may be done for either inland or sea conditions near coastal sites using Table 1. The table refers to the Beaufort Wind Scale of Wind Forces which is based on 10-minute mean wind speeds in knots. For ease of use, Table 1 also gives typical maximum gust speeds in m/s (and mph to the nearest 0.5 mph) for each Force.

The Met Office website http://www.meto.gov.uk gives forecasts for wind speeds at midday as an option for viewing in the UK regional weather forecasts. These forecasts often form the basis of those given in national newspapers. These Met Office forecasts are area mean wind speeds generally given in increments of 5 mph for a spread of locations from 20 to 50 miles apart. Table 1 shows how these may be related to the Beaufort Scale and typical gust speeds.

[3] The Eurocode BS EN 1991-1-4 *Action on structures: Wind actions* uses ten-minute mean wind speeds. It is anticipated that the National Annex will be similarly based. (This differs from the use of the map based on hourly mean wind speeds from BS 6399-2 that was referenced in the NOTE to subclause 5.2.2 of the National Application Document in DD ENV 1991-2-4).

Table 1: Beaufort Scale of Wind Forces					Wind Speeds			
Force	**Wind**	**Alert Level Note 1**	**Effect on Land**	**Effect at Sea**	**10min Mean**	**Met Office Note 2**	**Typical Gust**	
					knots	**mph**	**m/s**	**mph**
Winds of Force 3 or below do not generally affect the safety of erection operations (Green Alert Level)								
4	Moderate breeze	Yellow	Raises dust and loose paper; moves small branches	Small waves becoming longer; fairly frequent white horses	11-16	15	12.0	27
5	Fresh breeze	Blue	Small trees in leaf begin to sway	Moderate waves taking more pronounced long form; many white horses	17-21	20	16.0	36
6	Strong breeze	Red	Large branches in motion; whistling in telegraph wires; difficulty with umbrellas	Large waves begin to form; foam crests more extensive everywhere; probably some spray	22-27	25	20.0	44.5
7	Moderate gale	Black	Whole trees in motion; difficult to walk against wind	Sea heaps up and white foam from breaking waves begins to blow in streaks along the direction of the wind	28-33	30	25.0	56
All erection operations should have ceased if the wind reaches gale Force 7 (Black Alert Level)								
Note 1: Alert levels are often operated by Principal Contractors, and these are based on those adopted by Bovis Lend Lease. **Note 2:** The Met Office forecasts generally in increments of 5mph.								

A.3 DETERIORATING CONDITIONS

Another factor that has a very significant influence on the use of wind data is the period over which conditions are likely to change, in particular the time taken for wind to freshen from acceptable working conditions to becoming potentially unsafe. Table 2 relates the wind Forces in Table 1 and the Alert Levels noted to the possible warning period from forecasts and over which it would be reasonable to re-plan operations in general to accommodate freshening wind conditions.

Table 2: Deteriorating Conditions

Change in Wind Force	Alert Level Example	Typical Warning Period	Effect of Wind on Operations
3 to 4	Green to Yellow	1 hour	Wind begins to affect site operations which should be stopped and reversed as necessary, such as: • Use of mobile (telescopic) cranes; • Use of mobile access equipment; • Securing of unstable single components.
3 to 5	Green to Blue	4 hours	Wind enforces a cessation of site operations affected by wind and which cannot reasonably be stopped quickly and safely or reversed easily.
3 to 6	Green to Red	1 day	Wind reaches a speed that causes difficulty with securing materials held on site, such as lightweight decking or cladding panels which are vulnerable to being blown away. Difficulty in standing upright becomes noticeable in winds of Force 6 and above.
3 to 7	Green to Black	More than 1 day	Wind reaches a speed that causes personal discomfort and might eventually threaten the whole structure. All external operations on site except for emergency actions must cease as being too risky.

Hence, those in charge of site operations should always be wary of commencing individual activities such as lifts that could take more than one hour if the wind is already Force 3 and freshening. Similarly, the likelihood of gales will be forecast one or two days ahead, which gives managers and supervisors the opportunity to adjust the planned activities over that period. For more complex operations, such as two crane lifts of large sub-assemblies that might take hours to position and secure, the more formal concept of a safe "weather window" should be used[4]. Then, weather forecasts should be sought from a reliable source such as the Meteorological Office[5] and used alongside a detailed plan for the site operations to decide when it would be safe to commence work and what would be needed in terms of a contingency plan[6].

[4] In practice every operation that can be affected by the wind conditions is undertaken within a "weather window", albeit that the formal adoption of this concept is only evident when planning more complex and longer-lasting operations.

[5] When specific detailed weather forecasts are purchased from such sources, both mean and gust speeds in m/s are generally provided.

[6] See the BCSA *Guide to the Erection of Steel Bridges* for guidance on operation of a formal "weather window".

APPENDIX B MANAGEMENT

B.1 GENERAL

The responsibilities of managers and supervisors concerning safe erection in windy conditions fall into four areas:

- Developing a safe erection sequence and method that address the issues in B.3.
- Being aware of the possible effects of wind, as described in Appendix A.
- Ensuring that the site operatives are properly briefed.
- Managing operations on site to ensure site operatives follow the correct procedures[7].

In terms of managing operations on site, it is recommended that an anemometer is provided to facilitate the monitoring of the wind conditions. Larger modern cranes are generally equipped with such instrumentation, and a properly trained crane driver will be familiar with the capabilities of the crane being used. These are primary precautions towards ensuring that the crane is only used within its safe limits as far as wind is concerned.

As described in the BCSA *Code of Practice for Erection of Low Rise Buildings*, gangs erecting such structures will generally be using MEWPs to gain access to work aloft. If reliance is being placed on a crane-mounted anemometer, the key concern is that the MEWPs do not become unsafe to use before the crane itself. If that is the case, a separate check must implemented related to the critical wind speed for cessation of use of the MEWPs.

It should be noted that the height at which the anemometer is mounted on a crane or where manual readings are taken can influence the readings in relation to the planned operations. Typically, the critical height will be in the basket of the MEWP at operating level as that will also be the level to which steel components will be hoisted. Hence, it is a reading taken at or above this level that should govern, noting that when relying on a hand-held anemometer or one on the crane the reading should always be checked to see if it is measuring gust speeds in m/s or otherwise.

If an anemometer is not provided or available, then decisions will need to be based on a combination of site observations and weather forecasts, see Appendix A. As this information is less precise, it is recommended that an additional degree of conservatism be included.

Additional consideration may be needed for specially-rigged complex lifts or taller structures (over 20m). For such cases, a lift-specific or project-specific study of the effect of wind on the erection tasks should be undertaken. When using tower cranes for erection of multi-storey structures this assessment would need to be undertaken with the supplier of the crane, the Principal Contractor or specialist rigging company as appropriate.

B.2 ERECTION CODE REQUIREMENTS

The code of practice BS 5531 *Safety in erecting structural frames* states:

Erection work should not take place in weather conditions which introduce an undue element of risk. These conditions include:

(a) high wind;
(b) heavy rain;
(c) presence of frost or ice;
(d) heavy snow;
(e) poor visibility.

When conditions deteriorate to an extent when safe working is endangered, any further work should be restricted to that necessary to ensure the stability of the structure.

[7] If the Steelwork Contractor appoints a specialist erection subcontractor, then the performance of some obligations may inevitably devolve to the erection subcontractor. The Steelwork Contractor should still ensure that the guidance is being followed properly by agreeing the allocation of responsibilities in advance, checking that the subcontractor is competent to undertake the allocated responsibilities and monitoring their performance during the course of the work.

An erection operation which is already in progress and where suspension of work would introduce a hazard should whenever possible be completed.

B.3 EFFECT OF CONDITIONS

Not all erection activities are similarly affected by weather changes. Some working locations might be accessible without danger in quite high winds, and at those locations some activities may be undertaken that are relatively unaffected by wind, such as completing bolting up of connections. These activities might, therefore, be continued when other work has had to be stopped.

Considering the three principal safety objectives when erecting steelwork:

- **Stability of the part-erected structure.**

In high winds, one of the most critical stability problems is the potential toppling of a single un-tied column (sometimes termed the "flag-pole" condition). As described in Appendix C, this possibility needs to be considered in the design of the column base and in devising the method to be used to temporarily secure the column before it can be tied in. Typically, this would require the use temporary tying or struts. The number of single columns left untied should be kept to a practical minimum consistent with the need to complete a self-stable "box" of steelwork that should be the primary aim on commencement of erection. This may require the erection of several components before self-stability is achieved, and the expected duration of these activities needs to be related to the current and anticipated weather conditions on the site. If necessary and possible, a column can continue to be held in the crane whilst another crane is used to erect the components to tie in the column. Guys or struts can also be used but they often interfere with the safe operation of MEWPs and other plant on site; and providing suitable attachment points can be problematic.

- **Safe lifting and placing of steel components.**

Safe crane operation relies on the capacity of the crane to resist overturning during high winds arising from either full deployment of its jib or when components with large windage swing out of radius. The type of crane influences its capacity to resist overturning. Manufacturer's recommendations should always be checked and followed, and typical maximum wind Forces suited to each major type of crane used for steel erection are:

  - Force 4: Mobile telescopic crane;
  - Force 5: Crawler crane;
  - Force 6: Tower crane.

The typical maximum in-service wind speeds given in CIRIA SP 131 *Crane Stability on Site* are broadly comparable with the limits suggested here. Consideration also needs to be given to the dangers associated with lifted components that swing in the wind. Unless restrained, they can injure personnel, or dislodge or de-stabilise previously erected components.

- **Safe access and working positions.**

When mobile telescopic or crawler cranes are being used by an erection gang, mobile elevating work platforms [MEWPs] are the principal means of providing safe access for work at height during steel erection. The capability of a MEWP to operate during windy conditions should be checked against the manufacturer's or supplier's recommendations. If the MEWPs are not safe for use up to the same wind Force that is safe for operation of the crane being used by the same gang, then the capability of the MEWP may become the governing criterion if the gang are not ground-based. This is often the case when crawler cranes are in use as few MEWPs are rated for use up to wind Force 5 conditions.[8]

[8] BS EN 280 *Mobile elevating work platforms – Design calculations – Stability criteria – Construction safety – Examinations and tests* states that MEWPs need to be safe to operate in a wind pressure of 100 Pa which equates to a wind speed of 12.5 m/s. This is consistent with the 12.0 m/s limit adopted in this guide. BS EN 280 identifies this as Force 6, and although Force 6 would be associated with a 10-minute mean of around 12.5 m/s, this does not take into account the fact that Force 6 winds can gust up to 20 m/s (see Table 1). The 12.5 m/s limit is also quoted in the guidance on the effect of wind on MEWPs in CITB's GE 700 guide to *Construction Site Safety*, again mis-identifying this as Force 6.

B.4 ADDITIONAL PRECAUTIONS

As weather conditions can change from hour to hour, persons in charge of supervising erection work on site should regularly monitor weather conditions, and take appropriate decisions. Those in charge on site should continue to be alert to the effect of wind on working conditions when taking working breaks for meals etc. If a decision is made to stop work, then measures should be taken to ensure the maintenance of stability of the remaining part-erected structure.

Additional problems can occur if the erection sequence needs to be changed. For example, a pair of taller columns might be erected singly without it being possible to tie them in immediately, such that they will remain un-stabilised for longer than had been originally anticipated. On realising the danger as the wind freshens towards the crane-operating limit, the preferred practice would be to stop erection and take down the un-stabilised columns or to guy such columns (which, however, might well take longer). However, if the wind increases in strength more quickly than anticipated, such that it is no longer possible to operate safely but components have been left in a potentially dangerous condition, the designation and strict operation of an absolute exclusion zone will be necessary. Later, the stability of the previously erected components must be reassessed by a suitably competent person and a method of work for recovery of the situation agreed before work is restarted.

Table 3 observes these general principles and relates the recommendations of BS 5531 to key erection tasks that are likely to be affected by "high wind", and is based on the assumption that the weather conditions continue to deteriorate as the wind freshens, and that tasks in hand need to be completed, as recommended by BS 5531.

Table 3: Additional Precautions to be taken in Windy Conditions		
Task	**Risks to Personnel**	**Risk of Collapse**
	Additional precautions to limit risk to persons in windy conditions (Note 1)	Additional precautions to limit risk of structural or crane collapse in windy conditions
Lift and place columns onto foundations at ground level.	Only undertake task within lifting limitations of the crane. (Note 2) Exclude all persons not working to lift and place the column from a zone around the column foundation within a radius 1.5 times the column height. If winds exceed the assessed limit and the column cannot be made safe, establish an absolute exclusion zone around the column foundation within a radius 1.5 times the column height.	Keep crane hook attached to column until its base is fully secured. (Note 3) Do not commence erection without knowledge of wind conditions for which unguyed column has been assessed. (Note 4) Dismantle or guy single columns if column cannot be tied in within one hour, provided safe access can be arranged to re-sling column to crane hook. Carefully check the plumb of untied columns before re-commencing erection after the wind has abated sufficiently.
Lift and place components with high windage. (Note 5)	Only undertake task within lifting limitations of the crane, having made allowance for the effect of windage. Exclude all persons not working to lift and place the component from a triangular zone downwind of the crane with dimensions 1.5 times the crane height.	Even if it is safe to undertake lifting of the component into place, only commence if it can then be secured in position within 1 hour or a formal "weather window" approach has been developed and is being followed.
Work aloft using MEWPs. (Note 6)	Only undertake tasks that require use of a MEWP that can be safely stopped within 1 hour.	On task completion, bring booms of MEWPs to ground level.
Provision and use of mobile crane. (Note 7)	Only undertake tasks that require use of a mobile crane that can be safely stopped within 1 hour.	On task completion, bring down fixed and shorten telescopic crane jibs.
Use of crawler crane beyond Force 4.	Beyond Force 4, only undertake tasks that require use of the crawler crane that can be safely stopped within 1 hour.	On task completion secure the crane for developing wind conditions.
Use of tower crane beyond Force 5.	Only undertake tasks that require use of the tower crane that can be safely stopped within 1 hour. Ensure that personnel are safely secured against wind pressures being experienced at working positions.	On task completion secure the crane for developing wind conditions.
Stored materials, especially aloft.	As wind reaches Force 5, undertake a walk round risk assessment of materials stored on site and arrange for vulnerable materials to be secured. Re-inspect the condition and stability of the stored materials after the wind has abated sufficiently.	
Access to exposed locations aloft.	As wind reaches Force 5, make arrangements to bring all erection personnel down from wherever they are working aloft to safe working areas at low level.	
Provision of crawler and tower cranes.		If wind reaches Force 6, arrange for crawler crane jibs to be lowered to ground, and tower cranes to be put into storm condition.
Cessation of site activities.	If wind reaches Force 7, make arrangements to ensure that no erection personnel venture onto the site from a safe area.	Arrange for a competent person to re-inspect the part-erected structure before re-commencing erection after the wind has abated sufficiently.

Note 1: The persons considered are those directly involved with steel erection. Others who are not involved but are permitted access to the general area should be strictly excluded from the area of operations in windy conditions.

Note 2: Limitations on use of the crane specified by the manufacturer and/or supplier should be followed at all times.

Note 3: Fully secured generally means bolts tightened with baseplates packed and wedged as necessary.

Note 4: The need for clear information about the wind case assumed for a single unguyed column is explained in Appendix C.

Note 5: The effect of windage should take account of the area presented to the wind in relation to the weight of the component.

Note 6: The MEWPs referred to are those used for erection, generally the boom-type. Some can reach up to 30m.

Note 7: The use of the term mobile crane here includes telescopic and rough terrain cranes and mobile tele-handlers.

APPENDIX C DESIGN

C.1 THE DESIGNER'S ROLE

The term "designer" refers to all engineers who contribute to the design include both scheme and detail designers of the permanent works, and temporary works designers. Occasionally the final design of specialist items, such as metal decking, will be undertaken by engineers working for other parties. Generally the detail design and temporary works design will be undertaken by the Steelwork Contractor's engineers, who may also undertake the scheme design in design-and-build contracts.

The Steelwork Contractor has the responsibility for developing and managing the implementation of the erection method statement that is incorporated into the Principal Contractor's *Construction Health & Safety Plan*[9]. Hence, the primary responsibility for ensuring that the chosen erection method is consistent with the design is that of the Steelwork Contractor.

C.2 DESIGN ERECTION SEQUENCE

In order to discharge this responsibility, the Steelwork Contractor must be furnished with suitable information from the scheme designer of the permanent works, including clarification of the assumed design-basis method of erection. Whilst the final erection method statement will address stability, craneage and access, it is the scheme designer's primary responsibility to alert the Steelwork Contractor and the Principal Contractor to any safety issues that affect the stability of the part-erected structure. This responsibility follows from the requirement that where the management of risks during erection relies on design decisions, then it is incumbent upon designers (including connection designers) to make the assumed criteria known to those responsible for undertaking the erection.

The Steelwork Contractor will generally collate design information affecting erection from the various sources in the form of a design erection sequence. Often this will be based on standard methods such as those in the BCSA *Code of Practice for Erection of Low Rise Buildings.* In developing the erection method statement, a suitably qualified person should thus verify that the erection sequence is safe in terms of design. It is recommended that standard cases be developed that can serve as the basis of "default" instructions for inclusion in erection method statements. The use of "default" instructions makes it easier for managers and supervisors to brief the foremen, chargehands and erectors under their control.

C.3 DESIGN CASES

Site conditions

The codes of practice for design refer to three types of site conditions where wind actions need to be considered:

(i) Permanent conditions - These are experienced by the completed structure in normal use during its design working life. For buildings this is generally based on mean wind speeds with a mean recurrence interval (or return period) of 50 years, to which a factor of safety is then applied. Other factors are used to adjust the 50 year return period to longer periods or shorter periods (eg for temporary structures). A 50 year return period means that each year there is a 2% chance of exceedance - before safety factors are applied.

[9] Only suitably qualified specialist designers with erection experience should be used if Steelwork Contractors subcontract the development of the design erection sequence or checks for consistency between the erection method and the design erection sequence.

(ii) Transient conditions - These are defined in BS EN 1990 as a "design situation that is relevant during a period much shorter than the design working life of the structure and which has a high probability of occurrence". These can include transient environmental situations as well as the fact that the structure may pass through a series of stages during construction. As these stages will generally be short, they have often been viewed as temporary conditions. Although of short duration relative to a 50-year recurrence interval, transient conditions can be expected to last several days (possibly even for years on large civil engineering sites) including periods spanning over nights, weekends or holidays.

(iii) Working conditions - These occur during periods whilst work is actually taking place under continuous on-site management. This can be taken as including meal breaks, but it excludes periods when the site is unsupervised such as over nights, weekends or holidays.

This document does not address permanent conditions except where these are linked to the transient or working conditions.

Transient conditions

The principal issues to be considered for steel structures in the transient condition are well-documented in the BRE Special Digest SD5 *Wind loads on unclad structures.* This is an update in terms of BS 6399-2 of the primary previous reference – BRE Report BR 173 *Design guide for wind loads on unclad building structures during construction.*

One activity for which SD5 is applicable is that of the design of falsework including temporary works for steel erection. The UK code BS 5975 *Code of practice for falsework* is now partly superseded by BS EN 12812 *Falsework – Performance requirements and general design.* As an upper bound, BS 5975 gives limits for actual wind pressures on falsework over two years up to 30m high of 1230 Pa in England & Wales, and 1670 Pa anywhere in the UK. These imply effective gust wind speeds of 45 m/s (103 mph) and 52 m/s (120 mph) respectively. Application of SD5 will generally result in significantly lower design wind speeds and pressures.

Transient conditions during execution are thoroughly tabulated in the Eurocode EN 1991-1-6 *Actions on structures: General actions – Actions during execution.* That code considers such issues as the concurrence of transient execution conditions with other low probability situations like seismic actions or extreme wind events (eg cyclones or hurricanes). The code recommends that such extreme or exceptional events are treated as accidental limit states with lower required partial safety factors than those for the ultimate limit state.

Concerning the Nationally Determined Parameters related to transient design situations, EN 1991-1-6 recommends that even for operations lasting less than three days, the return period selected for assessment of climatic actions should not be less than two years – noting that the concept of mean return period is not appropriate for such short term durations as it is the 29% annual probability of exceedance that is relevant – before safety factors are applied.

EN 1991-1-6 also recommends that a minimum value for the basic wind velocity[10] during execution should be taken as 20 m/s for durations up to three months. Technical Guidance Note T20.002 published by CIC at www.safetyindesign.org suggests a value for *Vs* of 18 m/s (although T20.002 defines the transient condition as "working wind loads" which differs from the usage in BS EN 12812). The comparable minimum values derived from BS 5975 are 18 m/s inland and 20 m/s in coastal locations, which are recommended in this guide.

[10] This may be taken as equivalent to the site wind speed *Vs* in terms of BS 6399-2.

Like the values quoted from EN 1991-1-6, *Vs* is a mean value not a gust value, and the procedures in SD5 should be followed to derive the appropriate design wind speed, noting that this represents the effective wind speed *Ve* with no dynamic augmentation factor (see below).

Hence, as a general rule, part-erected assemblages need to be checked for the appropriate transient condition. For example, two or more columns along a gridline might typically be left overnight or over the weekend tied together, stabilised and restrained on their weak axes but cantilevering with respect to their strong axes. In such cases the transient case should be based on a minimum *Vs* of 18 m/s and the factors given in SD5 including the choice of shape-related force coefficients.

It should be noted that the management procedures recommended in Appendix B are based on general cessation of site operations at wind Force 6, ie actual gusts of around 20 m/s. Thus using a value of 24 m/s for the critical gust speed in design for a transient condition would provide the factor of safety of 1.4 on pressure (ie around 1.18 on wind speed). This is less onerous than using a *Vs* of 18 m/s (which would typically result in a gust wind speed of 24 m/s inland), but would still ensure that there was no risk of collapse whilst operations were being terminated during deteriorating conditions.

If conditions further deteriorated into a storm over a period of, say, three days, there would remain the possibility of a part-erected structure assessed for a 24 m/s gust speed becoming compromised in the period before work could re-commence. Hence the recommendation (see above) that a competent person should re-inspect the part-erected structure before re-commencing erection after the wind has abated sufficiently. This could generally be waived if the part-erected condition had been designed beforehand to cope with conditions that had not been exceeded during the storm.

Working conditions

BS EN 12812 introduces the concept of "working wind" which may be understood as the conditions whilst work is actually taking place under continuous on-site management. This could include short term breaks in physical activity during the same working day for meals etc, provided that management attention to the weather conditions remained alert during such breaks to remobilise operatives immediately to implement the precautions recommended in Appendix B.

Clearly, if the working condition is assessed on this basis, clear instructions must be issued that such conditions do not apply to periods outside actual working time (even overnight with a "good" weather forecast).

BS EN 12812 recommends a pressure of 200 Pa be used as a working wind to assess such conditions. This is consistent with an actual gust or effective wind speed Ve of 18 m/s and the wind reaching around Force 6. Thus, all physical working activities being continuously undertaken within one shift and observing the procedures set out in Appendix B should be assessed as being safe to at least a working pressure of 200 Pa.

There can be special circumstances where this proves impracticable[11]. This means that the work must take place in a "weather window" of especially calm conditions. As control of the residual risk in such conditions relies wholly on tight management procedures, clear instructions to this effect must be issued that include procedures for monitoring the developing wind conditions[12].

There may also be special circumstances where it would be appropriate to assess operations on a higher working wind (eg 300 Pa for exposed coastal sites), but specific modifications would then be needed to the procedures recommended in Appendix B.

In addition, BS EN 12812 recommends that a formal allowance be made for out-of-alignment conditions in the part-erected structure. A deviation of 1/100 is suggested and this is consistent with BS 5975. For steel erection this principally affects column verticality, and this value would generally be more than sufficient as, prior to final structural alignment, it would be unlikely that columns would be erected and secured outside of 100mm in 10m.

Dynamic conditions

Tall slender columns standing alone can be susceptible to dynamic effects such as galloping induced by vortex-shedding. In such cases a dynamic augmentation factor may be needed. In the absence of a specific assessment, the overturning moments derived from the wind speeds suggested above should be increased by a dynamic augmentation factor of 1.20 for columns susceptible to such effects.

Unless otherwise verified, it should be assumed that single un-tied columns taller than 10m will be susceptible to such effects if their height to minimum width ratio exceeds 50. If this rather complex verification is not undertaken, a restriction needs to be stated in the design erection sequence for this activity that states a low safe gust wind speed (such as wind Force 2 or below) and/or the need to provide immediate positive lateral support for the column before release from the crane.

If a column is susceptible to such effects, they may occur at speeds well below the design wind speed, and the concern is that the tendency of the column to topple will be increased by it swaying back and forth well beyond an out-of-plumb condition of 1/100. The dynamic effect would also tend to displace wedges prematurely. Hence, it is even more crucial in such cases that the site operations are managed and inspected to ensure that the base is securely wedged and tightened. Thus, any columns susceptible to dynamic effects should be specially identified as such on the erection drawings.

[11] An example of special circumstances might be where an exclusion zone might be impracticable and members of the public were passing close to the erection position. A possible solution could involve, say a weekend "possession" period during which members of the public were excluded. Another situation is where standard details have limited capacity to resist windage and special controls are needed.

[12] An example might be as follows:

- Columns shall only be released from the crane hook after they have been plumbed to better than height/200 and their bases are properly secured and wedged.
- Once properly wedged, columns can only be left free-standing within an exclusion zone, must never be left free-standing overnight and should not be left free-standing for an undue length of time.
- Single "flag-pole" columns taller than 6m can only be left in this temporary condition if the gust wind conditions are monitored by an anemometer mounted at or above the height of the column.
- The safe limits for the recorded conditions are a gust speed of 12 m/s (27 mph) for columns between 6m and 12m, and 7.5 m/s (17mph) for columns between 12m and 18m.

C.4 OTHER DESIGN CONSIDERATIONS

Support conditions

Whilst temporary guys or struts can be used to secure single columns against toppling, such measures would hinder the need for MEWPs and other mobile plant to be able to traverse the site. Providing suitably engineered attachment points or kentledge to fix the temporary supports is also problematic. Thus, with the exception of especially slender columns and possibly the first-erected columns that contribute to a stable box, it is rarely practicable to use temporary supports.

In the permanent works condition, column baseplates are generally grouted to ensure that they remain securely fixed to the foundations. Before that condition is achieved, column baseplates must be held securely in position by using steel packs and wedges in combination with the permanent holding down bolts. A minimum of four holding down bolts should generally be used. The procedures for doing this are described in the BCSA's *Code of Practice for Erection of Low Rise Structures.* The design erection sequence must state that the use of wedges is essential, and it should be made clear that those responsible for managing the site erection have no authority to omit the wedges because, say, access is difficult if columns are to be set in concrete pockets.

As the use of wedges is contributing to the scheme used to secure a column in place against out of plumb movement and specifically against wind-induced toppling, then, it is crucial that this is explained to those actually undertaking the erection. This is because the moment capacity of the base is the product of the tensile capacity of the bolts and the lever arm that they act on with respect to the point of pivot. If wedges are omitted, this has the effect of reducing the moment capacity of the base by a factor of nearly two.

The ability of a wedged base to maintain the stability of the part-erected structure depends on the conditions of the supports. Special considerations will apply where structural bearings are used, but for conventional concrete foundations there are three issues that need to be considered by the designer and may need clarification in the design erection sequence:

(i) <u>Concrete surface condition and crushing strength</u> - These need to be clean and firm enough to take the local forces from the wedges. The foundations will generally need to have cured for several days before being used to secure the columns. Sometimes the grade of mass concrete used for un-reinforced foundations may be insufficient to resist the local crushing from wedges. The design erection sequence can specify the minimum cure period and concrete strength required.

(ii) <u>Fixing bolts and concrete strength</u> - The fixing arrangement can be the weakest link against toppling of columns – either because the bolts fail in tension or because they pull out when the concrete spalls or the adhesive of a chemically-bonded bolt fails. Again, the design erection sequence can specify the minimum cure period and strength required.

(iii) <u>Over-turning moments</u> - The whole base will be subjected to an over-turning moment in the part-erected condition. Not only does the steelwork need to be assessed for this load case, but so does the base itself. As different load factors apply to the design of steelwork, concrete and the under-lying ground-bearing conditions, it is best to provide unfactored loads that define the transient conditions that the foundation designer needs to check.

Safety factors

The code guidance on the general choice of safety factor of 1.4 for wind would become 1.5 for wind as the leading variable action using EN 1991-1-6. There are factors as low as 1.1 suggested by some codes for short-term transient situations under active continuous control with very limited numbers of competent personnel involved.

For working conditions, this document recommends the use of a factor of 1.35[13] should be applied to the working wind pressure of 200 Pa used for assessing the safety of closely controlled day-to-day activities with active and continuous monitoring of wind conditions. The same factor should be applied to the gravity-induced actions arising from an assumed 1/100 lack of verticality. For transient conditions, the factors given in SD5 should be applied.

Robustness in the part erected condition

Most steel structures are quite robust when completed, but may lack this robustness in the part-erected condition. The designer may need to review this when considering working or transient conditions. Hence, the choice of design erection sequence may be affected by the consequences of local failure, such as the ability of the structure to accommodate large deformations before ultimate collapse. Three factors contribute to this capacity of steel structures: reserves of strength exist beyond nominal values; multiple load paths provide redundancy; and robust connections can contribute to the capacity to absorb deformation.

Some connection types are more robust than others in their ability to resist and distribute overload. As general examples: actual pins and two-bolt connections are less robust than four-bolt connections; connections through thin gauge cold-formed sections are less robust than those through hot-rolled sections; fin plates are more robust in some modes of rotation than another; moment connections are very robust during erection. Connections, including foundation bolts, also possess a reserve of strength from their partial factors for material resistance that are higher than the factors used for design of members.

Design assumptions

As it is not practicable to model every condition as the erection progresses, it is important to use sensible assumptions to select one or more design scenarios appropriate to the chosen erection sequence. On a multi-storey structure it could be an assessment of the moment resistance of a column splice to wind applied on the bare shaft of the column forming the top lift just after attachment before tying in. On a low rise structure key assumptions could include:

- What secondary components are fixed that could add to the effective area presented to the wind or to the eccentricity of dead loading.
- Whether any cladding or decking is in position as this affects both the wind and the ability of the panels to stabilise the structure by diaphragm action.
- Whether any members might need to be omitted or removed temporarily to provide access for large items of plant or equipment.
- Whether there are likely to be significant loads from stored construction materials occurring at the same time as wind actions.

[13] This is based on a factor of $K_{F,i}$ of 0.9 from BS EN 1990 associated with Reliability Class 1 applied to the general factor for leading variable actions of 1.5.

- Identification of any components that are at risk from dynamic excitation or "galloping" and the relevant precautions for their safe erection.

It is important that key assumptions are stated in the design erection sequence if they depend on management control of the sequence.

REFERENCES

BCSA *Code of Practice for Erection of Low Rise Buildings*

BCSA *Guide to the Erection of Steel Bridges*

BCSA *Task Specific Method Statement*

BRE Special Digest SD5 *Wind loads on unclad structures*

BRE Report BR 173 *Design guide for wind loads on unclad building structures during construction*

BS 5531 *Safety in erecting structural frames*

BS 5975 *Code of practice for falsework*

BS 6399-2 *Loading for buildings: Code of practice for wind loads*

BS EN 1990 *Eurocode – Basis of structural design*

BS EN 1991-1-4 *Actions on structures: Wind actions*

BS EN 12812 *Falsework – Performance requirements and general design*

BS EN 280 *Mobile Elevating Work Platforms - Design Calculations - Stability Criteria - Construction Safety - Examinations and Tests*

CIC T20.002 *Designing to make management of hazards associated with erecting steelwork easier*

CIRIA SP 131 *Crane Stability on Site*

CITB GE 700 *Construction Site Safety*

DD ENV 1991-2-4 *Actions on structures: Wind actions*

EN 1991-1-6 *Actions on structures: General actions – Actions during execution (yet to be issued as a BS EN)*

SCOSS SC/T/04/01 *Erection of Steel Structures: Learning from experience*

ACKNOWLEDGMENTS

This guide has been produced with the special assistance of:

Jim Martindale	Atlas Ward Structures Limited
Robin Sharples	Bison Structures Limited

BCSA Guide to Steel Erection in Windy Conditions

BCSA Publication No 39/05