TIN 027 — Tower Crane Out-of-Service Wind Speeds

Introduction

When planning the installation of a tower crane on a site the planning process must take into account both the in-service ***and*** the out-of-service wind speed on the crane. The out-of-service wind speed will have an effect on both the structure and base of the crane and thus a bearing on the stability of the crane. This Technical Information Note (TIN), which applies to all types of tower crane, outlines the steps to be taken in assessing appropriate out-of-service wind speeds for tower cranes in the UK.

Legal Requirements

The requirement to ensure that an appropriate out-of-service wind speed is taken into account when configuring a tower crane and designing the base for a particular location is contained in several pieces of legislation:-

- Health and Safety at Work etc. Act 1974. - Sections 2 & 3
- Provision and Use of Work Equipment Regulations (PUWER) 1998 – Regulation 20
- Lifting Operations and Lifting Equipment Regulations (LOLER) 1998 – Regulation 4
- Management of Health and Safety at Work Regulations 1999 – Regulation 3
- Construction (Design and Management) Regulations 2007

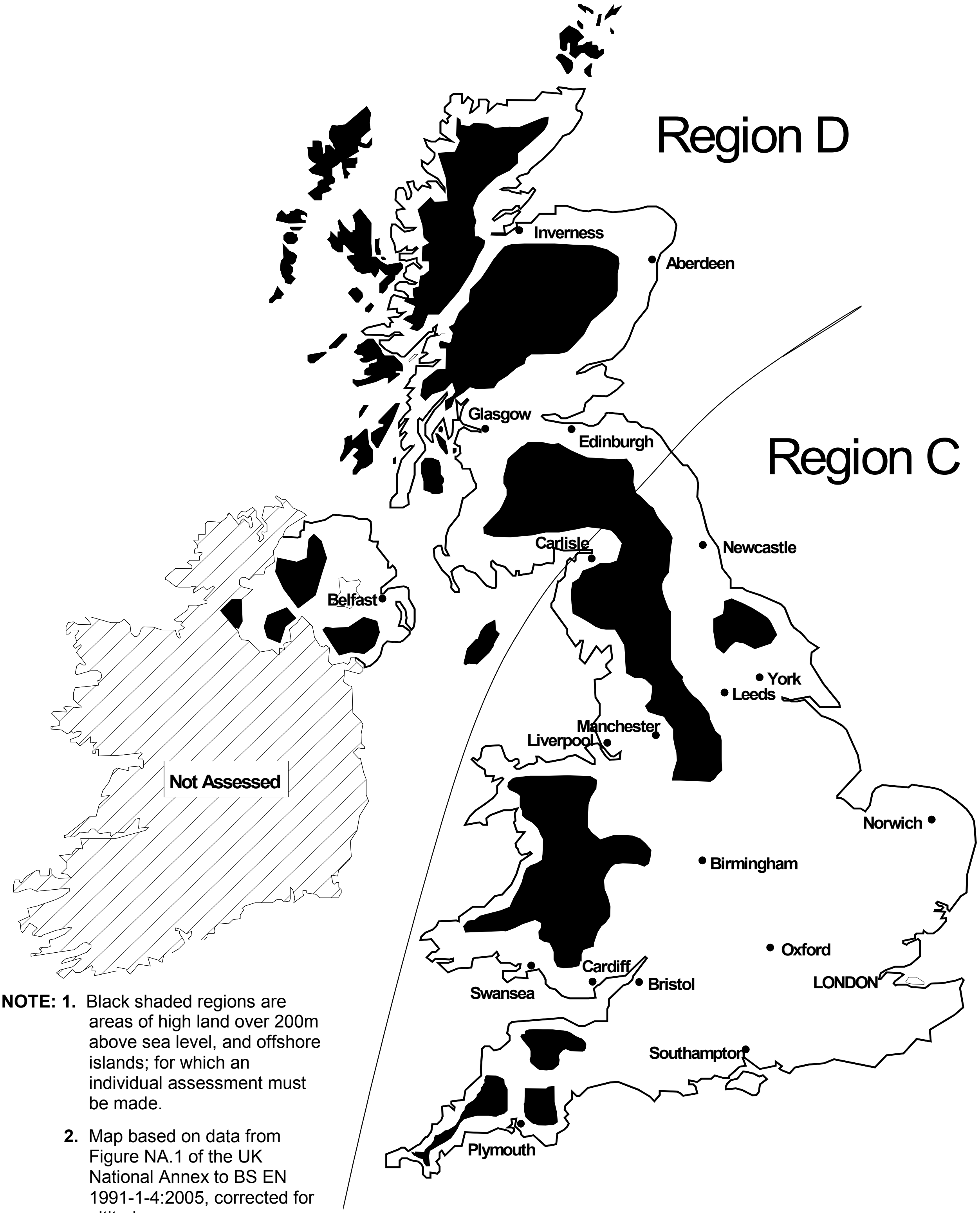
Current Requirements

The majority of tower cranes supplied into the UK in the past thirty years have been produced by manufacturers based in continental Europe, who have designed their cranes to their national standards such as DIN 15018 or the pan European standard FEM 1.001. These standards have specified one basic out-of-service wind speed, irrespective of geographical location, which is generally lower than those encountered in the more northerly and westerly parts of the UK.

Tower cranes produced in the past few years have been designed to the European Harmonised Standard for tower cranes - EN 14439:2006. This standard specifies that tower cranes should be designed to take account of out-of-service wind speeds laid down in the FEM standards 1.005. These are based on a *“reference storm wind velocity”* taken from the European Storm Wind Map (See **Figure 2**. FEM 1.005 allows the use of more precise national wind maps and the UK wind map is shown in **Figure 1**. Most tower cranes designed to EN 14439 are supplied with out-of-service wind loads to Region C with a recurrence interval of 25 years, consequently where tower cranes are to be erected in those parts of the UK falling into Region D, new build configurations and base/tie loadings will have to be obtained from the crane manufacturer.

FEM1.005 also permits site specific calculations to be carried out using site specific parameters (See **Annex 3**)

> The Health and Safety Executive advises that Region C and Region D out-of-service wind loads should be applied to **ALL** tower cranes regardless of age and whether or not the wind loadings with which they were originally supplied complied with FEM 1.001 or DIN 15018. The load cases specified in FEM 1.005 should also be applied.



NOTE: 1. Black shaded regions are areas of high land over 200m above sea level, and offshore islands; for which an individual assessment must be made.

2. Map based on data from Figure NA.1 of the UK National Annex to BS EN 1991-1-4:2005, corrected for altitude.

Figure 1 - UK Out-of-Service Wind Region Map for Tower Cranes

Annex 1 - Background

The majority of tower cranes supplied into the UK in the past thirty years have been produced by manufacturers based in continental Europe, who have designed their cranes to their national standards such as DIN 15018 or the pan European standard FEM 1.001. These standards have specified one basic out-of-service wind speed, irrespective of geographical location, which is generally lower than those encountered in the more northerly and westerly parts of the UK.

Tower cranes produced in the past few years have been designed to the European Harmonised Standard for tower cranes - EN 14439:2006. This standard specifies that tower cranes should be designed to take account of out-of-service wind speeds laid down in the FEM standard 1.005. These are based on a *"reference storm wind velocity"* taken from the European Storm Wind Map (See **Figure 2 in Annex 1**) in which Europe is divided into seven regions where the same reference storm wind velocities are applicable, designated A to G. Based on this "broad brush" approach the vast majority of continental Europe, plus southern England, falls into Regions A to C and consequently most tower cranes designed to EN 14439 are supplied with out-of-service wind loads to Region C, with a recurrence interval of 25 years and a roughness factor for *"flat open country"*. Unfortunately for tower crane users in the UK, the eastern, western and northern parts of England and all of Wales fall into Region D, whilst mainland Scotland and Northern Ireland fall into Region E. The standard allows the use of more precise national wind maps, but does not include a national storm wind map for the UK.

All this means that on the basis of the European Storm Wind Map, tower cranes erected in most parts of the UK, other than the south of England, will run the risk of loss of stability or overstressing of the structure if they are erected to maximum free standing height on bases designed using the crane manufacturer's standard out-of-service loading data. This problem has been recognised for a number of years by several major UK contractors who have set their own requirements to address this issue.

Effect of Increased Out-of-Service Wind Speeds

The effect of applying higher out-of-service wind speeds to a given height and configuration of tower crane is to increase the loads, both in the tower and on the base. This will result in one or more of the following:-

- reduction of the maximum freestanding height for a given tower specification;
- the need to use stronger tower sections to obtain the required height under hook (HuH);
- higher out-of-service base loads and moments;
- greater mass of base ballast;
- need for larger bases for a given freestanding height.

The overall effect is that cranes operated in Region D (See **Figure 1**)will require stronger tower sections and larger bases than identical cranes operating in Region C.

The global approach to calculation set out in FEM 1.005, based on one regional reference storm wind velocity, does not take into account local variations in the roughness of the terrain and may on occasions provide overly conservative values. FEM 1.005 Clause 3.5 allows site specific calculations to be made using site specific parameters of recurrence interval, location and roughness coefficients. Such calculations should always be carried out by the tower crane manufacturer or a competent engineer. Site specific calculations **may** enable a less costly configuration to be used when compared with the standard wind map approach set out on Page 1 of this TIN (See **Annex 3**).

NOTE: *The maximum wind speeds in which a tower crane may be operated, erected or climbed are fixed values for each make and model of crane and are independent of geographical location.*

A UK Specific Approach

As stated previously, the FEM standards permit the use of more accurate national wind maps. The UK National Annex to the Eurocode EN 1991-1-4:2005 *General actions - Wind actions*, was published in 2008 and contains a map of the UK showing the values of fundamental basic wind velocity $v_{b.map}$ before the altitude correction factor is applied. Taking these values and correcting for altitude, it has been possible to produce **Figure 1,** which shows that with the advantage of more precise information, England and Wales fall into Region C, whilst Scotland and Northern Ireland fall into Region D. **It is important to note that whilst this holds true for most areas up to 200m above sea level, higher or more exposed areas will require an individual assessment to be made.**

A more detailed explanation of **Figure 1** is given in **Annex 2.**

European Standards

The Harmonised European Product Standard for tower cranes is EN 14439:2006 + A2:2009, which gives presumption of conformity to the Essential Health and Safety Requirements of the Machinery Directive 2006/42/EC.

EN 14439 specifies that:-

"Calculation (proof of strength and stability proof) shall be done using:

- *the current standards (FEM 1.001 or DIN 15018-1, DIN 15018-2 and DIN 15019-1);*
- *Annex A for stability during erection or dismantling;*
- *FEM 1.005 for out-of-service stability."*

Clearly the calculation of out-of-service conditions should be carried out in accordance with FEM 1.005 - *Recommendations for the Calculation of Tower Crane Structures in Out-of-service Conditions,* published in November 2003. This standard addresses the specific application of FEM 1.004 – *Recommendation for the Calculation of Wind Loads on Crane Structures,* to tower cranes.

Both standards are based on the requirements of EN 1991-1-4:2005 *General actions - Wind actions,* which is part of a set of European Standards for the design of buildings and other structures, the *"Eurocodes"*. The FEM Standards however, have a simplified approach to the calculation of wind force.

EN 1991-1-4, FEM 1.004 and FEM1.005 define a *"reference storm wind velocity"* as:-

"the wind velocity:

- *with a recurrence interval of 50 years*
- *at 10m height*
- *above flat open country*
- *averaged over a period of 10 minutes"*

Europe is divided into seven regions A to G, where the same reference storm wind velocities are applicable. The vast majority of Europe falls into regions A to D, with the exception of the Scottish mainland which falls into region E. (See **Table 1**)

FEM 1.005 only considers two reference speeds, regions C and D, as *"they are representative of storm wind in Europe"* and goes on to say that *"Special conditions have to be agreed for cranes used in regions E, F and G where reference wind velocity is greater than or equal to 36 m/s".* This means that where a tower crane is to be used in Region E the designer will have to go back to FEM 1.004 Appendix 2, using a reference storm wind velocity of 36 m/s.

To calculate storm wind pressures on the tower crane structure the reference storm wind velocity is factored to take into account:-

- height of the structure above surrounding ground level
- roughness of the terrain (open ground, suburbs or urban area)
- recurrence interval
- location

The recurrence interval (5, 10 or 25 years) factors the reference storm wind velocity to take account of tower cranes being temporary structures which are exposed to the wind on a particular site for a limited period. FEM 1.005 specifies a minimum recurrence interval of 25 years for tower cranes unless a site specific calculation is carried out accordance with Clause 3.5 of FEM 1.005:2003.

Region	A/B	C	D	E
v_{ref} (m/s)	24	28	32	36

Table 1 - Storm Wind Reference Velocities

NOTE: *Lower reference wind speeds relating to permanent structures should not be used for the calculation of foundation loads arising from out-of-service wind forces*

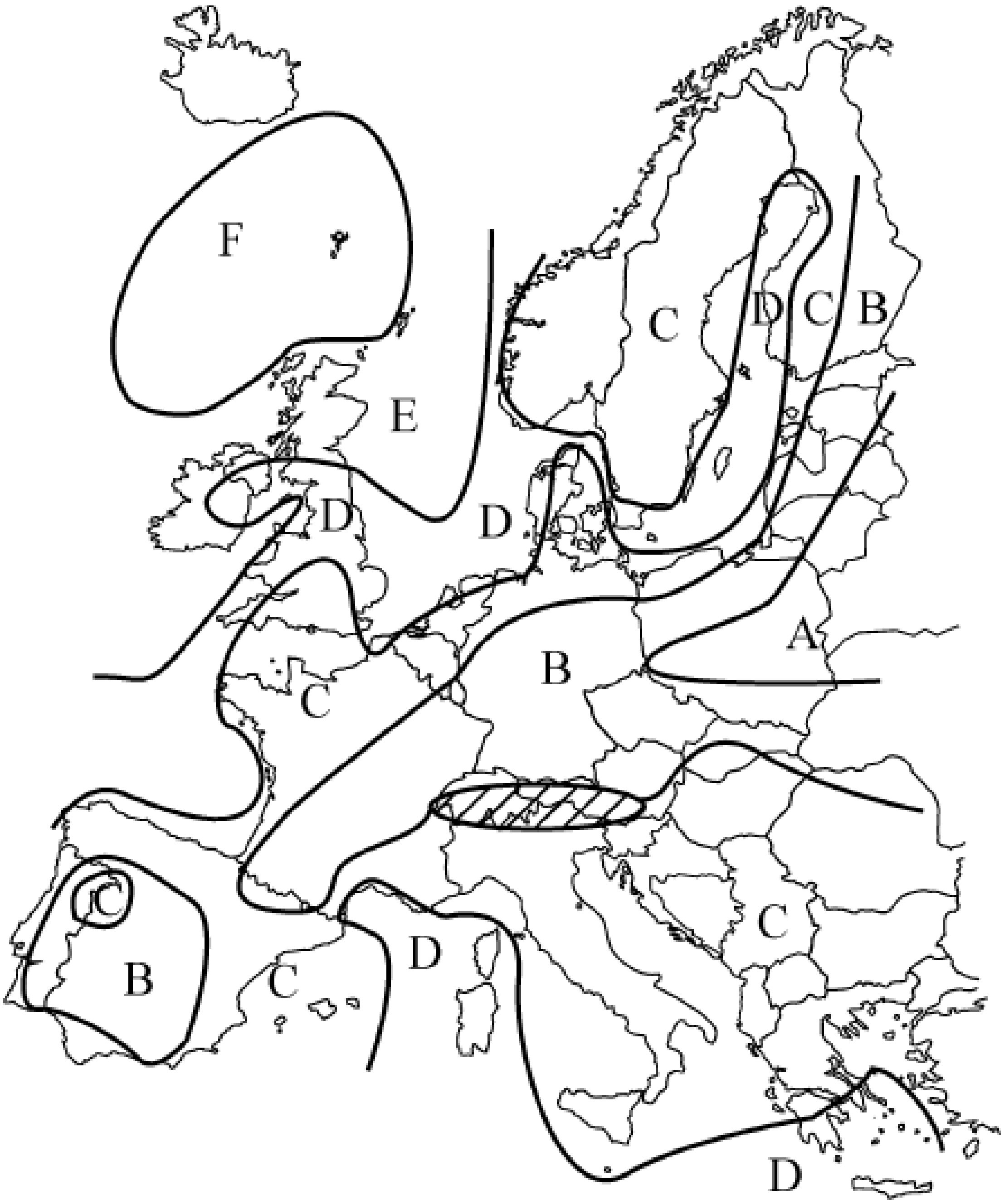


Figure 2 - European Storm Wind Map

Annex 2 – BS EN 1991-1-4:2005, the UK National Annex and Figure 1

In the past the most commonly used standard for assessing the effect of wind on structures in the UK has been BS 6399-2: 1997 – *Loadings for buildings – Part 2: Code of practice for wind loads.* This is being replaced by the Eurocode EN 1991-1-4:2005 *General actions - Wind actions.* Due to geographical and other differences between EU Member States, EN 1991-1-4 is supplemented by a National Annex for each member state. These National Annexes give details of any nationally determined parameters specific to individual member states which are referred to in the main Eurocode text.

Nationally determined parameters (NDPs) cover values, classes or methods to be chosen or determined at national level, and allow the EU member states to choose the level of safety, including aspects of durability and economy applicable to works in their territory, through their National Annex.

The National Annex also contains country-specific data, and states the method to be used if there are alternative methods allowed in the Eurocode.

In the case of the UK, the National Annex to EN 1991-1-4 contains a map of the UK showing the values of fundamental basic wind velocity $v_{b.map}$ in m/s before the altitude correction factor is applied. The definition of *"fundamental basic wind velocity"* in BS EN 1991-1-4:2005 is the same as that of *"reference storm wind velocity v_{ref}"* in FEM 1.004/1.005, i.e. *"The mean storm-wind velocity with a recurrence interval of once in 50 years, measured at 10 m above flat open country, averaged over a period of 10 minutes".* One importance difference however is that the National Annex values are at sea level whereas the European Storm Wind Map values appear to have been corrected for altitude.

Figure 1 has been constructed by taking the fundamental basic wind velocity $v_{b.map}$ from the National Annex and correcting the values obtained for height for those areas of the UK up to 200m using an Ordnance Survey relief map. Comparison of the values obtained with the reference storm wind velocities for Regions C, D and E from FEM1.004 has enabled the Region C/D dividing line to be plotted on a map of the UK. It is important to note that the Regions do not apply to the black shaded areas of higher ground and offshore islands. For these areas a site specific assessment must be made.

Out-of-service wind speeds in the Republic of Ireland have not been assessed. These may be found in Annex 1 of FEM 1.005:2003 which contains a national storm wind map for Eire.

Annex 3 - Site Specific Approach

FEM 1.005, *Recommendations for the Calculation of Tower Cranes Structures in Out of Service Conditions* specifies that the calculation of out of service wind loads should be carried out using the roughness factors for *"flat open country"* (α = 0.14 and β = 1).

Clause 3.5 specifies that in specific applications, different roughness coefficients may be used as specified in Appendix 2 of FEM 1.004, *Recommendations for the calculation of Wind Loads on Crane Structures.* In such a case, calculation of wind force is carried out using the appropriate reference wind velocity for the Region in which the crane will be erected and applying appropriate roughness factors determined by a site specific wind assessment. It is essential that this assessment is carried out by a person or organisation with expertise in wind engineering, as the presence and position of high structures near the site may well have a significant effect on roughness and other aerodynamic factors. These may lead to out of service wind forces on a crane which are greater than those obtained by simply applying the suburban or urban area roughness factors set out in FEM 1.004. The brief for the site specific assessment should be to determine which of the three roughness locations, flat open country, suburban or urban, is appropriate for the site, taking account of such factors as the site location, presence of high buildings and the closeness of buildings.

Example 1		*A site specific survey is carried out on a site in an urban area without high rise buildings. The survey concludes that the application of urban area roughness factors is appropriate,*
Example 2		*A site specific survey is carried out on a site in an urban area with many closely spaced high rise buildings and adjacent to a wide river. The survey concludes that due to the local effects of the high rise buildings and the river that the application of urban area roughness factors is **not** appropriate.*

> The Health and Safety Executive advises that if a site specific assessment is not carried out by a person or organisation with expertise in wind engineering, the roughness coefficients for *"flat open country"* must be used, together with the appropriate storm wind reference velocity from **Table 1** and **Figure 1**.

It is important to note that the application of different roughness factors will not always result in lower foundation loads or an improved tower configuration as the governing factor may well be the wind from the front or wind from the side load cases required by FEM1.005. Before embarking on a site specific wind survey it may well be worth asking the crane manufacturer which is the governing load case.