Guidance document GD 15

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GUIDANCE FOR WIND LOADINGS ON ROOF AND WALL CLADDING

INTRODUCTION

This guidance document introduces the reader to the key issues that need to be taken into account when calculating wind loadings. Buildings and their cladding are expected to withstand the worst that the weather can throw at them without risk of failure or loss of function. However, such performance is only possible due to the care that goes into their design and the attention to detail during the manufacture and installation of the building envelope. Building envelope designers and specifiers normally use British Standards and/or Eurocodes for the calculation of wind loads.

Metal cladding that has been specified as self-supporting must be capable of supporting its own weight plus any loading applied to it. For typical roofing, the loading is likely to include the profile self-weight, access for maintenance, snow loading (including snow drift) and wind loading, not to mention the weight of photovoltaic arrays (PVs) in many cases. In the case of metal decking there would also be the roof covering and services/ceiling/plant loads.

Of all the loading that the building envelope is likely to encounter, the wind has the greatest potential to cause damage to the cladding and even to the building structure. News stories about winter storms are often accompanied by pictures of buildings with damaged roofs or walls and, even where the cladding appears to be intact, local damage to joints and fasteners may result in a loss of functionality. However, with the correct design and specification of the building envelope, damage is avoidable except perhaps in the most exceptional of weather events.

As will be seen in this document, the accurate prediction of wind loading on a building is a complicated process due to the number of factors that influence wind pressure. Wind loading is normally calculated by suitably qualified engineers using the latest codes of practice and software. However, all construction professionals need to be aware of the basic principles of wind loading to ensure that they play their part in specifying and delivering a safe building.

It is necessary to perform wind loading calculations specifically for the building envelope in addition to those undertaken by the structural engineer for the structural frame. In the event where a structural engineer is not involved in the cladding design process, or when the roofing/cladding systems have been specified by a contractor or architect, it is essential that structural calculations for the specified systems are carried out. In contract, this is often the responsibility of the specialist subcontractor…or just overlooked!

Ideally the main contractor will demand provision of calculations for the roof sheeting and wall cladding and these will be reviewed and/or approved by the structural engineer.

Also ideally, the structural engineer will specify the building specific dynamic pressure q value to be used for the building.

WIND FORCES ON BUILDINGS

When the wind blows on a building, the change in wind speed as the air negotiates the obstruction in its path may result in either an increase or a decrease in pressure. When combined with changes to the internal air pressure the result is either a net positive pressure (on windward facing walls and the windward slopes of steep roofs) or a net suction (on leeward facing walls, on walls parallel to the direction of the wind and on roofs generally). Wind pressure and suction will both cause bending effects in the wall and roof cladding and, in extreme cases, may cause structural failure of the cladding profile or its attachment as can be seen in the photographs below.

All of the loading applied to the building envelope must ultimately be transferred to the foundations via the main building structure and, usually, light steel purlins and cladding rails. While positive wind pressure is transferred through direct bearing between the cladding and its support, resistance to wind suction depends on the method of attachment and the correct installation of an appropriate number of fasteners. It is therefore essential that the cladding, fasteners and supporting structure are all specified to resist the design wind loading on the building.

It is common practice for the structural engineer with overall responsibility for the building design to calculate the building wind loads as part of the structural design process. However, the wind loading calculated for the design of the frame often ignores the high local forces experienced by small areas of the building envelope. Furthermore, the wind loading applied to the face of a building is usually shared across the entire structure, whereas individual cladding components may be required to resist the full force of the wind alone.

FACTORS AFFECTING WIND LOADING

Wind loading is dependent on several factors relating to the location of the site and the geometry and orientation of the building. For this reason, wind loading is site and building specific, so must be calculated for each individual building. The main factors that influence wind speed are:

- Location
- Altitude
- Distance to sea
- Town or country
- Topography
- Wind direction
- Building height
- Building shape
- Location on the building envelope

Location

Put simply, some parts of the country are windier than others. A number of meteorological factors influence the wind speed and direction, well beyond the expertise of a typical structural engineer. Fortunately, the available meteorological data has been analysed to produce simplified guidance published as a code of practice. This guidance includes a 'wind map' of the UK, which may be used to estimate the 'basic wind speed' at any given location in the country. Correction factors are then applied to allow for wind direction, altitude and other factors. The Eurocode wind map (UK National Annex) is reproduced on page 5.

Altitude

Wind speed naturally increases with altitude. This is catered for in the British Standard and Eurocode by a correction factor that is applied to the basic wind speed off the map.

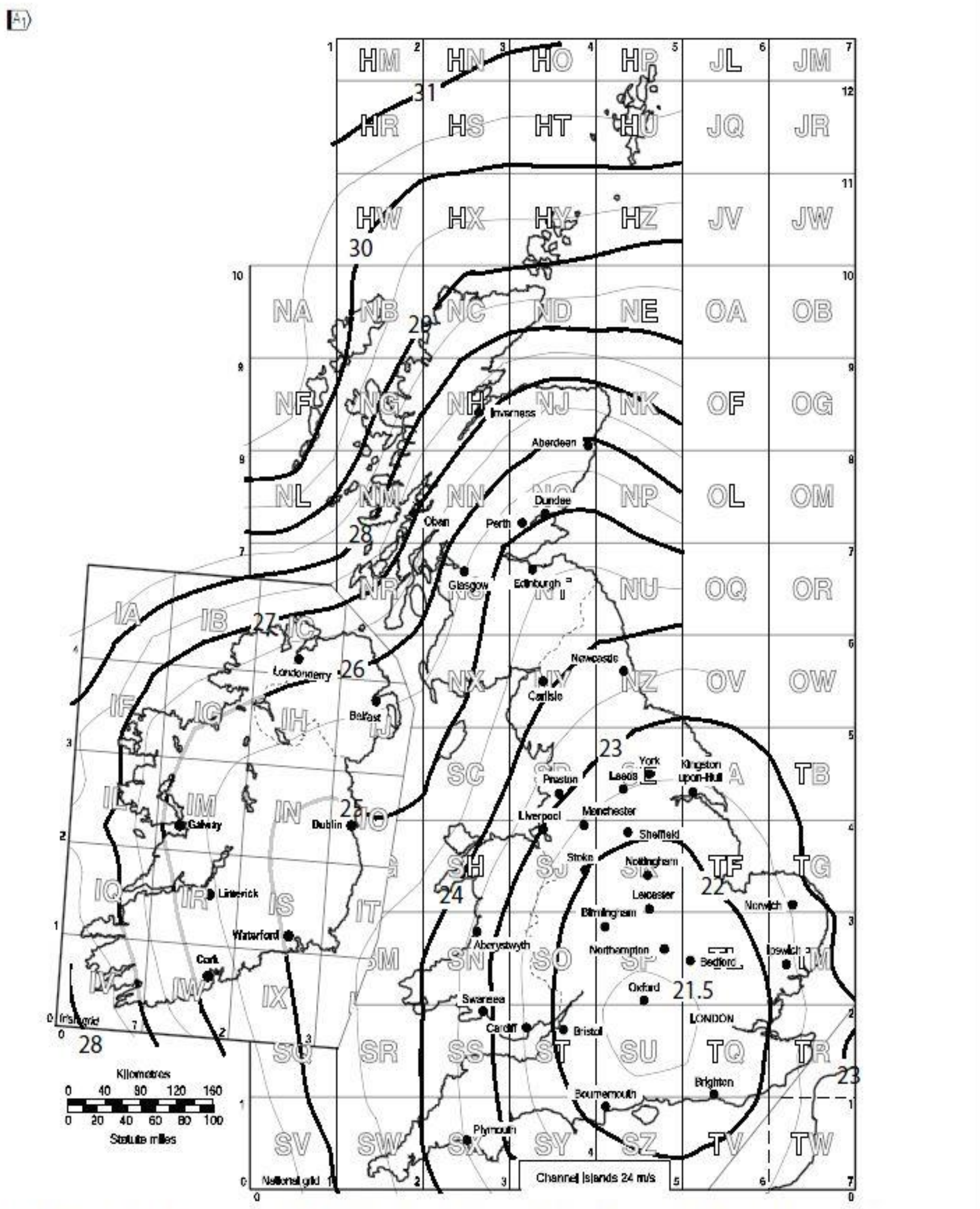
Distance to sea

The closer to the sea a site is, the greater the wind speed. The relationship between upwind distance to the sea and wind pressure is logarithmic in nature meaning that locations on the coast experience much higher wind loading than sites only one or two miles inland, whereas moving from 10 to 20 miles inland has a relatively small impact.

Town or country

Other buildings may provide shelter from the wind and this is reflected in the calculation methods used by the British Standard and Eurocode. The degree of shelter depends on the upwind distance from the site to the edge of town, so building designers need to know the precise location of their site when calculating the wind loading. The precise relationship depends on the building height relative to the surrounding buildings (a 10 storey hotel surrounded by two storey houses might as well be in the countryside).

Figure NA.1 **Value of fundamental basic wind velocity $v_{b,map}$ (m/s) before the altitude correction is applied**



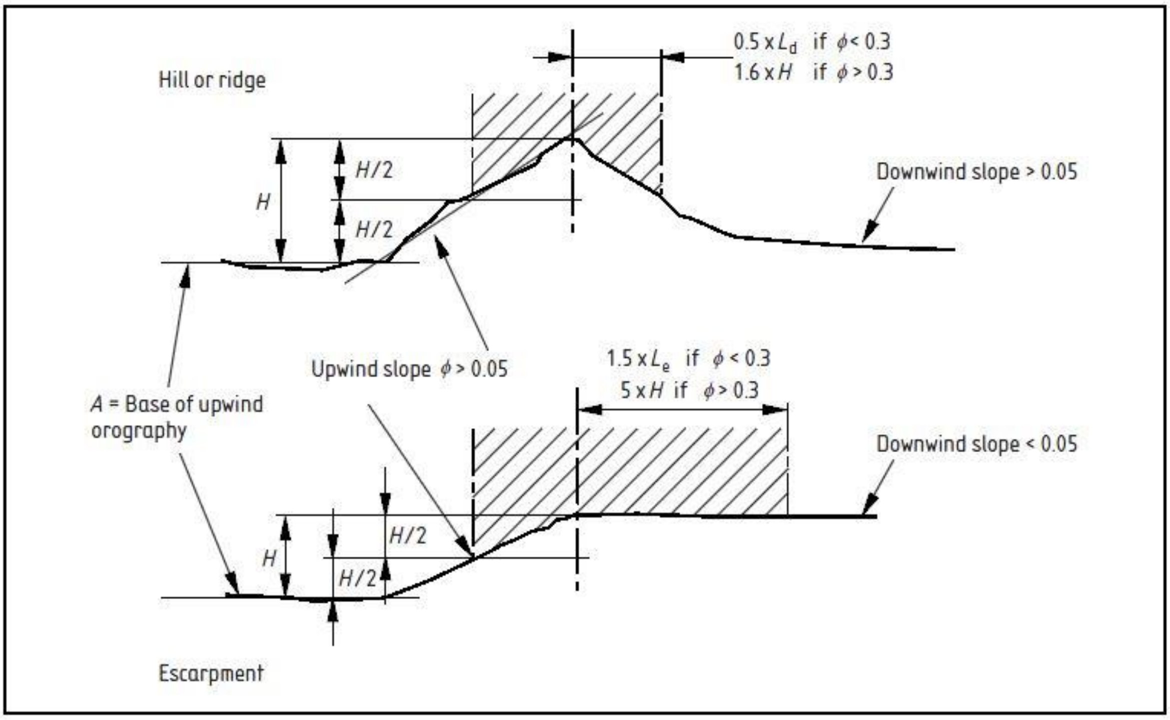
NOTE 1 This map is intended for sites in the United Kingdon, Isle of Man and Channel Islands only.
NOTE 2 The isopleths in the Irish Republic are shown for purposes of interpolation only.

Reproduced from National Annex to BS EN 1991-1-4 © British Standards Institute

Topography

Topographical features such as hills can increase wind speed as the air is forced over them, leading to local high wind pressures. For this reason, it is important for the person calculating the wind loading to have some familiarity with the site and not simply to rely on a postcode. BS EN 1991-1-4 talks about locations with 'significant orography', where wind loading is likely to be greater than the surrounding area. The Eurocode figure defining significant orography is reproduced below.

Figure NA.2 **Definition of significant orography (definition of symbols given in A.3(3))**



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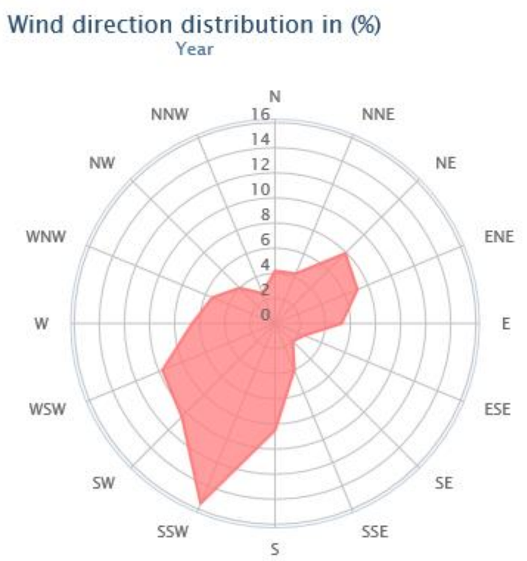
Wind direction

Wind speed is dependent on direction, with the strongest winds generally blowing from the south west. For this reason, when considering other factors such as distance to the sea or to the edge of town, it is important to consider the direction in which this distance is measured. A common approach adopted by engineers is to consider the wind blowing from several points around the compass and, for each direction, to measure the distance to sea and distance to the edge of the town and calculate the corresponding wind speed.

If the orientation of the building is known, the appropriate wind speed may be calculated for each face of the building. Alternatively, the greatest wind speed may be applied to all faces.

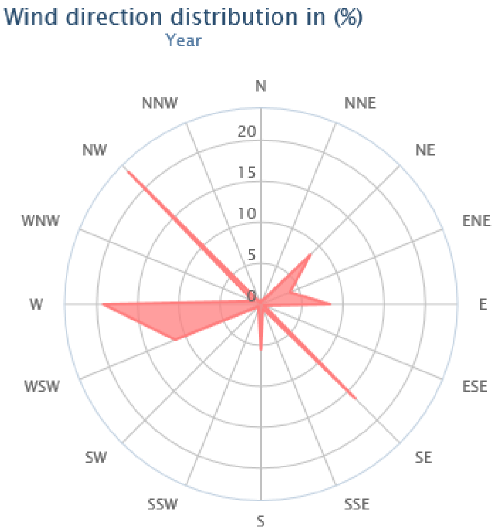
Wind direction distribution

Monthly and annual wind roses provide a graphical representation of the frequency and speed of the wind from each direction of the sixteen compass points for a specific location. The wind roses show the prevailing wind at a given site and in conjunction with average and gust wind speed graphs the information can be used to initially assess and ultimately used as an input to calculate the wind loading on the envelope and structure of a building. The following wind roses show the variation across three locations chosen across the UK.



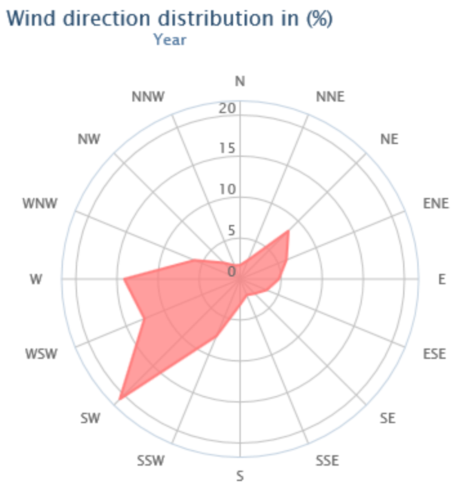
London: Average wind speed 10.9 mph (6 mph - 16.1 mph plus gusts)

(4.9m/s (2.7m/s – 7.2m/s plus gusts))



Grimsby: Average wind speed 6.6 mph (3 mph – 8 mph plus gusts)

(2.9m/s (1.3m/s – 3.6m/s plus gusts))

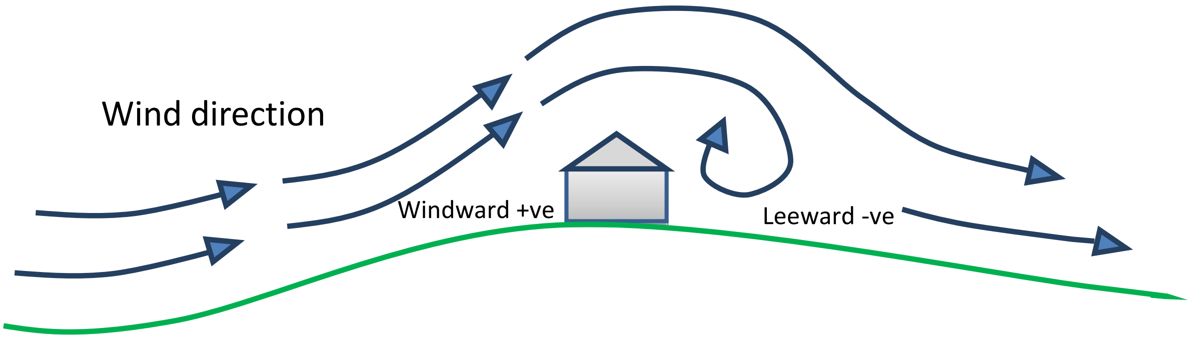


Great Dun Fel, Penrith: Average wind speed 27.8 mph (18 – 32 mph plus gusts)

(12.4m/s (8m/s – 14.3m/s plus gusts))

Information provided by Windfinder, www.windfinder.com

The diagram below demonstrates how the prevailing wind travels up and over a building with subsequent positive (+ve) windward pressure and negative/suction (-ve) leeward pressure on the cladding and structure of the building. The local topography and obstructions will have an effect on the flow over and around the building.



Building height

Taller buildings are exposed to stronger winds and this is reflected in the wind loading calculations in the British Standards and Eurocodes. Strictly speaking, the height that matters is the height exposed above neighbouring buildings or other sources of shelter, although conservatively the building height may be used in the calculations. For very tall buildings, the facade may be divided vertically with different wind pressures assigned to different heights above the ground. Even for single storey buildings, the height difference between eaves and ridge may be sufficient to alter the wind loading.

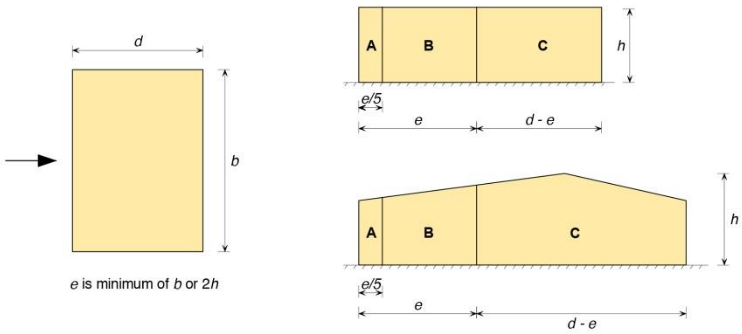
Building shape

The building aspect ratio (length to width), roof shape and roof pitch all affect the magnitude of the wind pressure and its distribution over the building envelope. The wind pressure acting on a building face is the product of the dynamic pressure (0.5 x air density x wind speed^2) and a pressure coefficient obtained from the design standard. Pressure coefficients are tabulated for various shapes of roof (flat, monopitch, duo pitch and hipped) for a range of roof slopes.

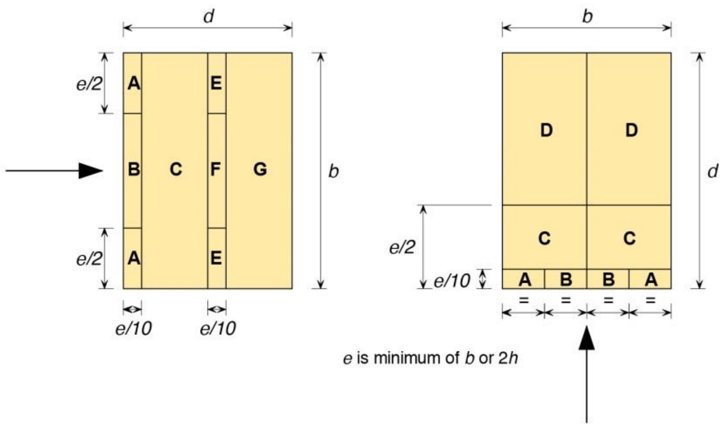
Location on the building envelope

The wind pressure varies with location on the building envelope. For example, the edges of a roof are subjected to higher pressures than the centre, so may require additional fasteners or closer purlin centres. The ridges and corners of roofs and the corners of walls are especially vulnerable to high wind loads.

The British Standard and Eurocode both deal with this issue by dividing the roof and walls into zones and assigning different pressure coefficients to each zone. The zones used by the Eurocode for walls and duo pitch roofs are shown below:



Wall zones



Roof zones for duo pitch roof

WIND LOADING CALCULATIONS

In order to design or specify the envelope elements correctly, it is necessary to estimate the maximum magnitude of wind loading that the building is likely to encounter over its life. This is a complex calculation that needs to take account of all of the factors listed above in addition to the probability of the design wind speed being exceeded over the design life of the building. To assist with this calculation, building envelope designers and specifiers are advised to use a recognised code of practice. Until March 2010, the code of practice for wind loading in the UK was BS 6399-2, but this has since been replaced by BS EN 1991-1-4 (although the former is still widely used). The latter standard is one of the structural Eurocodes and is applicable across the European Union, although each member state has its own National Annex that must be used when designing for that country.

A similar design process is used by BS 6399-2 and BS EN 1991-1-4. In both cases, the first step is to obtain a basic wind speed for the general location of the site using a published wind map. This wind speed is then adjusted to allow for the various factors described in the preceding section and converted into a ‘dynamic pressure’ (q value) for the building. The dynamic pressure is ***not*** the pressure acting on the cladding, but is merely a measure of the strength of the wind as it approaches the building.

If variations in distance to the sea and other direction-related factors are considered, as described above, the calculation process will result in several values of dynamic pressure, corresponding to the different directions. If the building orientation is known, the appropriate dynamic pressure may be selected for each wall and roof elevation. Alternatively, the maximum dynamic pressure may be applied to the whole building.

Having calculated the dynamic pressure, the actual pressures acting on the external face of the building may be obtained by multiplying the dynamic pressure by the appropriate pressure coefficients (Cpe and Cpi). These values are given in the National Annex to BS EN 1991-1-4 for walls and various shapes of roof. As noted above, the pressure coefficients are zone dependent, so each face of the building will have more than one external pressure value, depending on the number of zones.

The internal pressure within the building is calculated in a similar, but simpler, manner. There are two possible values for the internal pressure, one positive and one negative, depending on whether the wind is deemed to inflate the building (positive, by blowing into it) or deflate it (negative, by blowing past it). Special care should be taken in cases where a ‘dominant opening’ may result in a significant positive internal pressure. A dominant opening is an opening that might be open during a storm such as a vehicle door. The final step in the process is to subtract (or add) the internal pressure from the external pressure to obtain the net pressure acting on the roof or wall. It is this value that is used in the design of the cladding, fasteners and supporting structure.

The calculation methods for wind loading in both codes of practice are complex and sometimes difficult to follow, so it is essential that wind loading calculations are undertaken by a qualified structural or civil engineer. Software is also available; some examples of which may be obtained free of charge as part of the packages on offer by the purlin manufacturers. While the software removes the labour from the calculation process, it does not remove the responsibility for assessing all of the site and building factors noted above and ensuring that the calculation is fit for the building under consideration (that is, the old computer saying ‘garbage in, garbage out’).

BS EN 1991-1-4 aims to calculate the wind loading corresponding to the 1 in 50 year storm, so cladding and buildings designed to this standard should be able to withstand the typical winter storms with ease. Furthermore, when checking the ultimate resistance of cladding sheets or fasteners, the calculated wind loads are multiplied by a safety factor to provide an additional margin against failure. Therefore, if designed properly, no cladding should fail due to wind loading, except in the most extreme of cases.

The use of the 1 in 50 year event and safety factors does not mean that the envelope is ‘over designed’ and should not be used as an excuse for reducing the cladding loads; the margin of safety engineered into the calculations is essential to ensure with reasonable probability that the building envelope will not fail during its design life.

Note:

Cladding manufacturers typically publish their technical data in the form of load span tables. In producing these tables, it is common practice to divide the resistance (strength) of the cladding profile by the appropriate safety factor to give a ‘safe working load’.

When using these tables, specifiers should compare the published resistance values against the ‘unfactored’ wind loads. By contrast, fastener manufacturers often present the ‘characteristic’ resistance of their fasteners in their literature, in which case, the appropriate safety factors must be applied by the specifier (that is, divide the published resistance by the safety factor).

PRACTICAL CONSIDERATIONS

Design

The simplest way of calculating the wind loading on a given building is through the use of software. In many cases, the precise site location may be specified in the software by its postcode or grid reference. Alternatively, various online resources may be used to obtain the grid reference, altitude and other location data. Thanks to Google™, even the local topography and surrounding terrain may be surveyed without leaving the office. Some software is more comprehensive than others and will generate more accurate wind load data, so it is important to understand the functionality and limitations of the chosen software before using it.

In particular, software that takes account of the direction of the wind when assessing distance to the sea and terrain will give less conservative results than software that combines the worst direction, distance to sea and terrain into a single value.

It is most common to calculate wind loads without any reductions due to direction or shelter from nearby buildings, to be on the conservative side.

In terms of cladding resistance, specifiers should use the load/span tables published by the cladding manufacturers to assess whether the chosen profile and gauge is suitable for the proposed span and wind loading. In high wind load zones, it may be necessary to reduce the span of the cladding to avoid increasing the gauge of the material or depth of the profile.

Fasteners should also be specified using the manufacturer's data, but care should be taken to ensure that the appropriate safety factors are applied to the published data. (If the fastener manufacturer claims that the data relates to the 'characteristic' resistances, the values should first be divided by the appropriate γ_m value (see National Annex to BS EN 1993-1-3) to obtain the 'design' resistance and then by the appropriate load factor (typically 1.5 for wind) to obtain the safe working load).

The load factor is typically 1.5 for wind loads for profile design, but BS5427:96 advises a load factor of 2 for the fixing assembly.

Zones

As noted above, the ridges and corners of roofs and the corners of walls are especially vulnerable to high wind loads. While it is important not to ignore the high wind zones, care should be taken to avoid over-complicating the specification to the point where mistakes are likely to be made on site. For example, the wind zone lengths should be rounded off to the nearest whole sheet width to simplify matters for the cladding installers. Similarly, a standard fastener regime may be specified for most of the envelope with an increased frequency of fasteners in high wind zones.

PVs

The use of photovoltaic (solar) arrays is becoming commonplace on modern industrial and agricultural buildings. In some cases such as inclined arrays, the geometry of the panels may result in increased wind loading which will either be applied to the roof cladding or directly to the supporting steelwork. Where PV panels are installed in the plane of the roof, the overall impact on the roof loading is likely to be less, but there may be high local wind forces applied to the panels themselves. If in doubt, specialist advice should be sought.

CONCLUSIONS

Wind loading is site and building specific due to the many factors that influence the wind speed at a given location. The calculation of wind loading is complicated and requires the services of a qualified engineer or the use of software by an appropriately experienced person. However, it is essential that the wind loads are calculated for each and every building, since if not designed for, the force of the wind can cause failure of the cladding or even the building structure.

The wind load also varies between points on the building envelope, with ridges, corners and edges most susceptible to high wind pressures. These locations are likely to require careful detailing. However, with the correct design and specification of the building envelope, damage is avoidable except perhaps in the most extreme of weather events. If in doubt, seek the advice of a qualified structural engineer.

MCRMA member companies can advise on the suitability and performance of materials, systems and assemblies to ensure that the wind loading is calculated properly for every building and that the cladding and fasteners are specified accordingly. In addition, loading and roofing/cladding design information can be obtained from any of the independent roofing and cladding inspectors featured on the MCRMA web site at **www.mcrma.co.uk**

USEFUL RESOURCE

To support the project team and the installation contractors in the design and specification of roof and wall cladding systems and their fasteners, MCRMA has developed a dedicated page on its web site where a range of specialist web-based resources are available to assist with the calculation process.

The web page provides a series of links to other sites for specific input data, which is needed to complete the calculation and provide output data. The accompanying links provide an altitude or elevation finder, distance calculator for establishing distance of the building from the sea, weather maps of wind strength and direction plus links to UK weather stations for reports and historical data showing principal wind directions and frequency.

Visit **www.mcrma.co./wind-loadings-guidance/**

MCRMA ONLINE CPD PROGRAMME

This guidance document is available as an online CPD and is accredited by the CPD Certification Service. MCRMA's online CPD programme is open to anyone seeking to develop their knowledge and skills within the metal building envelope sector. Each module also offers members of professional institutions an opportunity to earn 60 minutes of credits towards their annual CPD requirement.

For more information and to take the CPD go to **www.mcrma.co.uk/online-cpds/**

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UK National Annex to BS EN 1990:2002 + A1:2005

UK National Annex to BS EN 1991-1-4:2005 + A1:2010 (Incorporating National Amendment No.1)

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