Introduction

This technical note provides a simplified method of calculation for wind loading, based on BS 6399: Part 2, for buildings in open country and not exceeding two storeys in height, and buildings in town not more than three storeys in height, assuming shelter from surrounding buildings. The calculated wind pressures are appropriate for windows in walls and cladding panels having a diagonal dimension of 5m or less. This approach may also be used for larger panels, but lower values and a more economic design may result from a full calculation based on BS 6399: Part 2.

The action of the wind on a building exerts a force in the form of a dynamic pressure which varies on each face, and across each face, of the building. In the case of wind blowing directly onto the face of a building a positive pressure is exerted on the windward face and a corresponding negative pressure (suction) is generated along the sides and across the leeward face.

Calculation Procedure

The calculation procedure set out in this technical note will lead the designer through a series of steps to obtain a design wind pressure on cladding panels or windows. It is important at the preliminary stage of design that the location and orientation of the building are considered and, where possible, information gathered on local wind loading pressures calculated on similar buildings in the vicinity. In the case of windows, performances are classified into pressures of 1200Pa, 1600Pa and 2000Pa as specified in BS 6375: Part 1. In cases where the calculated pressures are close to but greater than the upper rating of a window it may be more economic to conduct a full calculation based on BS 6399: Part 2, which may give a lower wind pressure because of the simplifying assumptions that have been made, whilst ensuring that the wind load is not under-predicted.

Stage 1 (basic dynamic pressure)

The geographical variation of the basic dynamic pressure ($q_b$) can be read from Figure 1. This shows the variation in dynamic pressure throughout the UK assuming a basic wind speed at 10m above mean sea level. The dynamic pressure values do not take account of topography or altitude which are considered separately.

Stage 2 (site-specific dynamic pressure)

The basic dynamic pressure is converted into a site-specific dynamic pressure ($q_s$) using the appropriate $S_a^*$-factors. The site dynamic pressure can be calculated for any particular direction and altitude as follows:

$$q_s = q_b \times S_a^* \times S_d^*$$

where:

- $q_b$ is the basic dynamic pressure (Figure 1)
- $S_a^*$ is an altitude factor (Table 1 or 2)
- $S_d^*$ is a direction factor (Table 4)

Note: The factors $S_d^*$ are applied to pressures $q$. They should not be confused with factors $S_v$ of BS 6339:Part2 that are applied to velocities $v$.

**Altitude and topography factor ($S_a^*$)**

Wind pressure increases with altitude above sea level. Wind pressure also varies with topography, particularly if the building is on or behind an upwind slope. The $S_a^*$ factor takes account of both effects and can be read from Table 1 or 2, depending on the significance of topography.

**Topography**

The topography has a significant effect on wind pressures for buildings in the shaded zone, as illustrated in Figure 2. It is important to note that topography is not considered significant if the ground slope upwind of the building is less than 0.05.

If topography is not significant then the site altitude (ALT) can be taken as the altitude above sea level of the building and $S_a^*$ takes account of both effects and can be read from Table 2.

If topography is significant then ALT is taken as the altitude above sea level of the upwind base of the slope (Figure 2).

The appropriate $S_a^*$ factors can be read from Table 1 where slope ($\psi$) is the average upwind slope. The assumptions made in Table 1 are:

1. The altitude of the site (ALT) is the altitude of the significant base topography;
2. The topographic location factor ($s$) is 0.8 for both hills and escarpments.

**Directional Factor**

The wind load is dependent on the orientation of the façade. Winds from the southwest generate the highest pressures but local site characteristics and building design may result in other wind directions giving more severe load cases. The method described in this Technical Note is applicable to rectangular buildings and wind loads in the four orthogonal directions normal to the building facades should be considered. For more complex building shapes reference should be made to BS 6339 Part 2.

The directional factor accounts for the orientation of the face of the building under consideration. If the orientation of the building is unknown or ignored, the value of the directional factor should be taken as $S_d^* = 1$.

The wind direction is defined in the conventional manner as in BS 6399: Part 2, i.e., an east wind is a wind direction of $\phi = 90^\circ$ and blows from the east to the site. Values of $S_d^*$ are given in Table 4 and the highest value for directions $45^\circ$ either side of normal to the face under consideration should be used. For each wind direction it will be necessary to make a separate assessment of upwind terrain, shelter and topography.

**Stage 3 (terrain and building factor)**

The terrain and building factor ($S_b^*$) can be obtained from Figure 3, which may be interpolated for a range of effective building heights. This factor accounts for the size and location of the building and is dependent on the building height, type of terrain and distance from the sea.

Sites are classified as town or country. Buildings in town are sheltered by other buildings and consequently wind pressures on them are lower. Buildings in the countryside and on the edge of town may not benefit from shelter in this way (depending on the wind direction considered).

For buildings in town terrain (i.e. where there is considered to be 2km of buildings upwind of the site), the effective height of the building ($H_e$) will depend on the shelter from surrounding buildings and the spacing to the building under consideration. The effective height is determined as follows:

a) If $X \leq 2H_o$, then $H_e$ is the greater of:

$$H_e = H - 0.8H_o \text{ or } H_e = 0.4H.$$
b) If $X \geq 6H_o$, then $H_e$ is given by:
$H_e = H$;

c) $2H_o < X < 6H_o$, then $H_e$ is the greater of:
$H_e = H - 1.2H_o + 0.2X$ or $H_e = 0.4H$.

where (Figure 4):

- $H_e$ is the effective height of the building;
- $H$ is the actual height of the building to the eaves;
- $H_o$ is the average upwind obstruction height;
- $X$ is the upwind spacing.

For the purpose of this calculation the obstruction height $H_o$ may be estimated from the average number of storeys of upwind buildings, taking a typical storey height as 3m. Permanent forest and woodland upwind of a building may be treated as town category.

The assumptions made in developing this chart are:

1. Sites in town are assumed to be at least 2km from the upwind edge of town;
2. For calculation purposes the actual distances from the coast have been taken as 2km, 10km and 50km for the categories <10km, 10 to 50km and >50km respectively;
3. No assumption has been made for the effective height of the building since these are calculated based on the three assumptions made earlier in this stage.

The effective dynamic pressure $q_e$ can be calculated from:

$q_e = q_b \times S_b^* = (q_b \times S_a^* \times S_d^*) \times S_b^*$

### Stage 4 (pressure coefficients)

Wind blowing onto a building will give rise to positive pressures on the front face and negative (suction) pressures on the sides and rear of the building. The suction pressures on the side walls will generally be of greater magnitude at the windward end and reduce further back along the building, especially if reattachment occurs (indicated by zone 3 in Figure 5).

The external pressure coefficient ($C_{pe}$) is the ratio of the static pressure acting on the surface of a building to the dynamic pressure.

The values of the external pressure coefficients for a typical rectangular (in plan) building will vary depending on the aspect ratio of the building and the direction of the wind in relation to the surface being considered. The loaded zones vary on each face of the building and across each face. For this application, only the orthogonal cases are considered; the standard method uses modified pressure coefficients to ensure that if these load cases are used the worst case loads are picked up correctly.

The pressure coefficients across the windward (front) face are positive and those across the side faces and leeward (rear) face are negative. The loaded zones on the sides of the building are divided into vertical strips from the upwind edge of the face, as shown in Figure 5. The scaling length (b) is given by:

$b = B$ or $b = 2H$, whichever is the lesser,

where:
- $H$ is the height of the building;
- $B$ is the crosswind breadth of the building, which will vary depending on the direction of the prevailing wind.

The values for the external pressure coefficients for the windward and leeward faces are given in Table 3 for $D/H \leq 1$ and $D/H \geq 4$, where:

- $D$ is the in-wind depth of the building;
- $H$ is the actual height of the building.

Ideally, a separate $C_{pe}$ value should be given for each cladding panel but, as this is impractical, average values should be used for most of the building structure with special attention being given to localised areas of high suction.
Where two buildings are located beside each other and the gap between them is less than b, funnelling will accelerate the flow and increase the negative pressure coefficient (i.e. higher suction values). Typical values of the pressure coefficients for the sides of a building are listed in Table 3 for each of the relevant exposure cases and should be applied as follows:

a) Where the gap between the buildings is less than b/4, or greater than b, the isolated values should be used;

b) Where the gap between the buildings is between b/4 and b then the funnelling values should be used.

Provided there are no dominant openings, the internal pressure coefficient \( C_{pi} \) should be taken as either -0.3 or +0.2, whichever gives the greater net pressure coefficient across the cladding panel or window. A dominant opening is defined as an opening with an area twice the sum of the openings in the other faces. Where dominant openings are present the internal pressure coefficients vary according to the ratio of the dominant opening area to the sum of the remaining openings as described in BS 6339: Part 2.

**External surface pressure**

The external surface pressure \( p_e \) acting on the exterior of the building can be expressed by:

\[
p_e = q_s \times C_{pe} \text{ (based on a maximum diagonal dimension of 5m)}
\]

The internal surface pressure acting on the interior of the building can be expressed by:

\[
p_i = q_s \times C_{pi}
\]

where:

- \( q_s \) is the dynamic pressure;
- \( C_{pe} \) is the external pressure coefficient on the cladding;
- \( C_{pi} \) is the internal pressure coefficient on the cladding.

**Net surface pressure**

The net surface pressure \( p \) for enclosed buildings, acting across the cladding, is given by:

\[
p = p_e - p_i
\]

The net load \( P \) (in N) on an area of cladding panel or window is given by:

\[
P = p \times A
\]

where:

- \( p \) is the net pressure across the surface (N/m², Pa);
- \( A \) is the loaded area (m²).

**Example**

Consider a two storey house of maximum height 7.5m at Swansea (Figure 6).

The site is 20km from the sea, the topography is considered significant and shelter is considered adequate because the building is 2km inside of the edge of town in the wind direction being considered.

Calculate the dynamic pressure in one wind direction for the purpose of obtaining a net surface wind load.

**Assessment using this technical note**

Obtain basic dynamic pressure from Figure 1 (Stage 1)

\[
q_b = 305 \text{N/m}^2 \text{ (interpolation used between the contours)}
\]

Calculate basic dynamic pressure \( q_b \) (Stage 2)

\[
q_b = q_s \times S_a^* \times S_d^*
\]

\( S_a^* \) calculated from Table 1 assuming topography to be significant, i.e. the site falls within the shaded region of Figure 2.

Slope (\( \psi_u \)) = 0.1 (Figure 6)
ALT = 50m (altitude at the base of the slope)

$S_a^*$ = 1.31

$S_d^*$ = 1.0 (ignores the effects of wind direction)

Site dynamic pressure is:

$q_s = 305 \times 1.31 \times 1.0 = 400 \text{ N/m}^2$

Effective dynamic pressure is given by:

$q_e = q_s \times S_b^*$ (Stage 3)

Assuming the building is on the edge of town in the wind direction being considered, and 20km from the sea with adequate shelter from surrounding buildings, the effective height of the building can be expressed as:

$H_e = 0.4 \times H$

$= 0.4 \times 7.5$

$= 3\text{m}$

The $S_b^*$ factor can be estimated from Figure 3.

$S_b^* = 1.6$

$q_e = 400 \times 1.6 = 640 \text{ N/m}^2$

Assessment using BS 6399: Part 2 (Standard method)

$V_e = V_b \times S_b$

where:

$V_b = V_e \times S_a \times S_d \times S_s \times S_p$

Obtain basic site wind speed of 22.2m/s (Figure 6)

Considering topography to be significant, $S_a$ should be taken as the greater of (Clause 2.2.2.2):

$S_a = 1 + 0.001 \Delta S$

and

$S_a = 1 + 0.001 \Delta T + 1.2 \times \psi_e \times s$

where:

- $\Delta S$ is the site altitude;
- $\Delta T$ is the altitude of the upwind base (significant topography);
- $\psi_e$ is the effective slope of the topographical feature;
- $s$ is the topographic location factor.

Now,

$\Delta T = 50\text{m}$

$\Delta S = 90\text{m}$

$\psi_e = 0.1$ (shallow upwind slope, therefore $\psi_e = \psi_u$ and $L_e = L_u$ (Clause 2.2.2.2.4))

The topographic location factor ($s$) can be calculated depending on the position of the site and the topographical features (Clause 2.2.2.2.5).

Horizontal position ratio:

$X/L_e = 70/400 = 0.175$

Height above ground ratio:

$H/L_e = 40/400 = 0.1$

Therefore, topographic location factor ($s$) is 0.85 (Figure 10).

Hence calculate $S_a$ from formula below:

$S_a = 1 + 0.001(\Delta T) + 1.2 \times \psi_e \times s$

$= 1 + 0.001(50) + 1.2 \times 0.1 \times 0.85$

$= 1.15$

or

$S_a = 1 + 0.001 \Delta S$

$= 1 + 0.001 \times 90$

$= 1.09$
Therefore $S_a = 1.15$

$S_d = 1.0$ \hspace{1cm} (Clause 2.2.2.3)

$S_a$ is the seasonal factor and for permanent buildings exposed to the wind for a continuous period of more than six months a value of 1.0 should be used (Clause 2.2.2.4).

$S_p = 1.0$ \hspace{1cm} (Clause 2.2.2.5)

$V_s = 22.2 \times 1.15 \times 1.0 \times 1.0 \times 1.0 \times 1.0 = 25.53 \text{m/s}$

Calculate dynamic pressure on a typical cladding panel by using:

$q_s = 0.613 \times V_c^2 \times C_a$

Size effect factor ($C_a$) is dependent on the site exposure and the diagonal dimension (a). For cladding units and their fixings ‘a’ should generally be taken as 5m (Clause 2.1.3.4), giving a size effect factor of 1.0. Therefore:

$q_s = 0.613 \times (31.7)^2 \times 1.0$

$= 614 \text{N/m}^2$

Comparison

The effective dynamic pressure obtained using this technical note gives a four per cent higher pressure because of the conservative assumptions made to simplify the calculation procedure of BS 6399: Part 2.

Calculation summary to obtain net surface load on window/cladding panel

Stage 1 - $q_b$

Obtain value of $q_b$ from dynamic pressure map (Figure 1)

$Q_b = ?$

Stage 2 - $S_a^*$ & $S_d^*$

Obtain altitude factor (Table 1 or 2)

$S_a^* = ?$

Obtain directional factor (Table 4)

$S_d^* = ?$

Calculate the site dynamic pressure from $q_s = q_b \times S_a^* \times S_d^*$

$q_s = ?$

Stage 3 - $S_b^*$

Effective height of building $H_e = ?$

Terrain factor (Figure 4) $S_b^* = ?$

Calculate the effective dynamic pressure from $q_e = q_s \times S_b^*$

$q_e = ?$

Stage 4 - $P_e$ & $P_i$

Obtain the external pressure coefficient $C_{pe}$ (Table 3) for each zone of the building, depending on the wind direction.

$p_e = q_e \times C_{pe}$

$p_e = ?$

Obtain internal pressure coefficients $C_{pi}$ for the internal face of the building (Table 5).

$p_i = q_e \times C_{pi}$

$p_i = ?$

Stage 5 - Net pressure, $p$

Obtain net pressure across the face of the cladding panels:
\[ p = (p_e - p_i) \quad p = ? \]

The net surface load on a cladding panel may be expressed as:

\[ P = p \times A \quad P = ? \]

**Note**

This design procedure is only representative of one wind direction under consideration. For other wind directions the terrain and \( S^* \)-factors will have to be re-calculated to obtain the net surface load on the cladding.

**Summary**

There appears to be scope for confusion when using BS 6399: Part 2 to calculate wind loading because it requires the detailed interpretation of the site location, and working with wind speeds and pressures. This technical note offers a quick design method for the cladding or window consultant and removes the complexities of BS 6399: Part 2 by using a four stage approach and working in terms of pressure throughout.

**References**


Tables

<table>
<thead>
<tr>
<th>ALT (m)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>&gt;300</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi=0.05$</td>
<td>1.10</td>
<td>1.20</td>
<td>1.32</td>
<td>1.43</td>
<td>1.56</td>
<td>1.68</td>
<td>1.82</td>
<td>See BS 6399: Part 2</td>
</tr>
<tr>
<td>$\psi=0.10$</td>
<td>1.20</td>
<td>1.31</td>
<td>1.43</td>
<td>1.55</td>
<td>1.68</td>
<td>1.81</td>
<td>1.95</td>
<td>for steep upwind slopes which</td>
</tr>
<tr>
<td>$\psi=0.15$</td>
<td>1.31</td>
<td>1.42</td>
<td>1.55</td>
<td>1.67</td>
<td>1.81</td>
<td>1.94</td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>$\psi=0.20$</td>
<td>1.42</td>
<td>1.54</td>
<td>1.67</td>
<td>1.80</td>
<td>1.94</td>
<td>2.08</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>$\psi=0.25$</td>
<td>1.54</td>
<td>1.66</td>
<td>1.79</td>
<td>1.93</td>
<td>2.07</td>
<td>2.22</td>
<td>2.37</td>
<td></td>
</tr>
<tr>
<td>$\psi=0.30$</td>
<td>1.66</td>
<td>1.79</td>
<td>1.93</td>
<td>2.07</td>
<td>2.21</td>
<td>2.36</td>
<td>2.52</td>
<td></td>
</tr>
</tbody>
</table>

Note: Where a building is positioned on the crest of a hill the action of the wind loading must be considered carefully.

**Table 1** Values of $S_a^*$ (significant topography)

<table>
<thead>
<tr>
<th>ALT (m)</th>
<th>$S_a^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>50</td>
<td>1.10</td>
</tr>
<tr>
<td>100</td>
<td>1.21</td>
</tr>
<tr>
<td>150</td>
<td>1.32</td>
</tr>
<tr>
<td>200</td>
<td>1.44</td>
</tr>
<tr>
<td>250</td>
<td>1.56</td>
</tr>
<tr>
<td>300</td>
<td>1.69</td>
</tr>
<tr>
<td>&gt;300</td>
<td>Consider significance of topography</td>
</tr>
</tbody>
</table>

**Table 2** Values of $S_a^*$ (topography not significant)

<table>
<thead>
<tr>
<th>Orientation $\phi$</th>
<th>D/H $\leq$ 1</th>
<th>D/H $\geq$ 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>windward</td>
<td>+0.8</td>
<td>+0.6</td>
</tr>
<tr>
<td>leeward$^o$</td>
<td>-0.3</td>
<td>-0.1</td>
</tr>
<tr>
<td>Side face</td>
<td>isolated</td>
<td>funnelling</td>
</tr>
<tr>
<td>Zone A</td>
<td>-1.3</td>
<td>-1.6</td>
</tr>
<tr>
<td>Zone B</td>
<td>-0.8</td>
<td>-0.9</td>
</tr>
<tr>
<td>Zone C</td>
<td>-0.4</td>
<td>-0.9</td>
</tr>
</tbody>
</table>

**Table 3** External pressure co-efficients $C_{pe}$
Note: The basic dynamic pressure map is derived from the Basic Wind speed map $V_b$ Figure 6 within BS 6399: Part 2.

**Figure 1** Basic dynamic pressure $q_b$ (N/m$^2$)
Wind loading on wall cladding and windows of low-rise buildings

Figure 2  Significant topography (shaded zone) for (a) hill and ridge; (b) escarpment and cliff

Figure 3  Values of terrain building factor $S_b$
Figure 4 Basic definition of obstruction height and upwind spacing

Figure 5 Variable dimensions and wall pressure data
Figure 6  Wind loading calculation example