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Draft for Development

Methods for assessing exposure to wind-driven rain

Projet à développer

Méthodes d'évaluation de l'exposition à la pluie battante

Entwurf zur weiteren Ausarbeitung

Verfahren zur Berechnung der Bewitterung durch Schlagregen

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This publication is not to be regarded as a British Standard.

It is issued in the Draft for Development series of publications and is of a provisional nature because the methods described are based on a new approach which is theoretically sound but requires to be applied in practice before it can be incorporated into a British Standard. It is recommended that it should be applied on a provisional basis so that information and experience of its practical application may be obtained.

A review of this Draft for Development will be carried out not later than two years after its publication. Notification of the start of the review period together with a request for the submission of comments from the users of this Draft for Development will be made in an announcement in the appropriate issue of *BSI News*. Observations which it is felt should receive attention before the official call for comments will be welcomed.

Foreword

This Draft for Development has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee.

During the current revision of CP 121 : Part 1 : 1973* the technical committee recognized the need to develop a method of assessing exposure to wind-driven rain which could be applied to many aspects of the design of masonry.

New data made available by the Meteorological Office has made it possible to develop more accurate methods of assessment of local wind-driven rain. A comparison with the method described in BS 5618 has revealed some significant regional variations.

It has become apparent that there are two distinct aspects of exposure to wind-driven rain, as follows:

- (a) average moisture content of masonry, for which the local annual index is the most significant factor;
- (b) rain penetration through the masonry, for which the local spell index is the most significant factor.

It should be emphasized that neither index is precise enough to enable fine distinctions between degrees of exposure to be made. Hence the user should always take account of local knowledge and experience.

Future work will include:

- (a) regular reviews of climatic data to take into account long term climatic changes;
- (b) research into the relation between exposure and the properties of individual materials, such as absorptive capacity, and the effects of evaporation and moisture content;
- (c) research into the relation between the roughness and topography factors and local building environments.

Methods

0 Introduction

Rainfall varies considerably across the country but is largely unaffected by local features. Conversely, the general wind speed does not change so much across the country but is very much affected by local features, such as the spacing and height of surrounding trees and buildings and whether the ground is flat or steeply rising.

Using measurements made at a very large number of sites, accurate maps have been produced which show how the rainfall varies across the country. In order to produce wind maps, local wind speed measurements have been standardized to the conditions which would occur in the middle of an airfield, 10 m above the ground. To determine the wind speed at a given location from the 'airfield' value, this procedure is reversed (see CP 3 : Chapter V : Part 2).

The quantity of rain falling on a vertical surface, such as a wall, at any point depends on both the intensity of the rainfall and the wind speed. The Building Research Establishment Report 'Driving Rain Index'* postulated that the quantity of rain falling on a vertical surface was proportional to the rate falling on a horizontal surface and to the local wind speed, and incorporated maps of an annual wind-driven rain index, which is the product of the average 'airfield' wind speed. Appropriate correction factors were given to compute the local value. (One version of this method, which expresses the index as a logarithmic value, is described in BS 5618.)

With the advent of computer analysis of meteorological data, the Meteorological Office was able to produce much more realistic values, based on the fact that prolonged rainfall was usually associated with stronger than average winds. New maps for the 'airfield' annual wind-driven rain index were prepared by summing the hourly products of wind speed and rainfall during the 15 year period 1959 to 1973 to obtain the average annual quantity. The data base has since been extended to 1981, producing values on average 26 % higher than those obtained by using the approach in the BRE Report (values in some regions e.g. South West England, increased by about 50 %). This data forms the basis for the local annual index method described in this Draft for Development.

Further work by the Meteorological Office suggested that at very low wind speeds the proportional relationship between wind speed and rainfall did not hold and a correction should be applied. To enable designs for 'worst expected' conditions to be based on the conditions prevailing in a spell of bad weather (see 2.1) a different set of maps was prepared showing the quantity of 'airfield' wind-driven rain falling on vertical surfaces during the worst likely spell of bad weather in any three year period, as well as new factors to compute the quantity falling on a wall in given surroundings in the same spell. This information has also been revised using meteorological data up to 1981 and forms the basis for the local spell index method described in this Draft for Development.

This Draft for Development also takes account of investigations by the Meteorological Office into the effect of steeply sloping ground on wind speed.

Attention is drawn to 'The computation and mapping of directional wind-driven rain indices for the UK'*, which is a publication being prepared by the Building Research Establishment.

1 Scope

This Draft for Development describes two methods for assessing exposure to wind-driven rain, namely the local spell index method and the local annual index method.

Appendix A gives worked examples.

NOTE. The titles of the publications referred to in this Draft for Development are listed on the inside back cover.

2 Definitions

For the purposes of this Draft for Development, the following definitions apply.

2.1 spell. A period or sequence of periods of wind-driven rain on a vertical surface of given orientation.

NOTE 1. A spell is of variable length and may include several periods of wind-driven rain interspersed with periods of up to 96 h without appreciable wind-driven rain.

NOTE 2. Typical spells are shown in figure 1. Each spell only relates to a particular orientation of the vertical surface at a given site. For example, at Plymouth during the spell shown in figure 1 vertical surfaces at 30°, 60°, 90° and 120° orientations remained dry, i.e. the spells for those directions were zero.

2.2 'airfield' index. The quantity of driving rain that would occur 10 m above ground level in the middle of an airfield, at the geographical location of the proposed wall.

2.3 'airfield' annual index, D_A . The average annual 'airfield' index for a given direction, in L/m^2 per year.

2.4 'airfield' spell index, D_S . The 'airfield' index for a given direction during the worst spell likely to occur in any three year period, in L/m^2 per spell.

2.5 local annual index, D_{LA} . The quantity of wind-driven rain in L/m^2 per year at a point in space where a wall is to be built, based on the 'airfield' annual index and corrections for roughness factor and topography factor.

2.6 local spell index, D_{LS} . The quantity of wind-driven rain in L/m^2 per spell at a point on the vertical face of a wall, based on the 'airfield' spell index and corrections for roughness factor and topography factor.

2.7 roughness factor, R . A factor which allows for the effect of neighbouring features on the wind speed.

2.8 topography factor, T . A factor which allows for the effect of local topography on wind speed.

*Obtainable from Building Research Establishment, Garston, Watford WD2 7JR.

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2.9 spell factor, S . A factor which allows for the effect of roughness and topography on spells at a particular site.

2.10 protection category. A description of the countryside in terms of the average height and spacing of protective features, e.g. buildings, trees, hedges.

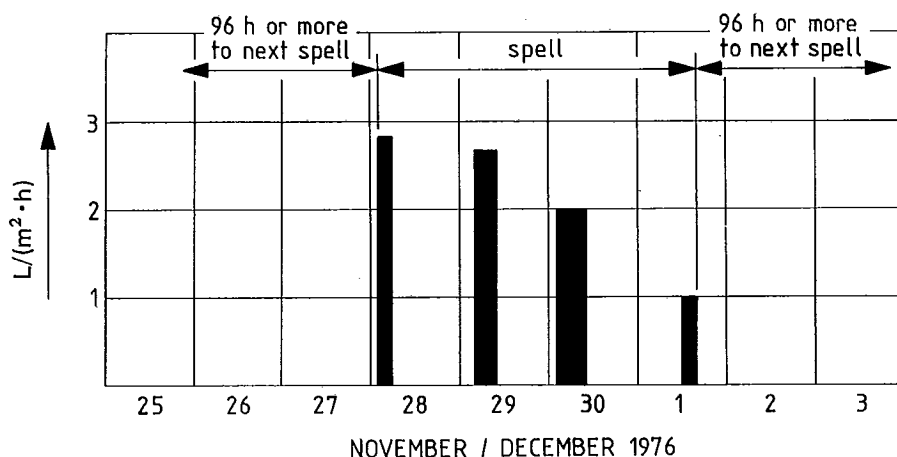
3 Choice of methods

The local spell index method for assessing exposure to wind-driven rain is a measure of the maximum intensity

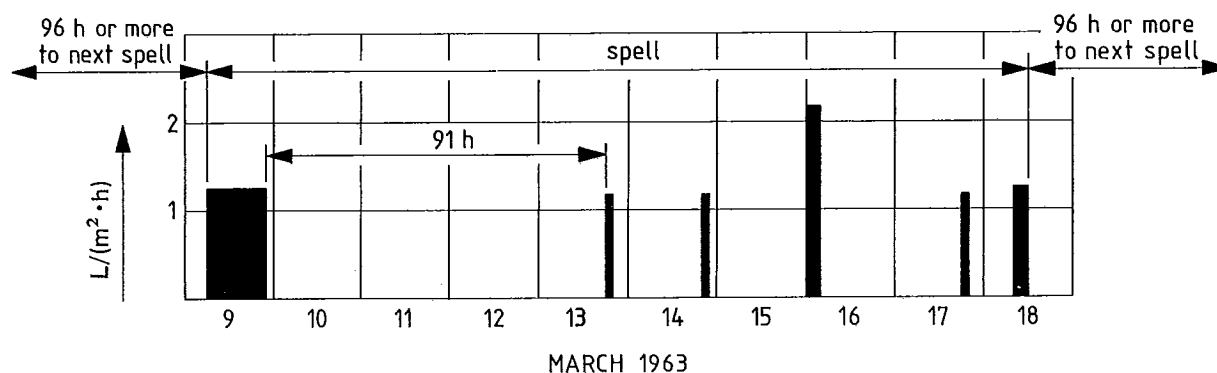
in a given period, whilst the local annual index method for assessing exposure to wind-driven rain is a measure of the total quantity in a year.

The local spell index method should be used when assessing the resistance of a wall to water penetration or when designing windows.

The local annual index method should be used when considering the average moisture content of exposed building materials or when assessing the likely growth of mosses and lichens.



(a) November/December 1976. Plymouth. South-west facing vertical surface (210° orientation)



(b) March 1963. Heathrow. South facing vertical surface (180° orientation)

Figure 1. Typical spells

4 General

The procedure for the two methods (see clause 3) is essentially the same, as shown on the typical worksheet in figure 2. In each case, the first step is to determine the 'airfield' index (see 2.2), using the wind-driven rain maps and the appropriate roses given in appendix B in conjunction with tables 1 or 2. The maps show variations in wind-driven rain over distances greater than 1 km whilst the roses show the variation according to the orientation of the proposed wall.

The second step is to relate the actual site and height of the wall to the 'airfield' condition. After assessing the protection category (see 2.10), the exposed height of the wall is found by subtracting from the actual height the average height of the surrounding features which protect it. If the ground within 1 km of the site is rising on a slope of more than 1 in 10, it may also be necessary to apply a ground height correction. This is because abrupt changes in local ground height affect the wind speed.

Knowing the exposed height of the wall and the protection category, the roughness factor, R , may be found from table 4. In certain circumstances local topography also has to be taken into account, since this can affect wind speed by up to 20 %. This effect is allowed for by the topography factor, T , given in table 5.

The two factors, R and T , show how the wind speed (and hence the wind-driven rain) is reduced or increased by the local environment compared with the 'airfield' site (see clause 0).

The local annual index, D_{LA} , is obtained by simply multiplying the 'airfield' annual index, D_A , by R and T , using the following equation:

$$D_{LA} = D_A R T$$

The relationship between the local spell index, D_{LS} , and the 'airfield' spell index, D_S , is more complex, necessitating the use of a spell factor, S , given in table 6, as follows:

$$D_{LS} = D_S S$$

5 Procedure

5.1 Basic data

The following information is needed for the assessment of the local wind-driven rain index:

- (a) geographical location of proposed wall (National Grid reference);
- (b) orientation of proposed wall;
- (c) maximum height of proposed wall measured, as shown in figure 3;
- (d) description of local site conditions, i.e. height and spacing of surrounding obstructions (see table 3 and figure 4) and marked changes in ground height within 1 km of the site, e.g. cliff, escarpment, knoll, obtained from contour maps.

5.2 Step by step procedure

NOTE. Some worked examples are given in appendix A.

5.2.1 Look at the appropriate wind-driven rain map in appendix B. Find the subregion in which the site is located (indicated by the code adjacent to the symbol $\otimes$). Where the site lies on or close to a boundary between two subregions, the calculation should be done for both subregions and the results averaged.

Find the geographical increment, i , for the site at the proposed wall. These increments are shown between contour lines; if the site lies on a contour line, the larger increment should be used. Increments may be positive or negative.*

5.2.2 Examine the rose for the particular subregion and method (local annual index or local spell index). Each rose gives 12 values corresponding to different orientations. Select the rose value, r , nearest to the orientation of the proposed wall. In case of doubt, take the average rose value.

5.2.3 Add the rose value to the geographical increment to obtain the map value, m .

$$m_A = r_A + i$$

or

$$m_S = r_S + i$$

NOTE. In crossing a subregion boundary either r or i or both may change. This is allowed for by taking the average value of m (see 5.2.1).

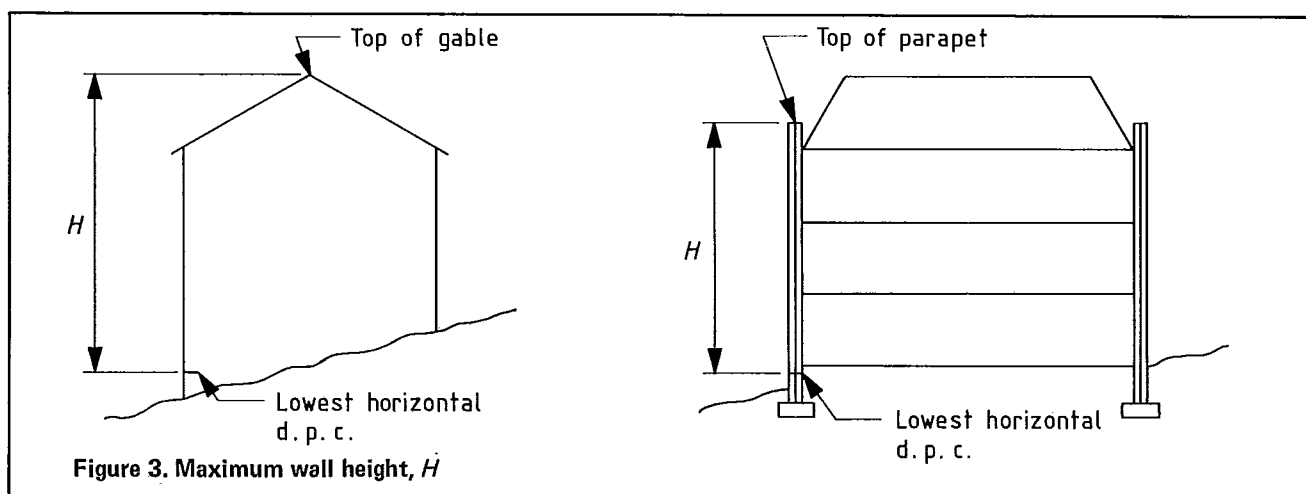
*On the maps values of i are shown in steps of 1 up to 6 and in steps of 2 above 6.

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Location:
Grid reference:
Orientation:
Map subregion:

		Spell index	Annual index
Geographical increment	i		
Rose value	r		
Map value ($i + r$)	m		
'Airfield' index (table 1 or 2)		$D_S =$ L/m ² per spell	$D_A =$ L/m ² per year
Protection category (table 3)			
Maximum wall height (figure 3)	H		
Protection height (table 3)	H_p		
Exposed wall height ($H - H_p$)	H_e		
Ground height correction (normally = 0)	H_g		
Corrected exposed wall height ($H_e + H_g$)	H_{ce}		
Roughness factor (table 4)	R		$R =$
Topography factor (table 5)	T		$T =$
	$T \times R$		
Spell factor (table 6)	S	$S =$	
Local driving rain index	D_L	$D_{LS} = D_S S$ L/m ² per spell	$D_{LA} = D_A R T$ L/m ² per year

Figure 2. Typical worksheet for wind-driven rain calculations



5.2.4 Obtain the 'airfield' index, D_A or D_S , corresponding to the map value from table 1 or 2.

NOTE. The difference in magnitude between 'airfield' annual and spell indices for a given map value reflects the different parameters being assessed (see clause 3).

Table 1. 'Airfield' spell indices

Spell map value, m_S	'Airfield' spell index, D_S	Spell map value, m_S	'Airfield' spell index, D_S
	L/m ² per spell		L/m ² per spell
0	3.1	20	31.7
1	3.5	21	35.6
2	4.0	22	40.0
3	4.5	23	44.9
4	5.0	24	50.4
5	5.6	25	56.6
6	6.3	26	63.5
7	7.1	27	71.3
8	7.9	28	80.0
9	8.9	29	89.8
10	10.0	30	101.0
11	11.2	31	113.0
12	12.6	32	127.0
13	14.1	33	143.0
14	15.9	34	160.0
15	17.8	35	180.0
16	20.0	36	202.0
17	22.4	37	226.0
18	25.2	38	254.0
19	28.3	39	285.0
		40	320.0

NOTE 1. 1 L/m² = 1 mm of rain.

NOTE 2. Values in the table have been calculated using the formula:

$$m_S = 16 + 19.93 \log_{10} (D_S/20)$$

Table 2. 'Airfield' annual indices

Annual map value, m_A	'Airfield' annual index, D_A	Annual map value, m_A	'Airfield' annual index, D_A
	L/m ² per year		L/m ² per year
0	100	20	1010
1	110	21	1130
2	125	22	1270
3	140	23	1425
4	160	24	1600
5	180	25	1795
6	200	26	2015
7	225	27	2265
8	250	28	2540
9	285	29	2850
10	315	30	3200
11	355	31	3590
12	400	32	4030
13	450	33	4525
14	505	34	5080
15	565	35	5700
16	635	36	6400
17	715	37	7185
18	800	38	8065
19	900	39	9050
		40	10160

NOTE 1. 1 L/m² = 1 mm of rain.

NOTE 2. Values in the table have been calculated using the formula:

$$m_A = 6 + 19.93 \log_{10} (D_A/200)$$

5.2.5 Assess the protection category using the information given in table 3. In case of doubt, record both protection categories on the worksheet.

5.2.6 Consider whether the ground facing the proposed wall is sloping more steeply than 1 in 10 within 1 km of the site. (Use contour maps where necessary.) If the slope is 1 in 10 or less steep, no ground height correction is required and the exposed wall height should be calculated as described in 5.2.7. However if the slope is steeper than 1 in 10, proceed as described in 5.2.7 and 5.3.

5.2.7 Calculate the exposed wall height, H_e , using the equation:

$$H_e = H - H_p$$

where

H is the maximum wall height;

H_p is the protection height.

Measure the maximum wall height as shown in figure 3.

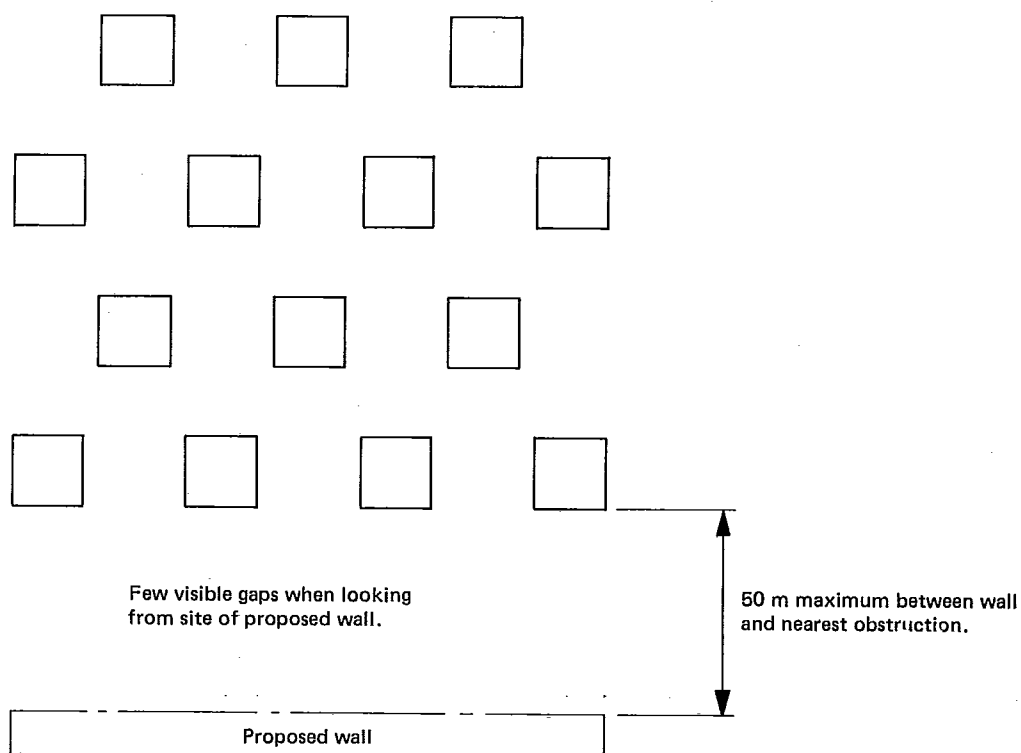
Assess the value of the protection height, H_p , using the protection categories given in table 3. H_p should be taken to be the general height of the surroundings facing the wall.

The maximum wall height may be above or below the general height of the facing obstructions and hence the exposed wall height may be positive or negative.

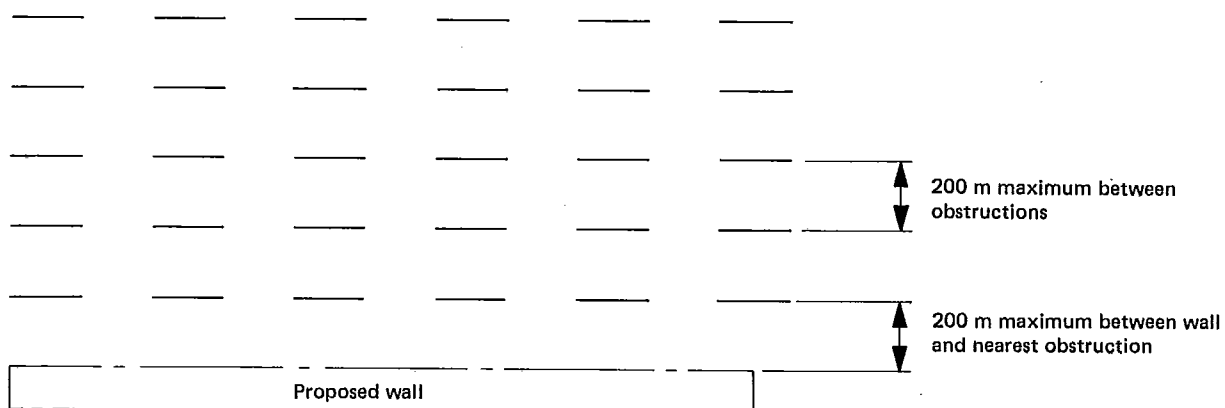
Table 3. Protection categories and values of protection height, H_p

Protection category	Description of terrain	Protection height, H_p
3	Surfaces covered by closely spaced trees or buildings where the proposed wall is no more than 50 m from the nearest obstruction (see figure 4(a)). Examples are well wooded parkland and forest areas, towns and cities. Where a wall is situated within this protection category but is within a distance equal to five times the height of the wall, H_w , or 50 m of a lower protection category, whichever is the greater, the wall should be considered to be within the lower protection category and the protection height for that category should be used.	m 5 or more
2	Flat or undulating country with frequent, low level, closely spaced obstructions*, such as hedges or walls around fields, not more than 200 m apart and where the proposed wall is no more than 200 m from the nearest obstruction (see figure 4(b)). Examples are farmland and country estates. Where the low level obstructions are more than 200 m apart, the protection height should be considered to be that shown for protection category 1.	1 to 5
1	Long stretches of open, level or nearly level, country, with no effective shelter*, which are more than 8 km from a coast or a large estuary. Examples are airfields, fens, moorlands or open farmland with hedges or walls around fields more than 200 m apart.	0 to 1
0	Long stretches of open level or nearly level country with no effective shelter*, which are within 8 km of a coast or a large estuary.	0

*Occasional obstructions, such as trees or buildings do not provide any additional shelter in protection categories 0, 1 and 2.



(a) Protection category 3



(b) Protection category 2

Figure 4. Protection categories 2 and 3

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5.2.8 Obtain the value of the roughness factor, R , for the exposed wall height and protection category from table 4.

In case of doubt, consider both protection categories and either choose one category on the basis of local knowledge or take the average value of R for the two categories.

5.2.9 Use the information given in table 5 and local knowledge to assess whether the local topography has a significant effect on the wind-driven rain value, i.e. T has a value other than 1.0. In case of doubt, take the average value of T for two possible alternatives.

5.2.10 Calculate the local spell index, D_{LS} , in L/m^2 per spell, using the following equation:

$$D_{LS} = D_S S$$

where

D_S is the 'airfield' spell index (from 5.2.4);

S is the spell factor (from table 6, using the values of R and T obtained from 5.2.8 and 5.2.9).

5.2.11 Calculate the local annual index, D_{LA} , in L/m^2 per year, using the following equation:

$$D_{LA} = D_A R T$$

where

D_A is the 'airfield' annual index (from 5.2.4);

R is the roughness factor (from 5.2.8);

T is the topography factor (from 5.2.9).

Table 4. Values of roughness factor, R

Exposed wall height, H_e or H_{ce}	Protection category (see table 3)			
	0	1	2	3
m				
200 to 300*	1.82	1.78	1.76	1.70
150 to 200*	1.72	1.66	1.61	1.54
100 to 150*	1.65	1.58	1.52	1.44
75 to 100*	1.56	1.48	1.39	1.30
50 to 75*	1.50	1.41	1.31	1.22
40 to 50*	1.42	1.31	1.21	1.10
30 to 40*	1.37	1.27	1.15	1.05
25 to 30*	1.32	1.21	1.08	0.98
20 to 25*	1.28	1.17	1.04	0.93
17½ to 20*	1.25	1.13	0.99	0.89
15 to 17½*	1.22	1.10	0.97	0.86
12½ to 15*	1.20	1.07	0.94	0.83
10 to 12½*	1.17	1.04	0.90	0.79
7½ to 10*	1.13	1.00	0.86	0.75
5 to 7½*	1.07	0.94	0.80	0.72
2½ to 5*	1.00	0.88	0.74	0.69
0 to 2½*	0.94	0.83	0.68	0.65
-2½ to 0*	—	—	—	0.62
-5 to -2½*	—	—	—	0.58
-7½ to -5*	—	—	—	0.56
-10 to -7½*	—	—	—	0.54
-12½ to -10*	—	—	—	0.52
-15 to -12½*	—	—	—	0.50
-17½ to -15*	—	—	—	0.47
-20 to -17½*	—	—	—	0.45
-20	—	—	—	0.42

*The range in each row includes the higher value but not the lower.

Table 5. Values of topography factor, T		
Description of topography	Topography factor, T	Remarks
Valley or grouping(s) of buildings liable to produce a funnelling of the wind	1.2	
Steep sided, enclosed valleys known to be sheltered from the wind	0.8	Such situations are very rare.
All other cases	1.0	For effect of local ground height, see 5.3.

Table 6. Values of spell factor, S	
Values of RT	S
1.9 to 2.1*	2.25
1.7 to 1.9*	1.98
1.5 to 1.7*	1.73
1.35 to 1.5*	1.54
1.25 to 1.35*	1.37
1.15 to 1.25*	1.25
1.05 to 1.15*	1.12
0.95 to 1.05*	1.00
0.85 to 0.95*	0.89
0.75 to 0.85*	0.76
0.65 to 0.75*	0.63
0.55 to 0.65*	0.47
0.45 to 0.55*	0.32
0.35 to 0.45*	0.18
*The range shown includes the higher value but not the lower.	

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5.3 Ground height correction

NOTE 1. The recommendations in this subclause are intended to reflect only those changes in ground height which could not be taken into account when preparing the wind-driven rain maps, i.e. changes within approximately 1 km of the site. They are of necessity general in nature and do not purport to represent fully the effect of wind speed changes over complex terrain.

NOTE 2. In some cases the results obtained following the procedure described in this subclause may be conservative, for example in sheltered areas at the foot of a very steep hill.

If any part of the slope in the direction from which winds will approach the proposed wall is steeper than 1 in 10 within approximately 1 km of the site, the exposed wall height given in 5.2.7 should be corrected by adding the local ground height, H_g , determined from figures 5(a), 5(b) or 5(c) as appropriate.

When using these figures, the following points should be considered:

(a) A is the point upwind of which all the land within approximately 1 km of the site is level or has a downward slope of 1 in 10 or less.

(b) B is the point downwind of which all the land within approximately 1 km of the site is level or has an upward slope of 1 in 10 or less. C is a point downwind of B at a horizontal distance Z' and D is a point downwind of C at a horizontal distance $3Z'$.

For cases where the land begins to slope downwards between B and C, take $H_g = Z' - 0.1a'$ from B to the point where the downward slope begins and $H_g = 0$ downwind of this point. (Figure 5c shows the downward slope starting at C.)

For cases where the land begins to slope downwards between C and D, interpolate as shown in figures 5(a) and 5(b) from C to the point where the downward slope begins and take $H_g = 0$ downwind of this point.



Appendix A. Worked examples

A.1 Map values

A.1.1 General

In each of the examples given in A.1.2 to A.1.4, map values are calculated for a south facing wall.

A.1.2 Centre of subregion

Consider Brighton on map 3.

The subregion is PH1 (see 5.2.1). The spell and annual rose values are $r_s = 26$ and $r_A = 15$ (see 5.2.2). The geographical increment, $i = +1$ (see 5.2.1). Hence the spell and annual map values are $m_s = 27$ and $m_A = 16$ (see 5.2.3).

A.1.3 Boundary between two subregions

Consider a place at grid reference ²790 ⁶880 (south of Stirling) on map 12.

Calculate the map values for both subregions as follows:

subregion	ED3	ED7
geographical increment, i	+5	+5
spell rose value, r_s	18	20
spell map value, m_s	<u>23</u>	<u>25</u>

The average map value of 24 should be used (see 5.2.1).

NOTE. The geographical increment is the same on both sides of the boundary (compare with A.1.4).

A.1.4 Meeting point of four boundaries

Consider a place at grid reference ⁴620 ¹765, just west of Pangbourne (see maps 2, 3 and 5). Calculate the map value for all four subregions, as follows:

subregion	HW1	LN1	OX1	SY7
geographical increment, i	+1	+1	+1	-2
spell rose value, r_s	21	21	21	25
spell map value, m_s	<u>22</u>	<u>22</u>	<u>22</u>	<u>23</u>

The average map value of 22.25, rounded down to 22, should be used (see 5.2.1).

NOTE. Both the geographical increments and the rose values vary when crossing one boundary (compare with A.1.3).

A.2 Protection categories

Consider the imaginary estate road shown in figure 6.

The protection categories for the wall of each house facing the road are as given in table 7.

Table 7. Examples of protection categories for a wall

House	Protection category	Remarks
A	3	See figure 4(a)
B	2	See figure 4(b)
C	2/1	Roughness factors to be averaged (see 5.2.8)
D	1	Sheds do not provide additional shelter (see footnote to table 3)

A.3 Simple worked example showing effect of orientation of wall

Consider the north and south walls of a building on the sea front at Hove, Sussex, National Grid reference ⁵290 ¹044 (see map 3).

Both, to the north and south of the site the ground is fairly level. Thus the topography factor for both directions is 1.0 (see table 5).

Looking from the building in a northerly direction, only buildings of general height 10 m can be seen. Thus the protection category for this direction is 3 and the protection height is 10 m (see table 3 and figure 4(a)). Looking from the building in a southerly direction, only the sea can be seen. Thus the protection category for this direction is 0 and the protection height is 0 m (see table 3).

The height of the walls is 10 m.

The local spell and local annual indices for north and south walls can now be assessed as shown on the worksheet in figure 7(a).

NOTE. The orientation of a wall affects both the protection category and the rose value.

A.4 Simple worked example showing effect of abrupt change in local ground height

Consider a building on the coast near Swanage, Dorset, National Grid reference ⁴036 ⁰784 (see map 2). The front wall faces south east and is 5 m in height.

Looking towards the south east, it can be seen that the building is near the top of an escarpment. A study of the 1:25000 Ordnance Survey map for the area shows that the height of the escarpment above sea level is 30.5 m but it is difficult to determine the average slope. However, local knowledge indicates a value of approximately 2 in 1. Other than the escarpment the terrain (mostly sea) is generally level. Hence the topography factor is 1.0 and the local ground height should be calculated using figure 5(a).

$$\begin{aligned}
 H_g &= Z' - 0.1a' \\
 &= 30.5 - 0.1 \times 15.25 \text{ m} \\
 &= 29.0 \text{ m}
 \end{aligned}$$

Looking in the same direction, only the sea can be seen. Thus the protection category for this direction is 0 (see table 3).

The local spell and annual index for the front wall of the building can now be assessed as shown on the worksheet in figure 7(b), taking the average rose value (see 5.2.2).

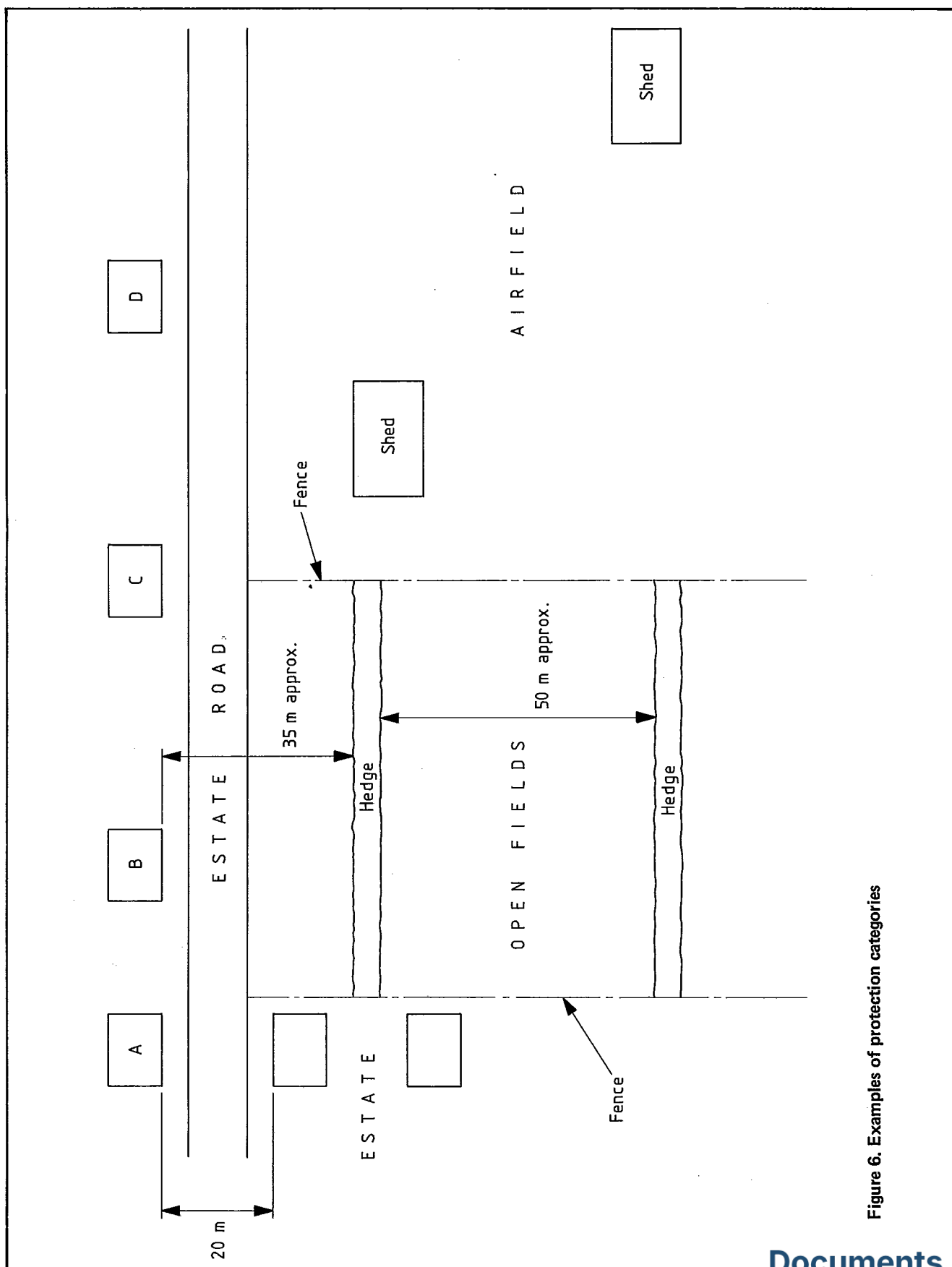


Figure 6. Examples of protection categories

Location: Hove, Sussex
 Grid reference: $5290^1 044$
 Orientation: N/S = $0^\circ/180^\circ$
 Map subregion: PH1

		Spell index	Annual index
Geographical increment	i	+1	+1
Rose value	r	15/26	2/15
Map value ($i + r$)	m	16/27	3/16
'Airfield' index (table 1 or 2)		$D_S = 20.0/71.3$ L/m ² per spell	$D_A = 140/635$ L/m ² per year
Protection category (table 3)		3/0	3/0
Maximum wall height (figure 3)	H	10 m	10 m
Protection height (table 3)	H_p	10/0 m	10/0 m
Exposed wall height ($H - H_p$)	H_e	0/10 m	0/10 m
Ground height correction (normally = 0)	H_g	0 m	0 m
Corrected exposed wall height ($H_e + H_g$)	H_{ce}	0/10 m	0/10 m
Roughness factor (table 4)	R		$R = 0.62/1.13$
Topography factor (table 5)	T		$T = 1.0$
	$T \times R$	0.62/1.13	
Spell factor (table 6)	S	$S = 0.47/1.12$	
Local driving rain index	D_L	$D_{LS} = D_S S$ $= 9.4/79.9$ L/m ² per spell	$D_{LA} = D_A R T$ $= 86.8/717.5$ L/m ² per year

(a) Example described in A.3.

Figure 7. Worksheets for worked examples

Location: Near Swanage, Dorset
 Grid reference: 4036⁰784
 Orientation: SE = 135°
 Map subregion: SY3

		Spell index		Annual index	
Geographical increment	<i>i</i>	0		0	
Rose value	<i>r</i>	24		13	
Map value (<i>i</i> + <i>r</i>)	<i>m</i>	24		13	
'Airfield' index (table 1 or 2)			$D_S = 50.4$ L/m ² per spell		$D_A = 450$ L/m ² per year
Protection category (table 3)		0		0	
Maximum wall height (figure 3)	<i>H</i>	5 m		5 m	
Protection height (table 3)	<i>H_p</i>	0 m		0 m	
Exposed wall height (<i>H</i> - <i>H_p</i>)	<i>H_e</i>	5 m		5 m	
Ground height correction (normally = 0)	<i>H_g</i>	29.0 m		29.0 m	
Corrected exposed wall height (<i>H_e</i> + <i>H_g</i>)	<i>H_{ce}</i>	34.0 m		34.0 m	
Roughness factor (table 4)	<i>R</i>			$R = 1.37$	
Topography factor (table 5)	<i>T</i>			$T = 1.0$	
	$T \times R$	1.37			
Spell factor (table 6)	<i>S</i>		$S = 1.54$		
Local driving rain index	<i>D_L</i>	$D_{LS} = D_S S$ $= 77.6$ L/m ² per spell		$D_{LA} = D_A R T$ $= 616.5$ L/m ² per year	

(b) Example described in A.4.

Figure 7. Worksheets for worked examples

A.5 Complex worked examples

A.5.1 Truleigh Hill (edge of a steeply sloping escarpment)

The details of the proposed wall and a general description of the site are as given in (a) to (d).

- (a) The location of the proposed wall is Truleigh Hill, Sussex, National Grid reference $5226^1 108$.
- (b) The orientation of the proposed wall is facing north along easting 226.
- (c) The maximum height of the proposed wall is 7.5 m.
- (d) The general description of the site is given in (1) and (2) as follows.

(1) *Topography*. Looking to the north, it can be seen that the site is on a hill crest rising well above the general level of the surrounding terrain.

(2) *Protection category*. Looking from the site in a northerly direction, occasional hedges about 1 m high and a few trees can be seen. However, the hedges are spaced more than 200 m apart.

Looking at the wind-driven rain map for the area (map 3), it will be seen that the relevant rose is GK1 and the geographical increment at the particular point on the map is +2.

$$\begin{aligned} m_S &= r_S + i \\ &= 16 + 2 \\ &= 18 \end{aligned}$$

or

$$\begin{aligned} m_A &= r_A + i \\ &= 3 + 2 \\ &= 5 \end{aligned}$$

To calculate the local ground height, H_g , it is necessary to determine whether any part of the northern slope of Truleigh Hill is steeper than 1 in 10 (see 5.3).

A study of the 1:25000 Ordnance Survey map for the area (see figure 8(a)) shows the contour lines to be very closely spaced, so it is necessary to prepare a profile or side elevation view of the land form. For convenience this may be drawn to a vertical scale ten times the horizontal scale (see figure 8(b)).

The slope of the land between various points can then be determined (see table 8).

Table 8. Slopes (Truleigh Hill, Sussex)

Slope between	Actual value
1 and 2	1 in 29
2 and 3	1 in 10
3 and 4	1 in 3
4 and 5	1 in 5
5 and 6	1 in 22

From table 8 and figure 8(b) it will be seen that the slope is 1 in 10 or less below point 3 and that point 3 coincides with point A in figure 5(a).

Using the formulae given in figure 5(c), values of H_g for a building at various points along the slope of Truleigh Hill are shown in column 1 of table 9. The corresponding values of H_{ce} , RT and S are shown in columns 3, 4 and 5.

The complete list of local wind-driven rain indices for the different points along the slope at Truleigh Hill are given in columns 6 and 7 of table 9.

Table 9. Local wind-driven rain indices (Truleigh hill, Sussex)

1	2	3	4	5	6	7	8
Location of proposed wall (See figure 8(b))	H_g	H_{ce}	RT	S	D_{LS}	D_{LA}	Remarks
	m	m			L/m ² per spell	L/m ² per year	
1	0	6.5	0.94	0.89	22.4	169.2	
2	0	6.5	0.94	0.89	22.4	169.2	
3	0	6.5	0.94	0.89	22.4	169.2	
4	80.5	87.0	1.48	1.54	38.8	266.4	$H_g = Z - 0.1a = 113 - 32.5 = 80.5$
5	95.0	101.5	1.58	1.73	43.6	284.4	$H_g = Z' - 0.1a' = 142.5 - 47.5 = 95.0$
6	95.0	101.5	1.58	1.73	43.6	284.4	Within Z' of point 5 $H_g = Z' - 0.1a' = 95.0$

NOTE. The only altitude changes which need to be considered are those between point C, upwind of which all the land within 1 km has a slope of 1 in 10 or less, and point A, downwind of which all the land within 1 km has a slope of 1 in 10 or less.