Appendix D: Extreme wind climates – a world survey

In this appendix, an attempt has been made to describe the general type of extreme wind climate, and to catalogue reliable design wind speed information available from many countries in the world. Classification is done on a national basis, although of course extreme wind climates do not follow national boundaries. For small countries without wind loading standards, or building codes with wind loading information, it would be appropriate to use information from neighbouring countries.

It should be noted that wind loading codes and standards are constantly under revision, and the values of design wind speed, zoning systems, etc., given in this appendix may change periodically.

D1 Severe wind strength classification system

There have been cases where major errors have been made in the general level of design wind speeds used for a particular country or region, by engineers from other parts of the world. This is most likely to happen in the tropical and equatorial regions, where the interface between very severe winds produced by tropical cyclones (typhoons, hurricanes), and the low extreme winds near the Equator where tropical cyclones do not occur, may not be clearly defined. It is very useful to have a general idea of the level of design wind speeds in a country or parts of a large country. This information may in fact be sufficient for the design of small buildings, and less important structures such as signs or poles.

Table D1 presents a simple classification system, which can be used to 'grade' any country or region in terms of its general level of wind speed. Nothing is stated in this Table with regard to the type of windstorm that is dominant in a country. A dominant storm type in one country can produce similar extreme value statistics to another storm type in a different country. Note that for some storm types, such as downbursts generated by thunderstorms, the 3-second gust may be a more relevant indicator than the 10-min mean.

Table D1 A classification system for design wind speeds (50 year return period wind speeds at 10 m height)

Level	*3-second gust (m/s)*	*10-min mean (m/s)*
I	<35	<22
II	35–45	22–30
III	45–55	30–35
IV	55–65	35–40
V	>65	>40

D2 Country by country survey

Unless stated otherwise, all design wind data in the following are referred to a 10–m height, in flat, open country, terrain.

D2.1 Antigua (see Leeward Islands)

D2.2 Argentina

Argentina is a large country and is affected by a range of different types of windstorms, although tropical cyclones do not occur. Large extratropical depressions are the dominant winds in the south (Patagonia and Tierra del Fuego). In the north east (Cordoba region), the dominant winds are caused by severe thunderstorms; tornadoes and downbursts ('tormentas') have caused failures of several high voltage transmission lines. Downslope and 'fonda' winds with severe gustiness occur in the Andes.

Early extreme value analyses (Riera and Reimundin, 1970; Viollaz *et al*., 1975) used the Frechet (Type II) Extreme Value Distribution to fit data from 63 stations in Argentina. This distribution (Section 2.2.1) is known to give excessively conservative predictions at high return periods. More recent extreme value analysis, based on the Gumbel distribution, for six stations in the north east of the country, gave 50-year return period gusts of 44 to 47 m/s. Thunderstorm winds were dominant in these records (de Schwarzkopf, 1995). *Extreme wind classifications: II, III.*

D2.3 Australia

This large continental country has a variety of severe wind types with large extratropical gales along the south coast and Tasmania moving from the west, and 'East Coast lows' in the Tasman Sea affecting the eastern coastline. Thunderstorm-generated downbursts originating from local convection are the dominant windstorms in the interior. The strongest recorded winds, at 10 m height, in the four major capitals of Sydney, Melbourne, Adelaide and Brisbane are also caused by local downbursts from thunderstorms. Severe tropical cyclones can affect the coastline within about 100 km from the sea between 25° S and 10° S latitudes. The most common and most severe occur on the west coast between 20° S and 25° S.

Analyses of extreme wind speeds for Australia have been carried out by Whittingham (1964), Gomes and Vickery (1976a and 1976b), Dorman (1983), and Holmes (unpublished). Wind speeds for structural design are given in Australian Standard AS1170.2 (Standards Australia, 1989). Four regions are defined; these are labelled from A to D with increasing basic design wind speeds. Regions C to D are considered dominated by severe to very severe tropical cyclones. In Region B (covering Brisbane), and the tropical coastal strip between 50 and 100 km inland, weaker tropical cyclones can occur (Table D2).

Table D2 Australia

Region	*Description*	*Classification*
A	Thunderstorm downbursts and synoptic winds (gales)	II
B	Weakening tropical cyclones	III
C	Moderately severe to severe tropical cyclones	IV
D	Severe tropical cyclones	V

D2.4 Austria

No values are specified in the draft Eurocode (C.E.N., 1994). However wind climate should be similar to southern Germany and Switzerland. *Extreme wind classification: II.*

D2.5 Barbados (see Windward Islands)

D2.6 Belgium

The draft Eurocode (C.E.N., 1994) specifies a single value of 10-min mean wind speed with a 50 year return period, of 26.2 m/s. *Extreme wind classification: II.*

D2.7 Belize

Belize in Central America experiences severe winds from hurricanes. Analysis of extreme wind speeds for the Commonwealth Caribbean, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986). This code specifies a 50-year return period 10-min mean wind speed of 36 m/s for the north of the country, and 30.5 m/s for the south. *Extreme wind classifications: IV (north); III (south).*

D2.8 Brazil

In Brazil, extreme winds are produced by a mixture of large extratropical depression systems, and local thunderstorm downdrafts (Riera and Nanni, 1989). However, the coastline of the South Atlantic does not experience tropical cyclones. Salgado Vieira Filho (1975) carried out extreme value analyses of wind speeds for forty-nine Brazilian stations, but used the conservative Frechet distribution for predictions, and apparently the data were not separated by storm type. More recent analyses by Riera and Nanni (1989) indicate that the thunderstorm winds are dominant in most locations. Jeary (1997b) lists 10 years of recorded wind speeds (from 3 m height) for three stations in Rio de Janeiro. The Brazilian wind loading code (NBR-6123, 1987) gives isotachs of 3-second gust speeds with 50-year return period varying from 30 m/s (north half of country) to 50 m/s (extreme south). *Extreme wind classifications: I (north of 20º); II (south central); III (extreme south).*

D2.9 Canada

Extreme winds in Canada are primarily generated by large scale synoptic systems, and surface extreme winds can be quite well predicted from gradient wind observations (Davenport and Baynes, 1972). An appendix to the National Building Code of Canada (NRC 1995) gives values of dynamic pressures. The equivalent hourly mean wind speeds with a 30-year return period range from 24 to 28 m/s in the main populated area around the Great Lakes (including Toronto, Montreal and Ottawa), to 30 to 35 m/s in Newfoundland, and in the Hudson's Bay area. *Extreme wind classifications: III (Newfoundland and north); II (rest of Canada).*

D2.10 China (including Taiwan)

China is a large country with a range of extreme wind types ranging from severe gales arising from synoptic systems in Siberia in the north-west, to typhoons along the southern coastline (Table D3). There is a region with downslope winds.

There is a combined loading code published by the Department of Standards and Norms, Ministry of Construction, which includes a wind loading section. This is also available as an English translation (GBJ-9 – Department of Standards and Norms, 1994). A map is included with this standard which gives contours of dynamic pressure in kN/m^2 (kPa). The standard states that the 'wind reference pressure' is calculated from the 10-min mean wind speed at 10 m height by the formula, $w_o = v_o^2\ /1600$. These values have a 50 year return period (recently revised from 30-year return period). Values of dynamic pressure on these contours range from 0.30 kPa to 0.90 kPa. For most of the country, the values are in the range 0.30 to 0.50 kPa.

D2.11 Denmark

Wind speed observations have been made in Denmark since the 1870s. The dominant source of extreme winds in Denmark is severe extratropical depressions moving in from the north Atlantic Ocean. Extreme value analyses of extreme wind speeds have been made by Jensen and Franck (1970) and several others.

The draft Eurocode (C.E.N., 1994) specifies a single value of 10-min mean wind speed with a 50-year return period, for Denmark, of 27.0 m/s. *Extreme wind classification: II.*

D2.12 Fiji

The Fijian islands are subject to periodic visits from tropical cyclones. *Extreme wind classification: IV.*

D2.13 Finland

The draft Eurocode (C.E.N., 1994) specifies a single value of 10-min mean wind speed with a 50-year return period, for Finland, of 23 m/s. *Extreme wind classification: II.*

D2.14 France

Like other Western European countries, the extreme wind climate of France is dominated by synoptic gales from large depression systems moving in from the Atlantic Ocean.

Table D3 China

Region	*Description*	*Classification*
Central mainland	Pressure contours from 0.30 to 0.50 kPa	II
North west and inner southern coast	Pressure contours from 0.60 to 0.70 kPa	III
Outer southern coast and islands, Hainan	Pressure contours from 0.80 to 0.90 kPa	IV
Taiwan	Severe tropical cyclones	V

The draft Eurocode (C.E.N., 1994) specifies four values of 10-min mean wind speed with a 50-year return period, for four zones in metropolitan France, ranging from 24 to 30.5 m/s. The highest values occur for zone 4, which includes parts of Brittany and Normandy, the Mediterranean coastline, and Eastern Corsica. *Extreme wind classification: (Zones 1 to 3): II Zone 4: III.*

D2.15 French Caribbean (see also Leeward and Windward Islands)

The draft Eurocode (C.E.N., 1994) specifies a value of 10-min mean wind speed with a 50-year return period, of 34 m/s, for the French territories of Guadeloupe and Martinique in the southern Caribbean, These territories experience visits from hurricanes, although apparently less frequently than the islands of the northern Caribbean. *Extreme wind classification: III (Martinique); IV (Guadeloupe).*

D2.16 Germany

The draft Eurocode ENV-1991-2-4 gives a map with a system of four zones. The highest wind speed zone, 3, is on the North Sea coast (Table D4). The main source of strong winds are gales accompanying large scale depressions moving into Germany from the west. The zone system given differs from an earlier zoning system for the Federal Republic (West Germany) by Caspar (1970).

Analyses by Schueller and Panggabean (1976) for stations in West Germany gave distributions for gust speeds, which give 50-year return period values between 35 and 50 m/s. An exception was Feldberg with 60 m/s; this is a mountain station, with topographic influences.

D2.17 Greece

The draft Eurocode ENV-1991-2-4 specifies a 50-year return period 10-min mean windspeed for Greece, of 36 m/s for the islands and coastal areas of the mainland within 10 km of the coastline. For the rest of the country, the value is 30 m/s. *Extreme wind classification: III.*

D2.18 Guam (U.S.)

This Pacific Island has experienced some of the strongest recorded tropical cyclones. The ASCE-7 Loading Standard specifies a 50-year return period gust speed of 76 m/s. *Extreme wind classification: V.*

Table D4 Germany

Zone	*Description*	*Classification*
1	Southern Germany	II
2	Northern Germany	II
3	North Sea coast	III
4		III

D2.19 Guyana

This country has an equatorial climate with low wind speeds. Analysis of extreme wind speeds for the Commonwealth Caribeena, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986) and by the Code of Practice of the Barbados Association of Professional Engineers (1981). The former specifies a 50-year return period 10-min mean speed of 18 m/s, and the latter gives a 50-year return period 3-second gust speed of 22 m/s. *Extreme wind classification: I.*

D2.20 Hong Kong and Macau

As for the rest of the south China coastline, Hong Kong and Macau are subjected to frequent visits from moderate to severe typhoons. Hong Kong has good quality recorded wind speed data extending more than a hundred years from 1884 to 1957, from the Royal Hong Kong Observatory, and since 1957, from Waglan Island. Analyses of extreme winds from typhoons has been carried out by a number of authors including Faber and Bell (1967), Chen (1975), Davenport *et al.* (1984), and Melbourne (1984), as reviewed by Jeary (1997a). Most of these studies have normalised the wind speeds to a height of 50 m, rather than 10 m. Design wind speeds in Hong Kong and Macau are set by the respective building departments.

The Hong Kong Code of Practice (Building Development Department, 1983) implies a 50-year return period 3-second gust wind speed at 50 m height of 68 m/s. This compares with the values obtained by Chen (1975) of 70.5 m/s using annual maxima, and by Melbourne (1984) of 63.5 m/s, using only recorded typhoon data; both used the Type I (Gumbel) Extreme Value Distribution. Lower values are obtained if the Generalized Extreme Value Distribution is used to fit the typhoon data. *Extreme wind classification: IV.*

D2.21 Iceland

Iceland is subject to Atlantic gales. The draft Eurocode ENV-1991-2-4 specifies a 50-year return period 10 minute mean at 10-m height, of 39 m/s for coastal areas within 10 km of the coastline. For inland areas, the value is 36 m/s. *Extreme wind classification: II.*

D2.22 India

India, a large subcontinental tropical country, has a range of extreme wind zones (Table D5), with extreme tropical cyclones being dominant on the east (Bay of Bengal) coast,

Table D5 India (refer to map in IS 875: Part 3, for details of zones)

Zone	*Description*	*Classification*
1	Tripura, Mizoram, Ladakh	IV
2	Coastal strips of Tamil Nadu (including Madras), Andhra Pradesh, Orissa, Guiarat, West Bengal (including Calcutta), Assam	III
3	Northern India including Delhi, central Tamil Nadu	III
4	Coastal strip on Arabian Sea, including Bombay, inland Madya Pradesh, Orissa	II
5	Most of southern India	II
6	Inland Karnataka, including Bangalore	I

and less frequent ones on the west coast. In inland areas, thunderstorms and monsoon winds are prevalent.

India has a good network of meteorological stations, and there have been a number of extreme value analyses of wind speeds summarised by Sharma *et al.* (1995). The Indian Standard for Wind Loads IS875 Part 3 (Bureau of Indian Standards, 1987) divides the country into six zones, giving 50-year return period gust wind speeds ranging from 33 m/s to 55 m/s.

D2.23 Indonesia

Like Malaysia and Singapore, Indonesia is entirely in the Equatorial zone, does not experience typhoons, and design wind speeds from weak thunderstorms and monsoonal winds are low. *Extreme wind classification: I.*

D2.24 Ireland

Ireland is a small island nation exposed to severe Atlantic gales on its west coast. A map showing contours of extreme wind speeds for Ireland appears in the British Code of Practice (British Standards Institution, 1997). The map in the draft Eurocode (C.E.N., 1994) has higher values, although nominally also 10-min mean wind speeds with a 50-year return period. The values in the British Standard are believed to be more reliable. *Extreme wind classification: II.*

D2.25 Italy

Italy is divided into nine zones (Table D6) with five basic wind speeds in the draft Eurocode (C.E.N., 1994). These are 10-min mean speeds with 50-year return period ranging from 25 to 31 m/s.

D2.26 Jamaica

Jamaica is in a region of hurricane formation in the Caribbean, and experiences severe winds from these events. Analysis of extreme wind speeds for the Commonwealth Caribbean, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986) and by the Code of Practice of the Barbados Association of Professional Engineers (1981). The former specifies a 50-year return period 10-min mean wind speed of 36.5 m/s, and the latter a 56 m/s peak gust. *Extreme wind classification: IV.*

Table D6 Italy (refer to map in ENV 1991-2-4, for details of zones)

Zones	*Description*	*Classification*
1, 2	Northern Italy (25 m/s)	II
3	Central and southern Italy (27 m/s)	II
4, 5, 6	Sardinia and Sicily (28 m/s)	II
7	Liguria (29 m/s)	II
8, 9	Trieste and islands (31 m/s)	III

D2.27 Japan

Japan is subject to typhoons from the Pacific in Kyushu and Okinawa, and temperate synoptic systems in the north of the country. The Architectural Institute of Japan has a contour map of design wind speeds (10-min mean, 100-year return period) in its wind load recommendations. Values range from 26 m/s to 44 m/s on the main islands, to 50 m/s on Okinawa which is subject to frequent severe typhoons. *Extreme wind classifications: II, III, IV, V.*

D2.28 Korea

The coastline of South Korea has some influence from typhoons on the south and east coasts and the island of Cheju, but these are relatively infrequent.

The Architectural Institute of Korea has a map of 10-min mean 100-year return period wind speeds varying from 25 m/s in the inland centre to 40 m/s at some points on the eastern and southern coastline. Seoul is specified as 30 m/s. *Extreme wind classifications: II, III, IV.*

D2.29 Leeward Islands

This group of islands is affected by hurricanes in the Caribbean. Analysis of extreme wind speeds for Commonwealth countries in the Caribbean, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986) and by the Code of Practice of the Barbados Association of Professional Engineers (1981). The latter specifies a 50-year return period 3-second gust speed of 64 m/s, based on the studies for Antigua. This value is also applicable to St Kitts-Nevis, Montserrat and the Virgin Islands. *Extreme wind classification: IV.*

D2.30 Luxembourg

The draft Eurocode (C.E.N., 1994) specifies a single value of 10-min mean wind speed with a 50-year return period, of 26 m/s. *Extreme wind classification: II.*

D2.31 Madagascar

No direct information is available, but the eastern coast can be assumed to have a similar extreme wind climate to Reunion Island, and Mauritius. *Extreme wind classification: III.*

D2.32 Malaysia

Malaysia is entirely in the Equatorial zone, does not experience typhoons, and has very low extreme winds from weak thunderstorms and monsoonal winds. Monthly maximum wind data are available from more than 30 stations in the country, including Miri and Kuching in East Malaysia (Sarawak).

Analysis of these data for 50-year return period gust values for 20 stations by the Malaysian Meteorological Service gave values between 24 and 32 m/s. There is evidence of higher wind speeds in the highland stations away from the coastal plains. *Extreme wind classification: I.*

D2.33 Mauritius

Like neighbouring Reunion, Mauritius in the Indian Ocean experiences land fall from a tropical cyclone about once every 5 years (Sites and Peterson, 1995). *Extreme wind classification: III.*

D2.34 Mexico

Mexico experiences extreme winds from hurricanes on both its Pacific and Caribbean coasts. For inland areas, thunderstorms are dominant. Extreme value analyses were carried out by Vilar *et al.* (1991), (also Lopez and Vilar, 1995), for the Mexican Electrical Utility (CFE) using the Generalized Extreme Value Distribution, for data from 57 stations. An isotach map resulting from this study shows 50-year return period 3-second gusts ranging widely from 28 m/s in the Mexico City area to 61 m/s on the Pacific coast.

Table D7 is not official, but describes zones based on the isotach map.

D2.35 Netherlands

The Netherlands is exposed to gales from the North Sea on the coast. The draft Eurocode ENV-1991-2-4 specifies three 'areas' with 50-year return period 10-min wind speeds, of 25, 27.5, 30 m/s. Amsterdam and Rotterdam are in Area 2 (27.5 m/s). *Extreme wind classification: II.*

D2.36 New Zealand

The main extreme winds in New Zealand are temperate synoptic systems, although the north of the country can experience the effects of decaying tropical cyclones. The map of basic wind speeds in the New Zealand Code of Practice (Standards New Zealand, 1992) shows seven wind regions. These have similar all-directional basic wind speeds (1000 year return period gusts) ranging between 43 and 48 m/s, but differ in their directional wind speeds. There are a number of mountain areas, especially in the South Island, where downslope winds occur – for these the wind speed is increased by a 'Lee Multiplier' of up to 1.35. *Extreme wind classifications: II, III (some mountain areas).*

D2.37 Norway

The draft Eurocode, ENV-1991-2-4, specifies several wind velocity profiles of 3–5 second gust wind speeds, which incorporate terrain effects as well as height variation. Two of these curves, E and F, incorporate gust speeds at 10 m height in open terrain of 45 m/s

Table D7 Mexico

Description	*Classification*
South of 24ºS excluding coastline	I
North of 24ºS excluding coastline	II
Within 50 km of Caribbean coast 50–100 km from Pacific coast	III
Within 50 km of Pacific coast	IV

and 50 m/s, respectively. Curves A and B correspond to 35 m/s and 40 m/s, respectively. (Curves C and D apply to built up areas, corresponding to open country exposure for Curves A and B, respectively.) *Extreme wind classifications: II (A and B); III (E and F).*

D2.38 Papua-New Guinea

The majority of Papua-New Guinea (including Port Moresby) is in the equatorial zone, and the design winds, originating from thunderstorms produced by local convective activity, are quite low. An extreme value (Gumbel) analysis for Port Moresby by Whittingham (1964) using only 11 years of data, gives a 50-year return period gust of 31 m/s. The addition of some extra years gives even lower values. The P-NG loading code gives a contour map with 50-year return period gust wind speeds ranging from 24 to 32 m/s. For the south-west tip 40 m/s is specified. Values for major centres are: Port Moresby 28 m/s, Lae 23 m/s, Rabaul 26 m/s. 34 m/s is specified for Honiara (Solomons).

The islands on the south west are occasionally exposed to developing Coral Sea cyclones, and should have higher design wind speeds. *Extreme wind classifications: I (most of country), II (south-west tip).*

D2.39 Philippines

The Philippines experiences typhoons from the south-west Pacific Ocean, which often cross the northern Philippines (Luzon) and reform in the south China sea. On the other hand, the southern island of Mindanao has little or no influence from typhoons, and effectively has an equatorial extreme wind climate. An extreme value analysis of 1-min average extreme wind speeds in the Philippines was carried out in the early 1970s by Kintenar (1971). This gave widely ranging 50-year return period values, and probably suffers from sampling errors due to short records.

The National Structural Code of the Philippines specifies three extreme wind zones with 1-min sustained wind speeds of 200 kph (55.5 m/s), 175 kph (48.6 m/s) and 150 kph (41.7 m/s), respectively. These values have been used for Table D8 below, but are probably conservative for Mindanao.

D2.40 Poland

The Polish wind loading standard PN-77/B-02011 gives 'characteristic' wind speeds of 20, 24, 27 and 30 m/s for four zones. In the largest zone, 20 m/s is specified. These values are 10 minute mean wind speeds, with a return period of 50 years. *Extreme wind classification: II, III.*

Table D8 Philippines

Zone in structural code	*Description*	*Classification*
I	Eastern Luzon	V
II	Remainder of Philippines	IV
III	western Mindanao, Palawan	III

D2.41 Portugal

The draft Eurocode (C.E.N., 1994) specifies a value of 10-min mean wind speed with a 50-year return period, of 31 m/s, for the Azores, Madeira, and the 5 km coastal strip of the mainland; 28 m/s is specified for the rest of the country. *Extreme wind classification: II, III.*

D2.42 Puerto Rico

As for other Caribbean islands, Puerto Rico is subjected to hurricane winds. The ASCE Standard (A.S.C.E., 1998) gives a basic design wind speed (3-second gust with 50-year return period) of 56 m/s. *Extreme wind classification: IV.*

D2.43 Reunion I (France)

This small island in the southern Indian Ocean has a design wind speed (10 min mean, 50-year return period) of 34.0 m/s specified in the draft Eurocode (C.E.N., 1994). According to Sites and Peterson (1995), Reunion experiences landfall of a tropical cyclone about once every 5 years. *Extreme wind classification: III.*

D2.44 Romania

The Romanian Standard STAS 10101/20-78 on Actions on Structures specifies five zones for design wind pressures. These pressures correspond to peak gust wind speeds (10-year return period) ranging from 27 m/s to 37 m/s. *Extreme wind classification: I, II.*

D2.45 Russia

Russia has a vast land area, with a range of extreme wind climates. The Russian loading SniP 2.01.07.85 specifies eight zones for design wind pressures. The specified values are 5-year return pressures with a 10-min averaging time, and range from 240 Pa for the central part of the country to 1200 Pa on the coastal part of the Far East, and the islands of the Barents Sea (Popov, 2001). *Extreme wind classification: II, III, IV, V.*

D2.46 Singapore

Like Malaysia, Singapore in the Equatorial zone, does not experience typhoons, and has very low extreme winds from weak thunderstorms and monsoonal winds (Choi, 1999). Good quality corrected monthly maximum extreme gust data are available from Tengah and Changi airfields. A Gumbel extreme value analysis for data up to 1997 from these data (Holmes, unpublished) gives 50-year return period gusts of 33 and 25 m/s, respectively. (However, a gust of 40.1 m/s was recorded at Tengah in 1984.) *Extreme wind classification: I.*

D2.47 South Africa

South Africa is subjected to severe thunderstorms on the inland high plains, and synoptic winds in the south. The Code of Practice for Loading of the South African Bureau of Standards (SABS 0160-1989) has a map showing design wind speeds for the country (50-

year return period, 3-second gust). This map is based on the analysis of annual maximum wind speeds by Milford (1987). The value given for the majority of the country is 40 m/s. This value is specified for the main cities of Johannesburg, Pretoria, Cape Town and Durban. A small zone around Beaufort West has a value of 50 m/s. *Extreme wind classification: II, III.*

D2.48 Spain

No data are given in the draft Eurocode (C.E.N., 1994), but the map in the E.C.C.S. Recommendations for the Calculation of Wind Effects on Structural Steelwork (E.C.C.S, 1978) gives values of 10-min mean wind speeds (50-year return period) of 22 m/s to 26 m/s for Spain. There are some downslope wind areas in Pyrenees. *Extreme wind classification: II.*

D2.49 Sri Lanka

The east coast of Sri Lanka is exposed to relatively weak tropical cyclones. A Building Code was prepared by an Australian consulting group in the 1970s. Three design wind zones are specified (Table D9).

D2.50 Sweden

The draft Eurocode (C.E.N., 1994) gives a contour map with values of 10-min mean wind speed with a 50-year return period, between 22 m/s (north-east) and 26 m/s south and west). For Stockholm, the value is 24 m/s. *Extreme wind classification: II.*

D2.51 Switzerland

The draft Eurocode (C.E.N., 1994) specifies values of 10-min mean wind speed with a 50-year return period, of 27.2 m/s over the vast majority of the country, including Zurich, Basel, Bern and Lausanne. There are a number of mountain areas where downslope wind occur, and for which higher values of 30 m/s and 33.3 m/s are specified. *Extreme wind classifications: II, III (some mountain areas).*

D2.52 Thailand

Thailand has a particularly mixed wind climate. Most of the country appears to be dominated by extreme winds from thunderstorms and monsoons. However occasionally typhoons have impacted on southern Thailand, as did Typhoon 'Gay' in 1989, inflicting considerable damage. Post-landfall typhoons can also affect north-west Thailand.

Table D9 Sri Lanka

Zone in Building Code	*Description*	*Classification*
1	50 km from east coast	III
2	Inland strip	II
3	South and west (including Colombo)	I

An analysis of historical gust data for sixty meteorological stations is described by Davenport *et al.* (1995), using Type I (Gumbel) Extreme Value Distributions. There were apparently siting problems for many of the anemometers, and although extreme winds caused by typhoons were separated, those from thunderstorms apparently were not.

The analysis by Davenport *et al*. (1995) proposed two design wind speeds based on 50-year return period 10-min means of 26.5 m/s and 30 m/s. The latter value applies to small zones on the east and north-west of Thailand. In recent proposals for a new Thailand loading code (Lukkunaprasit, 1997), these values were converted to nominal mean hourly speeds of 24.9 m/s and 28.2 m/s, respectively. *Extreme wind classification: II.*

D2.53 Trinidad and Tobago

Analysis of extreme wind speeds for the Commonwealth Caribbean, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986) and by the Code of Practice of the Barbados Association of Professional Engineers (1981). The former specifies a 50-year return period 10-min mean wind speeds of 20–28 m/s, and the latter gives a 50-year return period 3-second gust speed of 45 m/s for Trinidad and 50 m/s for Tobago. The latter values are based on a Frechet (Type II) Extreme value distribution (Section 2.2.1), and may be conservative. *Extreme wind classification: II.*

D2.54 United Arab Emirates

An analysis by W. H. Melbourne (unpublished) for Dubai using data from 1974 to 1989, gives a distribution which predicts a 50-year gust speed of 39.3 m/s. *Extreme wind classification: II.*

D2.55 United Kingdom

The U.K. is a small island country with a close network of meteorological stations, and high quality data. The main strong wind source is severe gales moving in from the Atlantic on the west. Design winds are generally stronger on the west, reducing further east.

Analyses of extreme winds for the U.K. have been carried out by Shellard (1958, 1962) and Cook and Prior (1987). The latter work was used for the design wind speed data in the British Standard BS6399:2.

BS6399:2 contains a map of 1-h mean wind speeds (50-year return period) ranging from 20 to 30 m/s. The latter values occur only for the Shetland Islands in the north. The map also covers the whole of Ireland. The map in the draft Eurocode (C.E.N., 1994) is identical, with Ireland omitted. *Extreme wind classification: II.*

D2.56 United States

The U.S.A. has a vast array of meteorological stations operated by the U.S. Weather Bureau, and other agencies, such as those involved in defence. Until fairly recently the standard extreme wind was the ‘fastest mile of wind’, calculated from the time taken by a cup anemometer to rotate through one mile. The introduction of Automatic Weather Stations has seen this measure replaced by a peak gust wind speed.

There have been many extreme value analyses for the United States, including those

Table D10 United States

Description	*Classification*
Central and western states	II
Atlantic and Texas coasts	III
Southern Florida and Louisiana, Alaska coasts	IV

by Thom (1960, 1968), Simiu *et al.* (1979) and Peterka and Shahid (1998). The latter analysis has resulted in the design wind map in the ASCE Loading Standard (ASCE, 1998). The latter contains two main zones, with 50-year return period gust speeds of 40 m/s and 38 m/s. The lower value applies to the west coast states (Table D10). The Atlantic Ocean and Gulf of Mexico coastlines have isotachs ranging from 67 m/s to 45 m/s. Alaska has contours from 40 m/s to 58 m/s. Hawaii has a basic wind speed of 47 m/s.

D2.57 Vietnam

Vietnam is influenced by typhoons over most of its coastline, although the influence is weaker on the southern provinces. For design wind speeds, Vietnam is divided into five zones with 20-year return period gust speeds ranging from 33m/s to 55 m/s, in the national loading code TCVN-2737 (values of dynamic pressure are given in the code). The zones of higher wind speeds occur close to the coast and reflect different degrees of influence from typhoons (Table D11).

D2.58 Windward Islands

These islands in the Caribbean are visited by developing hurricane, and weaker troptical storms. Analysis of extreme wind speeds for the former British colonies in the Caribbean, was carried out by Shellard (1972). These results have been used by the Caribbean Uniform Building Code (Caribbean Community Secretariat, 1986) and by the Code of Practice of the Barbados Association of Professional Engineers (1981). The latter gives a 50-year return period 3-second gust speed of 58 m/s based on studies for Barbados. This value is also applicable to St. Vincent, St. Lucia, Grenada and Dominica. *Extreme wind classification: III.*

Table D11 Vietnam

Zone in loading code	*Description*	*Classification*
I	Inland north and south	II
II	Inland north and southern coast	II
III	Central and northern coastline	III
IV, V	Offshore islands in north	IV

D2.59 Zimbabwe

Zimbabwe is an elevated land-locked country with most land at 1000 m above sea level or greater. The country falls between 15 and 22º South in latitude. The expected dominant windstorm in this environment would be thunderstorm winds created by local convection. The code of practice for wind loads (Central African Standards Institution, 1977) specifies a basic design wind speed (50 year return period gust) of 35 m/s, for the whole country. The analysis by Lewis (1983) for five different locations found higher and lower values than this. *Extreme wind classifications: I and II.*

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