An attempt towards wind zone demarcation for Sri Lanka

K.D.W. Nandalal and H. Abeyruwan

Department of Civil Engineering, University of Peradeniya, Sri Lanka

ABSTRACT: Sri Lanka uses a wind zone map prepared in 1978 for civil engineering structural designs. This map was seemingly based on the extent of local damage caused by the cyclone, which affected the east coast of the country in 1978 but not prepared based on wind speed measurements. This paper presents an attempt made towards preparing a wind zone map based on observed wind speeds at 15 weather stations in the country. The data used were annual maximum 3 minute average wind speeds recorded at about 10 m above ground level. Several probability distributions were tested for suitability and Extreme Value Type I (Gumbel) distribution was found to be the best fitting distribution for the maximum wind speeds at all the stations. A map demarcating wind zones for the country was prepared using the 50 year return period wind speeds resulted from the Gumbel probability distributions. The map prepared needs to be improved with more data for a longer period and taking more weather stations adopting the procedure presented in the paper.

KEYWORDS: Wind zone map

1 INTRODUCTION

Wind can be defined simply as air in motion. This motion can be in any direction, but in most cases the horizontal component of the wind greatly exceeds that in the vertical direction. Wind develops as a result of spatial differences in atmospheric pressure. Generally these differences occur because of uneven absorption of solar radiation at the Earth's surface. Wind, so initiated is influenced by the earth's rotation (Coriolis forces), and frictional effects, particularly near the Earth's surface. Knowledge of wind is applied in the fields of nautical, aeronautical, wind energy exploitation, pollution control, and structural design.

Wind induces pressure at points on an object in its path. The potential pressure available from the kinetic energy of the wind is called the dynamic pressure which is proportional to the square of the wind speed. The potential pressure occurs at points where the object brings the wind stagnant. The pressure distribution causes force to apply on the object. In designing Civil Engineering structures wind loads are important particularly for high rise structures as well as large span bridges. As such, countries or regions present their wind climate having studied the data collected from meteorological stations.

Sri Lanka is an island of area about 65610 km^2 situated in the southern tip of the Indian subcontinent between longitudes 80°–82° East and latitudes 6°–10° North. It is affected by monsoonal winds, thunderstorms and cyclones. Sri Lanka faced a very strong cyclone affecting the east coast of the country in November 1978. That caused severe damages to structures in the area destroying 6940 houses and damaging 74330 houses affecting about 615180 people. Poor design and construction practices that had been adopted in the country without proper wind resistance was observed to be the main reason for the huge damage. Thus incorporation of wind effects on structures in the design of structures was felt important. Conversely, Walker (1985) citing PADCO (1979) describes Sri Lanka has very low risk of occurrence of tropical cyclones with only 3 fully developed tropical cyclones having crossed the coast during the 20th century.

Immediately after the cyclone in the year 1978, on the request of the Sri Lankan government, an Australian consulting group along with the officers of the Department of Buildings, Sri Lanka prepared a wind map for the country, to be used in the design of structures. The wind map shown in Figure 1 in which the country was divided into three zones, viz., I, II and III, seems to be merely an extension of the Indian wind map. It does not show the features of any micrometeorological study based on long-term data obtained from Sri Lankan meteorological stations. Table 1 shows the suggested design wind speeds in the three wind zones.

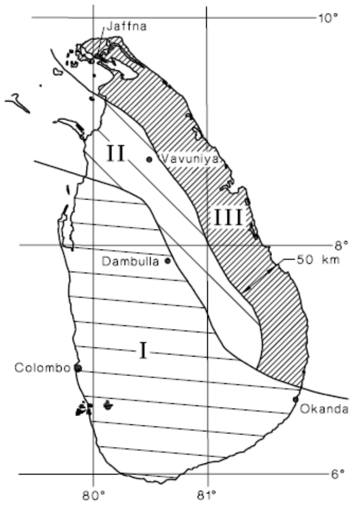


Figure 1. Sri Lankan wind zones (as shown in HB 212-2002)

Table 1. Design wind speeds (3 s gusts, 10 m height, open terrain at $z_0 = 0.02$ m)

Zone	Nominal 50 yr return period (m/s)	Nominal 500 yr return period (m/s)
I	32	40
II	39	45
III	44	57

This paper presents a study carried out to demarcate wind zones in Sri Lanka based on observed wind speeds to be used in the design of Civil Engineering structures.

Methodology

The common procedure adopted to estimate basic wind speeds is to perform extreme value analysis of micrometeorologically homogeneous data collected from well spaced regional meteorological stations. These conditions are determined by: averaging time; height above ground; and roughness of surrounding terrain (Simiu and Scanlan, 1978).

Daily maximum wind speed (3 min average) data at the heights of 10 m measured by the Department of Meteorology, Sri Lanka were collected. Fifteen stations were selected to cover different geographical regions of the country. Details of these 15 weather stations are given in Table 2 while Figure 3 depicts their locations.

Table 2. Gauging station details

Station	Period	No of years	Elevation (m)	Longitude (°)	Latitude (°)
Anuradhapura	1998-2007	10	92.50	80.44	8.37
Bandarawela	1998-1997	10	1225.30	80.98	6.85
Batticaloa	1998-2007	10	7.80	81.64	7.78
Colombo	1993-2007	16	7.30	79.85	6.93
Hambantota	1993-2003	14	15.50	81.12	6.12
Jaffna	2001-2007	7	---	80.01	9.67
Katugastota	2003-2007	5	---	80.60	7.32
Kurunegala	2003-2007	5	---	80.40	7.49
Mannar	1998-2007	10	3.60	79.96	8.93
Nuwara Eliya	1998-2007	10	1895.00	80.69	6.98
Pottuvil	1998-2007	10	---	81.83	6.88
Puttalam	1998-2007	10	2.13	79.86	8.05
Ratnapura	1998-2007	10	86.20	80.41	6.67
Trincomalee	1993-2005	13	79.00	81.18	8.57
Vavuniya	1998-2007	10	---	80.49	8.76

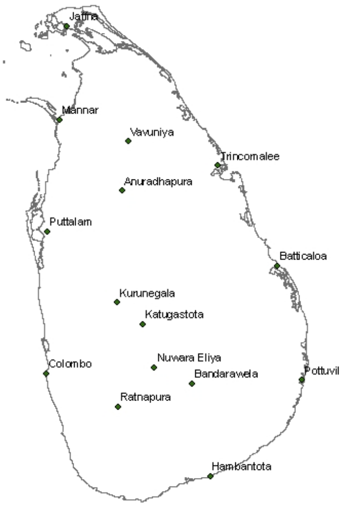


Figure 3. Locations of the gauging stations

Frequency analysis

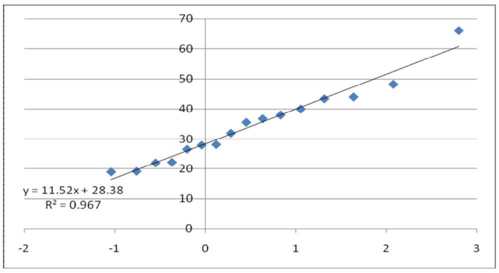
Annual maximum wind speeds were selected from the daily maximum wind speeds records at the fifteen stations. Following different probability distributions were tested for suitability for the data at all the weather stations.

Gumbel (GEV Type I) Distribution Function,
Log Gumbel Distribution Function,
Pearson Distribution Function,
Log Pearson Distribution Function,
Weibull Distribution Function, and
Log Weibull Distribution Function.

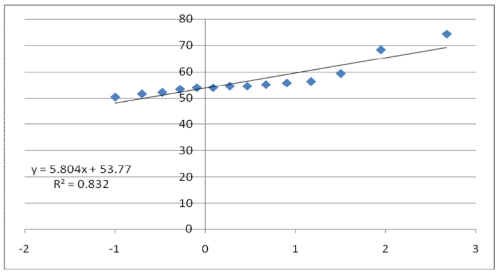
Then wind zone map was prepared using 50 year return period wind speeds obtained from the above frequency analysis. The wind speeds calculated based on 3 min average were converted to 3 s average wind speeds in the preparation of the map.

Analysis

The probability fittings showed that the Gumbel distribution as the best fitting distribution for the data sets. As examples, the probability distribution for two stations, viz., Colombo and Hambantota are shown in Figure 4. Other stations also showed a similar pattern.



(a) Colombo



(b) Hambantota

Figure 4. Gumbel frequency distributions (a) Colombo; (b) Hambantota (wind speed in km/h)

From the fitted distribution, maximum wind speeds (m/s) for different return periods were obtained for all the stations. Table 3 depicts the maximum wind speeds for different return periods at Colombo and Hambantota.

Table 3. Maximum wind speeds (m/s) for different return periods (Colombo and Hambantota)

Rank	Station	Return Period	Gumbel	Log Gumbel	Pearson	Log Pearson	Weibull	Log Weibull
1	Colombo	5	13.35	13.2	12.2	12.2	12.4	12.5
		10	15.37	16.2	13.6	15.0	14.5	15.2
		15	16.59	18.4	14.5	16.5	16.0	17.0
		25	18.16	21.5	15.2	17.5	17.0	18.8
		50	20.31	26.7	16.0	19.2	19.1	23.0
		100	22.48	33.2	16.9	22.0	21.0	28.0
		500	27.53	55.2	18.8	26.5	25.7	43.0
2	Hambantota	5	14.59	14.9	13.8	13.5	13.0	12.0
		10	16.99	19.3	15.9	16.5	15.4	14.5
		15	18.45	22.5	16.7	17.5	16.4	15.0
		25	20.32	27.4	18.0	18.5	18.0	17.5
		50	22.87	36.0	17.2	22.0	20.4	20.0
		100	25.46	47.4	20.5	23.5	22.5	24.0
		500	31.47	90.0	23.0	28.5	27.2	34.0

Out of these, the best fitting distribution was observed to be the Gumbel distribution. By using the equation given by Simiu and Scanlan (1978) for the conversion of wind speed based on averaging time to mean hourly wind speed, the average wind speeds at 3 s were determined. The wind speed data have been observed at 10 m above ground. The terrain is assumed to be having a roughness length equal to 0.05 m, which is the roughness length for a terrain with low vegetation such as grass and isolated obstacles (trees and buildings) with separations of at least 20 obstacle height (BS EN 1991-1-4, 2005).

The wind zone map prepared for the country for 3 s averaged wind speeds is presented in Figure 5.

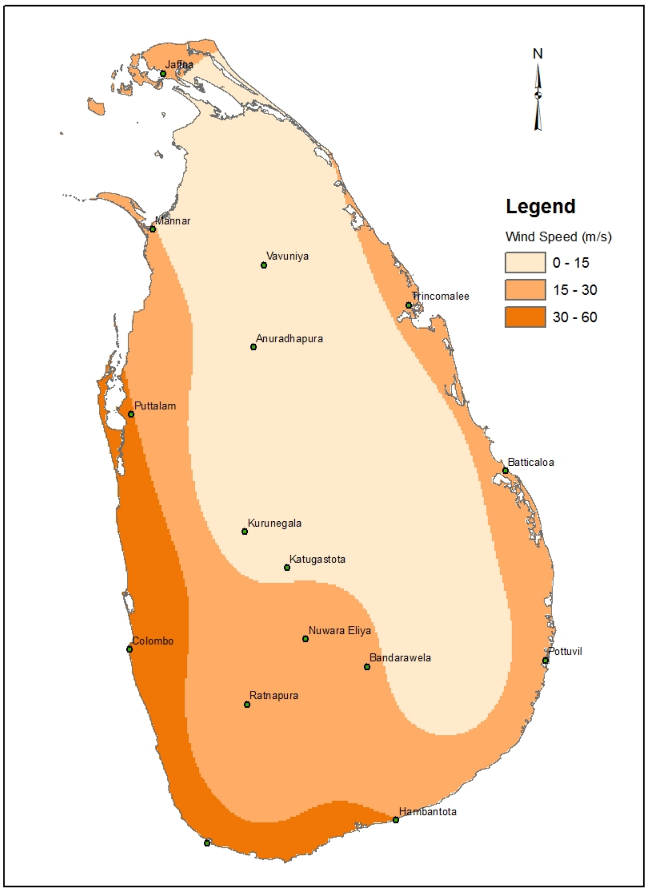


Figure 5. Wind zones (based on 3 s wind speeds)

Conclusions

The wind zone map for the country prepared based on wind speed data collected at 15 locations in the country is observed to be different to the map that is in use at present. The map that is being used at present has not been prepared based on observed wind speed data as mentioned before. The prepared wind zone map was obtained based on data for about 10 years on average at 15 locations only and this may be improved with more data for a longer period and more locations. This paper shows the method that should be adopted to prepare a wind zone map for Sri Lanka based on observed wind data.

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