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Study of extreme winds over North India

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ABSTRACT. Attempt has been made to develop maps for estimation of extreme wind and maximum mean hourly wind speed for different return periods north of 20°N over India. The procedure for obtaining information about extreme winds has been made simple for the convenience of design engineers engaged in designing buildings and other engineering structures on which calculation of wind pressure, offered by extreme winds, is needed.

1. Introduction

Estimates of maximum wind speed are generally needed by design engineers for designing buildings and other engineering structures. The structure which is to be designed should neither be uneconomical nor underdesigned. The design of such structures is usually based upon the maximum wind-speed that would be equalled or exceeded on the average once in T years, where T is the return period and may take the values from 2 to 100 years. The wind speed that would be equalled or exceeded once in 10 years' time has a return period of 10 years and the wind is known as 10-year wind. The probability that this value will be equalled or exceeded in a year is 0·10. This information is generally required by the design engineer for calculation of highest wind pressure on the engineering structure in order that it may withstand that pressure.

2. Method

Shellard (1958, 1962) has given a complete account of the extreme wind speed over Britain and Ireland. He analysed the wind speed data by applying Gumbel's extreme values method.

Gumbel's extreme values formula, as given by Chow (1953, 1964) using method of moment of estimating parameters, has been considered in the present study which is based upon data of eight stations north of 20°N over India. In India the anemograph stations are widely distributed and some stations which have been taken up for study do not have sufficient wind data. The data available for different anemograph stations for years of record are given in Table 2, both for extreme wind speed and yearly mean hourly wind.

3. Procedure

The highest wind speed recorded each year and also the yearly mean hourly wind was first reduced to effective height of 10 m of anemograph for each station by the formula followed by Shellard (1958) and given by Deacon (1955) and for mean hourly wind by Carruthers (1943). They are —

$$v_{10}=v_h\ (10/h)^{0\cdot17} \qquad \text{for mean speeds} \quad (1)$$

$$v_{10}=v_h\ (10/h)^{0\cdot85} \qquad \text{for gusts} \quad (2)$$

where h is the effective height of anemograph in metres agl, v_{10} the speed at 10 metres above ground level and v_h the recorded wind speed by the anemograph.

According to Chow (1953) utilising Gumbel's extreme values method (Gumbel 1941), the maximum wind that would be equalled or exceeded on the average once in T-years is given by —

$$X_T = \mu+\sigma\,[-1\cdot1-1\cdot795 \log_{10} \log_{10} T/(T-1)] \quad (3)$$

where T=Return period in years, given by

$$T=(n+1)/m$$

$\mu = [\sum_{m=1}^{m=n} X_m\,]/n$, arithmetic mean of the given extreme values

$\sigma = \sqrt{[n/(n-1)](\bar{X^2}-\mu^2)}$, standard deviation

$\bar{X^2} = [\sum_{m=1}^{m=n} X^2_m\,]/n$

n=total number of terms of the extreme values and

m=rank number such that m=1 for the highest and $m=n$ for the lowest extreme value in the series arranged in descending order of magnitude.

4. Results

The factor in the bracket in Eq. (3) is denoted by K_T and is known as frequency factor, first defined by Chow (1953). The value of K_T for different return periods has been calculated and is given in Table 1. The maximum wind speed or the maximum yearly mean hourly wind has been adjusted for 10 m agl for each of the anemograph sites by the Eqns (1) and (2). The mean and standard deviation are calculated by the relations given above. The equations for both maximum

TABLE 1

Frequency Factor

Frequency factor	Return Period						
	2	2·33	5	10	25	50	100
K_T	—0·1642	0·0000	0·7160	1·3040	2·0450	2·5920	3·1300

TABLE 2

Stations	Maximum yearly mean hourly wind at 10 m a.g.l.		Yearly extreme wind speed at 10 m a.g.l.	
	Period	$X_T = \mu + \sigma K_T$	Period	$X_T = \mu + \sigma K_T$
New Delhi	1950-65	$X_T = 8 \cdot 1000 + 0 \cdot 6613\ K_T$	1950-65	$X_T = 107 \cdot 0000 + 16 \cdot 1395\ K_T$
Allahabad	1949-65	$X_T = 5 \cdot 3600 + 1 \cdot 1863\ K_T$	1949-65	$X_T = 97 \cdot 9000 + 24 \cdot 1984\ K_T$
Jodhpur	1948-64	$X_T = 8 \cdot 8500 + 1 \cdot 2662\ K_T$	1948-64	$X_T = 95 \cdot 1000 + 11 \cdot 3078\ K_T$
Jaipur	1950, 1952-58, 1960-62, 1964-65	$X_T = 6 \cdot 5300 + 0 \cdot 9726\ K_T$	1952-58, 1960-65	$X_T = 82 \cdot 0000 + 16 \cdot 7829\ K_T$
Lucknow	1954-65	$X_T = 8 \cdot 3800 + 1 \cdot 3186\ K_T$	1954-65	$X_T = 95 \cdot 7000 + 14 \cdot 1810\ K_T$
Nagpur	1957-65	$X_T = 6 \cdot 4100 + 0 \cdot 6385\ K_T$	1957-66	$X_T = 99 \cdot 9000 + 14 \cdot 1927\ K_T$
Bhopal	1957-66	$X_T = 11 \cdot 0100 + 0 \cdot 8672\ K_T$	1957-66	$X_T = 95 \cdot 4000 + 12 \cdot 6946\ K_T$

TABLE 3

Magnitude of yearly extreme wind (EW) and yearly mean hourly wind (MHW) in km/hr at 10 m a.g.l. for various return periods

Return period (years)	New Delhi		Allahabad		Jodhpur		Jaipur		Lucknow		Nagpur		Bhopal	
	EW	MHW	EW	MHW	EW	MHW	EW	MHW	EW	MHW	EW	MHW	EW	MHW
2	104	7·99	94	5·17	93	8·64	79	6·37	93	8·16	98	6·31	93	10·87
2·33	107	8·10	98	5·36	95	8·85	82	6·53	96	8·38	100	6·41	95	11·01
5	119	8·57	115	6·21	103	9·76	94	7·23	106	9·32	110	6·87	104	11·63
10	128	8·96	129	6·69	110	10·50	104	7·80	114	10·10	118	7·24	112	12·14
25	140	9·45	147	7·78	118	11·44	116	8·52	125	11·08	129	7·71	121	12·78
50	149	9·81	161	8·43	124	12·13	126	9·05	132	11·80	137	8·06	128	13·26
10	158	10·17	174	9·07	131	12·81	136	9·57	140	12·51	144	8·41	135	13·72
100-yr value / 2-yr value	1·52	1·27	1·85	1·75	1·41	1·48	1·72	1·50	1·51	1·55	1·47	1·33	1·45	1·26
2-yr value / μ(mean)	0·97	0·99	0·96	0·96	0·97	0·97	0·96	0·99	0·97	0·97	0·98	0·98	0·97	0·99

	EW (mean)	MHW (mean)
100-yr value / 2-yr value	1·56	1·45
2-yr value / μ (mean)	0·97	0·98

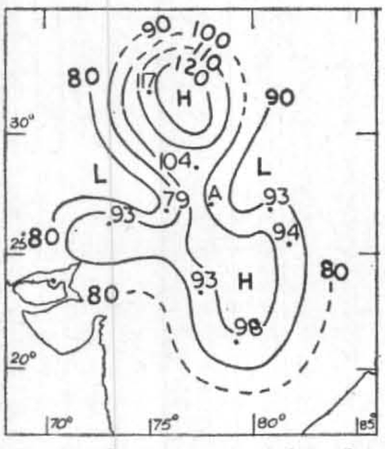

Fig. 1(a). 2-year extreme wind (km/hr)

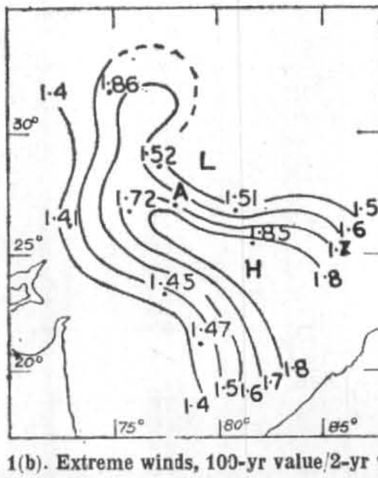

Fig. 1(b). Extreme winds, 100-yr value/2-yr value

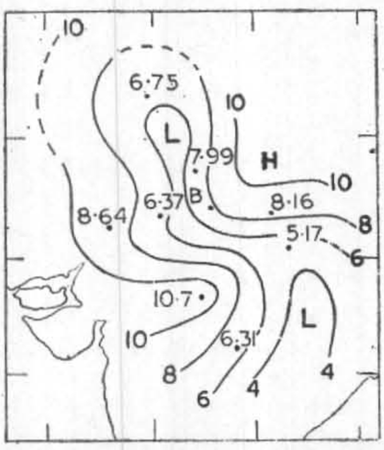

Fig. 2(a). 2-year mean hourly wind (km/hr)

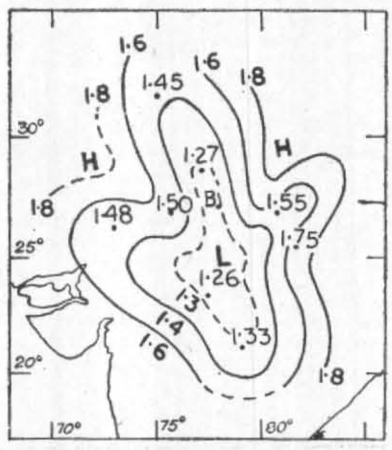

Fig. 2(b). Mean hourly wind, 100-yr value/2-yr value

yearly mean hourly wind and yearly maximum wind speed for all the stations are thus given in Table 2. Utilising these equations, X_T is calculated for different return periods for all stations considered and given in Table 3.

In case of Amritsar the extreme wind data was available for only 7 years, therefore empirical results were used to find out the 2-year value. The 2-year wind was seen, on the average, to be $0 \cdot 97$ times the mean of the annual series for both the cases. Therefore 2-year wind was obtained by multiplying the mean of the annual series of Amritsar by $0 \cdot 97$ which gave $6 \cdot 75$ km/hr and 117 km/hr as the yearly maximum mean hourly wind and yearly extreme wind respectively.

In Africa the estimation of short duration rainfall intensity for regions of sparse rainfall data has been made by Reich (1963). He has utilised 5 to 20 years of data for analysis by Gumbel's method. He has also utilised some of the empirical relationships developed by the U.S. Weather Bureau (Hershfield 1961) in making depth-duration-frequency analysis of rainfall. On similar lines 100/2-year ratio of extreme wind speeds were computed. This ratio varied between $1 \cdot 26$ and $1 \cdot 85$ both for extreme and mean hourly winds. It has been seen in the case of extreme wind that the 100-year value is on the average $1 \cdot 56$ times the 2-year value and in the case of mean hourly wind, it is $1 \cdot 45$ times the 2-year value.

This ratio has been utilised for finding out 100-year wind by multiplying 2-year maximum wind by this ratio. Fig. 1 (a) shows the isopleths of 2-year extreme wind speed and Fig. 1(b) the ratio of 100-year value to 2-year value. Similarly Figs. 2(a) and 2(b) show the 2-year mean hourly wind and the corresponding ratio of 100-year to 2-year value. Having found out 100-year and 2-year value for any points of a map (Figs. 1 and 2) the magnitude of maximum wind speed for any return period within 100-years period can be found out from the extreme value probability paper given in Fig. 4.

5. Estimation procedure

The following steps are adopted for estimation of the wind speeds for different return periods—

(*i*) Find out 2-year extreme or mean hourly wind for any point in Figs. 1(a) or 2(a).

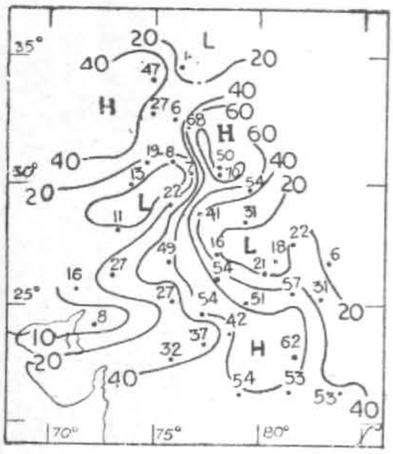

Fig. 3. Normal annual number of days with thunderstorms

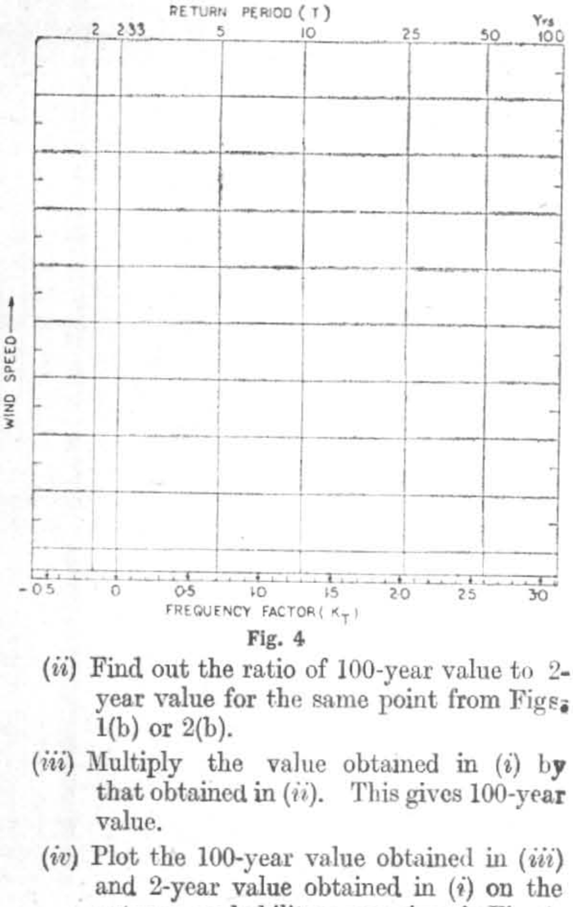

Fig. 4

(*ii*) Find out the ratio of 100-year value to 2-year value for the same point from Figs. 1(b) or 2(b).

(*iii*) Multiply the value obtained in (*i*) by that obtained in (*ii*). This gives 100-year value.

(*iv*) Plot the 100-year value obtained in (*iii*) and 2-year value obtained in (*i*) on the extreme probability paper given in Fig. 4.

(*v*) Join these two points by a straight line.

(*vi*) Read the magnitudes of extreme winds for differents return periods at the point of intersection of the straight line as in (*v*) and the return period ordinates.

6. Example

Suppose we want to find out the maximum wind speed for a return period of 50 years for a point A on Fig. 1(a). This point (Agra) has 97 km/hr as the 2-year value at 10 m agl. For the same point, the 100-year/2-year ratio is 1·7 (Fig. 1b). Therefore, 100-year value would be $97 \times 1{\cdot}7 = 165$ km/hr. In Fig. 4, plot 100-year value and the 2-year value and join them by a straight line and read the wind speed for 50 years return period. This gives 154 km/hr as the maximum wind speed that will be equalled or exceeded on the average once in 50 years. Similarly for 25 years it would be 143 km/hr and for 10-years 128 km/hr.

For the same point, *i.e.*, B in Fig. 2(a), the maximum mean hourly wind for 100, 50, 25 and 10 years return period would be 9·8, 9·4, 9·0 and 8·5 km/hr respectively.

7. Discussion

It has been seen, after comparing Figs. 1 and 2 with Fig. 3, which shows the isopleths of normal annual days with thunderstorm (India met. Dep. 1960) that the highs and lows of the 2-year values in the case of extreme wind follow the general pattern of highs and lows of annual thunderstorm days, while lows and highs in the case of mean hourly wind, lie over highs and lows respectively of annual thunderstorm day. This shows that in the convergence zone, where the yearly thunderstorm frequency is high, the yearly mean hourly wind is low and *vice versa.* Similarly the extreme wind is high in high frequency thunderstorm region and low in the low frequency thunderstorm region. In high frequency thunderstorm region, comparatively more highly convective clouds are likely to be formed to cause higher wind speed in general.

The isopleth of 2-year winds and the 100/2-year ratios are just tentative and may change their shape when data is available for more stations.

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