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Maximum wind pressure over India

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ABSTRACT. Maximum wind speeds in gusts at 26 stations in India have been studied and wind pressure maps prepared for different return periods by using the theory of distribution of extreme values.

1. Introduction

A knowledge of the maximum wind pressure likely in different parts of the country is of great importance and value to structural engineers. To meet this need, the ISI brought out in 1965 the Indian Standards *Code of Practice for Structural Safety of Buildings : Loading Standards* (Revised). Maps included in this publication show the maximum wind pressure that may be expected. The coastal values are estimates based on winds experienced when severe storms struck these areas. While these maps indicate extreme values, there is great demand for probabilities of different wind speeds likely in different parts of the country. To evaluate such probabilities, a good network of stations equipped with continuous recording wind instruments is essential. Although the network has been greatly improved and expanded in recent years, yet the number with over ten years continuous records is 26 only. Nevertheless, it was considered that it might be useful to examine the available wind data and present them in the form of probability values and maps. The results of the study are presented in this paper. Maps showing probabilities of maximum wind pressure for the different stations have also been included.

2. Data

There are 26 stations equipped with anemographs which have continuous analysed wind records for varying periods from 1944 but not less than 10 years. The highest wind speed in gusts recorded in each year have been collected for all such stations.

Wherever wind data were available for two sites at the same station, the higher value has been taken except for Calcutta and Bombay where the data at both the sites, *i.e.*, Dum Dum-Alipore and Colaba-Santacruz respectively, were analysed separately. Further since one of the basic requirements of the method used in the present study is that the data considered for analysis should be available for a continuous period, the wind data missing for a year in between have been interpolated by comparing three years data, *i.e.*, for the preceding year, the year in question and the succeeding year, with the corresponding data of the neighbouring station having more or less similar climatic environment. These stations are Jodhpur, Jaipur, Visakhapatnam and Gopalpur. For Jodhpur the station considered for interpolation is Jaipur and for Visakhapatnam it is Gopalpur and *vice versa*. Such occasions of missing data are, however, very few.

3. Variation of gusts with height

The heights of wind instruments at the different stations vary, but most of them are in the range of 10 to 30 m. The question of reduction of extreme gust values to a common height of 10 m was carefully examined in the light of available information. A formula for variation of gusts with height due to Deacon (1955) is $v_1/v_2 = (h_1/h_2)\ 0{\cdot}85$. This is based on too few observations. In India it has been noticed that two anemographs located in a nearby sites have shown widely varying values, *e.g.*, Dum Dum—Alipore, Colaba—Santacruz etc. Due to lack of sufficient observational data and the above consideration which introduce so much uncertainty reduction of data to standard height of 10 m was not made.

4. Method

The extreme value distribution due to Fisher and Tippet (type II) is $F(X)=\text{Exp.}\ [-(X/B)^{-A}]$

$F(X)$ is the probability of an extreme value being less than X; B is the scale parameter and A is a

TABLE 1

Maximum gust speeds (kmph)

Station	No. of yrs of record	Period	Speeds likely to be exceeded once in stated number of years						Highest speed on record	Mean annual speed max.
			2	5	10	25	50	100		
Ahmadabad	17	1953-1969	91	111	126	149	168	190	131	89
Allahabad	22	1948-1969	103	128	148	178	204	234	163	99
Bangalore	21	1949-1969	88	96	103	111	118	125	107	81
Bhopal	18	1952-1969	106	119	128	141	151	161	120	95
Bombay (Colaba)	26	1944-1969	96	104	109	116	122	127	127	87
Bombay (Santacruz)	17	1953-1969	85	98	107	121	132	144	113	80
Calcutta (Alipore)	24	1946-1969	114	129	140	155	168	181	138	102
Calcutta (Dum Dum)	22	1948-1969	114	132	145	164	179	196	147	106
Gaya	22	1948-1969	111	125	136	152	164	177	150	102
Goa	15	1954-1968	94	107	118	132	144	157	125	88
Gopalpur	22	1948-1969	103	119	131	148	162	177	144	97
Hyderabad	15	1955-1969	106	128	145	170	192	216	145	100
Jagdalpur	12	1958-1969	92	107	117	132	144	158	109	84
Jaipur	18	1952-1969	99	116	130	149	165	182	144	91
Jamshedpur	26	1944-1969	120	143	161	187	209	233	171	111
Jodhpur	18	1948-1965	112	139	161	193	220	252	152	104
Kodaikanal	22	1948-1969	101	112	119	130	139	148	114	92
Lucknow	16	1954-1969	106	121	132	147	160	174	126	100
Madras	22	1948-1969	99	115	127	143	157	171	136	94
Nagpur	20	1950-1969	114	129	139	154	166	178	138	105
New Delhi	22	1948-1969	119	135	147	164	178	192	159	107
Poona	22	1948-1969	92	106	116	130	142	154	122	87
Sagar Island	20	1950-1969	110	123	132	145	155	166	147	101
Veraval	12	1958-1969	103	120	133	151	166	182	122	94
Visakhapatnam	22	1948-1969	108	124	136	152	165	179	146	101
Baroda	10	1948-1957	72	78	82	88	93	97	83	68

parameter which depends on the shape of the distribution. On taking twice the logarithm it can be expressed as—

$$X = \text{Exp.} \left[\log B - \frac{I}{A} \log \log \left(\frac{I}{F} \right) \right] \quad (1)$$

If the return period is R, then $F = 1-(1/R)$.

It is well known that Fisher and Tippet type I distribution, when fitted on the logarithm scale, follows a type II distribution with the condition that $A = 1/b$ and $B = e^a$ where, a and b are the constants of type I distribution and are known as location and scale parameters respectively. They are taken as mean and standard deviations of the data series and are greater than zero. This relationship between the two distributions is of considerable advantage in computing the parameters of type II distribution as it is easier to work out parameters of type I distribution. The parameters of the type I distribution are first worked out on the logarithmic, values of the data instead of actual

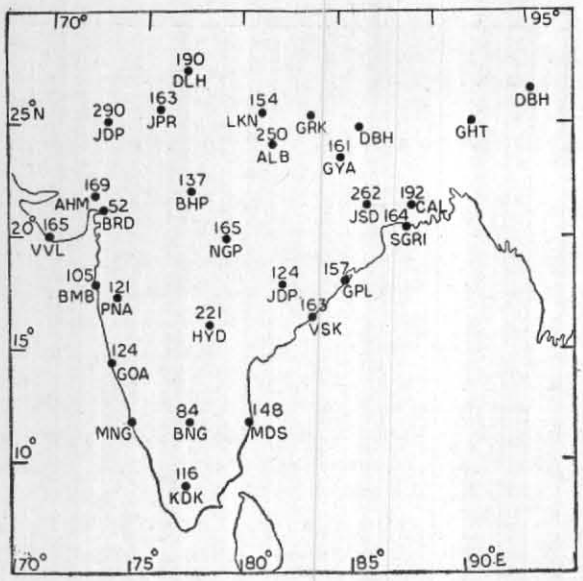

Fig. 1. Return period of 50 years

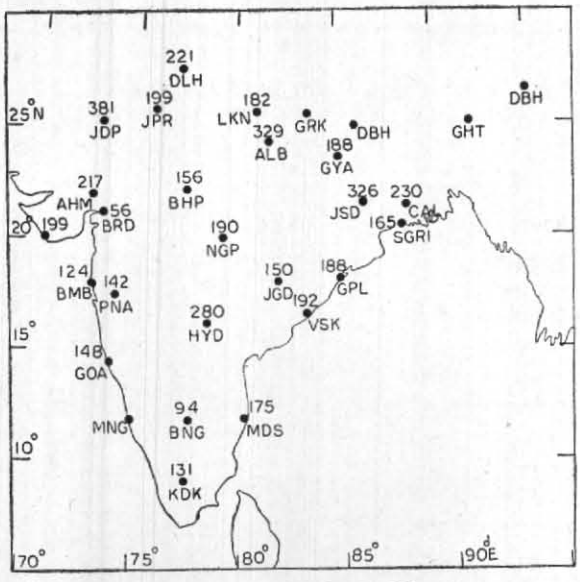

Fig. 2. Return period of 100 years

Maximum wind pressure in kg/m² for different return periods

values and are then converted to the parameters of type II distribution by the relations, $A=1/b$ and $B=e^a$. Having known A and B, value of X in (1) for different return periods for different value of F can easily be found out.

5. Computations

a and b were first found out from the logarithm of extreme wind values instead of actual values. The procedure given by Lieblein and described by Thom (1966) has been followed in calculating a and b. As a requirement of the above procedure the data series at each station has been divided into sub-groups of six items. In case of the data series not being a multiple of six, *viz.*, 10 items, the series will be divided into two groups of six and four items respectively and will be multiplied with corresponding weightages.

The values of F corresponding to different return periods 2, 5, 10, 25, 50, 100 years are 50, 80, 90, 96, 98, 99 respectively. Knowing the values of A, B and F for different return periods values of X were calculated using relation (1). The values of X for different return periods are given in Table 1.

6. Maximum wind pressure

The maximum wind pressure values for the return periods of 10, 25 , 50 and 100 years have been found using formula $P=KV^2$, where, P is the wind pressure in kg/m², V is the wind speed in kmph and K is a constant equal to ·006. These values are given in Table 2. Maps showing values of maximum wind pressure have been prepared for the return periods of 50 and 100 years and are shown in Figs. 1 and 2.

7. Discussion

1. Since type II distribution is bounded below at zero while type I is unbounded at both ends, it is logical to fit type II distribution in the case of winds as it has a strict lower bound of zero and no known physical least upper bound.

2. The results obtained by fitting type II distribution in respect of north Indian stations are compared with the results obtained by Sharma *et al.* (1967) by fitting type I distribution. It is noticed that in the former case, the values are generally higher than those in the latter case. In the latter case the values of wind obtained for the return period 5 years were compared with actual data recorded and it is found that the actual values in case of Jaipur and Lucknow have already been exceeded twice during the subsequent four years of their study which indicates that fitting of type I distribution is not satisfactory.

3. A comparison of the maximum wind pressure values obtained for different stations for 100 years return period and the values given in ISI map shows that in the former case they are generally higher except along east coast, where the values are generally lower. This is because of the fact that ISI map takes into account the estimated maximum wind speeds when severe storms struck the different parts of the coast. The two maps are therefore not

TABLE 2

Maximum wind pressure for different return periods

Station	Maximum wind pressure force (kg/m²) for the return period (year)			
	10	25	50	100
Ahmadabad	95	133	169	217
Allahabad	131	190	250	329
Bangalore	64	74	84	94
Bhopal	98	119	137	156
Bombay (Colaba)	71	81	89	97
Bombay (Santacruz)	69	88	105	124
Calcutta (Alipore)	118	144	169	197
Calcutta (Dum Dum)	126	161	192	230
Gaya	111	139	161	188
Goa	84	105	124	148
Gopalpur	103	131	157	188
Hyderabad	126	173	221	280
Jagdalpur	82	105	124	150
Jaipur	101	133	163	199
Jamshedpur	156	210	262	326
Jodhpur	156	223	290	381
Kodaikanal	85	101	116	131
Lucknow	105	130	154	182
Madras	97	123	148	175
Nagpur	116	142	165	190
New Delhi	130	161	190	221
Poona	81	101	121	142
Sagar Island	105	126	144	165
Veraval	106	137	165	199
Visakhapatnam	111	139	163	192
Baroda	40	46	52	56

strictly comparable. The main object of the present paper as mentioned earlier is to provide probability values based on data of individual stations with records of 10 or more years.

8. Probability maps

The preparation of maps of probability of maximum winds pressure was considered. As is well known extreme wind differ considerably even between two neighbouring sites, *e.g.*, the maximum wind speeds recorded at Colaba and Juhu (Bombay) were 80 and 94 mph respectively on the same day (22 November 1948). Other examples could be mentioned. The topography is also an important factor. A much closer network than the very sparse one of about two dozen stations for a country of India's size is essential for preparation of reliable probability maps. For these reasons, it is advisable not to draw isopleth maps as is usual with these two few data. They would be misleading. The probability values now derived and plotted on maps (Figs. 1 and 2) should, therefore, be regarded as applicable in their immediate neighbourhood only.

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