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 

\[ \frac{v_2}{v_1} = \left( \frac{h_1}{h_2} \right)^{0.85} \]

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 

\[ F(X) = \exp \left( -\left( \frac{X}{B} \right)^{-A} \right) \]

\( F(X) \) is the probability of an extreme value being less than \( X \); \( B \) is the scale parameter and \( A \) is a
| 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. |
|------------------|----------------------|--------------|-------------------------------------------------------------|-------------------------|------------------------|
| Ahmedabad        | 17                   | 1953-1969    | 91  111  120  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  107  87                      |                         |                        |
| Bombay (Santa Cruz) | 17                | 1953-1969    | 85  98  107  121  132  144  113  80                      |                         |                        |
| Calcutta (Ali pore) | 24                | 1946-1969    | 114 129  140  155  168  181  138  102                     |                         |                        |
| Calcutta (Dom Dum) | 22                | 1948-1969    | 114 132  145  164  179  196  147  106                     |                         |                        |
| 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                      |                         |                        |
| Jambsherdpur     | 26                   | 1944-1969    | 120 143  161  187  209  233  171  111                     |                         |                        |
| Jodhpur          | 18                   | 1948-1966    | 112 139  161  193  220  252  152  104                     |                         |                        |
| Kodalkanal       | 22                   | 1948-1969    | 101 112  119  130  139  148  114  92                      |                         |                        |
| Lucknow          | 16                   | 1954-1969    | 106 121  132  147  160  174  128  100                     |                         |                        |
| Madras           | 22                   | 1948-1969    | 99  115  127  143  157  171  135  94                      |                         |                        |
| Nagpur           | 20                   | 1959-1969    | 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                   | 1959-1969    | 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                      |                         |                        |

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

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

If the return period is \( R \), then \( F = 1 - \left( \frac{1}{R} \right) \).

It is well known that Fisher and Tippett 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
values and are then converted to the parameters of type II distribution by the relations, \( A = \frac{1}{b} \) and \( B = e^\alpha \). Having known \( A \) and \( B \), value of \( X \) in (1) for different return periods for different values 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 \( \cdot006 \). 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 Sharmas 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     | 50     | 100    |
|------------------|-----------------------------------------------------------------|--------|--------|--------|
| Ahmedabad        | 95                                                              | 133    | 169    | 217    |
| Allahabad        | 131                                                             | 190    | 250    | 329    |
| Bangalore        | 64                                                              | 74     | 81     | 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    | 211    | 260    |
| Jagdalpur        | 82                                                              | 105    | 124    | 150    |
| Jaipur           | 101                                                             | 133    | 163    | 199    |
| Jammu Saidpur    | 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    |
| Verral           | 106                                                             | 137    | 165    | 190    |
| Visakhapatnam    | 111                                                             | 139    | 163    | 192    |
| Baroda           | 49                                                              | 46     | 52     | 58     |

S. Probability maps

The preparation of maps of probability of maximum wind pressures was considered. As is well known extreme wind differ considerably even between two neighboring 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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