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Review of Indian Wind Code

IS:875 (Part 3) - 1987

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Review of Indian Wind Loading Code IS: 875 (Part 3) -1987

1.0 Wind Engineering Problem

Natural hazards, which commonly lead to disasters, are earthquakes, wind storms, floods, avalanches, landslides, etc. These lead to losses of life, property, industrial production and so on. There has been an increasing trend in the occurrence of hazardous events over the last few decades. Whereas generally there has been a reduction in the number of lives lost due to improved disaster management and mitigative methods, the economic losses continue to increase. As seen from Table 1, though natural hazards strike most (or many) parts of the globe, Asia-Pacific region is the worst sufferer from the resulting disasters. Table 2 gives the hazardwise break-up of losses for the period 1900-1976.

Table 1: Losses from all disasters for the period 1985 – 2000

	Worldwide	Asia-Pacific	Percentage
Lives Lost	536,250	443, 480	82.7
Economic Losses (US $ million)	895,800	426,270	47.5

Table 2: Hazardwise losses from all disasters for the period 1900 - 1976

	Gross	**Landslides, Avalanches, Volcanic Eruptions (%)**	**Cyclonic and other wind storms (%)**	**Floods (%)**	**Earthquakes (%)**
Deaths	4.85 m	2.93	10.83	28.10	58.14
People rendered homeless	232 m	-	12.07	75.48	12.45
Economic Losses	131200 m US$	7.62	36.43	18.37	37.58

Whereas high wind storms occur in many parts of India, the coastal states of Gujarat, Tamilnadu, Andhra, Orrisa and West Bengal are more seriously affected because of the occurrence of cyclonic storms. Each such storm causes widespread damage. The frequency of these storms is greater on

the east coast compared to the west. While the prime reason for wind induced disasters is the ferocity of the wind, equally responsible for it is the lack of preparedness to combat the impending disaster. There are several aspects which constitute preparedness, and more than one discipline of engineering sciences is involved, such as meteorology, oceanography, industrial aerodynamics and civil engineering. While the former two are required to determine the nature of the storm, the latter two are required to be engaged for determining the effect of storms on structures and for adequacy of their design to survive the storms and serve their designated function. Continuing research and development in all these related fields is necessary to create the base of information for use in mitigating wind disasters.

The current project addresses a major and perhaps a very significant part of this total package, namely, a revision of the relevant code of practice which specifies the information on wind and its effect on buildings and structures so as to incorporate the same into the procedures for their design. Such material, if appropriately prepared and implemented, is a key to the functionality and survival of structures against wind storms. Typically these codes are based on meteorological information, and, to a great extent on research and development in industrial aerodynamics/wind engineering, and their review is needed at regular intervals of time to take into account the latest developments.

Wind Storms fall into various types: (a) Frontal depressions, (b) Cyclones/Hurricanes/Typhoons, (c) Tornados, (d) Thunderstorms, (e) Squalls, (f) Dust devils, (g) Down slope winds

Amongst these various types of storms, cyclones constitute the worst threat of causing disasters. It is seen that the Indian region gets less than 10% of the events that occur globally, i.e., about 6 cyclones per year, mostly on the East coast. (See also Figs. 1 and 2). Yet the Indian sub-continental region has suffered most of the cyclonic disasters that occurred, as seen from Table 3. This is indicative of our lack of preparedness on a multiplicity of fronts, including, to an extent, the codes and standards available to the concerned engineering community to create wind-resistant construction.

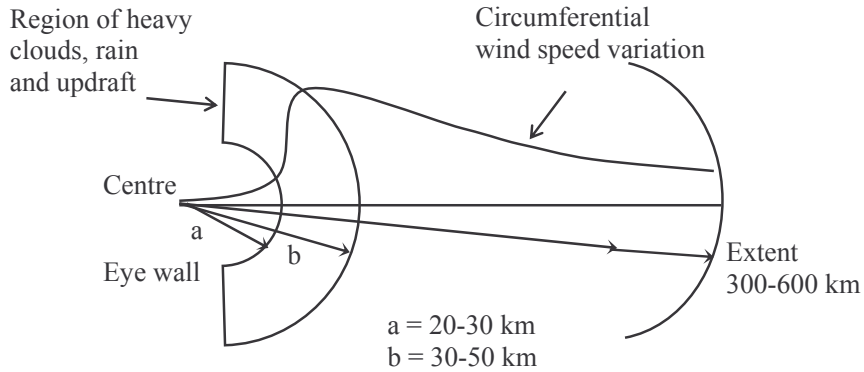
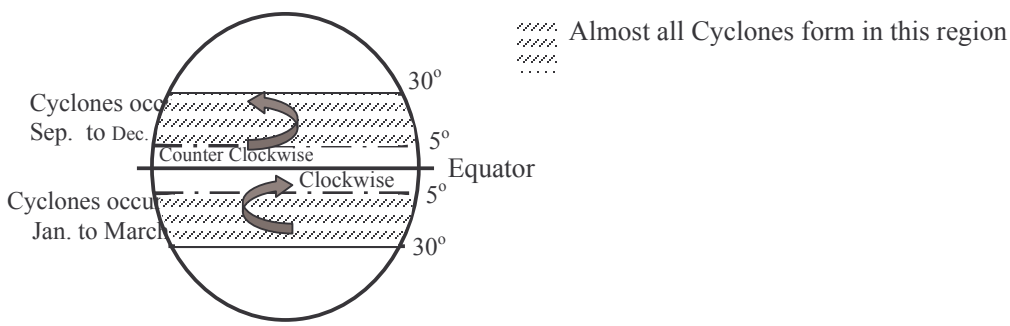


Figure 1: General Structure of a Cyclone



Notes:

1. *Total no. of Cyclones/year (Global) ≈ 80*
2. *North-Eastern Hemisphere the worst hit, experiences almost 45% of the Cyclones*
3. *India experiences about 6 Cyclones/year, mostly on the East Coast*

Figure 2 : General Distribution of Cyclones over the Globe

2.0 Nature of Wind and its Effect on Structures

Wind is a randomly varying dynamic phenomenon. Typically it is represented as a trace of velocity versus time. Figure 3 is typically representative of the variation of wind velocity. The randomly varying velocity can be broken up into a 'mean' plus a 'fluctuating' component. Within the earth's boundary layer, both components not only vary with height, but also depend upon the approach terrain and topography. While dealing with rigid structures, the consideration of the 'equivalent static' or mean wind is adequate. However, in dealing with wind-sensitive flexible structures, consideration of the fluctuating component becomes important. Such

parameters as wind-energy spectrum, integral length scale, averaging time and the frequencies of the structure become important.

Table 3 : Deaths associated with noteworthy Tropical Cyclones

India

Year	Deaths
1737	3,00,000
1833	50,000
1864	1,75,000*
1942	75,000
1971	10,000
1973	5,000
1977	10,000
1999	10,000

** 3 Events*

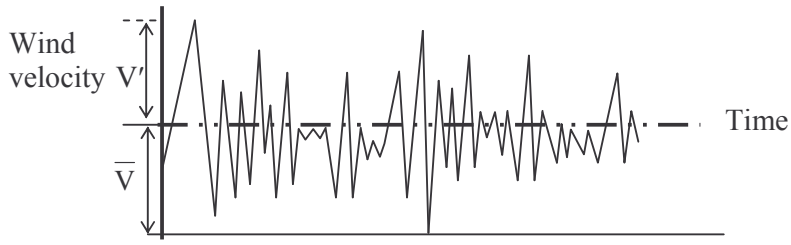
Bangladesh

Year	Deaths
1822	40,000
1876	2,50,000
1897	1,75,000
1960	5,149
1961	11,468
1963	11,520
1965	19,279
1970	3,00,000
1988	5,708
1991	1,32,000

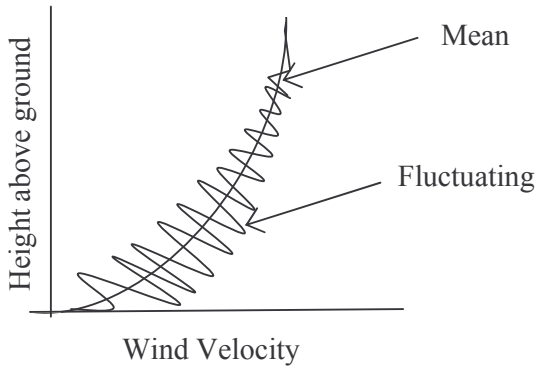
Other Countries

Year	Other Countries	Deaths
1780	Antilles	22,000
1881	China	3,00,000
1990	USA	6,000
1923	Japan	2,500
1960	Japan	5,000
1963	Cuba Haiti	7,196

(a)



$(V = \overline{V} + V')$



(b)

Figure 3 : Variation of Wind Velocity with (a) Time, (b) Height

New advances in application of aerodynamics to civil engineering structures have occurred in the last 3 decades. These have involved, amongst other aspects, a study of the influence of (i) Turbulence in the natural wind, (ii) Turbulence provoked/generated in the wind by the structure itself.

The buildings and other civil engineering structures are three-dimensional bodies with a large variety of shapes and have complex flow patterns and therefore varied pressure distributions. As a result, most 3-D studies rely partially or wholly upon experiments. Besides, the buildings are never sealed and wind pressures develop inside even in a closed building, with maximum values occurring in open buildings. These generally add to the pressures outside, creating worst possible effect on roofs, as well as walls. Studies on low-rise buildings have been made extensively, and while these continue to update existing wind loading information, new areas are also thrown up for enquiry. Such low buildings are rather rigid and have no significant dynamic response to wind, thus in a sense simplifying the problem.

Tall and slender structures are flexible and exhibit a dynamic response to wind. Tall structures vibrate in wind due to the turbulence inherent in the wind as well as that generated by the structure itself due to separation of the

flow. In case of tall structures, the dynamic forces acting in the direction of wind flow give the Along-wind response of the structure. However, the forces can also act in a direction nearly perpendicular to the flow, exhibiting an Across-wind response.

A body or a structure, such as a building, a tower or a chimney, when placed in a flow of air will experience pressures and forces. Such pressures and forces can be estimated experimentally, or, in some cases analytically, to varying degrees of accuracy. However, structures hardly ever occur in isolation. Rather, these are surrounded by other similar or dissimilar structures. 'Interference' from these leads to alteration of pressures or forces estimated for a 'stand alone' structure. This is termed as 'interference' effect and its estimation is largely dependent on experimental measurements.

3.0 Evaluation of Design Wind Loads

The mainstay of information for the designers of civil Engineering structures are the relevant codes of practice/standards/guidelines. In the case of unusual situations the state-of-the-art literature can also be helpful. The major sources on which wind loading codes are based comprise of the data on wind speeds collected mainly by the meteorological department, and results of research carried out to determine wind effects on structures. The latter takes recourse to wind tunnel tests on scaled models, computational methods, field tests and damage surveys. Out of these, the main body of information has been derived from wind tunnel tests. This has been an area of considerable research over the last few decades, and continues to evoke interest.

4.0 Current Status of Development – Internationally

Codes in general reflect the state of knowledge and practice in the relevant field. Wind loading codes are no exception, and these are based on meteorological data on wind and results of research about the effects of wind on structures.

There has been a substantial effort on developing codes of practice dealing with wind loading over the last 50 years. This is consistent with the status of wind engineering research, which has increased considerably during this period. The last 2-3 decades have been witness to substantial progress in

the understanding of the procedures to determine the design wind speeds from measured wind data, as well as of the response to wind of various kinds of structures, particularly buildings. Most leading codes have tried to keep pace with this changing scenario. However, the relevant Indian Code, having been drafted in the early eighties, has remained as such and there are apparently no moves afoot to revise the same in the near future. In broad philosophical terms many of these codes have commonality, yet they differ in detail. A move has thus been made during the last few years to study various codes to possibly create a greater degree of uniformity. Six International groups set up by the International Association for Wind Engineering (IAWE) are currently studying the problem.

Some of the major, well-prepared codes on wind loading are those written in Canada, U.K., U.S.A., and Australia, apart from the Euro Code. It is relevant to compare these briefly in broad terms, as follows:

1. Apart from content, these various codes also differ in style. Some, like the Canadian Code, are written very concisely and are backed up by a detailed commentary, which gives substantial information. Others, like the Australian version, include substantial information in the body of the Code itself. The Indian Code on wind loading follows the latter style.
2. All the codes draw upon a statistical analysis of the measured wind data to determine basic wind speeds at a standard height, and, carry out zoning of the respective country. It is common to deal with exposure or terrain categories, topographical effects, size of the structure and risk factors based on the life of the structure, to arrive at the design wind speed. There is, however, difference in adopting the averaging period, which varies from 2-3 seconds to 10 minutes to an hour. Quality and extent of data may, of course, vary from country to country.

   An issue of importance from the Indian point of view is the cyclonic wind speeds. Although implicitly these have been taken into account, studies have shown that the specified wind speeds for the coastal zones are exceeded in severe storms on the east coast. Likewise the Gujarat coast on the West has suffered considerable damage as a result of cyclonic storms in recent years. This is an issue, which needs to be addressed.

The Australian Code deals with the problem explicitly, by specifying higher wind speeds in the affected coastal belt.

3. A failure of the sheeted roofs and other claddings, which are otherwise strong enough to resist the wind pressure, may occur in strong winds. This happens on account of severe fluctuating pressures sustained at and near the fasteners. The latest version of the Australian code deals with the issue of local pressures in clear terms.

4. It has been clearly recognized by some of the latest codes that wind tunnel results are based on an idealized modelling of wind. In actual practice there is fluctuation in the directionality of wind. Further, pressures over larger areas are less co-related than those on smaller areas. Likewise loads on different parts of the structure are not fully correlated. Estimated wind load effects can thus be modified to account for these correlations.

5. Typical cases of buildings covered for providing information on pressure and force coefficients will indeed vary from code to code. Values given for the same cases also differ. A comparison of codes for pressure coefficients for a gable frame building showed considerable disparity in values. This may be expected from other such comparisons too. Several codes such as the Australian and ASCE 7 cover the information on building pressures in great detail, including canopies and effect of parapets. The coverage in IS: 875 (Part 3) is not as detailed. An important case missing in the IS: 875 (Part 3) is that of hipped roofs, which have superior performance in wind and are employed frequently.

6. The aerodynamic analysis of tall buildings, is dealt with in the major International Codes. The IS: 875 (Part 3) while dealing with the along-wind case does not cover the across-wind effects.

7. Interference amongst buildings and structures alters their response to wind. As has been mentioned in earlier part of this note, it is difficult to give generalized absolute values related to this issue of great importance, because of the variability of situations involved. However, there has been a good deal of research effort that has been made on this subject over the last few decades and it should be possible to evolve guidelines for the designer – to give the order of values arising due to interference effects,

and, also demarcation of areas around a structure which should be avoided, if possible, for placing one or more new structures from the stand-point of interference.

5.0 The Indian Scenario

As would be clear from earlier sections of this note, the main document dealing with wind loading in India is the IS: 875 (Part 3)-1987 which was drafted in the early 80s and other Indian design codes refer to this for determining wind loading. In broad terms this code imbibes the philosophy of the major wind loading codes available internationally. However, as mentioned earlier, many of these codes have been undergoing frequent revisions in recognition of the new and improved information becoming available through research efforts. The IS: 875 (Part 3)-1987 thus needs to be reviewed and updated likewise.

6.0 Revision Recommended

Keeping in view the information in the preceeding sections of this note, a revised version of the I.S: 875 (Part 3) -1987 has been prepared. While carrying out the revision it has been recognized that the version currently in force was prepared on contemporary lines and had incorpored material generally available till the end of the decade of 70s. Therefore changes have been brought about only where these would provide additional information or simplify and improve the usability of the code. The code consists mainly of four parts – (i) determination of design wind velocity, (ii) provision for pressure coefficients, (iii) provisions for force coefficients and (iv) determination of dynamic effects. A large body of the material has been retained. Changes where brought about are in varying degrees and can be categorized into three types:

1. *Minor Changes:* These are either typographical, or minor changes in style of writing, changes in figures for greater clarity, minor relocation of sections.
2. *Moderate Changes*: Consist of mainly rearranging or readjusting of already given material
3. *Major Changes*: These are numerous and consist of either revision of existing material or addition of new material.

These changes are brought out as examples in the note below, with greater emphasis on major changes.

6.1 Minor Changes

(i) The section 1 has been upgraded and notation as necessary have been added in section 2.

(ii) Editorial changes in Tables 18 (13*), 22 (18*).

(iii) Section 6.2.2.10 divided into two sections: 6.2.3.10* & 6.2.3.11*, and accordingly Table 20 has been divided as Table 15* and 16*.

(iv) Section 6.2.3 giving internal pressure coefficients relocated as 6.2.2*, likewise section 6.2.2 giving external pressure coefficients has been relocated as 6.2.3*.

(v) Appendix D has been deleted.

6.2 Moderate Changes:

(i) Sections 6.2.2.9 and 6.2.2.12 combined into section 6.2.3.8* with necessary reallocation of tables & figures.

(ii) Table 23(20*) has been consolidated.

6.3 Major Changes

(i) Design Wind Velocity:

The map of India in which different zones of the country are demarcated to show the basic wind speed was based on a statistical analysis of meteorological data. A study of wind speed data carried out at SERC Chennai, and observations by Indian Meteorological Department have shown that the speeds specified in the map are exceeded in cyclonic storms. There also has been an evidence of the occurrence of severe cyclones (such as the Orrisa super cyclone) on the east coast, which caused enormous damage. The Gujarat coast also experienced two cyclones in which much damage was caused. Keeping this in view and considering the important of the structures involved, a cyclonic regional factor k_4

* *number in the recommended draft*

(5.3.4*) has been introduced as a multiplier to the basic wind speed V_b. This is stipulated to be applicable in a 60 km strip on the east coast and the Gujarat coast which is expected to be more seriously affected in cyclones.

(ii) Wind Directionality Factor :

Considering the randomness in the directionality of wind and recognizing the fact that pressure or force coefficients are determined for specific wind directions, it is specified that for buildings, solid signs, open signs, lattice frameworks, trussed towers (triangular, square, rectangular) a factor of 0.90 may be used on computed forces. (Section 5.4.1*)

(iii) Effect of Area Used in Averaging Pressures:

Pressure coefficients are obtained by averaging pressures over a specified tributary area. The correlation decreases with increasing area. Appropriate factors K_a which is a reduction factor (section 5.4.2*) has been introduced accordingly.

(iv) Combination Factor K_c:

When taking wind loads on frames, of clad buildings, it is reasonable to assume that the pressures or suctions over the entire structure will not be fully correlated. Therefore when taking the combined effect of wind loads on the frame, the forces obtained in the frame may be reduced suitably. Factor K_c (section 6.2.3.13*) has been introduced accordingly.

(v) External Pressure Coefficients C_{pe}:

Several changes have been brought about in respect of external pressure coefficients. (Section 6.2.3*)

(vi) Interference Effects:

Changes are produced in the wind characteristics as it flows past any construction. In case it is a building or some other structures, the changes in the wind characteristics are termed as wind interference effects. The modified wind on striking a structure generally produces higher pressures due to increased turbulence, though a shielding effect occurs if the interfering and the interfered structures are very close to each other. The modification in the

wind characteristics and hence its effect on the structure under consideration depends on a large number of variables and is thus quite complex. For the purpose of obtaining the design wind pressures, the interference effect of wind is expressed by the ratio of the modified pressure / force to the pressure / force in case there is no interference, that is, for the structure in isolation.

Provisions to account for the interference effect in a building do not exist in any Wind Loading Code at present. These are being introduced for the first time in this code so as to provide guidance to the designer for preliminary design purpose. For important projects, it is envisaged that recourse will be taken to wind tunnel testing.

(vii) Dynamic Effects of Wind :

While a rigid structure (f_0 > 1Hz) hardly responds to the turbulence or gustiness in the wind, a flexible structure (f_0 < 1 Hz) or a flexible element in a structure would be set into vibrations, which may be quite complex depending upon the type of structure/element. The dynamic effect of wind, for the purpose of design, can be described by a gust effect factor, G also termed as dynamic response factor or simply as gust factor. Its value for relatively rigid structures (f_0 > 1 Hz) may be taken as 0.90.

A tall building would respond not only along–wind but may also have significant cross–wind dynamic response. The latter is difficult to estimate and needs wind tunnel studies for evaluation, though for a few cases response spectra for the cross–wind response are available and these are being included for the first time.

The estimation of the along–wind response, is recommended to be based on the *3–sec design gust wind speed as against the hourly mean wind velocity* in the present IS Code, which is consistent with the practice in some of the recent codes.

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