NS(2)

ORIENTATION OF INDUSTRIAL SHEDS AND STRONG WIND EFFECTS

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INTRODUCTION

The design of Industrial structures is often governed by the wind loads. IS:875-1987,Part-3 [1], has given comprehensive methodology for evaluating the wind loads on industrial structures. The extreme value analysis of windspeeds occurring at various meteorological stations has been used to arrive at the basic windspeed .The directional distribution of winds has not been utilised. It is possible to use the directional data together with pressure coefficients obtained on the model of an Industrial structure in wind tunnel testing to obtain optimum layout of Industrial complexes. It is assumed that the Industrial structures in a particular complex will not vary widely with the values of height to width ratio ,length to width ratio and the roof slopes remaining nearly the same. Wind velocity varies in a random manner in both time and space. Hence even on a rigid structure the load effects vary with time. This leads to enormous number of load cycles of differing magnitudes during the life of the structure, leading to accumulation of fatigue damage. When such structures are located in cyclone prone regions ,one of the basic consideration for planning could be minimization of fatigue damage prior to exposure to an extreme wind event like cyclone.

NON-CYCLONIC WIND LOADS

The hourly average windspeeds along with the direction have been obtained for the year 1995 (which was a cyclone free year for the site i.e

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Meenambakkam airport).The wind data was acquired using a Dines Pressure Tube Anemograph. The anemograph at Meenambakkam is kept at a height of 26.3 m above the ground level on the top of the control tower building of the old airport.The details of the surrounding land is shown in fig. 1.The area to the northwest is free of any obstruction in the form of buildings or hills. To the southwest lies a circular range of hills. The Pallavaram hills which is about 80 m high, is the nearest hill in this range and it is about 2.4 km away. These hills have not affected the observations is evident from the fact that the southwest is one of the predominant wind directions. The wind velocities are to be reduced to the standard height of 10 m .

Analysis Of The Wind Data For The Year 1995.

The hourly data was sorted and a frequency graph(fig 2a) was obtained with compass directions along the x-axis and frequency along the y-axis. Also a radar graph(fig 2b) was drawn. Both these figures indicate that the winds are predominantly from the west and the south east. The northwest, north and the north east sectors are seen to have much less frequency of winds.

Maximum and Minimum Windspeeds

The windspeeds range from 0 to 16.5 m/sec. The maximum and minimum windspeeds for each of the 16 compass directions have been plotted in fig 3. It is seen that the winds from the west have a clearly much larger maximum windspeed.

The figures 2 and 3 indicates that the predominant wind directions are W,SE and NE. A much more comprehensive 15 year wind speed data was also examined to see whether these predominant directions are relevant over a much larger data base.

Analysis Of Wind Data For 15 Years (1971 To 1985)

The data for 15 years(1971-1985) was analyzed and the frequency of the wind Vs direction graph and the radar graph with 16 compass directions was drawn. Critical evaluation of these also yielded a clear directionality for dominant winds from West,SE and NE. It was examined whether any clear orientation could be suggested for Industrial sheds in Madras in order to minimize the effect of strong winds based on the above data in conjunction with pressure data recorded in wind tunnel tests.

WIND TUNNEL EXPERIMENTS.

Fig.4 shows the details of a 1:50 model of the Industrial shed on which area averaged pressures were measured. The wind flow corresponding to category 2 terrain is simulated. Pressure traces were obtained corresponding to 8 locations on the roof for wind angles of 0 to 180 degrees in steps of 15 degrees with respect to the longitudinal axis of the model .More details of the testing have been reported elsewhere [2].

The mean pressure coefficients were determined using the formula

$$Cp = [\ p/(0.5\ \rho\ v^2)]$$

where

p = mean area averaged wind pressure

ρ = density of the air

v = mean windspeed at the reference point(eaves level).

The Cp_{mean} values for all the 8 locations were determined. The Cp_{mean} **value** vary significantly with wind angle. Panels 1 and 4 , 2 and 3, 5 and 8 , and 6 and 7 are symmetrically placed with respect to the long axis **of the** model(fig. 4).The variation in Cp_{mean} values on various panels for wind angles of 0 to 360 degrees is plotted (fig. 5).

DETERMINATION OF IDEAL ORIENTATION FOR INDUSTRIAL SHEDS.

To determine the most ideal orientation for an Industrial shed, the following studies were done.

(1) Wind Potential Estimates under constant windspeeds

The most adverse circumstance is one in which the wind velocity and Cp_{mean} value are both large. In the present case, higher windspeed is associated with larger frequencies(number of hours of wind loading during one year).The sum of the product of Cp_{mean} for different wind directions and the number of hours of wind loading from the corresponding direction during the year gives an estimate of the potential of the wind on a panel during the year. The most adverse condition is one in which the sum of this product is larger. The analysis was done for an average windspeed of 25 kmph for all directions and for different orientations. Therefore for each orientation of the Industrial structure, the product of wind frequency and Cp is determined for each direction of the wind. A curve can be drawn for each panel showing the variation of this product for different wind directions. The area under this curve gives the net effect on the panel due to one year of normal winds for that particular orientation. The best orientation is that for which this value is the least. Alternately, the total effect on the roof as a whole can be obtained by summing up the values at 4 locations. This can be done for all orientations. The best orientation for the roof as a whole is one for which the sum is the least.

Since 0 and 180 degree orientations are the same , the plot between 180-360 degrees is superimposed over the plot 0-180 degrees. It is seen that 67.5 to 90 degrees orientation from the north is the best.

The number of directions was reduced from 16 to 8 by clubbing adjacent directions first clockwise and then anticlockwise. The corresponding wind occurrence frequencies were also determined. And the above analysis was repeated.Clockwise clubbing(fig 6a) showed that 45 to 90 degrees orientation as the best orientation while the anticlockwise clubbing (fig 6b) yielded 90 degrees as the best orientation.

(2) Maximum Load Estimates

For each orientation of the Industrial shed , the worst value of the product of Cp_{mean} and the square of the average velocity given in fig.3 (representing the worst load on any panel) was determined for the year 1995. Fig. 7a obtained by superimposing the plot between 180 and 360 degrees over 0-180 plot clearly indicates that an orientation between 67.5 and 90 degrees is optimum. The plots obtained by reducing the number of directions from 16 to 8 by clubbing adjacent directions clockwise and anticlockwise (fig.7b and 7c) also indicate that 90 degree orientation as the ideal one.

(3) Fatigue Loading Estimates

The wind pressure traces obtained by testing the model of the Industrial shed in the BLWT for 20 seconds for each wind direction was analyzed. The peaks and the troughs were separated and the number of cycles of pressure determined using rainflow analysis. The effect of the number of cycles (n) was included by multiplying the pressure coefficient and the number of cycles of wind loading for a particular direction with the appropriate number of hours of wind loading. This calculation was done for all panels for all wind directions and the sum determined for each panel. This was repeated for all orientations (fig.8a). The product of Cp and n values adjacent directions were first clubbed clockwise and then anticlockwise and the above calculations repeated. The cases of clockwise clubbing (fig 8b) and anticlockwise clubbing (fig.8c) both yielded East-West orientation as the most favourable one with regard to fatigue effects due to wind.

A study of the wind rose diagrams of Meenambakkam and Nungambakkam clearly shows that directionality of winds as observed above is a macro-phenomenon with some local variations. As such, this information can be used in the analysis for determining the best orientation for Industrial building . Considering estimates of Wind Potential, Maximum Wind Load and Fatigue Loading ,the 90 degree(i.e. East west) orientation is ideal.

The wind rose diagrams given in [3] clearly shows that strong directionality exists for other locations like Bombay, Hyderabad, and Visakhapatnam. Similar studies could be done for these places to establish the best orientations for Industrial structures.

CONCLUSIONS

The wind data available from IMD over the past 100 years and more, can be used for planning of Industrial structures particularly with regard to their orientation to minimize loss or damage during extreme wind events such as cyclones. Data generated from tests on models of these structures in the wind tunnel would make a scientific orientation feasible based on estimates of wind potential, maximum wind load and fatigue loading as described in this paper.

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1. Hourly averaged wind speed and direction data for 1995
2. Windrose diagram (1971-1985)

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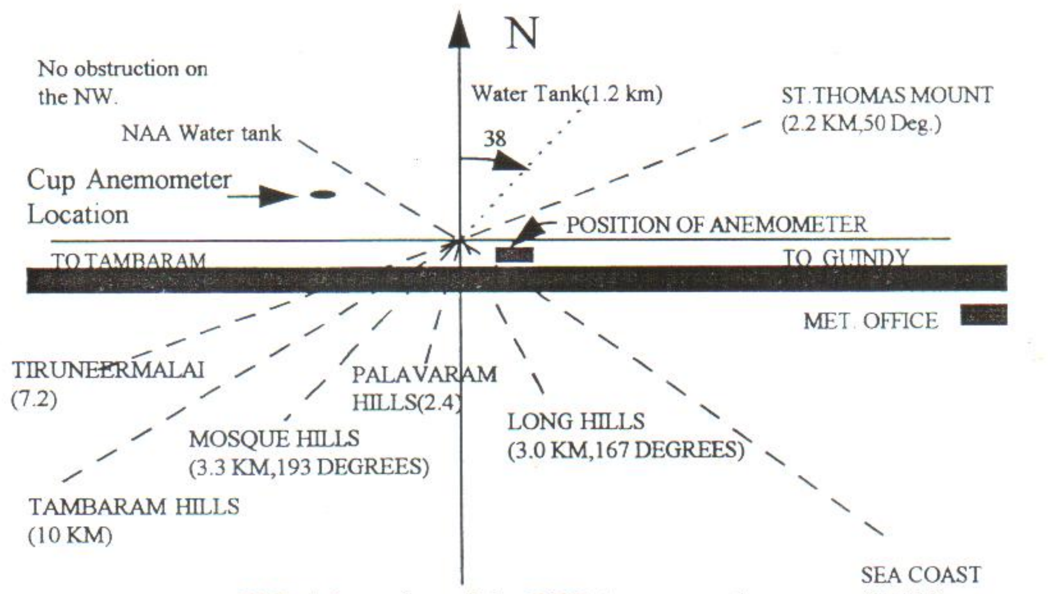


FIG. 1 Location of the DPT Anemograph at Meenambakkam

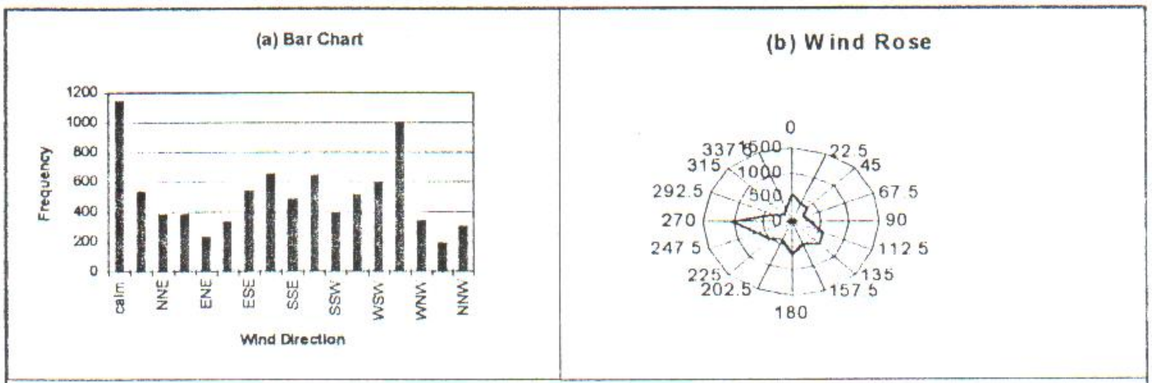


FIG.2 DIRECTIONALITY DISTRIBUTION

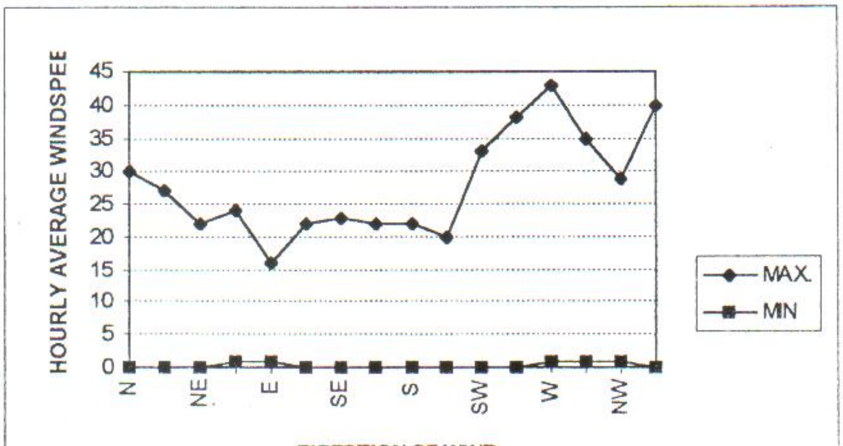
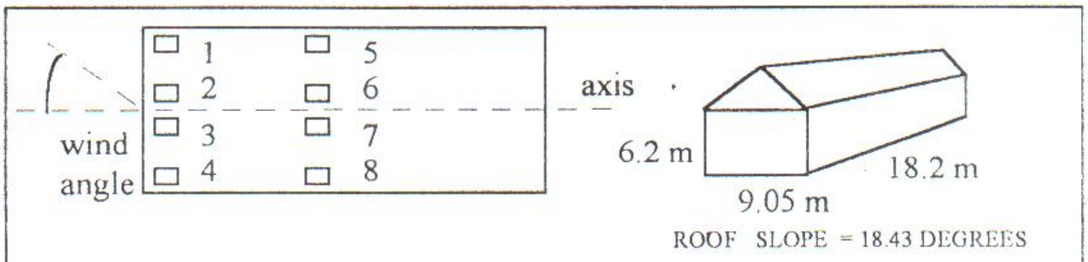


FIG.3 MAXIMUM AND MINIMUM HOURLY AVERAGE WINDSPEED FOR DIFFERENT DIRECTIONS



(a) PLAN OF THE MODEL WITH PANEL LOCATIONS

(b) DIMENSIONS OF THE PROTOTYPE INDUSTRIAL SHED

FIG.4 DETAILS OF WIND TUNNEL TEST

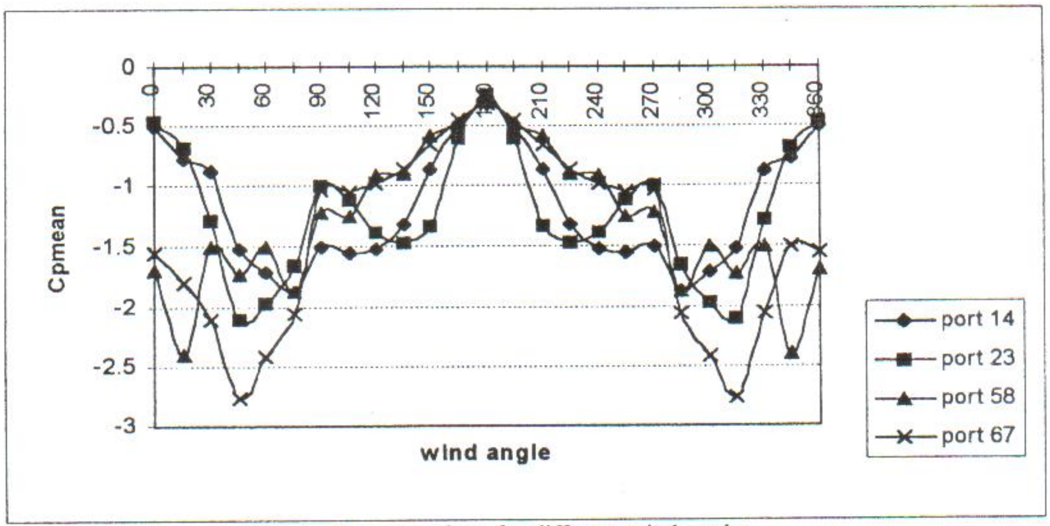


FIG. 5. Cpmean values for different wind angles

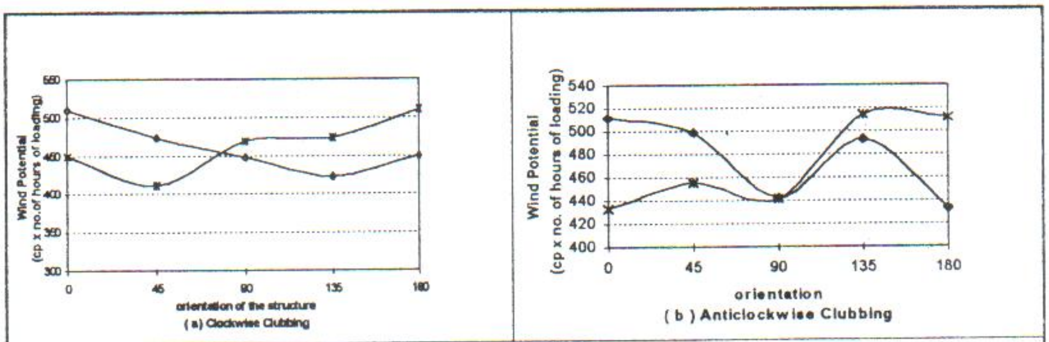


FIG.6 WIND POTENTIAL ESTIMATES

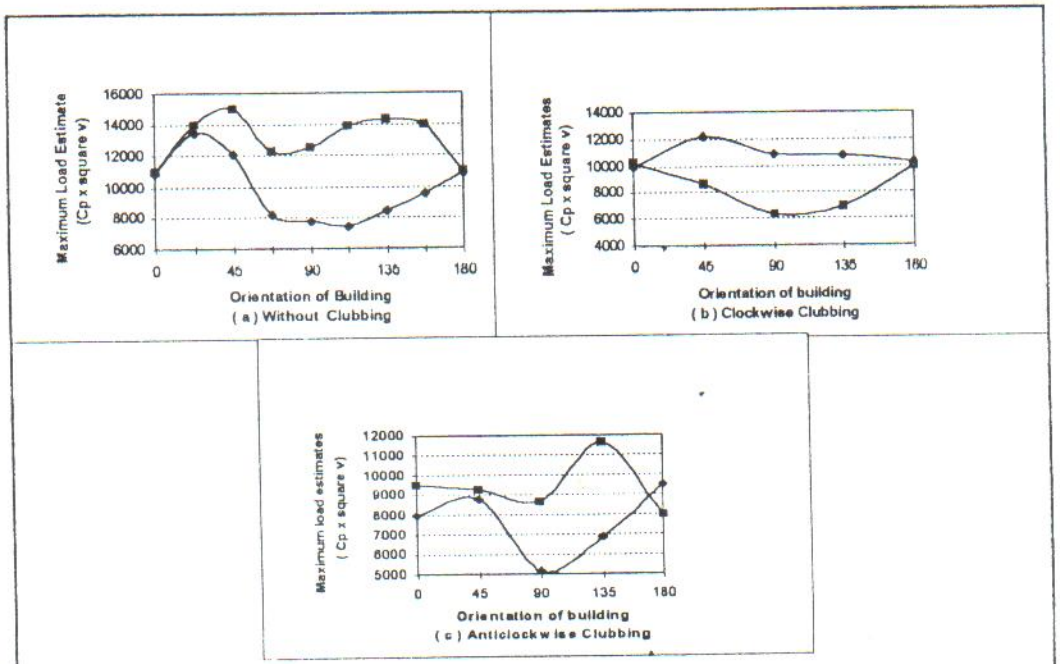


FIG.7 MAXIMUM LOAD ESTIMATES

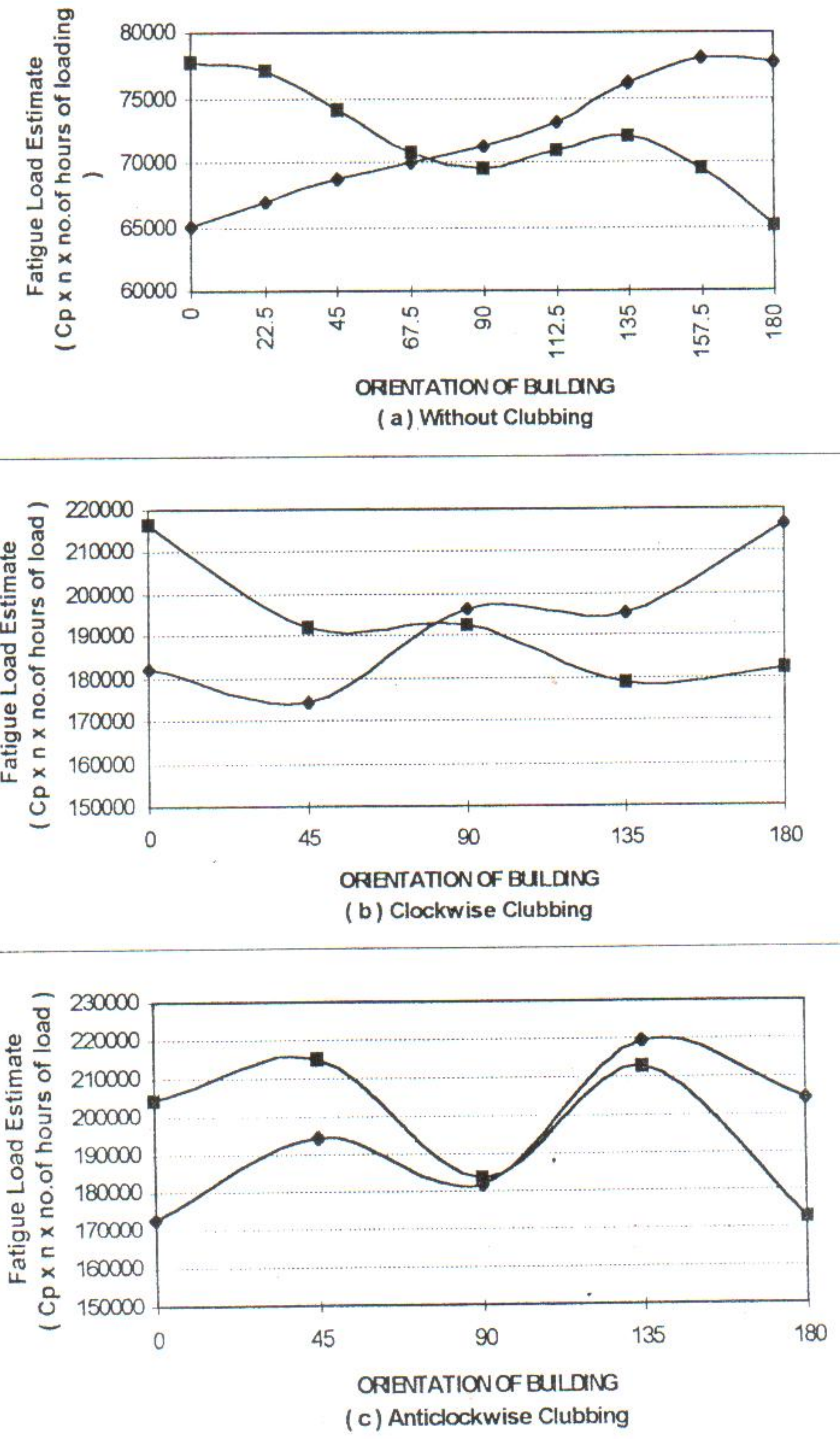


FIG.8 FATIGUE LOAD ESTIMATES