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A Comparative Study of Wind Forces on Tall Building by Static Method and Dynamic Method Per Is 875-Part-Iii (1987)

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Abstract: The paper discusses the method of calculation along wind response by gust factor method by considering the effect of change in terrain category .as described by the code (IS:875-(part 3)-1987). The present Indian standard on wind load(IS:875-(part 3)-1987). Gives procedure to determine along wind response of building which involves use of tables and charts, which are quite cumbersome to be used by practicing engineers. Further it does not give any procedure to determine across wind response. Tall buildings of height 100 have been analyzed for 1 to 4 terrain categories as per current code available manually and by a user ETABS program. Typical results of variation of shear force and bending moment have been included. The analysis of these building using present code indicates that for Terrain Category 1,2,3 and 4 by Static and Dynamic Method. The results for bending moment and shear force are it can be seen that the dynamic methods are considerably higher compared to static method because dynamic methods give higher value of bending moment and shear force compared to static method.

Keywords: Static and Dynamic Method, ETABS program.

1. INTRODUCTION

As the demand for taller, lighter and more slender structures continues to increase, so does the importance of designing for wind-induced building motion. Tall structures that meet the code for lateral drift requirements can still sway in strong winds. The recent disasters in United States due to the hurricanes also prove that existing buildings are not fully wind resistant Therefore it becomes necessary to review the computing techniques that are currently in use for the determination of along wind load. It is believed that ultimately wind load estimation will be made by taking into account the random variation of wind speed with time but available theoretical methods have not matured sufficiently at present for use in the Indian standard code. For this reason, static wind method of load estimation which implies a steady wind speed, which has the present Indian Standard for Wind Loads on Buildings and Structures (IS-875 (part-3):1987), recommends Gust Factor (GF) or Gust Effectiveness Factor (GEF) for calculating along wind load or drag load on flexible slender structures which includes tall buildings.

The procedure makes use of hourly mean wind speed and cumbersome charts to arrive at the Gust Factor. Following section discusses the steps to obtain along wind response as per (IS-875 (part-3):1987) Building of height 100, analyzed as per the (IS-875 (part-3):1987) . Manually and used E-TABS program, the results are compared. This paper discusses the methods for calculating along wind response by Static Method and the gust factor method(Dynamic Method) and by considering the effects of change in terrain category, as described by the present IS-code [IS:875-(part-3)-1987] with the help of examples of tall buildings 100m.

2. COMMON AERODYNAMIC MECHANISMS.

The following are the common aerodynamic mechanisms inducing loads on high-rise buildings.

Along-Wind Loads (Drag): As the name defines, this loading is in parallel with the wind direction. This loading has three components such as mean, background fluctuations and resonant fluctuations. Loading is mainly caused by oncoming fluctuating wind, architectural geometry of the building and structural properties of the building. All the codes address this loading.

Across-Wind Loads (Lift): As the name defines, this loading is perpendicular to the wind direction. Figure 1 pictorially shows both along-wind and across-wind loads. Like the drag loading, this loading also has the same three components though resonant component can be very high and the mean component can be close to zero. This loading is mainly caused by alternate shedding of vortices at both sides of the body inducing a force in the direction perpendicular to the wind. In addition to this, several other factors listed under drag have an influence too.

3. WIND EFFECTS ON STATIC STRUCTURES

In the case of static structures the flow interacts only with the external shape of the structure. When the structure is very stiff, deflections under the wind loads will not be significant, and the structure is said to be "Static". As the lowest mode frequencies are high, there is little energy in the spectrum of atmospheric turbulence available to excite resonance. The only design loading parameter of importance is the maximum load likely to be experienced in its lifetime. The parameters most relevant to the assessment of design loading are Influence functions, size parameters of the structure, load duration and assessment of load for design.

4. WIND EFFECTS ON DYNAMIC STRUCTURES

In the case of dynamic structures, there is an additional interaction with the motion of the structure. When the structure is sufficiently flexible, the response to wind loads is significant to the design of the structure. The conventional approach to the analysis of dynamic response of lightly damped structures is by resolving the response into the natural modes of vibration, characterizing each normal mode as a set of model parameters: 1) Model shape, 2) Model mass, 3) Model stiffness and 4) Model damping. Using these parameters a frequency response function can be defined that describes the dynamic characteristics of the structures.

5. ANALYSIS OF BUILDING FOR VARIATION

Category1. Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5m.

Category2. Obstructions having heights generally between 1.5 to 10m.

Category3. Terrain with numerous closely spaced obstructions having the size of building structures up to 10m in height with or without a few isolated tall structures.

Category4. Terrain with numerous large high closely spaced obstructions.

6. DYNAMIC EFFECTS

General- Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations along and across the direction of wind. In general, the following guidelines may be 'used for examining the problems of wind induced oscillations:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0. and

b) Buildings and closed structures whose natural frequency in the first mode -is less than 1-O Hz.

7. WIND DATA

Wind Zone: Basic wind speed	: 50 m/s
Terrain Category	: I, II, III, and IV
Class of Building	: C
Topography	: Flat

Wind speed, design wind pressure, loads to the building is calculated using standard IS codes.

8. MODEL DATA

The E-TABS software is used to develop 3D model and to carry out the analysis. The lateral loads to be applied on the buildings are based on the as per (IS-875 (part-3):1987)

9. DESIGN WIND SPEEDS FOR STATIC STRUCTURES

The basic wind speed Vb of a region correspond to certain reference conditions as highlighted in the earlier section, and shall be modified to include the effects of risk level, terrain roughness, height, structure size and local topography to obtain design wind speed, Vz in m/s at height z for the chosen structure as given below

$$Vz = Vbk1\ k2\ k3$$.[From IS:875(part 3) -1987]

Where:-

Vz = Design wind speed (in m/s) at height z

Vb = Basic wind speed for the site (50m/s)

k1 = Probability factor or risk coefficient with return periods.

k2 = Factor for the combined effects of terrain (ground roughness) height and size of the component on structure. Table-2, Terrain category1,2,3 and 4 , Class C . [From IS:875(part 3) -1987.]

k3 = Factor for local topography.

10. DESIGN WIND PRESSURE:

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity

$$Pz = 0.6Vz2$$.[From IS:875(part 3) -1987]

Where

Pz = Design Wind Pressure in N/m^2 at height z,

Vz= Design wind velocity (in m/s) at height z

11. EQUATIONS FOR GUST FACTOR AS PER PRESENT CODE (Dynamic Method)

According to IS: 875 (Part III) the following table is calculated using different relations. The basic wind speed Vb of a region correspond to certain reference conditions as highlighted in the earlier section, and shall be modified to include the effects of risk level, terrain Gust effectiveness factor method (AS PER IS-875 PART-III-1987) As discussed already, Gust Effectiveness Factor Method is a more realistic and rational approach to deal with wind loads for all type of structures .

12. HOURLY MEAN WIND SPEED WITH HEIGHT

The variation of hourly mean wind speed with height shall be calculated follows.

$$Vz= Vb*K1*K2*K3$$

Where:-
Vz = hourly mean wind speed in m/s at height "z";
Vb = basic wind speed in m/s;
K1= Probability factor;
K2 = Terrain and height factor;
K3 = Topography factor.

13. ALONG WIND LOAD

Along wind load on structure on strip area (Ac) at any height (z) is given by

$$Fz = Cf*Ae*Pz*G$$

Where,
Fz = along wind load on the structure at any height z corresponding to strip area Ae,
Cf = force coefficient for the building (Figure.5)
Ae= effective frontal area considered for the structure at height "z",
Pz = design pressure at height "z" due to hourly mean wind obtained as (N/m2)

G=gust factor (peak load/mean load) and is given by:

$$G = 1 + gfr\sqrt{(B(1+\emptyset)^2 + (\frac{SE}{\beta})}$$

where,
gf = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load, and r
r = roughness factor which is dependent on the size of the structure in relation to the ground roughness. The value of is given in Figure. 1.

The value of 'gf r' is obtained from (IS 875 PART-3 .FIG.8). L(h) =a measure of turbulence length scale is obtained from (IS 875 PART-3 .FIG.8)
B = background factor indicating a measure of slowly varying component of fluctuating wind load (Figure. 2) and is obtained from (IS 875 PART-3.FIG.9),
Where,
Cy b / Cz h
Cy = lateral correlation constant which may be taken as 10 in the absence of more precise load data,
C z = longitudinal correlation constant which may be taken as 12 in the absence of more precise load data,
b = breadth of a structure normal to the wind stream,
h = height of a structure
S = size reduction factor (Figure.3) is obtained from (IS 875 PART-3.FIG10),
$\frac{SE}{\beta}$ = measure of the resonant component of the fluctuating wind load.
E= measure of available energy in the wind stream at the natural frequency of the structure (Figure.4) is obtained from (IS 875 PART-3.FIG .11),

14. ALONG WIND LOAD

Along wind load on a structure on a strip area (Ae) at any height (z) is given by: ALONG WIND LOAD Along wind load on a structure on a strip area (Ae) at any height (z) is given by:

$$Fz = Cf*Ae*Pz*G$$

Where
C.F= force coefficient for the building .
Ae= effective frontal area considered for the structure at height z
Pz= design pressure at height z due to hourly mean wind obtained as . G = Gust Factor

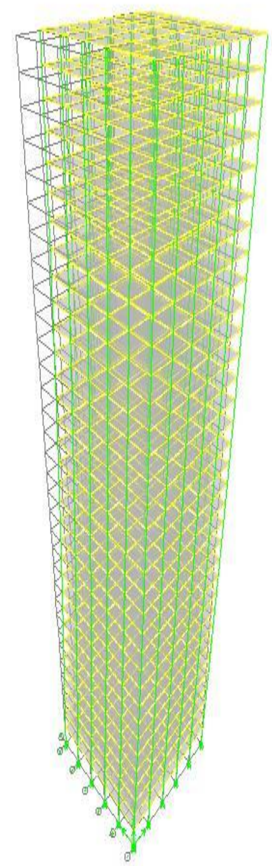

Fig1. A33 storey building under wind

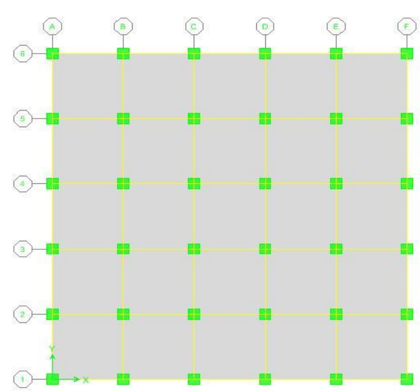

Fig 2. Typical floor plan of building size(25*25)

15-A COMPARATIVE STUDY OF WIND LOAD ON TALL BUILDING AS PER IS 875-PART-III (1987) BY STATIC AND DYNAMIC METHOD FOR 100 m BUILDING.

Building (1) particulars height 100 m for comparative static and dynamic method.

Table 1: Building particulars

Parameter	Building 1
Height (m)	100
Breadth (m)	25
Length (m)	25
Basic wind Speed (m/s)	50
Terrain Category	1, 2, 3 & 4
Drag Force Coefficient	1.30

Note:- Breadth considered normal to the wind direction and k1,k3and k4 taken as 1.0

Building 1 was used for the validation purpose . Bending Moment and Shear Force in building due to wind load under category 1,2,3and4 were calculated manually using graphs and charts of existing code along the height of the building.

Table 2 data for 100m building

Structure	**SMRF**
No. Of stories	**33**
Storey Height	**3.00 m**
Material property	
Grade of concrete	**M50**
Grade of Steel	**Fe 500**
Member Properties	
Thickness of slab	**0.150m**
Beam Size	**0.45 x 0.6 m**
Column Size	**0.800 x 0.800m 1.1x1.1 m**

Table 3:Comparative Study of Max shear force and Bending moment for Building(1) By static and dynamic method.

T.C	Max S.F. (kN)		Max B.M. (kN-m)	
	IS 875:1987 (PART3) STATIC METHOD	IS 875:1987 (PART3) DYNAMIC METHOD	IS 875:1987 (PART3) STATIC METHOD	IS 875:1987 (PART3) DYNAMIC METHOD
1	5205.794	7522	280744.3	420973
2	4489.254	7003	245384.7	393074
3	3837.368	4176	212894.5	368225
4	3135.699	3687	183889	219660

From Table 3 it can be seen that the dynamic methods are considerably higher compared to static method because dynamic methods give higher value of bending moment and shear force compared to static method from these it is quite clear that the structure design based on static method is unsafe for tall structure more than 100 m .For safe design dynamic method are to be adopted as the produce more value of shear force and bending moment

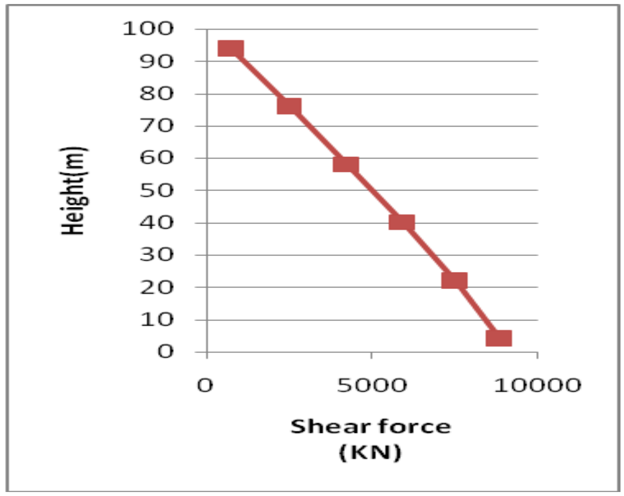

Fig .6: Shear Force variation for building (1) CT-1

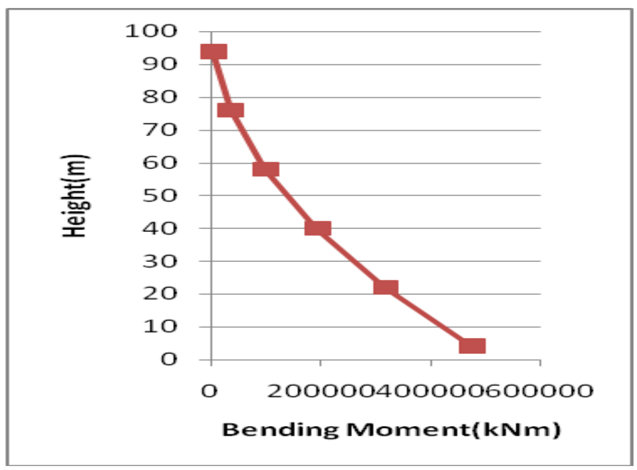

Fig.7. Bending moment variation for building (1) CT-1

19. CONCLUSIONS

Following conclusions are made by analyzing the building mentioned above as per present code of practice .

1. For a more realistic and safe design of the building gust effects are to be considered.
2. The gust factor decreases with the height because as the height of the frame increases the fundamental frequency decreases.
3. The gust pressures increase with height of building .the increase becomes considerable and my even become critical in the case of very tall building.
4. shear force and bending moment maximum at base of building.

20. REFRENCES

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