ESTIMATION OF WIND FORCE ON SQUARE TALL BUILDING WITH ACCEPTANCE RATIO1:1:7 BY ABAQUS

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Abstract: The development of high strength concrete, higher grade steel, new construction techniques and advanced computational technique has resulted in the emergence of a new generation of tall structures that are flexible, low in damping, slender and light in weight. These types of flexible structures are very sensitive to dynamic wind loads and adversely affect the serviceability and occupant comfort. This project presents the results using Abaqus software on square building models with an acceptance ratio of 1:1:7. The wind force on the models is evaluated from force records obtained from software under Abaqus for normal wind directions in an urban terrain condition s for category A. The same square building analyzed manually by IS 875 Part 3: 1987. The value obtained from this are compared with software results. The further study is made for the design and calculation of Gust Response Factor.

Keywords : Windward, Leeward, Guest Response, Acceptance Ratio.

1.INTRODUCTION

Importance Of wind Analysis on Tall Structures:

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to30 meters above ground.

Very strong winds (greater than 80 km/h) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. A feature of the. Cyclonic storms over the Indian area is that they rapidly weaken after crossing the coasts and move as depressions/lows in land. The influence of a severe storm after striking the coast does not, in general exceed about 60 kilometers, though sometimes, it may extend even up to 120 kilometers. Very short duration hurricanes of very high wind speeds called KalBaisaki or Norwesters occur fairly frequently during summer months over east India.

The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself

The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

The stability calculations as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind loads on vertical surfaces, roofs and other part of the building above general roof level. Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the building.

2.LITERATURE SURVEY

2.1 Wind Characteristics:

Basic Wind Pressures:

Figure1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic wind speed for some important cities/towns

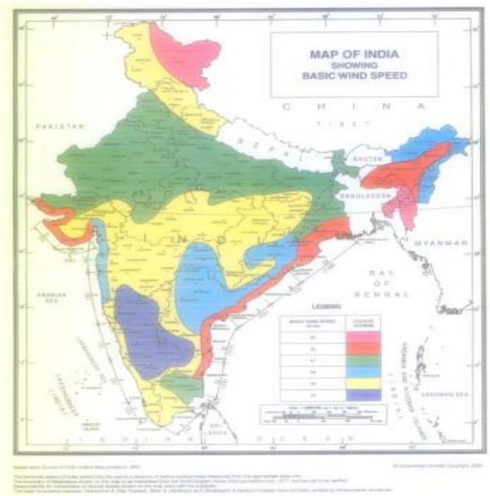

Fig. 1 Basic Wind Speed

2.2 Gradient Wind Speed:

The gradient wind is a balance of the Pressure Gradient Force, centrifugal and Carioles. A geotropic wind becomes a gradient wind when the wind begins flowing through curved height contours. The curving motion introduces a centrifugal (outward fleeing) force. The centrifugal effect can be felt when turning through a curve in a car. You stay with the car but it feels like you are being pushed sideways.

2.3 Gust Factor:

Only the method of calculating load along wind or drag load by using gust factor method is given in the code since methods for calculating load across-wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. However, such a theory must take into account the random nature of atmospheric wind speed.

2.4Turbulence characteristics

Gustiness occurs due to the velocity fluctuations present in the wind flow and this renders the forces exerted on the structure as dynamic forces. The degree of gustiness is given by standard deviation or RMS velocity value. The turbulent intensity can be obtained from SD and mean velocity and is given in equation.

$$I_u = \left(\frac{\sigma u}{\bar{U}}\right) \text{ or } I_u = \left(\frac{1}{ln(z/Zo)}\right)$$

where

I_u = turbulent intensity

σ_u = standard deviation

$\bar{U}_z$ = mean velocity at height 'z'

Z_o = terrain roughness length

Wind velocity has two components which are mean velocity that increases with height and turbulent velocity that remains same after gradient height. The variation of wind velocity with time has been illustrated in Fig. 3.3 and is given in equation

$$V_t = V + V'$$

Where,

V_t = wind velocity at any given instant of time‘t’

V = average wind

V’ = wind gusts

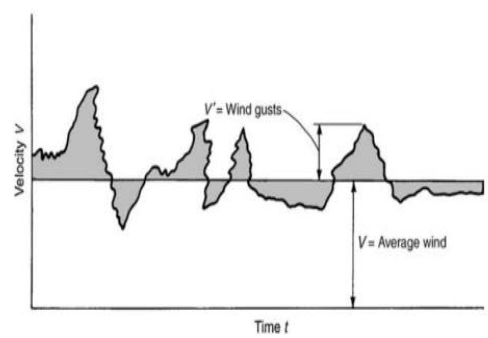

Fig. 2 Variation of wind velocity with time

As wind pressures are proportional to the square of velocities, with variation of mean Wind velocity, the mean pressures also fluctuate. The variation of pressure has been shown in Fig.2 and is given by:

$$P_t = P + P'$$

Where,

P_t = pressure at any instant of time 't'

P = Mean pressure

P' = Gust pressure

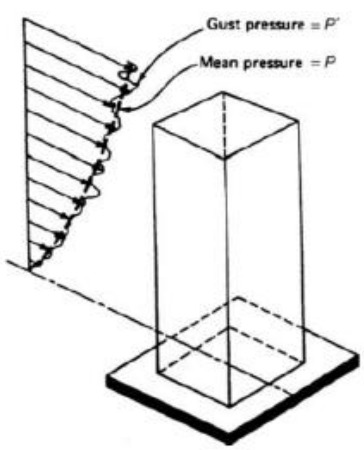

Fig 3. Schematic representation of mean and gust pressure at any instant of time't' Along wind and across wind motions

Under the action of wind flow, structure experience aerodynamic forces that include the drag force and lift force. Drag (along-wind) force acting in the direction of the mean wind and the lift (across-wind) force acting perpendicular to that direction. The Along-wind motion primarily results from pressure fluctuations in the windward and the leeward faces, which generally follow the fluctuations in the approach flow. The Across-wind motion is introduced by pressure fluctuations due to vortex shedding in the separated shear layers and wake flow field.

2.5 Wind force F

Along Wind Load - Along wind load on a structure on a strip area (A_e) at any height (Z) is given by:

$$F_S = C_f A_e P_z G$$

where

F_S = along wind load on the structure at any height z corresponding to strip area A_e

C_f = force coefficient for the building,

A_e = effective frontal area considered for the structure at height Z,

P_z = design pressure at height z due to hourly mean wind obtained as 0.6 V_z^2 (N/m^2)

3. Data Collection

Evaluation of wind force

Fig.10 (IS 875-3 Pg.51) shows the different faces of angles considered for the pressure measurement study. The chord length for each face is given as follows: Face A: 0-10cm, Face B: 10- 25cm, Face C: 25- 35cm, Face D: 35-50cm

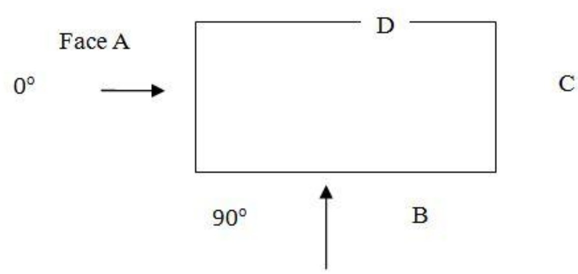

Fig 4.Forces on Tall Building

LEVELS	Z/H	HEIGHT in cm	Fx1987(0⁰)	Fy1987(90⁰)
1.000	0.1	7	298.5	904.4
2.000	0.2	14	397.5	1224.4
3.000	0.3	21	457.4	1420.9
4.000	0.5	35	1115.5	3473.5
5.000	0.7	49	1239.4	3874.3
6.000	0.8	56	655.7	2052.3
7.000	0.9	63	708.5	2256.7
8.000	0.95	66.5	390.4	1196.7
9.000	1	70	415.2	1310.2

Table 1 Calculation of force as per IS-875(part-3) 1987 Provisions

Level	Leeward (90°)	Windward(0°)
1.000	904.4	298.5
2.000	1224.4	397.5
3.000	1420.9	457.4
4.000	3473.5	1115.5
5.000	3874.3	1239.4
6.000	2052.3	655.7
7.000	2256.7	708.5
8.000	1196.7	390.4
9.000	1310.2	415.2

Table 2 Calculation of force as per IS-875(part-3) 1987 Provisions

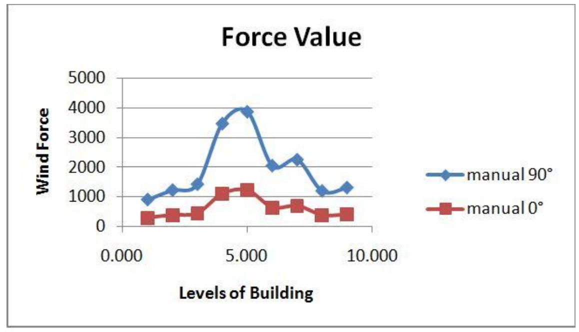

Fig. 5 Forces for manual solutions

4. RESULTS AND DISCUSSION

Unsteady numerical simulations have been carried out for a 1:1:7 square building model under uniform wind flow condition using two types of turbulence models available in ABAQUS software: (i) Realizable k-ε turbulence model, which is single scale type turbulence model and (ii) DES turbulence model with Realizable k-ε option, which is multi-scale type hybrid turbulence model. For the evaluation of pressure coefficients and drag and lift force coefficients, the reference wind velocity is taken as 10 m/s (same as the uniform input wind velocity) and reference area of projected area, i.e. 0.1 m x 0.5 m. Unsteady simulations have been carried out until stabilized mean and standard deviation values of Cd and Cl are obtained with respect to time as shown in Figs. 5.1 and 5.2 in IS: 875 (Part3) for Realizable k-ε turbulence model. A program has been developed for processing the numerically simulated Cp values to obtain distributions of mean Cp and standard deviation Cp values at 5 selected levels. Further mean Cd and standard deviation Cl values have been at these 5 levels and also for the overall building also. The following sections discuss some these results.

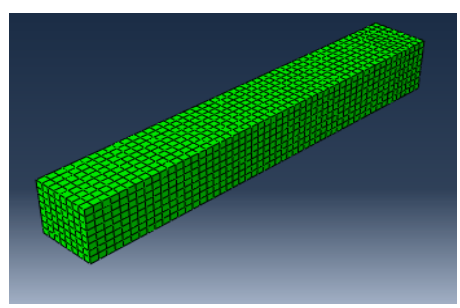

Fig 6. Basic Model Information

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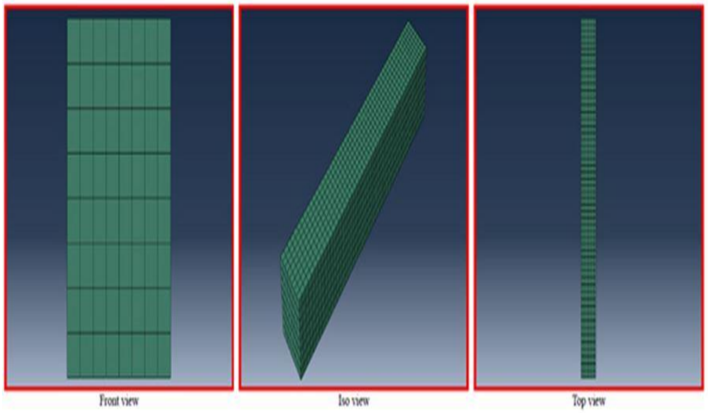

Fig. 7 Figures containing S Mises Results step=Step-1 increment=1

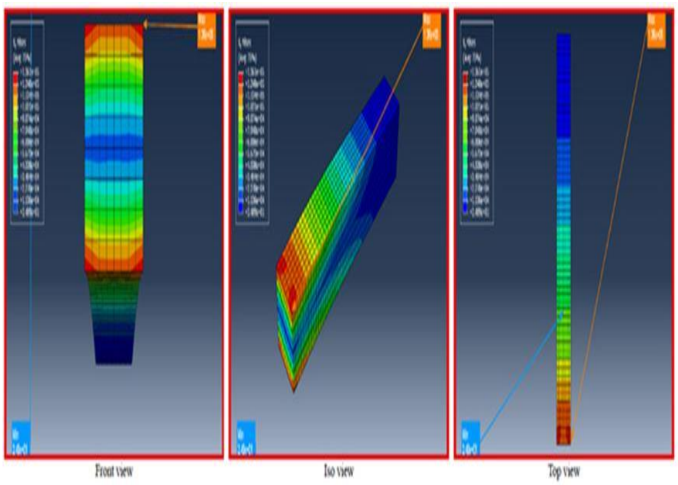

Fig. 8 Figures containing S Max_principal Results step=Step-1 increment=1

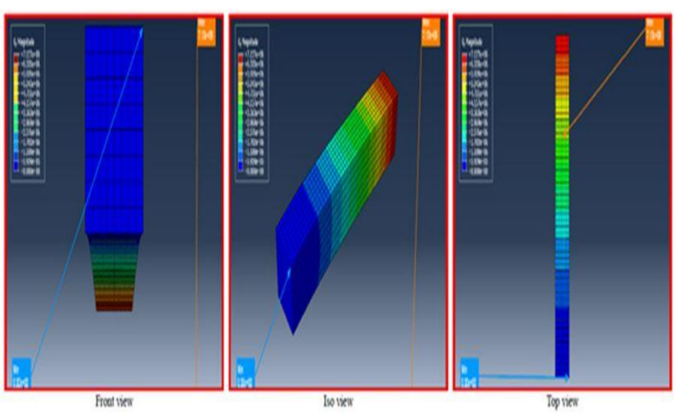

Fig. 9 Figures containing U Magnitude Results step=Step-1 increment=1

LEVELS	Z/H	HEIGHT in cm	Fx1987(0^0)	Fy1987 (90^0)
1.000	0.1	7	890	428
2.000	0.2	14	1100	556
3.000	0.3	21	1311	656
4.000	0.5	35	3364	1523
5.000	0.7	49	3764	1659
6.000	0.8	56	2042	984
7.000	0.9	63	2157	863
8.000	0.95	66.5	1297	466

Table 3 Calculation of force as per IS-875(part-3) 1987 Provisions

Level	Leeward (90°)	Windward(0°)
1.000	890	428
2.000	1100	556
3.000	1311	656
4.000	3364	1523
5.000	3764	1659
6.000	2042	984
7.000	2157	863
8.000	1297	466
9.000	632.840	310.187

Table 4 Calculation of force as per IS-875(part-3) 1987 Provisions

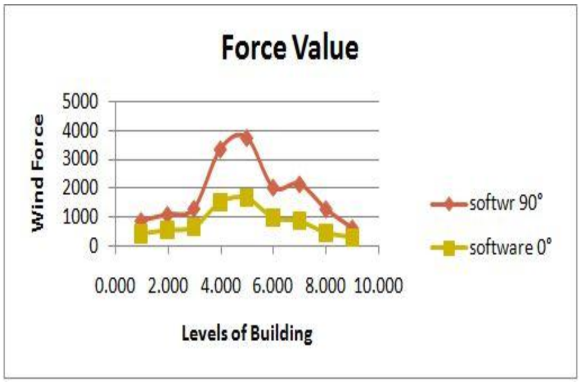

Fig. 10 Forces for software solutions

	manual 90°	manual 0°	software 90°	software 0°
1.000	904.4146	298.5422	890	428
2.000	1224.411	397.4522	1100	556
3.000	1420.865	457.3571	1311	656
4.000	3473.529	1115.506	3364	1523
5.000	3874.313	1239.415	3764	1659
6.000	2052.26	655.6747	2042	984
7.000	2256.651	708.4538	2157	863
8.000	1196.696	390.4345	1297	466
9.000	1310.187	415.227	632.840	310.187

Table 5: Comparison of force for both manual and soft ware solutions

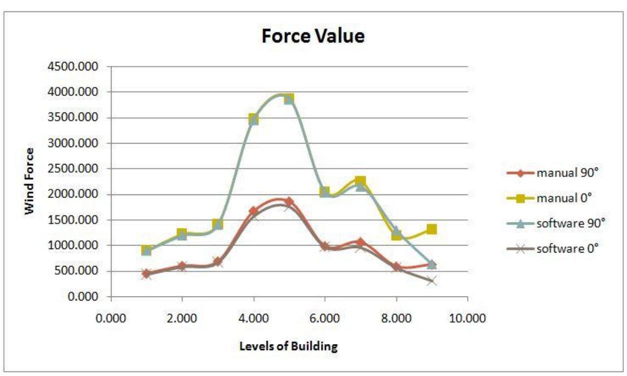

Fig. 11 Comparison of Forces for both manual & software solutions

5. CONCLUSIONS

Mean force value for 0^0 for Level 5 is always higher than all the other levels due to greater area of projection and edge effect at the ground level. For all other levels, values are almost same with IS: 875 (part-3) 1987 which indicates that these values are mostly governed by buffeting characteristics of approaching wind flow.

Mean force value for 0^0 for Level 5 is always higher than all the other levels due to greater area of projection and edge effect at the ground level. For all other levels, values are greater than with IS: 875 (part-3) 1987 of 0.3ratio which indicates that these values are not governed by buffeting characteristics of approaching wind flow.

Standard deviation of force coefficients shows decrease in value with height which shows that these parameters depend on the decrease in turbulence intensity with height.

Mean force value for 0^0level 5 is always higher than all other levels. With software of greater than of 0.2 ratio. Which initiate that the values are governed by buffering.

The value of force obtained from IS 875 Part 3 is 904.4146 for 90^0 for drag coefficient and 890 for 90^0 with Abaqus. This variation is due to vertex shedding and eddy formation in an urban terrain condition.

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BIOGRAPHIES

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