Analysis of High Rise Building for Wind Load

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Abstract— In present scenario high rise structures have technical and economic advantages in areas of high population density, and have become a distinctive feature of housing accommodation in virtually all densely populated areas around the world. In contrast with low-rise and single-family houses accommodate more inhabitants per unit of area of land and decrease the cost of structures. In the recent times, there had been so many catastrophic damages caused by high wind speed especially in the U.S. and in the coastal regions of India which prove that many buildings that are currently in use are not fully wind resistant. This paper we have calculate the wind load using gust factor method by the present IS code [IS: 875 – (Part 3) – 1987] and as per the new code [IS: 875 – (Part 3) – 2015) for zone 3 with terrain category 3 using STAAD PRO Software.

Key words: Catastrophic Damages, Wind Load, STAAD PRO

I. Introduction

From the beginning in the middle of last century and right up to the present day, high rise building has always been dominant land mark in the townscape.

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 flow 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. The wind speeds are measured with the help of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

In this paper comparison of result from the IS:875-Part3 (2015) code and IS:875-Part3 (1987) are discussed so that we can understand the applicability of wind load analysis using both codes.

II. Loading Calculation

A. Dead Load

- Self-weight of beam and column –As per STAAD
- Load intensity on slab = 0.125 x 25 =3.125 kN/m^2 (assume 125 mm thick slab)
- Floor Finish = 0.5 kN/m2 (IS 875 Part I)
  Total load on slab = 3.625 kN/m^2
- Outer wall load intensity=0.23 x 3.3 x 20 = 15.18 kN/m
- Inner wall load intensity =0.115 x 3.3 x 20 = 7.59 kN/m
- Parapet wall load intensity =0.23 x 1 x 20 = 4.6kN/m

B. Live Load

Live load on floors = 3kN/m^2
(As per IS: 875 Part II)

C. Wind Load

As per Gust factor method as given below

1) IS: 875 - PART3 - (1987)

a) Joint load

$$F = C_f\, Ae\, Pz$$

The above formula can be rewritten as

$$F = (C_f\, P_z\, G)\, Ae$$
$$F = P_i\, A_e$$

Where,

Pi = wind intensity pressure at that heights
C_f= force coefficient.
A_e=effective frontal area.
P_z =design wind pressure.
$Pz=0.6\,(Vz)^2$
V_z=hourly mean wind speed
G=Gust factor

b) Design wind speed (Vz)

Design wind speed is given by the equation

$$Vz = V_b\, K_1\, K_2\, K_3$$

Where,
V_b = Basic wind speed in m/s
K_1 = Risk Coefficient (Table 1 of IS 875- part3)
K_2 =Terrain, height and structure size factor (Table 2 of IS 875- part3).
K_3 = Topography factor (Clause 5.3.3.1 of IS 875 - part3).
Force coefficient for building (C_F)
From (Figure 4A of IS 875-part 3-1987)

Gust Factor $G = 1 + g_f r \sqrt{B(1+\emptyset)^2 + \frac{SE}{\beta}}$

Value of $g_f r$ and L (h) -From (Fig 8 of IS 875-part 3-1987)

B = background factor indicating a measure of slowly varying component of fluctuating wind load.

From (Figure 9 of IS 875-part 3-1987)

Value of Size reduction factor (S) - From Fig 10 of IS 875- part 3-1987

Value of gust energy factor (E) - From Fig 11 of IS 875- part 3 -1987

c) Factor Ø calculation

$$\emptyset = \frac{g_f r\sqrt{B}}{4}$$

And is to be accounted only for buildings less than 75 m high in terrain Category 4 and

For buildings less than 25 m high in terrain Category 3, and is to be taken as zero in all other.

d) Value of damping coefficient (β)

From Table 34 of IS 875 part III .β= 0.016 Far entire building.

2) IS: 875 - PART 3-(2015)

$$F = (C_f\, P_z\, G)\, Az$$
$$Fz = A_z\,(P_i)$$

Where,
P_i = Gust Pressure

Fz = design peak force along wind load on the building/structure at any height z;

Az = the effective frontal area of the building/structure at any height z, in m2

P_z = design hourly mean wind pressure corresponding to $V_{z,d}$ and obtained as 0.6 V_z^2(N/m^2);

$V_{z,d}$ = design hourly mean wind speed at height z, in m/s (see 4.4.4)

$$Vz = Vb\ k1\ k2\ k3\ k4$$

Where,

Vz = design wind speed at height z, in m/s;

k1 = probability factor (risk coefficient) (see 4.4.3.1) of IS Code;

k2 = terrain roughness and height factor (see 4.4.3.2) of IS Code;

k3 = topography factor (see 4.4.3.3) of IS Code;

k4 = importance factor for the cyclonic region (see 4.4.3.4) of IS Code

Cfz = the drag force coefficient of building/structure corresponding to the area Az; G = Gust Factor and is given by

$$G = 1 + r\sqrt{g_v{}^2(1+\emptyset^2) + \frac{H_S g_R{}^2 SE}{\beta}}$$

Where

r = roughness factor which is twice the longitudinal turbulence intensity, Ih,i .

gv = a peak factor for upwind velocity fluctuation

= 3.0 for category 1 and 2 terrains; and

= 4.0 for category 3 and 4 terrains;

Bs = background factor indicating the measure of slowly varying component of fluctuating wind load caused by the lower frequency wind speed variations

$$Bs = \frac{1}{\left(1+\frac{\sqrt{0.26(h-s)^2+0.46\, b_{sh}^2}}{L_h}\right)}$$

b_{sh} = average breadth of the building/structure between heights s and h.

L_h = measure of effective turbulence length scale at the height, h, in m

$= 85\left(\frac{h}{10}\right)^{0.25}$ for terrain category 1 to 3 and

$= 70\left(\frac{h}{10}\right)^{0.25}$ for terrain category 4

ø = factor to account for the second order turbulence intensity;

$$= \frac{g_v\, I_{h,i}\sqrt{Bs}}{2}$$

$I_{h,I}$ =turbulence intensity at height h in terrain category i;

Hs = height factor for resonance response.

$$=1+\left(\frac{s}{h}\right)^2$$

S = a size reduction factor given by

$$= \frac{1}{\left(1+\frac{3.5\, f_a\, h}{V_{h,d}}\right)\left(1+\frac{4\ f_a\, b_0\, h}{V_{h,d}}\right)}$$

Where,

b_0h = average breadth of the building/structure between 0 and h;

E = spectrum of turbulence in the approaching wind stream

$$= \frac{\pi N}{(1+70.8\, N^2)^{\frac{5}{6}}}$$

Where,

N = an effective reduced frequency

$$= \frac{f_a L_h}{V_{h,d}}$$

fa = first mode natural frequency of the building/structure in along wind direction, in Hz

V $_{h,d}$ = design hourly mean wind speed at height, h in m/s (see 4.4.4) of IS Code

β = damping coefficient of the building/structure (see Table 39) of IS Code

g_R = peak factor for resonant response

$$= \sqrt{[2\ln(3600 f_a)]}$$

III. DETAILS OF STRUCTURE

The detail of Structure which is designed are shown with the help of Figures as shown below.

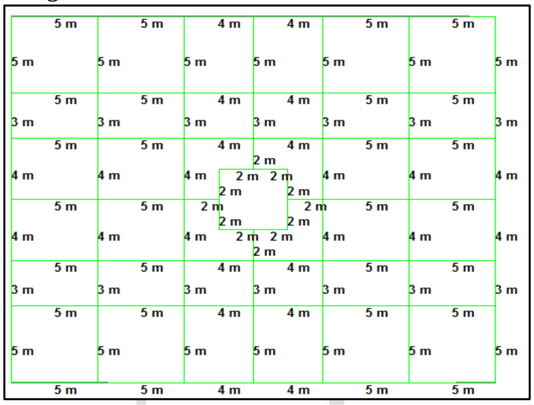

Fig. 1: Plan of Modeled Structure

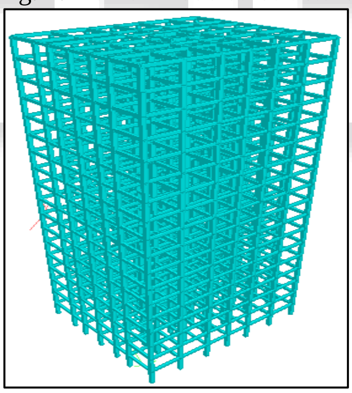

Fig. 2: Elevation of Structure

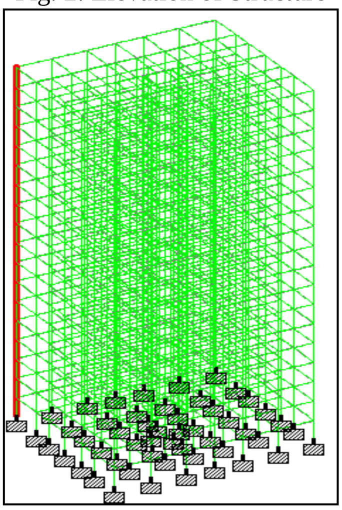

Fig. 3: Position of column where results taken.

IV. RESULTS

Results of different parameters such as Gust Factor, Gust Pressure, Bending Moment and Shear Force are shown with the help of graphs.

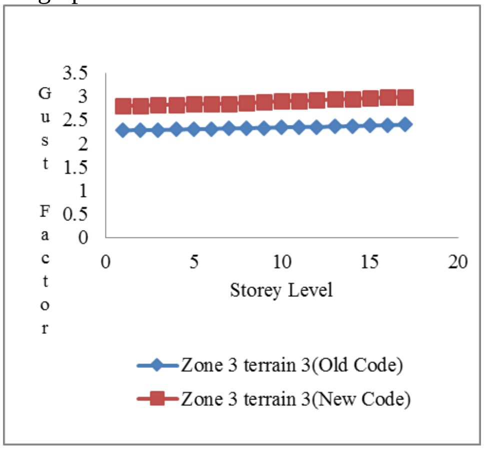

Fig. 4: Storey Level vs Gust Factor

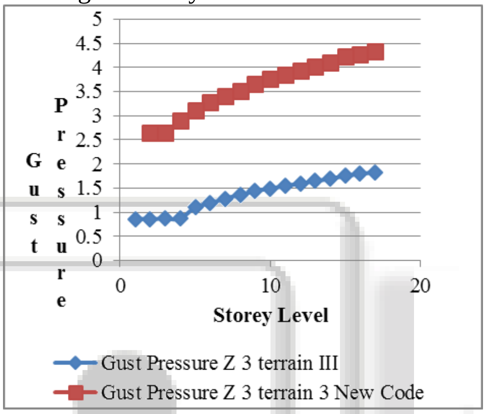

Fig. 5: Storey Level vs Gust Pressure

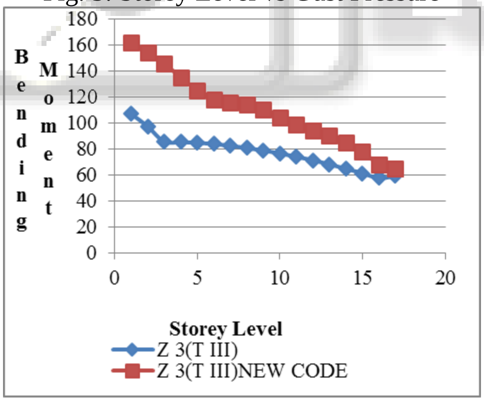

Fig. 6: Storey Level vs Bending Moment

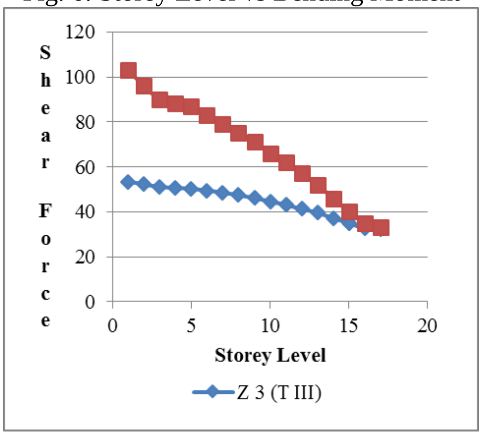

Fig. 7: Storey Level vs Shear Force

V. CONCLUSION

From the obtained result we can conclude that

1) Gust Factor has been increased for [IS: 875 – (Part 3) – 2015] as compared to [IS: 875 – (Part 3) – 1987]
2) The value of Gust Pressure has been also increased for [IS: 875 – (Part 3) – 2015] as compared to [IS: 875– (Part 3) – 1987]
3) There is also considerable amount of increase in Bending moment for model which is designed according to new IS Code that is for [IS: 875 – (Part 3) – 2015]
4) The maximum deflection in the top most storey is 57 mm for structure which is designed as per Old IS code and 192 mm in case of structure which is designed as per new IS Code.
5) So the New IS Code [IS: 875 – (Part 3) – 2015] will provide high safety to the structure as compared to Old IS Codes.

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