A COMPARATIVE REVIEW ON DESIGN WIND LOAD AS PER IS 875 PART III 1987 AND IS 875 PART III 2015

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ABSTRACT

The various stakeholders like professional, researcher, engineers, etc… use IS 875 (Part III) Design load (other than earthquake load) for Wind analysis on various structures. The various codal provisions are given for analytical and design purpose for different structures. Based on experience and research the codes are been revised. According to IS 875 P.3 2015 the various parameters are added and revised. This paper present a comparative evaluation of various parameters recommended in IS 875 P.3 1987 edition and 2015 edition.

KEYWORDS: Wind Speed, Wind Pressure, Gust factor, Wind Force, Interference Factor

1. INTRODUCTION

Wind is a large scale lateral movement of air from a high pressure range to low pressure range. The studies of wind at various meteorological observations by anemometer are useful for engineering purpose. Nature of wind speed increases with the height of building or structures. Also, the wind speed at different height does not remains constant. As per new code IS 875 P.3 2015 parameter considering high rise building or tall structures are also considered.

2. LITERATURE REVIEW

S. Kumar et. al. (2017) 32 storied RCC building of 96m high in cyclonic region has been taken for wind load analysis. They concluded that static pressure on coastal area is more as per revised code. Design wind pressure decrease with increase in tributary area of the structure. As per revised code the dynamic analysis gives design for along wind as well as cross-wind forces.

Dr. S.V. Joshi & S. Kawale (2017) calculated the wind load with gust factor and compared using IS code IS: 875 – (P.3) – 1987 and IS: 875 – (P.3) – 2015 for zone III with terrain category III in STAAD Pro. They had concluded that gust factor and pressure increases using revised code, Increase in the value of bending moment for the model using revised code and maximum deflection of 192mm are see in model using revised code.

Prakash Channappagoudar et. al. (2018) studied the performance of high rise building and concluded that lateral forces for dynamic analysis along x and z direction has reduced in code IS: 875 - (P.3) - 2015 when compared to earlier code, Displacement is reduced in model of IS: 875 - (P.3) - 2015 as lateral force reduces, Time period increases as there is increase in height for 27 floors and 39 floors acceleration is also reduced by modeling with new code and base reaction in two directions as per new code reduction is seen in the results.

H M Sreenidhi et. al. (2019) studied G+17 building for wind analysis and concluded that Gust factor, Lateral forces, Intensity, Displacement and Storey Drift at the top most storey has increased for IS: 875 (P.3) edition 2015 as compared to edition 1987.

3. OBJECTIVE

1. To review the codal provision clause in IS 875 P.3 1987 edition and 2015 edition.
2. To understand the difference in edition 1987 and edition 2015 code in a quick and simpler way.
3. To study the parameters with modeling a G+10 building using staad pro.

4. METHODOLOGY

The present study focus on the revised clauses for wind load calculation according to IS 875 P.3 2015 edition

1. Check for static method and dynamic method using clause 9.1 of IS: 875 P.3 2015
   (a) Closed structure buildings with a height to minimum lateral dimension ratio are as follows:

   Table: 1 Height to minimum lateral dimension ratio

static	< 5
dynamic	> 5

   (b) Natural frequency for a Structural Building in the 1^{st} mode are as follows:

   Table: 2 Natural Frequency in the 1^{st} mode

static	> 1.0 Hz
dynamic	< 1.0 Hz

2. Design Wind Speed (V z).
3. Design Wind Pressure (P z).
4. Design Wind Load (F)

5. DETAIL OF PRESENT STUDY

5.1 Comparison of important parameter IS 875 (Part III) in edition 1987 and edition 2015

Table: 3 Comparisons of Different Parameters

Sr. No	Parameter	IS 875 (Part III) 1987	IS 875 (Part III) 2015
1	**The design wind speed (V_z)**	**$V_z = V_b k_1 k_2 k_3$** k_1 risk factor k_2 size factor k_3 topography factor V_b basic wind speed at any height (m/s)	**$V_z = V_b k_1 k_2 k_3 k_4$** k_1 risk factor [based on clause 6.3.1] k_2 size factor [based on clause 6.3.2] k_3 topography factor [based on clause 6.3.3] k_4 importance factor for the cyclonic region [based on clause 6.3.4] V_b basic wind speed at any height (m/s) **Values of importance factor for the cyclonic region are given below:**

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>[Emergency services structures $k_4 = 1.30$]
[Industrial structures $k_4 = 1.15$]
[Other structures $k_4 = 1.00$]</td>
</tr>
<tr>
<td>2</td>
<td>Probability factor k_1 (risk coefficient)</td>
<td>$k_1 = \frac{X_{N,P}}{X_{50,0.63}} = \frac{A - B[\ln\{-\frac{1}{N}\ln(1-P_N)\}]}{A + 4B}$

N Expected Average design life of the structure (in Year)
P_N risk level (in N year consecutive)
$X_{N,P}$ wind speed at extreme for N and P_N
$X_{50,0.63}$ wind speed at extreme for N 50 year and P_N 0.63
Basic wind speed for A & B at different zone are as follows

<table>
<tr><th>Zone</th><th>A (kmph)</th><th>B (kmph)</th></tr>
<tr><td>33 m/s</td><td>33.2</td><td>9.2</td></tr>
<tr><td>39 m/s</td><td>84.0</td><td>14.0</td></tr>
<tr><td>44 m/s</td><td>88.0</td><td>18.0</td></tr>
<tr><td>47 m/s</td><td>88.0</td><td>20.5</td></tr>
<tr><td>50 m/s</td><td>88.8</td><td>22.8</td></tr>
<tr><td>55 m/s</td><td>90.8</td><td>27.3</td></tr>
</table>
</td>
<td>$k_1 = \frac{X_{N,P}}{X_{50,0.63}} = \frac{A - B[\ln\{-\frac{1}{N}\ln(1-P_N)\}]}{A + 4B}$

N Expected Average design life of the structure (in Year)
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<table>
<tr><th>Zone</th><th>A (m/s)</th><th>B (m/s)</th></tr>
<tr><td>33 m/s</td><td>23.1</td><td>2.6</td></tr>
<tr><td>39 m/s</td><td>23.3</td><td>3.9</td></tr>
<tr><td>44 m/s</td><td>24.4</td><td>5.0</td></tr>
<tr><td>47 m/s</td><td>24.4</td><td>5.7</td></tr>
<tr><td>50 m/s</td><td>24.7</td><td>6.3</td></tr>
<tr><td>55 m/s</td><td>25.2</td><td>7.6</td></tr>
</table>
</td>
</tr>
<tr>
<td>3</td>
<td>Terrain, height and structure size factor k_2</td>
<td>Factor changes with height of structure and terrain category (1, 2, 3 and 4) and also Class of structure (Class A, Class B or Class C)</td>
<td>Factor changes with height of structure and terrain category (1, 2, 3 and 4)</td>
</tr>
<tr>
<td>4</td>
<td>Hourly Mean Wind speed</td>
<td>--- Not considered ---</td>
<td>$\tilde{V}_{Z,H} = \bar{k}_{2,i} V_b$

$\bar{k}_{z,i}$ hourly mean wind speed factor for terrain category 1
$\bar{k}_{z,i} = 0.1423 [\ln(\frac{z}{z_{o\,i}})](z_{o\,i})^{0.0706}$
Design hourly mean wind speed at height z
$\tilde{V}_{z,d} = \bar{k}_{2,i} V_b \, k1 \, k3 \, k4$</td>
</tr>
</table>

5	**Turbulence intensity**	**--- Not considered ---**	The turbulence intensity variation with height for different terrain category. Terrain Category 1 $\mathbf{I_{z,1} = 0.3507 - 0.0535 \log_{10}(\frac{z}{z_{o\,1}})}$ Terrain Category 2 $\mathbf{I_{z,2} = I_{z,1} + \frac{1}{7}(I_{z,4} - I_{z,1})}$ Terrain Category 3 $\mathbf{I_{z,3} = I_{z,1} + \frac{3}{7}(I_{z,4} - I_{z,1})}$ Terrain Category 4 $\mathbf{I_{z,4} = 0.466 - 0.1358 \log_{10}(\frac{z}{z_{o\,4}})}$
6	**The design wind pressure (P_z)**	$\mathbf{P_z = 0.6\,(V_z)^2}$ V_z design wind velocity at height m/s	The basic wind pressure $\mathbf{P_z = 0.6\,(V_z)^2}$ V_z design wind velocity at height m/s The design wind pressure $\mathbf{P_z = K_d\,K_a\,K_c\,P_z}$ K_d wind directionally factor [based on clause 7.2.1] K_a area averaging factor [based on clause 7.2.2] K_c combination factor [based on clause 7.2.3] P_z basic wind pressure
7	**The total wind force (F)**	$\mathbf{F = C_f\,A_e\,P_z}$ C_f force coefficient depends upon shape of element plan size and wind direction A_e effective frontal area P_z design wind pressure Wind load $\mathbf{F = C_f\,A_e\,P_z\,G}$ G gust factor	$\mathbf{F = C_f\,A_e\,P_z}$ C_f force coefficient depends upon shape of element plan size and wind direction A_e effective frontal area P_z design wind pressure Wind load $\mathbf{F = C_f\,A_e\,P_z\,G}$ G gust factor $\mathbf{M = \sum F\,Z}$ M Bending Moment along wind base

<table>
<tr><td>8</td><td>Wind load on individual member (F)</td><td>$F = (C_{pe} \pm C_{pi})A\, P_d$

C_{pe} coefficient of external pressure
C_{pi} coefficient of internal pressure
A Structural element surface area
P_d wind pressure design</td><td>$F = (C_{pe} \pm C_{pi})A\, P_d$

C_{pe} coefficient of external pressure[based on Table: 5(values are modified)]
C_{pi} coefficient of internal pressure[based on clause 7.3.2]
A Structural element surface area
P_d wind pressure design</td></tr>
<tr><td>9</td><td>Wind Interference Factor (IF)</td><td>--- Not considered ---</td><td>Interference effect studied on tall structure is considered by multiplying (IF) with wind load

<table><tr><td>Zone</td><td>Z_1</td><td>Z_2</td><td>Z_3</td><td>Z_4</td></tr><tr><td>I F</td><td>1.35</td><td>1.25</td><td>1.15</td><td>1.07</td></tr></table></td></tr>
<tr><td>10</td><td>Dynamic wind response Gust factor (G)</td><td>$G = 1 + g\, f$
$r\sqrt{[B\,(1+\phi)^2 + SE/\beta}$

g f peak factor
r roughness factor [size of structure & roughness ground]
B background factor
S reduction size factor
E Wind stream energy at a natural frequency of the structure
ϕ building height less than 75m (in terrain IV) and 25m (in terrain III)
ϕ = 0 (Other than above feature structure)
β damping coefficient of structure</td><td>$G = 1 + r\sqrt{\frac{gv^2\, Bs\,(1+g^2)+Hs\, gR^2\, S\, E}{\beta}}$

r roughness factor [2 times turbulence intensity]
gv peak factor = 3 terrain 1 & 2
= 4 terrain 3 & 4
Bs background factor [based on clause 10.2]
Hs Height factor (resonance response) [based on clause 10.2]
gR Peak factor (resonance response) [based on clause 10.2]
S size reduction factor [based on clause 10.2]
E spectrum of turbulence [based on clause 10.2]
β damping coefficient of structure [based on Table: 36 clause 10.2]</td></tr>
<tr><td>11</td><td>Frequency of vortex (slender structure)</td><td>$\eta = \frac{S\, Vd}{b}$

S Strouhal No.
Vd wind velocity design
b breadth of the structure</td><td>$fa = \frac{St\, \bar{V}zH}{b}$

S Strouhal No. [based on clause 9.2.1]
$\bar{V}zH$ Mean hourly wind speed
b breadth of the structure</td></tr>
</table>

5.2 DETAIL OF STRUCTURE

Multi-storey Building:	G+10
Location:	Mumbai
Plan Area:	16m x 18m
Height of Building:	30m
Beam Size:	350 mm x 350 mm
Column Size:	450 mm x 450 mm
Slab Thickness:	150mm

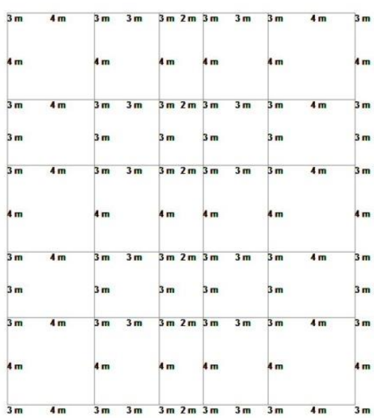

Figure: 1 Plan of building

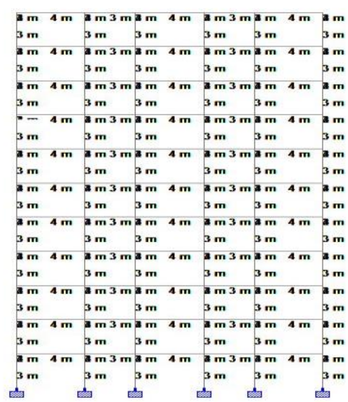

Figure: 2 Elevation of building

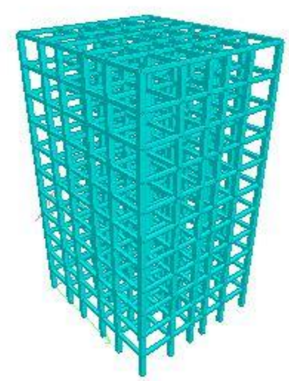

Figure: 3 3D Structure

5.3 LOADING CONDITIONS

Table: 4 Dead load calculation as per IS 875 (P.3)

Self-weight of Beams and Columns	as per Staad Pro
Self-weight of Slab	3.75 kN/m^2
Floor Finish	1.00 kN/m^2

Table: 5 Live load calculation as per IS 875 (P.3)

Live load on floors	3.00 kN/m^2

Table: 6 Wind load calculation as per IS 875 (P.3)

IS 875 (Part III) 1987			IS 875 (Part III) 2015		
The design wind speed	Vz = Vb k1 k2 k3		The design wind speed	Vz = Vb k1 k2 k3 k4	
risk factor	k1	1	risk factor	k1	1
topography factor	k3	1	topography factor	k3	1
basic wind speed at any height (m/s)	Vb	44	importance factor for the cyclonic region	k4	1
			basic wind speed at any height (m/s)	Vb	44
Height	k2	Vz	Height	k2	Vz
size factor at 10m height	1.05	46.2	size factor at 10m height	1.05	46.2
size factor at 15m height	1.09	47.96	size factor at 15m height	1.09	47.96
size factor at 20m height	1.12	49.28	size factor at 20m height	1.12	49.28
size factor at 30m height	1.15	50.6	size factor at 30m height	1.15	50.6
The design wind pressure (kN/m2)	Pz = 0.6 (Vz)2		The design wind pressure (kN/m2)	Pz = [Kd Ka Kc] 0.6 (Vz)2	
Design wind pressure at 10m height	Pz	1.280664		Kd	0.9
Design wind pressure at 15m height	Pz	1.38009696		Ka	0.8
Design wind pressure at 20m height	Pz	1.45711104		Kc	0.9
Design wind pressure at 30m height	Pz	1.536216	Design wind pressure at 10m height	Pz	0.829870272
			Design wind pressure at 15m height	Pz	0.824617036
			Design wind pressure at 20m height	Pz	0.897423977
			Design wind pressure at 30m height	Pz	0.943436041

6. RESULTS & DISCUSSION

Maximum Displacement

Displacement is reduced as per revised code 2015 edition compared with old code 1987 edition.

Table: 7 Comparisons of maximum displacements

Code	X Direction (mm)	Z Direction (mm)
IS 875 (Part III) 1987	45.661	33.615
IS 875 (Part III) 2015	28.089	20.662

Base Reactions

Reactions are reduced as per revised code 2015 edition compared with old code 1987 edition.

Table: 8 Comparisons of Base Reaction

Code	Fx (kN)	Fy (kN)	Fz (kN)
IS 875 (Part III) 1987	67.261	968.517	44.422
IS 875 (Part III) 2015	42.306	1068.037	28.438

Maximum Moment

Moment is reduced as per revised code 2015 edition compared with old code 1987 edition.

Table: 9 Comparisons of Maximum moment

Code	Mx (kNm)	My (kNm)	Mz (kNm)
IS 875 (Part III) 1987	93.106	0.029	134.526
IS 875 (Part III) 2015	58.557	0.017	83.941

Wind Force

Wind force on individual member is reduced as per revised code 2015 edition compared with old code 1987 edition.

Table: 10 Comparisons of Wind force on individual members

Code	X Direction (kN)	Z Direction (kN)
IS 875 (Part III) 1987	4.9945	1.3114
IS 875 (Part III) 2015	3.2364	0.8076

Wind Intensity

Wind intensity is reduced as per revised code 2015 edition compared with old code 1987 edition.

Table: 11 Comparisons of Wind intensity.

Code	Intensity (kN/m^2)
IS 875 (Part III) 1987	1.5362
IS 875 (Part III) 2015	0.9434

7. CONCLUSION

1. As per revised code, modification factor for cyclonic region (K_4) is added to design wind speed which improves behaviour of sea shore structures.
2. As per new code, Wind directionality factor for different structures, area averaging factor for load calculation and Combination factor combining external and internal pressure on roof and wall are added to design wind pressure.
3. The newly recommended code has interference factor for considering nearby existing building of similar size.
4. The new code has good analytical results for dynamic structures providing different parameters, roughness, height, peak factors etc.
5. Expressions for variation in height of mean hourly wind speed and turbulence intensity in any terrains have been suggested in new code.
6. The revised code will provide higher safety to the structures for static and dynamic analysis.

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