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Study on Gust Factor Method for Multi-purpose Cyclone Shelter

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Abstract

Cyclone is one of the major threat hovering over Indian coastal regions and need for safe shelter is now utmost to save the endangered population from the hazardous outcomes. Also, to save the structure from deterioration a multi-purpose cyclone shelter will be most affordable during emergency and nonemergency period. Present Indian Codal provisions underlines that the flexible structures ought to be designed by peak wind approach in addition to mean wind approach related to gust factor method and severe of the two is to be designed as design load. Use of gust factor method for high-rise structures is common but for low-rise important structures there are a few researches available. In this study two G + 1 and G + 2 storey models are considered and analyzed using IS 456:200, IS 1893: 2016 and IS 875: 2015 with gust factor method. Guidelines from Indian government for cyclone shelters and school buildings are followed and loadings from Indian Standards code are considered. This study aims to provide information on behavior of low-rise structure of a school building by changing height of the structures. For that MS-Excel spreadsheet was prepared for gust factor method and 80 models were prepared using ETABS software by changing height of column members, adding a new floor above existing structure, changing seismic zones & increasing basic wind speed. Various parameters such as storey force, base shear and maximum top displacement are scrutinized for above mentioned cases for four structures of different heights.

Keywords: Gust Factor Method, Multi-purpose Cyclone Shelter, Low-rise Structure, High Speed Wind Effects

1. Introduction

India is one of those countries which are quite vulnerable to natural calamities, such as, floods, droughts, earthquakes, cyclones and landslides. Mainly it is prone to nearly 100 percent cyclones of the world. There are 13 coastal states/ Union Territories encompassing 84 coastal districts which are affected by cyclones. Recurring cyclones account for a large number of deaths, loss of livelihood, loss of public and private belongings and extreme damage via high-velocity winds and storm surge also communication systems and trees are uprooted. Human beings living in habitations within a distance of 10 kms from the ocean coast are usually the worst affected with the inundation lasting for almost a week. A large number of people in those regions do not have access to safe shelters which are able to resist the cyclonic fury. As per the analysis carried out via the revenue authorities in the state of Odisha, the estimated susceptible population within a distance of 10 kms from the coast is 6.55 lakhs throughout 731 habitations.

In order to fight this the Ministry of Home Affairs, GoI has worked in the direction of building safe shelters for the coastal regions in case of emergencies and drafted the guidelines for design and construction of cyclone/ tsunami shelters under GOI-UNDP Disaster Risk Management Programme in 2006.

The sustainability of cyclone shelters relies upon on the use and maintenance throughout rest of the year. Use of the building as community centre/ school will allow the usage of the building as emergency safe heaven. Most of the cyclone shelters are of low height and there is less research available on low-rise cyclone resistant buildings. Also, as per new IS-875: 2015 code the information found on gust factor method is not clear about how and when to use this method for low-rise cyclone shelter design in which prominent focus is given only on the static wind forces rather than dynamic effects on the high-speed cyclonic winds. For the construction of the cyclone shelter main issues are found to be the design recommendations, sustainable use, accommodation capacity, location, and building height of the cyclone shelter, inner design, and structural specifications, etc.

2. Wind Load on Structure

Wind load produces three different types of effects on structure: static, dynamic and aerodynamic. The response of load depends on type of structure. When the structure deflects in response to wind load then the dynamic and aerodynamic effects should be analyzed in addition to static effect.

2.1 Peak Wind Approach- Static Method (PWA-SM)

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2.1.1 Design Wind Speed

$V_z = V_b\, k_1\, k_2\, k_3\, k_4$

V_b = Basic wind speed, in m/s
k_1 = Probability factor (risk coefficient)
k_2 = Terrain roughness and height factor (Table 2, IS 875 (Part 3): 2015)
k_3 = Topography factor
k_4 = Importance factor for the cyclonic region

- Structures of post-cyclone importance = 1.30
- Industrial structures = 1.15
- All other structures = 1.00

2.1.2 Design Wind Pressure

$p_d = K_d\, K_a\, K_c\, p_z > 0.7\, p_z$

$p_z = 0.6\, V_z^2$ = Wind pressure in N/ m^2 at height z
V_z = Design wind speed in m/s at height z
K_d = Wind directionality factor (for the cyclone affected regions = 1.0)
K_a = Area averaging factor

Tributary Area (A) (m^2)	Area Averaging Factor (K_a)
≤ 10	1.0
25	0.9
≥ 100	0.8

K_c = Combination factor (Table 19 of IS 875 (Part 3): 2015)

2.1.3 Design Wind Load

$F = C_f\, A_e\, p_d$

p_d = Design wind pressure at any height 'z' m
A_e = Area normal to wind direction contributing load at the desired height
C_f = Force coefficient (Figure 4 of IS 875 (Part 3): 2015)

2.2 Mean Wind Approach- Gust Factor Method (MWA-GFM)

The wind velocity at any location vary considerably with time. In addition to a steady wind there are effects of gusts which last for few seconds. And yields a more realistic assessment of wind load. In practice the peak gust is likely to be observed over an average time of 3.5 to 15 secs depending on location and size of structure. The intensity of gusts is also related to the duration of gusts that affects structures.

The gust effect factor accounts for additional dynamic amplification of loading in the along-wind direction due to wind turbulence and structure interaction.

Any building or structure which satisfies either of the below two criteria shall be examined for dynamic effects of wind:

(a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0.
(b) Buildings and closed structures whose natural frequency in the first mode is less than 1 Hz.

2.2.1 Along Wind Response

The design peak along wind base bending moment, (M_a) shall be obtained by summing the moments resulting from design peak along wind loads acting at different heights, z, along the height of the building/ structure and can be obtained from,

$M_a = \Sigma\, F_z\, Z$

F_z = Design peak along wind load on the structure at any height z

$= C_{f,z}\, A_z\, \bar{p}_d\, G$

A_z = Effective frontal area of the building/ structure at any height z, in m^2

$\bar{p}_d$ = Design hourly mean wind pressure corresponding to $\bar{V}_{z,d}$ and obtained as $0.6\, \bar{V}_{z,d}^{\,2}$ (N/ m^2)

$\bar{V}_{z,d}$= Design hourly wind speed at height z, in m/s

$= V_b\, k_1\, k_{2,i}\, k_3\, k_4$

$k_{2,i}$ = Terrain and height factor
$= 0.1423\, [\, \ln(z/ z_{o,i})\,]\, (z_{o,i})^{0.0706}$

$C_{f,z}$ = Drag force coefficient of the building/structure corresponding to area A_z

G = Gust factor = $1 + r\, [g_v^2\, B_s\, (1+\Phi)^2+(H_s\, g_R^2\, S\, E/\, \beta)]^{1/2}$

r = Roughness factor = $2\, I_{h,i}$

$I_{h,i}$ = Turbulence intensity = $[\, I_{h,3} = I_{h,1} + (3/\, 7)(I_{h,4} - I_{h,1})]$

g_v = Peak factor for upwind velocity fluctuation
= 3.0 for category 1 and 2 terrains, and
= 4.0 for category 3 and 4 terrains

B_s = Background factor
$= 1/\, [1 + \{(0.26\, (h - s)^2 + 0.46\, b_{sh}^2)^{1/2}/L_h\}]$

b_{sh} = Average breadth of the structure between heights s and h

L_h = Measure of effective turbulence length scale at height, h, in m
$= 85\, (h/\, 10)^{0.25}$ for terrain category 1 to 3
$= 70\, (h/\, 10)^{0.4}$ for terrain category 4

Φ = Factor to account for the second order turbulence intensity = $(g_v\, I_{h,i}\, (B_s)^{1/2})/\, 2$

H_s = Height factor for resonance response = $1 + (s/\, h)^2$

S = Size reduction factor

$= 1/\, [\{1 + (3.5\, f_a\, h/\, \bar{V}_{h,d})\}\{1 + (4\, f_a\, b_{0h}/\, \bar{V}_{h,d})\}]$

$b_{0,h}$ = Average breadth of the structure between 0 and h.

E = Spectrum of turbulence in the approaching wind stream
$= \pi\, N/\, (1 + 70.8\, N^2\,)^{5/6}$

N = Effective reduced frequency = $f_a\, L_h\, /\, \bar{V}_{h,d}$

f_a = First mode natural frequency of structure in along wind direction in Hz

β = Damping coefficient of structure

Kind of Structure	Damping Coefficient, β
Welded Steel Structure	0.01
Bolted Steel Structure/ RCC Structure	0.02
Prestressed Concrete Structure	0.016

g_R = Peak Factor for Resonant Response
$= [2\, \ln\, (3600\, f_a)\,]^{1/2}$

3. Multi-purpose cyclone shelter

Cyclone shelters have often been used for a short period of time during the events of natural hazards near the coastal region such as cyclone, tsunami or flood. The sustainability of cyclone shelters depends on the use and maintenance during the rest of the year when there are no natural hazards happening.

As huge investments are made to erect cyclone shelters, it is prudent that these structures are put to various other uses that will take care of maintenance of the shelters as well. The consensus seems to be on such uses that will not hinder the primary use (as cyclone shelter) of the structure. For example, use of the building as community centre and for school will permit the use of the building as emergency shelter without any difficulty.

The existing number of cyclone shelters in India is not enough to accommodate the vulnerable populations in coastal areas. The effectiveness of a cyclone shelter, thus, depends on the assessment for the number of likely users and considerations in design and structural aspects of the shelter.

It is necessary that the cyclone shelters are multi-hazard resistant since the coastal areas are multi-hazard prone. This will significantly increase the life of the structure, its utility, and hence the economic efficiency of the investment made.

The recommendations for construction of cyclone shelters deal with the following design and construction aspects: sustainable use, building, accommodation capacity, location, height of above MSL, height of the shelter, inner design, structural specifications, staircases, material selection, water supply, toilets and sewerage, construction of earthen bounds (killas), provision for helipads if need be.

In the guidelines given by National Disaster Management Division of Ministry of India the conceptual design of cyclone shelters has been given by technical officer Ankush Agarwal which is taken here as the plan of the model of cyclone shelter used as school building.

4. Problem formulation

In this study, RCC G + 1 and G + 2 building models are used in which G + 1 models are of 8.20 m and 9.20 m whereas G + 2 models are 11.40 m and 12.70 m high and have been analysed by linear static method and linear response spectrum method as per IS 1893: 2016 code and gust wind load has been calculated as per IS 875 (Part 3): 2015 code. Here, 8.20 m & 11.40 m high structures have first floor height of 3.50 m and 9.20 m & 12.40 m high structure have first floor height of 4.20 m. Their typical floor heights are 3.20 m and 3.50 m respectively.

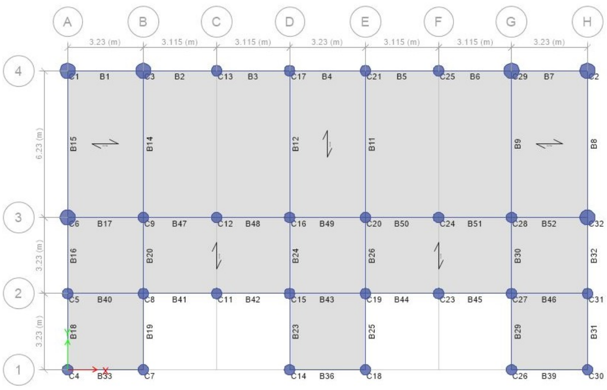


Figure 1: Plan of the Model

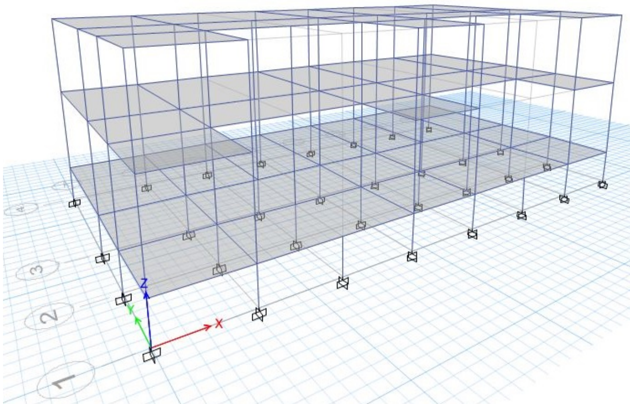


Figure 2: 3D view of G + 1 Model from ETABS

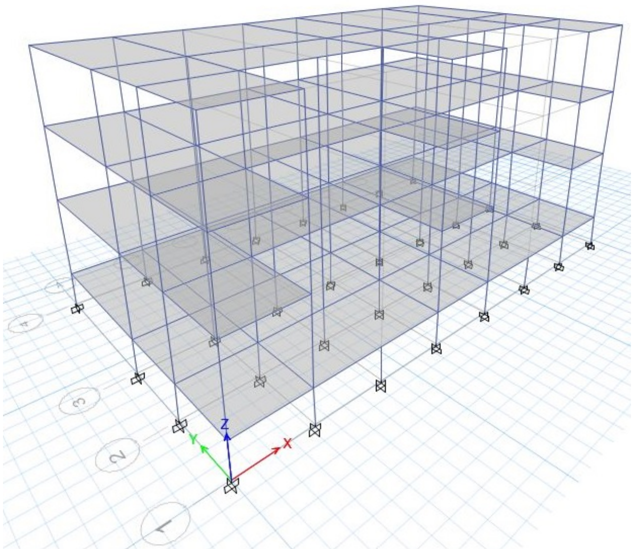


Figure 3: 3D view of G + 2 Model from ETABS

4.1. Selection of Element Sizes

- Location: The whole site considered at 1 m above surrounding ground level.
- Accommodation Capacity: In case of G + 1 building the clear plan area is of 1162 sq. ft which will accommodate about 165 students. Also total of minimum 500 people can take shelter at a time. In case of G + 2 building the clear plan area is of 2324 sq. ft which will about 330 students. Counting other open areas, a total of minimum 1000 people can take shelter at a time.
- Height of Cyclone Shelter: In the models the plinth level is raised 1.5 m above the raised ground level from surroundings. In models having 3.20 m typical floor height the first-floor height is taken as 3.50 m and in models having 3.50 m typical floor height the first-floor height is taken as 4.20 m for flow of water storm surge. The parapet height is considered 1.50 m in all cases.
- Building Materials: Soft soil strata is considered as cyclone shelters are often constructed at sandy soil of coastal region. The columns are rounded for easing the flow of storm surge. Here, we have severe exposure condition so according to Table 5 of IS code 456: 2000 grade of concrete is taken as M30 for all models.

- Staircases: Here two staircases are modelled inside the building at the centre which extends to the terrace level and other two are considered outside the building which go up to first floor only. All the staircases have total width of 3 m.

- Toilets: We have total area of 96 sq. ft of one toilet block which can have more than 5 toilets or 3 toilets & 3 urinals. In G + 1 storey building there are 2 toilet blocks and in G + 2 storey building there are 4.

4.2. Wind Load Details

Here, the steps for static and dynamic wind response for building height 8.20 m with wind speed 44 m/ s is presented for understanding the storey force calculations.

- Design Wind Pressure

  $V_z = V_b\, k_1\, k_2\, k_3\, k_4$

H	k_2	V_z (m/s)	$p_z = 0.6\, V_z^2$ (N/ m²)	$p_d = K_d\, K_a\, K_c\, p_z$ (N/ m²)	Check $p_d > 0.7\, p_z$
1.50	1.05	64.26	2477.93	2477.93	OK
5.00	1.05	64.26	2477.93	2477.93	OK
8.20	1.05	64.26	2477.93	2477.93	OK

- Design Wind Load

  $F = C_f\, A_e\, p_d$

Floor	H	Effective Height for Pressure (m)	Effective Frontal Area (A_e) (m²)	Storey Force F (kN)
G	1.50	1.75	38.7625	115.26
1st	5.00	3.35	74.2025	220.64
2nd	8.20	3.1	68.665	204.18

- Dynamic Wind Response

Floor	H (m)	$k_{2,i}$	$\overline{V}_{h,d}$ (m/s)	H_s	B_s	Φ	G	F (kN)
G	1.50	0.61	37.18	1.03	0.84	0.59	2.77	106.79
1st	5.00	0.72	43.94	1.37	0.84	0.51	2.48	255.82
2nd	8.20	0.76	46.72	2.00	0.84	0.47	2.40	258.85

4.3. Total Number of Model Analyzed

To compare effects of different wind speeds and various earthquake zones on the structure there were 80 models used with main 4 different heights of the structure.
Model No.: $H – E – W$

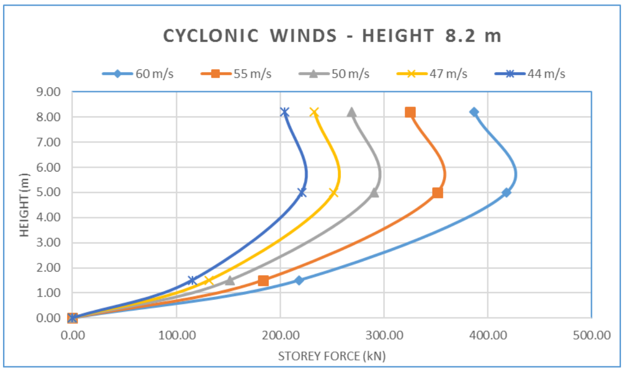
H = Structure height = 8.20 m, 9.20 m, 11.40 m, 12.70 m

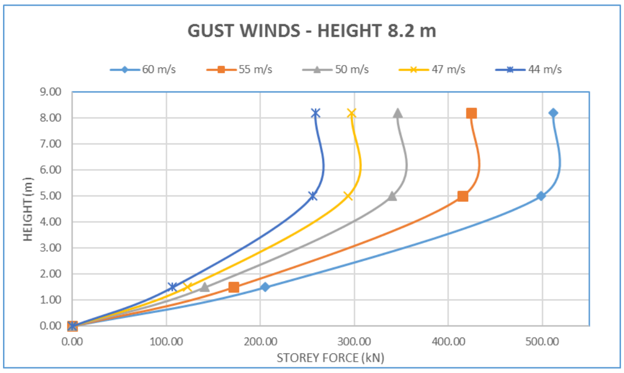
E = Earthquake zone = II, III, IV, V

W = Basic wind speed = 44 m/s, 47 m/s, 50 m/s, 55 m/s, 60 m/s

5. Graphs & explanation

5.1. Storey Response due to Different Wind Speeds





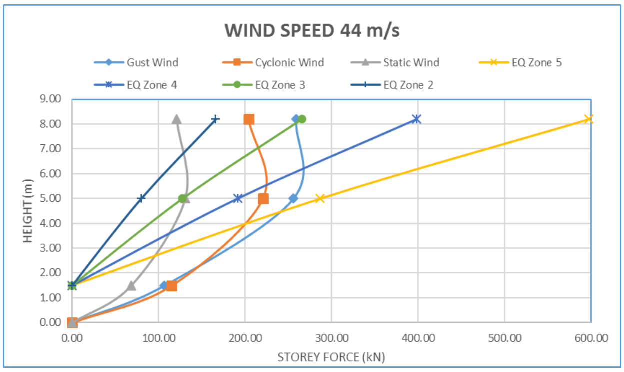
- Increase in storey force of the structure at different heights by increasing cyclonic wind speeds

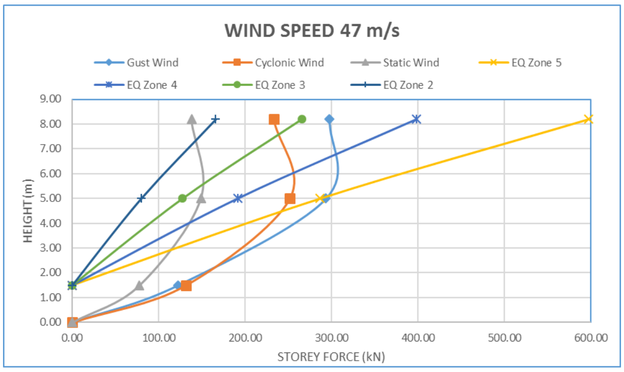
Cyclonic Wind Speed Increase	Percentage-wise Increase in Storey Force
44 m/s – 47 m/s	14.10 %
47 m/s – 50 m/	15.30 %
50 m/s – 55 m/s	21.00 %
55 m/s – 60 m/s	19.01 %

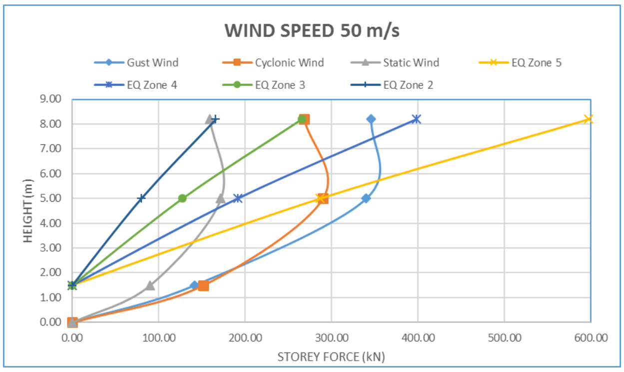
- Increase in storey force of the structure at different heights by increasing gust wind speeds

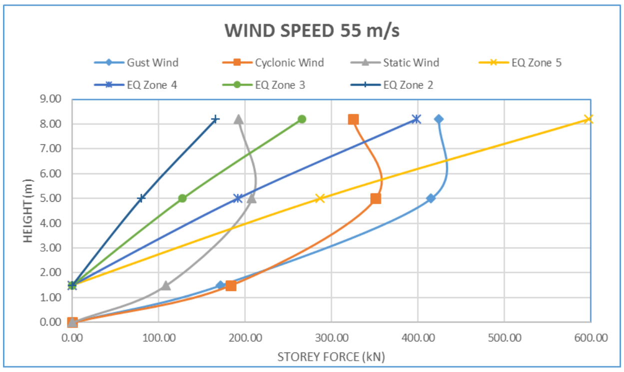
5.2. Storey Response due to Earthquake Forces & Wind Forces for a Particular Structure (Height 8.2 m)

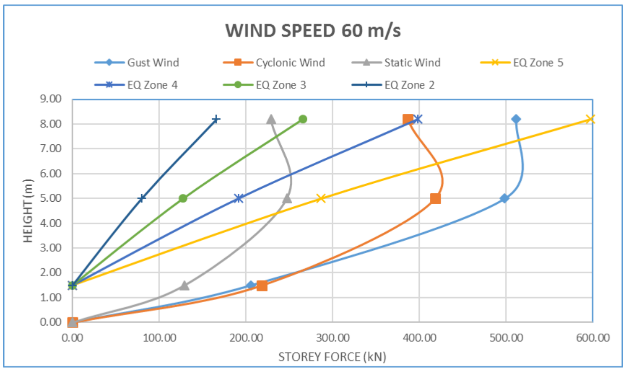
Gust Wind Speed Increase	Percentage-wise Increase in Storey Force for Different Heights			
	8.2 m	9.2 m	11.4 m	12.7 m
44 m/s – 47 m/s	14.65 %	16.37 %	14.83%	15.74%
47 m/s – 50 m/	15.98 %	16.16 %	16.19%	17.20%
50 m/s – 55 m/s	22.10 %	22.38 %	22.43%	23.89%
55 m/s – 60 m/s	20.15 %	20.42 %	20.47%	21.79%











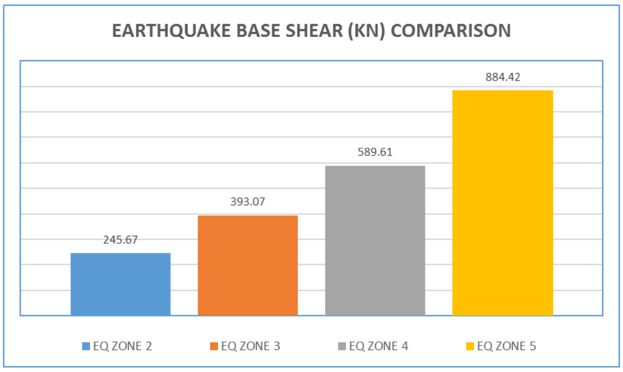
- Increase in height-wise storey force by comparing cyclonic wind forces and gust wind forces

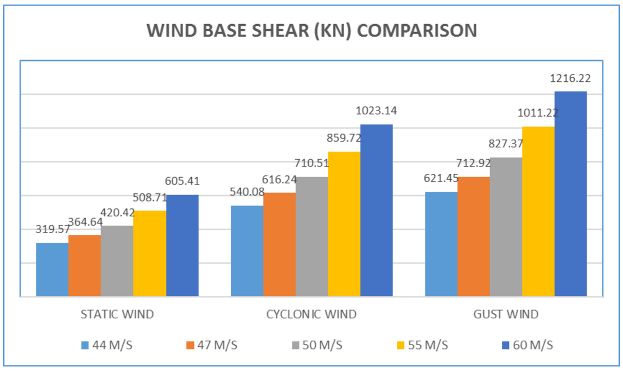
Storey-wise Height	44 m/s	47 m/s	50 m/s	55 m/s	60 m/s
1.50 m	-7.35 %	-7.12 %	-6.82 %	-6.36 %	-5.86 %
5.00 m	15.94 %	16.48 %	17.15 %	18.18 %	19.28 %
8.20 m	26.78 %	27.70 %	28.83 %	30.56 %	32.39 %

- Increase in height-wise storey force by comparing static wind forces and cyclonic wind forces
  - The increase in storey Force by changing the importance of structure from general building (static wind forces) to cyclone susceptible building (cyclonic wind forces) is found 69.00 % irrespective of change in height of building or wind speed.
- Increase in storey force due to change in seismic zones
  - Zone 2 – Zone 3: 60 %
  - Zone 3 – Zone 4: 50 %
  - Zone 4 – Zone 5: 50 %

  NOTE: This increase is same at any height of the structure.

5.3. Base Shear Comparison between Different Earthquake Zones & Different Wind Speeds (Height 8.2 m)





Increase in base shear of the structure due to earthquake forces by increasing the height of column members,
8.2 m – 9.2 m: 1.55 %
11.4 m – 12.7 m: 1.59 %

Increase in base shear of the structure due to earthquake forces by adding a new floor above the existing structure,
8.2 m – 11.4 m: 31.20 %
9.2 m – 12.7 m: 31.25 %

Increase in base shear of the structure due to wind forces by changing the importance of structure from general building to cyclone susceptible building: 69.00 %.
NOTE: This is irrespective of change in height of building or wind speed.

Increase in base shear of the structure due to wind forces by comparing the cyclonic wind forces and gust wind forces for different wind speeds,

Increase from Cyclonic Wind to Gust Wind	**Percentage-wise Increase in Base Shear for Different Heights**			
	8.2 m	9.2 m	11.4 m	12.7 m
44 m/s	15.07 %	15.94 %	20.52 %	33.53 %
47 m/s	15.69 %	18.48 %	21.36 %	35.57 %
50 m/s	16.45 %	19.45 %	22.38 %	37.96 %
55 m/s	17.62 %	20.95 %	23.95 %	41.45 %
60 m/s	18.87 %	22.52 %	25.60 %	44.95 %
Average Increase	16.74 %	19.47 %	22.76 %	38.69 %

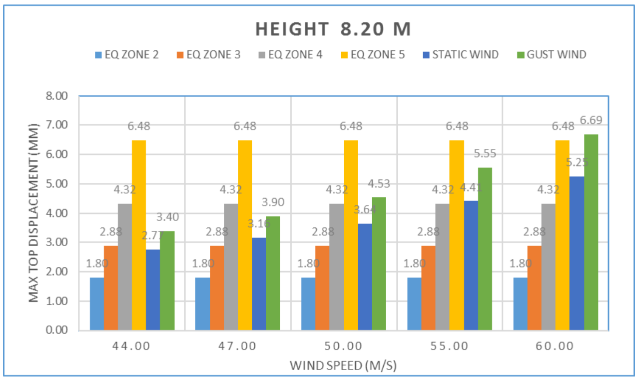
- Increase in base shear of the structure due to wind forces by increasing the height of column members,*

Height of Structures	**Static Winds**	**Cyclonic Winds**	**Gust Winds**
8.2 m – 9.2 m	12.20 %	12.20 %	14.81 %
11.4 m – 12.7 m	12.44 %	12.44 %	27.00 %

- Increase in base shear of the structure due to wind forces by adding a new floor above the existing structure,*

Height of Structures	**Static Winds**	**Cyclonic Winds**	**Gust Winds**
8.2 m – 11.4 m	39.21 %	39.21 %	46.39 %
9.2 m – 12.7 m	39.51 %	39.51 %	61.93 %

5.4. Maximum Top Displacement



- Increase in top displacement of the structure due to earthquake forces by increasing the height of column members,
  - 8.2 m – 9.2 m: 39.10 %
  - 11.4 m – 12.7 m: 34.26 %

- Increase in top displacement of the structure due to earthquake forces by adding a new floor above the existing structure,
  - 8.2 m – 11.4 m: 110.40 %
  - 9.2 m – 12.7 m: 103.07 %

- Increase in top displacement of the structure due to wind forces by comparing the static wind forces and gust wind forces for different wind speeds,

Increase from Static Wind to Gust Wind	**Percentage-wise Increase in Top Displacement for Different Heights**			
	8.2 m	9.2 m	11.4 m	12.7 m
44 m/s	22.64%	26.39%	29.02%	46.39%
47 m/s	23.45%	27.38%	30.08%	48.90%
50 m/s	24.40%	28.63%	31.36%	51.85%
55 m/s	25.88%	30.52%	33.33%	56.11%
60 m/s	27.46%	32.49%	35.39%	60.38%
Average Increase	24.77%	29.08%	31.84%	52.73%

- Increase in top displacement of the structure due to wind forces by increasing the height of column members,*

Height of Structures	**Static Winds**	**Gust Winds**
8.2 m – 9.2 m	51.62%	56.86%
11.4 m – 12.7 m	47.11%	70.38%

- Increase in top displacement of the structure due to wind forces by adding a new floor above the existing structure,*

Height of Structures	**Static Winds**	**Gust Winds**
8.2 m – 11.4 m	125.84%	138.63%
9.2 m – 12.7 m	119.13%	159.20%

*NOTE: Due to little variance between different wind speeds and wind forces the increase shown here is average.

6. Conclusions

In this study, multi-purpose cyclone shelters of different heights were analysed by applying loads as per IS 1893: 2016 and IS 875: 2015 codes and guidelines provided by various Indian government authorities. The requirement from NDMA guidelines for modelling of cyclone shelter were perceived thoroughly. From analysis of results, gust wind forces are governing as compared to earthquake forces for higher heights. Others conclusions are given below:

- Gust wind load is an increasing load with height and wind speed so its effect will always increase on structure compared to static wind load, which gives constant increase irrespective of other factors.

- First storey of the structures is found to be always more susceptible to wind forces than earthquake forces in all zones. Also, for higher wind speeds gust wind forces are governing factor.

- Cyclonic forces are more than gust forces for the first storey of all structures. Although with wind speed and height of structure increasing the difference between cyclonic forces and gust forces decreases.

- By increasing the height of the structure in any manner the increase in base shear due to earthquake forces and due to static & cyclonic wind forces is more or less similar. But increase in base shear due to gust wind forces in much more than earthquake forces.

- The same phenomenon is seen in maximum top displacement and storey drift i.e. any increase in height of structure will impact gust wind forces more than earthquake forces.

From these conclusions it may be noted that selecting proper height of structure based on requirement of the area is very important and its safety also depends upon height of the column members and total weight of the structure. So, as much as earthquake resistant structure may be, it is found to be still in danger to resist high cyclonic gust winds due to cyclones. As this is an emergency shelter at coastal regions selection of location of site, accommodation capacity, building material, etc. must be done thoroughly as well as in depth gust wind calculations must be carried out for minimum impact loading from cyclones.

Disclosures

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References

1. Y. Tamura, H. Kikuchi, K. Hibi, "Quasi-Static Wind Load Combinations for Low- and Middle-Rise Buildings", *Journal of Wind Engineering and Industrial Aerodynamics*, 2003
2. Leighton Cochran, Russ Derickson, "Low-rise Buildings and Architectural Aerodynamics", *Architectural Science Review Volume 48*, 2011
3. Gregory A. Kopp, Murray J. Morrison, David J. Henderson, "Full-Scale Testing of Low-Rise, Residential Buildings with Realistic Wind Loads", *Journal of Wind Engineering and Industrial Aerodynamics*, 2012
4. K. Rama Raju, M. I. Shereef, et al, "Analysis and Design of RC Tall Building Subjected to Wind and Earthquake Loads", *The Eighth Asia-Pacific Conference on Wind Engineering*, Chennai, India, 2013
5. S. Selvi Rajan, "Design of Cyclone Shelters Based on Wind Tunnel Studies*" The Eighth Asia-Pacific Conference on Wind Engineering*, Chennai, India, 2013
6. Aly Mousaad Aly, "Design of buildings for Wind and Earthquake", *Advances in Civil, Enviromental and Materail Research*, Busan, Korea, 2014
7. Bhupinder Singh, Ritu Goyal, Mayank Sharma, "Gust Factor Method for Wind Loads on Buildings and Indian Codal Provisions", *International Journal of Engineering Sciences & Research Technology, 2018*
8. Prakash Channappagoudar, Rakesh Hiremath, et al, "Parametric Comparison Study on the Performance of Building under Lateral Loads as per IS 875 (Part3): 1987 And Revised Code of IS 875 (Part 3): 2015", *International Research Journal of Engineering and Technology Volume 5*, 2018
9. Charan Rathikindi, Balaji, K.V.G.D, et al, "Prominence of k_4 Factor in Gust Factor Analysis for 30m & 60m Telecom Towers", *International Journal of Civil Engineering and Technology Volume 9*, 2018
10. B. Shobha, Dr. H. Sudarsana Rao, Dr. Vaishali. G. Ghorpade, "Effect of Wind Load on Low, Medium, High Rise Buildings in Different Terrain Category", *International Journal Of Technical Innovation In Modern Engineering & Science (IJTIMES),* 2018
11. B. Dean Kumar and B.L.P. Swami, "Wind Effects on Tall Building Frames-Influence of Dynamic Parameters", *Indian Journal of Science and Technology,* 2010
12. Azlan Adnan, Suhana Suradi, "Comparison on the Effect of Earthquake and Wind Loads on the Performance of Reinforced Concrete Buildings", *The 14th World Conference on Earthquake Engineering*, Beijing, China, 2008
13. Detailed Project Report on Multipurpose Cyclone Shelter under ICZMP, *Orissa State Disaster Management Authority*, 2009
14. Guidelines for Design and Construction of Cyclone/ Tsunami Shelters under GoI-UNDP Disaster Risk Management Programme, *National Disaster Management Authority*, Ministry of Home Affairs, Government of India, 2006
15. An Explanatory Handbook on Proposed IS 875 Wind Loads on Buildings and Structures, *IITK-GSDMA*, 2003
16. Guidelines for Improving Wind/ Cyclone Resistance of Housing Building Materials & Technology Promotion Council Ministry of Housing & Urban Poverty Alleviation, *Government of India*, New Delhi, 2010
17. A.K. Chopra, Dynamics of Structures: Theory and Application to Earthquake Engineering, *Pearson Education, 4th Edition*, 2012
18. IS 8827: Recommendations for Basic Requirements of School Buildings [CED 12: Functional Requirements in Buildings], *Bureau of Indian Standards*, New Delhi, 1978
19. IS 15498: Guidelines for Improving the Cyclonic Resistance of Low-Rise Houses and Other Buildings/Structures [CED 57: Cyclone Resistant Structure], *Bureau of Indian Standards*, New Delhi, 2004
20. IS 456: Plain and Reinforced Concrete - Code of Practice [CED 2: Cement and Concrete], *Bureau of Indian Standards*, New Delhi, 2000
21. IS 875 (Part 3): Design Loads (Other than Earthquake) for Building and Structure – Code of Practice, *Bureau of Indian Standards*, New Delhi, 2015
22. IS 1893 (Part 1): Criteria for Earthquake Resistant Design of Structures, *Bureau of Indian Standards*, New Delhi, 2016