The potency of IS 875 (Part 3) 2015 code provisions on A-type trusses in the cyclonic regions of India

Santhosh Kumar Baswa¹, BALAJI KVGD², Chandan Kumar Patnaikuni³

Department of Civil Engineering, GITAM, Visakhapatnam, 532001, Andhra Pradesh, INDIA
Email. santhoshamie@gmail.com

Abstract: SP 38:1987 Handbook for the design of trusses have been widely used by the structural engineers in India. The designs were recommended 1987 version wind load provisions. The revised version of IS 875 was released in 2015 with certain additional recommendations for computation of design wind pressures in static load consideration. In this paper comparative analysis was made on A-Type trusses for 9m and 24 m spans with STAAD Pro (8i) software to determine the extent of increase of truss forces. It was inferred that the trusses forces for smaller spans are more increased when compared to larger spans.

1. Introduction.
The typified designs illustrated for various spans with different slopes in the handbook SP (S&T) 38 1987 have the economical configuration for A-Type roof steel trusses. Because of the consideration of basic wind speed in the east coast, the region shall not be more than 50 m/s, the IS 875 2015 code has very clearly stated that the wind speed for the cyclonic region is to be modified by the cyclonic importance factor (k4 factor) for industrial structures and post cyclonic importance structure category. The off Shore wind speeds, which are generally extended up to 60 km inland after striking the coast, are already reflected in the code as a safety measure in 1987 and 2015 wind code versions.

2. Literature Review
Prem Krishna (2006); Subash and Tamurai (2007) as cited in Suresh Kumar, Cini et al. (2012) [1] pinioned for further investigation of the applicability of basic wind speed map of the east coast of India because of the occurrence of high-speed wind cyclonic storms on the east coast of India. N Laxman, S. Gomathinayana et al. (2009) [2] suggested for revision of the wind map in India with the significant conclusion that the maximum wind speed in coastal areas of the code of practice of IS 875 (Part 3) 1987 [3] is conservative. Kumar et al. (2018, 2017, 2017) [4], [5], [6] studied the effect of wind on transmission towers, monopole towers and steel chimneys. Markandeya Raju et al. (2017) [7] compared communication towers with different bracings subjected to wind.

Even though, the revised IS 875 (Part 3) 2015 [12] defines the same basic wind speed of the IS 875 (Part 3) 1987, the design wind speed in the cyclonic region is modified by the wind speed multiplication factor (k4) - importance factor. This k4 factor has numerical value 1.15 for industrial structures, and maximum value 1.30 for structures of post-cyclone importance structures. IS 875 (Part 3) 2011 Proposed draft and commentary [9] explained the factor 1.15 is referred for economic consideration of industrial structures and 1.30 is referred for emergency service purpose building categories such as cyclone shelters, hospitals, schools, communication towers in the cyclonic region considering to minimize the human loss during these cyclones. These cyclonic importance factors were already reflected in IS 15498 2004 [10].
3. Methodology

The height of the building less than 20m is defined as a low-rise building by the IS 875 (Part 3) 2015. By this definition, all spans with the roof slopes of A-type roof trusses illustrated from the SP 38 (S&T) 1987 handbook are related to low rise building category. These truss configurations for various spans and different roof slopes published by the Bureau of Indian standard through SP 38 (S&T) 1987 [11] have the minimum weight over different truss configurations. This standard considers the compound combination of N-type truss and fink/fan truss for economic weight consideration. In this paper, 9 m and 24 m span with roof slopes 1 in 3 and 1 in 5 of A-type roof angular type steel trusses are illustrated for computing the impact of cyclone factor. The analysis is made with STAAD Pro 8i software. The general methodology for load combinations is adopted from IS 800-2007 [12]. Wind load on individual members (Roofs, walls, etc.,) is computed from the equation (1)

\[ F = (C_{pe} - C_{pi}) \times A \times P_d. \]  

Where

- \( F \) = wind load acting in a direction normal to the individual structural element.
- \( C_{pe} \) = external Pressure Coefficients, (max at 45° wind angle)
- \( C_{pi} \) = internal pressure coefficients.
- \( A \) = roof area under consideration,
- \( P_d \) = design wind pressure.

The design wind pressure (\( P_d \)) is computed with equation (2).

\[ P_d = K_d \times K_a \times K_c \times P_z \]  

Where

- \( K_d \) = wind directionality factor which has a maximum numerical value of 1.00 in the cyclonic region.
- \( K_a \) = area averaging factor, which depends on the slope areas of the truss under the wind force consideration.
- \( K_c \) = combination factor. The code specified the combination factor has a value 0.90 for the frames of clad buildings since the suction /pressures inside and outside of structures are not fully correlated.
- \( P_z \) = The design wind pressure at any height above the mean ground level is computed by the relationship between wind pressure and wind speed as shown in equation (3).

\[ P_z = 0.6 \times V_z^2 \]  

Where

- \( V_z \) = designed wind speed in m/s at height z.

The basic wind speed (\( V_b \)) for important cities is obtained from figure 1 of IS 875 (Part 3) 2015 [12] and shall be modified to include the following effects to get design wind speed, \( V_z \) at any height, \( Z \) for the chosen structure: (a) risk level, (b) terrain roughness and height of structures, (c) local topography, and (d) importance factor for the cyclonic region.

It can be mathematically expressed with the equation (4)

\[ V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4 \]  

Where

- \( V_z \) = design wind speed at any height z in m/s;
k1 = probability factor (risk coefficient) (clause 5.3.1 of IS 875 (Part 3) 2015 [13] for general and industrial structures with 50 years of return period is 1.00 and for the most cyclonic Importance structures with the return period of 100 years is 1.08;
k2 = terrain roughness (Category 2) and height factor (clause 5.3.2 of wind code 2015) varying according to the height of the structure.;
k3 = (1.00) topography factor (clause 5.3.3 of wind code 2015); and
k4 = (1.15 for Industrial structures and 1.30 for post cyclonic importance structures) cyclonic importance factor for the cyclonic region (clause 5.3.4 of IS 875 (Part 3) 2015 [13]);

Vb is the basic wind speed in the east coast region is specified as 50m/s.

With the above information and equations (1) to (4) are utilized in computing the wind force on the truss. Then the combination of dead load and wind loads are computed with the general methodology. In this context, the live load cannot be taken into consideration, because in the cyclones period there is no possibility of expecting live load on the roof trusses.

The A-type roof steel truss for 9.00 m span with roof slopes of 1 in 3 and 1 in 5 and 24.00 m span with roof slopes 1 in 3 and 1 in 5 for low permeability, medium permeability and large permeability conditions are considered for this study. up to 5 % building opening (Cpi ± 0.20) is known as low permeability, for building openings from 5 to 20% (Cpi ±0.50) is referred as medium permeability and building openings more than 20% (Cpi ±0.70) are known as large permeability condition. The spacing of truss is 6 m and a column height of 9 metres are common for all spans and slopes. The truss diagrams are shown in figures A and B for 9m span and 24 m span. With the above data, all the models are simulated in STAAD Pro 8i software. The dead load and wind loads acting at the nodal points on the trusses are represented in figures 1 and 2. The percentage variation of truss forces for industrial structures category and post cyclonic category are produced in figures 3 and 4 respectively.

Figure 1. 9m span with 1 in 3 roof slope

Figure 2. 24m span with 1 in 3 roof slope
4. Discussions and Results

A type roof truss spans 9m and 15 m with roof slopes 1 in 3 and 1 in 5 have been simulated for total truss forces with IS 875 (Part 3) 1987 provisions. However, IS 875 (Part 3) 2015 revised version specified the $k_4$ factor for industrial and post cyclonic importance structures. Hence, the above-mentioned models with the $k_4$ factor have been stimulated for truss forces. The results obtained for both the models, i.e., 9 m and 24 m stimulated as per the provisions of IS 875 1987 and 2015 versions have been compared and presented in the figures 3 and 4.

For Industrial category of structures

The variations of truss forces are in the range of 51% to 56% for 9 m span and 29% to 32% for 24 m spans.

For post cyclonic importance structures

The variations of truss forces are in the range of 96% to 108 % for 9 m span and 50% to 78% for 24 m spans.

Figure 3. Variation of Truss forces for Industrial trusses

Figure 4. Variation of Truss forces for Post cyclonic Importance factor consideration
5. Conclusions
With the above discussions, the following conclusions are drawn.
1. The highest variation of truss forces for Industrial condition occurs for 9 m spans with slope 1 in 5 for low permeability condition. The recent review and observation of Tecle et al. (9) showed that Low internal permeability has a larger variation of truss forces.
2. The highest variation of truss forces for post cyclonic importance condition has occurred for 9 m span with slope 1 in 3 for low permeability condition.
3. The larger spans show the lesser variation of truss forces and there is a little variation of truss forces for change of slopes from 1 in 3 to 1 in 5.

References
[1] Suresh Kumar K, C Cini, Valerie Sift 2012 Assessment of design wind speeds for metro cities of India *The seventh International Colloquium on Bluff Body Aerodynamics and Applications (BBAA7)* Shanghai China September 2-6 2012
[2] Lakshmanan N, Gomathinaygam S, P Hari Krishna, A Abraham, Chitra Ganapathi S 2009 The Basic wind speed map of India with long- term, hourly wind data *Current science* 96 (7) p 911-22
[3] IS 875 (Part 3) 1987 (Reaffirmed 1997) Code of practice for design loads (other than Earthquake) for Buildings and Structures *Bureau of Indian Standards* New Delhi India
[4] Kumar M P, Vishalakshi D, Raju P M, Rambabu D 2018 Progressive collapse study of 220 KV transmission line tower with different bracing patterns *Disaster Advances* 11 (10) p 16-25
[5] Pavan Kumar M, Markandeya Raju P, Navya, M, Naidu G T 2017 Effect of wind speed on structural behaviour of Monopole and self-support telecommunication towers *Asian Journal of Civil Engineering* 18 (10) p 911-27
[6] Kumar M P, Raju P M, Babu N V, Roopesh K 2017 A parametric study on lateral load resistance of steel chimneys *International Journal of Civil Engineering and Technology* 8 (7) p 858-75
[7] Markandeya Raju P, Pavan Kumar M, Vishalakshi, D, Manoharini K 2017 Parametric comparison of communication towers with different bracings *International Journal of Civil Engineering and Technology* 8 (10) p 235-54
[8] IS 875 (Part 3) 2015 Design Loads (other than Earthquake) for Buildings and Structures-code of Practice *Bureau of Indian Standards* New Delhi India
[9] Prem Krishna, Krishen Kumar, Bhandari N M *IS 875 (Part 3) 2011 Wind loads on Buildings and structures Proposed draft & Commentary*
[10] IS 15498 2004 Guidelines for improving the cyclonic resistance of low-rise Houses and other buildings/structures *Bureau of Indian Standards* New Delhi India
[11] SP 38 (S&T) 1987 Hand Book of Typified designs for structures with steel roof Trusses (with & without crane) based on IS Codes *Bureau of Indian Standards* New Delhi India
[12] IS 800 2007 General Construction in steel Code of Practice *Bureau of Indian Standards* New Delhi India.
[13] Tecle Amaneul S, Girma T Bitsuamalk, Mousaad Aly 2013 Internal pressure in a low-rise building with existing envelope openings and sudden breaching *Wind and Structures* 16 (1) p 25-46