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Indian and Australian/New Zealand Standard for Design Wind Load on Tall Structures like Pressure Vessel and Tank: A Review

J. Pandya**, G. Acharya, Y. Shah
Department of Mechanical Engineering, Atmiya Institute of Technology and Science, Gujrat, India

Abstract

Wind load is one of the important loads influencing the design of a tall structure like pressure vessel and tank. Various major standards and codes has given the procedures and coefficients required for the calculation of wind load. This paper describes a comparison of wind load calculations for all structures like pressure vessel and tank between Indian standard IS 875 part 3 and Australia/New Zealand standard AS/NZ 1170 part 2according to their commonalities and differences. All parameters of wind speed, pressure and force has been discussed.

Keywords: *Wind code and standard, wind loading, design wind load, pressure vessel, tank*

****Author for Correspondence*** E-mail: jaiminpandya8992@gmail.com

INTRODUCTION

Wind load is one of the most important loads influencing the design of a pressure vessel or tank. For the design of a pressure vessel or tank considering the effect of wind load, it is required to calculate the design wind speed and wind pressure for different heights of a pressure vessel or tank. Various major standards and codes has given the procedures and coefficients required for calculation of wind load with respect to the various parameters, like for the importance of building, surrounding terrain, topography of building size of different geometric shapes and sizes of buildings. This paper describes a comparison of wind load calculations for tall structures like pressure vessel and tank between Indian standard IS 875 part 3 and Australia/New Zealand standard AS/NZ 1170 part 2 according to their the commonalities and differences. All parameters of wind speed, pressure and force has been discussed.

Wind apply force to the tall vertical structure like pressure vessel and tank so that pressure vessel or tank will behave as a cantilever beam which has wind load and fixed at the bottom. The bending stress induced in the pressure vessel or tank due to wind is zero at the top and maximum at the base. Due tothe bending, compressive stress will be induced at the leeward side of the pressure vessel or tank and tensile stress will be induced at the windward side of the pressure vessel or tank. Value of wind load must be determined to calculate the total stress value across vessel wall, to design supports and mounting. Wind load on pressure vessel or tank can be as calculated as follows [1]:

1. Calculate basic or site wind speed.
2. Calculate design wind speed from the basic or site wind speed.
3. Calculate design wind pressure and load.

DESIGN WIND SPEED

In the IS 875 part 3, basic wind speed map of India has been given. To consider the effects of terrain category, size of pressure vessel or tank, risk level and topography of location the basic wind speed has been modified with the help of modification factors. Figure1 and appendix-A of IS 875 part 3 gives basic wind speed across the India, according to different zones of the country. This basic wind speed (V_b) should be modified to obtain design wind velocity at any height of pressure vessel or tank. Design wind speed can be determined from the following equation [2].

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

Where,V_z is the design wind speed. V_b is basic wind speed. k_1 is risk coefficient or probability factor. k_2 is terrain, height and size factor. k_3 is

topography factorand$k_4$is importance factor for the cyclonic region. According to importance of structure, suggested design life and basic wind speed, risk coefficient or probability factor (k_1) can be selected from Table 1 of IS 875 part 3;
Terrain, height and structure size factor (k_2) can be decided with respect to terrain category and class of the structure. Selection of terrain categories is depending on obstructions across the pressure vessel or tank. The orientation and location of pressure vessel or tank can be decided according to wind direction. Terrain in which a pressure vessel or tank has erected can be classified into terrain categories. Category 1 is for exposed open terrain means it has very few or no obstructions and in which object surrounding the vessel is having the height less than or equal to 1.5 m.

Open sea coasts are also included in it. If terrain is open with obstructions between 1.5–10 m height, it will be considered as a category 2. If terrain is with very closely spaced obstructions having size of pressure vessel or tank up to 10 m with or without a few isolated structures, it will be considered as a category 3.Ifa terrain is having large and highly close spaced obstructions of more than 25 m height then it will be considered as a category 4.According to size of the pressure vessel or tank, it can be classified into three different classes. Class A is for vessel which has maximum dimension less than 20 m. Class B is for vessels having maximum dimension between 20–50 m. Class C is for vessels having maximum dimension greater than 50 m. wind speed can be varying with respect to height and terrain category. Value of this factor can be taken from Table 2 of IS 875 part 2 [2].

The basic wind speed V_b of Figure 1 in IS 875 part 3 is given with respect to level of location of pressure vessel or tank above sea level. It has not considered local topographic features of location which have significant effect on the wind speed and so that topography factor is considered in design wind speed calculation. Generally value of topography factor (K_3) can be assumed as 1. Appendix C of IS 875 part 3 gives method of evaluating the value of topography factor for values greater than 1.0 [2].

Wind speeds will be increased during the cyclones. For the safety of vessels, importance factor for the cyclonic region k_4 is considered. For the pressure vessel or tank of post-cyclone importance factor is 1.30, for industrial structures it is 1.15 and for remaining structures it is 1.00 [3, 4].

Australian/New Zealand standard AS/NZS 1170 part 2 defines the site wind speeds which will define design wind speed. The site wind speed can be calculated as follows [5]:

$$V_{sit,\beta} = V_R \times M_d \times M_{Z,cat} \times M_s \times M_t$$

Where, V_R is regional 3 s gust wind speed for Australia and New Zealand sites. M_d is wind directional multipliers. $M_{z,cat}$ is terrain/height multiplier. M_s is shielding multiplier. M_t is topographic multiplier. Regional wind speed (V_R) is based on 3-second gust wind. For Australian and New Zealand, regional wind speed (V_R) can be taken from Table 3.1, Figure 3.1(A) and Figure 3.1(B) of Australia and New Zealand standard AS/NZS 1170 part 2. It should be multiplied by wind direction multiplier (M_d) given in Table 3.2 and AS/NZS 1170 part 2 [5].

The orthogonal design wind speeds ($V_{des,\alpha}$) for pressure vessel or tank can be determined as the maximum of cardinal direction site wind speed ($V_{sit,\beta}$) by interpolation method between cardinal points within a range ± 45 ° with respect to the orthogonal direction being considered. $V_{des.\Theta}$ should be not less than 30 m/s for the pressure vessel or tank which has design life greater than 5 years and less than 25 m/s for temporary pressure vessel or tank which has design life less than or equal to 5 years [5].

According to terrain category and height of the pressure vessel or tank site wind speed must be modified by the use of terrain/height multiplier $M_{z,cat}$. Terrain category defines that terrain, over which wind flow approaches to the pressure vessel or tank and according to it terrain can be classified while calculating the wind load. Category 1 is for terrain which has totally exposed open terrain with very few or no obstructions or water surfaces. Category 2 is for open terrain with few obstructions having heights of 1.5–10 m. Category 3 is for terrain with closely spaced obstructions between 3 m to 5 m height. Category 4 is for terrain with comparatively large, high and narrowly spaced obstructions having heights generally between 10–30 m. According to height and terrain category, terrain/height multiplier $M_{z,\ cat}$ can be taken from Table 4.1 (a) of AS/NZS 1170 part 2 [5].

If shielding has been provided to pressure vessel or tank, than shielding multiplier M_s must be considered according to AS/NZS 1170 part 2.

Regional wind speed has not considered topographic features of location which can significantly affect the wind speed and so that topographic multiplier (M_t) is considered in design wind speed calculation. The topographic multiplier (M_t) shall be taken as follows [5]:

(a) For locations of New Zealand and Tasmania which is 500 m above sea level:

$$M_{tl} = M_{\ h} \times M_{lee}\ (1 + 0.00015\ E)$$

Where, M_h is hill shape multiplier can be taken from AS/NZS 1170 part 2. M_{lee} is lee (effect) multiplier can be taken from AS/NZS 1170 part 2. It can be taken as 1.0, except in New Zealand lee zones. E is site elevation above mean sea level.

(b) For the other locations in Australia, the larger value of M_h and M_{lee} can be taken:

A conservative approach is to design the pressure vessel or tank using the wind speed, factors and multipliers for the worst direction and condition.

DESIGN WIND PRESSURE AND FORCE

The wind pressure of the pressure vessel and tank at any height can be obtained by the following equation of wind pressure as given in IS 875 part 3 [2].

$$P_z = 0.6 \times V_z^{\ 2}$$

Where, p_z is wind pressure at height z and V_z is design wind speed at height z. The formula has coefficient 0.6 which is depends on the atmospheric pressure, air temperature and on a number of other factors. The value selected is for Indian atmospheric conditions. The design wind pressure p_d is suggested in proposed draft copy on IS: 875 (Part3) [3].

$$P_d = K_d \times K_a \times K_c \times P_z$$

Where, K_d is wind directionality factor, for circular structures like pressure vessel and tank this factor may be taken as 1.0. $K_a$isarea averaging factor, while considering local pressure coefficients it should be taken as 1.0. As the area increases, incoming wind becomes increasingly un-correlated.

K_c is combination factor. The cyclonic storms have wind speeds much higher than wind speed on the coasts where they have been formed and so that minimum 15% higher wind speed should be considered for distances up to 200 km into the sea[3].

When calculating the wind load of individual pressure vessel or tank element, the pressure difference between opposite faces of elements must be considered [3].

$$F = (C_{pe} - C_{pi}) \times A \times p_d$$

Where, C_{pe} is external and C_{pi} is internal pressure coefficient. A is surface area of pressure vessel or tank element and p_d is design wind pressure

The total wind load on that particular pressure vessel or tank can be calculated from force coefficient, projected area and design wind pressure as follows.

$$F = C_f \times A_e \times p_d$$

Where, F is the force in a given direction. A_e is projected area of pressure vessel or tank and C_f is the force coefficient for the pressure vessel or tank.

For structure like pressure vessel and tank,
A is Projected area = equivalent diameter × height of tank shell element
Force coefficient (C_f) for circular tank and pressure vessels can be taken from Table 2.3 of IS 875 part 3 with respect to height to diameter ratio and surface roughness [1].

According to IS 875 part 3,dynamic effect of wind on pressure vessel or tank should be checked if it satisfies either of following two criteria [2].

1. Pressure vessel or tank which has H/D ratio is more than about 5.0.

2. Pressure vessel or tank which has natural frequency of less than 1.0 Hz in its first mode.

The design wind pressures (P) according to AS/NZS 1172 part 2 can be determined for pressure vessel or tank as follows [5]:

$$p = 0.5 \times \left[V_{des,\theta}\right]^2 \times \rho_{air} \times C_{fig} \times C_{dyn}$$

Where, P is design wind pressure. $\rho_{air}$is air density, which is generally taken as 1.2 kg/m^3. $V_{des,\Theta}$ is orthogonal design wind speeds for pressure vessel or tank. $C_{fig}$is aerodynamic shape factor. It can be taken from AS/NZS 1172 part 2. For specific circular silos and tanks it can be determined from appendix C of AS/NZS 1172 part 2.C_{dyn}isdynamic response factor can be determined from AS/NZS 1172 part 2, but the value of it is 1.0 except where the pressure vessel or tank which has natural frequency of less than 1.0 Hz in its first mode. This pressure vessel or tank can be considered as a dynamically wind sensitive [5].

Design wind force derived from force coefficients:

$$F = 0.5 \times \left[V_{des,\theta}\right]^2 \times \rho_{air} \times C_{fig} \times C_{dyn} \times A_Z = p \times A_Z$$

Where, A_z is projected Area with drag force coefficient (C_d), C_d can be taken from appendix E paragraph 5 and Table E_3 of AS/NZS 1172 part 2[5].

CONCLUSION

This paper reviews the differences and similarities of Indian and Australian/New Zealand wind standards for calculation of wind load used in design of pressure vessel and tank. Scope of this paper is limited to wind load calculation of tall structures like pressure vessel and tank. The objective was to compare not only wind load calculation but also to identify the differences between various factors used in both standards and their value that contribute to the wind load. Indian standard IS 875 part 3 and Australia/New Zealand standard AS/NZ 1170 part 2 have same theoretical background and approach to calculate wind load, load for the same structure calculated by both standard can have different value. The main reason behind it is difference in consideration of factors and their value in standard [6–8].

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