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Parametric Study for Wind Design of Vertical Pressure Vessel as per Indian Standard

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ABSTRACT: *Like all other tall structures, determination of wind loads is important for industrial Pressure Vessel. All countries use different wind load standards. These different wind load standards are compared with each other in some studies. This paper describes a parametric study of wind load calculations on Vertical Pressure Vessel as per Indian Standard IS-875 (Part 4) (Ammendum 3rd 2006) with their latest addendums. The wind loads calculated, are applied to the design of structures to prevent failure due to wind. Calculated wind pressures as per different code on a Pressure Vessel produce actual loads on the structure. A good structural system for wind design is typically a strong, heavy system with robust connections to help resist loads as the wind blows across and over the structure.*

The Vertical Pressure Vessel is assumed to be made up of 3 components; First bottom dish which is supported on skirt, second intermediate Shell and Third top dish .The Vertical Pressure Vessel is 6.25 m tall and assumed which is located in urban terrain. The design wind speeds acting on vessel are to be calculated from corresponding codes.

The wind force are calculated on each component as per Code procedure and checked for variation occurred. The factors like Basic Wind Speed, Terrain Category, Exposure Category, Damping factor are changed during calculation, the variation on wind force is plotted on graph.

Keywords: *Gust Factor, IS-875, Parametric Study, Vertical Pressure Vessel, Wind Design.*

I. INTRODUCTION

Pressure vessels are containers for the containment of pressure either internal or external. This pressure comes from an external source or by the application of heat from a direct or indirect source or any combination of them. The pressure vessels are used to store fluid that may undergo a change of state inside as in case of boiler or it may combine with other reagent as in a chemical plant. Pressure vessels are commonly used in industry to carry both liquid and gases under pressure. The material comprising the vessel is subjected to pressure loading and hence stresses from all direction. The normal stresses resulting from this pressure are functions of radius of the element under consideration, the shape of the pressure vessel as well as the applied pressure.

Wind load is one of the important design loads for heighted structure greater than 10m. For Vertical Pressure vessel, tall buildings and high towers or mast structures, wind load may be taken as a critical loading, and complicated dynamic wind load effects control the structural design of the structure. In the on-going research project on tall buildings, the study of wind-induced demands is categorized as: along-wind and crosswind responses. Procedure for determining wind loads on buildings and other structures, in which pressures and/or forces and moments are determined for each wind direction considered, from a model of the building or other structure and its surroundings, in accordance with Different standards.

The IS code of practice (IS 875: Part 3 (1987)) and ASCE10 are widely used for estimating wind loads by the structural engineers all over the country.

II. PRESSURE VESSEL DESIGN

The Vertical Pressure Vessel is assumed to be made up of 3 components; First bottom dish which is supported on skirt, second intermediate Shell and Third top dish .The Vertical Pressure Vessel is 6.25 m tall and assumed which is located in urban terrain. The design wind speeds acting on vessel are to be calculated from corresponding codes.

2.1 Pressure Vessel Specification:

2.1.1 Design Parameters

Design Internal Pressure (for Hydro test)	6000.0 KPa.
Design Internal Temperature	280 C
Design External Pressure	103.419 KPa.
Design Internal Temperature	45 C
Minimum Design Metal Temperature	-29 C

2.1.2 Geometry Parameters

Part	I.D.	Height	Thickness	Corrosion Allowance
SKIRT	2500	2500	15	3
BOTTOM DISH	2500	50	15	3

SHELL	2500	3000	15	3
TOP DISH	2500	50	15	3
Note : All Dimensions are in mm.				

2.2 Design of Pressure vessel as per Wind Code (IS 875)

2.2.1: Determination of Velocity Pressure

There are some structural design standards that provide methods for developing wind loads and if we are to use them, we must make sure that we select the correct wind speeds for them to have the results be meaningful. Most established methods come with geographical wind distribution maps or tables that must be used with them. If we do that, we will find that the pressures generated by various methods are remarkably similar.

1] Basic wind speed, Vb (m/s) as per geographical location from IS 875 Part 3. Figure 1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2).

2] Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the design of a structure may vary depending on the direction of wind under consideration.

3] Design wind speed: The basic wind speed (Vb) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure.

a) Risk level;
b) Terrain roughness, height and size of structure; and
c) Local topography.

Vz = Vb x kl x k2 x k3,
Where kl = risk factor
k2 = terrain roughness factor
k3 = topography factor

4] Design wind pressure: The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

Pz =0.6 x Vz2 /9.81

2.2.2: Estimation of Aerodynamic Pressures or Forces

1] Force Coefficients (Cf)

The value of the force coefficient differs for the wind acting on different faces of a building or structure based on shape and height to breadth ratio are calculated from table 23.

2] Gust Factor (G)

Gust factor theory is designed which considers random nature of atmospheric wind speed. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the averaging time employed in analyzing the meteorological data and this averaging time varies from a few seconds to several minutes. The magnitude of fluctuating component of the wind speed which is called gust, which depends on the averaging time. In general, smaller the averaging interval, greater is the magnitude of the gust speed.

$$G = \frac{peak\ load}{mean\ load}$$

$$G = 1 + gfr\sqrt{[B(1+\emptyset)^2 + \frac{S * E}{\beta}]}$$

Value of Gust factor varies with variation in gfr factor, Background Factor, Size reduction factor.

3] Wind Force

The wind force on any object is given by

Fw = Cf x Pz x Ae x Kp

Where Ae – Projected Area

III. PARAMETRIC STUDY

1] Design Wind Pressure

In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. The Pressure variation with height variation for different categories is shown below.

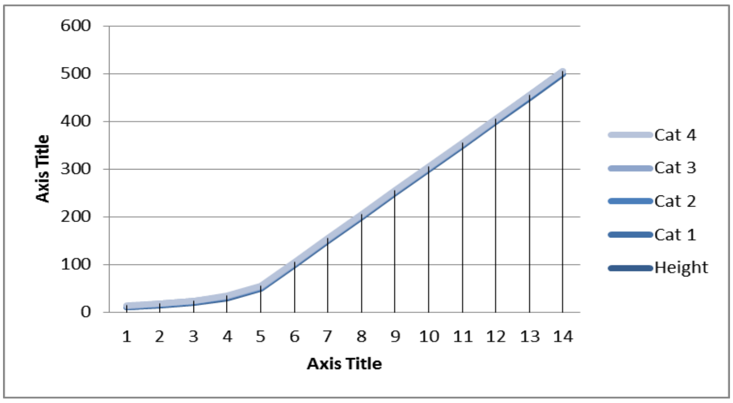

Figure 1 : pressure variation as variation in height and category

2] Gust Factor

Value of Gust factor varies with variation in gfr factor, Background Factor, Size reduction factor.

A] Gf*r Factor

Gf - peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load.
R - Roughness factor which is dependent on the size of the structure in relation to the ground roughness.
The variation in product of peak factor and Roughness factor is shown with change in Vessel height and Category.

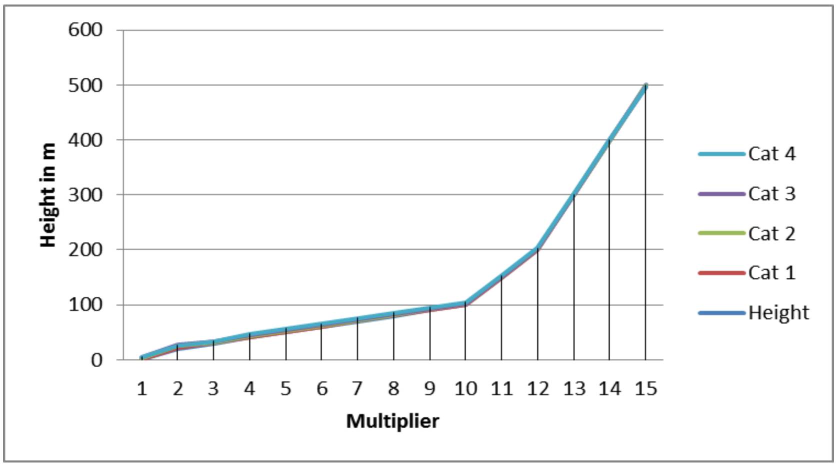

Figure 2: gust factor as variation in height and category

B] Background Factor,

Background factor indicates a measure of slowly varying component of fluctuating wind load. The Background Factor variation with Abscissa variation for different Lambda Values is shown below. Series in graph indicates different (Cy*b)/ (Cz*h) values.

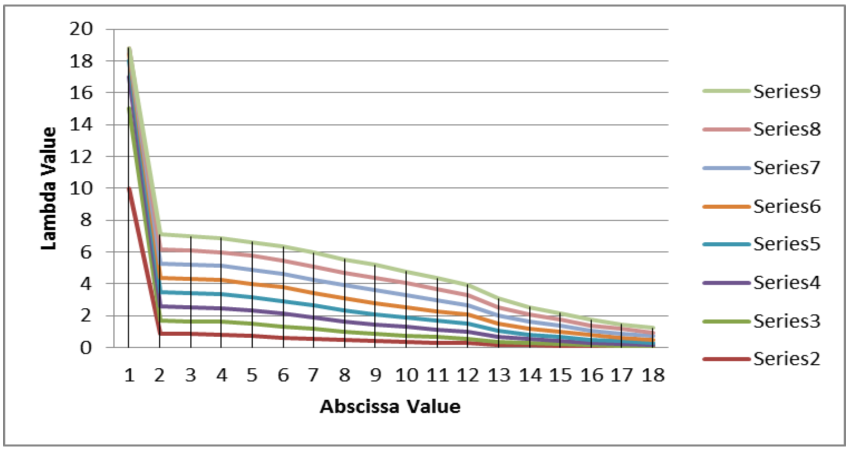

Figure 3: background factor variation as variation in lambda value

C] Size reduction factor

Size reduction Factor variation with Reduced Frequency variation for different Lambda Values is shown below. Series in graph indicates different (Cy*b)/ (Cz*h) values.

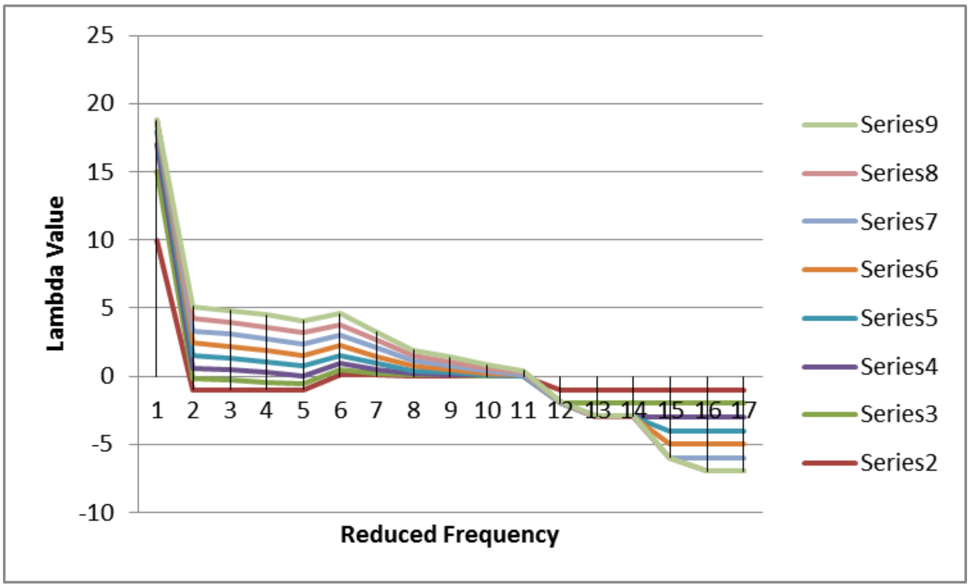

Figure 4: size reduction factor variation as variation in lambda value

IV. DISCUSSION AND CONCLUSION

In this study, structural wind load predictions for Simple Pressure Vessel using IS 875 have been calculated for different parameters keeping other parameters constant. Our results indicate that concerning the loads predicted by IS 875 code, the pressure values on edges stand much lower than that at higher values.

Among these 3 parameters that were evaluated in Gust factor, dynamic wind load, Background factor and Size reduction factor are two important parameters for safety criteria of pressure vessel that affect human perception to motion in the low range of Lambda value for different (Cy*b)/ (Cz*h) encountered in tall buildings.

Although many parameters were examined, the scope is limited to dynamically sensitive, Simple Pressure Vessel with 3 component supported on skirt. To accurately compare the parameters, the various equations in the codes/standards are written in a general format and corresponding graphs are plotted .

Research can be explored to take into account other parameters. Selection material referring to ASME standard can also been developed. The behaviors of pressure vessels in case of fluctuating load could be a challenging matter for future research.

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