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# Experimental and Numerical Investigation of the Buckling Behavior of Variable Thickness Steel Cylindrical Tanks under Wind Loading


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## ABSTRACT

Vertical cylindrical welded steel tanks are widely used for fluid and bulk storage in industrial and agricultural plants. They usually consist of a thin bottom plate, a cylindrical shell with uniform or stepped thickness and a closed-roof or open-top (with or without floating roof). With the development of economy and oil industry, more and more oil storage tanks are put into service in recent decades, especially large tanks.As typical thin-walled structures, tanks are very susceptible to buckling under wind load especially when they are empty or partially filled. Over the past few decades, buckling failures of cylindrical steel tanks and silos during windstorm have occurred in many countries and regions. Buckling of tanks sometimes even occurs under moderate wind load during their construction. Because of serious economic losses and environmental problems due to the destruction of storage tanks, studies about buckling of tanks under wind load have been conducted extensively over the past few decades.



**Keywords: wind load, buckling, stepped thickness, Cylindrical Tanks,**


## 1. Introduction

### Wind loads on tank

The wind load is simulated as pressure distribution acting on the circumferential shell. According to current code provisions for cylindrical shell structures, this pressure varies along both height and circumference of the shell. The height variation is not significant for tanks, hence the pressure is assumed to be constant along the height, as opposed to silos. It has been experimentally observed how cosine families can represent circumferential pressures on shells, so most of the formulations established to define circumferential patterns of pressure employ Fourier cosine series. Wind pressures p acting on the structure surfaces can be defined as:

$$p = c_p q(z) \quad (1)$$

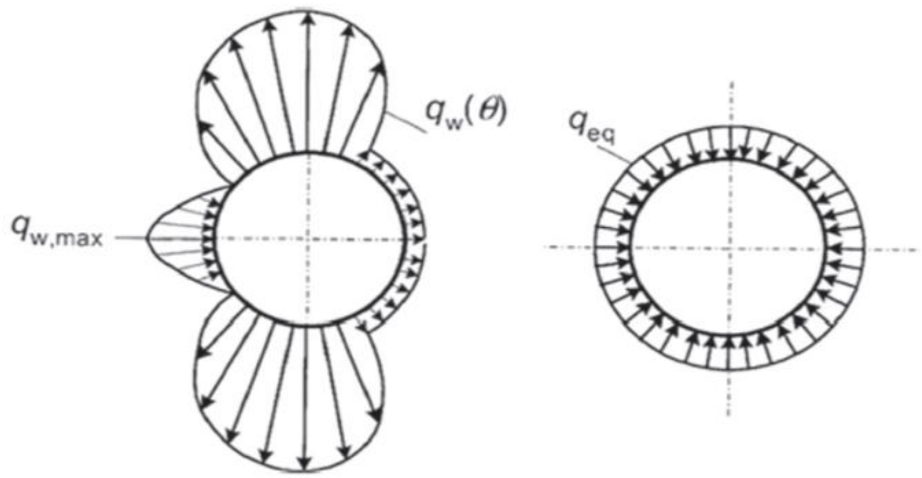
where Cp is the wind pressure coefficient and q(z) is the velocity pressure of incoming wind which varies with the height.

The wind pressure coefficients on cylinders usually vary along both the circumference and the height. As the variation along the height is not pronounced compared with circumferential variation, the wind pressure coefficient is generally assumed to be constant along the height and only dependent on the longitude. The distribution of wind pressure coefficient along the circumference of the cylinder has been proposed by several authors or specified by design codes, using the Fourier series decomposition expression as follows:

$$c_p(\theta) = \sum_{i=0}^{m} a_i \cos(i\theta) \quad (2)$$

where θ is the longitude measured from the windward, and ai is the Fourier coefficient.

Fig. 3. Distribution of wind pressure on cylindrical tanks (left) and equivalent uniform pressure(right).



## 2 .Background

**Kundurpi et al.** studied the buckling behavior of open-topped cylindrical tanks due to wind load based on the energy theory and compared with experimental evidence. It was shown that the engineering practice of determining buckling load was conservative.

**Uematsu and Uchiyama** investigated the buckling behavior of closed-ended, thin cylindrical shells by wind-tunnel tests. They found that the buckling load was not sensitive to the wind pressure distribution and the buckling behavior exhibited a pronounced nonlinearity. An empirical formula for the buckling pressure considering the height/radius ratio and the radius/thickness ratio was also proposed by them.

**Portela and Godoy** addressed the buckling of steel tanks with a conical or dome roof due to wind load, in which the imperfection sensitivity was examined through geometrically nonlinear analyses. They also investigated open-topped tanks using the same cylindrical wall model and wind load to confirm the roof effect on the buckling behavior of cylindrical tanks.

**Jaca et al.** adopted a reduced stiffness approach for evaluating the lower bound of buckling of open-top cylindrical tanks under wind load based on reduced energy model. They found that results obtained from reduced stiffness approach constituted a lower bound to those obtained from numerical analyses as well as experiments.

**Jaca and Godoy** noticed that windinduced damage of tanks occurred not only during windstorm but also under moderate wind load during their construction. They tried to reveal the mechanism of collapse through geometrically nonlinear analyses.

**Zhao et al.** investigated the buckling behavior of steel silos subject to wind pressure through a great deal of numerical analyses, which aimed to improve the understanding of buckling behavior of large circular steel silos subject to wind pressure. It was indicated that the buckling resistance of steel silo was closely correlative with loading conditions as well as geometrical parameters.

From literature reviewed above, it can be found that few studies have been conducted on the buckling behavior of practical studies have been conducted on the buckling behavior of practical open-topped steel tanks with stepped wall when they are subject to wind load including internal pressure.