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Wind loading on vertical panels with different permeabilities

A. Giannoulis [a], T. Stathopoulos [b], D. Briassoulis [a,*], A. Mistriotis [a]

[a] Department of Agricultural Engineering, Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece
[b] Centre for Building Studies, Concordia University, 1455, de Maisoneuvve Blvd. West, Montreal, Que., Canada, H3G1M8

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ABSTRACT

A review of previous research studies on wind loads on vertical panels is presented. This review includes all cases of vertical panels, namely non-permeable and permeable panels on the ground or elevated panels. Two different design codes, The European code on wind actions and the American design code, are examined and their guidelines for the proper design of vertical panels under wind action are presented and compared to the research work found in literature. Impermeable vertical panels on the ground are an extensively studied issue and there seems to be an agreement between previous works and design codes. Results provided on permeable vertical panels show wind load reduction only as a function of porosity. However, the aerodynamic behavior of a permeable panel is affected by the geometrical form of its porous structure as well. The limited number of studies published on wind loads on elevated vertical panels shows that more research for validation and expansion of existing results is necessary. Design codes prove themselves to be complete and useful guidebooks. However, discrepancies that appear regarding a number of the provisions of vertical panels shows that they could go through further refinement.

Contents

* Corresponding author. Tel.: +30 210 5294011; fax: +30 210 5294023.
E-mail address: briassou@aua.gr (D. Briassoulis).

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1. Introduction

Vertical panels are very useful structures used in agriculture and other applications for the last several years. Significant advantages of these structures, which led to their continuous use, were low cost and their simplicity rendering their construction quick and easy. Vertical panels could be categorized in three different types. Solid vertical panels on ground, more usually known as free standing walls or windbreaks, porous vertical panels on ground, with fences being the most common example of such structures and elevated vertical panels. The elevated panels could be either permeable or impermeable. A signboard is a common elevated panel.

Initially, vertical panels, or tree windbreaks, were used for agricultural purposes and as property protection means. Such structures are also used against dust, hail, snow, and insects, as well as for shading purposes, mostly in inclined positions. Porous vertical panels with different porosities, depending on the case, are commonly used.

Besides crop protection, vertical panels are frequently used for the protection against wind loads of other low-rise buildings and objects (Stathopoulos et al., 1994; Suaris and Irwin, 2010). Along with their wind loading reducing ability vertical windbreak panels have also been found to be efficient in successfully affecting ventilation of the protected buildings (Chang, 2006) and are therefore used as sufficient microclimatic and thermal control means (Jones and Oreszczyn, 1987; Wilkins, 2007). Moreover, elevated vertical panels are used as simple signboards for traffic matters or commercial signboards. Lately, very common applications of vertical solid panels often seen in highways are sound barriers (Omran et al., 1982). Finally pedestrian discomfort (Stathopoulos et al., 2007) is observed in big cities nearby tall buildings. The extent of this urban problem can be reduced with the use of porous vertical panels placed near the building.

Wind loads should be taken care of when designing vertical panels. Most of the time, these structures are exposed to high winds because a vertical panel serves to reduce high winds or protect its leeward side from them. The proper design of panels is necessary in order to provide human safety but also to avoid significant economical losses of the protected cultivations or other operations.

EN 1991-1-4 (2005) and ASCE 7-10 (2010) are design standards providing rules on the structural design of vertical panels subjected to wind loads. Their aim is to provide proper guidelines for the design of all types of vertical panels but in some cases the corresponding provisions can be considered insufficient while a number of disagreements would emerge when comparing them. Both codes are examined here in detail for the clarification of such discrepancies.

What follows in this paper is a review of the previous research work on vertical panels. Provisions from EN 1991-1-4 (2005) and ASCE 7-10 (2010) are also presented. Comparisons between previous research work and relevant values adopted by international standards are conducted in order to investigate deficiencies that may exist. The main intent is to contribute on the establishment of a reliable approach for calculating design wind loads acting on vertical panels.

2. Previous research work

The simplicity of a vertical panel was the main reason that many studies were devoted on such structures. Fig. 1 presents a vertical panel with its main geometrical characteristics as depicted in the majority of studies in literature. Symbols presented here follow EN 1991-1-4 (2005) nomenclature.

l	length of the panel
h	height of the panel
z_g	gap height (for $z_g=0$ the panel is not elevated)
z_{ref}	reference height (for the calculation of dynamic pressure; the height definition may vary with the standard or literature)
l/h	aspect ratio
$h/(z_g+h)$	clearance ratio (when equal to $1-z_g=0$ — the panel is not elevated)

Many studies are available in literature concerning vertical panels. The majority of these studies were wind tunnel experiments. Full-scale experiments have also been conducted but time and cost restricted many researchers from such works. Published results from both types of studies have been used in the formation of design code provisions. The development of numerical simulations (Cochran and Derickson, 2011) and progress made in providing better results encouraged computational research including computational analysis of wind loading. In some cases studies based on numerical simulations may not predict wind flow characteristics accurately yet and a validation by wind tunnel or field experiments is required. Despite that, numerical

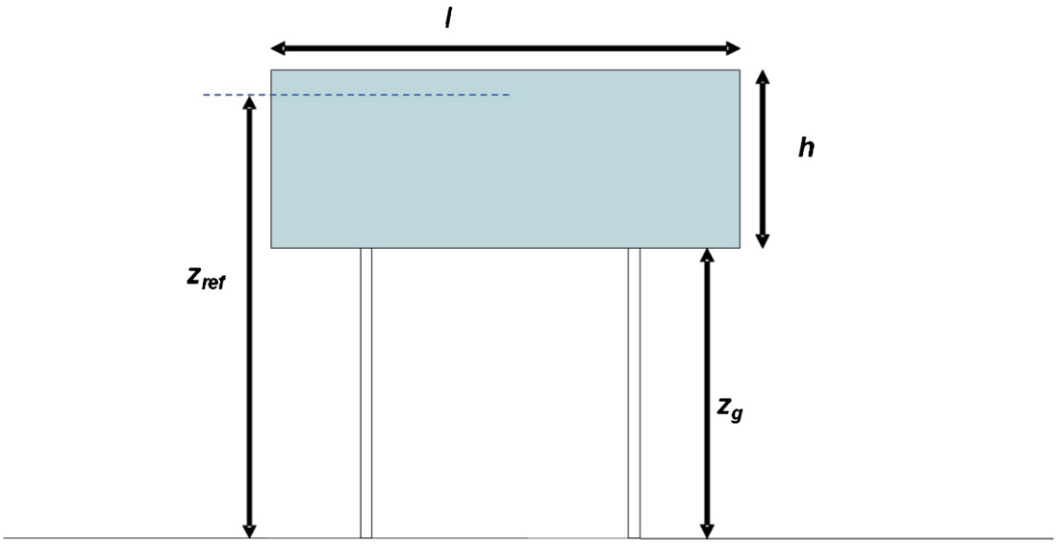

Fig. 1. Symbol key for vertical panels.