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Experimental and numerical study of wind pressures on irregular-plan shapes

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Abstract

This paper presents the results of a program of wind tunnel model tests on pressure distributions for irregular-plan shapes (L- and U-shaped models). The experiments were carried out in a closed-circuit wind tunnel and a multi-channel pressure measurement system was used to measure mean values of loads on 1:100 scale models. The same tests were carried out on a cube-shaped model as an experimental validation. The effectiveness of the model shape in changing the surface pressure distributions is assessed over an extended range of wind directions. The experimental data for the L- and U-shaped models showed different wall pressure distributions from those expected for single rectangular blocks. Furthermore, a Computational Fluid Dynamics (CFD) code was used to illustrate some particular cases and to provide a better understanding of the flow patterns around these irregular-plan models and of the pressure distributions induced on their faces. Computed pressure coefficients have also been compared with wind tunnel results for normal and oblique wind incidence. A general good agreement has been found for normal wind incidence whereas some differences have occurred for other directions.

Keywords: Wind engineering; Wind pressure coefficients; Wind tunnel testing; Irregular-plan shapes; Computational fluid dynamics

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1. Introduction

The innovative designs both in building forms and structural systems with the increased use of a boarder range of materials require an accurate description of the wind action and its interaction with the buildings. Therefore, more rational and refined wind design approaches have been adopted by standards in order to improve both design and analytical processes. While there is considerable research on cubical and cylindrical structures—a detailed review of this subject can be found in Meroney's paper [1]—only a few research studies analyse irregular shapes [2].

In the present work, pressure distributions on irregular-plan L- and U-shaped models were experimentally determined from wind tunnel tests carried out under uniform upstream flow. A cube-shaped model was also tested for comparison and validation purposes. Although L- and U-shapes are very common building configurations, experimental data for such shapes and different wind directions is very limited. Stathopoulos and Zhou [3] have examined wind loads for L-shaped plan view as well as for L-shaped cross section (stepped-roof building) through a numerical study. They have found a good agreement in the latter case between numerically and experimentally obtained results for normal wind incidence.

The aim of the present study is to assess the effects of different model shape on the surface pressure distributions over an extended range of incident wind directions.

2. Experimental program

The experiments were carried out in a $1.25 \times 1.00\,\mathrm{m}^2$ closed-circuit wind tunnel at Laboratório Nacional de Engenharia Civil (LNEC). More details about this wind tunnel and its functional characteristics can be found in [4].

A preliminary study was carried out in this wind tunnel for a cube under uniform upstream flow (uniform mean velocity and low turbulence intensity—less than 0.5%—except in the thin boundary layer near the wind tunnel floor) to validate the experimental process. The velocity in the wind tunnel was approximately 10 m/s. Symmetrical L- and U-shaped models were also tested under the same conditions.

The models used for the experiments were made of transparent PVC (3 mm of thickness), with a geometric scale of 1:100, and equipped with 35 taps located on each face tested. These pressure taps have been placed as near as possible to the sidewall and roof edges to attempt to capture the high-pressure gradients (suctions) occurring at points of flow separation. The roof is fixed by screws so as to be easily removed and to allow the access to the interior of the models. On the cube, although only the roof and one of the walls were monitored, all the faces were tested by rotation of the model. On the symmetrical L- and U-shaped models only the inner faces were measured, as the others were considered to present surface pressure distributions very similar to those of a rectangular block with the same dimensions. This fact is also supported by a study of Stathopoulos and Zhou [3]. The three models are shown in Fig. 1 while their dimensions along with the location of the pressure taps are shown in Fig. 2.

The cube was tested just for the normal incidence, while the other models were tested for several flow directions as shown in Figs. 8 and 9. For pressure measurements two different scanivalve transducer models were used: a multi-point electronic pressure scanner DSA3217 and a mechanical Scanivalve Model J. The latter, which belongs to an older