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Extreme value distributions for peak pressure and load coefficients

Henry W. Tieleman*, Mohamed A.K. Elsayed,
Zhongfu Ge, Muhammad R. Hajj

*Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University,
Blacksburg, VA 24061-0219, USA*

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Abstract

The distributions of peak suction forces in separation regions on a surface-mounted prism are well represented by the Extreme Value Type I (Gumbel) distribution. The distributions of the peak coefficients representing these forces from either laboratory or field experiments are obtained either with the method of moment estimators or with the analytical Sadek–Simiu analysis. The laboratory-based results are mostly independent of the method selected to obtain the distributions. On the other hand, those of the field data obtained with the method of moment estimators are dependent on the scatter of the individual peak coefficients and their distributions are based on peaks obtained over the duration of the number of successive records, while the Sadek–Simiu method is based on the duration of just a single record.

Keywords: Peak pressure coefficients; Peak load coefficients; Gamma distribution; Gumbel distribution; Method of moments; Sadek–Simiu procedure

1. Introduction

Wind load data presented in the ASCE 7 Standard (2002) are based on the compression of large amount of observations into a few numbers, without specification of the fractile of the listed coefficients. The single-valued pressure coefficient to be applied at a given

*Corresponding author. Tel.: +1 540 231 6891; fax: +1 540 231 4574.
E-mail address: Tieleman@vt.edu (H.W. Tieleman).

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location on a structure assumes these coefficients to be independent of incident turbulence intensity. However, wind tunnel results presented by Tieleman et al. (2003) reveal unambiguously that mean, rms, and peak pressure coefficients, and, therefore, the pressures themselves, vary indeed with turbulence intensity. It is generally accepted that sample records from wind tunnel experiments of fluctuating pressures and loads should be equivalent to 1 h in full scale or 1–2 min in the laboratory. Single peaks obtained from each of these short records may vary in magnitude from one sample record to another. Therefore, a stable estimate of extreme pressures and loads, at a certain level of non-exceedence, can only be derived from their distribution requiring a set of peaks each obtained from a single sample record that is one of a large set of sample records. For field observations, this requirement is a problem as wind conditions are seldom stationary for periods of 1 h or longer. Although the condition of stationarity in the wind tunnel is no problem, data acquisition and data handling for a large number of sample records requires excessive wind tunnel operating time including data analysis. In order to overcome these problems, a new procedure, developed by Sadek and Simiu (2002) from the National Institute of Standards and Technology (NIST), is employed to obtain from a single sample record wind load provisions at any level of non-exceedence. The method utilizes the full extent of the pressure and load time histories obtained from either field or laboratory experiments, permitting the future design of wind load sensitive parts of low-rise structures to be based on more accurate information.

2. Experimental

Surface pressure data analyzed in this work were obtained from the experimental building ($9.1\,\mathrm{m} \times 13.7\,\mathrm{m} \times 4.0\,\mathrm{m}$) at the wind engineering research field laboratory (WERFL) at Texas Tech University. The data consist of records of 15-min duration that were filtered at 10 Hz and sampled at 40 Hz. The laboratory data analyzed in this work are based on wind tunnel experiments of the 1:50 scale model of the WERFL building. The model was exposed to turbulent flows generated in the Clemson boundary-layer wind tunnel over seven different floor-roughness configurations (Tieleman et al., 2001). The turbulence intensities for the different configurations at roof height varied between 7.1% and 19.3% representing open terrain (category C) with a roughness-length range between 0.005 and 2.75 cm, respectively. Time histories from two sets of eight pressure taps provided the input for the analysis. Set A is located along a line normal to the leading edge at locations corresponding to the WERFL pressure taps 50900–50909 (Levitan and Mehta, 1992). Observations from this set were made for a zero azimuth angle, with the flow normal to the leading edge. Set B consists of eight pressure taps along a straight line originating from the roof corner and making an angle of 15° with the leading edge (Fig. 1). The amplified output signals from the pressure transducers were passed through tuned equalizers, filtered at 200 Hz, and sampled at 2000 Hz. The duration of the time histories obtained from the wind tunnel model is 2 min. For each flow condition and each azimuth angle, a total of 16 repeat records were acquired and analyzed. In order to obtain a more stable peak distribution, each of the 2-min sample records was divided into four 30-s sample records to obtain a total of 64 peaks. Tieleman et al. (2003) and Levitan and Mehta (1992) provide the details of the experimental setup, data acquisition and analysis of both laboratory and field experiments, respectively.