CONTENTS AUTHORS

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NEW APPROACH OF DETERMINATION DYNAMIC WIND LOAD OF THE BORA

Rasid Hadzović & Majudin Muratovic
Faculty of Civil Engineering Dzemal Bijedic University of Mostar,
USRC „Midhad Hujdur Hujka", 88104 Mostar,
Bosnia and Herzegovina

Bernardin Peros
Faculty of Civil Engineering University of Split
Matice hrvatske 15, 21000 Split
Croatia

ABSTRACT:
In Europe as in the rest of the world, wind is dominant load for high structures, especially for steel structures. Until now, used wind load standards have had a deterministic character and influence to structures is static. In the area of Balkan, the strongest winter wind is the Bora wind, which has a devastating character and can seriously impair the safety and structural stability. The paper deals with turbulence – dynamic characteristics of Bora wind characterized by fluctuations – the value of wind speed deviations from the average wind speed, which are the most important part of wind loads, because it directly affect the safety of the structure. Ergodicity should be confirmed. Wind as a non-stationary process should be converted into a stationary by ARIMA model (or similar), and forecast the wind speed. Wind load on structure has been determined as static – depending on the mean values of wind speed and dynamical – Power Spectral Density – PSD obtained by Fast Fourier Transformation – FFT of the autocorrelation function. The program created in MATLAB could determine wind loads. In this paper is given completely new approach for dynamical wind load instead „white noise", because new technologies in the world opening new horizons at different fields of research, especially in wind engineering.
Keywords: time series analysis, stochastic process, ergodicity, stationarity, wind load, ARIMA model, Fast Fourier transformation - FFT, autocorrelation function, Power Spectral Density – PSD

1. INTRODUCTION
This paper[1] presents a new approach to the determination of dynamic wind loads on structures. Dynamically sensitive structure in the construction industry reacts in every second of wind speed, so that a more realistic approach to the determination of wind loads on the basis second wind speed records in comparison with the currently used 10-minute wind speed records. Today's technology enables the recording of wind speed in seconds, which gives a special quality in future studies of wind. Just second records can provide a better dynamic component of the wind, which represents the most dangerous load on high structures. It is important to determine the approach to the determination of dynamic wind loads on structures. In the world, used rules recommend Power Spectral Density –PSD as a dynamic load. Thus, defined load is called "white noise" [4] attached to the concentrated modal force and assigned to at the top of the structure. This paper is precisely on this path, to make a

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point to a different – a new approach to determining the dynamic wind loads based on second wind speeds and PSD's grouped all over the height of a structure, in order to build reliable facilities.

2. BORA – WIND WITH DEVASTATING EFFECT

Bora is a typical wind of cold, winter period of the year. Has north or northeast wind direction, and comes from the mountains and carries cold, dry air, and it feels like a frigid wind.

Bora has a distinct vertical component of motion, and a restless strong air stream or turbulence. Precisely because of this uniqueness, Bora is not uniform, but alternating strong and weak strikes, called **gusts** (Italian ***reffolo***), with the considerably weak wind speed. Bora gusts can be twice the size of the mean values of wind speed, so they represent a greater danger of attack from the mean wind speed. This can especially be noted when measuring wind speed. Owing to large, gustiness and turbulence, Bora can be very damaging to buildings as well as for vegetation, especially for trees and forests. [9,10,11,12]

The actual wind is turbulent, depending on the roughness of the terrain through which passes. One of the great features of the wind is profile of mean wind speed at height with the turbulent characteristics. Turbulent wind characteristics depend of the direction and the averaging period. According to the intensity of turbulence and calculated factors of gusts, Bora wind set aside which turbulence characteristics are not represented adequately by 10-minute intervals , as recommended in EC1. To obtain a true picture of Bora gusts and an assessment of the brevity of the interval averaging wind speed for quality evaluation of turbulent wind speed components (dynamic wind load) is necessary to have the measurements of wind speed and direction at intervals shorter than 10 minutes [6]. This paper is based on records of wind speed and direction at second intervals, to get better representation of actual wind loads on structures.

Fluctuating part of wind speed is turbulent part, and change in height and in relation of the basic wind speed. The difference between the fluctuations and the mean wind speed has a large effect on the intensity of turbulence. Just the intensity of turbulence directly affects to the dynamic characteristics of the wind.

3. VERTICAL WIND PROFILE

Vertical wind profile is described by Power Law with coefficient of roughness α. If known α and wind speed at height z_1, it is possible to calculate wind speed at height z_2, by equation of Power Law:

$$\frac{U(z_2)}{U(z_1)} = \left(\frac{z_2}{z_1}\right)^{\alpha} \qquad \text{... (1)}$$

Loads on the structures operating at different heights of the structure such as 9 different heights as a uniform loads (Figure 1) [14].

4. NEW APPROACH TO THE DETERMINATION OF WIND LOAD ON THE STRUCTURE

Selection of required period of research should be taken by recommendation of Euro code 1 and the rules of the FFT, but wind direction data should be from the same direction mostly. Euro code 1 recommended period for wind blowing is duration from 4 to 12 hours, with a mostly recommended time of 8 hours [7]. According to the rules of FFT number of samples should be the value of 2^n, so the usable total number is 2^{15}= 32768 seconds.

Each longitudinal wind speed at a particular location is described by mean value and fluctuating component [4,5]:

$$v(t,r) = \overline{v}(z) + v'(t,r) \qquad \text{... (2)}$$

On the basis of the total wind speed, it is necessary to determine the wind load, which will be divided into static – the average load and dynamic – fluctuating part of the load:

$$q(t,r) = \overline{q}(z) + q'(t,r) \qquad \text{... (3)}$$

Static load will be applied by the vertical wind profile, as shown in Figure 1 from a) to c), and fluctuating part will be converted into a spectrum and as a modal load applied to the structure, as shown on Figure 1 at d).

A new approach to the determination of wind load is given in the following steps [1]:

1. In accordance with the statistical postulates of ergodicity of time series and wind direction, from the measured second records is necessary to choose the best period with the highest wind speeds,
2. Perform transformation from non-stationary series into stationary and forecast of wind speeds by using ARIMA model [8] (or similar) in accordance with the rules of stationary series [1,2]:
    a. perform the necessary transformation of the series by an exponential factor,
    b. make a necessary differentiation of series,
    c. make control of declining of autocorrelation coefficients,
    d. make control of forecasted time series by residuals in the range of $\pm 2\sigma$,
3. Using the Power law make calculation of wind speeds by vertical wind profile based on the forecasted data, and each level join second data series,
4. Calculate the total wind load to the EC 1 [3] separately for each height of the vertical profiles for every second of wind speed,
5. Perform division on the static and dynamic part of the wind load for each individual amount of the total load … (3),
    a. Determine the static load based on mean values of wind speed,
    b. Determine fluctuating part of load (dynamic wind load), as difference of the total wind load and mean values of load,
6. Perform autocorrelation of the fluctuating part of wind load,
7. Apply Fast Fourier Transformation – FFT to the autocorrelation values calculated from the previous step,
8. Perform FFT squaring the results from the previous step, to obtain Power Spectral Density – PSD.

Following the above-defined steps, the determination of static and dynamic loads can be done using a program made in MATLAB [13]. On this way will be obtained, for example 9 static loads by height of the structure separately for each level, and 9 different spectrums – PSD's, also at the same heights as shown in Figure 1.

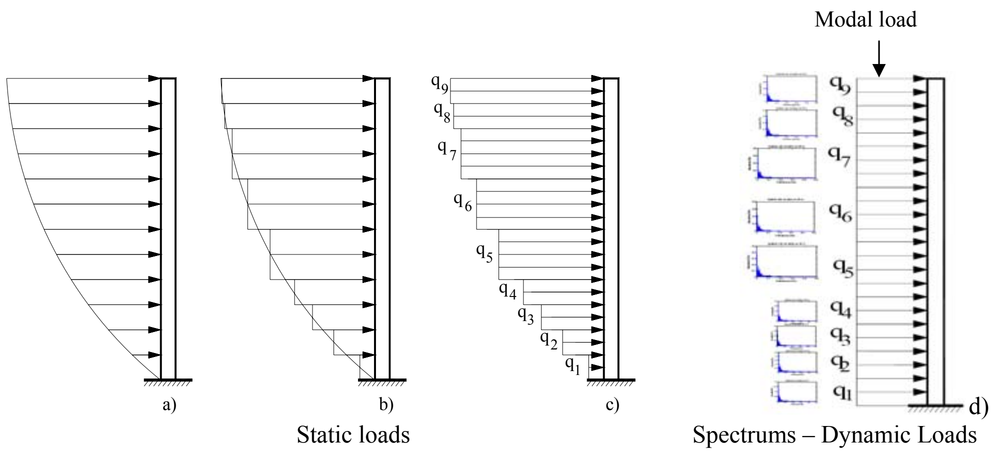

Figure 1: Transformation from vertical wind profile to static loads and dynamic loads by spectrums [1] and modal load

The separation is made on static and dynamic wind loads to structures and particularly will be applied to the structure. Static loads vary in height $q_1 \neq q_2 \neq \ldots \neq q_9$, while the dynamic load is modal $q_1=q_2=\ldots=q_9=1.0$ associated with the spectrums by height.

Separation of static and dynamic load is required to determine the individual influence of static and dynamic loads on structures, which is base of calculation of dynamic factors [4]. Calculation of structure should be based on random vibrations theory through civil engineering software.

5. CONCLUSION

This paper presents a new approach to determine wind loads on structures based on records of wind speed in seconds in accordance with the vertical wind profile. It is necessary to forecast wind speed based on the existing second records, and after that to establish the stationarity of series by the highest quality ARIMA model. The present approach by the PSD's determined as "white noise" attached to concentrated modal force and applied to the top of structures is different from the new approach, because the new one acting over the entire structure with all calculated spectrums together attached to uniform modal load, and the number of spectrums depends on the height of the structure and vertical wind profile.
This paper is a good foundation on the further research of Bora wind in the area of Balkan. Also, the new approach opens up new horizons for research using available modern technologies.

6. REFERENCES:

[1] Hadzovic R.: Uticaj dinamičkog opterećenja vjetra na sigurnost visokih konstrukcija (Effects of dynamic wind load on safety of high structures), doctoral dissertation, Faculty of Civil Engineering at University of Sarajevo, defended in 2011.
[2] Peros B.: Sigurnost konstrukcija dominantno opterećenih vjetrom (Safety of structures under dominant wind load), doctoral dissertation, Faculty of Civil Engineering at University of Zagreb, defended in 1994.
[3] Eurocode 1: Actions on structures – Part 1 – 4: General actions – Wind actions, EN 1991-1-4: April 2005.
[4] Holmes J.D.: Wind Loading of Structures, Taylor & Francis 2007.
[5] Li Y., Kareem A.: ARMA systems in wind engineering, Probabilistic Engineering Mechanics, 1990, Vol. 5 No.2
[6] Bajic A. & Peros B.: Referentna brzina vjetra – utjecaj perioda osrednjavanja (Referent wind velocity – influence of averaging period), Gradjevinar 53 (2001) 9, 555-562
[7] JCSS Probabilistic Model Code, PART 2 : LOADS, 99-CON-DYN/M0040, JCSS-Lungu & Rackwitz -08-12-97, http://www.jcss.ethz.ch/ , 2001.,
[8] Kovačić Z.J.: Analiza vremenskih serija (Time series analysis), University of Belgrade, Faculty of Economy, Belgrade, 1995.
[9] http://www.crometeo.net/
[10] http://klima.hr/
[11] http://hr.wikipedia.org/
[12] http://jadran.gfz.hr/
[13] Help Manual MATLAB
[14] Help Manual Windographer