Wind loading parameters – Measurements vs. Croatian standard

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ABSTRACT: New Croatian Standard assesses wind loads to be used in the structural analyses of buildings up to height of 200 m, bridges up to a span of 200 m and footbridges up to a span of 30 m. According to wind loading map territory of Croatia is divided in five zones, and mean reference wind speed for the fifth zone equals 50 m/s. This is extreme value, especially when other parameters (i.e. exposure coefficient) are taken into account. Eventually this can lead to increase of wind loading three or four times compared to the standards recently used. Intention of this paper is to discuss some issues which arise during project of wind protection of one motorway section in Croatia which is exposed to extreme wind loading.

Dynamic measurements of wind speed along mentioned motorway section are under way within scientific research of wind protection structures which are already built.

1 INTRODUCTION

Figure 1 is showing territory of Croatia which is divided into five zones regarding basic value of the reference wind speed. Maximum basic reference wind speed is \( v_{\text{ref},0} = 180 \text{ km/h} \). In the regions with this wind speed stormy and gusty wind called bora blows with even higher wind speeds.

2 DEFINING WIND LOADING ON THE STRUCTURE ACCORDING TO THE ENV 1991-2-4

Compared to the wind speed maps of other countries of CEN it is obvious that Croatia has very strong wind loading along the Adriatic coast and in the hinterland. Extreme is the fifth zone on the slopes of Velebit Mountain which equals \( v_{\text{ref},0} = 50 \text{ m/s} \). Measured values are showing that even stronger bora blows in this regions (Figure 2).

Following analysis will give wind load for the Maslenica Bridge superstructure. It is concrete arch bridge with a span of 200 m and is a part of the motorway which is exposed to extreme winds. For the
purposes of the safe traffic ongoing in case of strong wind it should be protected with additional structure. Strong wind blowing can severely influence vehicles stability on the bridge which is addressed to problem of traffic safety. Bridge level line is 90 m above the sea level and at that height high wind speeds occur.

Reference wind speed which is the basic parameter for wind loading calculation is given:

\[ v_{\text{ref}} = c_{\text{DIR}} \cdot c_{\text{ALT}} \cdot c_{\text{TEMP}} \cdot v_{\text{ref,0}} \]  \hspace{1cm} (1)

where:

- \( c_{\text{DIR}} = 1.0 \) – wind direction coefficient,
- \( c_{\text{ALT}} = 1 + 0.001a_s \) – altitude coefficient, \( a_s \) – altitude,
- \( c_{\text{TEMP}} = 1.0 \) – season coefficient.

According to the Figure 1 for the Maslenica Bridge \( v_{\text{ref,0}} = 50 \) m/s. Due to superstructure height above the sea level according to (1) this value should be increased approx. 10%:

\[ c_{\text{ALT}} = 1 + 0.001 \cdot 90,0 = 1.09, \]
\[ v_{\text{ref}} = 1.0 \cdot 1.09 \cdot 1.0 \cdot 50,0 = 54.5 \text{ m/s}. \]

Continuous wind loading on the structure is obtained from the reference wind speed:

\[ q = 0.5 \cdot \rho \cdot v_{\text{ref}}^2 = 0.5 \cdot 1.25 \cdot 54.5^2 = 186 \text{ kN/m}^2 \]  \hspace{1cm} (2)

Coefficient of exposure to the wind loading is \( c_c(z_e) = 4.25 \) and the dynamic coefficient \( c_d = 0.96 \).

Continuous loading per m’ of the superstructure for combination of dead load and wind load equals:

\[ w = 186 \cdot 4.25 \cdot 0.96 \cdot 0.9 \cdot 3.15 = 21.51 \text{ kN/m’} \]

Continuous loading per m’ of the superstructure for combination of dead load, live and wind load is:

\[ w = 186 \cdot 4.25 \cdot 0.96 \cdot 0.9 \cdot (2.0 + 2.0) = 27.31 \text{ kN/m’} \]

German standard which was widely used even in Croatia, defines wind loading on the structure which is 50–100 m above the ground level as 2.5 kN/m² for combination of wind and dead load:

\[ w = 2.5 \cdot 3.15 = 7.88 \text{ kN/m’} \]

and 1.25 kN/m² for combination of dead load, live and wind load:

\[ w = 1.25 \cdot (2.0 + 3.5) = 6.88 \text{ kN/m’} \]

Wind loading according to the HRN ENV 1991-2-4 has to be critically observed. Fifth zone reference wind speed is real value of the speeds which bora exceeds.

Figure 3. Results of the measurements – 3 second wind speed.

However increase of reference wind pressure with exposure coefficient is conservative condition which results in such increase of wind loading compared to the DIN 1072. On the other hand, DIN 1072 is not applicable to Croatian coastal airflow regimen because highest reference wind speed in Germany is 32.0 m/s which is valid for the 2nd zone in Croatia which does not cover coast and hinterland where strongest winds blow. All mentioned leaves uncertainties and should be critically observed. Such an increase of loading does not necessarily result in optimal structures that are to be built.

3 DYNAMIC MEASUREMENTS

As a part of the scientific project on traffic safety in case of severe wind dynamic measurements of the wind speed were done. Term dynamic measurement denotes measuring wind speed by means of driving vehicle equipped with the measurements set which consist of Vaisala ultrasound wind speed and direction sensor. Measurement set is installed on the car roof at height 2 m above the roadway surface.

Results of the measurements are then processed and for the purposes of further analyses cross and longitudinal wind speed components are shown in the diagrams (Figure 3).

4 TENSOMETRIC MEASUREMENTS

Preliminary static measurements were done on wind protection structure on the second test section. They were not done during critical wind speed so tensometric measurements showed stresses in moderate loaded structure which are only 10 percent of design values. These results are interpreted only as initial state of the structure and for comparison with future static measurements in stormy conditions, but not as mean of validation of wind barriers efficiency.
5 CONCLUSIONS

High mean wind speed in the coastal part of Croatia according to the ENV 1991-2-4 is strongly tightening up demands for structural safety and mechanical resistance. Compared to the codes that were used in the recent past it is obvious that such an increase of initial wind loading is unnecessary. Procedure for determining reference wind speed based on the basic values should therefore be critically observed and revised.

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REFERENCES
