The Dutch Wind Tunnel Guideline for Wind Loads

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Abstract

This paper addresses questions that arose during development and application of the Dutch guideline for wind tunnel testing to determine wind loads on buildings. This guideline (CUR 103) is being used since 2005, and a first revision is foreseen. Within this revision, the relation with Eurocode EN 1991-1-4 is established. Questions to be resolved concern data acquisition and data analysis choices. This could form the basis for a European standard. During the conference, a discussion on the need for a European guideline is welcomed.

1 Introduction

Wind tunnel tests in atmospheric boundary layer wind tunnels are well-accepted as tool to determine design wind loads on structures. Data from current building codes also originate from past wind tunnel investigations.

Large differences in results from different wind tunnels on similar building shapes have been reported in the past (e.g. Sill et al, 1992, Kasperski et al., 1996) These differences have been attributed to among others; the upstream roughness, the mean wind profile and turbulence characteristics and geometrical scale. Despite years of effort to better understand the wind flow in wind tunnels and the outcomes in terms of wind loads, such differences still exist. This often leads to discussions with structural engineers, building authorities and checking authorities about the validity of wind tunnel experiments.

Within the Netherlands, such a discussion led to the establishment of a working group that was asked to write a guideline, which could be used and understood by all parties involved in with an interest in wind tunnel experiments to determine wind loads. This guideline should include minimum demands to set up, carry out, analyse and report wind tunnel tests for wind loads on buildings. CUR guideline 103 was published in 2005 (CUR, 2005) and is since then used by the three wind tunnel institutes in the Netherlands. The procedures applied in the guideline are based on the now outdated Dutch code (NEN 6702).

The Eurocodes are obligatory for structural engineering calculations since early 2012. In the Dutch National Annex to EN 1991-1-4, the CUR guideline 103 is referred to. However, differences exist between the approach in NEN 6702 and the current approach in the Eurocode. The CUR guideline needs to be revised to adapt to these changes. This revision should be based on the Eurocode, and could form a basis for a joint European wind tunnel guideline.
2 A brief overview of the Dutch guideline

The CUR-103 guideline consists of 10 chapters, dealing with the definition, set-up, execution, analysis and reporting of the wind tunnel investigation. The outline of this guideline is presented in Table 1. The guideline is very brief in giving background information. It is written rather as a cookery-book for the wind tunnel institutes, their clients (usually represented by a structural engineer) and checking authorities. It prescribes quite strictly the procedures to follow, not only for setting up the experiment and executing the measurements, but also for the data analysis and reporting (which was a strong wish by the checking authorities). Other published guidelines (eg. ASCE, 1999, ASCE, 2012, WTG, 1995) do not include data analysis and reporting, or formulate very general recommendations, which need specialist knowledge to apply.

Table 1: Overview of the CUR-Recommendation 103 (guideline for wind tunnel research)

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When drafting this guideline, structural engineers and checking authorities demanded that the procedures should be transparent for all parties involved. Therefore, the provisions are written as minimum requirements for explicit parameters, rather than giving options. Some provisions that raised questions are discussed below. These will be presented and discussed during the conference.

3 Discussion on CUR guideline 103

A number of questions arose over the past years when applying this document, both between the three institutes involved directly, and with other parties, outside the Netherlands.

3.1 Sample frequency

The guideline gives no prescription for sample frequency and filtering. Frequencies used in the Dutch institutes lie between 250 and 1000 Hz. Filtering of the data can be applied by using a moving average of 0.1 s (local loads) to 3 s (global loads). However, choices are being made by the institutes individually. This choice may cause differences in results for similar tests.

3.2 Scaling

The requirements for scaling the flow and the model are quite straightforward. Strouhal number and Jensen number are specified as parameters, Reynolds number sensitivity must be taken into account. The blocking ratio is advised not to exceed 5%, otherwise corrections should be applied. These corrections however are not specified.
3.3 Turbulence intensity

The turbulence intensity (at any height) should be equal to or less than the full scale turbulence intensity. It is assumed that creating less turbulence than equivalent in full scale will lead to a safe set of loads obtained. This is in line with the demands set in the code, where an overprediction of the loads is accepted as being on the safe side.

3.4 Modelling the surroundings

One of the first issues during the development of the guideline concerned the effect of surrounding (shielding and interfering) buildings on the loads of new buildings. The discussion was whether it is allowed to apply reduced wind loads when it is not unlikely that the shielding building, causing the reduction, will disappear during the lifetime of the new buildings. In the end, this led to the conclusion that for the design of structures based on wind tunnel data, two situations need to be investigated: the first one including the present and in the near future planned surrounding buildings on the site and the second one where the height of all surrounding buildings has been reduced until 15 metres in full scale. An example of these two different configurations in a wind tunnel is given in Figure 1.

![Figure 1: Two configurations: full model (left) and until 15 m lowered surrounding buildings (right)](image)

3.5 Data analysis

For data analysis, three methods (A, B and C) have been defined, which are briefly described below.

3.5.1 Method A

Method A is applied only for the determination of the overall loads on buildings and explicitly stated not to be applicable to determine the local wind loads. The method is relatively cheap and based on the assumption that a quasi-steady approach is valid or at least gives safe results for the overall forces on the investigated building. Static force balance measurements or surface-integrated time-mean pressures result in time-mean force and moment coefficients at 24 wind directions (when applying intervals of 15°). The full-scale wind loads are obtained by combining the overall time-mean force and moment coefficients with the peak velocity pressures and with a dynamic amplification factor taken from NEN 6702. NEN 6702 prescribes peak velocity pressures at varying height for three different areas in the Netherlands. Open issues regarding the rather simple procedure of method A are the range of application and how to translate results from pressure measurements into floor-to-floor distributed loads over the building height, as well as how to treat wind directionality.
3.5.2 Method B

The second method B uses time series of pressures and/or forces. The force or pressure coefficients are obtained from extreme value analyses of these time histories. The extreme value analysis is based on the simplified Cook-Mayne analysis of extreme values of pressures; see (Cook, 1982) and earlier work referred to herein. This method incorporates the wind climate data in the same way as method A.

With regard to the extreme value analysis the following choices were made:

At each wind direction, the number of independent time-histories to analyse for extreme values is at least 24. This number is higher than the 16 proposed by Cook, but (much) lower than values suggested by others (e.g. Kasperki, 2009). The length of the time-histories represents at least 1 minute in full scale. It was assumed that 1 minute time histories include enough physical information to scale up to extremes of larger averaging times (say 10 or 60 minutes), if required.

A first analysis with combinations of sample lengths and number of samples have not lead to a conversion in resulting pressure coefficients. Since Dutch wind tunnel institutes all apply their own choices, a client is potentially faced with different results from different wind tunnels. This needs to be resolved before a next version of the guideline is produced.

3.5.3 Method C

The most elaborate method C combines the results of the extreme values analysis of aerodynamic coefficients with an extreme value analysis of the wind climate to obtain the load which is exceeded on average 1/50 years. A high quality database for the wind climate is available in the Netherlands from the Royal Netherlands Meteorological Institute KNMI, of which Gumbel parameters are determined which are being used in this procedure. However, the basis of method C differs from the basis of the Eurocode. For instance, all data in the Dutch database are hourly mean potential wind speeds, based on a (potential) roughness length of 3 cm at 10 m height, whereas the Eurocode uses 10 minutes mean based on roughness length of 5 cm. This implies that Method C has to be adjusted to fit into the Eurocode procedures.

4 Conclusion and further development

The guideline is in use since 2005. The main three operators of boundary layer wind tunnels in the Netherlands follow its procedures. Various open issues and questions are indicated and will be discussed at the conference. It is the intention to further study the effects of number of peaks and minimum record lengths to take. Further development towards a guideline towards a European document could be done under the CEN framework. Parties interested in contributing to such a document are welcome to join forces, and to discuss this further development at the conference.

5 References


CUR (2005), CUR guideline 103: in Dutch

