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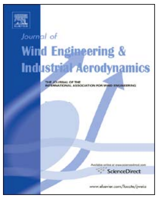

Wind sheltering effect of a small railway station shelter and its impact on wind comfort for passengers

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ABSTRACT

Shelters, instead of buildings, are used at small railway stations in Switzerland to protect waiting passengers from environmental loading such as wind, rain and sun. As they are mostly located on open terrain, small railway stations are exposed to wind and therefore require wind comfort analysis. Generally, the same shelter design is used for a large number of different railways stations at locations with different local climates. These shelters have to be designed carefully to protect the passengers for a large number of weather conditions with, for example, different wind speeds and wind directions. In this paper, a wind comfort study for a prototype of a railway station shelter is presented. Computational fluid dynamics (CFD) simulations are conducted to predict the local wind velocities in and around the shelter. The results based on amplification factors show a good wind sheltering efficiency of the prototype for most common weather conditions in Switzerland. Because the side and back walls of the shelter do not reach the ground, high wind velocities can be obtained at the level of the feet and legs. Simulations with modified side and back wall geometries show that the wind sheltering efficiency can be improved by introducing small modifications.

1. Introduction

At small railway stations passengers have to wait for trains often in an outdoor environment, because there exist no station buildings with indoor waiting halls. Therefore, the passengers are exposed to the environment and shelters may be needed to protect them from wind, rain and sun. In addition, the frequency of trains that stop at small railway stations is mostly low, because usually only regional trains stop at these stations. This can lead to long waiting times. Small railway stations can mainly be found in rural areas or close to small villages, where the stations are not sheltered by surrounding buildings. Often, the railway tracks are on a slightly higher level than the surrounding terrain and therefore the stations are exposed to stronger winds. Furthermore, shelters are often not designed individually for each small railway station. Instead, the same design is used for a large number of stations. Such a shelter design has to consider a large number of possible weather conditions in different climates in order to protect passengers from undesired effects related to wind, rain and sun. For example, it cannot be optimised to protect the passengers for just a small number of wind directions, which are the prevailing wind directions for the location of a single railway station. Finally, similar shelter geometries can be used for train, tram and bus stations.

There exist guidelines on the design of train, tram and bus stop shelters. For example OCTA (2004) published a detailed safety and design guideline for bus stop shelters. This extensive document gives information on recommended shelter designs, e.g. minimal roof dimensions are given. For most of the shelter design recommendations it is not specified, how they were derived. The guidelines were written for bus stop shelters, but the information can also be transferred to other shelter types like, for example, for tram or train stations. Besides guidelines, CFD (Computational fluid dynamics) simulations can also be used at the design stage to optimise the geometries of shelters in terms of wind comfort and rain sheltering.

CFD simulations are commonly used for wind comfort analysis. Based on the CFD results, the wind comfort is evaluated with wind comfort criteria. There exist a number of different wind comfort criteria that are applied in the literature. Janssen et al. (2013) gives an overview and evaluation of the most commonly used wind comfort criteria. They compared different criteria and found that wind comfort studies can lead to very different results depending on the used wind comfort criteria. One of the most commonly used wind comfort criteria in recent studies is the Dutch wind nuisance standard (NEN 8100,

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2006). Other important wind comfort criteria, which are presented in Janssen et al. (2013), are criteria by Isyumov and Davenport (1975), Lawson (1978) and Melbourne (1978). The NEN 8100 uses 5 m/s as critical wind speed for the wind comfort. The local wind comfort is evaluated based on the probability that the local wind speed exceeds 5 m/s at the studied location. Threshold values for these probabilities are given for different activities (sitting, strolling and traversing).

Wind comfort studies based on CFD simulations are often conducted for urban areas. Janssen et al. (2013) compared the different wind comfort criteria based on a CFD study, which was conducted for the campus of the Eindhoven University of Technology. Another example for a wind comfort study in an urban environment was conducted by Blocken and Persoon (2009). The aim of this study was to predict the impact of new high-rise buildings on the wind comfort close to a football stadium.

In other studies the wind comfort for individual buildings or other constructions are analysed. Montazeri et al. (2013) proposed a new façade concept to improve the wind comfort on balconies of high-rise buildings. Better wind sheltering could be achieved using a new second-skin façade concept. The efficiency of the second-skin façade was evaluated with NEN 8100. A similar study was conducted by Zheng et al. (2016), where they analysed the wind comfort for outdoor platforms that connect three megatall towers at different levels above the ground. A combined approach with wind tunnel measurements and CFD simulations was used to study the wind comfort on the platforms with two wind comfort criteria (NEN 8100 and Lawson, 1990). A rather large number of studies that investigate the performance of windbreaks and their impact on the wind comfort can be found in the literature. Studies on wind breaks often focus on the impact of their porosity on the wind comfort downstream of the windbreaks (e.g. Gandemer, 1981; Perera, 1981; Frank and Ruck 2005; Santiago et al., 2007). Other effects that have been studied are the impact of the windbreak geometries and the combination of windbreaks on the wind downstream of the windbreaks (e.g. Gandemer, 1981). There exist also a number of studies, where sheltering efficiency of roofs or shelters have been analysed. Van Hooff et al. (2011) presented wind flow and wind driven rain results obtained by CFD simulations of sports stadia with different geometries. The shelter efficiency of sport stadia is important for the comfort of the spectators, but often not carefully studied.

Only a limited number of wind flow studies for buildings, roofs or shelters at railway stations can be found in the literature. And only a small fraction of these studies focus on the wind comfort or sheltering efficiency. Hur et al. (2008), for example, conducted CFD simulations to study wind loads on a railway station. Although the results of these CFD simulations could be used for a wind comfort analysis, such an analysis was not presented in their paper. Kubilay (2014) studied the rain sheltering efficiency of an urban public transport station for buses, trams and trains that consists of number of roofs with complex geometries. These complex roofs were not designed to shelter from wind and therefore the wind comfort was not studied and the wind speeds are only analysed in connection with the wind-driven rain analysis. At railway stations, wind can also be caused by trains passing through the stations at high speeds. The impact of these train-induced winds on the wind comfort and the risk for danger on the passenger platform was studied by Khayrullina et al. (2015) with CFD simulations. They conducted this study for an underground railway station. Underground railway stations are studied in the literature due to the complex flow structures and need for efficient ventilation systems, for example, in case of fire (e.g. Rie et al., 2006; Teodosiu et al., 2016). Finally two studies can be found in the literature, where the sheltering efficiencies of shelters at small (tram and bus) stations were investigated. Moya et al. (2014) studied how wind breaks can be used at tram stations in Melbourne (Australia) to protect the passengers from wind in the waiting areas. Kaijima et al. (2013) conducted a CFD study to evaluate the shelter efficiency of different shelter designs at bus stops. Unfortunately the results are not discussed in detail and no wind comfort criteria were applied.

In this paper, a wind comfort study for a prototype of a shelter design for small railway stations is presented. A number of constraints had to be considered for the prototype design. The shelter has to have a high wind, rain and sun sheltering efficiency to protect the passengers from wind, rain and sun and a ticket machine and an information screen from rain and sun only. Further, the manufacturing process and the maintenance have to be cost effective. Finally, the shelter should have an attractive design. CFD simulations are conducted for the wind comfort analysis. Due to the low local wind speeds for most of the weather conditions and locations in Switzerland and, therefore, the low probability of wind speeds exceeding 5 m/s (NEN 8100), no wind comfort criteria is applied in this study. Instead, amplification factors are studied and streamlines are analysed. Based on the amplification factors, it is determined, what wind speeds at 10 m height lead to discomfort in the sheltered area of the railway stations. In this study, gustiness is not considered for the wind comfort analysis, but it can be taken into account by using lower threshold values (< 5 m/s) for the wind speeds at which discomfort is assumed (Janssen et al., 2013). The results of the same CFD simulations will be used in a next step for wind-driven rain simulations to evaluate the rain sheltering efficiency of the prototype. For this, the numerical wind-driven rain model developed Kubilay et al. (2013, 2014, 2015) will be used and the results will be published in a separate publication. In this paper, only the results of the wind simulations are presented. According to our best knowledge, this is the first detailed wind comfort analysis for a train station shelter. Although one specific shelter prototype is studied, the results of this study can also be transferred to other similar shelter designs, because the wind-sheltered area has a commonly used design.

The structure of the paper is as follows. The shelter prototype geometry studied in this paper is given in Section 2. In Section 3 details of the numerical simulations are presented. In Section 4 the simulation results are presented. First, streamlines and amplification factors for different wind directions are compared, including the influence of minor modifications in the geometry. Then, averaged wind speeds and hours with uncomfortable wind speeds at different locations in Switzerland with different climates are given. Finally, based on the amplification factors, wind speeds that cause local discomfort are determined. In Section 5 the obtained results are discussed and in Section 6 the conclusions are drawn.

2. Shelter prototype geometry

The study presented in this paper is conducted for a prototype of a shelter that was designed to be installed at small railways stations in Switzerland. Fig. 1 shows the shelter prototype geometry as it was used for the CFD simulations. The shelter prototype was designed by Swiss Federal Railways (SBB) and the design is their intellectual property. Some small geometrical details were simplified to avoid the need of having very small grid cells to resolve the flow around these details. The prototype consists of a sheet metal construction. The side and back walls are made out of glass (blue in Fig. 1). The prototype is 4.8 m long, 1.5 m wide and the distance from the ground to the bottom side of the roof is 2.7 m. There is a vertical clearance from the ground to the seats along the side and back walls of the shelter. This clearance helps to remove leafs and litter from the sheltered area and prevents collection of these in the sheltered area. In addition, in winter, snow accumulation can be avoided. However, snow accumulation is not considered critical in this case, since for weather conditions with light snowfall, the snow mainly accumulates outside the waiting area of the shelter and for heavy snowfalls the snow has to be removed from the platforms due to safety reasons before it can reach the waiting area of the shelter due to snowdrift. The side wall covers only the half of the shelter with a width of 0.75 m. The area below the roof is separated into two parts by the support structure. On the smaller side of the prototype the ticket machine is mounted on the support structure. The other side is the