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Research Article

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Buffeting Wind Load on Antennas with Rooftop Site

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Abstract

Most of the mobile phone antennas are located in urban areas. An economical solution is to place the antennas on top of existing buildings. In practice, any effect that the building has on the antenna wind load is neglected. Wind tunnel investigations and numerical simulations show that the wind loading might increase in some cases by up to 30% compared with the free flow.

Keywords: Wind engineering; Wind loading of antennas; Wind tunnel experiment

Introduction

Within the last years a large number of mobile phone antennas have been built. Most of them are located in urban areas where the need of mobile connections is highest (Figure 1). An economical solution is to place the antennas on top of existing buildings, as in that case no site has to be bought for a free standing tower. The most relevant design case comes from the wind loading due to turbulent gusts. But the turbulence is largely affected by the building at the top of which the antenna is placed. The building geometry and the position of the antenna on the roof top may, on the one hand, result in an acceleration of the wind flow, which increases the quasistatic response. Due to the separation of the flow at the building, turbulences may, on the other hand, result in a higher dynamic resonant response, in addition to the free flow turbulence. All these effects are usually not taken into account when designing the antenna. The codes always assume free flow acting on the structure. In the past, wind tunnel tests on models of large industrial chimneys have shown that the interference effect due to a neighboring building may lead to a significant increase in the response of the chimney [1]. Depending on the height of the chimney in relation to the building height, stresses may increase by up to 50%. In general it was found that the interference factor increases with a decreasing chimney height. The huge amount of installed mobile phone antennas represents a considerable risk potential. Investigations into this problem have not been carried out yet. Even if the general problem of interference between building and antenna is known, a solution is possible only with wind tunnel tests. Measurements have therefore been made for the wind flow over the roof top of scaled models in the boundary layer wind tunnel of the Institute of Steel Structures at TU Braunschweig.

Wind Tunnel Tests

Wind tunnel setup

The Institute of Steel Structures operates a boundary layer wind tunnel (BLWT) for building aerodynamics. The BLWT is of the open suction Eiffel type. The boundary layer is simulated with various flow conditioning devices, such as spires and fence barriers at the test section entrance and roughness elements in the run up track. The

Figure 1: Mobile phone antennas in urban areas

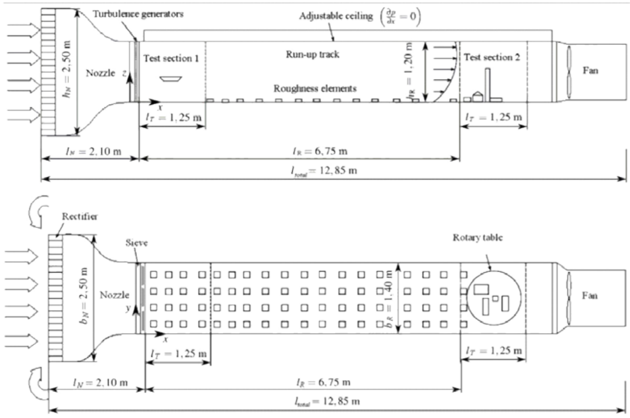

Figure 2: Side and plan view of the BLWT.

total length of the wind tunnel including the fan is 12.85 m (Figure 2). The wind flow in the tunnel is driven by an axial fan at the end of the tunnel. The maximum speed is 25 m/s. To study the wind effects in all directions, the models are placed on a turntable with a diameter of 1.2 m. As explained above, for a simulation of the natural boundary layer, turbulence generators in addition to fence barrier and a surface roughness are used.

Wind profile measurements

The time-varying wind velocities are measured with the TFI Cobra Probe. This is a multi-hole pressure probe, which is able to measure the 3 components of velocity with a high time resolution up to 2,000 Hz. Hence, this sensor is suitable for turbulent flow fields. The measurements using the Cobra Probe have been carried out along the axis where the antenna is supposed to be Figure 3. The geometric scale is chosen to be 1:100. Compared to usual boundary layer experiments with a scale of 1:300-1:500, a larger scale is used here where the wind flow only in the surface boundary layer is simulated. As a first step, the wind profiles of the longitudinal component without any building in homogenous roughness are measured and compared with free flow

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wind profiles from the literature. Due to the higher geometric scale, not all parameters of the natural wind flow could be simulated in scale. The sampling frequency is 1,200 Hz, and the sampling period is 120 seconds. The velocity scale is about 1:2.9; therefore the time scale is 34:1. Hence, the sampling period is equal to a number of 6 storms of 10 minutes each, so the results are stable in a statistical sense. In Figure 4, the profiles of the mean wind velocity and the turbulence intensity of the incoming flow (free flow) are shown. The mean wind speed profile is a good approximation of an urban area of terrain category III (TCIII) according to Eurocode 1 [2]. The turbulence intensity at the roof top (z≈21 m) is about 20% and between the TC II value of 16% and the TC III value of 23%.

Roof top wind profiles

In a second step, a building model 21 × 21 × 21 cm in size is placed on the turntable. This model represents a 7-storey building that is typical

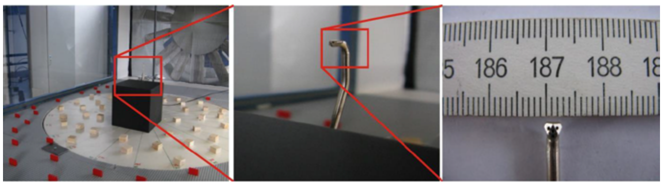

Figure 3: Building and Cobra-probe on the turntable

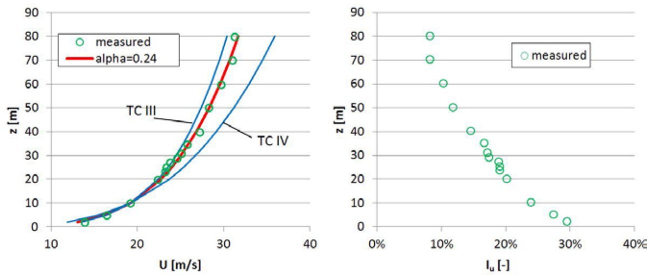

Figure 4: Profile of the mean wind speed and turbulence intensity (full scale).

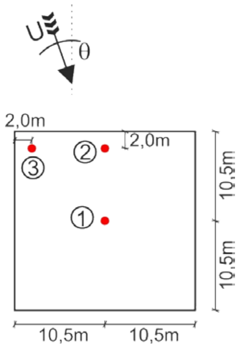

Figure 5: Plan view on the roof top and wind profile positions (full scale).

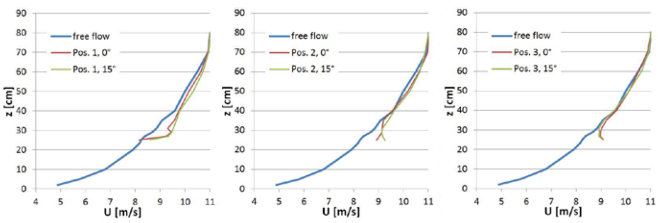

Figure 6: Roof top wind velocity profiles.

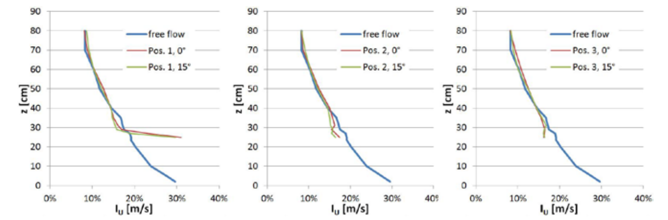

Figure 7: Roof top turbulence intensity profiles.

of residential buildings in urban areas. Wind profiles above the roof top are measured at three positions for 0° and 15° angle of wind incidence. Position 1 is the center of the roof, position 2 is on the centerline but windward 2 cm from the roof edge, and position 3 is at the windward roof corner, 2 cm from each edge (Figure 5). The first measuring point is 4 cm above the roof top. Results of the measured roof top wind velocity profiles are shown in Figure 6. The profiles differ significantly for each position. At position 1, the influence of the building is visible up to a height of about 60 to 70 cm, which is about 3 times the building height h. Close to the roof top (h+4 cm), the wind velocity is equal to the undisturbed flow, but the wind velocity increases very much and a maximum value of 110% of the free stream profile is reached at h+6 cm. The wind angle θ has no significant influence. At position 2, the free stream profile is not influenced by the building above a height h+20 cm. below this height, a more or less linear wind velocity profile is visible, which results in a maximum increase of the wind speed of 12%. At position 3, the wind is equal to the undisturbed flow above 10 cm from the roof top. A negative slope of the wind velocity profile appears close to the roof top; and maximum speedup is close to the roof top (h+4 cm) and has a value of 110%. In Figure 7, the profiles of the turbulence intensity are shown for the three different locations. At position 1, the turbulence intensity close to the roof top increases to a value higher than 30%. But above a height of about 40 cm, the profiles are equal to the free stream profile. The latter applies to all positions and angles of wind incidence. At position 3, a reduction of turbulence in the near roof top region is visible. The disturbed region is equal to that of the wind velocity profile. The increase of wind speed combined with a reduction in turbulence leads to the conclusion that the wind profile is influenced predominantly by the blockage effect.

Simulation of Buffeting Response

In practice the roof top antenna is designed on basis of the assumption that the building does not have any effect on the wind profile. The free stream wind profiles are used and cut below the building roof. As a first step, a mobile phone antenna on a 21 m high building with a flat roof is designed using this assumption. As a second step, the design is checked using the measured wind time history as loading.

Antenna structure

The antenna is an H*=4 m high cantilevered structure with a pipe section that supports mobile phone antennas with an overall wind resistance on $C_f{\cdot}A = 5\ m^2$. The cantilever is a pipe section with a diameter of 139.7 mm and a wall thickness of 8 mm. The total weight of the antennas is 150 kg. The fundamental frequency is 3.2 Hz. The antenna is designed so the bending stress is about 90% of the allowable stress for S355 steel when using the Eurocode procedure and free flow The overall damping, including aerodynamic damping, is set to 1.3% of the critical damping.

Results from eurocode 1 procedure

The procedure from EN 1991-1-4 Annex B is used to calculate the buffeting response. The procedure is based on the work done by Solari [3-5]. Measured mean wind velocity and turbulence intensity are used as input at the effective height. Width and height of the structure are set to 1.0 m × 2.0 m. The results of the calculations are given in Table 1. The EC gives an increase of the loading of about 40% for position 1. The high turbulence intensity is responsible for this value. However, looking at the background of the procedure it could not be used for structures in a disturbed flow, because the shape of the wind profile and the power spectral density of free flow are requirements for this model.

Results from time series analysis

For comparison, a dynamic time history analysis where the measured wind history is scaled in time and amplitude to the full scale has been done following the quasi-steady theory. Size effect is included in the time series from Lawson's TVL formula using a moving average of 0.3 seconds [6]. This averaging acts approximately comparable to the aerodynamic function as a low pass filter and takes into account the reduced correlation of small gusts. This is known as equivalent static gust concept [7]. For free flow this gives approximately the same results (Table 2). The duration of the time history is equal to 1,800 seconds so the results could be considered as stable in a statistical sense. Results of the analysis are given in Table 2. The bending moments are not taken as the maxi-mum values from the time series but the extreme values following the concept of Davenport [8] with The maximum increase of the response due to wind is about 31% only. Compared to Table 1 the results from the time series analysis are reduced about 10% for all cases. Figure 8 shows a comparison of the results. In addition for position 1 a 6 m high antenna is calculated. Here due to the large gradient of the turbulence intensity the response is reduced and exceeds the free flow assumption only by 8%. In Figure 9 a comparison of the power spectral densities of the bending moment is shown. In the figure on the left side the increase of turbulence compared to the free flow is visible for position 1. The power spectral densities for position 2 and 3 are shown in the right figure, here the shape of the response spectra are similar.

	free flow	position 1	position 2	position 3
max M_y [kNm]	19.4 kNm	27.8 kNm	23.4 kNm	22.4 kNm
max M_y [%]	100%	143%	120%	115%

Table 1: Base bending moments from EC1 procedure.

	free flow	position 1	position 2	position 3
max M_y [kNm]	17.9	25.5	21.1	20.1
max M_y [%]	92%	131%	109%	103%

Table 2: Base bending moments from time domain analysis.

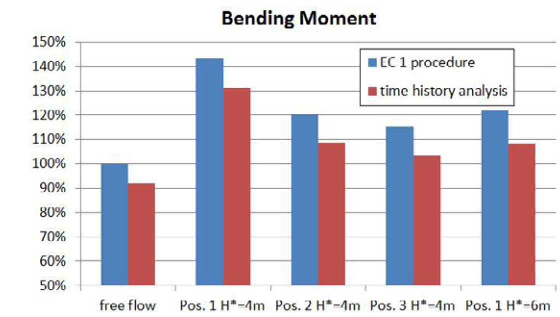

Figure 8: Comparison of maximum base bending moments.

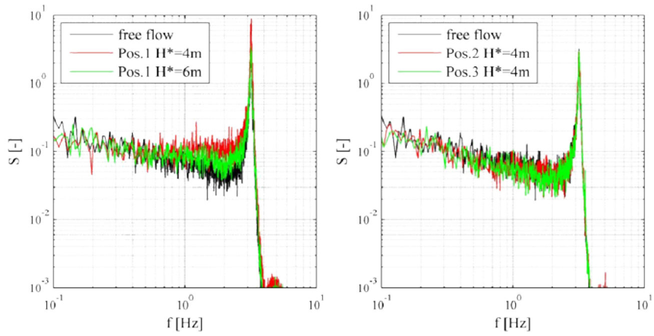

Figure 9: Normalized spectrum of base bending moment.

Conclusion and Outlook

The wind loading on roof-top antennas differs significantly from the assumption of a free stream flow acting on the structure. The loading on an antenna close to the roof might in-crease by up to 30% when it is placed in the center or at the windward side of a flat roof. However effect of the gust size on the structure is included in the results but based on the simple TVL-formula only. Therefore in the future, measurements with a high frequency force balance are planned to measure directly the wind loading on the antenna including the size effect. Variation of building size, roof shape, antenna size and position is also planned in the future to give valuable data for the design process.

References

1. Aldasoro HA, Clobes M (2011) Wind Structure and Gust Response of slender Chim-neys considering Interference Effects. CICIND-Technical Meeting, Edinburgh, Scotland 22-23.
2. (2010) EN 1991-1-4: Eurocode 1: Actions on structures – Part 1-4: General actions –Wind actions.
3. Solari G (1982) Alongwind Response Estimation: Closed Form Solution. J struct division 108: 226-244.
4. Solari G (1993) Gust Buffeting. I: Peak Wind Velocity and Equivalent Pressure. J Struct Eng 119: 365-382.
5. Solari G (1993) Gust Buffeting. II: Dynamic Alongwind Resonse. J Struct Eng 119: 383-398.
6. Lawson TV (1980) Wind effects on buildings – Applied Science Publishers Ltd. 1.
7. Dyrbye C, Hansen SO (1996) Wind Loads on Structures. John Wiley and Sons 229.
8. Davenport AG (1961) The application of statistical concepts to the wind loading of struc-tures. Paper 6480.