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WIND
ENGINEERING
FLUID
DYNAMICS

Stationskvarteret in Slakthusområdet, Stockholm, Sweden

Wind environment assessment

20.0032

June 16, 2020 - Revision 2

The purpose of the present memo, prepared for Atrium Ljungberg AB, is to assess the wind environment around the planned structure in Stationskvarteret in Slakthusområdet, Stockholm, Sweden.

The memo is based on information forwarded by Lundgaard & Tranberg Arkitekter in April and June 2020.

In a given focus area, the wind environment is assessed based on the wind conditions in the area as well as on the activities for which the area is intended. The perception of the wind environment in an area should if possible live up to the expectations of its users.

The contents of the memo and the illustrations are based on the experience of *Svend Ole Hansen ApS* from numerous previous wind environment assessments and on wind tunnel experiments with similar structures in which the wind environment was measured.

1 Background

A structure with mostly shopping at the ground level and offices in the levels above the ground is to be erected in the historic area of Stationskvarteret in Slakthusområdet, Stockholm, Sweden. The building is located on the land parcel *Sandhagen 2*. Its projected floor plan dimensions are approximately 83 m in length and 46 m in width. The terrain slopes by 1.7 m along the short side of the building so that its height from the ridges of the M-shaped roof to the street level is approximately 30.4 m to the level of *Rökerigatan* along the southwestern facade and 28.7 m to the level of *Arenavägen* along the northeastern facade.

A 3D illustration of the building at Sandhagen 2 and its immediate surroundings can be seen in Figure 1. Figure 2 shows an aerial photograph of the area.

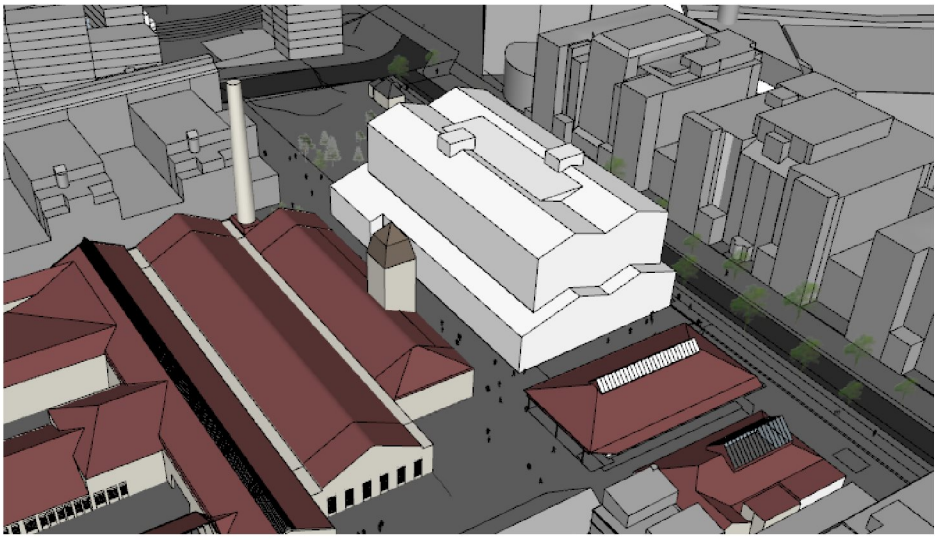

Figure 1. 3D model of the planned structure in Stationskvarteret in Slakthusområdet, Stockholm, Sweden seen from the south. The structure is shown with white surfaces.

The present assessment pertains to the wind environment at terrain level around the planned structure.

The effects of existing greenery and other local wind barriers are not taken into account in the assessment of the wind environment. Many of the recommendations in this memo may be fulfilled by applying local sheltering elements such as trees, shrubberies, and other types of greenery appropriately.

2 Overall wind conditions

The structure is to be built in an historic area south of the Stockholm city center. To the north and east, the area is surrounded by relatively densely positioned multistorey buildings. The density and height of the buildings in the area constitute surface roughness for the wind from these directions. This slows it down near the ground and leads to more turbulence. The increased turbulence may have a negative impact on the perceived wind environment in the area.

The areas to the south and west are mostly suburban, typically with somewhat smaller buildings and more vegetation. This may lead to slightly higher wind speeds from these directions. Combined with the fact that winds from these directions are the most frequent, this means that the area may be particularly exposed to southwesterly winds.

Figure 2 shows the terrain around the building at Sandhagen 2 along with a wind rose indicating the frequency of winds from different directions.

Figure 2. Aerial photo of the area with a blue rectangle indicating the location of the building at Sandhagen 2 and a wind rose for the Stockholm area indicating qualitatively that winds from southeasterly directions are the most frequent.

The wind conditions around a structure are created by the local atmospheric wind conditions as well as by the effects of the structure itself, of nearby structures, and of other objects in the area. These conditions are taken into consideration in the assessment of the wind environment.

3 General remarks on wind environments

This section concerns some overall issues of wind environments around structures and some of the measures that may be taken to handle these issues.

3.1 Wind flow around structures

The wind flow around a structure affects the wind environment at terrain level. When the wind encounters a structure, it will slow down. The pressure on the windward side of the structure will be higher than in the free wind field while the pressure on the other sides of the structure will be lower. This pressure gradient will lead to an air flow around the structure from the windward side to the leeward side. The flow is especially powerful along the sides of the structure and the air velocities will be high if the pressure difference from the windward to the leeward side of the structure is large.

The extent and layout of zones of turbulence and of zones sheltered from the wind is determined by the geometry and shape of the structure. Curved shapes or shapes with rounded corners lead to air flows with less turbulence but significantly higher velocities than sharp-edged structures. Strong turbulence can arise at corners on the windward side of a structure.

Wind corridor effects can arise if a group of structures are arranged so that the wind can freely move between the structures along a long, open corridor. As the wind is forced into these corridors, high wind velocities may arise. The wind speeds may be particularly high due to funnel effects at narrow points along the wind corridor where it is forced through a constricted cross section.

3.2 Wind barriers

Calm wind environments are crucial to the perceived quality of outdoor spaces such as balconies, terraces, rooftop gardens, gardens at terrain level, courtyards, and communal areas. Properly designed and arranged wind barriers of different types can provide lee and a pleasant and calm wind environment. In addition to increasing the perceived quality of outdoor spaces, such wind barriers extend the parts of the year in which they can be used.

Wind barriers of greenery such as shrubberies and trees are well-suited to providing lee due to their porous nature. The openings in between the branches and leaves of plants permit the wind to move through but slows it down diffusely. This reduces the occurrence of large vortices on the leeward side of the barrier. Evergreen plants are recommended for such purposes if the outdoor space is intended for usage in all seasons. Deciduous plants can be used if the outdoor space is primarily intended for usage in the summer, e.g., at outdoor seating spaces at restaurants or cafés. The time it takes for the greenery to attain sufficient size and density to provide lee should be taken into account. If plants are to be positioned on a constructed base — such as in a rooftop garden — the depth of soil available may limit the size of the greenery.

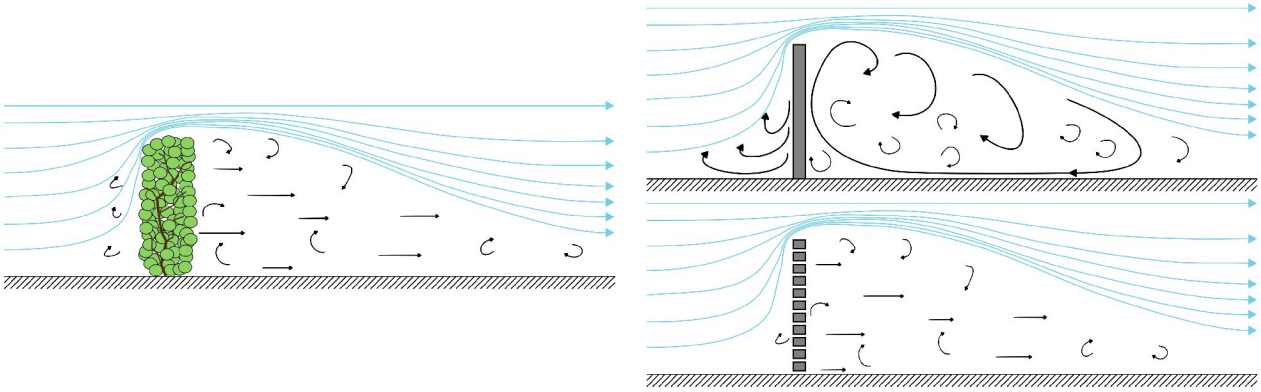

Figure 3. Wind barriers: Greenery (left) is well-suited to providing lee due to its permeability which reduces the creation of large vortices in its wind shadow. Impermeable wind screens (top right) may lead to strong turbulence in their wind shadow while openings in wind screens (bottom right) reduce this.

Impermeable wind barriers, such as glass screens, provide lee immediately behind the screens but they may lead to unpleasant turbulent vortices in their wind shadows. Making the screens permeable reduces the risk of such turbulence. The effect of a wind barrier thus depends on the degree to which the barrier is permeable. A permeability or opening ratio of 1/3 is usually the best choice. Optimally, the barrier should be more permeable at its top and less so further down.

The wind barriers should have adequate height to be effective. Usually, barriers intended to provide lee locally, i.e., to the area immediately behind them, should be as high as the zone within which the users are. Typically, this means that barriers should be 1.25 m high to provide lee for people sitting down and 1.75 m high to provide lee to people standing up.

3.3 Common solutions

Locally, around restaurant or café seating arrangements, wind barriers are likely to be necessary. These should be placed as close as possible to and around the seating arrangements and they should be designed in accordance with the guidance given above. Ideally, these wind barriers should enclose the service areas from all sides to prevent the wind from sweeping down to the ground within the areas, see Figure 4. The barriers may be movable, permitting the owners or users to place them as they see fit, and they should be designed in accordance with Section 3.2.

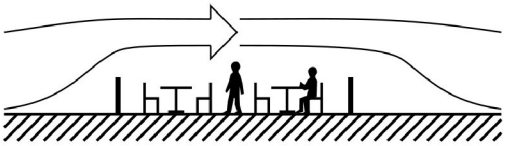

Figure 4. Wind barriers around seating arrangements.

It may also be necessary to prevent wind from sweeping down to ground level between buildings. This can be attained with canopies, trees, cantilevered roofs, or other objects that serve as a kind of horizontal wind barrier against the wind, see Figure 5.

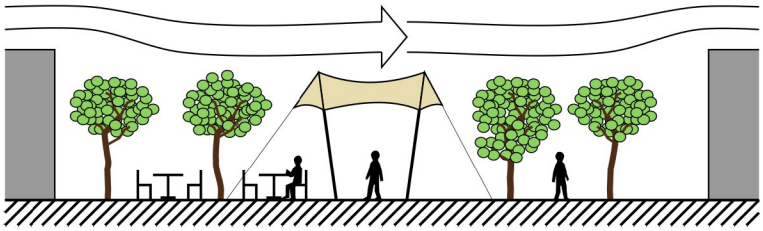

Figure 5. Objects such as trees or canopies create a canopy effect that may prevent the wind from sweeping down to the ground between buildings.

This approach yields a kind of *canopy effect* which may improve the wind environment greatly in open squares or in streets where the buildings are otherwise far enough apart to let the wind sweep down to ground level. As may be gauged from the figure, the effectiveness of this solution increases with the density of the obstacles presented to the wind — denser trees, less spacing between them, and relatively impermeable canopies.

4 Focus areas and levels of activity

The requirements for the wind environment is assessed in focus areas depending on their intended use and the activity level of their users. The strictest requirements apply to areas where the users expect to be able to stay for a long time without much physical activity and, conversely, the most lenient requirements apply to areas through which the users simply expect to pass. In Table 1, the classification system applied in this assessment is shown. This system includes four categories ranging from 1 to 4 with 1 being the category with the most lenient requirements and 4 being the category with the strictest requirements.

Table 1. Classification of areas leading to differentiated requirements based on user expectations. Category 4 leads to the strictest and category 1 leads to the most lenient requirements.

Category	Duration of stay	Activity level	Examples
1. Fast walking	Brief	High	Paths, roads, and other areas intended for transport, e.g., walking, jogging, cycling
2. Strolling	Brief	Medium	Paths and areas intended for leisurely walking such as in parks ans shopping streets
3. Standing	Brief	Low	Parks and squares.
4. Sitting	Long	Low	Outdoor sitting areas at restaurants, cafés and theaters.

Figure 6 shows an overview provided by Lundgaard & Tranberg Arkitekter of the focus areas in the area around the building at Sandhagen 2.

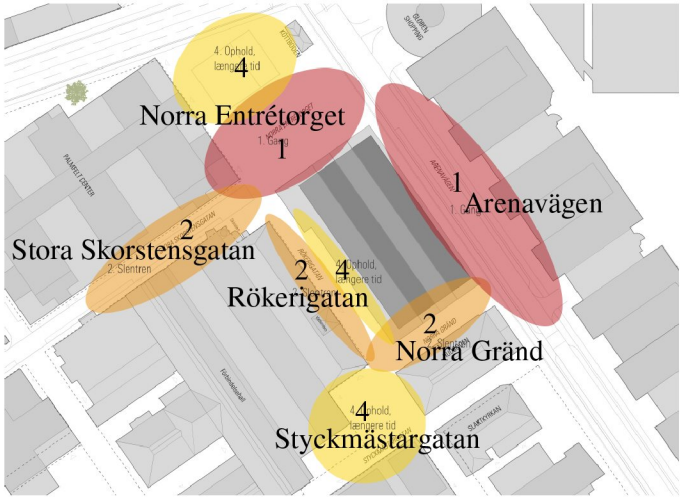

Figure 6. Focus areas around the building at Sandhagen 2 numbered and classified in accordance with Table 1. Figure obtained from Lundgaard & Tranberg Arkitekter.

The yellow zones in Figure 6 should allow for outdoor sitting areas of restaurants and cafés, while the orange zones should be comfortable to users strolling in the streets. Finally, the red zones are intended for traffic.

5 Wind environment in Stationskvarteret

The following subsection concerns the overall wind conditions in the area, and the following subsections then deal with individual areas around the building at Sandhagen 2 one by one.

5.1 Overall wind conditions

The density of buildings in the area is relatively high. This often means that it is possible to create good wind conditions at terrain level since the wind will tend to sweep over the area and not down between the buildings. The layout of the buildings in the area to the southwest is, however, rectilinear and regular with long, straight streets along two main directions. Generally speaking, this allows the wind to sweep along the terrain level along these streets and may lead to unfortunate wind corridor effects.

As shown in Figure 2, the area is dominated by southwesterly winds. Wind corridors that allow for winds — particularly from these directions — to sweep unhindered along an open surface may lead to frequently unpleasant wind conditions.

Figure 7. Plan of the area with added overall wind corridor effects.

As indicated in Figure 7, the area around the building at Sandhagen 2 lends itself to corridor effects particularly along the major roads of *Palmfeltsvägen* and *Arenavägen*. This is especially likely for southwesterly winds along Palmfeltsvägen which stretches from *Norra Entrétorget* in the northeast and relatively straight for about 500 m towards the suburban landscapes southwest of the area. Two other minor corridors may lead to unpleasant winds — along *Stora Skorstensgatan* and *Styckmästargatan* which also trace from the area around the building in a southwestern direction. These are, however, narrower and shorter than the corridor along Palmfeltsvägen and therefore less likely to be critical. The red zone in Figure 7 shows that part of Norra Entrétorget is exposed to winds from the southwest, leading to a risk of uncomfortable wind conditions. The open space in Norra Entrétorget will lead to reduced wind velocities from the wind corridor, but near building corners, wind conditions may still be uncomfortable due to the wind corridor.

The implications of the overall wind conditions outlined here will be assessed in the following subsections which deal the wind conditions area by area.

5.2 Norra Entrétorget

As shown in Figure 6, Norra Entrétorget is subdivided into two areas within which different activities are intended.

The southeastern half of the square is somewhat sheltered from the wind by the adjoining buildings. Additionally, the wind conditions in this half of the square are not subject to strict requirements, as it will mostly be used for pedestrian traffic. Its users will be content with occasionally relatively high winds as they are just passing through. The building layout here is expected to result in satisfactory wind conditions.

The northwestern half, however, is to be used for long stays with a low level of physical activity. This sets a high standard for the wind environment. This half of the square is also exposed to the south-eastern winds from Palmfeltsvägen. Even though the wind speeds will be reduced due to the wide spaces in the square itself, relatively strong winds from Palmfeltsvägen may lead to uncomfortable wind effects, especially near building corners. Additional measures therefore should be taken here to ensure a good wind environment. The wind conditions in the northwestern part of Norra Entrétorget are not strongly affected by the building at Sandhagen 2 at the southeastern end of the square but rather by the buildings immediately around it.

One way to improve the perceived quality of the wind environment at Nörre Entretorget could be to add trees along Palmfeltsvägen and Arenavägen. If deciduous, these trees would improve the wind environment in the square in the summer time. This is also expected to be the time of year in which users would use outdoor restaurant and café service areas. This, along with trees on the square itself, could to some extent lead to a kind of canopy effect, see Figure 5.

This improvement is, however, not expected to be sufficient in itself. Locally, around restaurant or café seating arrangements, wind barriers are likely to be necessary and may be designed as described in Section 3.3. The most important sides to shield from the wind are those facing the open areas in Palmfeltsvägen and Arenavägen.

If a structure is built on Norra Entrétorget, this may have either favorable or adverse effects on the wind environment in the square. Whether it will have one or the other depends largely on its general shape and location.

5.3 Styckmästargatan

This subsection pertains to the small square south of the building at Sandhagen 2 and labelled as *Styckmästargatan* in Figure 6. As shown in the figure, this zone should be suitable for stays of long duration and low physical activity.

The wind conditions in this area are largely unaffected by the building at Sandhagen 2. As indicated in Figure 7, winds may occasionally sweep along Styckmästargatan and lead to uncomfortable wind conditions. Most of the square is, however, sheltered by the buildings around it. Users tend to accept poor wind conditions in part of an area if they can move to a different part of the area to seek shelter from the wind. Due to the irregular shape of the square, it will usually be possible for the users to find shelter. This will of course not be the case if restaurants and cafés have fixed seating areas in windy zones.

If this is the case, the measures described in Section 3.3 may be applied — trees or canopies to

improve the overall wind environment in the square and local wind barriers such as greenery or wind screens around outdoor serving areas.

5.4 Stora Skorstensgatan and Norra Gränd

This subsection concerns the streets as *Stora Skorstensgatan* and *Norra Gränd* in Figure 6. As shown in the figure, this zone should be suitable for strolling or leisurely walking users.

The wind conditions in this area are largely unaffected by the building at Sandhagen 2. As indicated in Figure 7, winds may occasionally sweep along Stora Skorstensgatan and Styckmästargatan leading to uncomfortable wind conditions in these two areas. To prevent winds from sweeping down to ground level, it is therefore recommended to place trees along the streets if possible. This should have the effect that winds passing over the buildings in the area do not reach ground level where they may bother the users, see Figure 5.

5.5 Rökerigatan

This subsection treats the *Rökerigatan* in Figure 6. As shown in the figure, this zone should be suitable for strolling or leisurely walking users but it is also intended to be used for an outdoor café or restaurant service area. As mentioned above, it will usually be necessary to add local wind barriers around seating areas as shown in Figure 4. This is because of the high user expectations to such areas, and as such, this is also the recommendation for the seating arrangements in Rökerigatan.

The wind conditions may be uncomfortable near the southern corner of the building at Sandhagen 2. This is because wind flows speed up when forced around a building corner. Seating arrangements in Rökerigatan should therefore not be placed close to this corner.

Rökerigatan traces along a northwest-southeast axis, and as can be seen from Figure 2, winds along this axis are not predominant. For winds from other directions, the buildings on either side of the street are tall enough to provide lee at the ground level. With the exception of the areas near the building corners, winds are therefore unlikely to bother the users at ground level. As winds along the axis of the street are infrequent, it is not deemed necessary to add trees to the street. Adding them anyway may, however, still lead to a perceptible improvement of the wind environment in the street.

5.6 Arenavägen

As winds along Arenavägen are relatively infrequent, winds will rarely sweep down in this street. When these infrequent winds do occur, though, the street presents a corridor along which the wind may sweep and lead to uncomfortable wind conditions, see Figure 7. User expectations are, however, typically low in streets intended for traffic, so the area is expected to have a sufficiently comfortable wind environment. Adding trees would, however, still improve the wind environment perceptibly and would serve to improve the conditions on Norra Entrétorget.

6 Conclusion

The recommendations for the individual focus areas are discussed area by area. Greenery such as trees are recommended along most of the long, straight streets of Slakthusområdet. This serves to remedy some of the unfortunate effects of having networks of long, reectilinear streets. This is also a recommendable solution in squares and other open areas, where users are expected to stay for an extended period of time. Around restaurant service areas, it is generally recommended to erect local wind barriers to provide lee to the users.

Given that the recommendations in this memo are implemented, it is deemed that the wind environment around the structures will be satisfactory.

Copenhagen, June 16, 2020

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