New Urban Design Approaches with Snow Simulations for Cold and Snowy Cities

Tsuyoshi Setoguchi
Associate Professor, Graduate School of Engineering, University of Hokkaido, Japan

Abstract
An urban design which reduces snow problems is one of the most important approaches in heavy snow and cold climate cities. In this paper, the author evaluated the urban design for the new Wakkanai Station redevelopment project in Hokkaido, Japan. Wakkanai City is the northernmost city of Japan, and is located in a strong snowstorm area. Two types of station design, the Trapezoid type and the Curved-surface type were tested in snow simulations using a wind tunnel that belongs to the Hokkaido Northern Regional Building Research Institute.

Comparing the two types of Wakkanai Station redevelopment design, the Curved-surface design is better suited to alleviate the negative impact of snowdrifts on the pedestrian pathway. The formation of snowdrifts in the public areas will be less likely to occur due to obstructions, and there will be better access for passenger transfer and better approach for public transportation and private vehicles. But some provision for the shelter of pedestrians from strong wind should be included in the redevelopment plan.

The results of this simulation will be reflected in the station redevelopment planning and design of this project. This urban design study with snow simulations might provide the most progressive approach.

Keywords: Urban design; snow and cold cities; snow simulation; wind tunnel; station redevelopment

1. Introduction
An urban design which accounts for local climactic conditions is one of the most suitable approaches for every city. It is an important point to clarify how to apply urban design concepts to protect areas with a harsh winter climate in cities that are located in cold regions that experience heavy snowfall, like Hokkaido, Japan. Specifically, significant issues should be addressed concerning the environmental impact of snow and cold wind in public spaces in these cities. In addition, desirable urban designs that provide better environments in public spaces that protect against snow and cold wind in winter should be developed. The necessity has been felt for original approaches to urban design in such cities. An urban design which reduces snow problems (e.g. snowdrifts or blowing snow) is one method of promoting "symbiosis" between humans, snow and cold climate in those cities.

In this paper, the author targeted the redevelopment project of the new Wakkanai Station, in Hokkaido Japan. The actual project was started in 2003 and produced by the City of Wakkanai, as part of the Urban Revitalization Program in Japanese Local Cities. The author and Wakkanai City started the co-research project for a desirable design for the new Wakkanai Station with consideration given to the local climate in winter. The author focused on station designs for protecting pedestrians, vehicles and train operation against snow and wind. These days, a station should be designed to meet three fundamental requirements. The first is that a station serves as a communication point in the city; many people meet there even without riding trains, so this requires the design of community spaces both inside and outside of the station. The second concerns the provision of accessibility for pedestrians and passengers; they should be assured a safe approach to the station. The third involves insuring the safe operation of trains and vehicles; a station is a base of public transportation.

For the achievement of these requirements in the Wakkanai Station redevelopment, two types of station design were tested in snow simulations, a Trapezoid type and a Curved-surface type. The results of these simulations will be reflected in the station redevelopment planning and design of this project.

Many environmental assessments on building design have been conducted in Japan based on wind simulation tests alone, but there has been little published research on "urban design with both snow and wind" factors taken into account other than that by Yoshizaka et al. (1942) and this author, Setoguchi

*Contact Author: Tsuyoshi Setoguchi, Associate Professor, Graduate School of Engineering, University of Hokkaido North 13 West 8, Sapporo City, Hokkaido, 060-8628 Japan
Tel: +81-11-706-6242 Fax: +81-11-706-6242
E-mail: setoro@eng.hokudai.ac.jp
(Received April 6, 2007; accepted March 4, 2008)
(2003\textsuperscript{2}, 2004\textsuperscript{3}, 2006\textsuperscript{4}). Yoshizaka has indicated desirable low-rise building locations and directions with which to alleviate the effect of snow and wind in the mountainous rural area of the Tohoku region in Japan, where it snows heavily in winter.

Bosselmann (1984\textsuperscript{5}, 1989\textsuperscript{6}, 1998\textsuperscript{7}) produced useful studies for downtown Toronto in Canada, and showed that new developments with high-rise buildings cause environmental problems due to alterations in wind and sunlight patterns in the surrounding districts. He compared the environmental impact of high-rise and medium-rise buildings in wind simulation tests using a wind tunnel. These results showed that new developments with medium-rise buildings had a reduced negative environmental impact on their surrounding areas, and proved that such buildings are one of the more desirable urban design elements for downtown developments.

Tomabechi (2002\textsuperscript{8}) carried out a different kind of simulation; that of snow impact using a wind tunnel. His approach was to show desirable building locations regarding snow and wind in Hokkaido, Japan. The results of the simulation tests were useful, but their effectiveness was only applicable to building design, not to city planning or urban design.

To this author's knowledge, there have been few researches on the environmental impact of snow and wind on urban design using snow simulation tests utilizing a wind tunnel (Table 1.).

| Order | Name of Municipality | City, Town or Village | Frequency of Snowstorms (per day) |
|-------|----------------------|-----------------------|----------------------------------|
| 1     | Rebun                | Town                  | 51.7                             |
| 2     | Suttsu               | Town                  | 44.2                             |
| 3     | Matsumae             | Town                  | 42.5                             |
| 4     | Esashi               | Town                  | 42.5                             |
| 5     | Rumoi                | City                  | 42.5                             |
| 6     | Haboro               | Town                  | 37.9                             |
| 7     | Iwanai               | Town                  | 36.9                             |
| 8     | Wakkani              | City                  | 35.7                             |
| 9     | Rishiri              | Town                  | 35.5                             |
| 10    | Enbetsu              | Town                  | 34.2                             |

2. Methodology

2.1 Local Climate of Wakkani City in Winter

Hokkaido is located in the northern part of Japan, which is a cold and heavy snowfall region. There are many cities and towns which experience snowstorms in winter in Hokkaido. Cities in the cape area, including Wakkani City especially, experience strong snowstorms frequently. Table 2. shows the frequency of snowstorms for cities and towns in Hokkaido.

Wakkani City is hit by snowstorms frequently, and is second only to Rumoi City in terms of such frequent cities. On a typical day in winter its chance of experiencing a snowstorm is 35.7 times the national average, and so its citizens must cope with snowstorms almost every day. Although heavy snowfall and snowstorms are one of the most important issues concerning urban design, not enough consideration is given to this problem by planners. As Japan's northernmost city Wakkani City is definitely located in a strong snowstorm area.

2.2 Methodology

Table 1. References of Researches on Environmental Impact of Snow and Wind Using Wind Tunnel

| Simulation Type | Building design | Urban design |
|-----------------|-----------------|--------------|
| Using Only Wind | (Many researches)| Bosseleman | (1984, 1989, 1998) |
| Using Wind & Snow | Tomabechi (2002) | Yoshizaka (1942) | Setoguchi (2003\textsuperscript{3}, 2004\textsuperscript{4}, 2006\textsuperscript{5}) |

Fig. 1. shows snow data during the winter season in downtown Wakkani as observed by the Meteorological Agency from Dec. 2003 to Mar. 2004. In that year, snow cover began from the beginning of December and continued until the end of March of the following year. Thus, the ground was covered with snow for around four months in Wakkani. The depth of snow increased step by step from December and reached a peak of 89cm on February 28th.

As for the wind environment, according to the climate data of the Meteorological Agency covering...
the last five years from Dec. 1999 to Mar. 2004, there was strong wind with snow blown from the north (N) and west-southwest (WSW). Strong wind velocities mostly come from the north in Wakkanai City, so the strongest wind velocity from a northerly direction was adopted for the snow simulation tests (Fig.2.).

2.2 Wind Tunnel for Snow Simulation Tests

The snow simulation tests were carried out using the wind tunnel in the Hokkaido Northern Regional Building Research Institute. The wind tunnel test area is seven meters long, 150cm wide and 70cm high in the tunnel cross section

2

(Fig.3.).

The first step in the procedure is to assess the differences between the actual weather data and that of the snow simulation tests with models

2, and to try to modify the weather data for the simulations. Local wind conditions are quantified by testing scale models of the district in a boundary layer of the wind tunnel. The wind tunnel tests give a ratio between the wind speeds at the location where the weather data was recorded. A turbulence intensity, or gustiness, was recognized in the district, but these factors were also considered in changing wind velocities in the wind tunnel simulations during several trials. Increased turbulence is assumed to be equivalent to an increase in wind speed, using a relationship that has been found for the mechanical effects of wind (Fig.4.).

3. Assessment Points for the Planning Issues

3.1 Planning Issues regarding the new Wakkanai Station renewal project (Fig.5.)

For planning regarding the new Wakkanai Station, the following three issues were addressed. They were pointed out as urban design issues before the snow simulation tests. The new Wakkanai Station Complex was planned for the site as seen in Figs. 6. and 7. The height of the building was 12.5 meters (42mm in the model).

A1) Planning for an urban axis with a desirable pedestrian mall for the connection of the downtown and port area

The downtown area and port area are divided by the JR railway line, and Wakkanai Station is located between them. Since a downtown revitalization program has been started in the downtown area and waterfront parks are planned in the port area in the next decade, an urban axis with a pedestrian mall connecting them is an important requirement in the station redevelopment plan.

B1) Easy transfer access between the station and buses, taxis and vehicles

For easy transfer access from JR Wakkanai railway station to buses, taxis and private vehicles, no barrier (e.g. snowdrifts) should be located between them even in winter. The JR station, public bus stops, taxi bays and the requirements of private
vehicular traffic should be integrated with the station square to allow for smooth transfer among them.

C1) Better train operation in Wakkanai Station
For better operation of trains approaching the station, no barrier (e.g. snowdrift) should be located in the railway area.

3.2 Assessment Items regarding the Snow Simulations (Fig.5)
For the implementation of these planning objectives even in winter, the following three assessment items were addressed regarding each issue. These assessment items were verified in snow simulation tests using the wind tunnel. Basically, these items were based on the concept of reducing impingement upon pedestrian activity, public transportation and train operation caused by winter snowdrifts in the redevelopment of Wakkanai Station.

A2) No snowdrifts should be permitted on the pedestrian mall of the urban axis connecting the downtown and port area. Various activities will be performed on the pedestrian mall, such as transfer among the various forms of public transportation, passage from downtown to the port area, and entrance to the station building. Even in winter, snowdrifts should not be obstacles to the pedestrian network.

B2) To allow easy transfer access, no snowdrifts should be permitted at the connection points between the station and the square. And easy removal of snow should be required in the station square in winter. Enormous piles of snow should not be left in the square because they would interfere with vehicular and pedestrian traffic. Snow storage space should also be required in the square.

C2) No big snowdrifts should be permitted in the railway area of the station. Since the railway line into Wakkanai Station ends there, much snow will tend to pile up in this area and it will be hard to remove it. For better train operation, big snowdrifts should not be allowed to occur in the railway area and it should be free from the need for snow removal.

3.3 The Ideas of the Station Design
The author focused on distinguishing the impact of snow and wind depending on the building design between the Trapezoidal station type and the Curved-surface station type. The two general site plans are shown in Figs. 6. and 7.

The idea of the Trapezoidal type was that the prevailing strong wind would be induced to turn away to the west side of the station area by the trapezoidal shape of the north side elevation. It would be assumed to protect pedestrian activities and moving vehicles from snowdrifts, while to protect passenger’s activities from strong snowstorms; a small shelter was designed for the front side of the station.

The Curved-surface type was also based on similar ideas for the protection of pedestrians and vehicles from snowstorms. This shape assumed that the prevailing wind would turn away not only to the west side, but also upward on the station building as well. Much of the wind would turn upward when it hit the curved surface, because the wall was sloped at 45 degrees to the ground. It is also assumed that the wind would turn back to the station square and away to the west side in the same manner as with the Trapezoidal type. The Curved-surface type also provided the same small shelter for passengers.
4. Results of the Snow Simulation Tests

In the findings of the snow simulation tests with snow and wind, several snow problems were observed with both of the station building designs.

4.1 Trapezoid station type (Fig.8.)

a) Big snowdrifts were spread to the pedestrian mall (see point A). Pedestrians crossing from the downtown to the port area will encounter snowdrift barriers. Walking on the pedestrian mall in winter will be difficult and it will be hard to remove the snow in the mall.

b) Big snowdrifts were formed around the bus stops (see point B). The snowdrifts were caused by the façade of the station building. Strong wind with heavy snow was turned back by the surface of the building wall, resulting in a reduction in wind speed, which caused the snowdrifts. In addition, piled up snowdrifts were formed around the bus stops, which were located at wind speed reduction points. Passengers accessing the bus stops will encounter snowdrifts when they attempt to board a bus. The snowdrifts around the bus stops will negatively impact both passengers and pedestrians. The buses will also experience some operational difficulties due to the snowdrifts. Frequent snow removal will be required around the bus stop area, and this will detract from the effort to remove snow for maintenance of the station square.

c) Big snowdrifts were formed in the railway area and on the station platform (see point C). They measured 9.7mm in the model and this will result in 291cm of piled up snow in the railway area. It will be difficult to remove the snow there. This big snowdrift is thought to have been caused by the merging of strong winds through the narrow area of the east side and beyond, upward of the station. These snowdrifts in the railway area will have to be removed to the parking area for better train operation.

4.2 Curved-surface station type (Fig.9.)

a) No snowdrift was observed on the pedestrian mall, unlike what occurred with the Trapezoid type (see point D). A very little snow-like dust did remain on the mall, but not enough to be an impediment to pedestrians. The pedestrian pathway should allow for easy connection from the downtown area to the port area, and easy access from the station building to the bus stops, without intervening snowdrifts. But it does appear that the wind velocity on the pedestrian mall may be stronger than that as will occur with the Trapezoid type, and a strong prevailing wind may blow into the street and the station square. A shelter for protection from this strong wind is required in the designs for the pedestrian pathway.

b) No snowdrifts were formed around the bus stops and taxi bays (see point E). However, snowdrifts were observed a little further out on the north side of the station when compared with those of the Trapezoid type.

The snowdrifts in the station square were caused by the backlash of snow and wind from the wall surface of the station building. This means that more backlash wind from the building wall will be flooded out to the square. Thus, in the case of snowdrifts being formed on the pedestrian mall and bus stop area, strong wind and snowstorm may occur there instead.

Compared to the trapezoid type, the snowdrifts are reduced and stronger wind is anticipated on the pedestrian mall. Which is worse, the snowdrift or the strong wind? The author predicts that snow removal on the pedestrian pathway will require more effort than for the protection of pedestrians from strong wind and snowstorm. This is because, while pedestrians and passengers may desire to go inside the station building or the shelter to protect themselves from strong winds, they will not need to wait for buses outside, as this is the first bus stop on the bus route.

Pedestrians and passengers might desire to go inside the station building or the shelter to protect themselves from strong winds and snowstorms. Passengers will not need to wait for buses outside because this is the first bus stop on the bus route.
Fig. 8. Snow Simulation Results of the Trapezoid Station Type

Fig. 9. Snow Simulation Results of the Curved-surface Station Type
c) An enormous snowdrift was observed in the railway area with the Curved-surface station type (see point F). It measured 7.1 mm in the model, which will result in 213 cm of piled up snow in reality. It might be difficult to remove the snow there. At times the operation of trains may be impeded by this snowdrift. Therefore, it must be practicable to move this snow from the railway area to the parking area behind the station building. It is also assumed that a strong wind will flow out to the parking area and that snowdrifts will also pile up there. But this should not create a big problem because removing snowdrifts from the parking area will be relatively easy. Thus, the author should have a design strategy leading to the snowdrifts being formed in the parking area, not in the railway area. Therefore, the building design for this area should be reconsidered based on this analysis.

5. Conclusions and Further Study

Comparing the two types of station design in the new Wakkanai Station development plan, the Curved-surface station design is better suited to alleviating the negative impact of snowdrifts on pedestrians and passengers. The formation of snowdrifts in the public area and station square will be less likely to occur due to obstructions, and there will be better access for passenger transfer and better approach for public transportation and private vehicles. But some provision for the shelter of pedestrians from strong wind should be included in the redevelopment plan.

Regarding the other negative impacts of snow in the observation on the railway area, the results were similar for both station designs. Both station designs provided evidence that big snowdrifts will be formed in the railway area of the train approaches and on the platform.

The design of the station should be reconsidered in order to lessen the negative impact of snow in the railway area to insure better train operation, as well as to ease the task of snow removal. Snowdrifts should be induced to form in the parking area behind the building, because they can be removed more easily in this area through the use of heavy equipment, which greatly reduces the amount of necessary manual labor.

The finding that the covered walk and shelters caused snowdrifts to form around them was of great significance. Snowdrifts caused by the covered walk would be impediments to pedestrian and public transportation during winter. It is supposed that the covered walk reduced wind speed, which aided in the formation of snowdrifts alongside it. Thus, the covered walk must be designed with careful attention paid to its site plan and section plan.

This snow simulation research was performed only midway through the entire proscribed design wind tunnel test simulation process of the Wakkanai Station redevelopment project. These snow simulations tested only two types of station design, so more variable station designs (e.g. form and height design) should be tested using the same snow simulations. The results of this paper are based solely on the wind tunnel tests, which is only one of the criteria on which such planning is based; therefore further testing should proceed under actual climatic conditions.

Notes

*1 The wind tunnel for snow simulation is one of the biggest in Japan.
*2 The snow model used white soil powder that has 8.5% moisture content and an average diameter of 20 µm. This indicates a very dry and small particle powder. The piles of powder on the models indicate snow cover. They were measured by a laser beam manufactured by Keyence LK 2500.

References

1) YOSHIZAKA, T. (1942) Model Study on the Snow Stock Environments Surrounding Buildings. Snow and Ice.
2) SETOGUCHI, T. (2003) A Study on Efficiencies for Reducing Snow Damages on Infill Developments in the Downtown Area, The Proceedings of the International Symposium on City Planning.
3) SETOGUCHI, T. (2004) Efficiencies of Infill Developments against Snow Problems in Winter Cities - The Snow Simulations for Desirable Block Designs Using Wind Tunnel -, Journal of Asian Architecture and Building Engineering, pp. 335-340.
4) SETOGUCHI, T., TSUTSUMI, T. (2006) Urban Design Guidelines for the Urban Complex Redevelopment Project Provided from Environmental Assessments with Snow and Wind Simulations – The New Urban Design Approaches with Snow and Wind Environmental Assessments for Snow and Cold Regions -, Journal of Architecture and Planning, pp.131-138.
5) BOSELLEMMANN, P. and ARENS, E. (1989) WIND, SUN AND TEMPERATURE - PREDICTING THE THERMAL COMFORT OF PEOPLE IN OUTDOOR SPACES. Building and Environment, Vol. 24, No. 4, pp.315-320.
6) BOSELLEMMANN, P. (1998) DOWNTOWN TORONTO URBAN FORM AND CLIMATE, Representation of Places - Reality and Realism in City Design. – University of California Press.
7) BOSELLEMMANN, P. (1998) INFLUENCE OF SNOW AROUND BUILDINGS ON EVACUATION ACTIVITIES, Journal of Architecture, Planning and Environmental Engineering, No. 560, pp.167-172, 2002.10.