Efficiencies of Infill Developments against Snow Problem in Winter Cities
- The Snow Simulations for Desirable Block Designs Using Wind Tunnel -

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Abstract
It is important to clarify how to apply urban design principles to protect areas within winter climates. Therefore, a question is addressed that do the blocks after infill developments provide desirable environment against snow, or not. The purpose of this paper is to answer this question and clear to understand the desirable block images for reducing snow problems (snowdrifts and snow blow) on its surrounding public spaces on infill developments in Winter Cities. Author studied the differences of the snow problems between “before” and “after” the infill developments consisted of medium-rise buildings in Downtown Sapporo on snow simulation tests using wind tunnel.

On this snow simulation tests, snow problems in the blocks and streets were improved after the infill developments. One of the main reasons of the observations is considered that the little variation of the building heights reduces snow problems on the public spaces in the blocks. For making the desirable spatial images in Winter Cities, the blocks have to be consisted of medium-rise buildings and unified the heights of buildings. The infill developments with medium-rise buildings with unifying building heights are effective against snow problems in downtown area, and making the desirable special block design for Winter Cities.

Keywords: winter cities; snow simulation; infill developments; block design; Sapporo City

1. Introduction
In Japan, there are various regions from Hokkaido to Okinawa, but urban design approaches in each region are similar to each other. For example, encouraging the design of open spaces is considered one of the better urban design approaches throughout Japan, but in Hokkaido, designing open spaces is not always good, because of the problem of snow-pileup in the open spaces. Fundamentally, design approaches for urban design should take into account regional climates, and unique approaches and theories for urban design have to be conceived in each region. Especially in Hokkaido, it is very cold and there is much snow in winter, making it a very different climate from the main island of Japan.

In “Winter Cities” which are located in heavy snow and cold regions like Hokkaido, it is important to clarify how to apply urban design principles to protect areas within winter climate. Specifically, considerable issues should be addressed concerning the environmental impact of snow and wind on public spaces, in addition to developing desirable urban designs for providing better environments in public spaces that protect against snow and wind in winter. In considering these issues, we have to study urban block designs for reducing the effects of snow and wind on public spaces, because urban blocks are the most important units for studying the relationship between public spaces and urban designs. The need has been felt for original approaches to urban design in Winter Cities. The urban design for reducing snow problems (e.g. snowdrifts or blowing snow) is one method of “symbioses” between humans, snow and cold climate in Winter Cities.

In Downtown Sapporo, in resent years, many redevelopment projects have been carried out under decreasing land prices. Most of these new redevelopment projects have been done on infill developments that medium-rise buildings are developed on vacant lands or rebuilt from low-rise wooden buildings. In several years, many infill developments will be carried out in Downtown Sapporo.

Therefore, a question is addressed that do the blocks after infill developments provide desirable environment against snow, or not. The purpose of this paper is to answer this question and clear to understand the desirable block images for reducing snow problems on its surrounding public spaces on infill developments in Winter Cities. Author studied the differences of the snow problems between “before” and “after” the infill developments consisted of medium-rise buildings in Downtown Sapporo on snow simulation tests using wind tunnel.

The author targeted for this study Downtown Sapporo,
the northernmost big city in Japan and one of the biggest Winter Cities in the world. Basically, Downtown Sapporo consists of original block patterns named “Shokumin-Kukaku,” which were developed in the Meiji era. Most of block units are unified, but there are various spatial shapes on the blocks, and there are no forward-looking goals concerning spatial shapes of them. Some of them are made up of confused and mixed special shapes, i.e. the blocks consist of high-rise, low-rise buildings and vacant lands.

There are many studies concerned with environmental assessment for urban design with only wind simulation tests, but there has been no published research of environmental assessment with snow and wind in Japan except for Yoshizaka et al (1942). They showed desirable low-rise building locations and directions against snow and wind in mountain rural area of the Tohoku region in Japan, where it snows heavily in winter.

Bosselmann (1984, 1989, 1998) produced useful studies of Downtown San Francisco in U.S. and in Downtown Toronto in Canada, and showed that new developments with high-rise buildings cause environmental problems due to wind and sunlight the surrounding areas. He compared the environmental impacts of high-rise and medium-rise buildings with wind simulation tests using a wind tunnel. These results showed that new developments with medium-rise buildings reduced the environmental negative impact on their surrounding areas, and proved that medium-rise buildings were one of the more desirable urban designs in downtown area. In San Francisco, environment impact evaluations on new developments are required by ordinance and its results must be considered in a public hearing by the city planning committee. Wind simulation tests studying environmental impact provide useful data and influence to the public hearing.

Tomabechi (2002) used a different simulation of snow impact using a wind tunnel. His approach is to be showed desirable building locations regarding snow and wind in Hokkaido, Japan. The results of the simulation tests were useful, but the effectiveness of those results was only applicable for building design, not for city planning and urban design.

To the author’s knowledge, there is little research on the environmental influences of snow and wind for urban design with snow simulation tests using wind tunnels (see table 1).

Table 1. References of Researches for Environmental Impacts with Snow or Wind Using Wind Tunnel

| Simulation          | Building design | Urban design          |
|---------------------|-----------------|-----------------------|
| Using Only Wind     | (Many researches) | Bosselmann (1984) et al. |
| Using Wind & Snow   | Tomabechi (2002) | This paper / Yoshizaka (1942) |

2. Targeted Study Area for Snow Simulation Tests

Downtown Sapporo was started to develop for commercial and residential districts by Hokkaido Development Agency in 134 years ago (Meiji era). The blocks of the study area measure 60 Kens by 60 Kens (approx 108m by 108m, 1 Ken = approx 180 cm). A block was divided two small blocks by an alley with 11m widths located in center of the block. One small block measures 60 Kens (approx 108m) by 27 Kens (approx 49m).

![Fig. 1. Location of Hokkaido and Sapporo City](image)

![Fig. 2. The standard block and parcel sizes in Downtown Sapporo](image)
The small blocks were divided into small parcels for commercial land use. Basically, a small block was divided into six parcels equally along a long side of the small block; one parcel area measured 18m by 49m (Figure 2). Some of these parcels were divided into two or four parcels again, measured 18m by 24m or 9m by 24m. At present, many old wooden buildings and vacant lands have been remained on these parcels. Some of these wooden buildings were rebuilt, or some of these vacant lands were developed.

As concerned with city planning regulations of this district, land use is for commercial area and Floor Area Ratio is permitted up to 800%. In this district, many offices, commercial areas within medium-rise buildings around from 8 to 10 stories are located.

3. Methodology

3.1 Wind Tunnel for Snow Simulation Tests

The snow simulation tests were carried out using the wind tunnel in Center for Environmental Design Research (CEDR) of University of California Berkeley. The wind tunnel has following dimensions: 64 feet (19m 51cm) overall and 49 feet (14m 94cm) length of tunnel working section, 7 feet (213cm) width and 5 feet (152cm) height of tunnel cross section. The fan that has 66-inch (168cm) wheel exhausting vertically is located under the lee and provides wind in the tunnel. The simulation test area is 12 feet long, and has a 12 by 17 by 10 feet (366cm by 518cm by 305 cm) operating room and the tunnel may be operated closed or as an open side jet (figure 3).

The first step in the procedure is to assess the differences between the weather data and that on the snow simulation tests with models, and make changes the weather data to make it represent the studies. Local wind conditions are quantified by testing scale models of the district in a boundary layer wind tunnel. The wind tunnel tests give, for each wind direction, a ratio between the wind speeds at the location where the weather data was recorded. The turbulence intensity or gustiness was recognized in the district, but these factors were also considered in changing wind velocities on the wind tunnel simulations in the several trials. Increased turbulence is assumed to be equivalent to an increase in wind speed, using a relationship that has been found for mechanical effects of wind (See reference 2).

3.2 Models for Snow Simulation Tests

For the snow simulation tests, targeted nine block models of Tanuki-kouji district were made of Styrofoam in scale of 1 to 300. The lengths of the district are 336m (in the north-south direction) by 406m (in the east-west direction) therefore the district models of nine blocks measured 1120mm long by 1353mm wide for the snow simulation tests.

Snow models were made of very small firing styrene beads with 1mm or less diameter. These beads were spread on all area of no building spaces of the models before the snow simulation tests. These beads were piled on around three layers and the beads covered the entire ground models, and ground surface of the models could not be seen. As for materials of the ground models, there was no friction between the beads and the models.

On the snow simulation tests, author assumed snow blow and snowdrifts area on the ground as well as blown beads and drifted beads area on the model. All beads blow area was assumed all snow blow area, and the beads remained only one layer (as seen as possible) for partial snow blow area, for realizing the differences of snow blowing level. More drifted beads area was assumed snowdrift area. These models for snow simulations were only useful for realizing the distinguish the negative impacts of snow between infill or no infill developments in the blocks.

3.3 Local Climate in Downtown Sapporo in Winter

Figure 4 shows the snow data during a winter season in Downtown Sapporo observed by the Meteorological Agency in 1999. The author adopted this climate record because it recorded the deepest snow in last five years. In this year, snowfall began on November 16th and it continued until 10th April; land was covered with snow for five months in Sapporo City. Depth of snow increased step by step from December, and its peak was 142cm on 25th February. The days covered with snow over 90cm depth were 31 days from February to March.
Figure 5 shows the wind directions (16 directions) and velocity data on snowfall days during the winter season from November 16th to April 10th. It shows strong wind with snow blown from between north and west-southwest and from south-southeast (SSE), the strongest wind velocity was 9m per second from the northwest (NW), and 10m per second from SSE, and average wind speed from each direction was 3.1m per second from NW, and 2.5m per second from SSE. Having strong wind velocities from NW and SSE in Downtown Sapporo. The strongest wind velocity from SSE direction was adopted in the snow simulations.

3.4 Criteria of Infill Developments on the Blocks for the Snow Simulations

Many infill buildings have been developed on the blocks in the targeted district. The scales of these infill developments depend on the parcel scales divided from a block as showed in chapter 2. The question then arises which is better spatial block image between “before” and “after” the infill developments against snow problems. Do the infill developments reduce the snow problems? To answer these questions and for approaching the desirable spatial block images, the snow simulation tests were carried out.
Author assessed the snow problems for two blocks on the infill developments in Downtown Sapporo using wind tunnel simulation tests. The infill developments were under following conditions.

New infill type buildings were developed on the vacant sites or rebuilt from the wooden buildings one or two stories in the blocks. Heights of the buildings were eight stories in front of streets and five stories inside of blocks, because of maximum FAR and city zoning regulations. All buildings more than two stories were remained on its sites. On impossible development sites as too small area for reconstructing to eight or five stories buildings, they were remained. Differences of between “before” and “after” infill developments are shown on figure 6.

Fig. 7. Snow problems BEFORE and AFTER infill developments with SSE wind *3
4. Results of the Snow Simulation Tests

On the snow simulation tests with SSE direction wind, the snow problems were reduced after the infill developments. Author pointed out effects of infill developments against snow as follows (see figure 7).

1) Buildings on the vacant sites as infill developments stopped snowdrifts and snow blow on the sites (point A).

2) Even if in front of the high and big bulk building, snow problems were reduced. Because the heights of surrounding buildings of the high building were almost unified, the air turbulence was reduced after the infill developments (point B).

3) On the void spaces among the buildings, the snow problems were also reduced, because some buildings were rebuilt as infill developments on the block (point C).

4) Snow did not blow so much on the streets, and the snow problems on the street were improved (point D).

Effects of the infill developments on the vacant sites were clearly; the snow problems were reduced.

5. Conclusions and Further Study

On this snow simulation tests with wind tunnel, snow problems (snowdrifts and snow blow) in the blocks and streets are improved after the infill developments. One of the main reasons of the observations is considered that the little differences of the building heights reduces snow problems on the public spaces in the blocks. It seems the infill developments on those vacant lands with similar building height in the same block will be effective against snow problems. For making the desirable spatial images in Winter Cities, the blocks have to be consisted of medium-rise buildings and unified the heights of buildings. The infill developments with medium-rise buildings with unifying building heights are effective against snow problems in downtown area, and making the desirable special block design for Winter Cities. Making the desirable public spaces with reducing snow problems provides better human activities for the pedestrians in the blocks, and produces one of the achievements for revitalization of downtown area.

There are, however, some remaining issues concerned with this study:

1) In this research, only two development models were adopted for snow simulation tests; various development models have to be researched with the

snow simulation tests.

2) These conclusions were arrived at with only the snow simulation tests using wind tunnels; out-door real observations for researching snow problems in public areas and streets are required for comparing to these snow simulation tests.

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Notes

1) Since the purpose of this paper is to clarify assessments of negative impact of snow on infill developments, the testing wind speed was required to that distinguishes clearly between the infill and no infill developments.

2) The depth of snow with 90 cm corresponds to three layers of snow model beads on the snow simulation tests.

3) All piled beads that were snow models were blown means snow blow all area, blown beads partially means area of snow blow partially, drifted beads means snowdrifts area.

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