Study on the Securement of Smooth Traffic Flow on Roundabouts in Cold, Snowy Regions

By
Mr. Tetsuya Ogami, Researcher, CERI, PWRI, Japan
Mr. Masatoshi Makino, Senior Researcher, CERI, PWRI, Japan
Mr. Masahiro Ishikawa, Researcher, CERI, PWRI, Japan
Mr. Yuji Yanagisawa, Team Leader, CERI, PWRI, Japan

1. Introduction
Roundabouts have been actively introduced in many countries due to the higher levels of safety, traffic flow and economic efficiency they offer compared to general intersections. Japan is no exception to this trend. Guideline development and other steps are being taken in an effort to introduce roundabouts. In addition, demonstration data on test roads are being collected. However, the introduction of roundabouts in Japan has so far been limited, and methods for roundabout winter management have not yet been developed.

In this context, the authors examined an efficient snow removal method for roundabouts by performing a wide range of tests on a simulated roundabout with the aim of enhancing road transportation safety in winter.

2. Cold, snowy regions in Japan
Approximately 60% of Japan’s land area is made up of cold, snowy regions, in which as many as 28 million people live. This is a situation found in few other places worldwide. The city of Sapporo in Hokkaido (Japan’s northernmost island) is the only urban area in the world that has a population of over one million combined with annual snowfall totaling as much as five meters.

3. Study principles
① For efficient snow removal at roundabouts
Vehicular swept paths for different types of snowplow were measured to investigate their suitability for a roundabout and allow the proposal of a snowplow selection method.

② For enhancement of roundabout safety in winter
Changes in actual visibility and driver influence resulting from different snow pile locations and heights were surveyed to allow the proposal of appropriate snow locations and heights.
4. Vehicular swept path test

A vehicular swept path test was conducted to determine the effectiveness of each type of snowplow in removing snow (traveling) at roundabouts.

In the test, snowplows were driven on a simulated full-scale roundabout to obtain RTK-GNSS measurement data. For measurement, a fixed station was set up at the test track and mobile stations were mounted on top of the test vehicles. Based on the measurement results, vehicle locations and travel directions were ascertained. Continuous vehicular swept paths and the positions of the four corners of the traveling vehicles were also surveyed by superimposing them onto pre-registered map data (using road configurations and vehicular external dimensions).

4.1 Test conditions

- Test vehicles: snow-removing truck, snow-removing motor grader, snow-removing wheel-type loader
- Travel patterns: loop, right turn, straight line, left turn
- Travel speed: speed expected in snow removal operations, minimum speed
- Measurement and analysis interval: 1 sec.

4.2 Test results

<table>
<thead>
<tr>
<th>Snowplow/Features</th>
<th>Schematic diagram of the test snowplows</th>
</tr>
</thead>
</table>
| Snow-removing truck (10-ton class) | Superior mobility and comfort
| Snow-removing motor grader (4.0-m class) | Superior workability and ability to remove compacted snow
| Snow-removing wheel-type loader (13-ton class) | Superior maneuverability

Features of typical snowplows

<table>
<thead>
<tr>
<th>Snowplow/Features</th>
<th>Schematic diagram of the test snowplows</th>
</tr>
</thead>
</table>
| Snow-removing truck (10-ton class) | Superior mobility and comfort
| Snow-removing motor grader (4.0-m class) | Superior workability and ability to remove compacted snow
| Snow-removing wheel-type loader (13-ton class) | Superior maneuverability

Installation of GNSS instruments

Example: snow-removing wheel-type loader

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Vehicle passage point (In m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front tips</td>
<td>Rear tips</td>
</tr>
<tr>
<td>Front left-side</td>
<td>Rear left-side</td>
</tr>
<tr>
<td>A</td>
<td>4.84</td>
</tr>
<tr>
<td>B</td>
<td>4.79</td>
</tr>
<tr>
<td>C</td>
<td>4.81</td>
</tr>
<tr>
<td>D</td>
<td>4.80</td>
</tr>
</tbody>
</table>

5. Proposal of a snowplow selection method

- The vehicular swept path test revealed that the snow-removing wheel-type loader was capable of traveling along the edge of the central island and the outer circumference of the circulatory roadway, which the snow-removing truck and snow-removing motor grader could not do. Accordingly, the snow-removing wheel-type loader was deemed to be best suited for the simulated roundabout (circulatory roadway outer diameter: 26 m; central island diameter: 8 m).
- On roundabouts with larger central island diameters, snow-removing trucks and snow-removing motor graders, which have better mobility and workability than snow-removing wheel-type loaders, can be used.
- It is also necessary to adequately consider the conditions of roundabout approach roads and the types of snowplows already positioned there.

The snowplow types to be used must be selected in consideration of field conditions in addition to the results of vehicular swept path testing.
6. Visibility confirmation test
A test concerning the visibility of drivers and pedestrians at a roundabout in snowy conditions was conducted. In the test, simulated snow piles and objects (moving vehicles and pedestrians) were positioned at the simulated roundabout, and pictures were taken from the eye heights of drivers and pedestrians using digital cameras to show how they saw each other. By comparing images with varying shooting conditions (objects, snow heights, etc.), changes in visibility were determined. The number of pixels in the visible area of the objects was also counted for quantitative assessment of the visible area.

6.1 Test conditions
- Objects: passenger cars, snow-removing motor graders, pedestrians (dummies)
- Simulated snow piles: at 7 locations (central island and entrance/exit)
- Simulated snow pile height: 0 m, 1.2 m, 1.5 m
- Camera: digital single-lens reflex (with fixed 50 mm lens)

6.2 Test results
- The results of the visibility test confirmed that actual visibility for a snow height of 1.5 m differed significantly from that for a height of 1.2 m.
- As a specific example, a survey was carried out in which a car was located at “Position C” on the circulatory roadway and a pedestrian was located at “Position b” on the sidewalk to allow examination of vision from each point. The results for a snow height of 1.5 m showed that only the head of the pedestrian (approx. 4% of the total body area) was visible from the car, and only the top of the vehicle (approx. 19% of its total area) was visible from the pedestrian’s point of view. In contrast, when the snow was 1.2 m high, the entire vehicle (100%) was visible, and the pedestrian was visible from the chest up (approx. 21%).
- The lower part of objects used in these tests (dummies and vehicles) tended to have a larger visible area. In some cases, it increased more than fivefold when the snow height decreased from 1.5 m to 1.2 m, quantitatively confirming that differences in visibility exceed differences in snow height.

7. Subjective assessment test
A subjective assessment test was conducted to determine the degree of hindrance caused by each snow pile to driving performance. In the test, 17 subjects drove on the simulated roundabout where simulated snow piles were positioned, and assessment was made using a questionnaire (with answers indicated on a scale of 1 to 7). The snow piles were simulated by attaching white netting to survey poles.

7.1 Test conditions
- Simulated snow piles: at 7 locations (two different profiles for Traffic Island A)
- Simulated snow pile heights: 1.2 m and 1.5 m
- No. of snow piles evaluated: 16
- Test vehicle: passenger car (Toyota Cardina)
- Travel route: Entrance → Circulatory roadway (loop) → Exit
7.2 Test results
The results of the questionnaire answered on a scale of one to seven were standardized for each subject to give standard values in order to facilitate comparison for each snow pile. A subjective assessment score for each pile was found by averaging all the subjects’ standard values. In this case, higher scores mean a greater hindrance to driving performance.

- Standard value (a) = (Individual assessment score – Average score) / Standard deviation
- Subjective assessment score = \( \frac{1}{n} \sum_{j=1}^{n} a_j \)

※Focus of attention : Pedestrians > Traveling vehicles
※Snow height : 1.5 m > 1.2 m
※Snow location vs. snow height : Location > Height
※Comparison of snow profile : influenced by the range of vision

8. Proposal for snow pile locations and heights
【Snow pile locations】
The results of the subjective assessment test indicated that it was best to pile removed snow on the “Central island”, “Entrance A”, “Exit B”.
However, the amount of snow piled at “Entrance A” may increase due to daily snow removal operations. In such cases, snow will need to be piled at “Exit A” on the adjacent approach road to the roundabout. Thus, it is considered optimal to pile snow removed from the roundabout at the “Central island” and “Exit B”.

【Snow pile heights】
The results of the subjective assessment test indicated that variations in subjective assessment scores (indicating the degree of hindrance) were smaller for snow heights than those for snow pile locations. However, in the visibility confirmation test, actual visibility varied significantly. Accordingly, a snow height of 1.2 m was considered preferable.

- Snow pile locations = 「Central island」 and 「Exit B」 are the most preferable
- Snow pile heights = 「1.2 m」

9. Summary
【Results】
- This study enabled identification of a snowplow selection method and the proposal of snow pile locations and heights in consideration of visibility.

【Future tasks】
- Tests involving vehicular swept paths on winter road surfaces will be conducted.
- Snow removal operation procedures and the costs associated with removing and piling snow will be examined.