BASIC TESTS TO SELECT SNOW–REMOVAL VEHICLES AND TO DETERMINE HOW SNOW PILES AFFECT PASSING VEHICLES, TOWARD THE ADOPTION OF ROUNDABOUTS IN JAPAN

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ABSTRACT

Roundabouts are recognized as safe grade intersections, and they have been actively adopted in the U.S. and Europe. Engineering guidelines have been developed for roundabouts in Japan, and the first roundabout here was built to replace a signalized intersection. The time is ripe for Japan to introduce roundabouts to its road systems.
However, because snowy cold regions account for about 60% of Japan's land area, it is necessary to address various issues related to winter maintenance before introducing roundabouts to these cold regions. Few studies have addressed techniques for managing and maintaining roundabouts in winter.
Thus, for the purpose of collecting data that can be referred to for roundabout installation in snowy cold regions, tests were conducted at a simulated roundabout whose circulating roadway had an outside diameter of 26 m.
In the tests, snow removal vehicles were used for measuring the vehicular swept paths, and the minimum central island diameter that allowed the vehicles to remove snow was identified for each type of vehicle.
Additionally, simulated snow piles were used for investigating how snow piles from snowfall or snow removal affect driving behavior.
This paper outlines these tests and their results.

1. BACKGROUND

Traffic accidents in Japan numbered about 660,000 in 2012, and measures for ensuring traffic safety are a critical issue in this country. Traffic accidents are more frequent at intersections than at other road sections. Accidents at intersections account for 54% of all road accidents in Japan (42% in urban areas and 12% elsewhere). Accidents at basic road sections account for 42% (30% in urban areas and 13% elsewhere)[1]. Safety measures for intersections are essential for reducing the number of road accidents.
In the U.S. and Europe, roundabouts are recognized as safe grade intersections and are actively installed in the road systems there (Photo 1)[2].

Photo 1 - A small-scale single-lane roundabout
in a suburban area of the United States

In a roundabout, vehicles within the circulating lanes are given priority and fewer conflicts take place than at a conventional intersection; thus, roundabouts are effective in reducing road accidents.
Additionally, roundabouts do not cause traffic disturbances during prolonged or large-scale power failures at times of disaster, because they do not rely on electrically powered traffic signals.
In Japan, guidelines have been developed for introducing roundabouts to the road systems here [3]. In fact, Japan's first roundabout which replaced a signalized intersection has already been built [4]. It seems the time has come for the full-scale installation of roundabouts.
The snowy cold regions that account for 60% of Japan's land area are home to about one-fourth of Japan's population (Figure 1)[5]. Most of the major cities in these cold regions have more snowfall than the major Northern cities in other countries (Figure 2)[6,7,8].

Figure 1 - Specified snowy cold regions in Japan

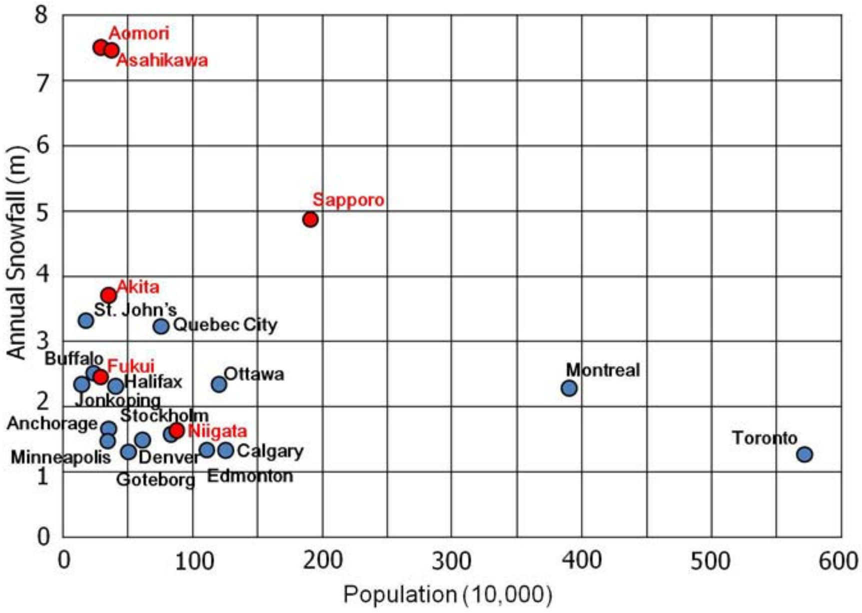

Figure 2 - Annual snowfall and population in major Northern cities

Toward increased use of roundabouts in Japan, studies are needed regarding maintenance and snow removal in winter. However, few studies have been done in the U.S. and Europe on winter maintenance techniques for roundabouts.

For example, a report on interview surveys conducted by Pochowski et al.[9]with the state DOTs of Kansas, Maryland, New York and Wisconsin shows that plows push snow through roundabout and then to side of road, except at some areas of Maryland, where plows push snow to central island. The same report shows that snow removal equipment is used to reduce height of snow piles at roundabouts in New York so that the snow piles do not impede sight distance.

In that report, however, neither the applicability of various snow removal vehicles to roundabouts nor the relationships between the height/location of snow piles and changes in the driving behavior are quantitatively evaluated.

2. OBJECTIVE

Efficient snow removal necessitates uninterrupted operation by a same snow removal vehicle on approaches and the roundabout. However, the applicability of various types of snow removal vehicles to roundabouts has not been quantitatively determined.

Snow removed from the roadway is usually piled at the roadside, and the height of snow piles differs greatly from day to day due to snowfall and snow removal. In fact, roadside snow piles can adversely affect traffic safety and the smooth flow of vehicles when they block the view of drivers and pedestrians. Furthermore, snow removal essential for winter road maintenance needs to be conducted by using techniques that depend on the location of the space for piling snow. Thus, the snow-piling space that is available can affect the structural design of a roundabout.

Based on the above considerations, tests were conducted for taking measurements of the swept paths of typical snow removal vehicles at a simulated roundabout for the purpose of collecting data that will help in selecting types of snow removal vehicles that are appropriate for roundabouts.

Furthermore, driving tests were performed with passenger cars to collect data on changes in the driving behavior and drivers' subjective assessment of hindrance caused by snow piles, for the purpose of quantitatively understanding the locations and heights of snow piles that have the least impact on drivers.

3. TESTS FOR COLLECTING DATA ON THE SWEPT PATHS OF VARIOUS SNOW REMOVAL VEHICLES

Measurements were taken of the swept paths of various snow removal vehicles, toward understanding what diameter of central island allows each type of snow removal vehicle to operate. The measurement results are expected to be used to help allocate the right types of snow removal vehicles to the right places.
A series of tests were conducted at a simulated roundabout set up at the Tomakomai Winter Test Track of the Civil Engineering Research Institute for Cold Region (CERI). The place, the period of testing and the structure of the simulated roundabout are as below:

- Place: Tomakomai Winter Test Track of CERI
  (Address: 211 Aza Kashiwabara, Tomakomai, Hokkaido)
- Periods: [Summer] August 2, 2011
  June 18, 2012 (Tests using a tractor with snow plow)
  [Winter] February 1, 2012
- Simulated roundabout structure (Figure 3)
  - ・Outside diameter of circulating lanes: 26.0 m
  - ・Diameter of central island: 14.0 m
  - ・Circulating lanes width: 6.0 m (including an apron 1.0 m in width)
  - ・Entry/exit width: 3.25 m
  - ・Entry curve radius: 13.0 m
  - ・Exit curve radius: 15.0 m

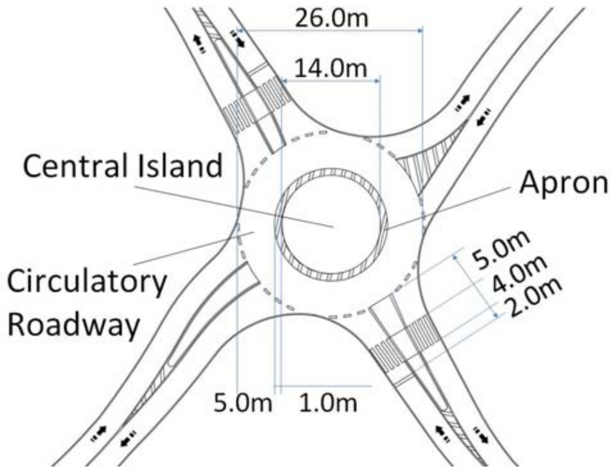

Figure 3 - Simulated roundabout structure

3.1. Test Method

In the tests for collecting data on swept paths, snow removal vehicles traveled the simulated roundabout under dry surface conditions (in summer) and on compacted snow (in winter). Vehicle positions and traveling directions were measured with RTK-GNSS receivers (Photo 2) set at the testing site (= fixed station) and on the top of each vehicle (= mobile station). Continuous swept paths and pass points were confirmed by using preregistered maps and data on the external size of each vehicle.
The instruments and conditions of measurement are as below:

- Instrument specs
  - ・GNSS receiver (fixed station): TOPCON Hiper-II (1 unit)
  - ・GNSS receiver (mobile station): TOPCON GR2100 (2 units)

・GNSS receiver (mobile station): TOPCON LEGACY-E (1 unit)
・Analysis software: Scan Survey (Be System Co., Ltd.)

- Measurement conditions
  ・Data acquisition intervals: 1 sec
  ・Intervals of analysis/ drawing: 1 sec

Photo 2 - RTK-GNSS receivers

3.2. Test Vehicles

For collecting data on swept paths, three types of snow removal vehicles were used. Removal of fresh snow is an essential part of snow removal operation, and these vehicle types are the most suitable for removing fresh snow (Figure 4)[10].

・Snow removal truck (10 t, 6 x 6): UD CZ520
・Snow removal motor grader (4.3 m, high-speed type): Mitsubishi 7G
・Tractor with snow plow (13 t) : Kawasaki 70Z2

The snow removal truck and the snow removal motor grader used in the tests are front-wheel steering vehicles. The tractor with snow plow has an articulated steering system. To survey the swept paths of these snow removal vehicles and the behavior of the tractor's snow plow, two mobile receivers were installed on the truck and the grader, and the tractor was equipped with three mobile receivers.

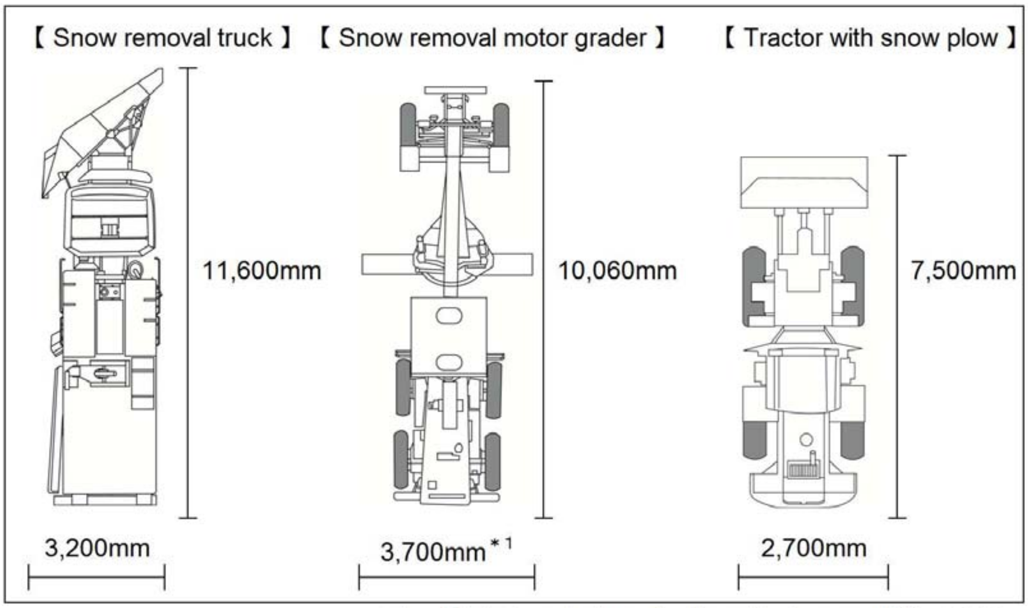

Figure 4 - Test vehicles (outline dimensional drawing)

3.3. Vehicle Movement Patterns

On the assumption that snow removal vehicles are required to travel in a straight line, turn right, turn left or go around in snow removal operation, these four patterns of vehicle movement were used in the tests. The test vehicles were required to keep their snow plows directed toward the central island when they traveled in a straight line or made a right turn, and toward the outer circumference of the circulating lanes when they made a left turn. The performance of each vehicle type during travel was evaluated. To understand the minimum radius of central island that would allow each type of vehicle to remove snow from the roundabout, each test vehicle ran around the roundabout while delivering its highest turning performance without regard to the contour of the outer circumference of the central island. Measurements were taken regarding the speeds at which each vehicle type was assumed to travel during actual snow removal as well as the minimum traveling speed of each type of vehicle.

At the end of the tests in winter, the test vehicles removed snow from the circulating roadway, and their swept paths were measured.

3.4. Test Results

The snow removal truck failed to run along the outer circumference of the central island (Figure 5). When the snow removal truck and the snow removal motor grader made a right or left turn at the exit, part of their external vehicle bodies often failed to stay within the width of the exit (Figure 6).

Measurements at several points along the course that the test vehicles traveled show that the minimum turning radius of the tractor with snow plow is smaller than the minimum turning radii of the other test vehicles, and that the tractor with snow plow can travel along the outer circumference of the central island and the circulating lanes. Additionally, the entry/exit width was great enough for the tractor with snow plow to make a right/left turn without using the roadside space.

The minimum turning radii under different conditions when the vehicles go around the circulating roadway were compared in order to quantitatively evaluate the effects of various road surface conditions and traveling speeds on swept paths (Table 1).

Because no significant differences were found in the minimum turning radii under various conditions, it is probable that the differences in the surface conditions and traveling speeds used in the tests were not great enough to affect the swept paths.

The minimum turning radii of the snow removal truck on the summer road surface were larger than those on the winter road surface. This seems attributable to deviation by the truck operator who drove the truck along the apron.

These test results indicate that a tractor with snow plow is the most suitable vehicle for snow removal at a simulated roundabout with circulating lanes that are 26 m in outside diameter and with a central island that is 14 m in diameter. It was also confirmed that the snow removal truck and the snow removal motor grader were usable for snow removal operation at roundabouts with central islands of 15 m and 11 m in diameter respectively.

Thus, in selecting the appropriate types of snow removal vehicles, it is necessary to refer to these test results and to take into consideration the roundabout structure as well as the snow removal vehicles used on the roads accessing the roundabout, so that appropriate types of snow removal vehicles are allocated to the right places.

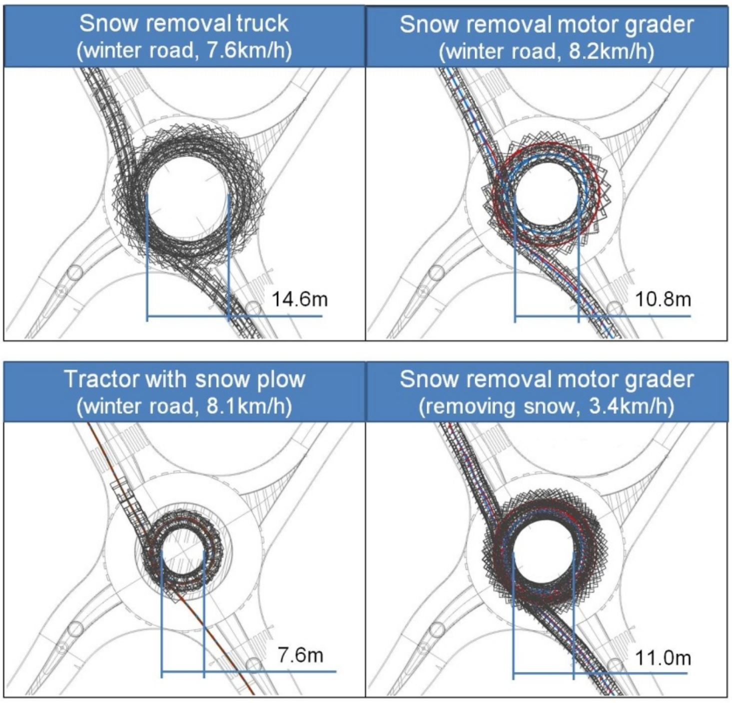

Figure 5 - Measured swept paths (Tests of vehicles in circulating flow)

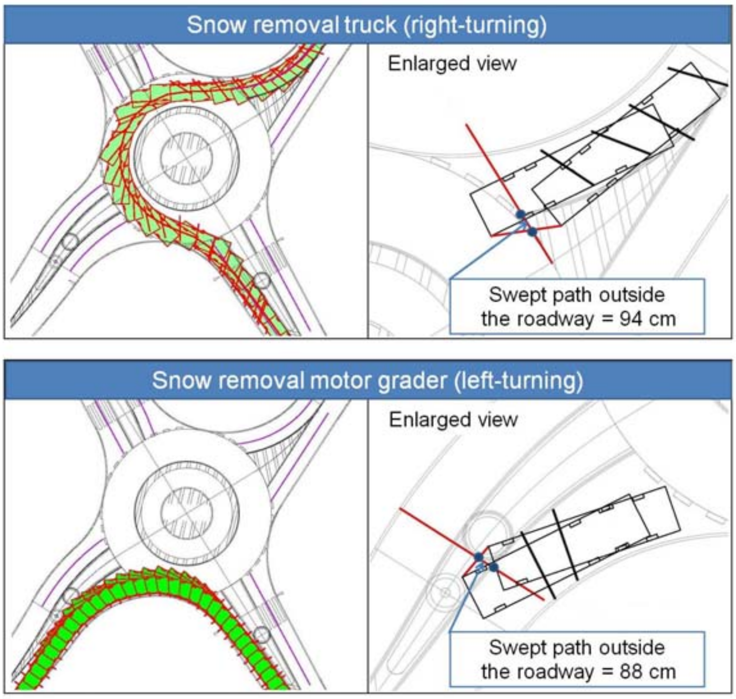

Figure 6 - Test results of swept paths
(Tests of the snow removal truck making right turns and
of the snow removal motor grader making left turns)

Table 1 - Comparison of the minimum turning radii

	Summer road surface		Winter road surface	
	Minimum speed	Snow removal operation speed	Minimum speed	Snow removal operation speed
Snow removal truck	8.2m	8.2m	7.3m	7.3m
Snow removal motor grader	5.5m	5.6m	5.6m	5.4m
Tractor with snow plow	–	3.4m	4.2m	3.8m

The minimum turning radius is the mean of the turning radii of the rear axle

4. DRIVING TESTS USING PASSENGER CARS

Driving tests using passenger cars were conducted to identify how snow piles affect drivers. These tests aimed at understanding the following effects:

- The effects of snow piles on drivers' subjective judgment of hindrance
- The effects of snow piles on driving behavior (i.e., traveling speed)

In the tests, each test subject drove a passenger car in the simulated roundabout with simulated snow piles. The hindrance to driving caused by snow piles was subjectively evaluated by the driver and by measuring traveling speeds. The changes in traveling speed are the changes in driving behavior.

To understand how the snow pile effects differed depending on the traveling conditions, the tests used various conditions, including multiple heights of snow piles, for collecting data on drivers' subjective assessment of hindrance and on traveling speeds.

The simulated snow piles used in the tests were made of ranging poles and white sheets.

4.1. Test Location and Period

The location and period of the tests are as shown below:

- Place: The simulated roundabout used in the tests for measuring swept paths of snow removal vehicles (Figure 3)
- Period: June 19 - 21, 2012

4.2. Locations, Heights and Distributions of Snow Piles

In the driving tests, seven snow piles were placed at the central island, the traffic islands, and the entry and exit of the roundabout; snow piles of four different heights ranging from 0 m to 1.5 m, were simulated.

Two distribution patterns of snow piles were used. One is a standard pattern in which snow is piled up extensively except at the roadway and the pedestrian walkway (Figure 7). The other is a non-standard pattern in which parts of the snow piles in the standard distribution pattern are removed to make other vehicles and pedestrians in the roundabout more visible to drivers (Figure 8). Specifically, the diameter of the snow pile in the central island was reduced from 14 m to 8 m, and each of the snow piles in traffic islands A and B, entry B and exit A were cut at a corner of the snow pile by 1 m. The snow pile in traffic island A was also cut at the corner adjoining the circulating roadway. The area of the cut extends from the middle of the border with the circulating lanes to the corner facing the entry. Entry A and entry B are the same as those in the standard pattern.

- Locations of snow piles: Central island, traffic islands A and B, entries A and B, and exits A and B (7 places in total)
- Height of snow piles: 0 m,1.0 m,1.2 m and 1.5 m (4 patterns)
- Snow distribution patterns: Standard and Non-standard (2 patterns)

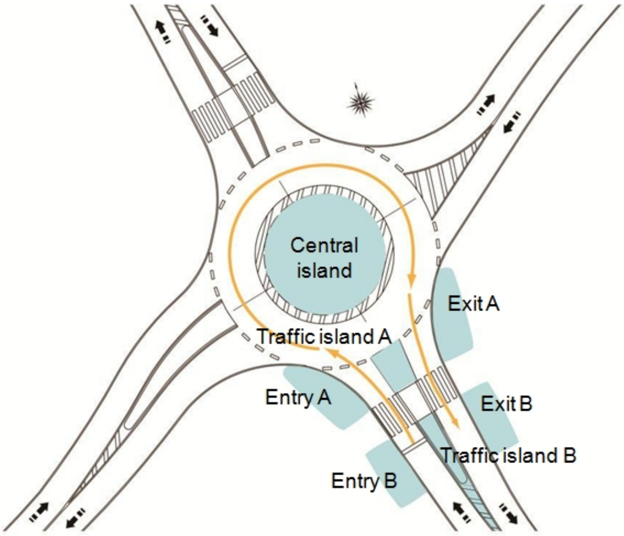

Figure 7 - Snow pile distribution pattern (standard) and the test track

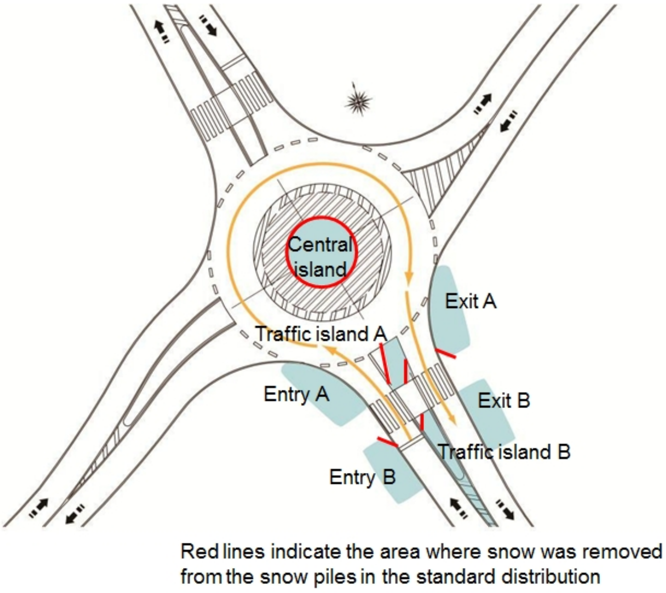

Figure 8 - Snow pile distribution pattern (non-standard) and the test track

4.3. Course of Traveling and Traveling Conditions

Each test subject drove a passenger car (Toyota Corolla Fielder). They started the car at the entry, made a circuit of the circulating lanes and stopped at the exit (Figure 7 and Figure 8). The start and end points are each 40 m from the circulating roadway.

Traffic control was implemented by means of either a "YIELD" sign or a "STOP" sign, by which the vehicles entering the roundabout are required to yield to vehicles within the circulating roadway.

Snow pile height, the snow pile distribution pattern, or the means of traffic control was changed from test to test. Each subject made a circuit of the roundabout four or five times consecutively under the same traveling conditions. A vehicle entered the circulating roadway or a pedestrian entered a crosswalk during one or two of the four or five rounds. The subjects were not given prior information regarding the timing or the traveling direction of each vehicle or pedestrians entering the roundabout.

The situation of the tests is shown in Photo 3.

- Traffic control method: YIELD or STOP (2 patterns)
- Other traveling vehicles: Existence or Non-existence (2 patterns)
- Pedestrians: Existence or Non-existence (2 patterns)

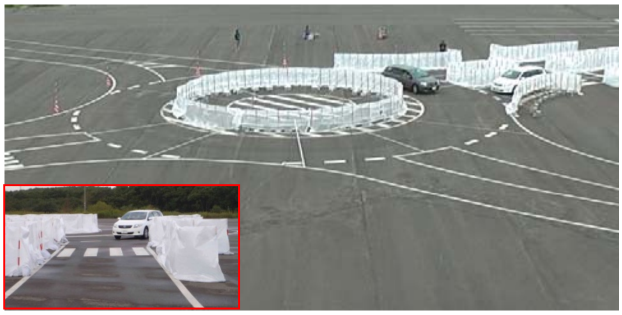

Photo 3 - Situation of the tests (with snow piles 1.2 m high)

4.4. Test Subjects

Ten male or female subjects who had never driven a car in a roundabout took part in the tests. They were in the age groups ranging from 20s to 50s, and none of them were visually impaired. The eye height of these subjects during driving ranged from 116.0 cm to 121.5 cm (Table 2).

Table 2 - Test subjects

Subjects	Gender	Age	Years of driving experience	Annual mileage	Eye level*1
A	Male	26	7 years	15,000km	120.5cm
B	Male	38	9 years	10,000km	119.0cm
C	Male	34	13 years	10,000km	121.0cm
D	Female	47	29 years	10,000km	116.0cm
E	Female	47	20 years	1,000km	120.5cm
F	Male	44	24 years	3,000km	121.0cm
G	Male	42	8 years	8,000km	121.5cm
H	Male	51	33 years	10,000km	119.5cm
I	Female	56	26 years	25,000km	118.0cm
J	Male	55	34 years	10,000km	118.5cm

*1 : The eye level of each subject in the test car was measured

4.5. Results of the Drivers' Subjective Assessment

The drivers in the tests subjectively evaluated the degree of hindrance posed by the snow piles under various traveling conditions. The subjects were asked to evaluate the degree of hindrance on a seven-point scale shown in a questionnaire (Figure 9).

Table 3 shows the objects that drivers are assumed to stay alert to (i.e., objects that drivers cannot visually confirm due to snow piles but they are always watchful for) while they are traveling in the roundabout.

Q: Please evaluate the impact of each snow pile on your driving behavior on the 7-point scale below:

【The first run】 Name:

Central island	1.2m	1	2	3	4	5	6	7
Traffic island A	1.2m	1	2	3	4	5	6	7
Traffic island B	1.2m	1	2	3	4	5	6	7
Entry A	1.2m	1	2	3	4	5	6	7
Entry B	1.2m	1	2	3	4	5	6	7
Exit A	1.2m	1	2	3	4	5	6	7
Exit B	1.2m	1	2	3	4	5	6	7
		Little hindrance						Great hindrance

Figure 9 - Questionnaire

Table 3 - Objects that drivers stay alert to

Locations of simulated snow piles	Traveling conditions		
	Traveling on the circulating roadway	Traveling at the entrance	Traveling at an exit
Central island	Another traveling vehicle	Another traveling vehicle	–
Traffic island A	–	Another traveling vehicle	Pedestrian
Traffic island B	–	Pedestrian	Another traveling vehicle
Entry A	–	Another traveling vehicle	–
Entry B	–	Pedestrian	–
Exit A	–	–	Pedestrian
Exit B	–	–	Another traveling vehicle

The degrees of hindrance subjectively scored by the test subjects for the snow piles at various locations were standardized (i.e. (value −mean) / standard deviation) for each driver to make snow pile cross-comparisons easier. Additionally, the hindrance scores given for each snow pile by the subjects were averaged in order to determine a standard value (Table 4, Figure 10, Figure 11, and Figure 12). In the subjective assessment of hindrance, the greater the standard value of a snow pile, the greater the negative impact of the snow pile on driving behavior.

The subjective assessment brought the following results or presumptions:

- The great differences in the standard value among the snow piles at different places suggest that a snow pile's degree of hindrance depends on the pile's location.
- The standard value is high at entry B, exit A and traffic islands A and B relative to the standard values of snow piles at other locations. The objects that drivers stay alert to include pedestrians at these four locations; the drivers do not have to be cautious about pedestrians at other locations. This suggests that drivers are particularly concerned about the presence of pedestrians while driving.
- The standard value for a snow pile increases with increases in its height, which indicates that the hindrance to drivers caused by a snow pile depends on its height.
- For the snow piles distributed in a standard pattern, the standard values of the snow piles 1.0 m in height are significantly lower than the standard values of the snow piles 1.2 m or 1.5 m in height, and the differences in the standard value depending on the location of snow piles are relatively small when the snow piles are 1.0 m high. It is presumed that when the snow piles are 1.0 m high, the eye level of drivers while traveling (Table 2) is higher than the top of the snow piles and, thus, visibility is fairly good in comparison with other situations in the roundabout when snow piles are higher.
- On the other hand, the standard values for the snow piles 1.2 m or 1.5 m in height are

lower for the snow piles distributed in the non-standard pattern than the standard values for the snow piles of the same heights distributed in the standard pattern. Specifically, the standard values of the snow piles 1.5 m in height in the non-standard pattern are similar to the standard values of the snow piles 1.2 m high in the standard pattern. It is probable that visibility is better in the roundabout with the non-standard pattern of snow piles than in the roundabout with the standard pattern of snow piles.
Although the configurations of the snow piles at entry A and exit B are the same in the tests either with standard or non-standard patterns of snow piles, the standard values are lower in the tests using non-standard patterns. The reason for these results has not been identified.

- No distinct differences due to the difference in the traffic control method were confirmed under any conditions regarding the heights and locations of snow piles. Thus it is concluded that the method of traffic control does not affect the hindrance to drivers caused by snow piles.

Table 4 - Results of the subjective assessment (standard values)

Traveling conditions			Locations of snow piles							Average score
Means of traffic control	Snow pile distribution	Heights of snow piles	Central island	Traffic island A	Traffic island B	Entry A	Entry B	Exit A	Exit B	
YIELD	Standard	1.0m	-1.18	-0.93	-1.19	-0.81	-0.96	-0.67	-1.15	-0.98
		1.2m	-0.30	0.89	0.33	0.18	0.46	0.57	0.15	0.33
		1.5m	0.23	1.66	0.84	0.82	1.37	1.50	0.93	1.05
YIELD	Non-standard	1.0m	-1.07	-0.69	-0.77	-0.88	-0.82	-0.71	-0.83	-0.82
		1.2m	-0.95	0.07	-0.17	-0.70	-0.42	-0.11	-0.64	-0.42
		1.5m	-0.51	1.02	0.61	0.36	1.05	0.99	0.49	0.57
STOP	Standard	1.0m	-1.18	-0.53	-0.73	-1.00	-0.73	-0.67	-1.07	-0.84
		1.2m	-0.60	0.82	0.35	-0.07	0.49	0.56	0.09	0.23
		1.5m	0.04	1.46	0.92	0.39	1.45	1.39	0.54	0.88
Average score			-0.61	0.42	0.02	-0.19	0.21	0.32	-0.17	–

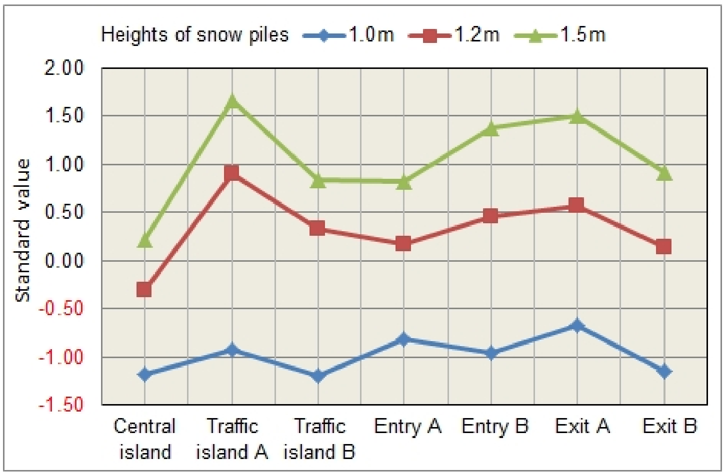

Figure 10 - Results of subjective assessment
(Traffic control: YIELD; Snow pile distribution: Standard)

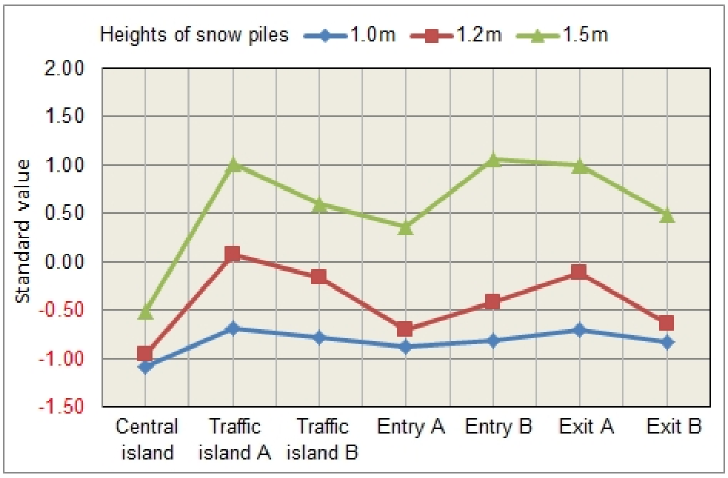

Figure 11 - Results of subjective assessment
(Traffic control: YIELD, Snow pile distribution: Non-standard)

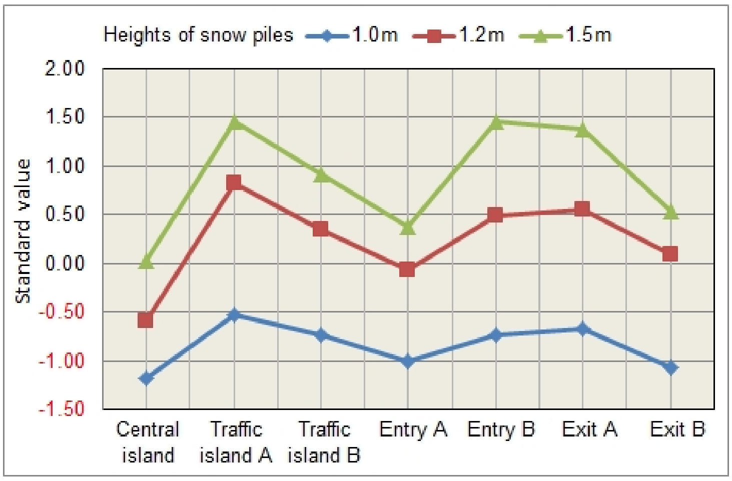

Figure 12 - Results of subjective assessment
(Traffic control: STOP, Snow pile distribution: Standard)

4.6. Results of Driving Behavior Measurement

The passenger car used in the tests was equipped with a data logger with a GPS receiver (V-boxmini, Racelogic Ltd.) for measuring the traveling speed per meter under each predetermined condition of snow pile height/distribution and traffic control. To prevent low traveling speeds immediately after the test car was started and immediately before the car was stopped from affecting the data, data collection was started when the car reached a point 20 m short of the circulating roadway and was stopped when the car had traveled 20 m in the exit from the circulating roadway.
The collected data were graphed to show correlations between the traveling speed and the position of travel along the road section for measurement. This graph helps visualize the changes in driving behavior within the section of the roundabout where measurements were taken (Figure 13). The average traveling speed was calculated for each section of the roundabout (i.e., the entries, the circulating roadway, and the exits), in order to evaluate the effects of different traveling conditions on the traveling speed (Table 5).
In calculating the average traveling speed, data that were collected when the test car was approaching another vehicle or a pedestrian in the roundabout were excluded, for the purpose of eliminating the effects of such vehicles or pedestrians on the average traveling speed. Data for exclusion from calculation were determined by using the video image taken from a mobile elevating work platform (Photo 3).
The data on driving behavior lead to the following findings and presumptions.

- Because the traveling speed was significantly reduced when the test car was traveling near the point of entry to, or exit from, the circulating roadway where the crosswalks were located, it is presumed that drivers were particularly cautious while driving in these areas.
- The traveling speed decreased with increases in the snow pile height. This indicates that the snow pile height affects driving behavior. The decrease in traveling speed with increases in the snow pile height was particularly significant at the entry and the exit, in comparison with the decrease at the circulating roadway.
- The reduction in traveling speed was greater when the snow pile height was increased from 1.0 m to 1.2 m than when it was increased from 0 m to 1.0 m or from 1.2 m to 1.5 m. It is presumed that this difference in the reduction of the traveling speed is causally related to the drivers' eye level as shown in the subjective assessments of hindrance, and that areas not visible to drivers increase significantly when the snow pile height is increased from 1.0 m to 1.2 m.
- The differences in snow pile distribution had no obvious effect of traveling speed.
- The average traveling speed was higher when a YIELD sign was employed as the means of traffic control and drivers were not required to stop temporarily than when a STOP sign was used. However, the difference in the average traveling speed between YIELD and STOP decreased with increases in the height of snow piles.

Table 5 - Results of driving behavior measurement

Traveling conditions			Average traveling speed for the data-collection section (km/h)			Average traveling speed for the whole section (km/h)
Means of traffic control	Snow pile distribution	Heights of snow piles	Entry section	Circulating roadway section	Exit section	
YIELD	Standard	0m	21.14 (103.8%)	17.63 (104.3%)	21.64 (108.6%)	19.13 (105.1%)
		1.0m	20.37 (−)	16.89 (−)	19.92 (−)	18.20 (−)
		1.2m	16.37 (80.4%)	15.46 (91.5%)	16.81 (84.4%)	15.91 (87.4%)
		1.5m	13.63 (66.9%)	14.72 (87.2%)	13.78 (69.2%)	14.32 (78.7%)
YIELD	Non-standard	1.0m	18.21 (−)	16.36 (−)	19.13 (−)	17.29 (−)
		1.2m	15.79 (86.7%)	16.14 (98.7%)	16.52 (86.3%)	16.14 (93.4%)
		1.5m	11.64 (63.9%)	15.34 (93.8%)	14.17 (74.1%)	14.37 (83.1%)
STOP	Standard	0m	17.41 (112.9%)	15.95 (101.9%)	18.57 (114.9%)	16.76 (106.7%)
		1.0m	15.43 (−)	15.65 (−)	16.17 (−)	15.71 (−)
		1.2m	12.84 (83.2%)	15.41 (98.5%)	14.09 (87.1%)	14.64 (93.2%)
		1.5m	12.25 (79.4%)	15.17 (97.0%)	13.51 (83.5%)	14.27 (90.8%)

Percentages in comparison with the traveling speed when snow piles are 1.0 m high are shown in parentheses

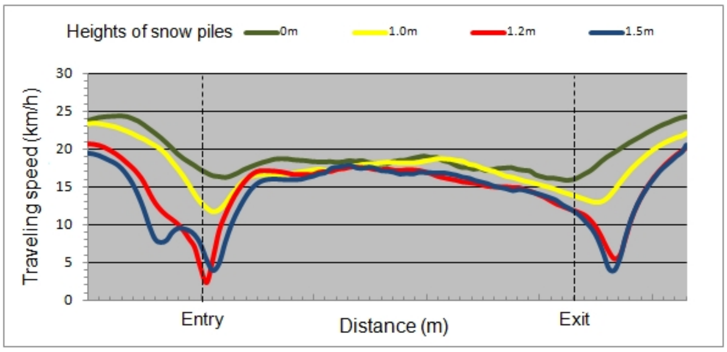

Figure 13 - Examples of the changes in driving behavior in the data collection section (Subject: H, Traffic control: YIELD, Snow pile distribution: Standard)

5. SUMMARY

For the purpose of collecting data that can be referred to when considering the installation of roundabouts in snowy cold regions of Japan, tests were conducted with typical snow removal vehicles at a simulated roundabout having a circulating roadway with an outside diameter of 26 m. Tests were also conducted by using simulated snow piles, toward identifying how driving behavior would be affected by snow that is accumulated from snowfall or is piled up by snow removal vehicles.
The tests helped to identify the minimum radius of the central island that would allow for each vehicle type to remove snow from the roundabout.
Under the test conditions, the effects of different traveling conditions (snow pile height, snow pile distribution pattern, means of traffic control) on drivers' subjective assessments of hindrance and driving behavior were quantitatively evaluated.
In the future, additional data will be collected through driving tests in which the height of snow piles varies from one location to another, and the data will be used for understanding better about the heights and locations of snow piles that do not significantly affect driving behaviors.

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