# COMPARISON OF THE MODELS OF DIFFERENT TYPES OF SNOW FENCES IN COLD WIND TUNNEL

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## 1. Abstract

Snow fences are used to reduce the quantity of drifting snow and increase the visibility on the roads. There are many types of snow fences in use through the world. Approximately 1/20 scale models of eleven different types of structural snow fences (Japanese Collector and Blower types, Chinese Vertical and Inclined types, USA Wyoming, Russian, French, Swedish, Norwegian, Canadian and Concrete) were prepared. They were tested under the same laboratory conditions at the cold wind tunnel of the Cryospheric Environmental Simulator (CES) at the Shinjo Branch, Nagaoka Institute of Snow and Ice Studies, National Research Institute of Earth Science and Disaster Prevention, Japan. The catch efficiency, drift volume, dimensionless drift area, rate of collection, shape of the drift both on the leeward and windward sides of each model are compared.

The experiment results showed that the normalized catch, expressed as “Mass per unit width of fence /Time”; was highest for Norwegian type model (4.544 g/cm/min), and the lowest for the Russian type model (0.788 g/cm/min). The correlation matrix including all the physical parameters of eleven models tested, showed that the normalized catch of the model is best related to the normalized depth of the model (h/H). The dimensionless drift lengths of all the models extended from 1 to 26 L/H ratio on the leeward side. Models with vertical slats had leeward side drift further down with a more homogeneous distribution of snow in distance.

## 2. Introduction

Winds over 4m/s or more start to lift the snow from the ground surface, carrying it in suspension, saltation and in mix mode until it is deposited when the barrier is met. Snow fences are installed near roads and highways to prevent snow from drifting over the roadway. There are two types of fences that are currently used today; the structural (man-made) snow fences made of metal, wood or plastic, and living snow fences, which are barriers made of groups of trees and shrubs.

During the last two decades, the transportation of snow by wind has been modeled by Iversan (1981), Pomeroy (1989), Naaim-Bouvet (1997) , Sundsbo (1997) and studied in detail by many researchers, among others are Anno and Konishi (1981), Anno (1985), Naaim-Bouvet and Brugnot

(1992) by using different materials to substitute snow. Also snow drift has been investigated with outdoor experiments by Kobayashi (1979), Tabler (1991), Anno (984), Kitami Institute of Technology (1986), Jairell and Schmidt (1987), Hachnell, et al. (1997). A series of wind tunnel experiments on saltation layer structure of drifting snow were realized by Sato, et.al. (1999), Kosugi, et.al. (2000), Sato and Kosigi (2001) and Japanese snow fence model use to control drift was lost done by Takeuchi et al. (2001), using artificial snow.

Outdoor laboratory testing of snow fences help to answer the questions such as how snow fences interact with terrain, how visibility changes with time during the blizzard, how snow fences reduce the road ice and improve visibility in blizzard, often within days or weeks. The outdoor modelers gain lots of real snow, without the expense of large cold rooms. However, they lack the control over wind speed and direction, which wind tunnels provide (Jariell and Schmidt, 1987). The similitude of drift geometry and drift development rate must be preserved in outdoors modelling of snow drift. There are less outdoor modelling data for snow drifts. Haehnell,et.al.(1997) compared the prototype drift geometries and development rates with corresponding preliminary model data obtained in a snow drifting wind tunnel, and concluded that some inaccuracies in the model drift geometry and development rate which may result from distortion in snow transport concentration and particle trajectory lengths.

In snow drifting simulation in the cold wind tunnel, the snow from the supply source as loose snow is moved by the drag force exerted on the snow particles. The drifting begins when the surface shear stress; **τo** exceeds a threshold value, which depends on the size, shape and the weight of the snow particles and on the strength of any inter-particle cohesive forces.

It is generally accepted that it is not possible to satisfy all the dimensionless parameters at model scale, therefore the model is distorted and some means of interpreting the effect of distortion must be determined. The correct modeling requires that the geometry, flow patterns, and snow particle trajectories are all scaled by the same ratio; then flow patterns and particle trajectories have the same shapes in both the models and the prototype situations.

Comparison of the models tested, is made by computing the storage capacity, snow collected, volume ratio, bottom gap, saturation profile, location of the drift both on leeward and windward sides of the fence and rate of catch in time. These experiments are not done to set up the criteria to set up the best model to represent the existing prototypes but to compare the different models under the same wind, rate of snow supply, and duration of storm , temperature and humidity conditions.

## 3. Method of Experiments

The scaled models of eleven different structural snow fences (Figure 1) were tested under the same laboratory conditions at the cold wind tunnel of the Cryospheric Environmental Simulator (CES) at the Shinjo Branch, Nagaoka Institute of Snow and Ice Studies, the National Research Institute of Earth Science and Disaster Prevention, Japan (Figure 2). The cold wind tunnel is a return flow, closed circuit type with a test section of 14 m long, 1 m wide, and 1 m high. The air temperature of the cold room can be controlled between – 30°C and 25°C.

A scale model is placed in the wind tunnel, keeping the wind velocity and snow supply rate (erosion rate also) controlled, the deposition patterns are defined and compared for different types of fence (Figure 3).

The linear ratio between the model and prototypes of the structural fences tested varied between 1/16 to 1/22 according to the nearest size of the wood element available in the market to make the models.

A snow seeder located at 4.5 m distance in upwind direction from the model supplied snow particles into the air flow to enhance the development of drifting snow. The same old deposited snow after grinding and screening, was used for the snow seeder as that spread on the floor and sintered later by sprinking water. The rate of snow supply could be varied from 1% to 100%, where 100 % corresponds 3.55 g/cm.s.

From the snow supply tank, the eolian snow was supplied at a rate of 4% ( 0.148 g $cm^{-1}$ $s^{-1}$), more or less vertically from the snow surface and accelerated into the downwind direction toward the fence by aerodynamic drag forces. The snow particles are collected by a snow removing filter inserted, after the downwind end of the test section. Turbulent flow of wind around the models was provided by creating a rough surface on the steel base plate of the wind tunnel by covering it with 80 cm by 150 cm by clothes.

The wind speed was kept constant at 7 m/s (0.29 m/s of friction velocity of snow) and the wind flow pattern was stabilized before each test and this has been checked by reading the automatic control panel of wind velocity. The mean velocity was approximately horizontal and the particles could only rise less than 10 cm above the ground on the windward side of the models and it was observed that the moving snow particles bounce along, close to the surface in a mode of saltation.

The snow surface and the roughness of on the test surface were determined by measuring with Laser Displacement Sensor (Figure 4). The standard vertical measuring range of the sensor is 300 +/- 100 mm, and equipped with the infrared laser beam with a measuring resolution of 50 μm. The vertical measurements were done when there was no snow, i.e. at the beginning of the test. When the drift was formed same measurements were repeated and the difference was the height of the snow at the measurement point. The measurements were repeated after each intermission in order to determine the rate of accumulation and shape of the drift. Then the shape and the amount of the drifted snow were defined. The density values of the drifted snow and the supplied snow were measured separately for each model tested. When the snow removed from the test area , the same “no snow case” measurements were repeated to see if there was any change in the test platform and roughness of the surface.

Particle distribution analysis of the snow supplied during the tests and also the drifted snow on the lee ward side of the fence is necessary to understand , if possible, the rate of passing of the particles through the fences of different porosity. As the size of the grains of the snow supplied from the

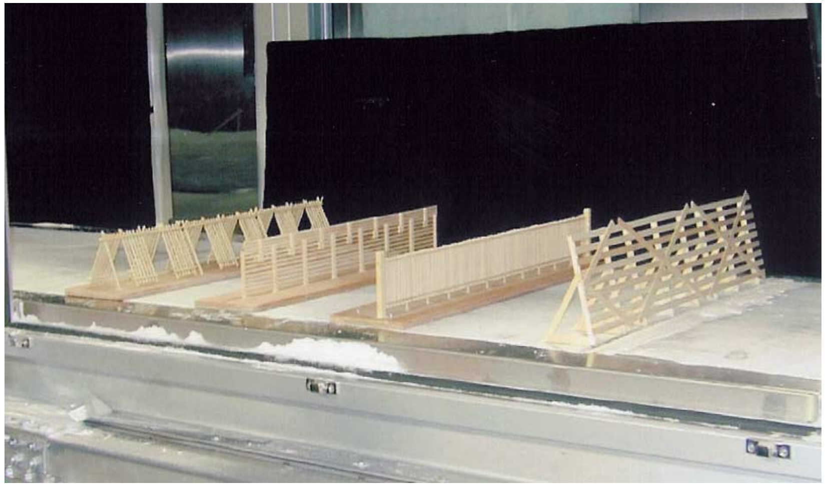


Figure 1. Scaled Snow Fence Models Tested (From Right To Left Wyoming, Canadian, Norwagian And Russian Types) In Cold Wind Tunnel

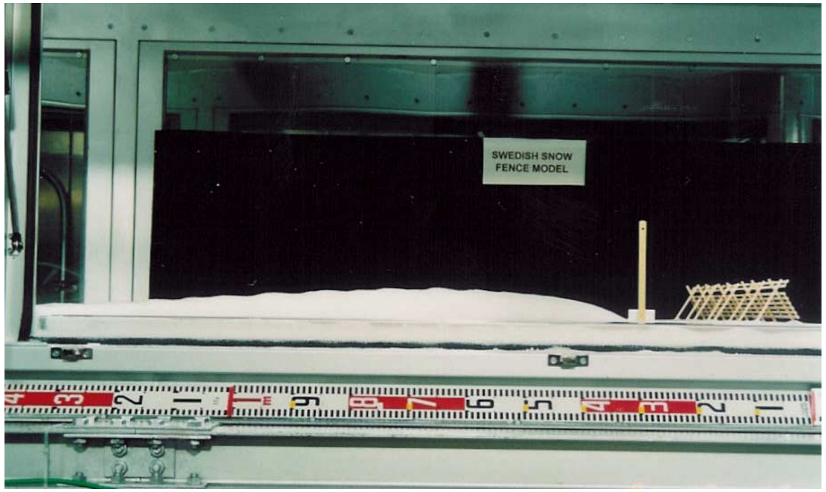


Figure 3. The Drifted Snow Catch On The Leeward Side Of A Scaled Snow Fence Model (Sweedish Type) Tested In

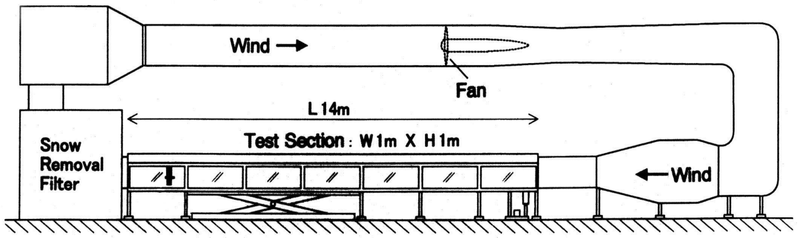


Figure 2. Schematic Crossection Of Cold Wind Tunel Of Shinjo Branch (Sato And Kosigi, 2001).

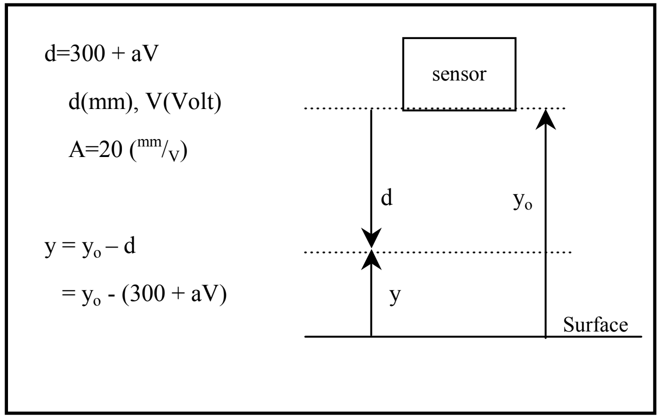


Figure 4. Laser Displacement Meter Used In Test

seeder increases, the percentage of the particles in saltation mode increases but in suspension mode decreases.

In order to determine the cross sectional areas of the snow particles obtained from the seeder, National Institutes of Health (NIH) Image software was used. For this purpose, during the experiments the snow samples from the seeder is taken and photographed by microscope and also the scale of the photographs is defined. After digitizing the scaled photographs of the snow particles, using NIH Image software, the area of the particles, and the equivalent diameter of each particle is determined by Excel. Then particle size distributions of the snow is determined.

Measurement of the snowdrift of each model was made at certain intervals to follow the speed of the drift formation and continued for more than one hour for some of the models tested , to reach the almost equilibrium heights. The snow drifts locations, geometry and the size were scaled down in proportion to model fence heights (Table 1).

## 4. Analysis

The snow deposition patterns show variations in shape and amount. Also the locations of the drifted material with respect to the fence change from one model to another.

Before the experiments, the wind velocity in cold wind tunnel was made homogenous and the snow seeding started 5 minutes later. The vertical profile of wind velocity in the same cold wind tunnel had been studied in detail under the same geometrical conditions by Takeuchi et al. (2001) for an average value of 7 m /sec of wind. Therefore wind velocity profile testing was not repeated.

In the three particle distribution analysis done during the tests, it was found out that the snow supplied had about the same particle distribution and it fitted to Gamma type of statistical distributions. The average diameter of the snow supplied for the tests varied between 0.323 mm and 0.406 mm .The density values of the snow are given in Table 1.

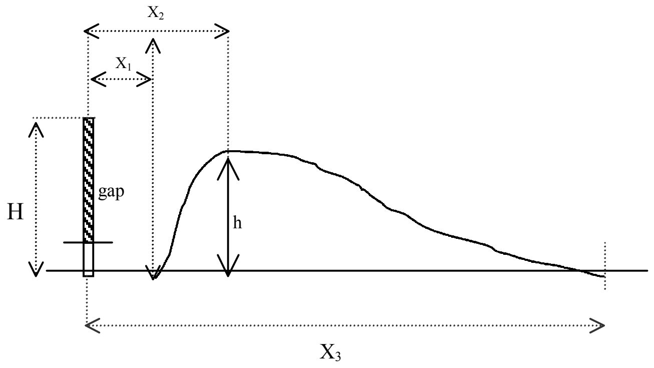
In computing the real height of the snow drifted on the leeward side of the fence, the procedure used is described as follow: At first, before the start of the test, the roughness of the test area around the fence is mesured along the main axis (Y=0.0) and the right ( Y=-60.0) and left hand ( Y=+60.0) sides of the axis and recorded as “no snow case”. The longitudinal profiles along these lines are best fitted with an correction equation before necessary corrections are made on point mesurements and the corrected profiles along these axes are used to estimate the roughness of the path and also the original height of the surface before the test starts.

With the start of the test, the drifted snow profiles on the wind ward side ( if it was formed) and the leeward side are determined by measuring the heights of the snow at 5, 10, 15, 20, 25, 35, 45, 55, 70, 75 minutes (Figure 5) , by the same techniques along the the same three longitudinal profiles used in “no snow case”. Also according to the shape of the drifted snow usually three transverse sections are also measured. The difference give the real snow height and the rate of accumulation of snow, e.i. catch of fence.

## Table 1. Physical Parameters Of The Fence Models And Experiment Results (*1)

| A | B | C | D | E | F | G | G' | H | I | J | K | L | L' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of fence | H Height [mm] | L Length [mm] | Total area [mm$^2$] | Total opening [mm$^2$] | Porosity [%] | Gap with ground [mm] | Gap with ground (nondimensional) | Inclination [α° ] | Model scale | Density of drifted snow [g/cm$^3$] | Density of supplied snow [g/cm$^3$] | Wt (mass) of drifted snow [g] | h/H (snow depth) |
| Wyoming | 158 | 762 | 110490 | 35728 | 32,3 | 15 | 0,0949 | 75 | 1/20 | 0,377 | 0,424 | 17973,4 | 0,961 |
| Japanese Collector | 178 | 610 | 87840 | 14325 | 16,3 | 35 | 0,1966 | 90 | 1/20 | 0,388 | 0,446 | 7740,9 | 0,686 |
| Norwegian | 97 | 700 | 60900 | 18060 | 29,7 | 10 | 0,1031 | 90 | 1/22.6 | 0,417 | 0,443 | 8250,2 | 0,882 |
| Concrete | 67 | 750 | 41250 | 10240 | 24,8 | 12 | 0,1791 | 90 | 1/19.4 | 0,431 | 0,423 | 7734,3 | 0,998 |
| Canadian | 90 | 800 | 64000 | 32120 | 50,2 | 10 | 0,1111 | 90 | 1/15.4 | 0,455 | 0,457 | 12305,4 | 0,645 |
| Swedish | 80 | 800 | 72000 | 28960 | 40,2 | 10 | 0,1250 | 60 | 1/20 | 0,502 | 0,471 | 16820,6 | 0,875 |
| French | 100 | 805 | 64400 | 2850 | 44,3 | 20 | 0,2000 | 90 | 1/20 | 0,490 | (*3) 0,461 | 24909,0 | 0,879 |
| Chinese Vertical | 275 | 755 | 151000 | 30525 | 20,2 | 75 | 0,2727 | 90 | 1/20 | 0,466 | 0,450 | 15219,8 | 0,373 |
| Russian | 100 | 760 | 79800 | 49170 | 61,6 | 5 | 0,0500 | 60 | 1/20 | (*3) 0,457 | 0,457 | 3573,5 | 0,271 |
| Chinese Inclined | 265 | 755 | 151000 | 30525 | 20,2 | 75 | 0,2830 | 70 | 1/20 | 0,512 | (*3) 0,468 | 19401,1 | 0,238 |
| Japanese Blower | 160 | 610 | 63440 | (*2) | (*2) | 56 | 0,3500 | 90 | 1/22 | 0,511 | (*3) 0,467 | 1708,5 | 0,250 |

|  | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|
| Type of fence | Test duration [min] | X1/H | X2/H | X3/H | Total Catch Efficiency g/cm$^2$ | Catch Efficiency 1 g/cm$^2$/min | Catch Efficiency 2 g/cm$^2$/min | (*4) Mass [g/cm] | Mass/Time [g/cm/min] |
| Wyoming | 75 | 1,359 | 4,225 | 15,384 | 16,267 | 0,217 | 0,960 | 316,703 | 4,223 |
| Japanese Collector | 55 | 2,397 | 3,318 | 10,156 | 8,812 | 0,160 | 0,444 | 140,398 | 2,553 |
| Norwegian | 35 | 1,244 | 4,068 | 14,842 | 13,547 | 0,387 | 2,505 | 159,031 | 4,544 |
| Concrete | 35 | 1,340 | 4,910 | 17,904 | 18,750 | 0,536 | 4,923 | 151,347 | 4,324 |
| Canadian | 55 | 4,637 | 10,202 | 21,911 | 19,227 | 0,350 | 2,762 | 248,164 | 4,512 |
| Swedish | 125 | 2,130 | 7,971 | 26,446 | 23,362 | 0,187 | 2,103 | 355,798 | 2,846 |
| French | 120 | 1,911 | 6,333 | 22,241 | 38,679 | 0,322 | 2,076 | 468,238 | 3,902 |
| Chinese Vertical | 125 | 3,884 | 4,856 | 8,713 | 10,079 | 0,081 | 0,161 | 280,614 | 2,245 |
| Russian | 125 | 2,608 | 6,556 | 17,158 | 4,478 | 0,036 | 0,286 | 98,499 | 0,788 |
| Chinese Inclined | 120 | 4,031 | 5,039 | 9,042 | 12,848 | 0,107 | 0,230 | 226,040 | 1,884 |
| Japanese Blower | 90 | 3,578 | 4,728 | 8,916 | 2,693 | 0,030 | 0,074 | 101,439 | 1,127 |



(*1) Based on real model measurements
(*2) Undefined
(*3) Estimated by Calculation
(*4) Per unit width

When the test is finished, the same “no snow case” measurements are repeated to see if there is difference in the roughness of the test ground both on longitudinal and transverse sections measured during the test. If the Displacement sensor can not near the walls of the cold wind tunnel, the snow height are measured manually.

## 5. Results and Discussion

The testing of all the snow fence models were completed at four experiments; June, July, August and October 2000 . At each experiment, there are three steps. The first step is to prepare the test setup, which covers measuring the irregularities and roughness on the test ground as “no snow case” by using Laser Displacement Sensor, and the second step is to mesure the snow profiles at seven and eight independent intervals, and the last stage is measuring the grain size distribution of the drifted snow, measuring the density of the snow supplied and the snow catch drifted on the leeward side of the fence models, and remeasuring the roughness of the test set up as “no snow case”.

The physical parameters of the models tested, the test durations, and the normalized values of all test results are tabulated in Table1. After completion of all the cold wind tunnel experiments with snow fence models, then the maximum height of the drift, distances to the start and end of the drift are normalized according to the height of the model as for Norwegian type snow fence model as shown in Figure 5. The variation of normalized maximum drift depth with respect to normalized distance from the models is given in Figure 6. The variation of drift mass per unit with respect to time is given in Figure 7. Figure 8. The relation between total weight of drifted snow and the catch mass per unit width for all the models tested is given in Figure 8.

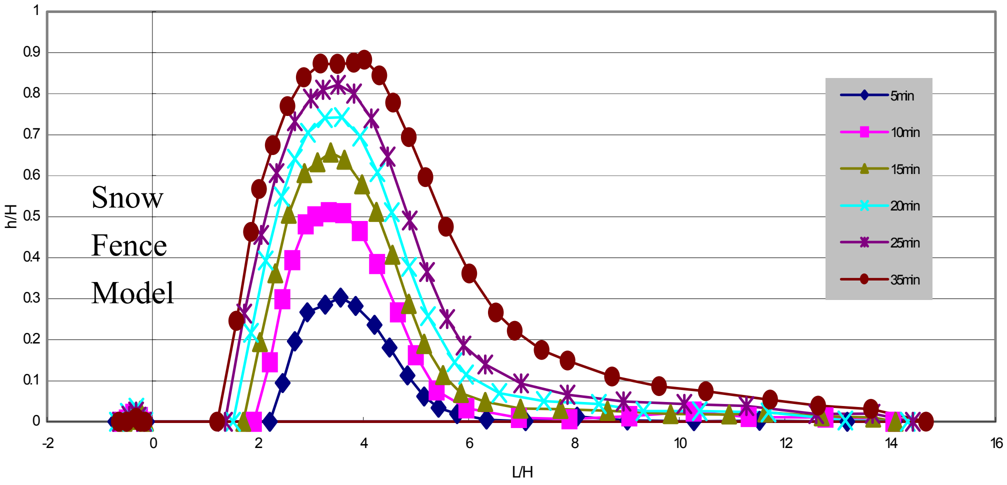


**Figure 5. The Rate Of Accumulation of Norwagian Snow Fence Model**

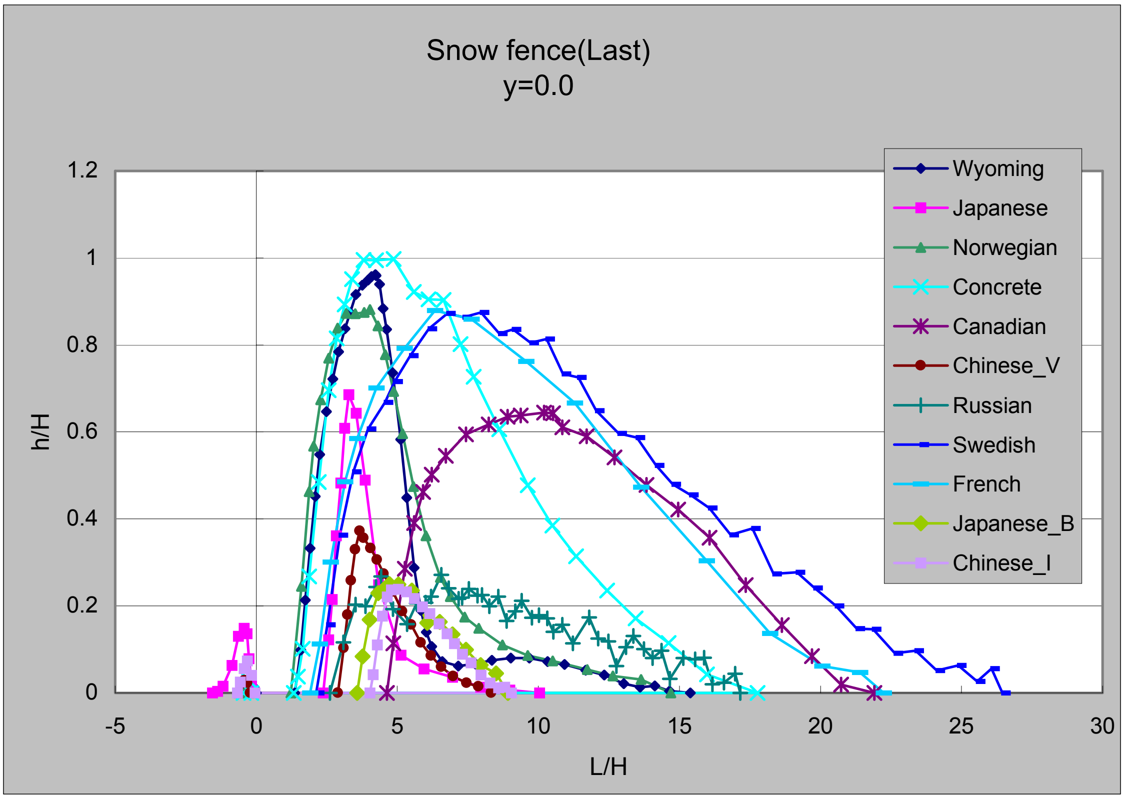


**Figure 6. The Variation Of Normalized Maximum Drift Depth With Respect To Normalized Distance From The Fence Models Tested**

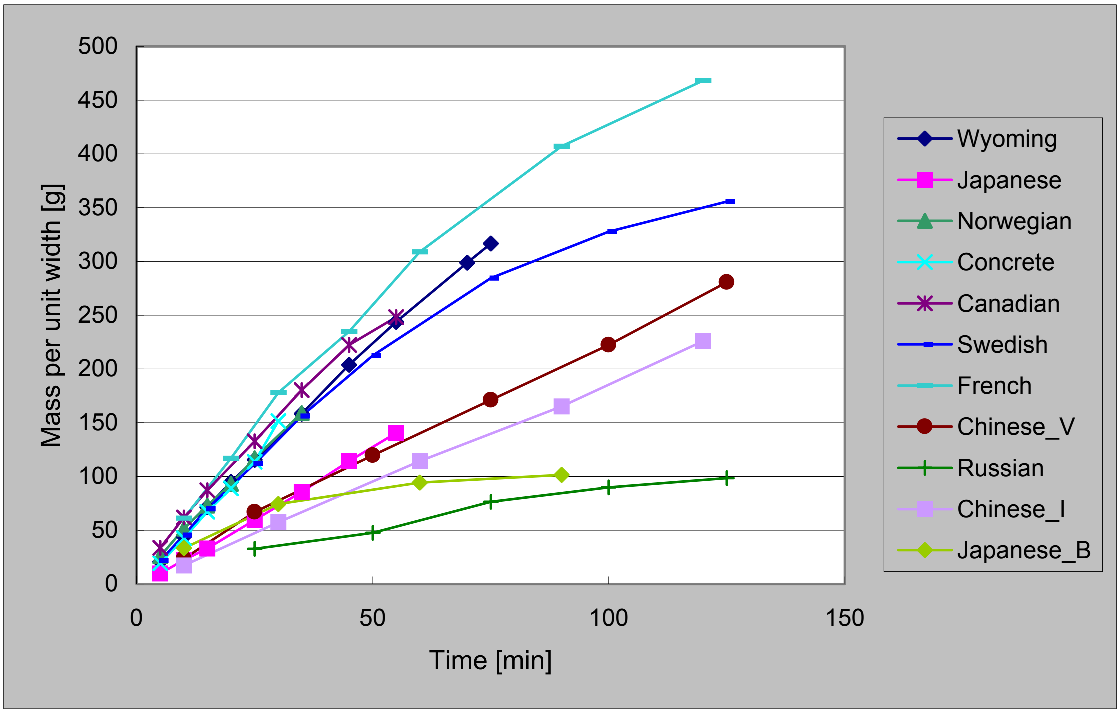


**Figure 7. The Variation Of Mass Per Unit With Respect To Time**

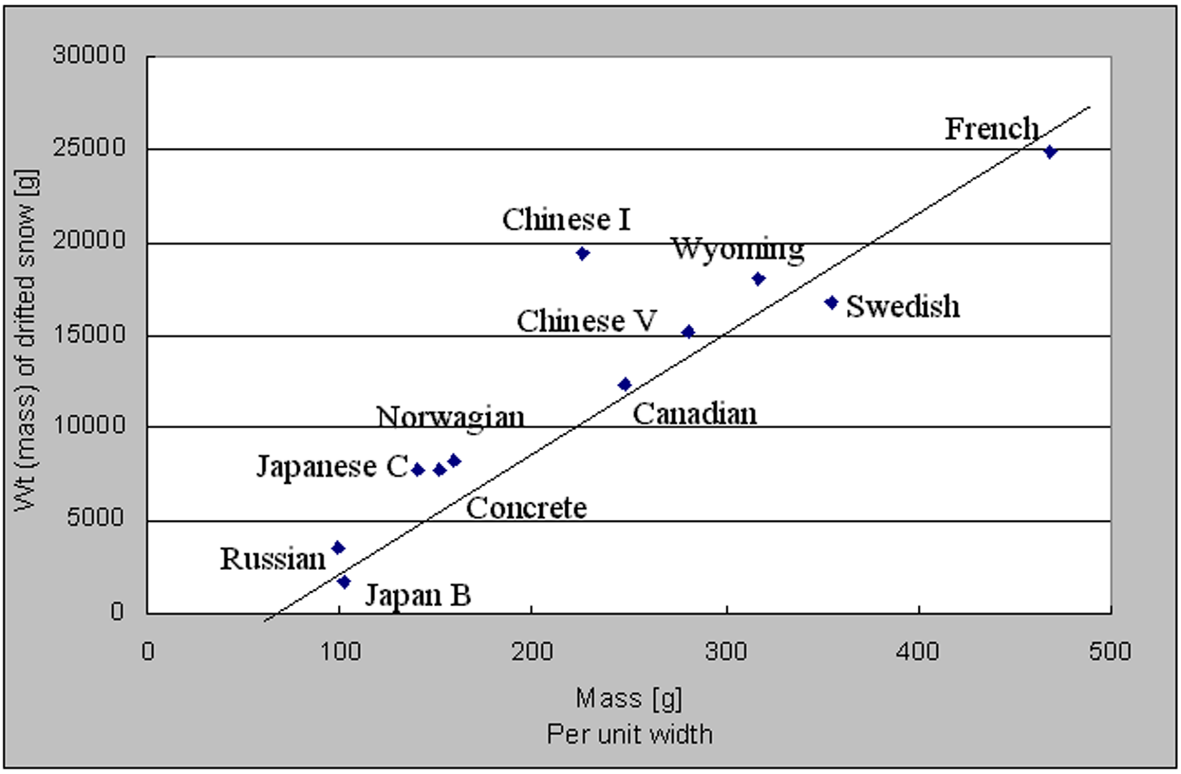


**Figure 8. Relation Between Total Weight (Mass) Of Drifted Snow And Catch Mass Per Unit With For All The Models Tested.**

## 6. Concluding Remarks

When the the final shapes of the drifted snow were compared (Figure 6), it was observed that, Norwegian, Japanese vertical, Wyoming, and Chinese vertical had their heighest catch at a distance four times the height of catch, whereas Chinese inclined, French, Canadian, Swedish fence models maximum depths shifted away from the fence with different ratios. In case of Russian fence, the shape of the drifted snow profile was observed as very undulating. The same undulation but in softer mode was also observed in case of Swedish fence.

The location of the drifted snow on the leeward side of the fence was found to be nearer to the fence in case of Concrete, Norwegian and Wyoming models and farer for Canadian, Chinese inclined and Japanese blower and the others in between. The end of the drift, i.e. where the road shoulder can be located was found to be at about 10 times of the height ( L/H ratio) for Japanese collecter and Blower, Chinese vertical and inclined models , and the others were at 15 to 27 (L/H). It is very important to remember the nominal heights of the first group, being minimum prototype height 3.5 m.

The snow accumulation on windward side of the fence was observed more in Japanese, Chinese (Vertical and Iinclined) and less in Wyoming and Norwegian snow fence models' testing. When the normalized times to reach the equilibrium height of the models were compared , it was found out that those with the lowest porosity has the shortest and the one with the highest porosity had the longest time as expected. Also the gab of the model with the ground played an important role on it.

## 7. Acknowledgements

This research has been initiated by the special fund of the Science and Technology Agency, Japan to the first author and it is greatly appreciated. The authors wish to thank Dr. Y. Kamata and Mr.T.Takeda for operating the wind tunnel and equipments and their help in the measurements and the analysis of snow grain size, to Dr.F.Naaim-Bouvet and Mr.Xu JunRong for providing the prototype dimensions of French and Chinese snow fences respectively.

## 8. References

- Anno, Y., (1984). “Applications of Anno's modeling conditions to outdoor modeling of snowdrifts.” Cold Regions Science and Technology 9: 179-181.
- Anno, Y., (1985). “Modelling a snowdrift by means of activated clay particles.” Annals of Glaciology 6: 48-52.
- Anno, Y., Konishi, T., (1981). “Modelling the effects of a snowdrift preventing forest and a snow fence by means of actived clay particles.” Cold regions science and Technology 5: 43-58
- Haehnell,R.B., Lever,J.H. and Tabler,R.D., (1997). “Field Measurements of Snowdrift Development Rate.” Western Snow Conference, Banff, Canada.
- Iversen, J. D., (1981). “Comparison of wind-tunnel model and full-scale snow fence drifts.” Journal of Wind Engineering and Industrial Aerodynamics 8: 231-249.
- Jairell,R.L. and R.A.Schmidt., (1987). “Constructing Scaled Models for Snow Drift Tests Outdoors”. Western Snow Conference ( Vancouver, BC, Canada) Proceedings 56: 170-173.
- Kitami Institute of Technology, (1986 ). Studies on Improvement of Snow Fences, sponsored by Sanwa Shatter Co, (Report in Japanese),212 p.
- Kobayashi,S., (1979). “Studies on Interaction Between Wind and Dry Snow.” The Institute of Low Temperature Science, A:No:29,pp1-64
- Kosugi,K., Sato,T., Sato,A., Sugiura,K., Nishimura, K., Maeno, N., (2000). “Saltation Lengths of Drifting-snow Particles over Hard-snow Surfaces.” Int. Symp. On Snow,Avalanches and Impact of the forest,Insbruck, Austria
- Naaim,F., Brugnot G., (1992). “Transport De la Neige par le Vent.” Cemagref, Division Nivologie, France.
- Naaim-Bouvet, F., (1997). “Contribution a la Modelisation Physique et numerique du Transport de Neige par le Vent.” ( Ph.D.Thesis, University of Grenoble)
- Pomeroy, J. W., (1989). “A Process-based Model of Snow Drifting.” Annals of Glaciology 13: 237-240.

- Sato,T., Kosigi,K., Sato, A., (1999). “Wind Tunnel Experimentsof Drifting Snow Using Snow Particles.” Cold Region Conference, pp 50-54, Japan.
- Sato, T., Kosigi, K., (2001). “"Saltation Layer Structure of Drifting Snow Observed in Wind Tunnel" Annals of Glaciology, 32.
- Sundsbo ,P., ( 1997). “Numerical Modelling and Simulation of Snow Drift.” Applications to Snow Engineering, NTNU Engineering Doctorate Thesis, Trondheim.
- Tabler, R. D., (1980). “Self-similarity of Wind Profiles in Blowing Snow Allows Outdoor Modeling.” Journal of Glaciology 26(94): 421-434.
- Tabler, R. D., (1991). “Snow Fence Guide.” Washington, National research Council, Strategic Highway Research Program.
- Tabler, R. D. and L. Jairell, (1980). “Studying Snowdrifting Problems with Small-scale Models Outdoors.” Western Snow Conference.
- Takeuchi,Y., Kobayashi,S., Sato,T., Izumi, K., Kosigi, K., Wang,X.,Zhang, J., Peng,Y., (2001). “The Effect Of Wind Direction on Drift Control by Snow Fences.” Annals of Glaciology, 32, 159-162.