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Schaerer, P. A.

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STUDY OF SNOW PROBLEMS ON EXPRESSWAYS IN JAPAN

Report prepared for Nihon Doro Kodan

by Peter Schaerer

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TERMS OF REFERENCE

Nihon Doro Kodan (Japan Highway Public Corporation) invited experts from Canada for a study visit of snow and ice control problems on national expressways built and maintained by Nihon Doro Kodan. The visit was made 20 February to 3 March 1978 by P.J. Carr of the British Columbia Department of Highways, J. Hode Keyser of the Ecole Polytechnique de Montreal, and P.A. Schaerer of the National Research Council of Canada.

During the visit information concerning snow and ice control on expressways in Japan was obtained from meetings with staff of Nihon Doro Kodan at their headquarters in Tokyo, at construction offices in Sapporo, Nishine, Sendai, and at several maintenance offices. Observations on location were made at the Doo Expressway, the Tohoku Expressway between Kazuno and Sendai, the Kanetsu Expressway between Yuzawa and Nagaoka, and the Hokuriku Expressway between Fukui and Tsuruga. All the meetings were well organized, chaired, and documented.

This report deals with the impressions concerning avalanches and drifting snow, two topics in which the author has special expertise.

OBSERVATIONS OF SNOW AND AVALANCHES

It was noted that Nihon Doro Kodan is engaged in a program of collecting data concerning snowfall, weather, and avalanches at planned and constructed expressway sites. The importance of these observations for making decisions concerning the design of the highways and the maintenance facilities must be stressed. Nihon Doro Kodan relates certain design elements to the 10-year maximum depth of snow on the ground, and it was agreed that snow depth is a better choice for this purpose than annual snowfall.

Information about actual avalanche occurrences is valuable for studies concerning avalanche control. It is recommended that observations of avalanches be carried out during as many years as possible before the expressways are built. Observations from the ground usually yield better results than observations made from aircraft, therefore surveys from helicopters or airplanes should be limited to inaccessible terrain. Information about the type of observations that should be made are contained in the Canadian Standards for avalanche observations.

TYPES OF AVALANCHES

The avalanches that threaten the expressways occur on steep natural slopes and on man-made slopes in deep cuts. The natural and man-made avalanche paths frequently cannot be avoided because of the wide curves and low horizontal grades required by the geometric design standards for expressways.

The natural avalanche paths that could be observed during the study tour were rather short. The starting zones were not higher than 300 m above the valley and many of them were covered with a thin forest. This would lead to the conclusion that the avalanches are usually smaller than those observed in Canada.

Information received from the staff of Nihon Doro Kodan and the literature describing avalanche studies in Japan indicate that the majority of dangerous avalanches near highways are full-depth ones that run during the snow melt season in March. The surface-layer avalanches that occur earlier in the winter seem to be small. This was confirmed during the visit when no large avalanche deposits were discovered near the travelled route. The lack of recent avalanches was evident particularly in the Kazuno-Nishine area where, according to experience in Western Canada, the snowfall recorded by Nihon Doro Kodan could produce, on the average four periods of avalanche activity per winter.

In the areas visited the cut slopes had a standard gradient of 1:1 and berms at 7 m differences of height. Experience shows that this type of slope would favor the formation of avalanches, because in Canadian studies most avalanches were observed to start on slopes with inclines of 40 to 45 degrees when no deep snow drifts were present; furthermore, tensile stresses that could lead to a failure develop in the snow at the edge of the berm.

RECOMMENDATIONS FOR AVALANCHE CONTROL

The high-speed and high-volume traffic on expressways demands that avalanches be controlled. They must not be allowed to slide onto the roadways under uncontrolled conditions.

Avalanche control methods found practical in other countries include the modification of terrain, structures, and artificial release. At expressways artificial release through explosions or other methods should be considered for natural avalanche paths with infrequent avalanches only, because the method requires extensive control of traffic and closure of the highway. The artificial release must not be applied at cut slopes because the avalanching snow would be deposited on the highway and would have to be hauled away. Furthermore, the time required for the release of the avalanches and snow removal would be intolerably long.

Japan has a high standard of avalanche control on their National Highways and National Expressways. Retaining barriers and snow sheds were evident at numerous avalanche sites, even on highways with low traffic volumes. In Canada, avalanches would not be controlled on highways with similar avalanche and traffic conditions.

Because avalanches are caused by a combination of several factors such as snowfall, temperature, wind, shape and incline of terrain, and vegetation, and because the relative significance of them varies with the area, caution must be used in applying control measures. A type of control proven in one avalanche area may not necessarily be the most advantageous in another. For this reason it is recommended that avalanche control be studied for each area individually.

AVALANCHE CONTROL ON CUT SLOPES

Several alternatives that may be investigated for avalanche control on cut slopes follow. In all alternatives attempts should be made to plant trees on the cut slopes.

a) Reduction of the slope gradient - Experience in Western Canada shows that cut slopes with a gradient 1:2 do not produce avalanches. Slopes with a gradient 1:1.5 do not usually produce avalanches or only small ones when:

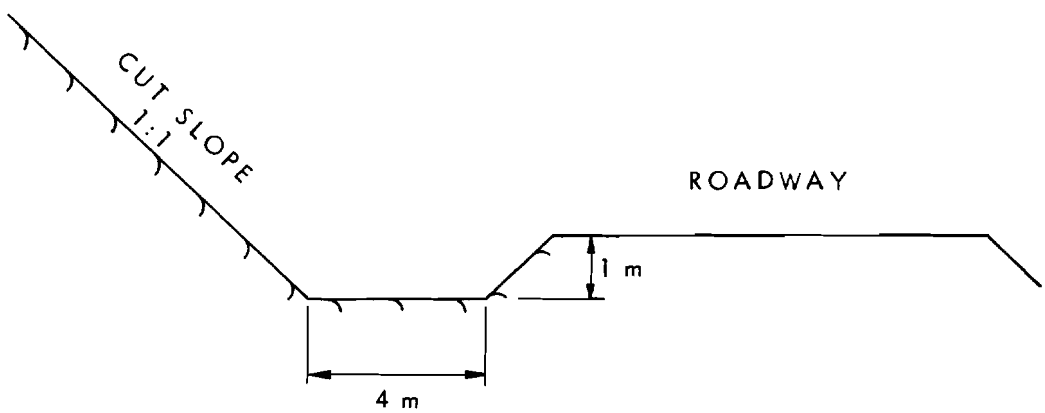
   - there is no accumulation of drifting snow
   - the snow depth does not exceed 2 m
   - there are no irregularities such as rock outcrops

   It is not known whether or not these conclusions are applicable to avalanche conditions in Japan, and it is recommended that studies be made concerning the influence of the slope incline on the formation of avalanches. Observations of test slopes would be advantageous. A lower incline is usually needed to maintain the motion of the avalanche rather than to initiate it, therefore studies must distinguish between the slope gradient at the point of fracture and that in the avalanche trace.

   A reduction of the slope gradient in cut slopes may not only inhibit the formation of avalanches but has the additional benefits of reducing erosion, giving better conditions for the growth of vegetation, thus being aesthetically more pleasing.

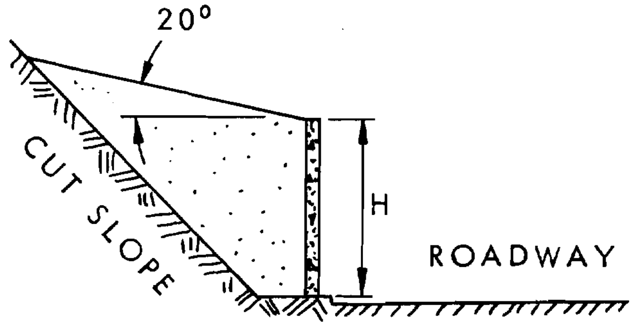
b) Retaining barriers - Barriers when built high enough and spaced densely enough are the most effective avalanche control, but are probably also the most expensive. The height of the barriers must take into consideration the depth of snow from snow fall and drifting as well as snow deposited on the slope by snow blowers.

c) Wide ditch - A ditch 4 m wide and 1 m deep at the toe of the cut slope would catch the avalanche snow on short slopes.



The method could be applied at slopes not higher than 15 m and at locations where it would be easy to obtain the additional width of cross section.

d) High barrier at the toe of the slope - A barrier or concrete wall at the toe of the cut slope will catch the avalanche snow.



The space behind the barrier, height H, must be sufficient to store the expected volume of avalanche snow and snow deposited by snow blowers.

The volume of avalanche snow A is:

$$A = Cr \cdot Cd \cdot L \cdot D$$

where

L = length of the slope

D = maximum depth of snow

Cr = coefficient of the roughness of the ground;
on smooth, even ground Cr = 1
on ground with berms, rock, shrubs, Cr = 0.5

Cd = coefficient taking into account the increase of density of the sliding snow, dry snow Cd = 0.75
wet snow Cd = 0.5

e) Berms - In Canada berms across slopes were found to have limited success in inhibiting avalanches, but experiments in Japan appeared to be favourable. Berms are probably more successful in areas with wet snow which deforms plastically and relieves stresses more readily than dry snow. This would lead to the conclusion that berms could be applied in Honshu, but not in Hokkaido.

AVALANCHE CONTROL ON NATURAL SLOPES

The alternatives of control listed for cut slopes may also be applied at natural avalanche slopes. In addition to the methods discussed, deflectors and reforestation should be considered.

Deflectors of earth or concrete can usually be built at relatively low cost, but they require space for the structure and room for the avalanches to run out harmlessly.

A dense forest in the starting zone of the avalanches is an effective control, but many years are required before the trees will grow large enough. Retaining barriers might have to be applied in the meantime.

DRIFTING SNOW

The principal problems with drifting snow at the expressways of Nihon Doro Kodan appear to arise from the location of snow fences, the formation of drifts behind guard rails, and the restricted visibility because of blowing snow. Snow drift problems are being given much attention. A study of fences is being carried out at the Tohoku Expressway South of Morioka and should yield valuable information. Sketches of the snow fences lay-out at the Sasson Expressway, discussed at the meeting on March 23rd at Sapporo, show that snow drift problems are being studied conscientiously and the snow fences planned according to the best knowledge.

a) Fence location - A basic rule requires fences to be placed at about a 90° angle to the direction of the wind, but the difficulties are to estimate the direction of the wind which would produce snow drifting and to account for variable wind directions. Experience has shown that the best fence location is found by trial and error on the site. About three winters of experimenting are usually necessary, and for this reason portable, removable fences should be used initially.

In complex terrain, such as cut and fill sections over short distances, interchanges, tunnel entrances, and irregular boundaries of forests, the wind is often deflected and forms drifts at unexpected locations. In such cases the location of drifts and countermeasures can be studied in a model test. Model studies in a waterflume, developed by F.H. Theakston at the University of Guelph, Ontario, Canada, have been found most successful.

b) Drifts at guard rails - This problem exists in Canada to a lesser degree because there is little need for embankments higher than 1.5 m in open terrain, and the medians are wide and require no barriers. There does not appear to be any ready solution for the prevention of drifts at guard rails. One method of mitigating the problem would be to build the highway fill sections about as high as the maximum snow depth and sloping them with a gradient 1:4 or less. The flat slopes would eliminate both the need for guard rails and the formation of drifts at the shoulder, but drifts would still form at the barrier in the median.

c) Restricted visibility - This problem is encountered frequently in Canada, particularly on the Prairies, and the only solution known is to warn road users and to close the highways when necessary.

CONCLUDING REMARKS

The study visit showed that Nihon Doro Kodan is making a strong effort to find solutions to snow problems on the National Expressways.

Thanks are due to Mr. Mitsuyoshi Maeda, President of Nihon Doro Kodan for making this visit possible.