文章编号: 1008- 2786(2005)01- 043- 10

# The Occurrence and Mitigation of Drifting Snow and Avalanche Hazard in the Mountains along the Jinghe-Yining Railway, Tianshan, China

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**Abstract:** In this paper, the meteorological factors along the Jinghe-Yining Railway are estimated and analyzed. After carrying out the field investigations and the laboratory analyses, the principles of designing the railways in the regions where snow disasters occur frequently, and of preventing and controlling measures of snow disasters, are put forward. It is considered that the suitable height of the railway embankment is in a range of 200~ 1 500 cm. If the embankment is lower than 200 cm, the deposition of drifting snow is easy to occur on the railway; the drifting snow deposition may not occur if the embankment slope is steep, the slope of the cuts is gentle, the cuts are deep, and the angle between the cutting alignment and the prevailing wind direction is small. It is suggested fences secondarily using corridors and lower wind-guiding boards mainly, and with side wind-guiding boards, snow-catching. In the regions where the avalanche disasters occur frequently, it is suggested to build the open railway sections on the south side of hills. The permanent buildings and facilities should be built away from the movement and deposition areas of avalanches. The principles of preventing and controlling the avalanche disasters along Railway are to elongate the tunnel fronts for about 3 m and to build the avalanche-guiding dikes at the upper side of the tunnels so as to ensure the safety of the tunnel fronts. During construction of the project, the vegetation along both sides of the railway, especially the trees and shrubbery, should be protected as far as possible.

**Key words:** Jinghe-Yining Railway; drifting snow disaster; avalanche disaster; mitigation; the Tianshan Mountains
中图分类号: U213. 1$^{+}$ 53, X4　　文献标识码: A

The arid areas in northwest China are regions with serious shortage of water resources, and also the mountain regions rich in snowcover resources in China. Among the 3 main seasonal snowcover regions in China[1], the snowcover resources in Xinjiang provide one third of the total in China[2]. Particularly the snowfall is heavy in the Yili River Valley in the western part of the Tianshan Mountains[3].

With increasing development of western China, the Jinghe-Yining Railway is proposed construction to promote the economic development in the Yili region, Xinjiang (Fig. 1). Snowfall is heavy in the Yili region[4], however, the snow disasters occur frequently along the railway. The frequent occurrence of drifting snow restricts the route selection of the railway and will affect the normal operation after the railway is constructed. Currently, there are no available measures to mitigate the drifting snow hazards along the railway. In this paper, the formation and control of the snow hazards along the railway are further ana-

收稿日期(Received date): 2004- 09- 11; 改回日期(Accepted): 2004- 11- 15。
基金项目(Foundation item): 科技部重点基础前期专项(2002CCA046000)资助。[This work supported by The ministry of Science and Technology (Grant No. 2002CCA04600).]
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lyzed based on the field investigations along the railway route and the observed data.

# 1 Estimation of the maximum snowcover depth and the maximum west wind speed

The formation, occurrence and development of the snow hazards along the Jinghe-Yining Railway are strongly affected by the meteorological factors, especially the maximum snowcover depth and the maximum wind speed in winter. These are the main factors affecting the occurrence of snow hazards and the estimation of their risk degree. These meteorological factors, however, can only be estimated by using mathematical methods based on the limited observed meteorological data from the vicinities.

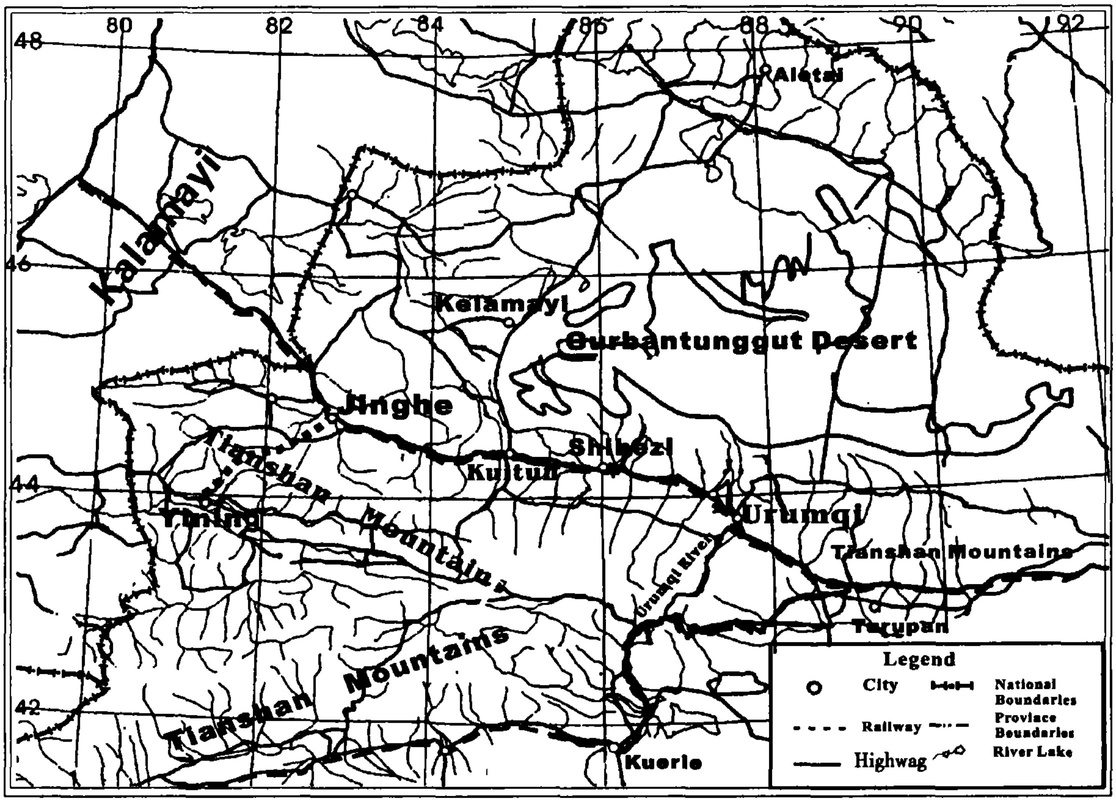


**Fig. 1 Map of Northern of Xinjiang**

## 1.1 Estimation of the of maximum snowcover depth

The maximum snowcover depth in winter is one of the meteorological factors causing the occurrence of drifting snow and avalanches. The maximum snowcover depths along the Jinghe-Yining Railway sections with the serious snow hazards in winter (from November to next March) are estimated for design purposes.

The extreme values of the maximum snowcover depth occurring once every 30, 50, 100, 150 and 200 years at Yining, Nilka, Subbutai and Menmaral are separately calculated (Tab. 1).

## 1.2 Estimation of the maximum west wind speed

Generally, the west wind blows when a weather system occurs in the Yili Region. Therefore, the occurrence of drifting snow hazards is not only closely related to the maximum snowcover depth, but also to the maximum speed of the west wind bringing about the snow drifting. For researching the drifting snow hazards, the 10-minute average wind speed at the height of 2 m should be determined . The extreme

**Table 1　The designed extreme values of the maximum snowcover depth (cm) in winter along the Jinghe-Yining Railway**

| Meteorological Station | | Yining | Nilka | Subbutai | Menmaral |
|---|---|---|---|---|---|
| Elevation (m a.s.l.) | | 663 | 110 5 | 152 0 | 176 0 |
| Estimated values of 40-year averages | Annual precipitation (mm) | 263 | 372 | 592 | 819 |
| | Precipitation in winter (mm) | 106 | 96 | 153 | 212 |
| | Maximum snowcover depth (cm) | 34 | 34 | | |
| Measured or investigated maximum snowcover depth (cm) | | 89 (1968) | 66 (2000) | 140 (2003) | |
| Estimates value of the maximum snowcover depth | Every 30 years | 65 | 61 | 160 | 221 |
| | Every 50 years | 72 | 65 | 171 | 236 |
| | Every 100 years | 82 | 70 | 184 | 254 |
| | Every 150 years | 88 | 73 | 191 | 264 |
| | Every 200 years | 93 | 75 | 197 | 272 |

values of the maximum wind speeds from the western, northwestern and southwestern winds are calculated in this paper.

The extreme values of the maximum winter wind speeds of the western, northwestern and southwestern winds occurring once every 30, 50, 100, 150 and 200 years at Yining are calculated separately (Tab. 2).

In order to convert the wind speed at the height of 10 m to that at the height of 2 m, the exponential profile of wind speed near the ground surface can be expressed as

$$V_{2m} = \left(\frac{Z_{2m}}{Z_{10m}}\right)^{\alpha} V_{10m} \qquad (1)$$

Where, $V_{2m}$ and $V_{10m}$ are the wind speed respectively; $Z_{2m}$ and $Z_{10m}$ are the heights respectively; and a is the exponent[5].

Because the Yining Meteorological Station is located in the suburbs of a large city and the strong speed is one of the researched issues in this paper, the a value of 0.16[5], which is suitable for calculating the strong wind, was chosen. In the equation above, when $Z_{2m} = 2\text{m}$, and $Z_{10m} = 10\text{m}$, the simplified equation becomes

$$V_{2m} = \left(\frac{2}{10}\right)^{0.16} V_{10m} = 0.773_{10m} \qquad (2)$$

The corresponding values are calculated with equation (2) (Tab. 2 and Tab. 3). By using the data in Tab. 3, it is calculated that the ratio of the 10-minute average maximum wind speed at the height of 2 m between Subbutai and Yining is 5.26/3.50= 1.50. This value was multiplied by all the designed extreme values of the 10-minute average maximum west wind (W, SW and NW) speed at the height of 2 m at Yining in Tab. 4. Thus the extreme values of the west wind (W, SW and NW) speed occurring once every 30, 50, 100, 150 and 200 years at Subbutai were obtained (Tab. 2).

## 2　Characteristics of drifting snow hazards and their control

### 2.1　Characteristics of drifting snow hazards

From downstream along the Botitaled River, most of the railway sections run along the top of the hills where the wind speed is high and the drifting snow hazards are serious. The areas with drifting snow hazards are mainly located in the places near the Botitaled River and the places downstream from it to the debouchure of the Buliekai River (Downstream from the Debouchure is a plain where the drifting snow hazards seldom occur).

According the multi-year observed data, the average snowcover depth there was 80 cm. According to the meteorological estimation, the average maximum snowcover depth is 140 cm, and the maximum snowcover occurring once every 30 years are 220 cm in the lofty mountain and 160 cm in the gently-sloping hilly regions.

It should be emphasized that the dominant disastrous type of the drifting snow hazards along the Jinghe-Yining Railway are the deposition of drifting

**Table 2 The extreme values of the maximum wind speeds (10- minute average) in NW, W and SW wind directions in winter along the Jinghe-Yining Railway**

| Meteorological Station | | Yining | | | Yining | | | Subbutai | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Elevation (m a.s.l.) | | 663 | | | 663 | | | 1520 | | |
| Measured height (m) | | 10 | | | 2 | | | 2 | | |
| Sources of wind speed value | | Measured value | | | Value converted with exponential profile of wind speed, $n = 0.16$ | | | Value estimated with wind speed proportional coefficient (1.50) | | |
| Wind direction | | NW | W | SW | NW | W | SW | NW | W | SW |
| Average maximum wind speed (m/s) | | 6 | 12 | 5 | 5 | 9 | 4 | 7 | 14 | 6 |
| Measured or calculated maximum wind speed (m/s) | | 13 | 20 | 10 | 10 | 16 | 8 | 15 | 23 | 12 |
| Designed extreme values of the maximum wind speed | Every 30 years | 12 | 17 | 10 | 9 | 14 | 8 | 14 | 20 | 12 |
| | Every 50 years | 13 | 18 | 10 | 10 | 14 | 8 | 15 | 21 | 13 |
| | Every 100 years | 14 | 18 | 12 | 11 | 14 | 9 | 16 | 21 | 14 |
| | Every 150 years | 15 | 19 | 12 | 11 | 14 | 9 | 17 | 22 | 14 |
| | Every 200 years | 15 | 19 | 13 | 12 | 15 | 10 | 17 | 22 | 15 |

**Table 3 Comparison of the maximum wind speed between Yining Meteorological Station and Subbutai Automatic Meteorological Station**

| Meteorological Station | Yining Meteorological Station | | | | Subbutai Automatic Meteorological Station | | |
|---|---|---|---|---|---|---|---|
| Item about wind | 10- minute average maximum wind speed at height of 10 m (m/s) | Wind direction | Time | 10- minute average maximum wind speed at height of 2 m (m/s) | 10- minute average maximum wind speed at height of 2 m (m/s) | Wind direction | Time |
| April 17 | 5 | SW | 17:00 | 4 | 6 | WSW | 18:00 |
| April 18 | 5 | W | 01:00 | 4 | 6 | WSW | 23:00 |
| April 19 | 4 | W | 15:00 | 3 | 5 | WSW | 15:00 |
| April 20 | 6 | W | 23:00 | 5 | 4 | W | 24:00 |
| April 21 | 3 | SW | 20:00 | 2 | 6 | W | 20:00 |
| Average value | 4.6 | | | 3.6 | 5.4 | | |

**Table 4 Comparison of the west wind speeds between Menmaral Mountain and Yining Meteorological Station in winter**

| Item | Menmaral Mountain (east-west main gully in the upper part of Borbosun Gully) | | | Yili |
|---|---|---|---|---|
| Temporary wind measurement sites | Bottom of gullies | South slope of the main gully, the relative height to the gully bottom is 30 m. | Top of the a hill over the south slope of the main gully, the relative height to the gully bottom is 80 m. | Yining Meteorological Station |
| Sources of values of the wind speed and wind direction | At the height of 2 m, 2- minute average wind speed from the measured data | | | At the height of 10 m, 10 - minute average wind speed from the measured data |
| Wind speed(m/s) / wind direction | 3 / W | 5 / W | 5 / W | 6 / W |
| Sources of values of wind speed | At the height of 2 m, calculated 10- minute average wind speed | | | |
| Wind speed(m/s) | 3 | 5 | 5 | 4 |
| Average wind speed(m/s) | 3 | 5 | | 4 |

snow in the cuts. Drifting snow has an important feature in that it tries to smooth the snow surface or to fill and level up the cuts so as to recover the original mountain slopes[6-8]. The original mountain slopes will be cut in constructing the railway. Thus, the original air current profiles will be destroyed, and the deposition of drifting snow will occur in the cuts. Therefore, the deposition of drifting snow in the cuts is the main hazard type along the railway. According to our statistics data, there are 55 sites of drifting snow deposition in cuts, which provides the highest proportion of the drifting snow hazards. Secondly, the detoured drifting snow along the curved railway sections and the drifting snow from the ridges are also types of drifting snow hazards needing to be controlled.

### 2.2 Principles of controlling the drifting snow hazards

The high embankments are advantageous for reducing the deposition of drifting snow. The average maximum snowcover depth in this region is 140 cm, and the maximum snowcover depths occurring every 30 years are 220 cm and 160 cm in the Menmaral and Taosubbutai regions respectively. In the design of highways, it is requested to design the height of the embankments to be 60 cm higher than the average maximum snowcover depth[9]. We suggest that the embankment height of the railway on the southern slope of the Boroholo Mountain be over 200 cm at least so as to reduce the deposition of drifting snow on the railway embankments.

In order to thoroughly control the serious drifting snow hazards in this region, it is planned to construct corridors which are the most effective for controlling the drifting snow hazards along the railway sections with cuts, and to construct some wind-guiding boards and snow-catching fences along the suitable railway sections[10,11]. However, there needs to be open fields to construct the wind-guiding boards. Thus, the original terrains need to be improved sometimes, the mountain slopes windward from the wind-guiding boards cannot be too steep, the slopes leeward from the wind-guiding boards need to be smoothed so as to let the drifting snow current pass through smoothly. The lower wind-guiding boards are generally constructed along the railway sections with low-filled embankments. The opening height of the wind-guiding boards along the embankments with a little higher height should be rectified so as to let the accelerated wind from the lower wind-guiding boards blow the deposited snow away from the railway.

### 2.3 Principles of designing the railway embankments in the areas with frequent occurrence of snow hazards

#### 2.3.1 Principles of designing the slope angle

The analytical results of previously observations and experiments are shown as Fig. 2. The results show that the influence of change of the windward slope to the wind speed over the road surface is slight, the wind speed at the road shoulder and in the central area of the railway surface does not change with the increase of the slope angle. The wind speed at the toe of the windward slope and 1m to the embankments toe changes rapidly with the change of the slope. The steeper the embankment slope is, the lower the wind speed at the toe of windward slope of the embankments. The wind speed at the foot of slope is sharply reduced with the increase of slope angle of the embankments, and the deposition of drifting snow becomes more serious. Therefore, the slope angle of the embankments has no influence to the wind speed over the road surface but has a great influence to the wind speed at the toe of the slope, the steeper the slope is, the lower the wind speed at the foot of the toe will be. According to the characteristics of the wind speed changes, the principle of designing the slope of embankments is that the slope of embankments should be steep if the conditions are allowable.

#### 2.3.2 Principles of designing the height

When the drifting snow current passes through the railway embankments, the wind speeded is obviously sped up because the air current is compacted. Therefore, if the railway embankments are high enough within a certain range, the deposition of drifting snow does not occur generally when the drifting snow current passes across the railway embankments. In the previous studies of designing the highway embankments along the road sections with frequent occurrence of drifting snow disasters, it was requested that the height of the highway embankments be 60 cm higher at least than the local thickness of natural snowcover so as to preventing the deposition of drifting snow[9].

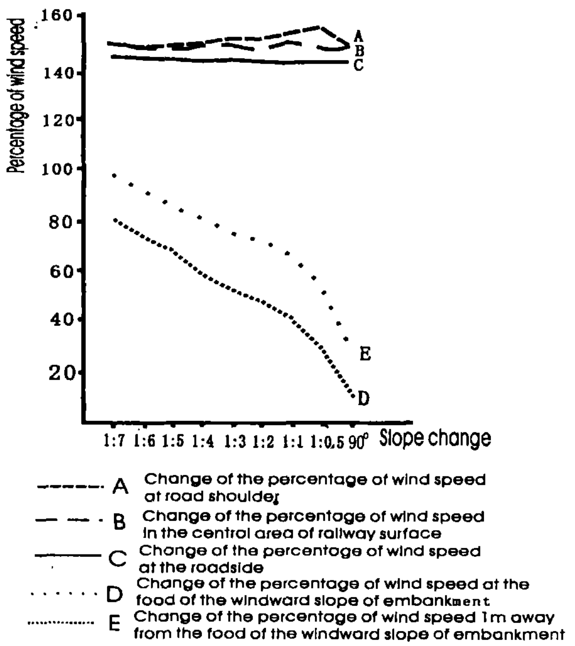


**Fig 2 Influence of the change of windward slope along an embankment section of 1.7 m in height on the wind speed at wind field of 20 cm in height**

(It is assumed that the wind speed at the windward slope of embankments over 20 cm in height is 100%)

The influence of the embankment height on the wind speed over the road surface is shown as Fig. 3. The figure reveals that, within an embankment height range of 0~ 1.5 m, the higher the embankment is, the higher the wind speed over the road surface will be, and the increased amplitudes of wind speed at the road shoulder, roadside and in the central area of the road are similar. However, it does not mean that the higher the embankments are the better. According to measured results on a highway[10], the wind speeds over the central area of the highway surface is 179%, 182% and 94% of that over the flat snow surface when the embankments is 1.5m, 7.5m and 15.0m higher than the flat snow surface.

The average maximum snowcover depth is 140 cm in the regions with frequent occurrence of snow hazards along Jinghe-Yining Railway; the maximum snowcover depths occurring once every 30 years are 160 cm and 190 cm in the gentle-sloped hilly regions downstream from the Botitaled River and the south slope with the frequent occurrence of snow hazards respectively. Thus, the suitable height of embankments in this region should be in a range of 200~ 1 640 cm if the average snowcover depth of 140 cm is taken in the calculation; it should be in a range of 250 ~ 1 690 cm if the maximum snowcover depth of 190 cm occurring once every 30 years is taken in the calculation.

## 2.4 Principles of Designing the Cuts

When the drifting snow current passes over the cuts, the wind speed is sharply reduced due to the sudden enlargement of the wind section. In Fig. 2, the parts of the slope height with the negative values mean the influence of cuts to the wind speed over the road surface. The figure reveals that, within a cutting depth range of 0~ 250 cm, the deeper the cuts is, the lower the wind speed over the road surface will be, especially over the sides of the cuts. If the wind speed unaffected by cuts is 100%, the wind speeds over the central area of the cuts of 100 cm and 200 cm in depth are about 80% and 50% respectively. Therefore, the snow grains carried by drifting snow currents are seriously deposited in the cuts shal-

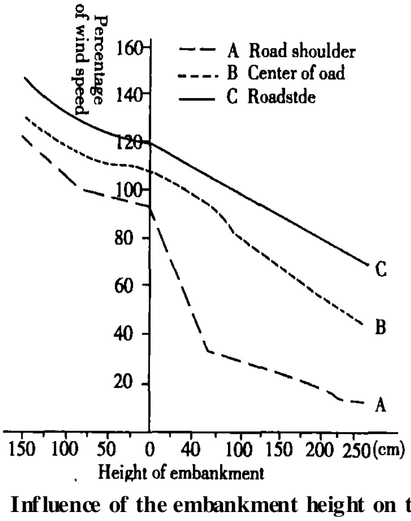


**Fig. 3 Influence of the embankment height on the wind speed over railway surface**

lower than 200 cm, which will seriously block the traffic. It is mainly related to the slope length of the cuts (i. e. the snow storage capacity of the cuts or the critical stored snow volume) and the drifted snow volume from the windward slopes of the cuts whether the deposition of drifting snow occurs in the cuts deeper than 200 cm or not (Fig. 4).

A lot of measured data reveal that the deposition of drifting snow may occur in the cuts when the windward slope of the natural snowcover is 1∶7[9]. The deposition of drifting snow occurs in the marginal zones of the windward slopes first, and then extends gradually towards the central area of the cuts (Fig. 4). There is an apex at the front of a deposition body of drifting snow, and its angle is always about 45°. There is only a little deposited snow on the railway surface before the front of the deposition body of drifting snow extends to the railway margin (i. e., the BC line in the figure) in the cut, and the railway traffic is almost not affected; if the deposition of drifting snow continues, the front of the deposition body of drifting snow will extend over the BC line and the railway will be buried by snow, and the railway traffic will be blocked. Therefore, the BC line is called the critical line of blocking traffic, and the total stored snow volume in the triangle ABC is called the critical stored snow volume of the slope. During the whole season with heavy snowfall and strong wind, the railway traffic will not be blocked if the shifted snow volume from the windward slope is smaller than the critical stored snow volume of the slope, and conversely, the railway will be buried by the deposition of drifting snow.

The critical stored snow volume can be obtained by multiplying the area of the triangle ABC with the unit length, the shifted snow volume from the windward slope of the cut is jointly affected by the snowcover area, snowcover depth, wind speed, duration of drifting snow and angle between the cut alignment and the prevailing wind direction. The shifted snow volume can be expressed as

$$V = khvts \cdot \sin\beta \qquad (3)$$

Where, $V$ is the shifted snow volume; $k$ is a coefficient; $h$ is the snowcover depth, $v$ is the wind speed; $t$ is the duration time; s is the snowcover area where the snow grains can be blown away; and $\beta$ is the angle between the prevailing wind direction and the cut alignment. Equation (3) reveals that the shifted snow volume from the windward slope of the cut is closely related to the angle between the prevailing wind direction and the cut alignment. The angle between the prevailing wind direction and the cut alignment is smaller, the shifted snow volume from the windward slope of the cut will be less. If the angle is zero, the shifted snow volume also will be zero, and the deposition of drifting snow will not occur in the cut. Therefore, the smaller angle is advantageous for preventing the deposition of drifting snow.

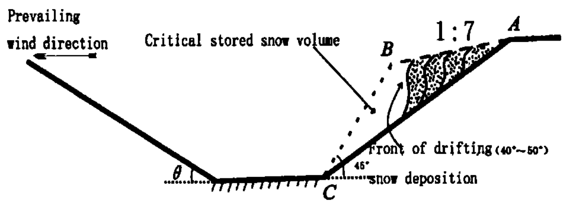


**Fig. 4 Sketch figure of drifting snow deposition in a cut**

The factors mentioned above are different for different cuts, so the total shifted snow volumes during the whole snowcover duration are difficult to calculate. Thus it is difficult to determine an accurate design value for the stored snow volume on the windward slope of each cut to prevent the deposition of drifting snow. However, the area of the triangle $ABC$ is large, the critical stored snow volume of the slope is high, and the probability that the railway will be buried by the deposited snow is small if the slopes of the cuts are long, gentle and deep.

# 3 Avalanche hazards and their control measures

## 3.1 Characteristics of the avalanche hazards

The important conditions for the occurrence of avalanches are the steep slopes and high elevation difference. Therefore, the avalanche hazards occur mainly from the lofty mountains in the region unstream from the Botitaled River to the front of Menmaral Tunnel. The avalanche hazards are serious in the region because of the thick snow cover, large elevation differences, steep mountain slopes and the well-growing grasses all facilitate the occurrence of avalanches. According to our investigations, there is a possibility for avalanches of various sizes to occur from all the slopes. According to the statistical data, the average snow cover depth and the average maximum snowcover depth are 86 cm and 140 cm, respectively in the areas where the avalanches frequently occur. Therefore, a snow cover depth of 140 cm is taken to calculate the possible avalanche volumes and the possible converging avalanche volumes. The disastrous types of avalanches are mainly the slope avalanches and the slope-gully avalanches. The characteristics of the avalanches occurring easily the south and north sides of hills are different. The snow on the south side of the hills melts easily, so most of the avalanches on the south side of hills occur during the snowfall season. The duration of avalanche occurrence is short, the large avalanches are less frequent, and the consequences of disasters are relatively less serious. The snow on the north side of hills does not melt rapidly, so the avalanches on the north side of hills may occur from the beginning of snowfall season until the next snow melt season. The duration of avalanche season is long, tremendous avalanches are more, the volume of avalanches is high, and the hazards are serious.

### 3.2 Principles of route selection in the areas with frequent avalanche hazards

1. The advantageous terrains should be used fully in the route selection of the railway, and the open railway sections should be selected on the south side of hills as much as possible. As mentioned above, the snowcover at the north side of hills is shadowy and humidity, the avalanche hazards are serious. On the south side of hills, the size of the avalanches is relatively small, the hazards are slight, and the hazardous period is short. Fresh-snow avalanches occur frequently, but their volumes are small, and their prevention and control are easy. Therefore, the open sections of the railway should be selected on the south side of hills as far as possible in the areas upstream from the Botitaled River.

2. The permanent buildings and facilities should be located away from the movement and deposition areas of the gully avalanches as far as possible. The bodies of the gully avalanches generally converge, their speed is high, the avalanches have a strong wallop and the potential for serious destruction. If the railway and bridges are perpendicularly extended in opposition to the route of the gully avalanches, they are prone to be destruction.

3. The piers, extension lines and tunnel fronts of the railway must be away from the movement and deposition areas of the avalanches. They should be constructed on the ridge sites between two avalanche gullies so as to avoid the destruction of avalanches to the railway as far as possible.

4. The railway should be constructed on the upper parts of the slopes as far as possible because the avalanche bodies on the lower parts of slopes are the largest.

### 3.3 Principles of mitigating the avalanche hazards

1. There are the slope avalanches from the upper side of the most tunnel fronts, so the tunnel fronts should be extended for 3 m so as to prevent the avalanches from entering the tunnels and to ensure the safety of the tunnels.

2. During the construction of the project, the natural vegetation, especially the tress and shrubbery that can fix the snow on the slopes, should be protected as far as possible.

3. During the construction of the project, the original slopes should not be destroyed as far as possible so as to protect the natural vegetation and be advantageous for preventing and controlling the avalanche hazards.

## 4 Conclusions and discussion

1. The wind speeds are high and the prevailing winds are westly in the areas downstream from the Botitaled River, where the drifting snow hazards fre-

quently occur.

2. In the areas where the drifting snow hazards occur frequently, the deposition of drifting snow in the cuts is the main disaster type, near the ridges. According to the characteristics of drifting snow deposition along the Jinghe-Yining Railway, the principles of designing the embankments are put forward: the suitable height of the embankments for preventing drifting snow hazards is in a range of 200~ 1 500 cm, the embankments are subject the deposition of drifting snow if they are lower than 200 cm, and the deposition of drifting snow is not easy to occur on the embankments with steep slopes. The principles of designing the cuts of Jinghe-Yining Railway are also put forward: the slope of the cuttings should be gentle, the cuttings should be deep, and the angle between the cutting alignment and the prevailing wind direction should be as small as possible. The measures for preventing and controlling the drifting snow hazards are dominated by corridors and wind-guiding boards, assisted by side wind-guiding boards and snow-catching fences.

3. The avalanche hazards along the Jinghe-Yining Railway occur mainly in the lofty mountain areas upstream from the Botitaled River to the front of the Menmaral Tunnel. The most disastrous types are the slope avalanches and slope-gully avalanches. On the south side of hills, most of the avalanches occur during the snowfall season; the duration of the avalanches is short; the tremendous avalanches are less; and the avalanche disasters are slight. At the north side of hills, the snow cover is not easy to melt; the duration of occurring avalanches is long; the tremendous avalanches are more frequent; the avalanche volumes are great; and the avalanche disasters are serious.

4. The principles for route selection of the railway are: the open railway sections should be constructed on the south side of hills; the permanent buildings and facilities should be away from the movement and deposition areas of the convergent and gully avalanches.

5. The principles of preventing and controlling the avalanche hazards along the Jinghe-Yining Railway are: all the tunnel fronts need to be prolonged for 3 m; the avalanche-guiding dikes should be constructed on the upper side of the tunnels based on the avalanche disaster situation so as to ensure the safety of the tunnels; during the construction of the project, the natural vegetation, especially the trees and shrubbery, should be protected as far as possible.

Through field investigations and laboratory analysis, the formation, occurrence and distribution of the snow hazards along the Jinghe-Yining Railway are basically understood. The principles of locating the railway and the measures of preventing and controlling the hazards in the areas where they frequently occur are put forward. The theoretical basis for the principles of designing the embankments and cuts in the areas with the serious drifting snow hazards is plentiful, and this will fill in some gaps in the previous studies.

## 5 Acknowledgements

The study is supported by the Early-stage Special Program of Key Foundation, Ministry of Science and Technology of China (2002CCA04600) and the Knowledge Innovation Program of Chinese Academy of Sciences (KZCX2- 305).

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# 新疆精(河)–伊(宁)铁路沿线雪害形成机制及其防治工程措施

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摘要: 天山西部的降雪丰富, 伊犁河流域年最大雪深普遍超过 60 cm, 中国科学院天山积雪与雪崩研究站和伊犁的最大雪深分别高达 152 cm 和 89 cm。因此, 天山西部山区风吹雪和雪崩灾害较多, 严重影响着当地的交通安全。新疆精(河)–伊(宁)铁路经过的缓坡丘陵区是风吹雪灾害多发区, 崇山峻岭区是雪崩灾害多发区。通过对铁路沿线的气象要素进行分析与推算, 结果表明, 该地区的最大风速平均值 14.0 m/s, 30 a 一遇的最大风速与最大积雪深度分别为 20.3 m/s 和 160 cm; 平均冬季降水量 153.2 mm, 为风吹雪灾害的发生提供了物质与动力条件。在风吹雪多发区, 风吹雪的主要危害类型是路堑型风吹雪沉积, 其次为低路堤型风吹雪沉积等。经过野外考察和室内分析, 基本上查清了精(河)–伊(宁)铁路沿线风吹雪的发生与分布规律, 并且针对性地提出了铁路在雪害多发区的设计原则和雪害防治方法。认为路堤防风吹雪的适宜高度为 200~1 500 cm, 路堤若低于 200 cm, 路面上易发生风吹雪沉积; 若路堤的边坡较陡, 则路面上不易发生风吹雪沉积; 路堑边坡的角度越小, 路堑越深, 路堑走向与主导风向的夹角越小, 风吹雪沉积越不易发生; 风吹雪的防治应以防风吹雪走廊和下导风板为主, 并辅以侧导板、挡雪墙等工程。

精–伊铁路雪崩灾害主要发生在崇山峻岭区, 主要类型为坡面雪崩和坡面沟槽雪崩。阳坡雪崩多发生在降雪季节, 雪崩危害相对较少; 阴坡积雪不易融化, 雪崩危害大。阴坡雪崩在整个冬季从开始下雪直到次年春季积雪融化以前都可发生, 危害时期长。在雪崩灾害的多发区, 铁路选线时明线工程最好能选在阳坡, 永久性建筑物或设施要尽量避开沟槽雪崩的运动区和堆积区; 铁路线横穿河流处, 桥梁的桥墩和铁路延伸线一定要避开沟槽雪崩的运动区和堆积区, 尽量选在两雪崩之间的山梁或山脊处, 隧道出入口也要选在突出的山嘴或山梁等正地貌部位。在其他条件允许的情况下, 线路应尽量向坡面的上部抬升。精–伊铁路沿线雪崩灾害治理原则: 在所有的隧道出入口, 隧道再向外延伸 3 m, 上方再修建导雪堤, 可保隧道口的安全; 在工程建设过程中, 要求尽量少地破坏铁路两侧的植被, 特别是树林和灌木。

关键词: 精(河)–伊(宁)铁路; 天山; 风吹雪; 雪崩; 防治工程