STUDY ON SNOW DISASTER PREVENTION AND TREATMENT ALONG G312 GUOZIGOU HIGHWAY IN XINJIANG

Xiaoguang Chen and Junchao Li
Xinjiang Traffic Science Institute
No. 17 Jingyilu, Urumqi, Xinjiang, China, 830000
Tel: 86-991-5813414, Fax: 86-991-5813882
Email: xg_chen0991@sina.com

1. Abstract

National Highway G312 is an important trunk line from China to the Western Asia and Europe. In Winter, the snow disaster at Guozigou influences the transportation a lot along this line, sometimes the traffic would be cut, and sometimes at worse it causes people's lives. From 1996 to 1999, we carried thorough and comprehensive research on snow disasters at Guozigou, the reason was analyzed, experimental constructions were built. We summarized our former experience in snow prevention constructions and experimental projects, assimilated the advanced experience in Japan, Switzerland and Russian, put forward the construction methods and biological methods for treating the snow disasters at Guozigou, and finished the construction design.

2. Introduction

National Highway G312 is the longest highway from the east to the west in China, and it is an important trunk line from China to the Western Asia and Europe, it has a large traffic and considerable economic significance. The Guozigou section of this line is on the west part of Northern Tianshan Mountains, the physiognomy is of Tianshan Mountainous area, the sea-level is 1710 – 2130m, the line crosses water corroded mountainous area, the geology structure is complicated and mainly of marine facies stratum. The climate in summer is warm and wet with abundant rain-fall; In water, it is cold and the maximum thickness of snow cover is over 140 cm..

The Guozigou section is 80 km, the accumulated length of sections with wind-blown snow is about 6km, and that of sections with snow-slide is about 2km, Every year in winter the snow disaster (wind blow snow, snowslide) caused a lot of transportation disasters. According to incomplete statistics, since 1960, the snowslide has caused 26 lives lost; from Mar 15 to Mar 16 in 1999 the continuous wind blow snow blocked more than 5,000 vehicles in Guozigou for more than 38 hours.
For the snow disaster at Guozigou, we have carried comprehensive study of treatment methods. After deep investigation, winter observation, analysis of the reason for snow disaster, treatment methods research and experimental engineering, we finally finished the design of snow disaster prevention engineering.

3. Reason for the Wind-blown snow and snowslide

3.1 Reason for wind-blown snow

The sections with wind-blown snow were mainly at K4741-K4753 before and after the hill (See figure 1) and at K4762-K4779 in the channel along the brook. The reason of wind-blown snow at K4741 – K4750 was mainly that the down-hill wind caused highway leeward snow deposit; At

K4750-K4751, the up hill wind and great excavation caused weak wind area, and large amount of snow particle deposited there; At K4751 - K4753, most of road base was of half excavation half filling, because of the change of the profile of topography which slowed down the speed of wind, the wind-blown snow fell down, and deposited on the road surface. The wind speed at these sections was generally 6-15m/s. At K4762-K4779 section along the brook, the great change of temperature formed air current, and a snow wind current along road line caused deposit of snow, the snow cover on road surface was about 0.8-1.2m, and the wind speed was about 8-18m/s.

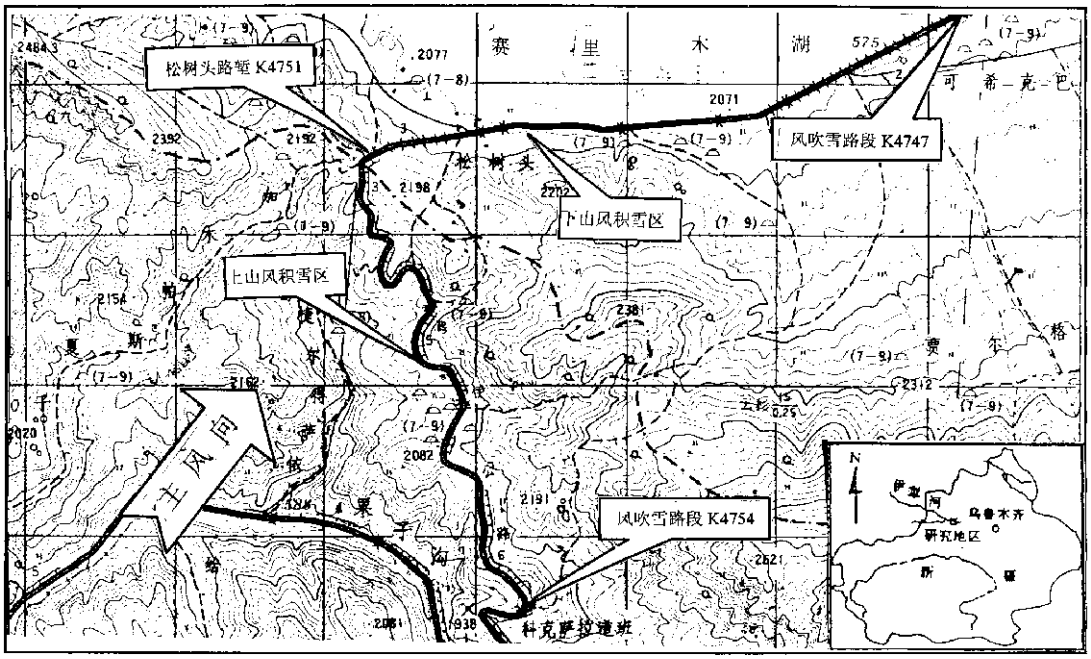

Figure 1 Plan view of highway sections with wind-blown snow

3.2 Reason for snow slide

Snowslide at Guozigou took place concentratively at K4767 – K4771 sections in the channel along the brook (See Figure 2). There were facing sun slope snowslide and shady slope snowslide. The facing sun slope snowslide was represented by red-soil slope at K4767+400 – K4768+700; and the shady slope snowslide was represented by white-soil slope at K4769+560. The reason for frequent snow slide was of many aspects, the main reasons were: (1) Large amount snow deposit; (2) Enough area of snow conflux; (3) Suitable topography for snow slide; (4) Suitable grade which can cause slide and suitable ground surface conditions.

The reason for frequent facing sun slope snow slide was that there was 5 valley slopes which formed a snow slide area up the 200-300 high steep stone walls, their grades fell into the snow slide suitable grade segment 24^{o} ～55^{o}. See Table 1.

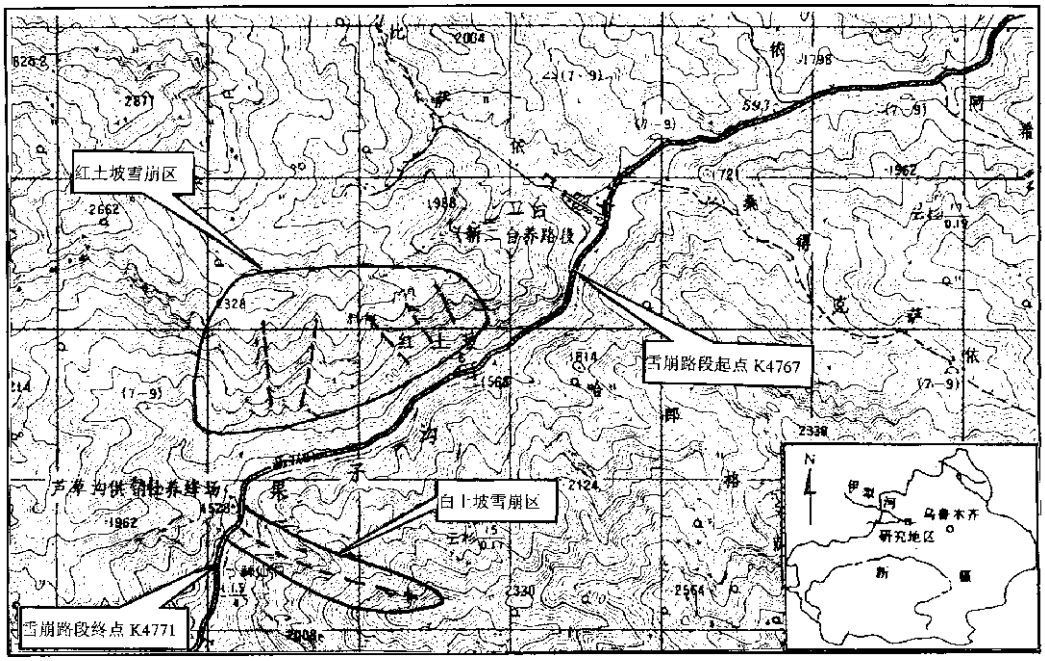

Figure 2 Plan view of snow slide sections

These five slopes had very good biology coverings, the height was about 30-80cm. The soil on these slopes was of humus soil plus small stones, 0.4-1.0m under the surface was the rock base. When the winter comes, the vegetation withered and falls down, which forms a good slide surface for snow slide.

Table 1 Grades of 5 slopes and snow slide sections

No.	Length of Snowslide slope	Width of Slope（m）	Minimum grade	Maximum Grade	Average Grade	Area of snow conflux
No.1 slope	490	33～180	21°	55°	35°	50225
No.2,3 slope	600	20～210	25°	63°	36°	69000
No.4,5 slope	490	25～180	26°	59°	38°	52185

In the early winter, because of the temperature change, it is easy to form an ice shell on the fallen down snow surface. As the snow accumulates, the ice shell was kept. Under the the action of weight, the covering snow is easy to slide and snow slide takes place.

The path of shady white soil snow-slide is in a large gully (See figure3). From the origin of snow slide to the deposit area, the sea level difference is about 740m, the length of gully is 1500m. At the snow slide area, the slope area is about 300×400m, the flowing area is of gullies about 1300m long，the grade 32°，50～200 m wide, the two sides are of sheer precipices and overhanging rocks and have few branches. The under cushion is good growing vegetation. The suitable snow slide conditions make frequent occurrences at this area, the general snow amount of snowslide is about 8000-8000 m^3. The damaged trees showed the high speed and great energy of

snow slides.

4. Damage extent of wind-blown snow and snowslide

4.1 Extent of damage of wind-blown snow

Figure 4 Traffic Cut

Figure 5 Snow Deposit On Slopes

The snow conflux area of wind-blown snow at K4741～K4753 is 15750000m^2，and 1430000m^2 at K4750～K4753，the wind-blown snow frequently caused the leeward snow deposit and bad driving sight. According to statistic materials, the number of traffic cuts caused by wind-blown snow is about 15-20 each year.

4.2 Extent of damage of snowslide

According to incomplete statistics, during 1994 and 1998, there were total 16 sun facies red-soil slope snowslides at K4767+400～K4768+700, the amount of snow was about 100～16800m^3，caused 8 traffic cuts, three lives. There are snowslides when the snowfall reached the average level at this section. There was a large scale snowslide in 1994 at K4769+560 the shady white-soil slope, the amount of snow was 80000m^3, a wagon was buried, 14 of total 17 people were dead.

It can be seen that there was a high frequency of snowslide in the sun facies slopes with small amount of snow and a low frequency in the shady slopes with fast speed and large amount of snow, they are all badly endangering the highway transportation.

5. Comparison of methods of snow disaster prevention

5.1 Methods of wind-blown snow prevention

The methods of wind-blown snow treatment are classified into snow blocking and snow guiding engineering. The snow blocking engineering mainly includes snow fence, snow protection wall and snow protection woods; The snow guiding engineering includes wind guiding board, blowing snow fence etc.

5.1.1 Snow blocking engineering

The function of snow blocking engineering is to slow down the speed of wind-blown snow, cause snow deposit, decrease the snow content in the wind, so that there is no or less deposit of snow on the road surface.

a. Snow fence (See Figure 6)

They were made from wood, metal and lattice materials. Because the wood structure has less strength, short usage time and is easy to be damaged, now it is used little. The metal structure fence is used widely in Japan, Swetherland, it has strong strength, long usage time, but it is expensive and used little in China. There are two types of snow lattice fence: one is metal lattice, the other plastic lattice. Many types of plastic lattice were made in China, they can satisfy the requirements of snow blocking. But plastic lattice ages fast, general when without or with little press, it can be used in 5 – 10 years. If it is pressed continuously in a long time, plus the aging effect of ultraviolet radiation, its usage time would be greatly reduced. The metal lattice is made from steel wire, strong and can be used longer. Except accident damages, only normal maintenance is required.

Snow fences have fixed and mobile fences two kinds. Fixed fences are used in areas with small snow conflux area; Mobile fences are used in areas with large snow conflux area, as snow accumulated on the back of snow fence, the snow blocking effect of snow fence is reduced gradually, it is needed to move their location so that the snow fences can play their functions. At Songshutou and places along Tianshan Highway with large amount of snow, snow fences were all used.

Snow fences need protection and maintenance, besides normal maintenance, it is need to prevent from the damage by animals or people.

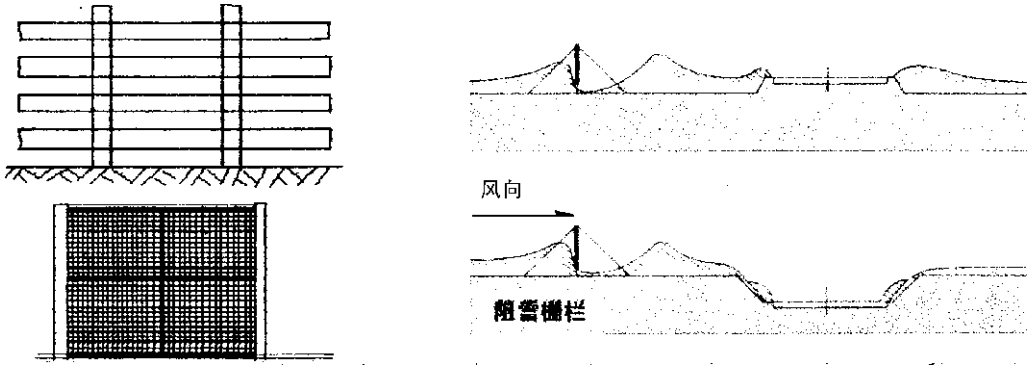

Figure 6 Type of snow fences

b. Snow protection wall

Snow protection wall can also purify the snow current. They can be of brickwork, stonework or even earthwork. The function of snow protection wall is to cause the snow deposit on the back of the wall when the snow current goes up the top of the wall. Because wall is air proof, its effect is not as good as snow fences.

Snow protection walls also need frequent maintenance, when together used with snow fences and snow protection woods, they can protect snow fences and snow protection woods.

c. Snow protection woods

Snow protection woods (see figure 7) have good effect. From the research results of foreign countries, there are lots of panegyric for snow protection woods. If the water, soil and climate are suitable, generally the method of snow protection woods combined with other engineering methods is adopted. Snow protection woods have two functions: one is snow blocking, the other is water and soil preservation and environment improvement. The snow deposit on the back side of snow protection

woods provides the necessary water for tree growing. Usually the woods grows very slow, so some engineering methods are needed in the early period.

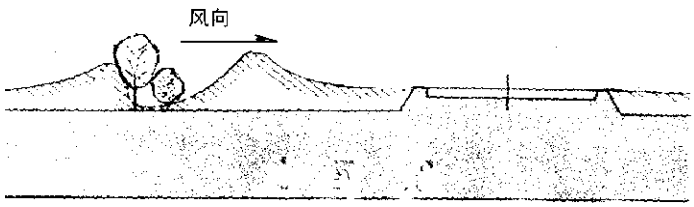

Figure 7 Snow protection woods

5.1.2 Snow guiding engineering

Snow guiding engineering includes wind guiding board and blowing snow fence. Snow guiding constructions are mainly placed near the road base and facing the windward. The wind guiding board has up guiding board, down guiding board and side guiding board.

Up guiding board (see figure 8) is used for excavation sections. It is generally placed up the trench facingthe windward. The larger the angle of the board, the fast the snow-wind speed, the snow wind pass over the trench, and snow is thrown to the far side of the road.

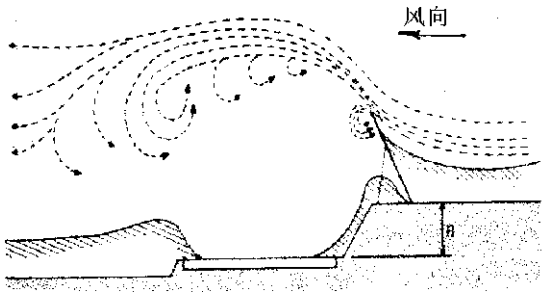

Figure 8 Up Guiding Board

Down guiding board is to increase the speed of snow wind when passing the profile of road base, so as to blowing away the deposited snow. Down guiding boards can only be used when the wind speed is not fast, there is snow deposit on the surface of road and the deposited snow can only be blown away by wind guiding board. Down guiding board is usually used wide and leeward areas.

Side guiding board is used to change the moving direction of snow wind, can be used for excavation road sections.

Wind guiding board can be made of concrete, wood and other airproof materials.

The function and usage conditions of blowing snow fence are the same as wind guiding board. They can be made from wood and aluminum materials. Aluminum fences have longer life-span but expensive. Wood fences have short usage time and easy to be damaged, not used little.

5.1.3 Comparison and Determination of Wind-blown Snow Prevention Scheme

According to the site investigation of the road section endangered by snow wind near Songshutou, and comparison of engineering effect economic evaluation for methods: snow fence, snow protection

wall, snow protection woods, woods + fence, woods + fence + snow deposit pit, after comprehensive analysis, we think that woods + fence + pit this kind of engineering and biological combined method is inexpensive and has good effect. We recommended this method in long views. (see figure 9)

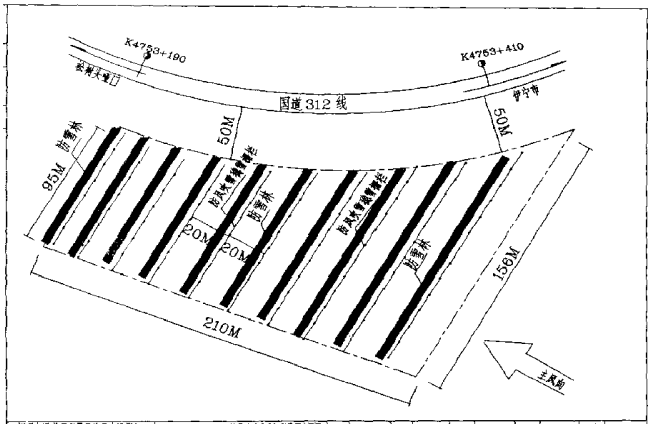

Figure 9 Plan view of wind-blown snow treatment engineering

5.2 Comparison and Choice of Snowslide prevention and treatment engineering methods

Snowslide prevention and treatment engineering has snowslide prevention methods and snowslide protection methods. The snowslide prevention methods aim at snow stabilization at snowslide origin area so that the snow can not slide. The snowslide protection methods aim at hurdling the movement of snow at snowslide movement areas, so as to reduce the energy of snowslide and make the loss minimum.

Prevention methods include: Snow protection woods, snow stabilization fence, horizontal steps, snow stabilization wall etc.

Protection methods include: hill, energy reducing pool, snow protection wall, snow guiding bank, snow protection corridor etc.

5.2.1 Prevention Methods

a. Snow prevention woods

If the water and soil condition permits, the combined biological and engineering method is an effective way, that is to adopt the comprehensive treatment method of combining snow prevention woods and snow stabilization engineering. The advantage is the snow stabilization engineering can first prevent the occurrence of snowslide, secondly protect the growing of young trees, and thirdly provide necessary water for trees to grow. As the trees gradually grow up, their roots, trunks and branches can play functions and eventually replace the snow stabilization engineering constructions.
First of all, the species of fast growing trees shall be selected and the cost of tree planting and caring shall be considered

b. Snow stabilization fence

The function of snow stabilization fence is to stabilize the snow on the slope, prevent the occurrence of snowslide. The fences can be made from wood, metal, concrete, lattice, steel, or

concrete plank.

Wood fences have short usage time, weak strength, easily rotten, and harmful to the environment, now little used.

Fences made from steel and steel plate or steel and lattice have high strength, long usage time, but expensive.

Concrete fences made of concrete pole and fences or concrete pole and concrete plank also have high strength and long usage time. The transportation shall be considered if the height changes much. Figure 10 shows the most commonly used fence types.

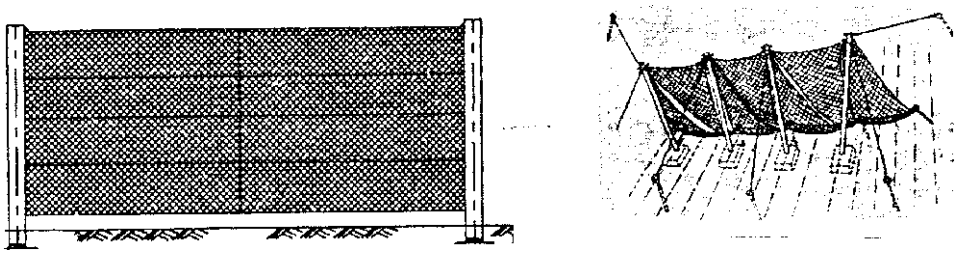

Figure 10 Snow stabilization fence

c. Horizontal steps

Horizontal steps shall be constructed on slopes with thick soil, usually excavated along contour line. As steps have support function, their snow stabilization effect is in evidence. When steps are used separately, the slope grade shall not be too steep (usually under 35^{o}). If using steps on steep slopes, the construction amount is high and that is easy to destroy naturally environment. In order to be economic and let steps play their full functions, steps shall be used with other snow stabilization methods.

d. Snow stabilization wall

Snow stabilization wall is used along the path of snowslide oon slopes or gullies. When constructing the walls, site materials shall be used, the wall shall be constructed by using dry laying, this is advantageous for water drainage and icing and melting damage. The top of the walls shall be fixed by wire cage.

5.2.2 Protection Measures

a. Snow blocking wall

Snow blocking walls belongs to snow blocking engineering, their function is to slow down the speed of snowslide, reduce the energy and also stabilize the snow. The walls are placed at narrow paths of snowslide, it is suitable for gully snowslide treatment. The walls can constructed by using site materials and are very cheap. the wall shall be constructed by using dry laying, The top of the walls shall be fixed by wire cage. The size of wall shall be determined according to the impact of snowslide.

b. Hill

Hills usually constructed at the end of snowslide path. Hills can slow down the snowslide speed and disperse snowslide energy. In order to keep the whole strength of hills and water and soil preservation, trees and grass shall be planted on hills.

c. Energy reducing pool

Energy reducing pools are not separately constructed, usually they function with hills and walls. The excavation of pools is used as the filling for hills and snow blocking banks. Hills are placed before other snow blocking constructions, facing snow wind.

Because of abruptly change of the profile of snowslide path，when the snow reaches the energy reducing pool, it falls and its speed and energy are reduced, then blocked by hills, the energy is greatly reduced.

d. Snow guiding bank

The principle of snow guiding bank is to guide the snowslide energy, its function is to change the movement direction of snowslide, and lead the snow far from the endangered constructions. The bank is constructed at the down area of snowslide movement, and have a small angle to the direction of snowslide movement.

e. Snow protection corridor

Snow protection corridor let the snow pass through on its top, so the passing vehicle and people are protected from snowslide. There are successful example of this kind of corridor, it is suitable for area with no wind-blown snow. For those areas with serious wind-blown snow, wind-blown snow shall be first treated and cleared before corridors are set up.

5.2.3 Choice of snowslide prevention and protection measures

In terms of the principle of prevention, considering the characteristics of topography, geology and snowslide at Guozigou, compared all kinds of measures, for the sun facies red-soil slope, the snowslide is treated by snow stabilization engineering measures, including snow stabilization fences + steps + wall + woods.

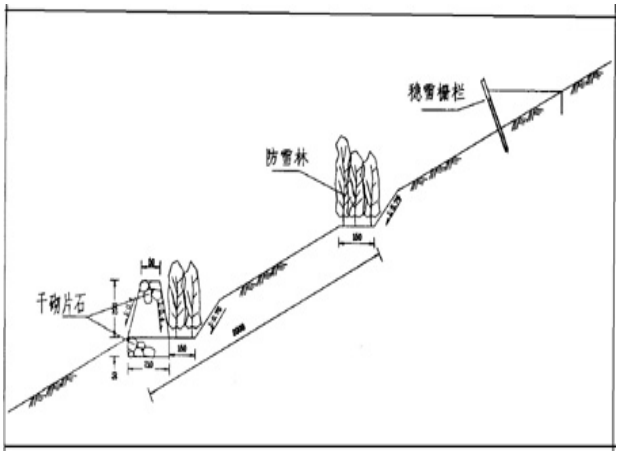

Figure 11 Snowslide prevention and protection engineering measures

For the shady white soil slopes, considering the topography characteristics, the measure for snow slide treatment is mainly snow stabilization banks working with horizontal steps, snow fences and planted trees. This is shown in figure 11.

6. Combining engineering and biological treatment measures

The prevention and protection measures of snow-blown snow and snowslide are all have engineering measures and biological measures.

The engineering measures have the character of fast effect, short age and large amount of investment for maintenance. The biological measures though take effect very slow, but have long term effect, not only reduce the damage of traffic cut and poor eyesight by wind-blown snow and prevent snowslide from take place, a large amount water was preserved, this is good for environment protection. Combining these two kinds of measures, making best use of the advantages and bypass the disadvantages, the treatment will be ideal.

The climate of Guozigou is warm, wet, rich of rainfall, very suitable for trees growing. The key is to select suitable types of trees which grow fast and are suitable for snow disaster prevention. At present, the work of tree choosing and plant experiment is carrying out.

Our practice have repeatedly proved that the combination of engineering measures and biological prevention measures, the basis engineering measures protecting the effective implementation of biological measures, and finally realizing biological prevention, is the root measure for snow disaster prevention.

7. Design of the experiment snow disaster prevention and protection construction

7.1 Snow disaster prevention and protection experiment construction

During the research, the study team completed wind-blown snow and snowslide prevention and protection experiment construction. The wind guiding board experiment (see figure 12) for wind-blown snow treatment showed that wind guiding boards were suitable at certain topography and climate conditions; the snow protection bank (1996-1997) for snowslide treatment had effectively prevent snowslides and the biological environment was gradually recovered. (see figure 13)

Figure 12 Wind guiding board experiment

Figure 13 Snow bank experiment

7.2 Design of snow disaster prevention and protection constructions

After site investigation and observation and reason analysis, the design of the construction for snow disaster treatment was complete, and then the experimental construction was set up. We summarized our former experience in snow prevention constructions and experimental projects, assimilated the advanced experience in Japan, Switzerland and Russian, put forward the construction methods and biological methods for treating the snow disasters at Guozigou, and finished the

construction design.

For wind-blown snow treatment, the design includes 84550 trees, 13 banks, 1200m fences.

For snowslide treatment, the design includes 13 banks 4000m fences, 20000 trees, 2754m steps at K4767～K4770 red-soil slopes, and 2000m fences, 14 banks (11 of them are consolidated by wire cage), more than 8000 trees.

8. Conclusion

Comprehensively treating disasters, especially the research and actually engineering of biological treatment there is not much, it is believed that this kind of treatment combining engineering and biological measures will be implemented and play it function in disaster reduction.

Reference

1. Xie zichu etc, <Tianshan snow and snowslide>, Hunan Teacher University Press，1996.
2. <Highway Snow Disaster Prevention Study> Science and Technology Committee of Xinjiang，1974.
3. Hu ruji etc, <Mountain Highway Snow Disaster Prevention>. Science and Technology literature Press, 1989
4. Li Changlin, Huanglidu, Lijunchao, <Snowslide Prevention At Guozigou of China>, 3th International Ice & Snow Conference, Japan, 1996
5. Li Changlin, Li Junchao, Chen Xiaoguang, Highway Snow Disaster Prevention, <Highway>，2000（1）
6. < Snow Fence>　Japan ,1988