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Ministry of Transport and Roads
Of Kyrgyz Republic

COUNTERMEASURES MANUAL FOR ROAD DISASTER PREVENTION

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CHAPTER 1 INTRODUCTION

1.1 General

The movement of goods and passengers is 95% dependent on traffic. The network of roads with a length of about 34,000 km within the country is an important economic infrastructure tool in the life of population and communication with the border states. The Kyrgyz Republic is a mountainous country, about 90% of country's territory is located at an altitude of 1000 m above sea level, about 40% at an altitude of 3000 m. Most of the roads pass through mountainous areas, so rockfalls, landslides and disasters caused by snowfall often occur. These natural disasters cause human and material losses, the closure of roads causes isolation of the region and delayed freight traffic.

The occurrence of road disasters leads not only to human casualties and damage to state property, but also has a significant impact on the region’s logistics and social economy during lengthy rehabilitation works. Thus, it is necessary to pre-install structures against road disasters in the appropriate area where a natural disaster may occur. And in order to minimize damage after a disaster has occurred, it is necessary to take appropriate measures.

1.2 Outline of Road Disaster Prevention Management System in Kyrgyz

The outline of road disaster prevention management system in Kyrgyzstan is shown in the figure below. In this regard, MOTR prepared these manuals concerning road disaster prevention in collaboration with JICA.

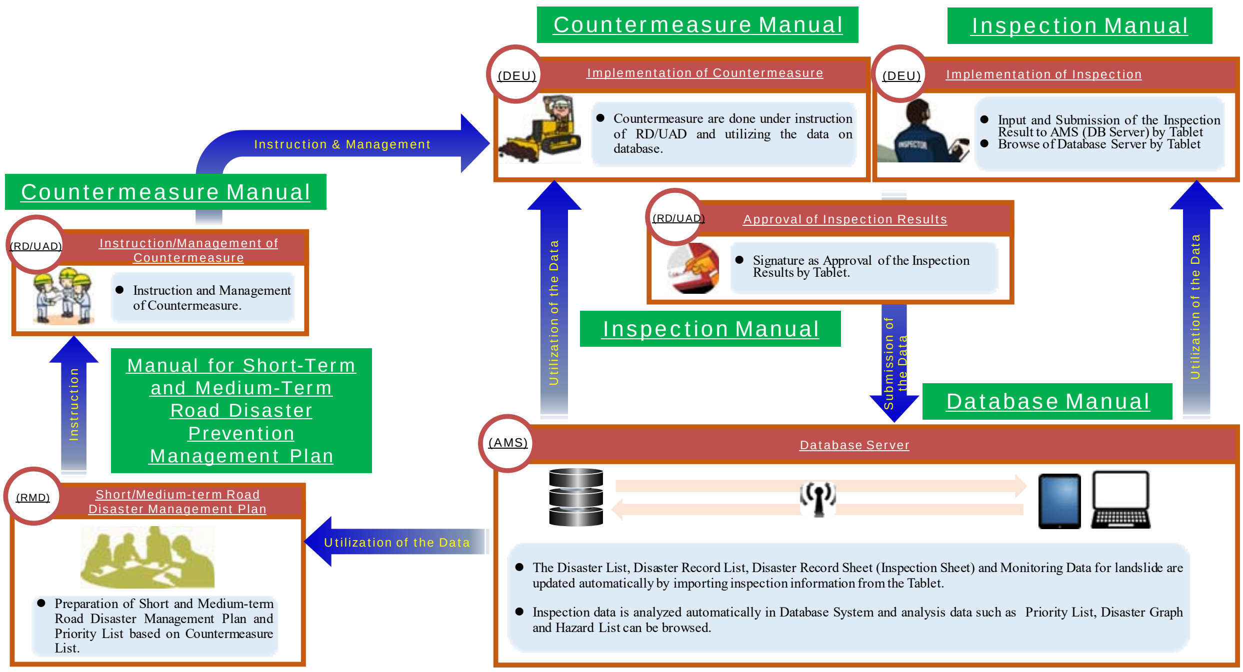


Figure 1.2-1 Outline of Road Disaster Prevention Management System

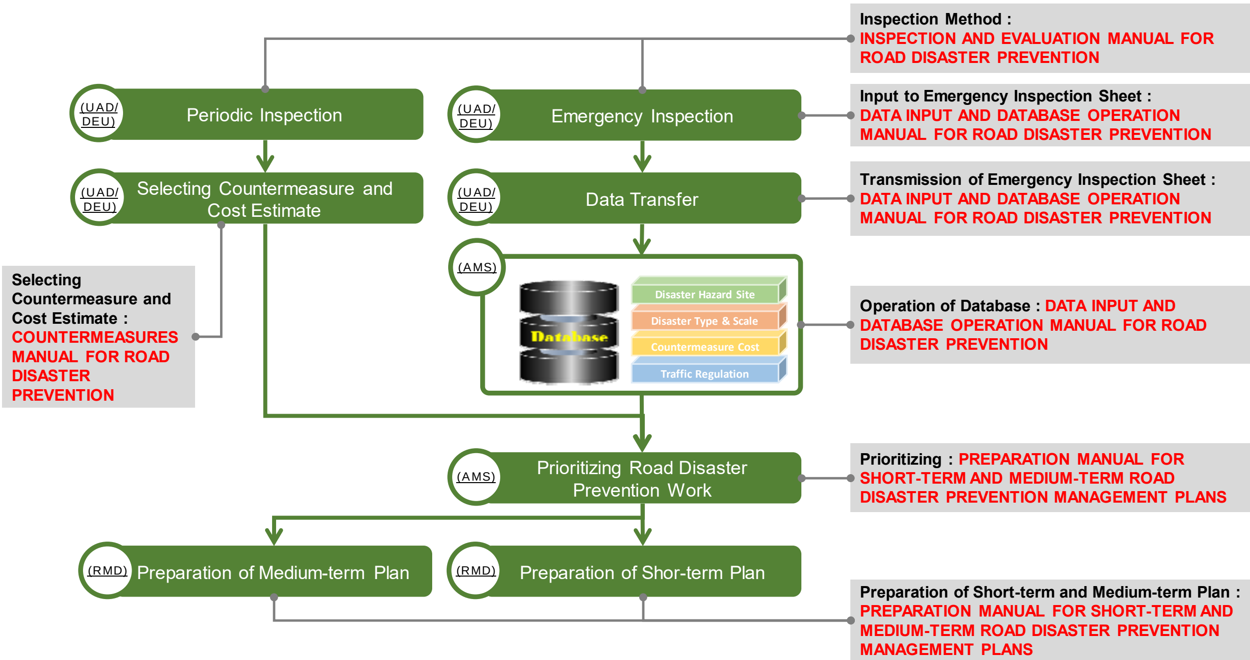


Figure 1.2-2 Flowchart of Preparation of Road Disaster Prevention Management Plan

This manual is above mentioned “Countermeasure Manual”. It describes the form of disaster occurrence, selection of engineering activities for each type of disaster and main of engineering activities.

CHAPTER 2 TYPE OF ROAD DISASTERS

2.1 Classification and Type of Occurrence of Road Disasters

The classification of road disaster in this manual is as itemized below.

- Rockfall
- Landslide
- Slope Collapse
- Debris Flow
- Riverbank Erosion
- Avalanche
- Snowdrift

The types of occurrence of road disasters are as presented the following paragraphs.

2.1.1 Rockfall

Rockfall is a phenomenon where foliated rocks and gravel due to enlarged cracks (caused by joints, foliation and stratification developed in the bedrock) in the bedrock or outcropped rocks, boulders and gravel originally contained in talus material, pyroclastic material or a gravel bed with low degree of compaction start to fall down a slope.

There are many hazardous locations of rockfall in Kyrgyz since most of principal road run through at mountain. Besides, the scale of rockfall disaster in Kyrgyz is quite large.

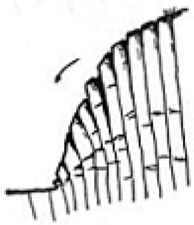
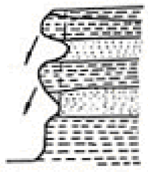
Photo 2.1-1 Blocked Vehicular Traffic due to Rockfall (DEP30)

Photo 2.1-2 Accumulated Rockfall at Back of Wall (DEP9)

The types of occurrence of rockfall are as presented the followings.

Table 2.1-1 Types of Occurrence of Rockfall

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
(1) Uprooting Type	1) Dropping of gravel located on a sandy slope containing gravel		Terrace and pyroclastic material, etc.	
	2) Sliding down of gravel contained in the sediment above the bedrock		Heavily weathered rock on talus, colluvial soil, hillside slope or cut slope	Loose stone type rockfall may occur depending on the relative positions of the bedrock and sediment.
(2) Flaking Type	1) Exfoliation along the surface of discontinuity in the bedrock		Bedrock with many cracks or continual cracks	Different forms, such as sliding, falling over and falling, take place depending on the directions of the slope and cracks; special attention is required in regard to the degree of looseness.

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
	2) Exfoliation of the surface of a highly weatherable or erodsible bedrock	 	Weatherable soft rock or alternation of soft and hard rock layers from the Neogene onwards	The scale is generally small but the falling of large rocks may occur at an overhang section of alternated soft and hard rock layers.
(3) Others	1) Increased instability of residual boulders, etc. on a ridge due to weathering or erosion		Weathered granite, etc.	Not frequent but tends to be on a large scale.

2.1.2 Landslide

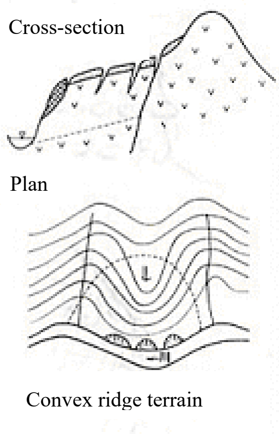
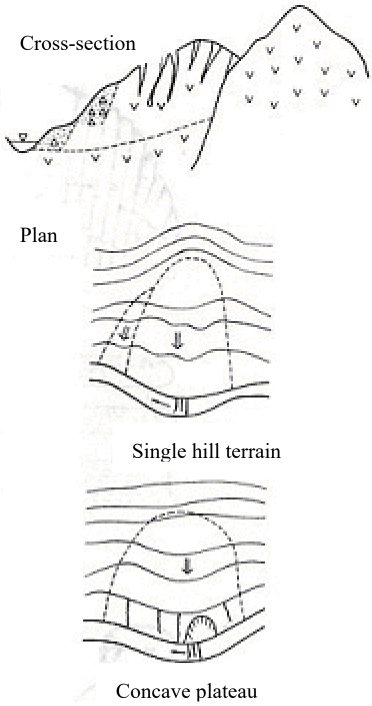
A landslide is a phenomenon where the soil mass above a boundary deep in the ground gradually shifts downward due to groundwater rising and imbalance of soil mass. Horseshoe shaped or arc shaped head cliff is formed at the top of landslide. Likewise, heave or prominence is occurred at the bottom of landslide. Hence, a lot of landslide are recognizable by topographic map or aerial photograph. Landslide is characterized by occurrence condition like terrain, topography and groundwater.

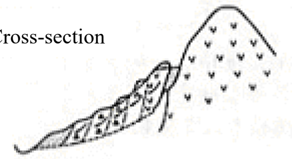
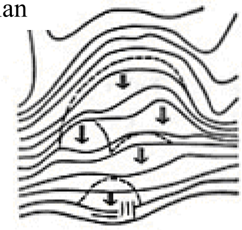
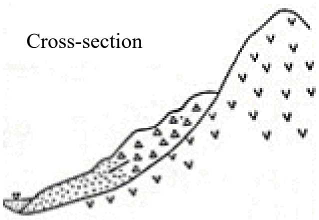
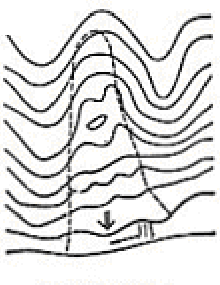
Photo 2.1-3 Deformed roadway due to landslide (DEP9)

Photo 2.1-4 Head cliff due to Landslide (DEP959)

The types of occurrence of landslide are as presented the followings.

Table 2.1-2 Types of Occurrence of Landslide

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
(1) Bedrock Landslide	1) Convex ridge terrain with a chair or boat-type sliding surface; often starts at a saddle section 2) Bedrock or lightly weathered at the head and weathered rock at the bottom 3) Sudden occurrence makes its prediction very difficult; careful reconnaissance and a detailed survey are required		Often affected by a fault or fracture zone; Tertiary formations, crystalline schist and Mesozoic and Paleozoic formations	Triggered by large-scale earthworks, submersion of part of the slope, earthquake or heavy rain
(2)Weathered Rock Landslide	1) Convex plateau terrain, single hill, concave plateau terrain with a chair or boat-type sliding surface 2) Weathered rock with many cracks at the head and sediment mixed with boulders at the bottom		Crystalline schist, Mesozoic/Paleozoic formations or Neogene formation affected by a fault or fracture zone	Triggered by a downpour, abnormal thawing, earthquake or medium-scale earthworks
(3) Colluvial Deposit Landslide	1) Multiple hill or concave plateau terrain with a stair or layer-type sliding surface which can be divided into 2 – 3 blocks		Colluvial deposit from crystalline schist, Mesozoic/Paleozoic formations, Neogene formation or serpentinite	Triggered by thawing, typhoon, downpour or medium-scale earthworks

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
	2) Mainly consists of sediment containing gravel and becomes clay at the bottom 3) Intermittent activity repeated every 5 – 20 years; landslide hysteresis is clear from the topographical point of view and can be checked with a topographical map of 1 to 5,000 or 1 to 10,000; interviews with local people are also useful	Cross-section  Plan  Multiple hill terrain		
(4) Clayey Soil Landslide	1) Gently sloping concave terrain with a multi-blocked stair or layer type sliding surface; closer relation between the blocks than (3) 2) Mainly consists of clay or clay containing gravel 3) As landslide movement is semi-continuous with a recurrence every 1 – 5 years, its presence is well-known locally.	Cross-section  Plan  Gently sloping concave terrain	Neogene formation, fracture zone and solfataric soil	Easily activated by a downpour, thawing, river erosion or small-scale earthworks

2.1.3 Slope Collapse

A slope collapse is a phenomenon where the surface soil/rock above a boundary in the ground shifts downward. Slope collapse is occurred by a rainfall or denudation although the slope is stable at normal condition. Slope collapse due to heavy rain tend to occur in the following condition.

1) Steep slope (Steeper than 30 degree)

2) Slope which has knick point (There is sharp change on slope)
3) Concave slope,
4) Slope which has gentle slope at the upper portion

3), 4) are easily formed a pool.

Slope Collapse from Road Shoulder to Lower (DEP30)

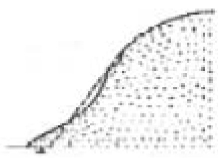
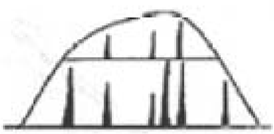
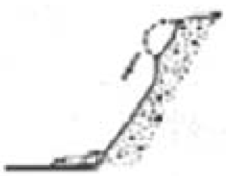
Slope Collapse on Cut Slope (BNT Road)

Figure 2.1-1 Slope Collapse

There are many Talus which is accumulated by continuous slope collapse and weathered rock in Kyrgyz. Some source of accumulated talus is from 200 m in height above road surface. The accumulated talus is stable gradient from 30 to 35 degree. However, the increasing accumulated talus might cause a traffic disturbance and a large scale of road disaster. The accumulated talus might be a pathway for a rockfall.

The types of occurrence of slope collapse are as presented the followings.

Table 2.1-3 Types of Occurrence of Slope Collapse

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
(1) Erosion, collapse	Dry and wet cycle, Slaking, Rainfall will cause gully erosion. Sometimes it will be develop to deep collapse.	 	Volcanic ash soil Disintegrated granite Fine sand Tuff(Tertiary) Weathering slate Top soil	Cutting slope Poor vegetation work
	2)Overhung		Volcanic clastic material Terrace deposit(sand and gravel) Colluvial deposit	Cutting slope which lose the lower part

Category	Description	Schematic Drawing	Typical Geological Features	Remarks
(2) Weathering rocks and layer	Surface of the rocks will be collapsed by weathering.		Mud stone Tuff Weathering slate Schist Terranolite	Cutting slope is tend to weathering faster

2.1.4 Debris Flow

A debris flow is a phenomenon in which soil at the bottom of a valley or upstream moves because of heavy rain, melting snow or earthquake and flows in hydraulic bores out of the valley. The occurrence of debris flow simultaneously requires three elements, such as steep slope, enough water and movable soil. The most of debris flow occurs on the slope which gradient is steeper than 15 degree. The most of debris flow stops and accumulates on the slope which gradient is from 2 to 10 degree. However, the fine sand comes down to the section of gentle slope.

	
DEP50: Sedimentation of debris flow on the road	DEP959: Sedimentation of debris flow on the road

Figure 2.1-2 Example of Debris Flow Disaster on Road

The types of occurrence of debris flow are as presented the followings. The outline is as shown in Figure 2.1-3. Debris Flow Caused by Fluidization of Sediment on Streambed

Sediment on the steep streambed is fluidized by intense rainfall and melting snow.

2.1.4.1 Debris Flow Caused by Sediment of Hillside Collapse

Soil of hillside collapse is fluidized by mixed with water. It is hard to distinguish this type of occurrence of debris flow from slope collapse.

2.1.4.2 Debris Flow Caused by Collapse of Landslide Dam

Landslide dam is generated by temporary suspension of stream flow due to landslide. The erosion due to overflow or landslide dam break causes the debris flow.

2.1.4.3 Debris Flow Caused by Fluidization of Soil Mass of Landslide

The clod of landslide with high moisture content mainly fluidizes and becomes debris flow.

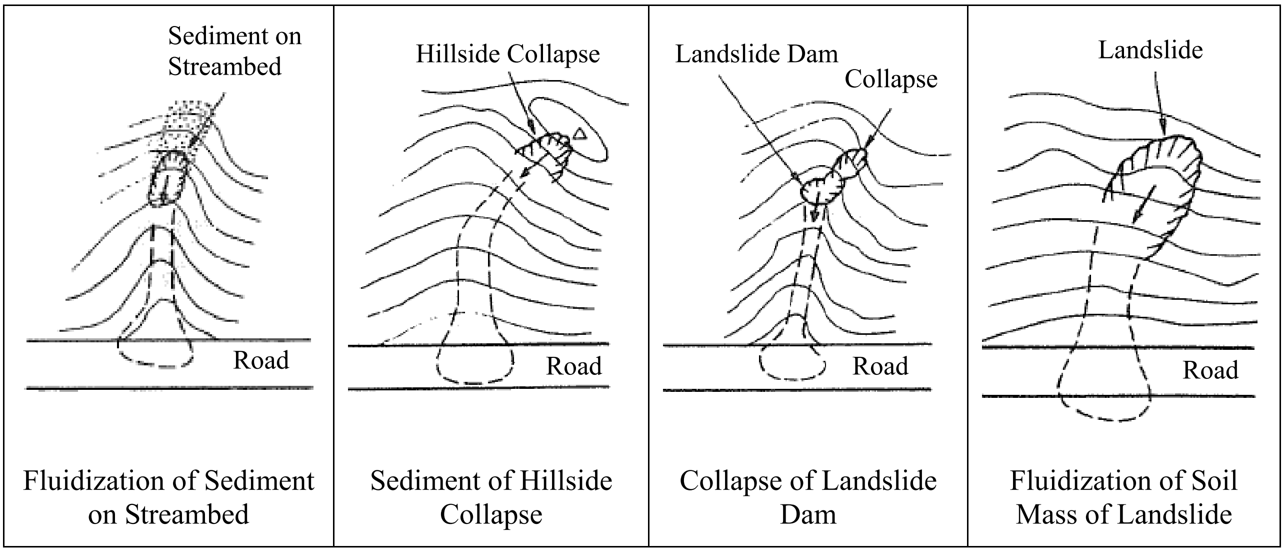


Figure 2.1-3 Type of Debris Flow Disaster Occurrence

2.1.5 Riverbank Erosion

The scale and shape of riverbank erosion depends on the river configuration, slope material terrain, type/condition of vegetation, situation of infiltration flow and discharge variation.

The cause of riverbank erosion has two following mechanisms.

- Fluvial/Hydraulic erosion process, Toe erosion process due to scouring force of river flow
- Slope/Mass failure process due to bank stability (caused by additional embankment, or riverbed scouring, etc.)

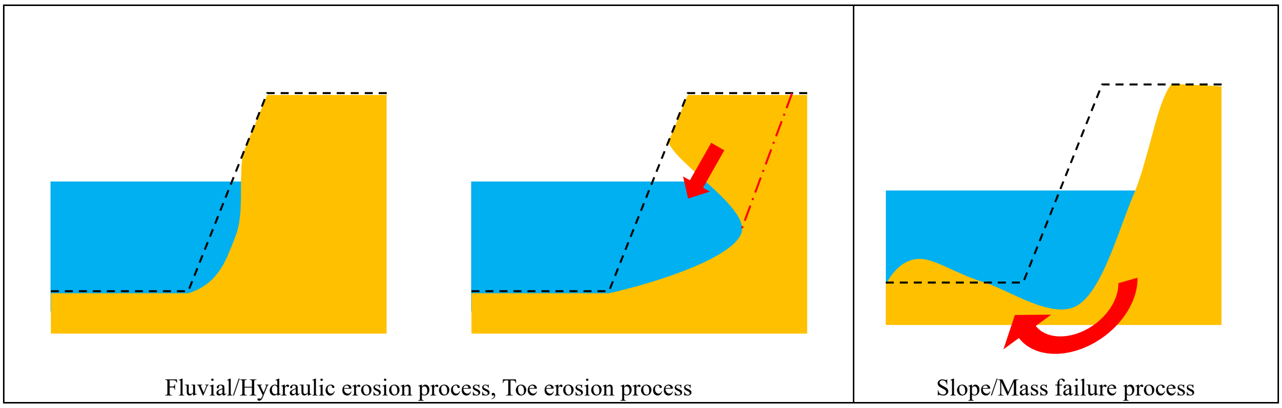


Figure 2.1-4 Type of Riverbank Erosion Disaster Occurrence

Even though revetment is installed, the revetment will be collapse due to inadequate structure/material. The sample of damaged/collapsed revetment is as shown in Figure 2.1-5.

		
Collapsed due to riverbed erosion at foundation of revetment (inadequate foot protection)	Washed out slope protection due to inadequate size/weight of block	Collapsed due to coming out of fine materials underneath the revetment (inadequate filter cloth)

Figure 2.1-5 Sample of Damaged/Collapsed Revetment

2.1.6 Avalanche

An avalanche is a natural phenomenon in which the snow accumulated on the slope changes the potential energy at such a speed that it can be identified with the naked eye by the action of gravity, a phenomenon of several seconds to 1 to 2 minutes. An avalanche is categorized as follows based on the form of occurrence etc.

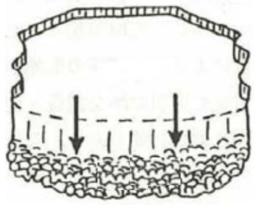
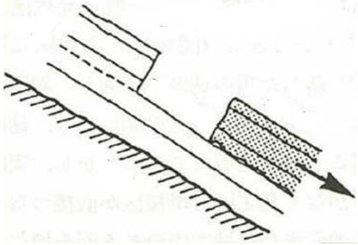
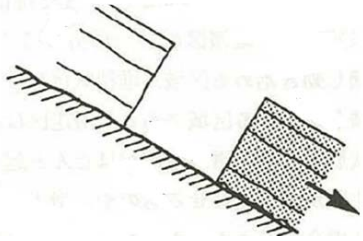
Form of occurrence	(1) Point occurrence avalanche  一 Wedge shaped 一 Generally small scale	(2) Planar avalanche  一 It starts to move all together over a fairly wide area 一 Generally large scale
Slide surface position	(1) Surface avalanche  Slide surface is inside the snow cover 一 Generally occurred in winter	(2) Full depth avalanche  Slip surface is ground 一 Generally occurred during snow melting season
Snow quality of the avalanche layer	(1) Dry snow The avalanche layer (starting snow cover) doesn't contain moisture	(2) Wet snow The avalanche layer (starting snow cover) contains moisture

Figure 2.1-6 Classification of avalanches (Source: Course on the basics of studying snow and ice Ⅲ, Avalanche and Snowdrift)

Avalanche trace on 126 km of BO road

Split surface in the upper part of the slope at the 121-km of Bishkek-Osh road

A small avalanche in the road
(near 123 km of BO road)

Artificial avalanche release

Figure 2.1-7 Avalanches on Bishkek-Osh road

2.1.6.1 Avalanche generation mechanism

An avalanche occurs when the driving force of the snow layer on the slope exceeds the resistance force. Since the snow cover layer is directly affected by changes such as weather (atmospheric condition) and heat transfer from the surface of the earth, physical properties (density, hardness, snow particle shape) change rapidly in a short time. This is called metamorphosis. Therefore, snow cover stability violently changes in a short time. The snow on the slope is normally affected by gravity as shown in Figure 2.1-8, and slowly moving and deforming due to glide and creep. However, in a situation where a surface avalanche occurs, a slip surface is formed due to a change in weather conditions such as snowfall and change in temperature, some sort of trigger collapses the balance between the resistance force and the driving force, resulting in avalanche.

Main factors of increase in driving force and decrease in resistance force are as follows.

· Increase of driving force: increase in snow cover due to snowfall etc.
· Decrease of resistance capacity: Changes in internal structure (snow quality) of snow, melting of snow due to rising temperature, rain etc.

Figure 2.1-8 (on the left side) shows the driving force and resistance force of snow cover, as shown as diagram in Figure 2.1-8 (on the right side). After the snowfall, the snow cover layer transforms and stabilizes after a time (old snow). If there is snowfall (fresh snow) on the stabilized snow cover, and there is a weak layer between old snow and fresh snow, avalanche occurs with the weak layer as a sliding surface. Form factors of the weak layer are as shown in Figure 2.1-4Figure 2.1-8, Table 2.1-4 and they are diverse. Therefore, in order to know whether a weak layer was formed or not, it is necessary to dig the snow cover and check the cross section of the pit.

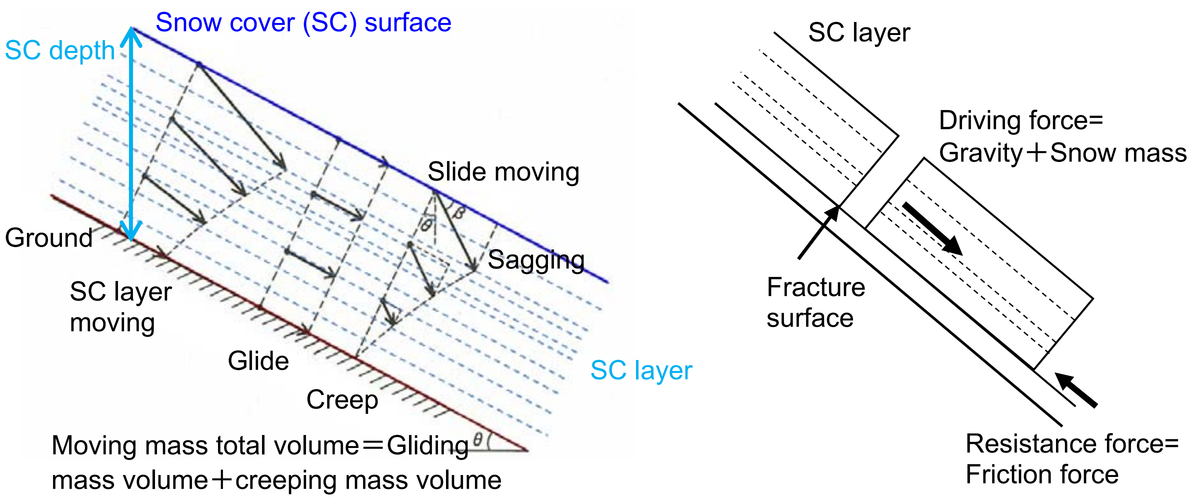


Figure 2.1-8 Glide and creep of slope snow cover and rupture of snow cover

Table 2.1-4 Periods of formation and changes in the structure of the snow cover layer and natural factors

Period	Beginning period (during snowfall)	Second period (on the surface)	End period (After burying)
Environmental factors	Crystal form (presence / absence of clouds, shape, size), temperature, wind speed	Long wavelength radiation, temperature, short wavelength radiation, wind speed	Overhead snow layer, snow temperature, temperature gradient, water supply
Structural factor	Initial structure (filling degree, density, combined structure)	Melting, Freezing, redeposition, scraping, sublimation evaporation · condensation	Consolidation, sintering, melting, freezing, sublimation evaporation · condensation
Feature	A wide variety of layer structures (Thickness from several mm to several cm)	Rapid change near the surface	Slow change (several days), decrease in number of layers

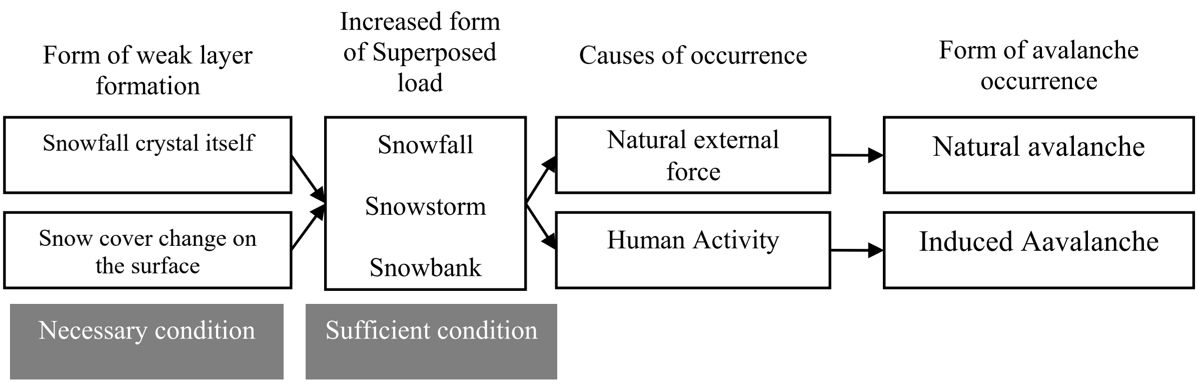


Figure 2.1-9 Avalanche occurrence flowchart

(Source: Course on the basics of studying snow and ice Ⅲ, Avalanche and Snowdrift)

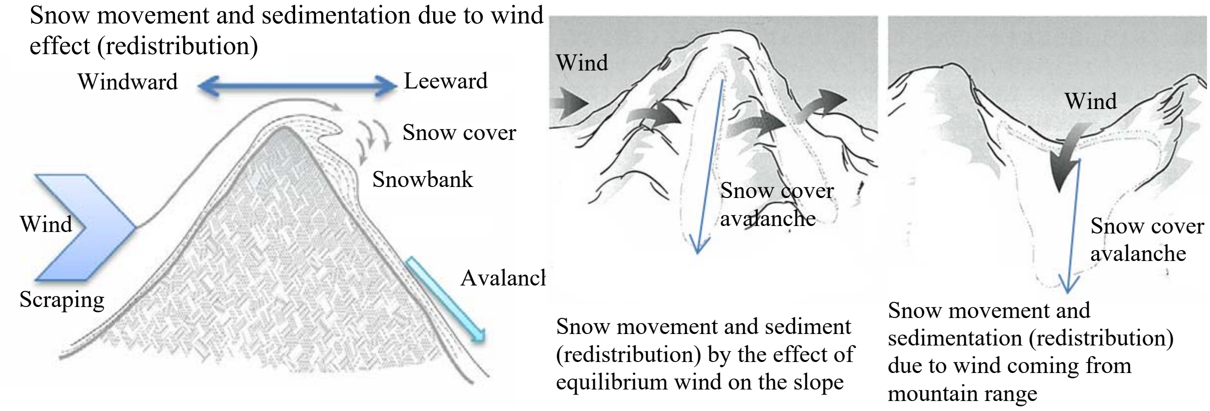


Figure 2.1-10 Causes of avalanche occurrence (Source: Avalanche risk management)

Also, weak layers may be formed by micro topography such as uneven topography, so it is impossible to know precisely where the weak layer is formed. On the other hand, snowfall, which is the cause of driving force, is affected by wind and topography, so snow cover depends on them.

A full depth avalanche is a phenomenon in which the entire layer of snow cover falls off starting from the surface of the ground. Such avalanches are usually formed due to the sliding of snow cover from the land surface. Figure 2.1-11 shows cracks, humps, snow wrinkles that appear as a precursor to the full layer avalanche.

(Source: Course on the basics of studying snow and ice Ⅲ, Avalanche and Snowdrift)

Figure 2.1-11 Precursory phenomenon of full-layer avalanche

2.1.6.2 Avalanche occurrence and zone of deposition

The avalanche route is divided into a generation zone, avalanche pathway, and a sedimentary zone as shown in Figure 2.1-12, but the boundaries between them are not clear. Also, the maximum reachable distance is empirically set as Figure 2.1-13.

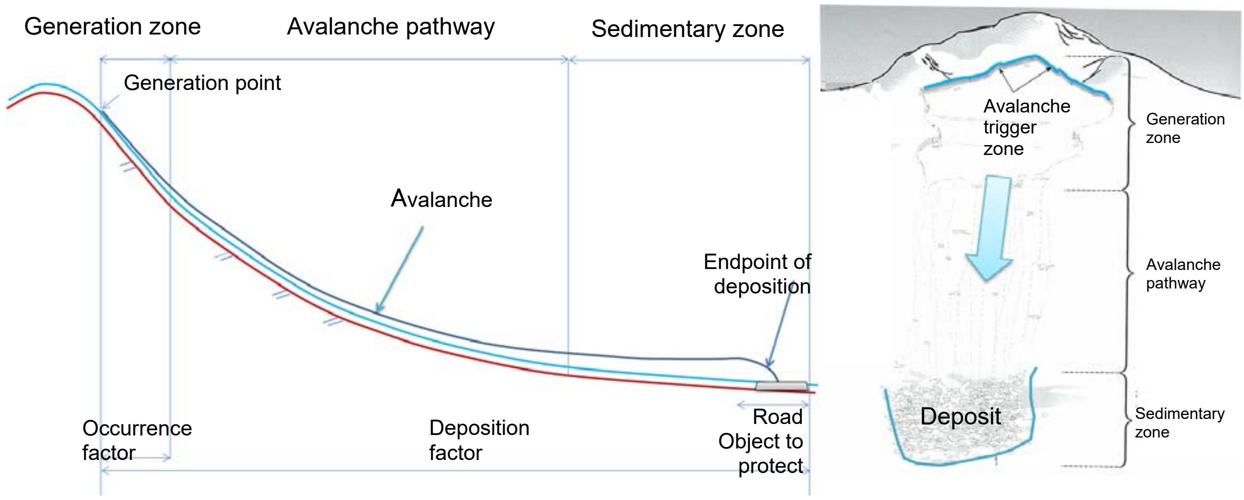


Figure 2.1-12 Section of Sediment Movement (Right figure; modified avalanche risk management)

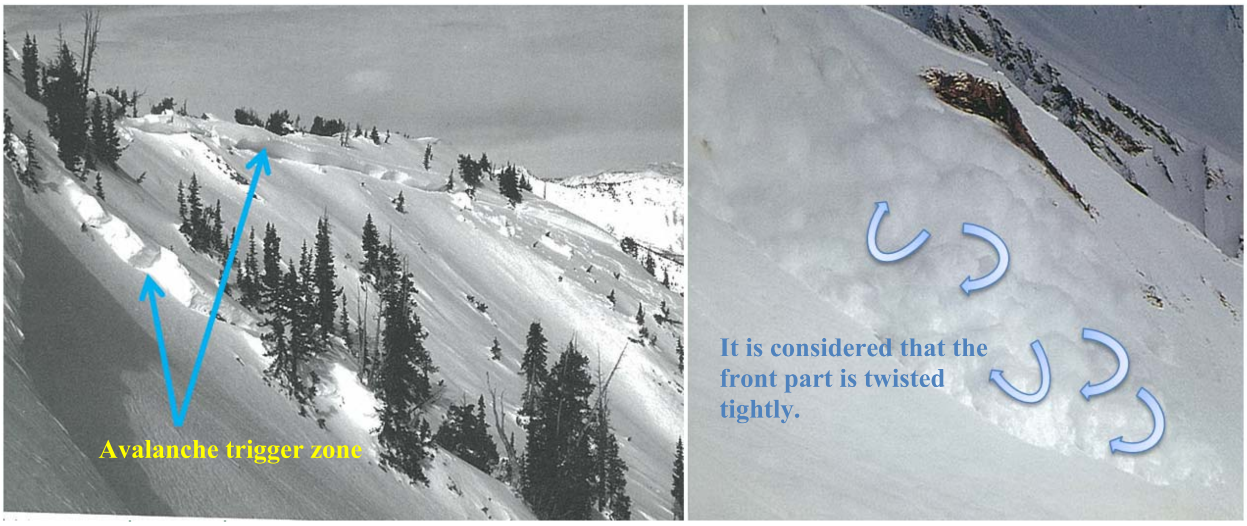
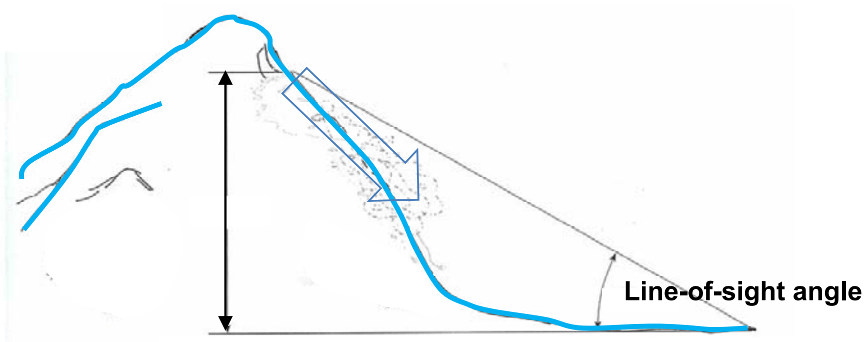


Figure 2.1-13 Avalanche occurrence area and flow front
(Source: Left, Avalanche Risk Management, Categories, Right: AVALANCHE!)



Surface layer avalanche: maximum about 18°, full layer avalanche: maximum about 24°
(Source: Avalanche risk management)

Figure 2.1-14 Rough calculation of the maximum avalanche distance, based on practical rules (Line-of-sight angle)

Actually, the reachable distance is not determined only by the line of sight, but the maximum reachable distance of the avalanche depends on the avalanche occurrence position, scale and terrain as shown in Figure 2.1-15.

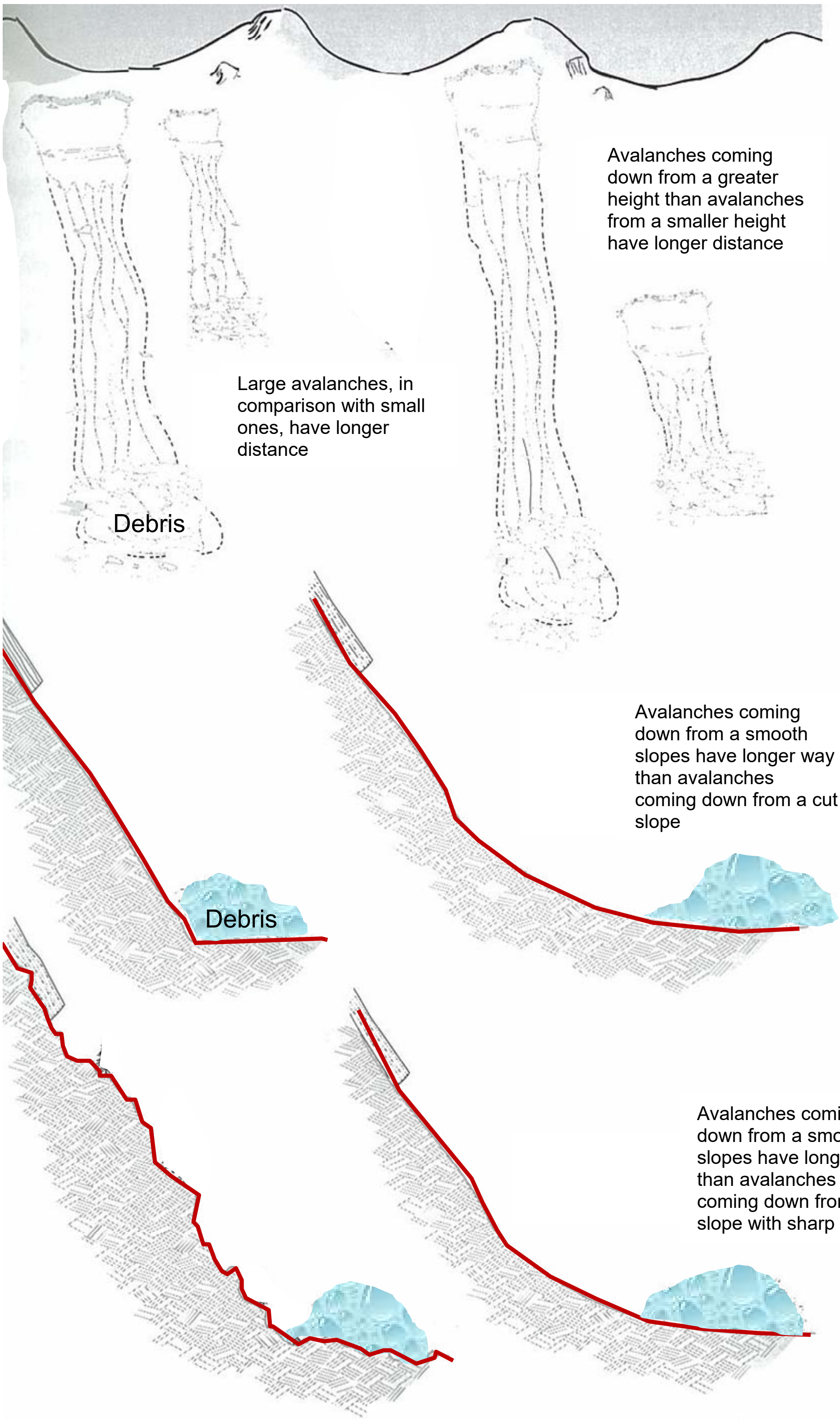


Figure 2.1-15 Avalanche pathway distance determination factors (Source: Avalanche risk management)

2.1.6.3 Features of avalanches in Kyrgyzstan

In the Kyrgyz Republic there are avalanches from dry snow caused by heavy snowfalls, as well as avalanches from wet snow due to rains in April. It is believed that these avalanches, being surface avalanches, are subdivided into various types of formation factors: a factor of heavy snowfall, a factor of loose snow, and also an icing factor.

Among the frost-shaped avalanche, there is not much snow in the target site, it is cold and sunshine, so the temperature gradient in the snow layer becomes large, so that the adhesion between the particles is small and even the snow coarsens. Rainy rough snow is easily collapsed by external factors such as rainfall, so it is considered to be a cause of avalanche in the target area. This avalanche has a danger of occurring even if there is not much snow depth. In years with heavy snowfalls, it is necessary to be careful of avalanches because of this, and in little snowy years because of a loose layer of snow and icing.

Table 2.1-5 Main causes and outline of surface avalanches

Classification		Outline
Weak layer type	New snow type	Hexagonal snow crystals with a wide surface without roughness in the windless time lie horizontally and become slippery.
	Frost form	There are coarse-grained, fine-grained and surface-icy types. However, they are all loose and have weak grip.
	Hailstone	Over time, the hailstones are not grouped and how the balls rotate easily, which is why the surface snow cover easily slides over them.
Type of heavy snowfall		With a large amount of accumulation of new snow (in case of snowfall) in a short time, the snow cover lying before the snowfall (old snow) serves as a slippery slide, in which new snow comes off at once.

Shaded places - the most likely formation reasons in the Kyrgyz Republic

The avalanche that occurred on the BO road in the past has occurred on the slope where the slope is large and the line of sight is 20 to 25 °, which is colored green to yellow in the lower figure. Along with places where avalanche occurred in the past, it can be said that there is a danger of avalanches on similar slopes.

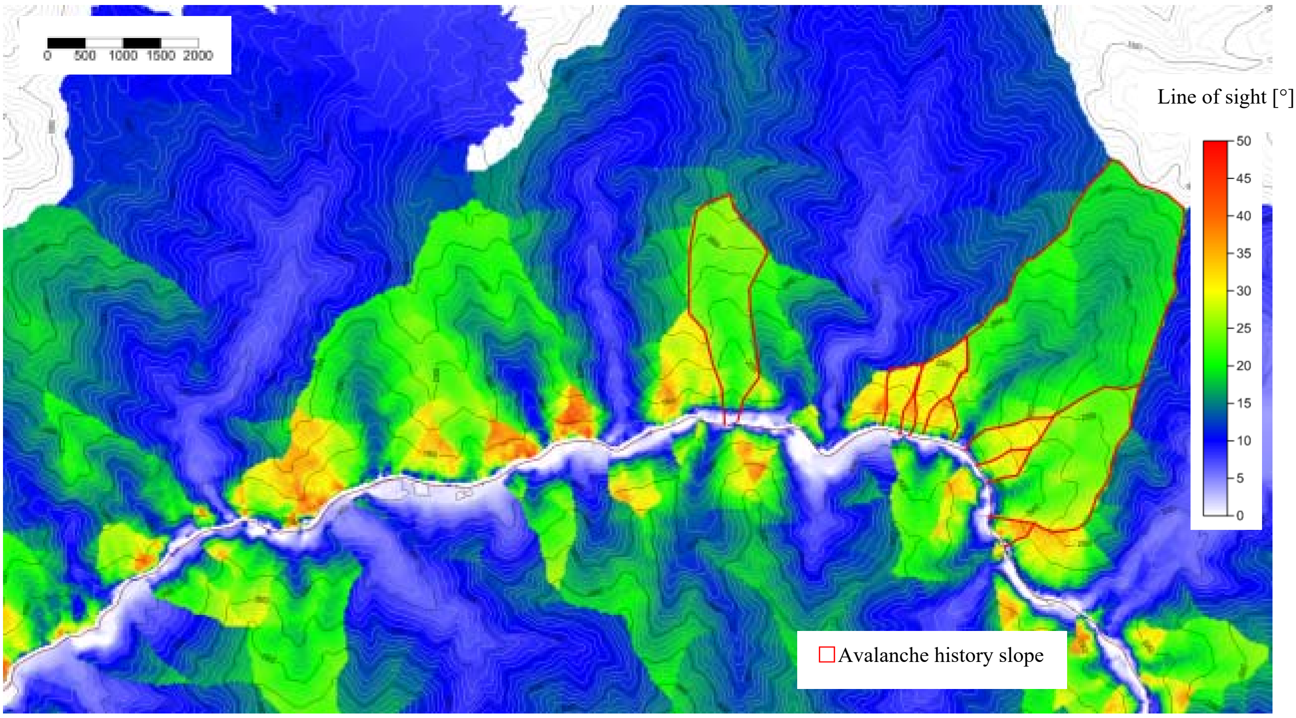


Figure 2.1-16 Line of sight distribution from BO road (DEU 23)

2.1.7 Snowdrift

Snow drifts are a natural phenomenon, when a blizzard is formed due to strong wind, and snow particles move in the form of saltation, suspended and creeping, in which, in areas of weakening of the air flow, more snow accumulates than on the plain. It is well known that a snow cover of 10 cm on the road creates difficulties for the stable movement of passenger cars, and upon reaching 20 cm, this will become impossible. Therefore, it is necessary to carry out road maintenance (snow plow) so that the snow cover does not reach 10 cm.

Also, when strong browning snow occurs, the amount of snow particles existing in the space increases, making it difficult for human eyes to see the other side of the road. This is called Visibility Failure, comfortable and stable operation becomes difficult when the visibility is 200 m or less, and the possibility of a traffic accident increases when the visibility is less than 100 m. When the visibility is 50 m or less, it can not normally operate because it is a "white darkness" where almost no visibility can be obtained. Due to this visibility failure, a deviation from the road, a collision accident to the preceding vehicle, and a frontal collision accident with the oncoming vehicle occur。

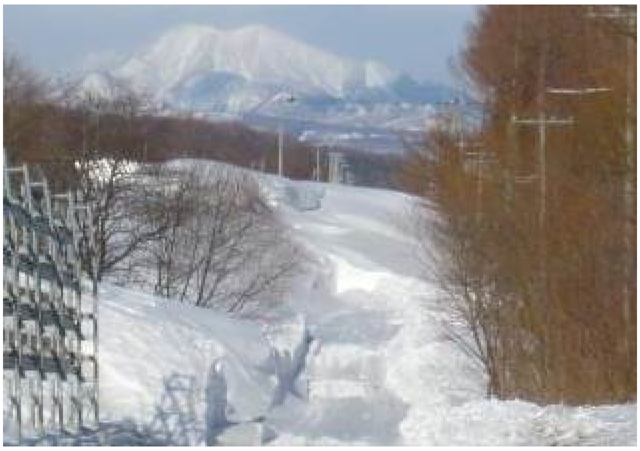


Photo 2.1-5 A state of snowdrift on the road

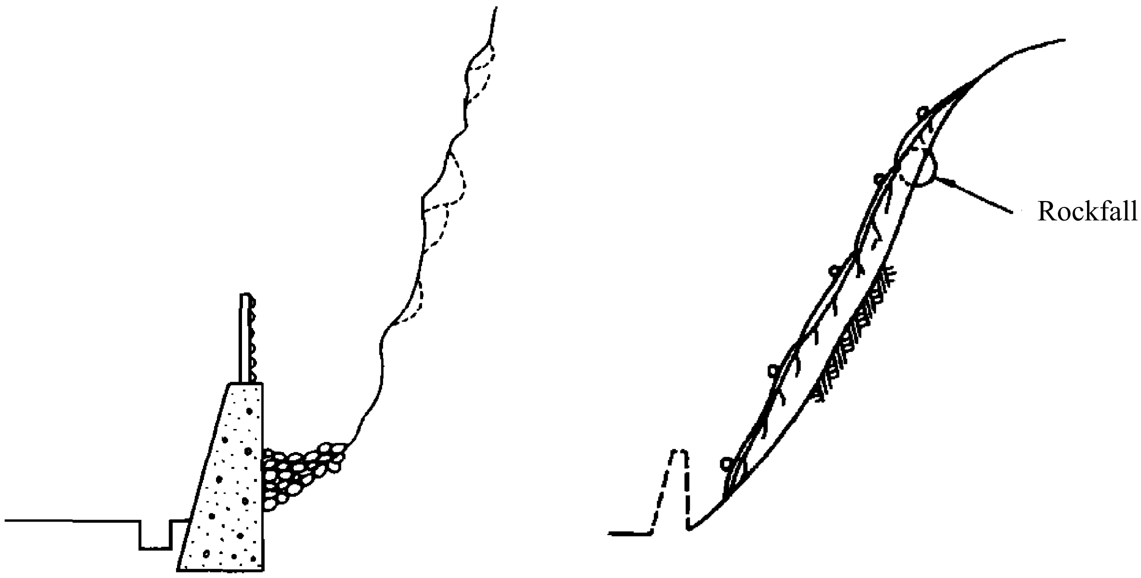
Photo 2.1-6 A state of visibility disorder

CHAPTER 3 COUNTERMEASURES AGAINST ROCKFALL

3.1 General

Basic policy of the Countermeasure work for rockfall is as follows.

- Rockfall protection work (mitigating the damage by rock fall) and Rock Fall prevention work (addressing the sources of rock fall) are selected by the condition of site (scale and location of the unstable rock and rock area). According to the situation of the site, these two types of countermeasure method should be combined for mitigating the risk.
- The cutting work is the most stable way of the permanent measures construction. But it will need consideration for stability of slope after the cutting, possibility for the new collapse or landslide by weathering and filtering of the rainfall.



Protection work (retaining wall and the fence) Prevention work (rock protection net)

Figure 3.1-1 Section of Sediment Movement

3.2 Selection of Countermeasures

3.2.1 Classification of Countermeasures

Table 3.2-1 Comparison Table of Countermeasures against Rockfall (1/2)

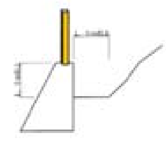
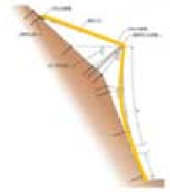
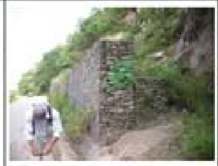
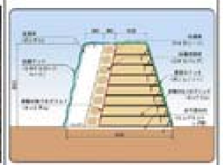
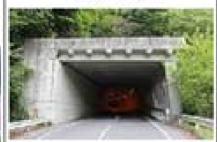
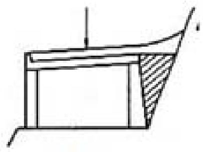
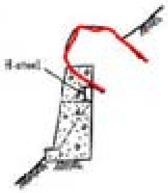
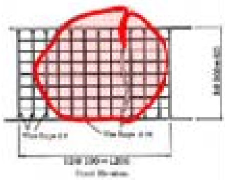
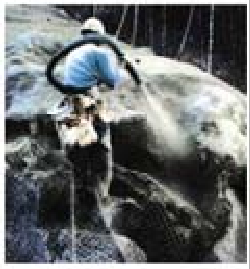
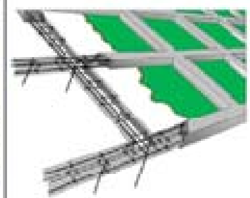
Condition	Rock fall protection work (mitigating the damage by rock fall)			
Type	Protection Fence	Protection Net	Retainig Wall	Rock Shed (Rock Keeper)
Photo / Schematic illustration	  Protection fence  Protection fence (High impact type)	  	 Gabion Wall   Reinforced soil wall	 Rock keeper   Rock shed
Construction conditions	Small rock fall on the slope Enough spece for the setting the fence. Some type are applied for higher impact load of the rock mass.	Small rock fall on the slope It is no necesesity for the space side of the road. Some type are applied for higher impact load of the rock mass.	Middle and large rock fall from the slope. Enough spece for the side of the road. Embankment type wall(Reinforced soil wall) is applied for the huge rock fall.	Middle and large rock fall from the slope. The site cannot implement other ways cause of the size and jumping height of the falling rocks. Falling rock mass will move to the valley side.(Rock shed)
Maintenance	Periodical removing of the rock deposit.	Periodical inspection. Repairing and replacement of the conponent	Periodical removing of the rock deposit.	Periodical inspection
Propriety for the construction	Checking the space and geological stability for the foundation of the wall and the anchor bolt.	Checking the geological stability for the anchor bolt. Need the working space and acces rosd to set the material.	Checking the space and geological stability for the foundation of the wall. Embankment type wall(Reinforced soil wall) need the enough space to construction.	Checking the space and geological stability for the foundation.
Application possibility in Kyrgyzstan (Bishkek - Osh road, DEP9and30)	For small and middle rock fall. Depend on the constructiing space. Cannot use for the large(over 3-5m) rock mass. Materals should be import from other country.	For small and middle rock fall. Higher slope and protruded rock massis not available for construction. Need the survey for procurement for the materials.	Gabion wall and concrete wall should be constructed in domestic work in Kyrgyzstan. But high impact load rock fall need other type wall like embankment type wall (Reinforced soil wall).	The problem is road closing under construction. Design and construction tecnology should be imported from other country.
Cost	Small rock fall 18,000(COM/m) High impact type 500,000～600,000(COM/m)	Small rock fall 4,200(COM/m²) High impact type 12,000(COM/m²)	Gabion wall(H=3m) 84,000(COM/m) Concrete Wall(H=3m) 120,000(COM/m) Reinforced soil wall 600,000(COM/m)	Rock Keeper 900,000(COM/m) Rock shed 1,500,000(COM/m)

Table 3.2-2 Comparison Table of Countermeasures against Rockfall (2/2)

Condition	Rock Fall prevention work (addressing the sources of rock fall)			
Type	Concrete Foot Protection	Wire rope and net	Shot crete	Frame work (Crib work)
Photo / Schematic illustration	 	 	 	 
Construction conditions	Supporting the unstable rocks by concrete mass Setting space and base rock	Supporting the unstable rock by wire rope and steel net Topographic and geologic condition is related to the anchor work	Spraying the concrete or mortar to the unstable rock or weathered slope. This type work is not applied to debris slope. Machine for spraying the concrete is need for this work.	The frame made from concrete and rainforce bar keep the stability of the slope by covering. Anchor bolt should be set on the cross point of the frame. There are two way to construct the crim work. One is using spraying the concrete by machine and the other is placing the concrete for molding flask .
Maintenance	Periodical inspection	Periodical inspection	Periodical inspection	Periodical inspection
Proprety for the construction	Higher and steep slope is difficult to set the stable scaffold.	Higher and steep slope is difficult to set the stable scaffold.	This work needs removing the protruded big rock mass. Higher and steep slope will increase difficulty to setting the machine and materials.	This work needs rounding the surface and removing the protruded rock mass. Higher and steep slope will increase difficulty to setting the machine and materials.
Application possibility in Kyrgyzstan (Bishkek – Osh road, DEP9and30)	This work is low cost and available for local unstable rocks. So many unstable rock slope will not be efficient.	This work is available for local unstable rocks. So many unstable rock slope will not be efficient. Need the survey for procurement of the material and quantity of the construction work.	This work is available for small cutting slope. Higher and large slope will have risk of safety and difficulty of the rounding work on the slope. Need the survey for procurement of the material and quantity of the construction work.	This work is available for small cutting slope. Higher and large slope will have risk of safety and difficulty of the rounding work on the slope. Design and construction tecnology should be imported from other country.
Cost	30,000(COM/㎡)	12,000(COM/㎡)	600(COM/㎡)	18,000(COM/㎡)

3.2.2 Criteria for Selection of Countermeasures

Countermeasure Work Selection Flow is shown as Figure 3.2-1. This flowchart is based on the chart which is used in Japan regularly. So that some work method is difficult to adopting for Kyrgyzstan by technical restriction and situation of distribution service. So, in case of selection the countermeasure work, considering the social viewings is important.

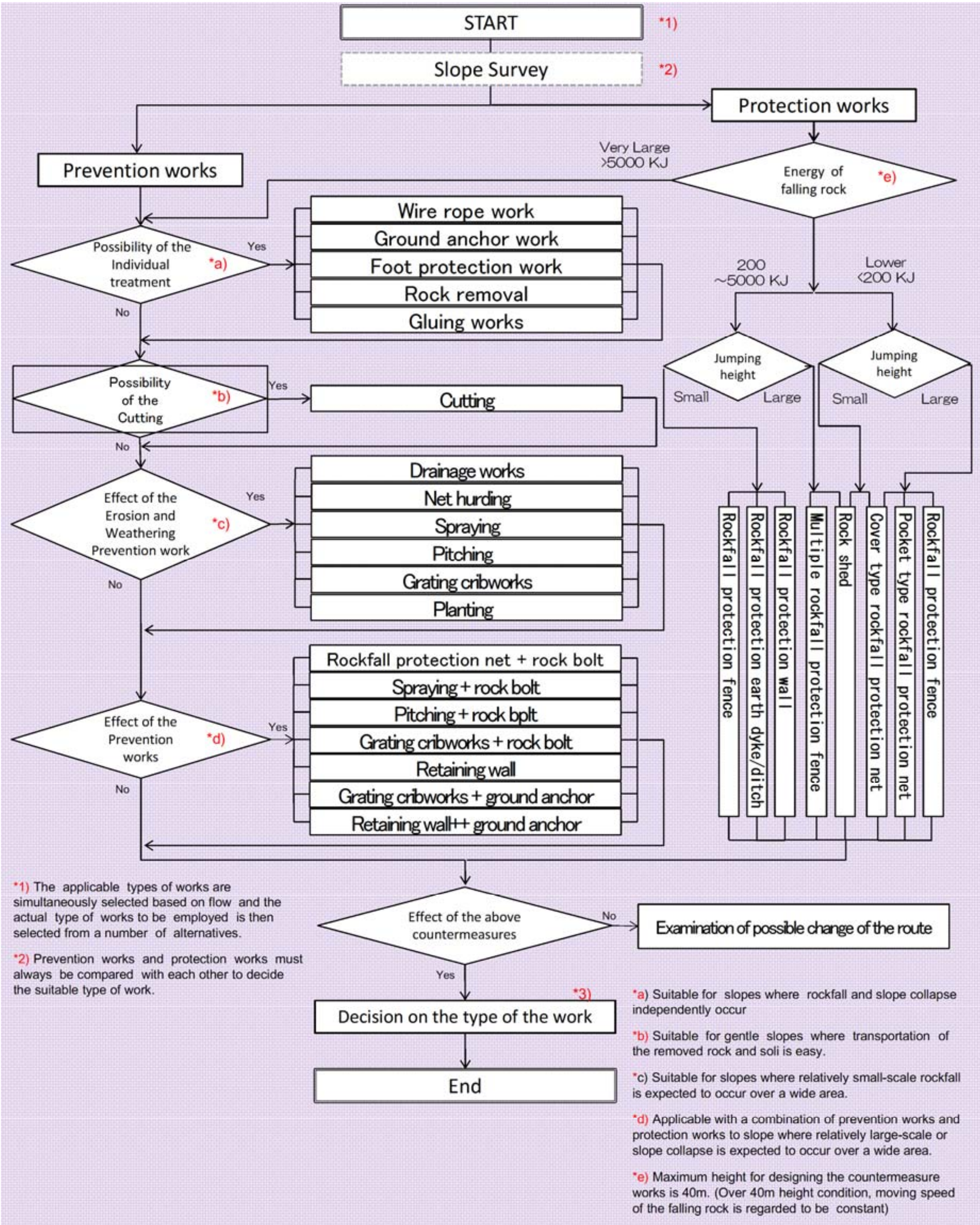


Figure 3.2-1 Selection Flowchart of Countermeasures

3.3 Structural Detail of Main Countermeasures

In this section, explanation for structure and function of following methods as typical countermeasure works.

Rockfall protection work (mitigating the damage by rock fall)

1. Protection Fence
2. Protection Net
3. Retaining Wall／Reinforced soil wall
4. Rock Shed

Rock Fall prevention work (addressing the sources of rock fall)

1. Concrete Foot Protection
2. Wire rope and net
3. Shot crete
4. Frame work (Crib work)

3.3.1 Rock fall protection work (mitigating the damage by rock fall)

For the design of rock fall protection work, it is firstly necessary to assume the external forces to be dealt with by a structure. In this context, it must be noted that the weight and velocity of falling rocks and the working direction to and location at a rock fall protection works of falling rocks considerably vary depending on such factors as the topography, geology, degree of weathering of the slope, vegetation and the presence of any other rock fall prevention or protection works at the site. Accordingly, the most suitable values representing these factors must be estimated based on field investigation results and past experience of rock fall.

Rock fall protection works can be designed by either the energy calculation method or the static strength calculation method. In the case of a rock fall protection net and a rock fall protection fence, design calculation at the time of their construction is not necessarily required. Instead, their specifications can be determined based on the specifications used for similar slopes.

(1) Protection Fence

A rock fall protection fence is an effective countermeasure for relatively small-scale rock fall and the type and dimensions should be determined based on the slope conditions. As a standard structure, this method is made from steel fence and steel net. This method is set at the end of the slope or in the middle of the slope supporting by independent foundation or combined by retaining wall.

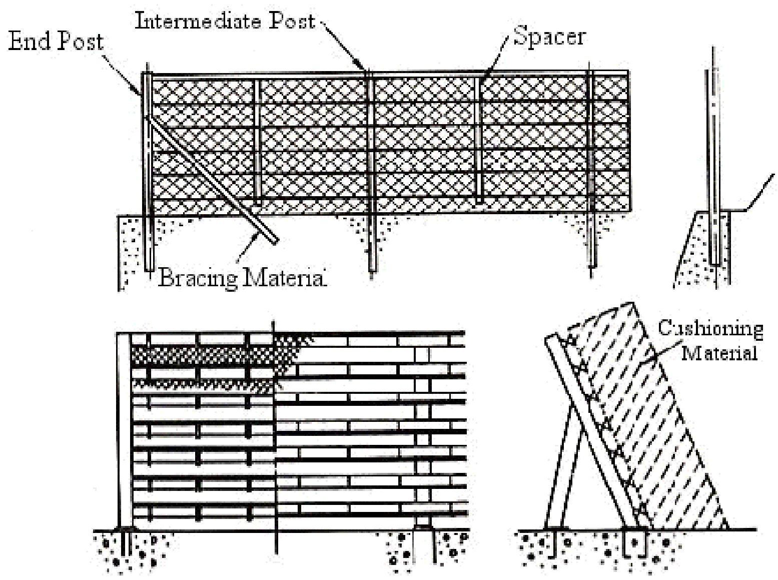


Figure 3.3-1 Components of protection fence

To mitigate the road disaster, this type of work is tended to located along the road. For planning this type of construction, considering the road width and viewing distance on the traffic is very important.

And this type of structure needs enough space of capture area of the rockfall. Then periodic inspection for amount of the falling rocks and rock removing maintenance work is important.

(2) Protection Net

A rock fall protection net uses such lightweight materials as a wire net and wire ropes to entirely cover a slope which has a rock fall hazard and there are two types of such net as described below.

i. Cover type rock fall protection net

ii. Pocket type rock fall protection net

The former intends to confine rocks which have lost their binding power with the ground with friction between the net and the ground and the tensile force of the wire net, producing a function which is similar to that of rock fall prevention work. In contrast, the latter consists of hanging ropes, posts, wire net and wire ropes. The upper part has an entrance for falling rocks and it has the function of absorbing the energy of falling rocks through collision between the net and the falling rocks.

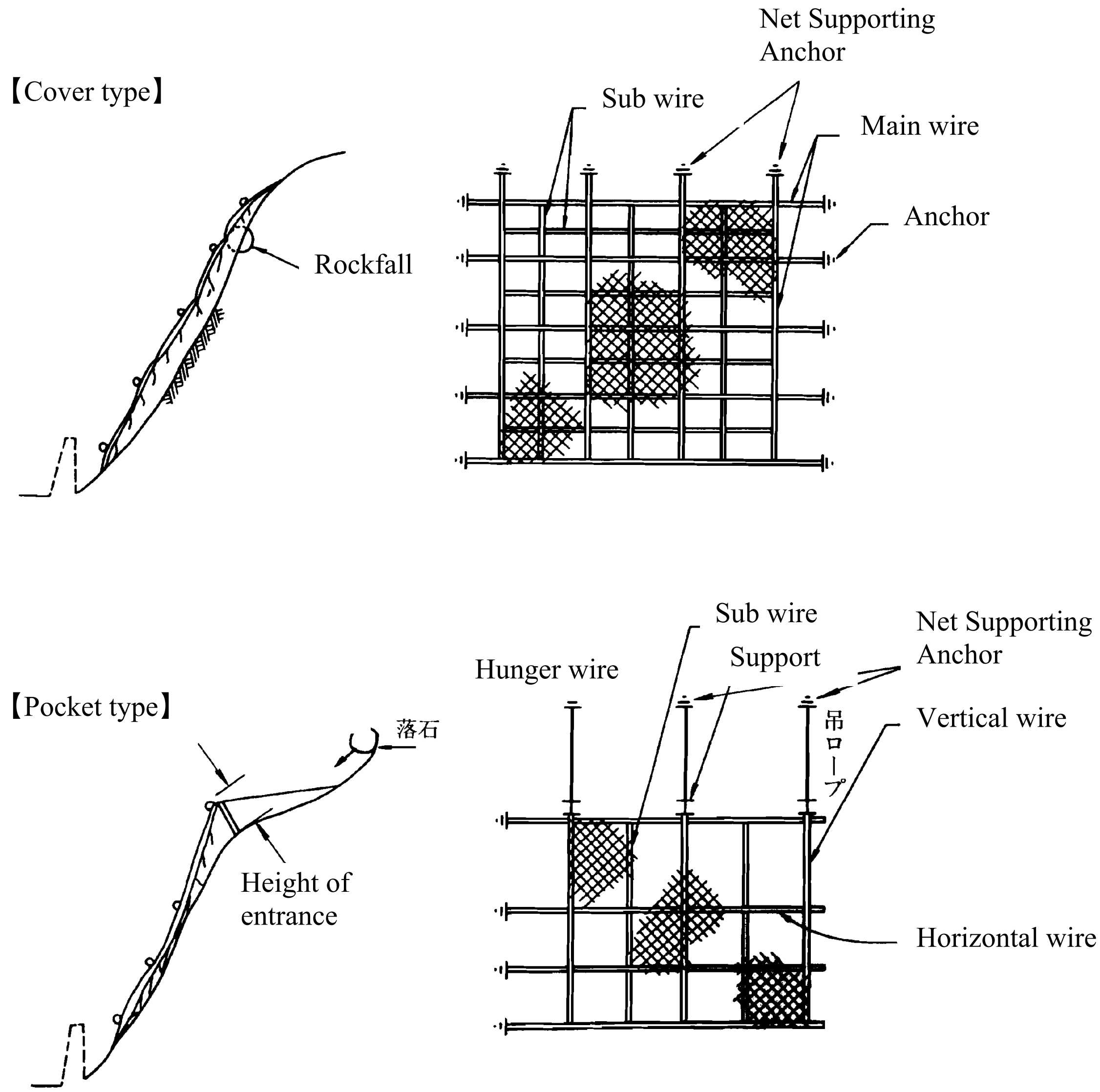


Figure 3.3-2 Components of protection net

And this type of structure needs enough space of capture area of the rockfall. Then periodic inspection for amount of the falling rocks and rock removing maintenance work is important.

(3) Retaining Wall

If the load from falling rocks is small, gabion retaining walls and concrete retaining walls can be introduced. But durability and design basis are not sufficiently established, so the reliability as a countermeasure work is inferior.

Reinforced earth walls used in Japan are developed to cope with large impact load. The structure is strength the embankment which is stacked like a retaining wall.

For designing this type of work, advance consideration for enough space for road and impact for the road traffic.

Basic structure of the reinforced soil wall is shown in Figure 3.3-3.

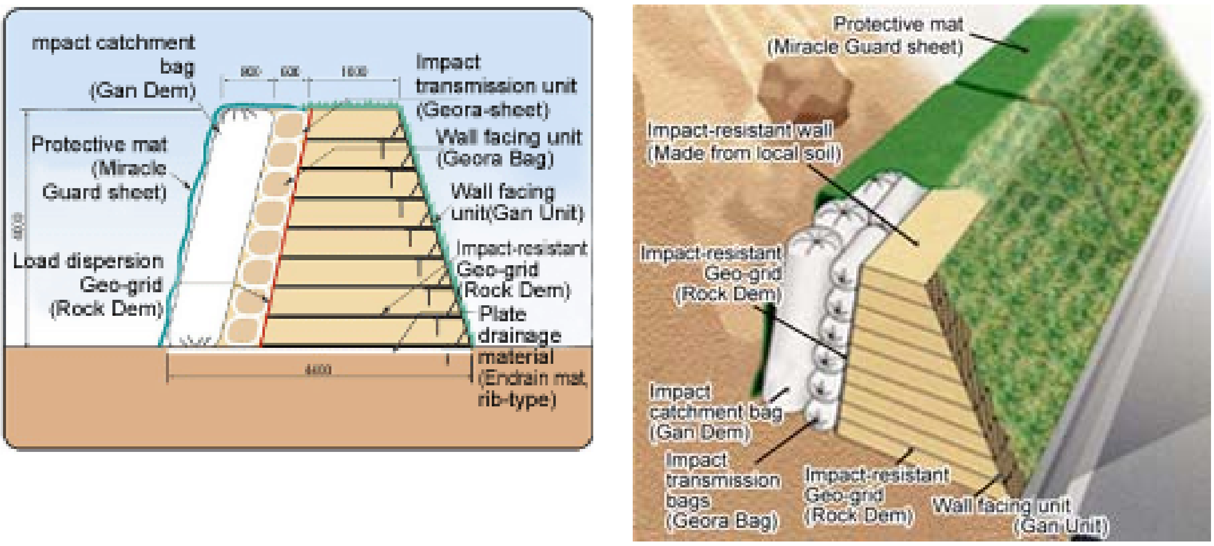


Figure 3.3-3 Structure of the reinforced soil wall

And this type of structure needs enough space of capture area of the rockfall. Then periodic inspection for amount of the falling rocks and rock removing maintenance work is important.

(4) Rock Shed

A rock shed is used where there is a series of steep slopes with a high rock fall hazard with little room at the roadside, where an expected large-scale rock fall cannot be prevented by a rock fall protection fence or where the high falling height suggests that falling rocks may well jump over a rock fall protection fence.

Fig shows some types of rock shed structure. Design and construction process is different for the structure and type of the concrete.

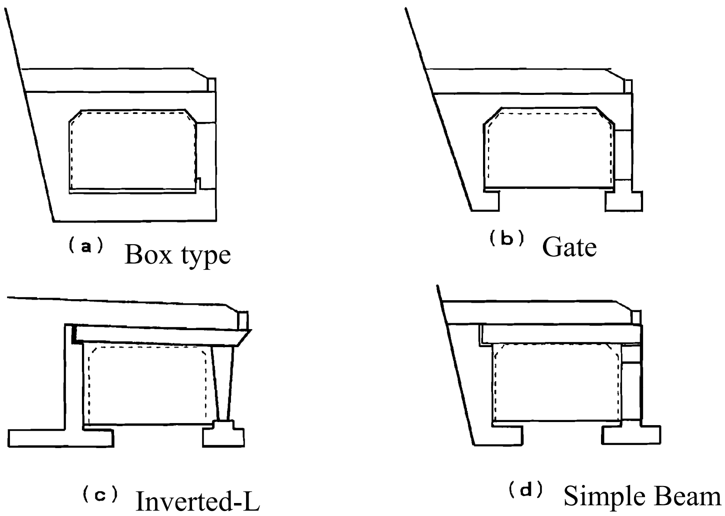


Figure 3.3-4 Types of Rockshed

This type of countermeasure work need huge amount of budget and construction period. Then detail inspection for geological and topographical condition of the unstable rocks and construction area, construction conditions at temporary works (whether to be closed, whether there is a difficult season to construction etc.) should be done.

3.3.2 Rock Fall prevention work (addressing the sources of rock fall)

(1) Concrete Foot Protection

Moving of unstable or cracked rock causing by the gravity are supported by this method. In-situ concrete is tightly fixed between the ground and the unstable rock mass. In some cases, H steel, reinforced bars, etc. are fixed inside the concrete to make the stability more reliable. Basis of design calculation is difficult to set up, then there is a risk that the effect will be lost if earth pressure is applied from behind more than the target rock mass. Rock layer should be needs for the foundation of this structure. Sand and extremely weathering rocks base is not applied to this type of countermeasure work.

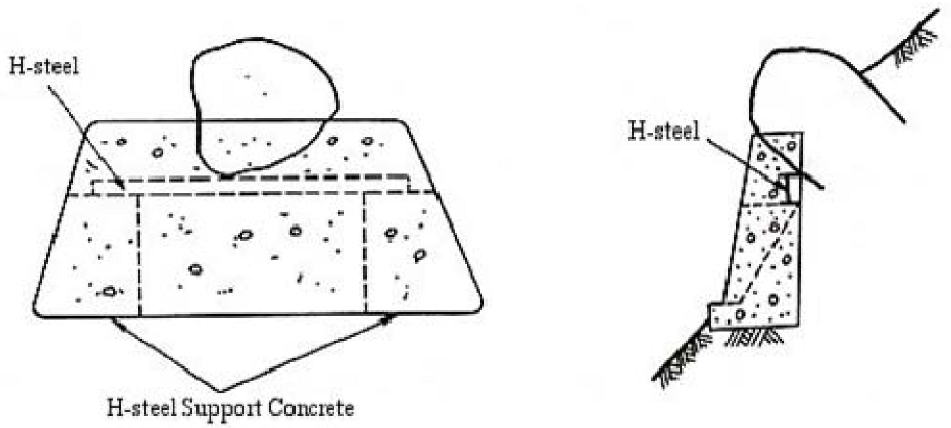


Figure 3.3-5 Concrete Foot Protection

(2) Wire rope and net

This type of work is applied to the unstable rocks on the slope. Mesh type of wire ropes covers the rock mass and end of the wire are fixed to the ground by anchor bolts. The design condition is that the strength of the wire and the supporting force of the anchor are sufficient for the downward movement energy of the rock. As a condition of on-site construction, it is necessary to secure the transport route of material and the safe working scaffold. Also ensure the geology of the ground suitability for casting the anchor part.

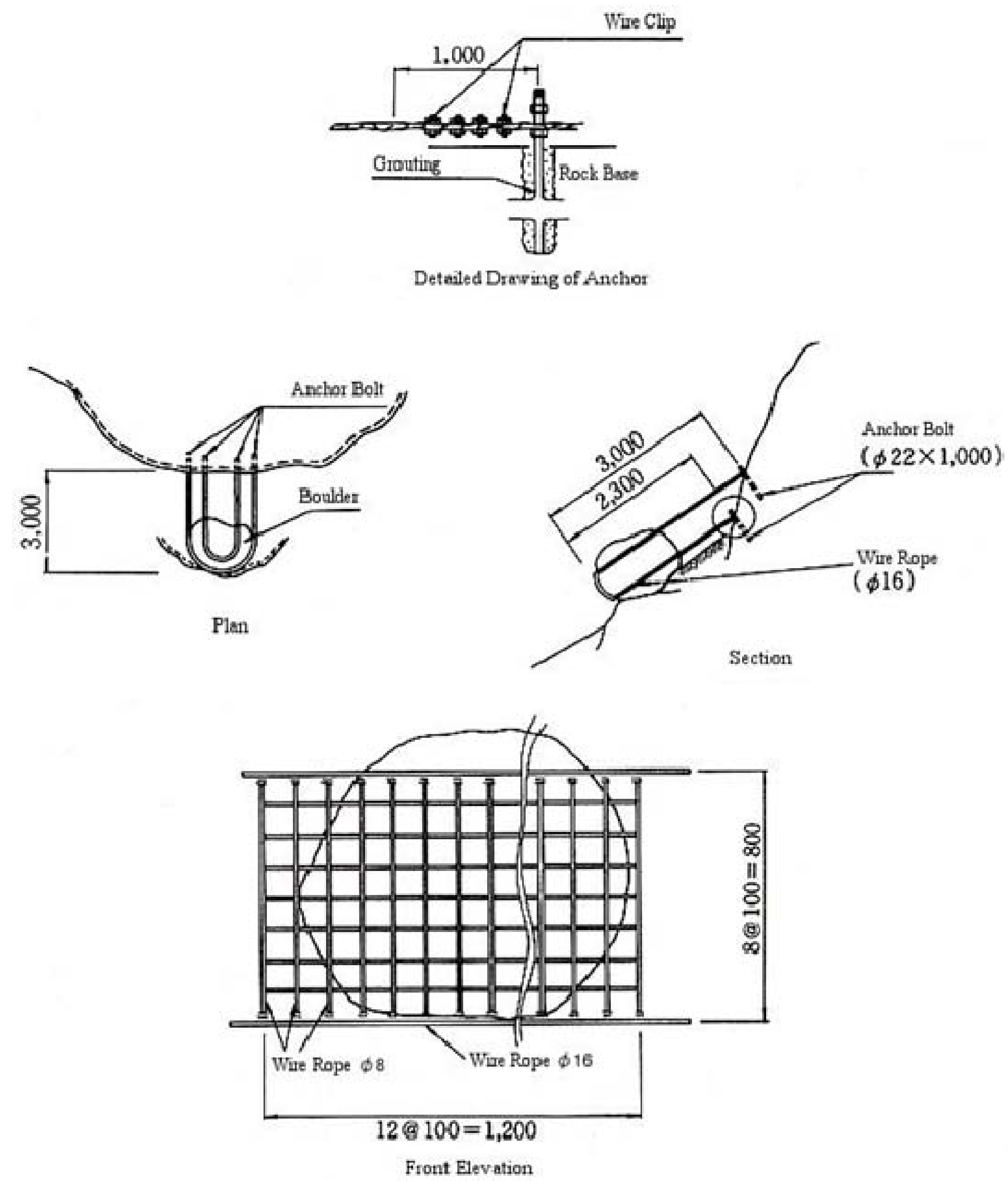


Figure 3.3-6 Wire rope and net

(3) Shotcrete (Mortar and Concrete Spraying)

Shotcrete work is splaying the mortar and concrete to the cutting slope or natural slope. This work has the function for preventing the small-scale rock fall, weathering, erosion.

This is used on easily weatherable rock and rock likely to be weathered and stripped off even though there is no spring water in slope and there is no danger for the time being as well as for mudstone not suited to vegetation.

The thickness of spraying is determined by taking account of the slope conditions and weather conditions, and the standard thickness of spraying is 8 to 10 cm for mortar spraying and 10 to 20 cm for concrete spraying.

Prior to spraying, it is required to lay the wire mesh over the face of slope and to anchor it. The standard number of anchors is 1 to 2 every square meter. When spring water is present on the spraying surface, the introduction of sufficient drainage facilities is necessary (Figure 3.3-7).

When thick spraying is required because of a steep gradient or when the slope surface is considerably uneven, an increase of the number (density) of anchor pins or anchor bars is desirable depending on the actual need.

As part of spraying, weep holes should, in principle, be introduced at a standard rate of at least one hole per 2 – 4 m2 of the spraying area. As the durability of spraying is significantly affected by the weather conditions, particularly during the work, in addition to the composition of the admixture, spraying work conditions, equipment performance and skill of workers, careful attention must be paid to the timing of the work and the working hours. In principle, spraying should not be conducted in the following cases.

i. Normal spraying work is severely disturbed by strong wind.
ii. Proper curing cannot be expected because the temperature is near freezing point.
iii. The cement is likely to be washed away from the spraying surface because of strong rain.
iv. Spraying operation is likely to be disturbed by extreme drying due to strong wind and fine weather.

While the guidance admixture ratios by weight of cement, sand and aggregate are C:S = 1:4 (C: cement weight; S: sand weight) for mortar spraying and C:S:G = 1.4:1 – 1:4:2 (G: aggregate weight), a cement volume of more than 400 kg/m3 and the adoption of a water-cement ratio of not more than 60% are desirable. The strength of the mortar and concrete should be decided after trial mixing using 15 N/mm2 (150 kgf/cm2) as the yardstick.

This type of work is not applied for extremely protruding rocks and overhung part. For some sites, cutting and shaping work is necessary for preparing work.

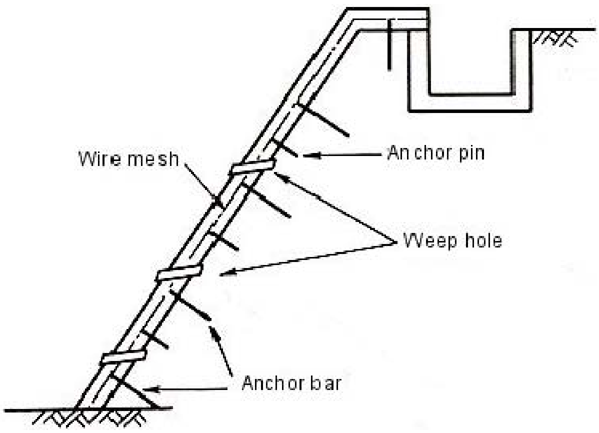


Figure 3.3-7 Example of Mortar Concrete Spraying

(4) Frame work (Crib work)

Frame work is applied for the slopes that the surface is cracky rock or needing to protect early. The structure is reinforcing bar arranged in a lattice as a core and continuous placement of concrete with rectangular cross section. This type of work has the function which stabilizing the face of the slope.

Shotcrete cribworks are used for slopes consisting of bedrock with many cracks or slopes of which the protection is urgently required. While the standard function of spray cribworks are the good workability means that spray cribworks can be applied for slopes with an uneven slope surface. Moreover, the shape of cribworks can be flexibly changed in accordance with the slope conditions.

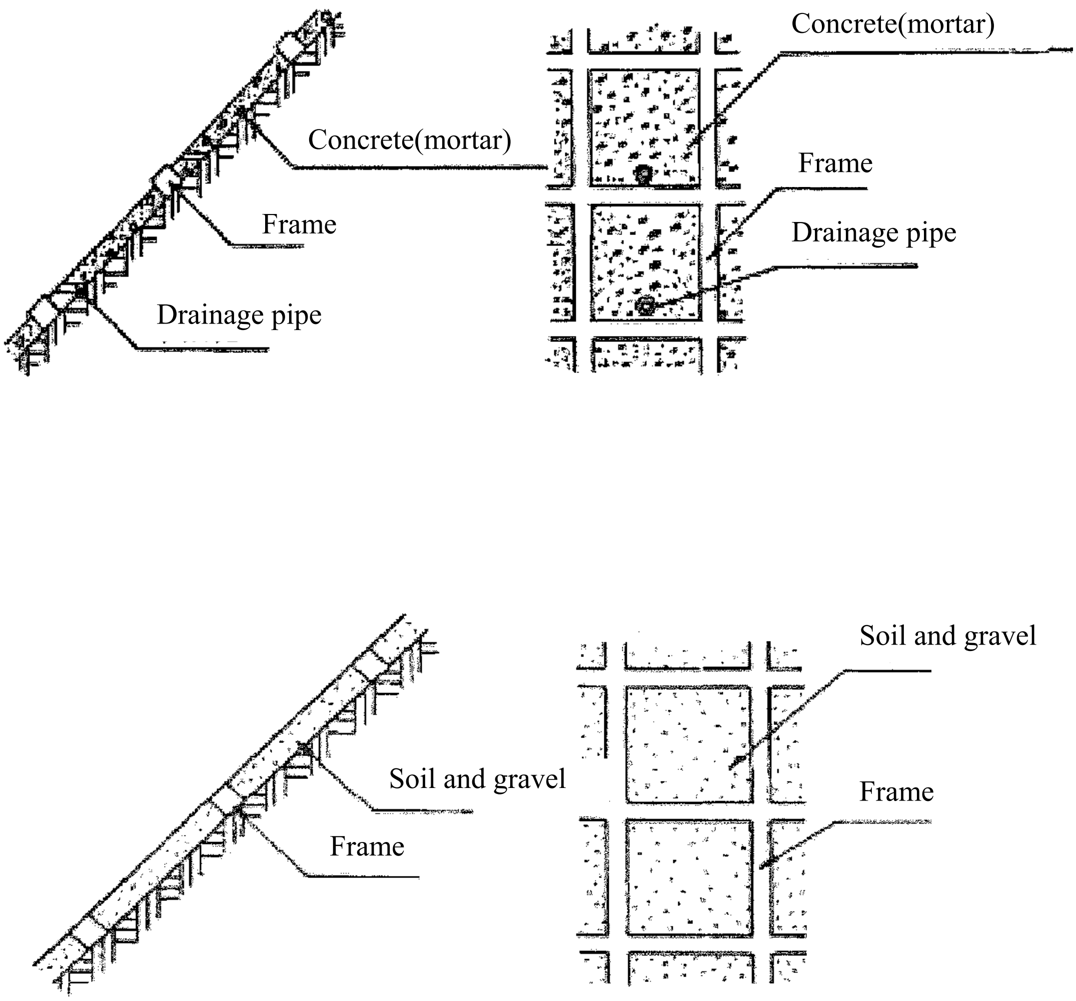


Figure 3.3-8 Example of Frame work

CHAPTER 4 COUNTERMEASURES AGAINST LANDSLIDE

4.1 General

Basic policy of the Countermeasure work for landslide is as follows.

1. After recognizing the signs of moving, starting the inspection or monitoring for the area and activity of the landslide. (Refer to the Inspection Manual)
2. Control work is better to apply for temporary countermeasure work.
3. Control works and Prevention works are combined to apply for long-term countermeasure works referring to the inspection result.

Movement of landslide is slowly than rockfall and slope collapse. So, it is possible to conduct the inspection and monitoring at the time of early stage for catching the sign, before the activities become so fast. It is important that designing the appropriate countermeasure work based on landslide scale and mechanism by inspection result.

And landslide will need for long period to stop their movement after they have moved continuously. Also, countermeasure work against landslide will need huge budget, so it is important to do the inspection at the early stage. Early response for landslide countermeasure work is very effective action for keep stability.

Deformation on the road surface are occurring due to the moving of landslide (DEP9)

Sliding cliff are occurring due to the moving of landslide (DEP959)

Figure 4.1-1 Section of Sediment Movement

4.2 Selection of Countermeasures

4.2.1 Classification of Countermeasures

Typical countermeasure work for landslide is as follows.

Table 4.2-1 Comparison Table of Countermeasures against Landslide (1/2)

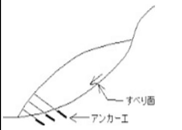
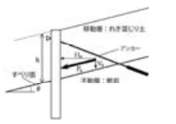
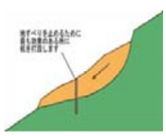
Countermeasures for Landslide (1/2)				
condition	Prevention works			
Type	Ground anchor work	Pile with anchor work	Steel Pile work	Shaft work
Photo / Schematic illustration	 	 	 	 
Construction conditions	High intensity steel material is used for pulling element. Connecting to the pressure receiving portion of the earth's surface (grating cribwork or pitching plate, etc.) receive the sliding force of the landslide mass. By providing an initial tension prior to sliding, it is possible to stabilize before the variation is large.	The ground anchor is installing between the steel piles. The fulcrum of the anchor becomes the head of the steel pipe. In order to integrate the steel pile and the anchor, this work require the H-steel for coupling to the horizontal direction.	Insert a steel pipe in the vertical hole by drilling of large diameter. Concrete will be packed inside and outside of the steel pile. The pile will be fixed to the base ground layer and stabilize the moving of the landslide.	Digging a vertical pit with a diameter of 2.5 ~ 6.5m. Inside the pit will be filled by reinforced concrete. Expect the same function as the steel piles. This work is placed lower part of landslides.
Maintenance(with the monitoring of landslide	Monitor for tension force of the anchor. Checking the deformation of the anchor head and the receiving pressure part.	Monitor for tension force of the anchor. Checking the deformation of the anchor head and the receiving pressure part. Monitor for deformation of steel pile	Monitor for deformation of steel pile	Monitor for deformation of shaft work
Propriety for the construction	This method has been adopted in a number of landslide areas. There must be no hindrance of land use that lower part of the landslide area shold be used for the pressure receiving part.	This method is applied by the upper part of the landslide areas. It is placed just below the road and houses. There is an effect to prevent the conservation target is moved downward by the activity of landslides.	This method has been adopted in a number of landslide areas. This method is suitable for the landslide which lower slope is gentle and anchor work is difficult to set up	Construction costs will be huge. This work is adopted for the landslide which moving force is so large and keep the safety for the very important target.
Application possibility in Kyrgyzstan (For technically highly advanced and the project cost is so expensive, these works shold start from the international support.)	Effect of stabilizing can be expected for medium to small-scale landslides. Construction position shold be lower part or foot of the landslide. This construction method is better used in combination with control works.	This type of work is adopted for the road condition which shifting the line is not easy.This method shold be aplied for the landslide which head is near the road.	Effect of stabilizing can be expected for medium to large-scale landslides. This construction method is better used in combination with control works.	Long-term budget plan is essential. It takes a big time than inspection and design costs to other construction methods.
Cost	40,000(COM/m)	Anchor : 40,000(COM/m) Pile : 100,000(COM/m)	100,000(COM/m)	1,000,000(COM/m)

Table 4.2-2 Comparison Table of Countermeasures against Landslide (2/2)

Countermeasures for Landslide (2/2)

condition	Control works			
Type	Cachment Well	Lateral Boring	Earth removal work	Countreweight Embankment work
Photo / Schematic illustration	  	  	 	 
Construction conditions	Discharging the underground water from inside of the well. It will decreace the groundwater level. Good workerbility will be expected for gentle slope and wide area. This type of constructiuon work is applied for large schale landslide.(depth of moving block is deep)	Discharging the underground water from lateraql boring. It will decreace the groundwater level. This method is mainly constructed from lower to foot part of landslide. It will need slope and wall for construction in the land slide area.	Remove the rock and soil mass from the head of the landslide. This is one of method for reducing the sliding power of landslide. Should be noted for the stability of the slope after the earth removal and the secondary movement behind the slope. Caution must be required for surface water and rainfall which infiltrating into the cutting surface.	Making the embankment at the foot of the landslide. The embankment will be the counterweight for the moving of landslide. Caution must be required for 1) dreinage syetem of the embankment 2) stability of the embankment 3) surface protection of the embankment.
Maintenance(with the monitoring of landslide	Monitoring for the water discharge. Monitoring for the deformation of well	Monitoring for the water discharge.	Monitoring for the stability of cutting slope and cutting surface.	Monitoring for the stability and drainage of the embankment.
Propriety for the construction	Drainage plan (drainage boring work, channel work) is required for leading the discharge water to the outside of the landslide areas.	Drainage plan (channel work) is required for leading the discharge water to the outside of the landslide areas.	In advance must be examined for the disposal location of cutting mass.	This type of method should be implemented for using suitable material for embankment.
Application possibility in Kyrgyzstan (In advance these work requires detailed investigation of landslide activity mechanism)	There are some large landslide area which is facing to the road. Sufficient effect can be expected by groundwater conditions.	There are many landslide area which is facing to the road. Sufficient effect can be expected by groundwater conditions.	There are many landslide area which is facing to the road. Sufficient effect can be expected by landslide conditions.	There are many landslide area which is facing to the road. Sufficient effect can be expected by landslide conditions.
Cost	20,000,000～35,000,000 COM/1well Well excavating; 560,000 COM/m	16,000 COM/m	3,000 COM/㎥	2,600 COM/㎥

4.2.2 Criteria for Selection of Countermeasures

Selection Flowchart of Countermeasures is Figure 4.2-1.

Selection of countermeasure work for landslide is to activate the planned safety factor as a goal. To set the planned safety factor is depend on the increasing ratio from the current safety factor. In order to set the safety factor, it is necessary to analyze the variation mechanism of the landslide including the slip surface depth, scale and groundwater distribution state based on detailed inspection. So, selecting and designing the countermeasure works should be conduct carefully by using the various data of inspection result. But some types of landslide will be moving so fast before the detail inspection has been terminated. In such cases temporary countermeasure works is necessary to stabilize the moving. Emergency measures should be implemented mainly by landslide control works, as cutting, embankment, drainage work, etc.

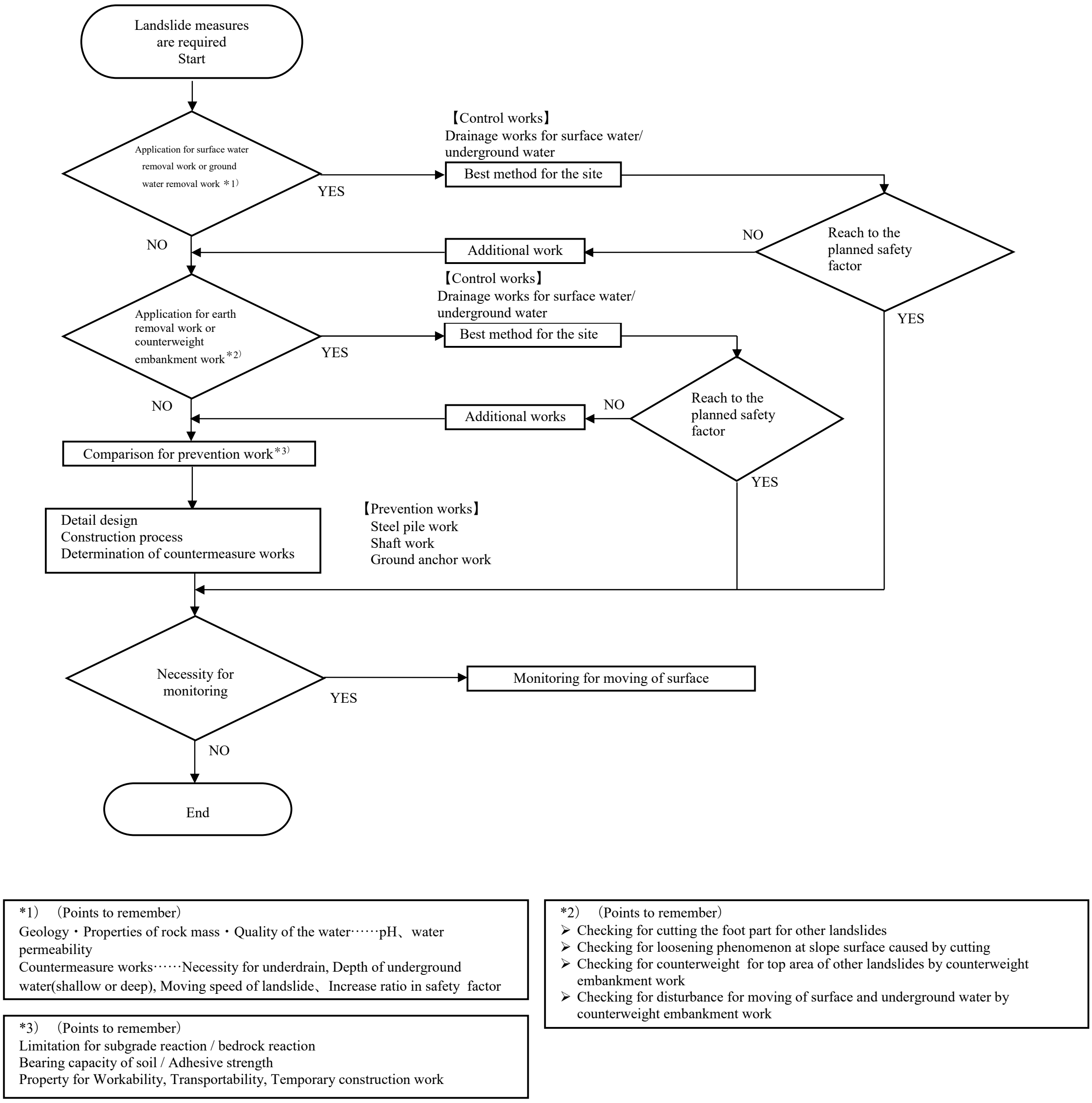


Figure 4.2-1 Selection Flowchart of Countermeasures

4.3 Structural Detail of Main Countermeasures

This section shows the structure and function of following typical countermeasure works for landslide.

【Landslide control works】

1. Catchment Well
2. Lateral Boring
3. Earth removal work
4. Counterweight Embankment work

【Landslide prevention works】

1. Ground anchor work
2. Pile with anchor work
3. Steel Pile work
4. Shaft work

4.3.1 Control works

(1) Catchment well

This type of countermeasure work is one of groundwater drainage work. Drilling the horizontal drainage radially holes from inside the vertical well. The diameter of the well is 3.5 ～4.0 m. The ground water discharged into the well is lead to outside of the landslide area. This type of countermeasure work has the function of decrease the underground water level.

Drainage well is introduced when the required length of lateral boring is too long and when concentrated water drainage is required near the basement layer. It is introduced at a relatively good ground site and has a diameter of mainly between 2.5 m and 4 m. The natural drainage of the collected water through drainage boring works (up to some 100 m in length) or a drainage tunnel is desirable. The lateral boring works to collect water should be 20 – 50 m in length and 8 – 16 boring holes should be introduced across the sliding surface in a radial manner from the drainage well. Planned decreasing underground water level is 5m for standard.

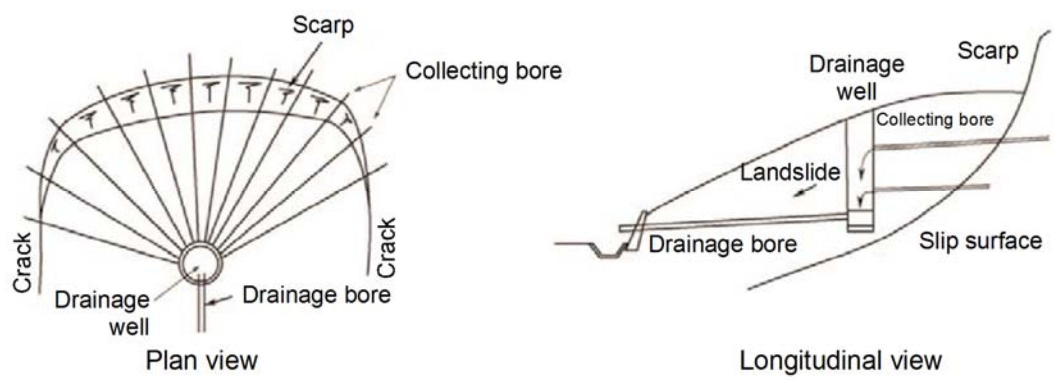


Figure 4.3-1 Components of Catchment Well

(2) Lateral Boring

The diameter of the bore hole is 66 mm and, after completing the drilling work, hard vinyl chloride pipe or gas pipe attached with a strainer should be inserted as hole-protecting and water-collecting/draining pipe to an aquifer. The end portion of the drain pipe should be protected by gabion or concrete wall.

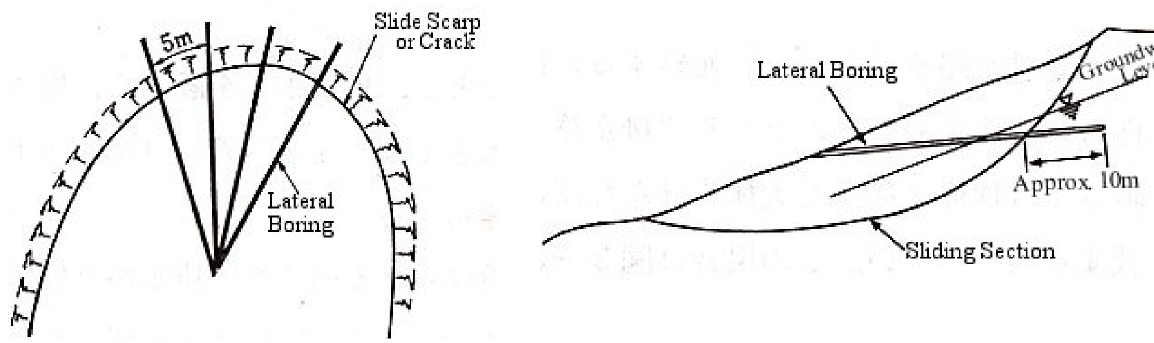


Figure 4.3-2 Components of Lateral Boring

(3) Earth removal work

Normally earth is removed from the head portion of landslide area and not from the tail portion except special cases. Earth removal works are one method by which the most reliable effects can be expected and are therefore frequently used for medium and small-scale landslides.

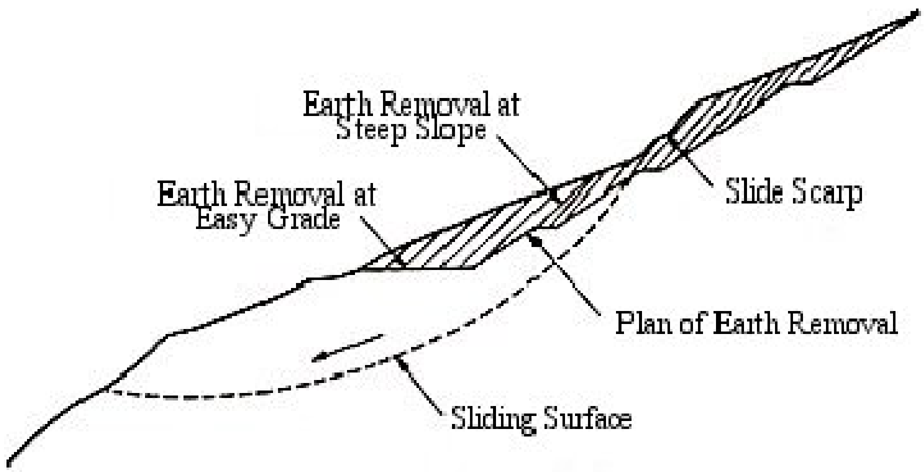


Figure 4.3-3 Cutting Area of Earth Removal Work

(4) Counterweight Embankment work

Earth is filled on the lower portion of landslide area to stabilize the slope according to the counter weight. However, earth at the tail portion of landslide area is specially disturbed and soft. Thus, if earth is filled near the tail portion, the foundation ground may sometimes collapse or the pore water pressure in landslide mass may increase due to the disturbance of the groundwater flow, thereby making the landslide area unstable. Because of this, the groundwater should be completely drained and then filling works should be performed.

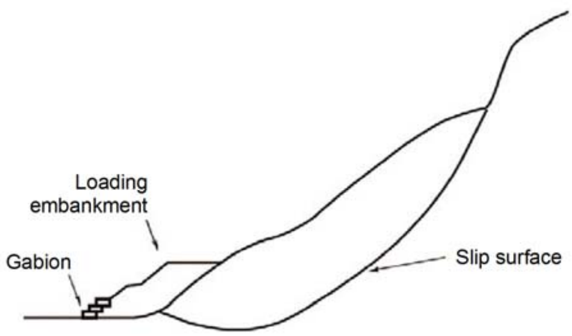


Figure 4.3-4 Loading of Embankment

4.3.2 Prevention works

(1) Ground anchor work

Ground anchor works use high strength steel as the tension member in a relatively small borehole and have a structure whereby bearing plates receive the reaction force. Ground anchor works have the advantage over other types of control works in that they are capable of working a sufficient suppression force by having an initial tensile force prior to major displacement by landslides. They are generally used for small to medium-scale landslides in rock or weathered rock and are often combined with pile or shaft works. They are also used to convey suppression force in association with a retaining wall, cribworks or independent bearing plate, etc.

Careful examination is required in regard to determination of the design load of ground anchor works, way of adding initial tensile force and long-term stability of the fixed part. Moreover, double anti-corrosion treatment must be applied to ensure the durability of ground anchor works.

This method has been adopted in a number of landslide areas. There must be no hindrance of land use that lower part of the landslide area. Effect of stabilizing can be expected for medium to small-scale landslides. Construction position should be lower part or foot of the landslide. This construction method is better used in combination with control works.

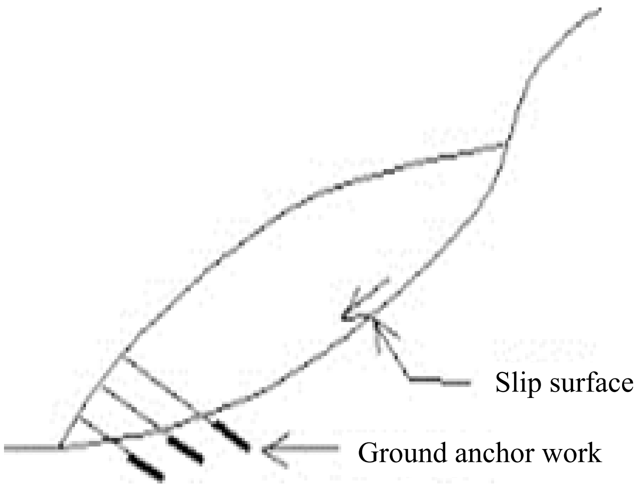


Figure 4.3-5 Ground Anchor Work for Landslide

(2) Pile with anchor work

The ground anchor is installing between the steel piles. The fulcrum of the anchor becomes the head of the steel pipe. In order to integrate the steel pile and the anchor, these works require the H-steel for coupling to the horizontal direction. This method is applied by the upper part of the landslide areas. It is placed just below the road and houses. There is an effect to prevent the conservation target is moved downward by the activity of landslides. This type of work is adopted for the road condition which shifting the line is not easy. This method should be applied for the landslide which head is near the road.

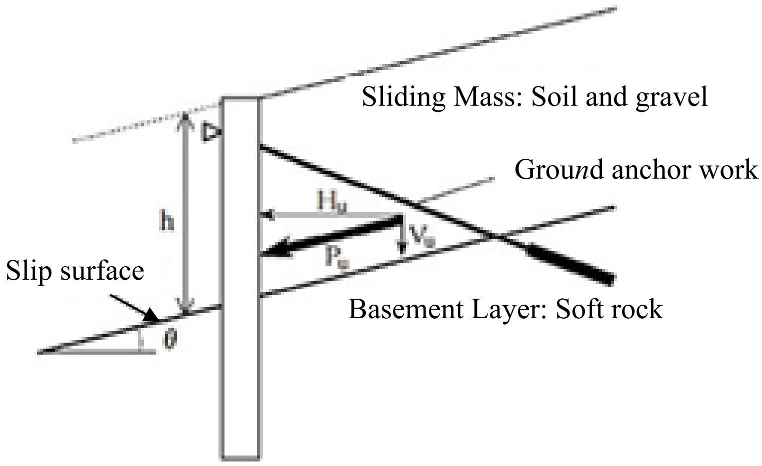


Figure 4.3-6 Pile with Anchor Work

(3) Steel Pile work

Insert a steel pipe in the vertical hole by drilling of large diameter. Concrete will be packed inside and outside of the steel pile. The pile will be fixed to the base ground layer and stabilize the moving of the landslide.

It is desirable to carry out the pile works at a place where the bedrock is strong and the pile is fully able to withstand a moving soil mass. However, if the motion of a landslide is vigorous and the movement exceeds 1 mm per day, the effect of piles cannot be expected since each pile reacts individually unless they have all been placed at the same time in the landslide area. Pile works are not suitable for these areas.

H-section steel piles, reinforced concrete piles and steel pipe piles are used for the insertion method. A bore hole with a large diameter (about 35 to 40 cm) is first driven, and a steel pipe with a diameter of about 30 cm is then inserted to the hole. The inner space of the pipe is then filled up with concrete, and the gap between the pipe and bore hole wall of bore hole is filled with grout.

This method has been adopted in a number of landslide areas. This method is suitable for the landslide which lower slope is gentle and anchor work is difficult to set up. Effect of stabilizing can be expected for medium to large-scale landslides. This construction method is better used in combination with control works.

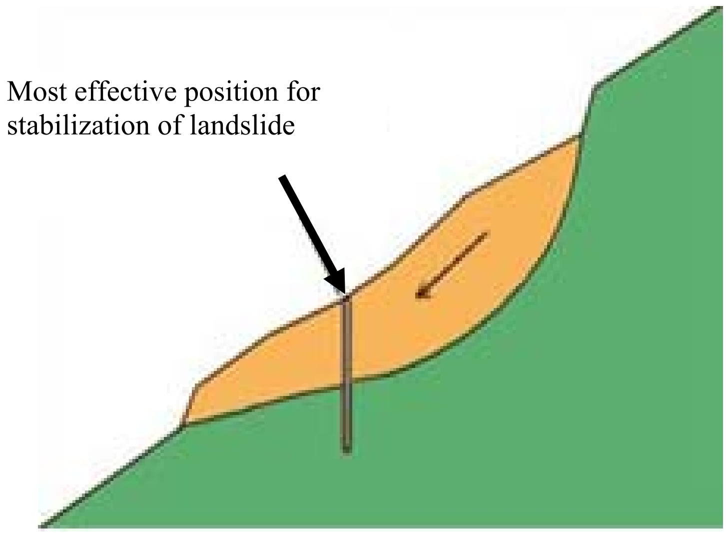


Figure 4.3-7 Pile Work for Landslide

(4) Shaft work

Digging a vertical pit with a diameter of 2.5 ~ 6.5m. Inside the pit will be filled by reinforced concrete. Expect the same function as the steel piles. This work is placed lower part of landslides. Construction costs will be huge. This work is adopted for the landslide which moving force is so large. Also, this work is adopted for keep the safety for the very important target.

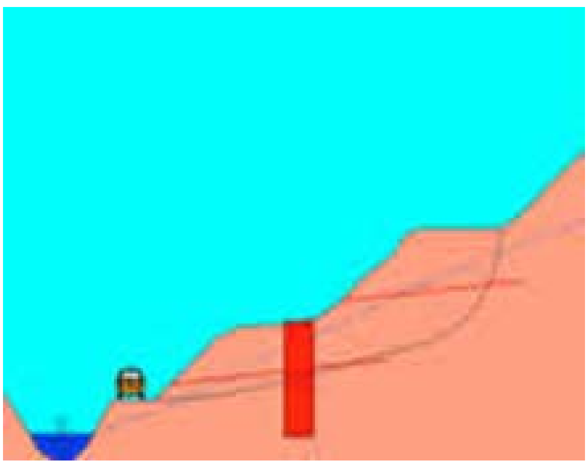


Figure 4.3-8 Shaft Work for Landslide

CHAPTER 5 COUNTERMEASURES AGAINST SLOPE COLLAPSE

5.1 General

Basic policy of the Counterwork for slope collapse is as follows.

1. Predict and examine about expansion of range of collapse and possibility of collapse on adjacent slope after the slope collapse occurred.
2. Consider the disaster prevention measures of the sites which have high disaster risks by periodic inspection.
3. Consider the necessity of the slope protective works when constructing a new cutting surface by road improvement.

Like as rockfall, slope collapse is a disaster in which it is difficult to predict occurrence scale and the occurrence timing. As many cases, new collapse which is not subject to periodic inspection occurs by heavy rain. Therefore, it is necessary to study countermeasures by the risk of disaster for around the disaster occurrence site and the site with disaster record as 1) and 2).

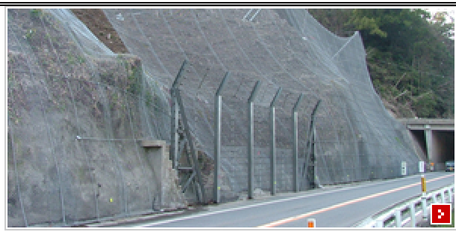
Slope collapse is a disaster that often occurs in cutting surface. So, road managers should need to pay attention for declining the balance of the slope after the cutting work. Therefore, as shown in 3), when forming a cutting surface in a new road improvement work, it is necessary to examine the risk of slope collapse and to review and budget countermeasures as necessary.

Figure 5.1-1 Occurrence of slope collapse (Japan 2010, Yamanashi Prefecture)

5.2 Selection of Countermeasures

5.2.1 Classification of Countermeasures

Table 5.2-1 Major Classification and Type of Countermeasures

Type	Prevention Work	Protection Work
Picture	 Grating crib work  Wire and the nail work (Non- flame work)	 Protection net and fence  NETIS No. HR-070033-A High energy protection fence
Outline	Surface of the slope is protected by some structure or vegetation. Nailing to the slope by certain interval and length will unite the earth mass and structure on the surface. The length and standard of the structure will be determined by scale of the collapse.	These methods prevent that the sliding material will reach to the protected target. The countermeasure works will need the enough strength and space for the moving deposit. For protecting the road, retaining wall, fence, steel net are used generally. In some case rock shed work will cover the road and pass the sliding deposit to the valley side for keeping the safety.
Construction condition	This type of work is applied to the site that the depth of the sliding mass has known by inspection or sliding mass is weathered rock. But this work cannot apply to deep debris deposit. Periodical maintenance is necessary to these works. Basically it is maintenance free till the material will be aging or broken.	Maintenance work for protection work will need the removing the deposit of sliding mass. And checking for the material of the structure, damaged material should be changed for unbroken one.

5.2.2 Criteria for Selection of Countermeasures

Countermeasure Work Selection Flow is shown as Figure 5.2-1.

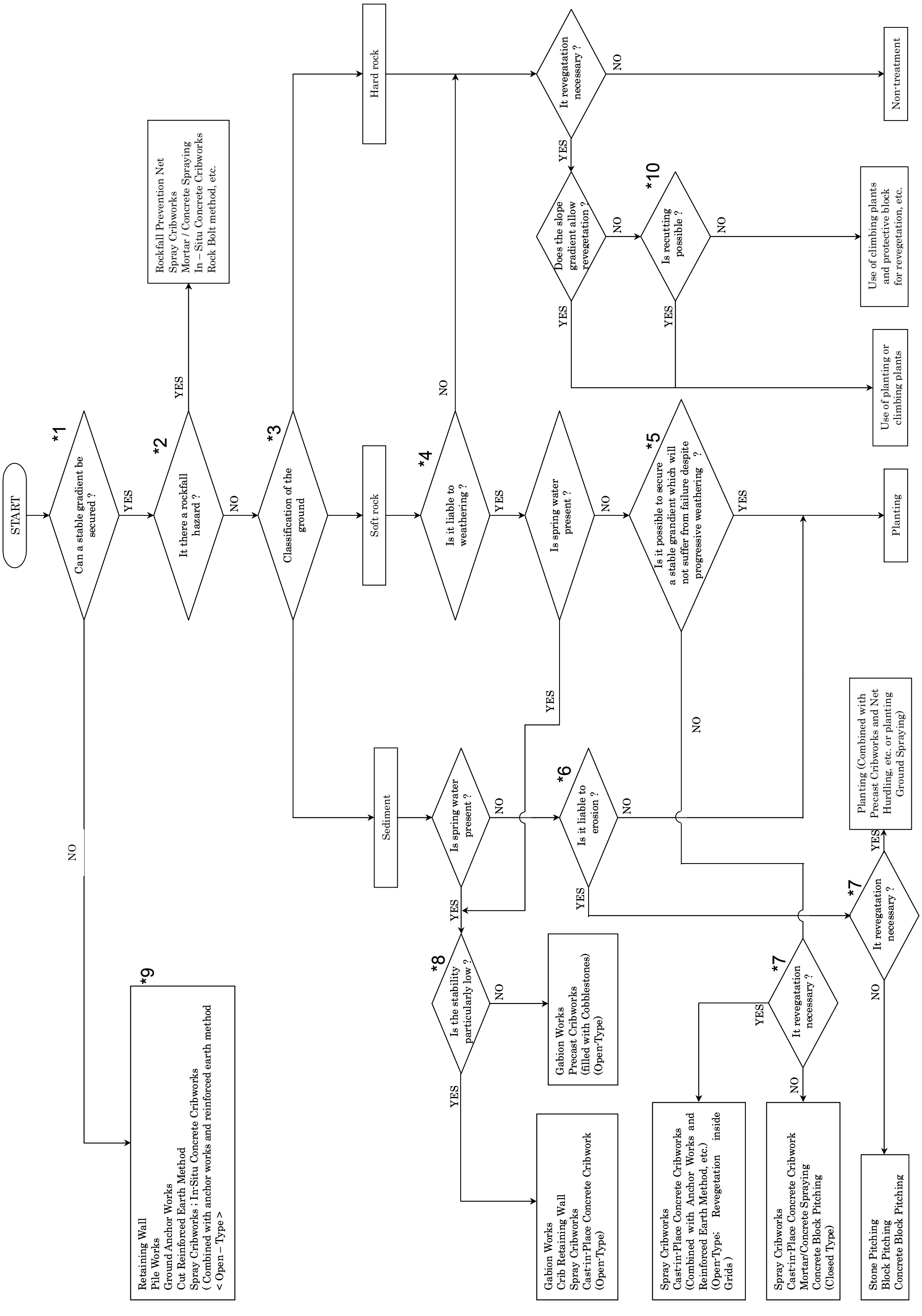


Figure 5.2-1 Selection Flowchart of Countermeasures

This flowchart is the selection way of the countermeasure construction method on the cutting surface, and it is used as a generally in Japan. Firstly, re-cutting for slope is possible or not should be considered. If possible select the optimum construction method by judging the stability based on the geological condition of the cutting surface and the presence of spring water. Also consider the necessity of vegetation work. In Kyrgyzstan, rock fall disasters occur frequently because many cutting slopes are rock slope and they do not have the protection work. In addition, there is not landscape protection project and the vegetation is difficult to grow on the rock slope. Therefore, the need of vegetation work is low at the present time.

Many cases of collapse on a natural slope have been reported from several DEPs. Since it is a collapse at the terminal part of a long mountain slope, it is almost impossible to reshape the slope. Also in the above-mentioned countermeasure work selection flow, when the cutting surface shaping is impossible, the following construction method is selected.

1. Retaining wall
2. Pile works
3. Ground anchor works
4. Cut Reinforced earth method
5. Spray Cribworks ; Cast-in-Place Concrete Cribworks (Combined with anchor works and reinforced earth method)

All of these methods stabilize the slope by the strength of the structure. These methods are classified into "prevention works" in the category of landslide protection works. Conditions of the site are so many cases. But the design works should be done after the detail inspection for the scale of the moving mass and soil quality. Same as the rockfall protection works, we can apply "retaining wall and protection fence" or "Reinforced soil wall". These works are described in "Chapter 3 Countermeasures against Rockfall".

5.3 Structural Detail of Main Countermeasures

Countermeasure by structures for slope surface is applied to the following cases.

- Cannot keep stability without surface protection. Also, vegetation work is not applied.
- Cannot keep long term stability from erosion using only vegetation work.
- Possibility for slope collapse, rockfall, frozen.

Typical countermeasures by structure for slope collapse is described below.

5.3.1 Reinforced earth work

Reinforced earth works mean a construction method involving the use of various reinforcing materials to stabilize embankment slopes and cut slopes of which the gradient is much steeper than slopes which have no reinforcing material.

Reinforced earth work which applied to slope collapse is drilling holes at regular intervals and installing the reinforced bar fixed by filler material. Fixing part on the slope surface is integrated with grating crib or steel wire. Other case independently small steel plate is set on the top. Length of reinforce bar is approximately 3 to 10 m, length is determined by thickness of the unstable soil mass and depth of base layer.

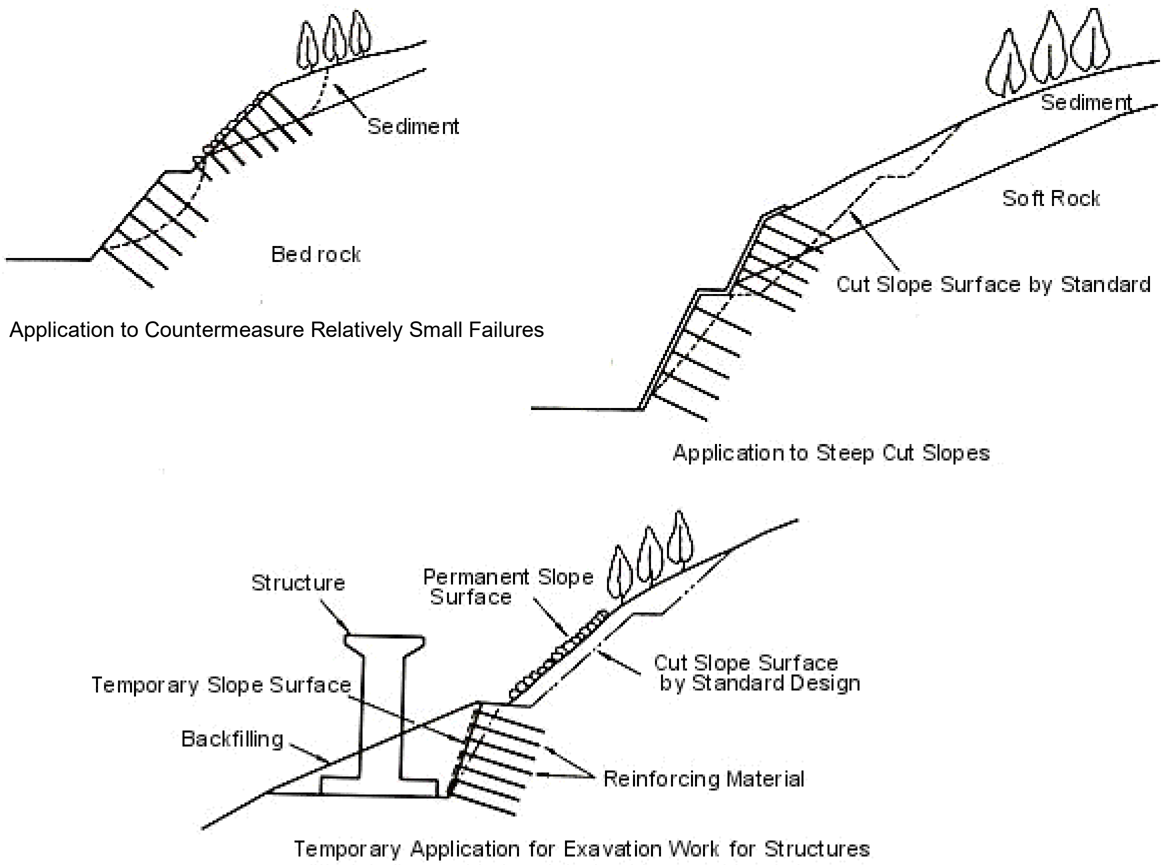


Figure 5.3-1 Application Example of Reinforced Earth Works for Cut Slopes

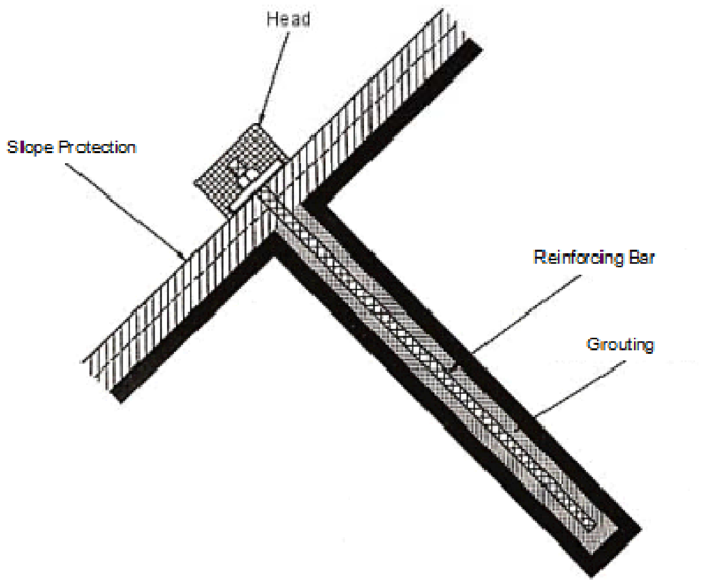


Figure 5.3-2 Formation of Reinforced Earth Works for Cutting Slopes

5.3.2 Grating crib work

Grating crib work is one of the countermeasure work for cutting slope. Sometimes this work is applied with reinforced earth work, in other cases using by independent method of construction. And this type of countermeasure work is classified by setting way of the concrete material “Spray Cribworks” or “Cast-in-Place Concrete Cribworks”.

This work covers the cutting slope and natural slope continuously. And these works keep the surface stability for preventing the erosion and weathering. But these works do not have the opposing force for landslide or slope collapse. So, combines the reinforced earth work or ground anchor work for strengthen the construction effect for necessary.

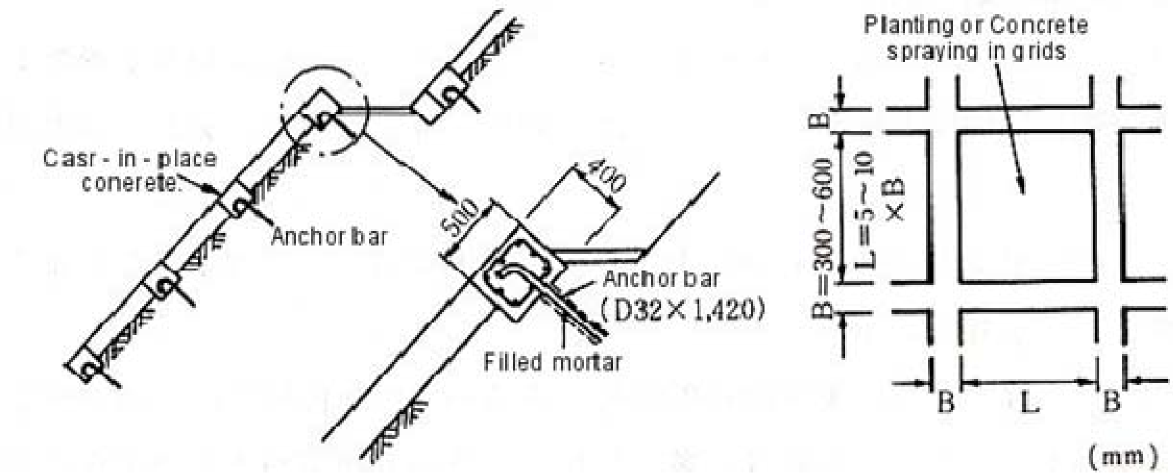


Figure 5.3-3 Example of Cast-in-Place Concrete Cribworks

5.3.3 Mortar and Concrete Spraying

This is used on easily weatherable rock and rock likely to be weathered and stripped off even though there is no spring water in slope and there is no danger for the time being as well as for mudstone not suited to vegetation.

The thickness of spraying is determined by taking account of the slope conditions and weather conditions, and the standard thickness of spraying is 8 to 10 cm for mortar spraying and 10 to 20 cm for concrete spraying.

Prior to spraying, it is required to lay the wire mesh over the face of slope and to anchor it. The standard number of anchors is 1 to 2 every square meter. When spring water is present on the spraying surface, the introduction of sufficient drainage facilities is necessary (Figure 5.3-4).

When thick spraying is required because of a steep gradient or when the slope surface is considerably uneven, an increase of the number (density) of anchor pins or anchor bars is desirable depending on the actual need.

As part of spraying, weep holes should, in principle, be introduced at a standard rate of at least one hole per 2 – 4 m2 of the spraying area. As the durability of spraying is significantly affected by the weather conditions, particularly during the work, in addition to the composition of the admixture, spraying work conditions, equipment performance and skill of workers, careful attention must be paid to the timing of the work and the working hours.

In principle, spraying should not be conducted in the following cases.

1. Normal spraying work is severely disturbed by strong wind.
2. Proper curing cannot be expected because the temperature is near freezing point.
3. The cement is likely to be washed away from the spraying surface because of strong rain.
4. Spraying operation is likely to be disturbed by extreme drying due to strong wind and fine weather.

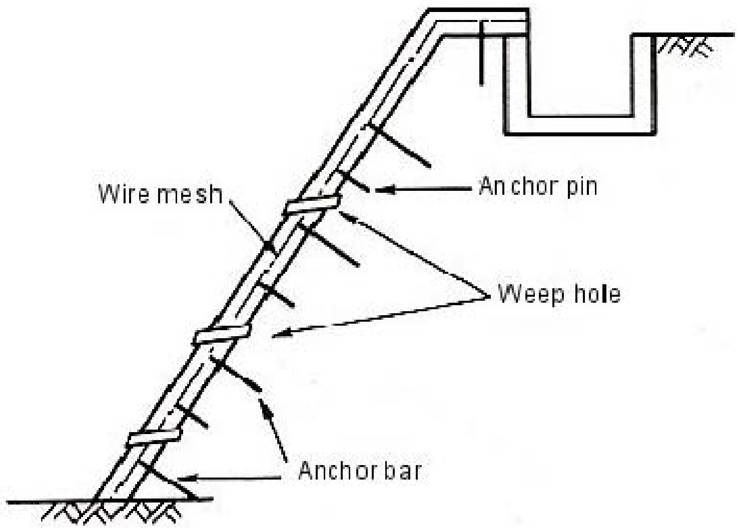


Figure 5.3-4 Example of Mortar Concrete Spraying

5.3.4 Concrete Pitching

This is used when concrete block cribwork or mortar spraying is considered to be not appropriate for the slope of bedrock with many joints or loose talus cone layer.

For large or steep slopes, it is desirable to reinforce the concrete with reinforcing bars or wire mesh and also to install non-slip anchor pins or anchor bolts (refer to Figure 5.3-5).

The plain concrete pitching will require a minimum thickness of about 20 cm. In principle, non-slip anchors should be placed at a rate of one anchor per 1 to 2 m2 , and the depth of embedment should be 1.5 to 2.0 times the thickness of the concrete. It is important to determine the length of anchor pins or anchor bars to suit such specific purposes as the prevention of slope failure and slippage of the concrete pitching depending on the geological conditions of the site.

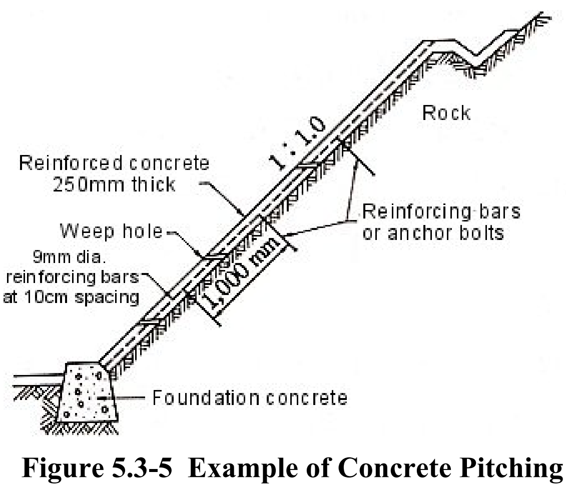


Figure 5.3-5 Example of Concrete Pitching

CHAPTER 6 COUNTERMEASURES AGAINST DEBRIS FLOW

6.1 General

The basic concept of countermeasures against debris flow for the road disaster prevention is given below:

- To study the countermeasure by road structures, like diversion road, culvert and cause way.
- To study the countermeasure by sediment control facilities like sabo dam if it is difficult to mitigate the road disaster by the road structures.
- To study the non-structural measures if the road disaster might not be mitigated by structural measures due to the large-scale debris flow, and structural measures cannot be implemented due to budgetary constraints

The section of sediment movement and riverbed gradient is as shown in Figure 6.1-1.

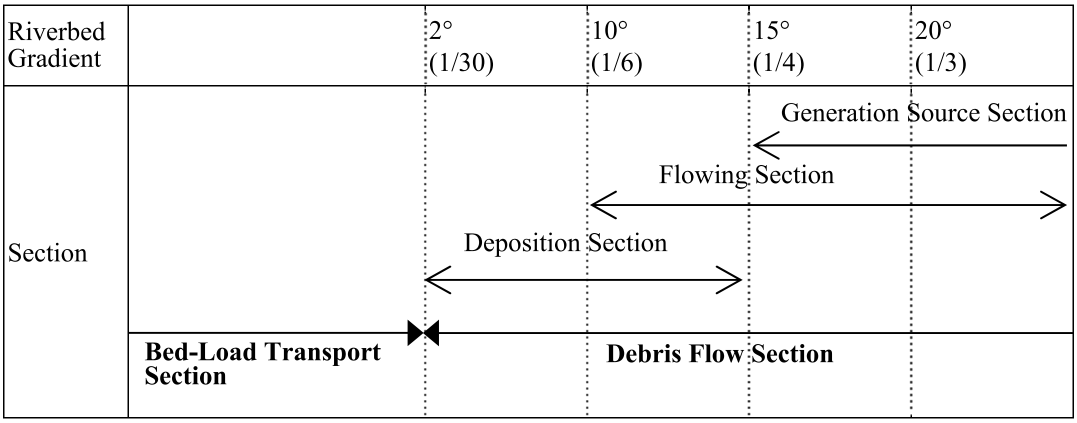


Figure 6.1-1 Section of Sediment Movement and Riverbed Gradient

The type of countermeasures against debris flow depends on the section of sediment movement. The countermeasures for hillside slope at the place of occurrence are not mentioned on this paragraph because these countermeasures method is mentioned on "CHAPTER 4 COUNTERMEASURES AGAINST LANDSLIDE" and "CHAPTER 5 COUNTERMEASURES AGAINST SLOPE COLLAPSE".

The revetment work which is included countermeasures against debris flow is not mentioned on this paragraph because these countermeasures method is mentioned on "CHAPTER 7 COUNTERMEASURES AGAINST RIVERBANK EROSION".

6.2 Selection of Countermeasures

6.2.1 Classification of Countermeasures

The major classification and type of countermeasures are as presented in Figure 6.2-1.

Table 6.2-1 Major Classification and Type of Countermeasures

Classification	Type of Countermeasures
Mitigation of Sediment Production	Refer to Countermeasure against Landslide, Collapse and Riverbank Erosion, Sabo Dam
Guiding of Debris Flow	Bridge, Culvert, Causeway, Shed, Tunnel
Capture of Debris Flow	Sabo Dam
Realignment of Road to avoid Debris Flow	Diversion Road

6.2.1.1 Mitigation of Sediment Production

The debris flow disaster is occurred by sediment production due to slope collapse at the generation source section, landslide dams collapse, landslide and fluidized sand deposit on streambed. The mitigation of sediment production contributes to road disaster prevention from debris flow. This work is basically the same as countermeasure works against landslide, slope collapse and riverbank erosion.

This countermeasure is effective if the location of sediment production is identified and the area is limited based on the detailed investigation. This countermeasure is often inept in the Kyrgyz Republic since it is difficult to identify the generation source of debris flow and the area is widespread.

6.2.1.2 Guiding of Debris Flow

The shed, bridge and culvert to prevent traffic hindrance from debris flow include in this classification. The size of debris flow shed shall be determined by the size of streambed, scale of debris flow and traffic volume, etc. The size of bridge and culvert shall be secured the capacity to pass through the peak discharge of debris flow. The height of bridge girder and top slab of culvert shall be higher than the design debris flow level plus freeboard. The both height and width of bridge and culvert shall be more than twice the maximum size of the debris.

The causeway also includes in this classification. The causeway is able to protect the road from erosion by debris flow. However, it should be noted that debris flow runs through the road and affects the road traffic even after the construction of causeway, basically. Therefore, information provision or announcement of debris flow to road user, placement of heavy equipment to promptly remove the debris on the road, and formulation of communication system should be combined with construction of causeway to mitigate the impact on road traffic.

6.2.1.3 Capture of Debris Flow

Sabo Dams/Sediment Control Dams are the most common countermeasure against debris flow. The main purpose of Sabo Dams/Sediment Control Dams is 1) to reduce/prevent the volume of sediment discharge and 2) be gentle slope of streambed for prevention of bed scouring. Hence, the mitigation of road disaster is expected by this function. There are two types of dam, which are impermeable and permeable types.

The impermeable type has weep hole/underdrain to discharge the stream flow, and capture the debris flow in normal time as well as flood time. The permeable type captures the debris flow during flood and streams with the captured debris flow in normal time. This does not prevent supplying earth and sand toward downstream. Additionally, the permeable type does not separate the ecological system due to sabo dam construction, which can reduce the influence on an ecological system.

6.2.1.4 Realignment of Road to avoid Debris Flow

It is desirable that the road is detoured at upstream or downstream of debris flow deposition section because the streambed is fluctuated due to debris flow occurrence in this section. Moreover, the bridge which has enough clearance to pass through the debris flow shall be installed.

Regarding above countermeasures, the comparison tables are as given in Table 6.2-2 and Table 6.2-3.

Table 6.2-2 Comparison Table of Countermeasures against Debris Flow (1)

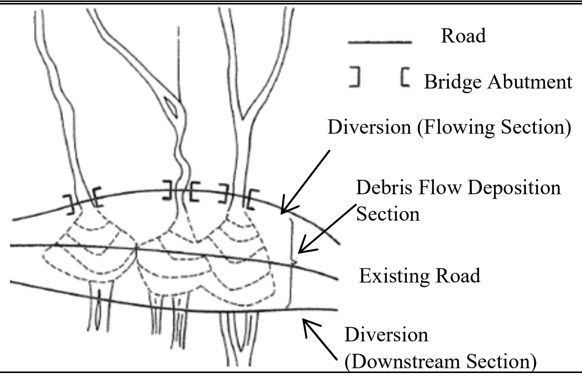
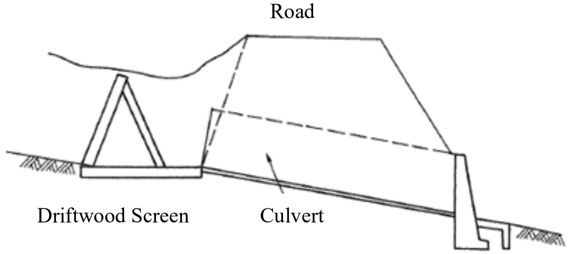
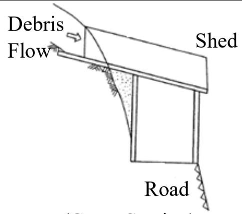
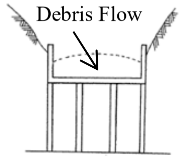
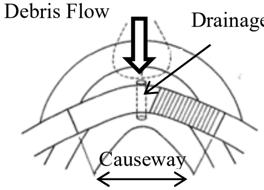
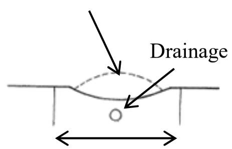
Type of Structure	Diversion Road	Bridge	Culvert
Outline Drawing/ Picture			
Description	The existing road is detoured at upstream or downstream of debris flow deposition section. The alignment of diversion road shall be avoided at the debris flow deposition section where the slope of the riverbed is steeper than 2 degrees (2°).	The section under bridge shall be secured the capacity to pass through the peak discharge of debris flow. The height of bridge girder shall be higher than the design debris flow level plus freeboard. It is advisable not to install the bridge pier at the riverbed.	The section area of culvert shall be secured the capacity to pass through the peak discharge of debris flow. The both height and width of culvert shall be more than twice the maximum size of the debris. Screen is required to install if it is expected that debris flow involve a lot of driftwood.
Applicability	This type is applicable in case of that the road alignment is able to shift to the upstream or downstream of debris flow deposition section. Riverbed Gradient: 2° / 10° / 15° / 20° Section: Generation Source Section; Flowing Section; Deposition Section; Bed-Load Transport Section; Debris Flow Section Particularly, the road which is occurred large-scale and frequent debris flow shall be considered this countermeasure.	This type is applicable in case of that the road elevation is higher than riverbed and the width of river is comparatively wide. The channel section at the upstream and downstream of bridge as well as under the bridge shall be secured the capacity to pass through the peak discharge of debris flow. Besides, the bridge abutment and the riverbank of upstream and downstream of bridge shall be protected against the flood and debris flow. After the flood, the debris at the upstream and downstream of bridge as well as under the bridge shall be immediately removed to secure the discharge capacity. Hence, maintenance cost to remove the debris shall be considered. The traffic control or detour is required during construction.	This type is applicable in case of that the road elevation is not greatly differ from riverbed and the width of river is comparatively narrow. The channel section at the upstream and downstream of culvert as well as the culvert itself shall be secured the capacity to pass through the peak discharge of debris flow. Besides, the thickness of culvert and concrete cover to reinforcement shall be considered the wear allowance. Riverbank/riverbed protections are installed at upstream and downstream of culvert to prevent from scoring by debris flow. After the flood, the debris at the upstream and downstream of bridge as well as inside of culvert shall be immediately removed to secure the discharge capacity. Hence, maintenance cost to remove the debris should be considered. This type is applied in the Kyrgyz Republic. Proper design and maintenance is required. Otherwise, some culverts are damaged due to inadequate riverbank/riverbed protections and others culverts are not functioning due to sedimentation. The traffic control or detour is required during construction.
Approximate Unit Cost	Asphalt Pavement: 3(Thousand KGS/m^2), Bridge: 3,400 (Thousand KGS/m)	3,400 (Thousand KGS / m)	270 (Thousand KGS / m)

Table 6.2-3 Comparison Table of Countermeasures against Debris Flow (2)

Type of Structure	Debris Flow Shed	Sabo Dams / Sediment Control Dams	Causeway
Outline Drawing/ Picture	 Road (Cross-Section)  Road (Front View)	 Impermeable Type  Permeable Type	 Plan  Longitudinal Section
Description	Debris flow shed is applicable if there is no space at the side of road and the elevation of riverbed is higher than the road surface. The slope of shed shall be approximately the same gradient as the existing riverbed not to deposit on the shed. Likewise, the width of shed shall be approximately the same width as the existing stream. The height of sidewall of shed shall be higher than the design debris flow level plus freeboard.	Sabo Dams/Sediment Control Dams are the most common countermeasure against debris flow. The main purpose of Sabo Dams/Sediment Control Dams is to reduce the volume of sediment discharge. The dam body shall capture the debris flow and discharge the flowing water. There are two types of dam, which are impermeable and permeable types.	When elevation of riverbed is approximately the same height as the elevation of road surface and debris flow is allowed to pass over the road surface, causeway is cost-effective. The thickness of pavement at causeway shall be thick to prevent from scouring caused by debris flows. The material of causeway shall be durable concrete structures. Traffic Control is required during /after debris flow. The removal of debris on the causeway and in the drainage is required after debris flow.
Applicability	This type is applicable in case of that the road elevation is lower than riverbed. The structural principle is the same as snow shed and rock shed. This type was applied in the Kyrgyz Republic as a snow shed. The traffic control or detour is required during construction. Furthermore, the construction duration is longer than the other countermeasures since this construction is required the larger space and longer time due to concrete placement and using heavy equipment. The space for foundation of the shed is required. Additionally, It is advisable to install the foundation on the stable rock for the stability.	This type is applicable in case of that it is difficult to cope with debris flow on the road like the other countermeasures. This type was applied in the Kyrgyz Republic using by the material of grouted riprap. Maintenance road from main road to dam site should be constructed. Removal of debris flow at the upstream of dam body is required for the proper/effective functioning. It is advisable to install the foundation on the stable rock for the stability. The traffic control or detour is basically not required during construction.	This type is applicable in case of that the road elevation is not greatly differ from riverbed The channel section at the downstream of causeway shall be secured the capacity to pass through the peak discharge of debris flow. Besides, the thickness of causeway shall be considered the wear allowance. Riverbank/riverbed protections should be installed at the downstream of causeway to prevent from scoring by debris flow. After the flood, the debris on the causeway and at the downstream of causeway shall be immediately removed to secure the discharge capacity. Hence, maintenance cost to remove the debris should be considered. This type is most applied as the countermeasures against debris flow in the Kyrgyz Republic. Proper design and maintenance is required. Otherwise, some causeways are damaged due to inadequate riverbank/riverbed protections at the downstream and others causeways have slight traffic hindrance due to sedimentation. Longitudinal gradient of road shall be considered the vehicle traffic. The traffic control or detour is required during construction.
Approximate Unit Cost	3,400 (Thousand KGS / m))	136,000 (Thousand KGS / dam))	4 (Thousand KGS / sq. m)

6.2.2 Criteria for Selection of Countermeasures

The selection flowchart of countermeasures is as illustrated in Table 6.2-1.

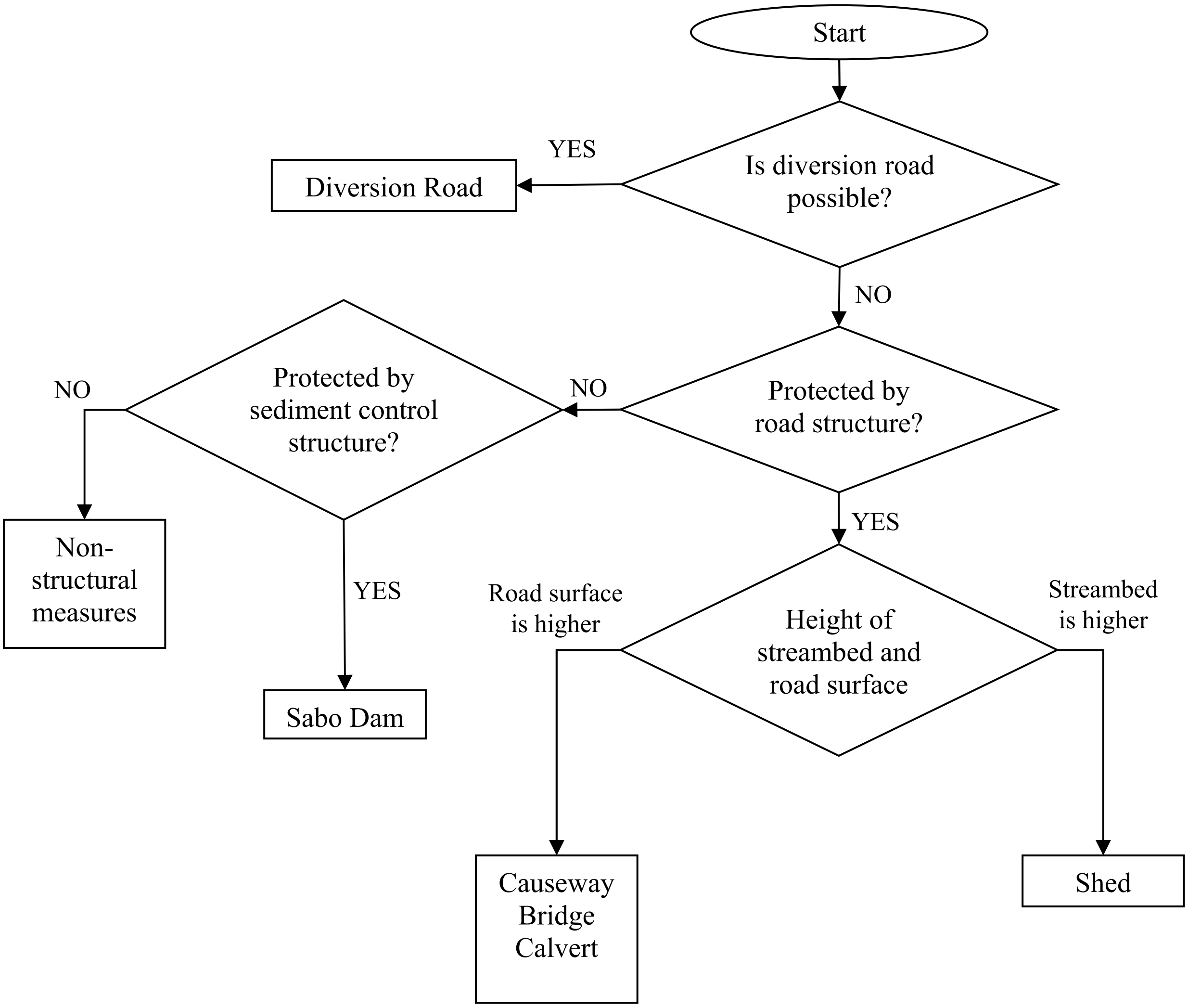


Figure 6.2-1 Selection Flowchart of Countermeasures

Countermeasures against debris flow shall be selected by the importance of road, type/frequency/scale of debris flow and relationship between road and streambed elevation. The points of attention to select the countermeasures are shown in the followings:

- Bridge, shed and tunnel are applicable in the section which is priority road and has high occurrence rate and large scale of debris flow.
- Debris flow shed is applicable when the streambed is higher than the road surface.
- Culvert or causeway is applicable when the elevation of streambed is almost the same height as the road surface. Information provision or announcement of debris flow to road user, placement of heavy equipment to promptly remove the debris on the road, and formulation of communication system shall be combined with construction of causeway to mitigate the impact on road traffic.
- Sabo dam is applicable when it is difficult to mitigate the road disaster by the road structures

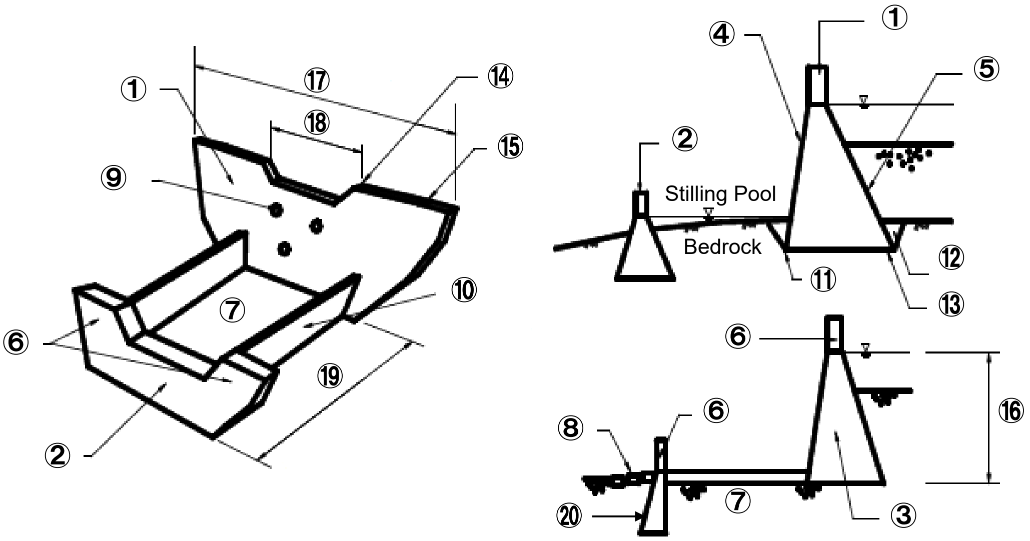
- Non-structural measures are applicable when the road disaster might not be mitigated by structural measures due to the large-scale debris flow, and structural measures cannot be implemented due to budgetary constraints

6.3 Structural Detail of Main Countermeasures

6.3.1 Sabo Dam

6.3.1.1 Components of Sabo Dam

The components of sabo dam are as given in Figure 6.3-1.



①	Main Dam	⑪	Toe of Dam
②	Sub-Sabo Dam	⑫	Backfill
③	Main Body	⑬	Heel of Dam
④	Front Face Slope (Downstream Side)	⑭	Shoulder of Opening
⑤	Back Face Slope (Upstream Side)	⑮	Crest Wing
⑥	Wing Wall	⑯	Height of Dam
⑦	Apron	⑰	Width of Sabo Dam
⑧	Riverbed Protection	⑱	Crest Opening
⑨	Drainage Pipe	⑲	Front Protection Work
⑩	Side Wall Revetment	⑳	Vertical Wall

Figure 6.3-1 Components of Sabo Dam

Apron is structure to protect the foundation ground from dropped water and gravel from dam crest. Sub-sabo dam is installed to provide stilling pool and to absorb energy of overflow water. On the other hand, the vertical wall is structure to prevent scoring at the downstream of apron

Generally, it is desirable to construct a dam on a streambed with rocks on both banks to prevent deep scouring at the toe of the downstream slope caused by overflowing water and prevent destruction by erosion of both banks. A narrow location with wider channel width upstream is desirable for saving cost. However, such conditions are not always available. A dam for preventing runoff of riverbed sediment shall be constructed even under poor conditions. When no rock exists on the streambed, the toe of the downstream slope shall be protected by providing an apron, a sub-sabo dam or a vertical wall according to the bed conditions.

In this case, sufficient consideration shall be given to possible destruction of an apron by piping phenomenon caused by seepage of water and possible scouring immediately downstream of a vertical wall.

The height of a dam shall be determined based on the calculated volume of manageable sediment (Vm) and a sufficient geological study of its foundation. When a dam is on the sand and gravel, that dam is called a floating dam. The height of the floating dam shall be less than 15 meters, and safety of the floating dam against bearing force and piping phenomenon shall be highly considered.

Moreover, the maintenance road is required to operate and maintain the sabo dam and to remove the debris at the upstream side of sabo dam as appurtenant facilities of sabo dam.

6.3.1.2 Type and Material of Sabo Dam

The type and material of sabo dam is shown below.

Impermeable Type	Permeable Type
	
Impermeable type has weep hole/underdrain to discharge the stream flow, and capture the debris flow in normal time as well as flood time.	The permeable type captures the debris flow during flood and streams with the captured debris flow in normal time. This does not prevent supplying earth and sand toward downstream. Additionally, the permeable type does not separate the ecological system due to sabo dam construction, which can reduce the influence on an ecological system.

Figure 6.3-2 Type of Sabo Dam

Concrete Type	Grouted Riprap
	
Concrete is common material for sabo dam construction	Grouted riprap is mixed concrete with boulders and saved volume of concrete. This type was constructed on 432.8km along BO road, in DEP 38.

Figure 6.3-3 Material of Sabo Dam

6.3.1.3 Required Survey for Plan and Design of Sabo Dam

The required survey for plan and design of sabo dam is as shown in Table 6.3-1.

Table 6.3-1 Required Survey for Plan and Design of Sabo Dam

Type of Survey	Description
Topographic/ Geodetic Survey	Watershed division, recapitulative terrain condition in watershed is comprehended based on the terrain map and aerial photograph. Besides, topographic survey is conducted at the construction site of sabo dam.
Geological / Geotechnical Survey	Presumption of the volume of sediment production and discharge, survey of slope collapse risk, selection of countermeasure location, resource research for design of countermeasure (utilization for existing survey result and geological survey map), field survey (site reconnaissance, boring survey, simple penetration test, elastic wave exploration, etc.) and physical testing shall be carried out.
Hydrological Survey	Precipitation Data (Analysis of precipitation data to study the debris flow design scale for countermeasures, and collection and analysis of rainfall data during debris flow occurrence.
Survey of Sediment Production	Sediment production from denuded land, moving sediment from streambed, sediment production due to slope collapse at mountainside/stream and investigation of maximum pebble diameter are included in this survey

6.3.2 Causeway

6.3.2.1 Applicable Location of Causeway

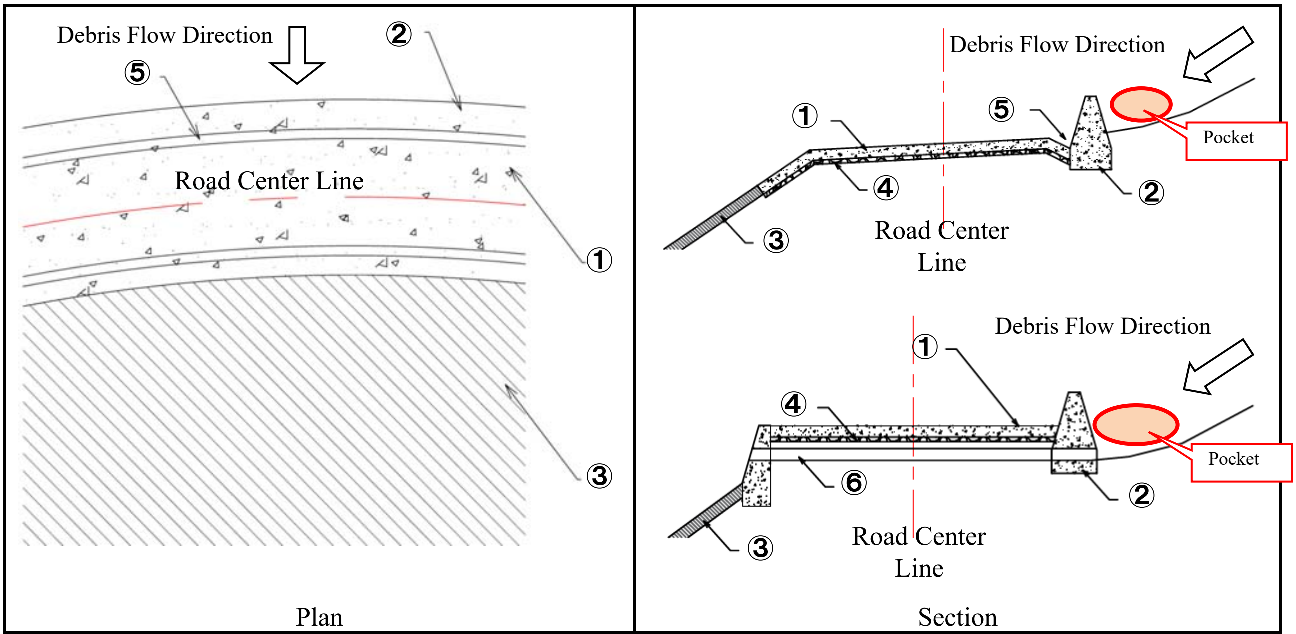
Applicable and inapplicable location of causeway is as presented below.

Applicable Location	The location where streambed elevation is the same elevation as road surface, gradient of streambed is gentle, and the streambed is large in width.
Inapplicable Location	The location where streambed elevation is different elevation from road surface, gradient of streambed is steep, and the streambed is small in width like V-shaped valley.

It is necessary to consider the installation of underdrainage and the road antifreeze if the causeway is installed at the region where the road may be frozen.

6.3.2.2 Components of Causeway

The components of causeway are as given in Figure 6.3-4.



①	Concrete Pavement (Thickness: t=300mm)
②	Retaining Wall or Slit Wall (Concrete Type or Grouted Riprap Type)
③	Slope Protection (Concrete Type, Grouted Riprap Type, Gabion Type or Cribwork)
④	Subbase
⑤	Side Ditch
⑥	Drainage Pipe or Culvert

Figure 6.3-4 Components of Causeway

Road surface of causeway shall be inclined longitudinally and laterally so that debris flow smoothly passes through on the road. On the other hand, the longitudinal and lateral gradient of road shall be conformed to road design standard to prevent traffic hindrance. It is desirable that retaining wall/slit wall is installed at the mountain side to prevent the accumulation of debris on the road. It is preferable that the space between retaining wall/slit wall and slope at mountain side (here called Pocket) is secured as large as possible. The accumulated debris at the Pocket as well as on the road should be removed after the occurrence of debris flow.

The countermeasure against scouring on the slope is occasionally implemented since the debris flow might scour the slope at the valley side

It is necessary to install the drainage pipe/culvert at the section where a stream always pass over the road and road may be frozen so that the road surface will not be puddled/frozen. The operation and maintenance of the drainage pipe/culvert is required to avoid blocking up.

It should be noted that debris flow runs through the road and affects the road traffic even after the construction of causeway, basically. Therefore, information provision or announcement of debris flow to road user, placement of heavy equipment to promptly remove the debris on the road, and formulation of communication system should be combined with construction of causeway to mitigate the impact on road traffic.

6.3.2.3 Required Survey for Plan and Design of Causeway

Required survey for plan and design of causeway is as shown in Table 6.3-2.

Table 6.3-2 Required Survey for Plan and Design of Causeway

Type of Survey	Description
Condition of Stream	The width and length of stream, depth of sedimentation/scoring and gradient of streambed is measured. Besides, the size of boulder, gravel and driftwood which causes clogged drainage facilities and others stream condition are investigated.
Hydrological Condition	Survey of water depth and width during normal and flood.
Hydrological Survey	Precipitation Data (Analysis of precipitation data to study the debris flow design scale for countermeasures, and collection and analysis of rainfall data during debris flow occurrence.

CHAPTER 7 COUNTERMEASURES AGAINST RIVERBANK EROSION

7.1 General

Riverbank erosion does not occur in an unexpected fashion comparing to the slope and snow disaster, and smaller influence on road traffic than other natural disasters. Besides, the prediction of riverbank erosion is easier than other natural disaster since the riverbank erosion is confined to the location that road is close and parallel to river, specifically outside of curved portion.

However, the annual number of disaster occurrence and cost of rehabilitation have a higher proportion of flood disaster. Additionally, collapse of bridge due to riverbank erosion has a substantial impact to road traffic and the rehabilitation is required much time and cost.

When river improvement planning and structure designing are planned, it is necessary to understand the characteristics of river. The shape of the river is formed through the recurring effects of scouring, meandering and sedimentation as a result of perennial and annual maximum floods. The shape/configuration of a natural river generally depends on the parameters of riverbed gradient, riverbed material and the annual maximum flood. Moreover, the riverbed materials can be roughly assessed through the riverbed gradient too. It means that the riverbed gradient information can roughly provide the phenomenon of the stream and river characteristics. Therefore, when the river improvement planning is discussed as a first step before river structure could be designed, it is necessary to undertake the river survey and the actual river (riverbed) gradient. However, since actual cross-sectional survey as well as riverbed gradient determination from the result of the said survey is difficult, the importance of understanding the river characteristics according to long-range section is introduced in this guideline.

In the same segment, the roughness and/or sand bar conditions are almost the same. Tus, it means that the velocity of flow and phenomena of scouring are almost the same range in the same segment. It is very useful to make a river planning and the designing of structure, if the river segment of target stretch for improvement is identified. A river system is classified into several segments as shown in Table 7.1-1.

Table 7.1-1 Classification of River Segment and its Characteristics

Classification	Segment M	Segment 1	Segment 2		Segment 3
			2-1	2-2	
Geography	← Mountain →	← Alluvial → ← Narrow Plane	Narrow Plane → ← Natural Levee	Natural Levee → ← Delta	Delta →
Diameter of Typical Riverbed Materials d_R	Various	More than 2cm	4cm～1cm	1cm～0.3mm	Less than 0.3mm
Riverbank Material	Many types of soil and rocks appear on the banks as well as on riverbed.	Riverbank material is composed of thin layer of sand and silt which is same as the riverbed.	Lower layer of the riverbank material is the same as the riverbed. Medium layer is composed of medium/fine sand. Surface layer is composed of mixture of fine sand, clay and silt.		Silt and Clay
Gradient	Various	1/60～1/400	1/400～1/5000		1/5000～Level
Meandering	Various	Few bend/meander	Heavy meandering		Large and small meandering

Classification	Segment M	Segment 1	Segment 2		Segment 3
			2-1	2-2	
Bank Erosion	Heavy	Heavy	Medium. Mainstream course changes where bigger riverbed materials exist.		Weak. Location/course of stream is almost fixed.
Water Depth of Annually Maximum Flood	Various	0.5～3m	2～8m		3～8m

7.2 Selection of Countermeasures

7.2.1 Classification of Countermeasures

The major classification and type of countermeasures material is as shown in Table 7.2-1.

Table 7.2-1 Major Classification and Type of Countermeasures Material

Classification	Type of Countermeasures Material
Revetment	Concrete Block, Wet Stone Masonry, Concrete Retaining Wall, Gabion Mattress, Steel Sheet Pile (SSP), Riprap
Foot Protection	Concrete Block, Gabion Mattress, Stone Bagging Unit, Riprap
Spur Dike	Massive Concrete Block (Overflow Type), Concrete Block (Non-overflow Type), Boulder Riprap

7.2.2 Revetment

The external force which contributes to erosion depends on the river flow velocity. The revetment protects the collapse of riverbank due to erosion, scouring and/or riverbed degradation.

Revetment shall be designed based on the existing site conditions, such as river flow velocity and direction, embankment material, topographical, morphological, and geological conditions of the riverbank, etc. Further, revetment shall be designed to withstand the lateral forces due to high velocity flow, when located in flow attack zone, on a weak geological condition of riverbank, and with poor embankment materials.

The revetment structure shall consist of slope covering works, foundation works and foot protection works. The components of revetment are illustrated below.

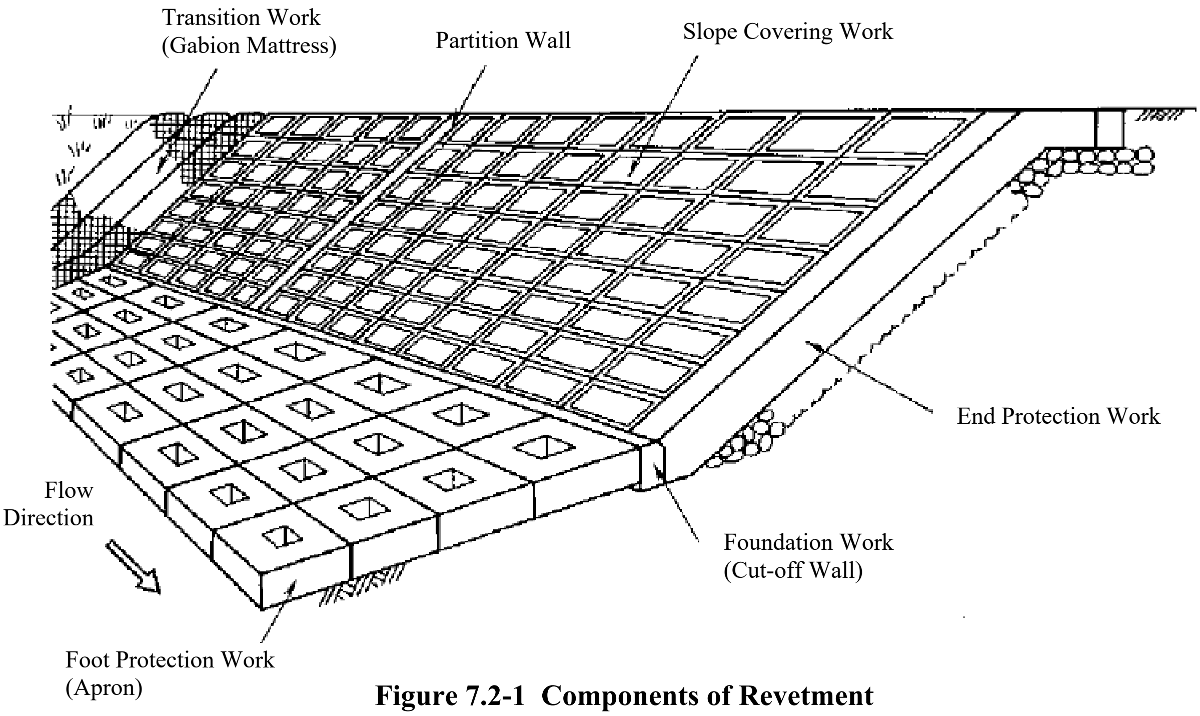


Figure 7.2-1 Components of Revetment


Concrete Block


Concrete in Retaining Wall


Grouted Riprap


Gabion Mattress

Figure 7.2-2 Sample of Revetment Type

7.2.3 Foot Protection

Foot protection works shall be adequately placed in front of the revetment foundation to prevent scouring. The foot protection shall have a minimum width of 2.0 meters towards the centerline of stream. In some cases, it is very difficult to set the foundation if the ordinary water level area is so deep and is influenced by high tide. However, if scouring is likely to occur down to the level of the deepest riverbed, the foundation of revetment should be placed deeper. In such case, steel sheet pile or concrete sheet pile should be provided with provision of adequate foot protection works in front of the sheet pile foundation to prevent scouring.

The type of foot protection work shall be determined based on river conditions, convenience in construction, economy, etc. The basic requirements for the foot protection work are as follows:

- Sufficient weight against the flow forces
- Sufficient width to prevent scouring in front of the revetment
- Durability
- Flexibility for the fluctuation of riverbed

Concrete Block

Grouted Riprap

Boulder Riprap

Gabion Mattress

Figure 7.2-3 Sample of Foot Protection Type

7.2.4 Spur Dike

A spur dike is a river structure with the following functions:

- Increases the flow roughness and reduces the flow velocity around the riverbank.
- Redirects river flow away from the riverbank.

The causes of bank erosion, scouring or riverbed degradation and/or damages of banks must be analyzed thoroughly to establish an appropriate river improvement plan. At present, planning and design of spur dikes and its effect are not quantitatively verified but analyzed from the past records.

Basically, spur dikes are classified into permeable and impermeable/semi-permeable types, as described below:

(1) Permeable Type

Spur dike of this type is made of piles and frames, preferably in series. Its purpose is to reduce the river flow velocity at the immediate downstream of the spur dike and induce sedimentation. In cases where piles cannot be driven due to the presence of boulders on the riverbed, crib frame, skeleton works or concrete block type shall be used.

(2) Impermeable/Semi-Permeable Type

This type of spur dike is made of wet masonry (impermeable) or concrete blocks and loose boulder (semi-permeable), preferably in series. Its purpose is to divert the river flow direction away from the riverbank.

Impermeable/semi-permeable type is classified as:

1) Overflow Type

Its main purpose is to reduce the river flow velocity. This type of spur dike shall be considered as a series of spur dike. At least three (3) spur dikes shall be planned.

2) Non Overflow Type

Its main purpose is to change the river flow direction away from the riverbank. This type of spur dike shall be considered as strong structure.

Any damage on the spur dike, especially at the tip, as a result of strong velocity during floods or sediment runoff, etc., may not be considered as a major problem provided that the structure functions are achieved in relation to its intended purpose.


Concrete Block


Boulder Riprap


Gabion Mattress

Figure 7.2-4 Sample of Spur Dike Type

Table 7.2-2 Comparison Table of Countermeasures against Riverbank Erosion (1)

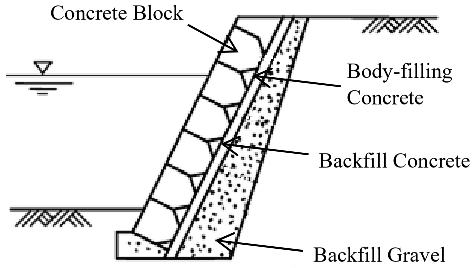
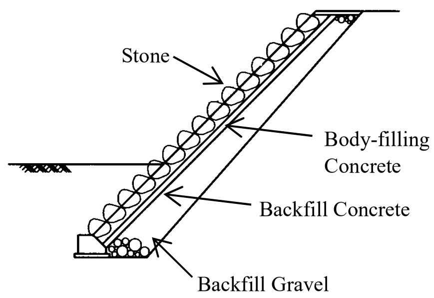
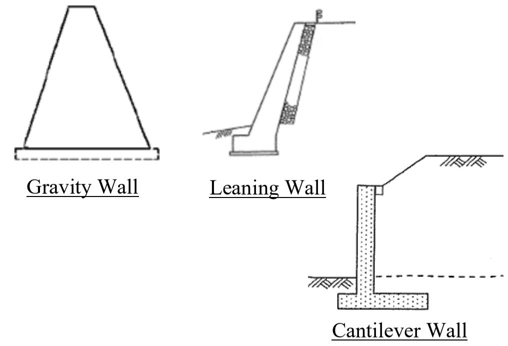
Type of Structure	Revetment		
	Concrete Block	Wet Stone Masonry	Concrete Retaining Wall
Outline Drawing / Picture			
Description	● Concrete blocks are piled up, and the each block is integrated by body-filling concrete. ● The steep slope at the back is maintained by the balance between weight of concrete block and earth pressure.	● Stones are piled up, and the each stone is integrated by body-filling concrete. ● The steep slope at the back is maintained by the balance between weight of wet stone masonry and earth pressure.	● This concrete structure is generally categorized into gravity wall, leaning wall, cantilever wall (like L-shaped, inverted T-shaped), etc. ● The stability calculations like sliding, overturning and bearing are required.
General Applicability	● The standard slope gradient is 1:0.5. ● This type is applicable at the place of small earth pressure, such as stable ground and embankment. ● Concrete block is resistant to bounding stone bounding stone and high flow velocity. ● Steep slope is buildable to integrate concrete block into body-filling concrete. ● The applicable height of this structure is 5m and lower. ● This structure is vulnerable to earthquakes.	● The standard slope gradient is 1:0.5. ● This type is applicable at the place of small earth pressure, such as stable ground and embankment. ● Wet stone masonry is resistant to bounding stone bounding stone and high flow velocity. ● Steep slope is buildable to integrate stone into body-filling concrete. ● The applicable height of this structure is 5m and lower. ● This structure is vulnerable to earthquakes.	● The standard slope gradient is from vertical to 1:0.2. ● This type is resistant to high flow velocity and applicable at the place of strong current compared with other revetments. ● The applicable maximum height of gravity wall, leaning wall and cantilever wall is 5m, 10m and 10m, respectively. ● Concrete retaining wall is resistant to earthquakes when aseismic design is considered.
Approximate Unit Cost (Revetment Height =5m)*	100 (Thousand KGS / m)	85 (Thousand KGS / m)	Gravity Wall: 200 (Thousand KGS / m) Leaning Wall: 140 (Thousand KGS / m) Cantilever Wall: 150 (Thousand KGS / m)

Table 7.2-3 Comparison Table of Countermeasures against Riverbank Erosion (2)

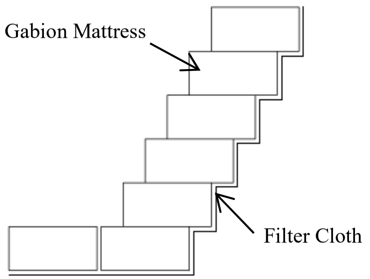
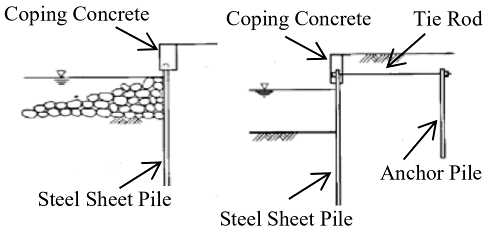
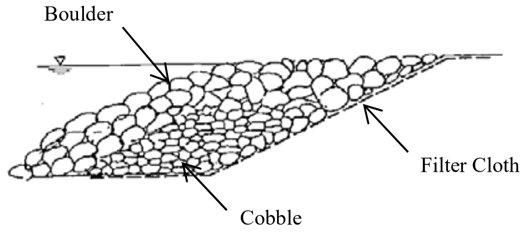
Type of Structure	Revetment		
	Gabion Mattress	Steel Sheet Pile (SSP)	Riprap
Outline Drawing / Picture			
Description	● The gabion mattress which is woven from iron wire is filled with adequate sized stone. ● Proper size and weight of gabion mattress prevents river flow from riverbank collapse and erosion. ● Gabion mattress shall be mutually connected by reinforcing bars or wires. ● It is advisable that iron wire of gabion mattress is coated by zinc galvanizing and aluminum alloy.	● This type is upright revetment utilizing SSP. ● There are two kinds of SSP revetment, which are Free-standing Type and Tie-rod Type. <u>Tie-rod Type:</u> SSP is installed at river side and anchor pile/wall/SSP is driven at land side. The SSP at river side is connected with anchor pile/wall/SSP by tie-rod.	● The riverbank and riverbed is protected by stones, like boulders and cobbles. ● The gaps between stones are utilized as habitat and resting-place for fin and insect. ● Natural landscape is preserved and created at the shoreline.
General Applicability	● Gabion mattress has flexible formation. ● It is necessary to consider about corrosion and cutting of iron wires. Particularly, the placement of gabion mattress under following condition is not applicable: 1) acid river section which is pH5 or lower, 2) high salt concentration river section which annual chloride ion concentration is 450mg/l or higher, 3) section including humus soil at riverbank and riverbed, 4) section including bounding stone causing damage and gall of iron wires. ● This structure is vulnerable to earthquakes. ● To prevent from washout of riverbank material, filter cloth should be installed. ● This type has high draining performance.	● Temporary cofferdam and dewatering is not required for this construction. ● SSP is comparatively resistant to high flow velocity. ● This material has impermeable function. ● It is necessary to consider about corrosion of SSP. ● SSP revetment is resistant to earthquakes when aseismic design is considered. <u>Free-standing Type:</u> It is applicable when there is not enough construction space at land side. However, it is generally not applicable when the height from riverbed to top of SSP is higher than 3m and the condition of riverbed is soft ground. <u>Tie-rod Type:</u> It is not applicable when there is not enough space for tie-rod at land side.	● The resistant to high flow velocity depends upon the size of stone. ● Mechanized construction is available and rehabilitation of riprap is easy. ● This type is vulnerable to earthquakes. ● To prevent from washout of riverbank material, filter cloth should be installed. ● This type has high draining performance.
Approximate Unit Cost (Revetment Height =5m)	82 (Thousand KGS / m)	Free-standing Type (with counterweight of riprap): 220 (Thousand KGS / m) Tie-rod Type: 240 (Thousand KGS / m)	20 (Thousand KGS / m) (Excluding Material Cost)

Table 7.2-4 Comparison Table of Countermeasures against Riverbank Erosion (3)

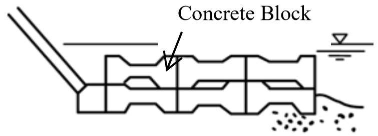
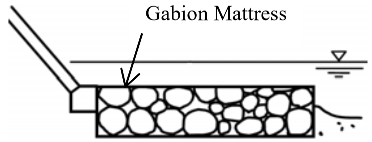
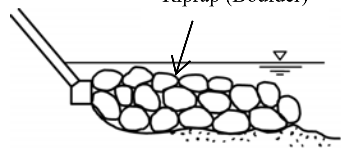
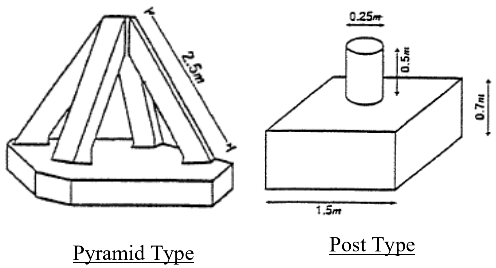
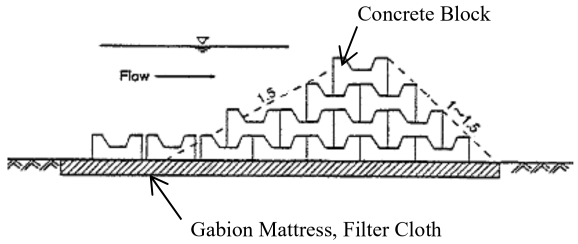
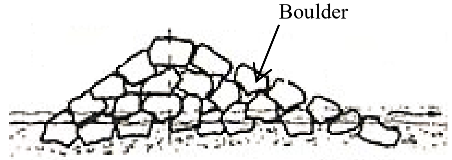
Type of Structure	Foot Protection			
	Concrete Block	Gabion Mattress	Stone Bagging Unit	Riprap
Outline Drawing / Picture			 http://www.maedakosen.jp/mdk/product/kasen/negatame/d-1.html	
Description	● Concrete blocks which are mutually connected by reinforcing bars and wires are piled up in front of base of revetment. ● The cross sectional width of foot protection shall be 2m and wider.	● The gabion mattress which is woven from iron wire is filled with adequate sized stone. ● Gabion mattress shall be mutually connected by reinforcing bars or wires and piled up in front of base of revetment. ● It is advisable that iron wire of gabion mattress is coated by zinc galvanizing and aluminum alloy. ● The cross sectional width of foot protection shall be 2m and wider.	● The bag body which is woven from durability and weather resistance material is filled with concrete wastes and stones and piled up in front of base of revetment. ● The cross sectional width of foot protection shall be 2m and wider.	● The base of revetment and riverbed is protected by boulders ● Boulders which are larger than riverbed material are piled up in front of base of revetment. ● The cross sectional width of foot protection shall be 2m and wider. ● The slope gradient of riprap shall be approximately 1:2.0 ~ 1:3.0.
General Applicability	● The size/weight of concrete block is against river flow, and the total cross sectional width of foot protection copes with riverbed lowering and scouring. ● It is desirable to install filter cloth under the concrete block in case that the riverbed material is sand. ● It is difficult to conduct the underwater construction, maintenance and rehabilitation.	● The size/weight of filling stone is against river flow, and the total cross sectional width of foot protection copes with riverbed lowering and scouring. ● It is necessary to consider about corrosion and cutting of iron wires where bounding stone is accumulated on riverbed.	● The weight of stone bagging unit is against river flow. ● The maintenance and rehabilitation work is easy. ● Temporary cofferdam and dewatering is not required for this construction. ● It is necessary to consider about ruptured bag body where bounding stone is accumulated on riverbed. ● The riprap is installed without leveling of riverbed.	● The weight of boulder is against river flow, and the total cross sectional width of foot protection copes with riverbed lowering and scouring. ● Mechanized construction is available, and maintenance and rehabilitation of riprap is easy. ● Temporary cofferdam and dewatering is not required for this construction. ● The riprap is installed without leveling of riverbed.
Approximate Unit Cost	24 (Thousand KGS / m^3)	14 (Thousand KGS / m^3)	14 (Thousand KGS / m^3)	1 (Thousand KGS / m^3) (Excluding Material Cost)

Table 7.2-5 Comparison Table of Countermeasures against Riverbank Erosion (4)

Type of Structure	Spur Dike		
	Massive Concrete Block (Permeable Type, Overflow Type)	Concrete Block (Impermeable Type, Non-overflow Type)	Boulder Riprap (Impermeable Type, Non-overflow Type)
Outline Drawing / Picture			
Description	● Prismatic column and cylinder is installed on the large concrete slab. ● The height of massive concrete block is comparatively lower. ● Small scale flood passes over the spur dike which is functioning as groups to decrease in speed of flow velocity and prevent from erosion at riverbank and riverbed.	● Concrete blocks which are mutually connected by reinforcing bars and wires are piled up ● The height of concrete block is comparatively higher to prevent flow and keep the flow away from riverbank, which prevent from erosion at riverbank.	● Boulders which are larger than riverbed material are piled up. ● The height of boulder riprap is comparatively higher to prevent flow and keep the flow away from riverbank, which prevent from erosion at riverbank. ● Mechanized construction is available, and maintenance and rehabilitation of riprap is easy.
General Applicability	● The general planning and design of spur dike is not confirmed since the prediction of river flow and riverbed movement is difficult. Hence, the planning and design of spur dike should be modified and verified based on the actual construction. ● The type of spur dike should be selected on the basis of the record of past river improvement project and construction along the same or similar river. ● However, the review and verification of structural design for spur dike against river flow and scouring is necessary.		
	This type is applicable at the upper stretch of river: ● Terrain: Alluvial fan ● Typical grain size of riverbed material: d_R>2cm ● Riverbed gradient: Approximately 1/60～1/400 ● Depth of low-water channel: 0.5m ~ 3m	This type is applicable at the middle stretch of river: ● Terrain: Alluvial plain ● Typical grain size of riverbed material: 0.3mm<d_R<4cm ● Riverbed gradient: Approximately 1/400～1/5000 ● Depth of low-water channel: 2m ~ 8m	This type is applicable at the lower stretch of river: ● Terrain: Delta area ● Typical grain size of riverbed material: 0.3mm>d_R ● Riverbed gradient: Approximately 1/5000 ~ horizontal ● Depth of low-water channel: 3m ~ 8m
Approximate Unit Cost	24 (Thousand KGS / m^3)	24 (Thousand KGS / m^3)	1 (Thousand KGS / m^3) (Excluding Material Cost)

7.2.5 Criteria for Selection of Countermeasures

The mechanism of river erosion differ the topographical, geotechnical and hydrological condition. Besides, the hydrological condition varies by the moment. Traditionally, applicable type of the structures, like revetment, foot protection and spur dike, has been selected in different according to the location while repeating collapsed and improvement.

The performance specification or safety degree of revetment has not been developed although the checking method of mechanical stability for revetment is gradually elucidated recently.

The countermeasures for riverbank erosion should be selected on the basis of the design velocity, gradient of slope, availability of construction materials near the site, ease of construction works and economy, the record of past river improvement project and construction along the same or similar river.

The selection flowchart of countermeasures is as described in Figure 7.2-5.

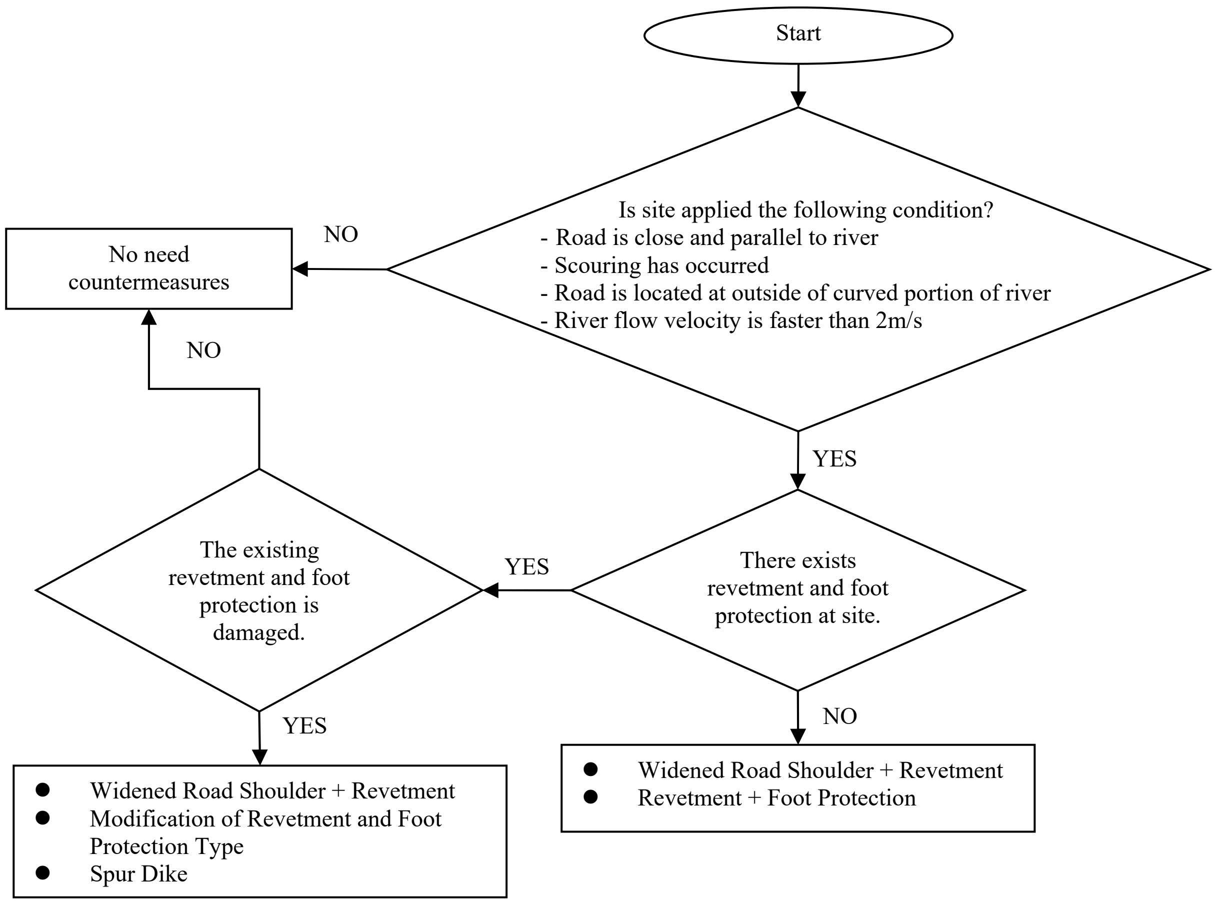


Figure 7.2-5 Selection Flowchart of Countermeasures

The applicable countermeasures by segment are as given in Table 7.2-6.

The type of spur dike should be selected on the basis of the record of past river improvement project and construction along the same or similar river since the mechanism of river flow at spur dike is complicated and difficult to figure out.

Table 7.2-6 Applicable Countermeasures Type by Segment

Segment	Durability	Revetment	Foot Protection	Spur Dike
Segment 1 d_R>15cm (Riverbed Gradient: 1/60～1/150)	High	Wet stone masonry, Concrete block (with backfill concrete), Concrete retaining wall	Concrete block (layered placing), Riprap	Impermeable Type, Non-overflow Type
	Low	Dry stone masonry, Concrete block (without backfill concrete), Connected block by wire		
Segment 1 2cm<d_R<15cm (Riverbed Gradient: 1/100～1/400)	High	Wet stone masonry, Concrete block (with backfill concrete), Concrete retaining wall	Concrete block (layered placing), Riprap, Gabion mattress, Stone bagging unit , Wooden mattress	Impermeable Type, Non-overflow Type
	Low	Dry stone masonry, Riprap, Gabion mattress, Connected block by wire		
Segment 2-1 1cm<d_R<4cm (Riverbed Gradient: 1/400～1/2000)	High	Wet stone masonry, Concrete block (with backfill concrete), Concrete retaining wall	Concrete block (layered and random placing), Riprap, Gabion mattress, Stone bagging unit , Wooden mattress	Impermeable Type
	Low	Dry stone masonry, Riprap, Gabion mattress, Connected block by wire		
Segment 2-2 0.3mm<d_R<1cm (Riverbed Gradient: 1/700～1/5000)	High	Wet stone masonry, Concrete block (with backfill concrete), Concrete retaining wall, Steel Sheet Pile	Concrete block (layered and random placing), Riprap, Gabion mattress, Stone bagging unit , Wooden mattress	Permeable Type
	Low	Dry stone masonry, Riprap, Gabion mattress, Connected block by wire		
Segment 3 d_R<0.3cm (Riverbed Gradient: 1/5000～Level)	High	Wet stone masonry, Concrete block (with backfill concrete), Concrete retaining wall, Steel Sheet Pile	Concrete block (random placing), Riprap, Gabion mattress, Stone bagging unit , Wooden mattress	Impermeable Type
	Low	Dry stone masonry, Riprap, Gabion mattress, Connected block by wire		

7.3 Structural Detail of Main Countermeasures

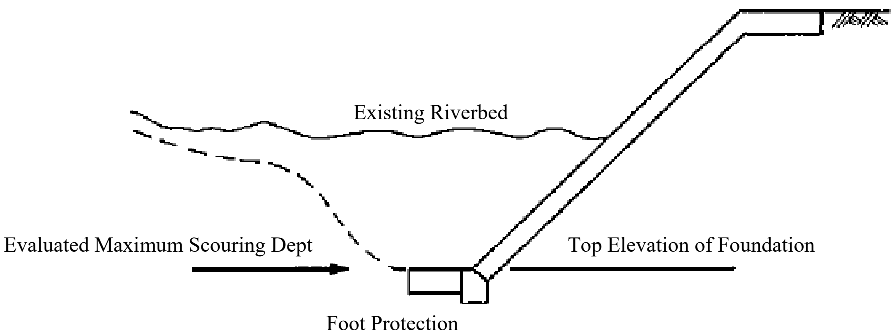
7.3.1 Revetment and Foot Protection

7.3.1.1 Depth of Foundation

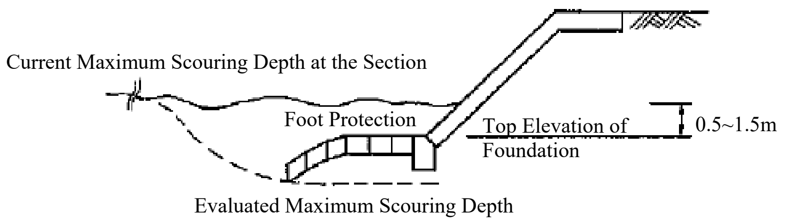
The depth of the foundation shall be deeper than 1.0 m from the maximum scouring depth. If there is a difficulty to calculate the maximum scouring depth, it should be 1.0 m below from the deepest riverbed.

The following four (4) cases can be considered for the top elevation of the foundation work:

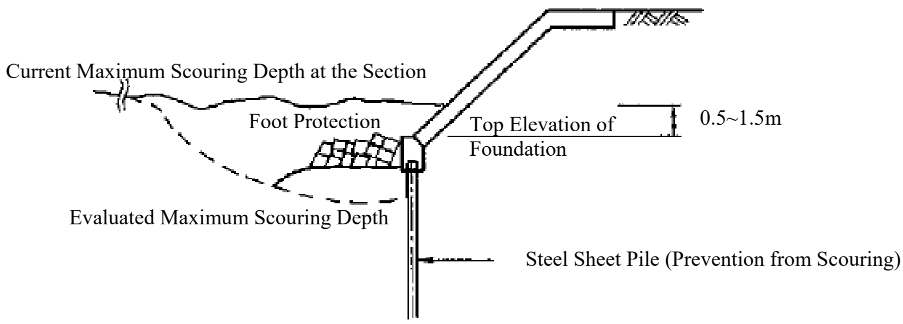
- The top elevation of the foundation work is set at the maximum scouring depth, and the minimum foot protection work shall be installed. This is applicable in Segment 1.



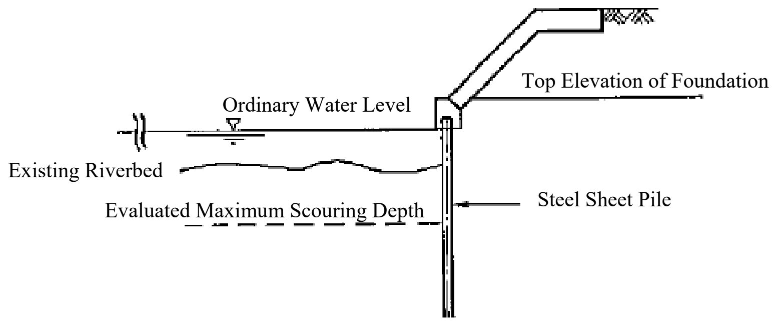
- The top elevation of the foundation is set above the maximum scouring depth, and the flexible foot protection shall be installed to cope with the scouring.



- The top elevation of the foundation is set above the maximum scouring depth, and the foundation work by sheet pile and the foot protection shall be applied in order to cope with scouring.



- In cases it is difficult to have adequate depth of embedment for the foundation work, such as high ordinary water level, tidal river, etc; cantilever sheet pile shall be installed as foundation work.



7.3.1.2 Filter Cloth

Filter cloth is installed behind the backfilling material to prevent the coming out of fine materials underneath the revetment due to flow forces or the residual water pressure. Particularly, Dry stone masonry, Concrete block without backfill concrete, Connected block by wire, Riprap and Gabion mattress is required to install the filter cloth at the grounding area of the structure because the gap of the structure is larger than the soil particles.

7.3.1.3 Backfilling Materials/Weep Hole

- For rigid type revetment, backfilling materials shall be installed in order to reduce the residual water pressure to the covering work and to fix the covering work to the original bank slope.
- For permeable type revetment such as wooden fence type and gabion mattress type, the backfilling materials shall not be installed.
- The backfilling materials shall be with high permeability, such as crushed gravel, etc.
- Thickness of the backfilling materials shall be 30-40 cm for wall type and 15-20 cm for pitching or lining type.
- In case of the site with high residual water pressure, such as revetment of the excavated river, weep hole shall be installed.

7.3.2 Spur Dike

Applicable direction, dimension, length and interval of spur dike should be selected in consideration of the record of past river improvement project and construction along the same or similar river. In this paragraph, the experimental specification of spur dike is presented as follows.

7.3.2.1 Direction of Spur Dike

The right-angle spur dike is usually adopted because of its average effects. On the other hand, the direction of spur dike experientially has several angles (θspur) toward the upstream or downstream. The relationship between the alignment of spur dike and scouring/sedimentation is as shown in Figure 7.3-1. Likewise, experimental direction of spur dike by segment is as given in Table 7.3-1.

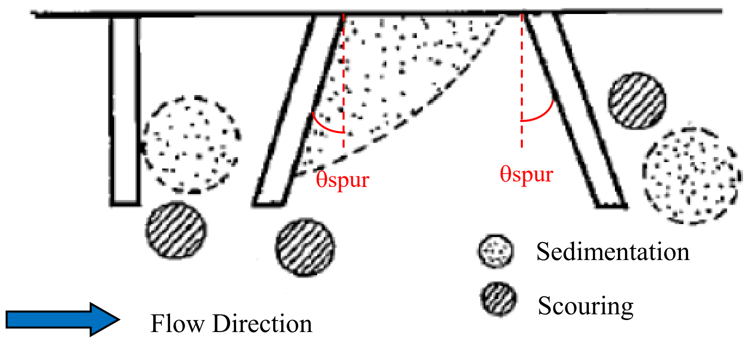


Figure 7.3-1 Relationship between Spur Dike Alignment and Resulting Sedimentation Scouring

Table 7.3-1 Experimental Direction of Spur Dike by Segment

Segment	Direction of Spur Dike
Segment 1	The direction of spur dike has angle toward the downstream to prevent the scouring at the head of spur dike.
Segment 2-1	Right Angle or Toward Upstream (θspur =0~15 degree)
Segment 2-2	Right Angle or Toward Upstream (θspur =0~15 degree)
Segment 3	Right Angle or Toward Upstream (θspur =0~15 degree)

7.3.2.2 Dimension

The experimental width of the crest of a spur dike is as shown in Table 7.3-2.

Table 7.3-2 Experimental Width of Crest of Spur Dike

Water Depth During Flood	Flow Velocity During Flood		
	Slower than 2m/s	2m/s ~ 4m/s	Faster than 4m/s
Lower than 5m	2m	4m	6m
5m ~ 10m	4m	6m	8m
Higher than 10m	6m	8m	10m

The experimental length, height, interval and crest gradient of a spur dike is as shown in Table 7.3-3.

Table 7.3-3 Experimental Length, Height, Interval and Crest Gradient of Spur Dike

Type	Length	Height	Interval	Crest Gradient
Overflow Type	Less than 10 % of river width	0.2~0.3 times water depth during flood In sandy river: 0.5~ 1.0m above the ordinary water level during rainy season	2~4 times length of spur dike or 10~30 times height of spur dike At meandering section: less than 2 times length of spur dike	1:20 to 1:100 (Vertical to Horizontal)
Non Overflow Type	-	Same height as water depth during flood	30 ~50% of length of sandbar	-

The side slope of a non-permeable spur dike in the upstream side ranges from 1:1 to 1:2, whereas in the downstream side ranges from 1:1 to 1:3, (Vertical to Horizontal).

For the concrete block or gabion type spur dike, the weight of a block or the grain size of filling boulders shall be determined in accordance with the design velocity. For the riprap (boulder) type, the grain size of the filling boulders shall be determined by adjusting the size.

CHAPTER 8 COUNTERMEASURES AGAINST AVALANCHE

8.1 General

In general, type of countermeasures will change depending on the size of the avalanche and the size and shape of the slope. Figure 8.1-1 shows a typical cross-section of medium- to large-scale avalanche slope. In other words, the avalanche flow thickness exceeds h=10 m. In addition, there are steep slopes facing the road, as well as small ones, having a profile as in Figure 8.1-1. Protective measures are also subdivided into measures intended for generation zone, the zone of the avalanche path and also for the zone of deposition and stopping, as shown in Figure 8.1-1. Engineering methods are selected and installed depending on the state of conflict between slope, avalanche and location of the road (the object of protection).

In cases where it is difficult to arrange countermeasures facilities, soft measures may be required.

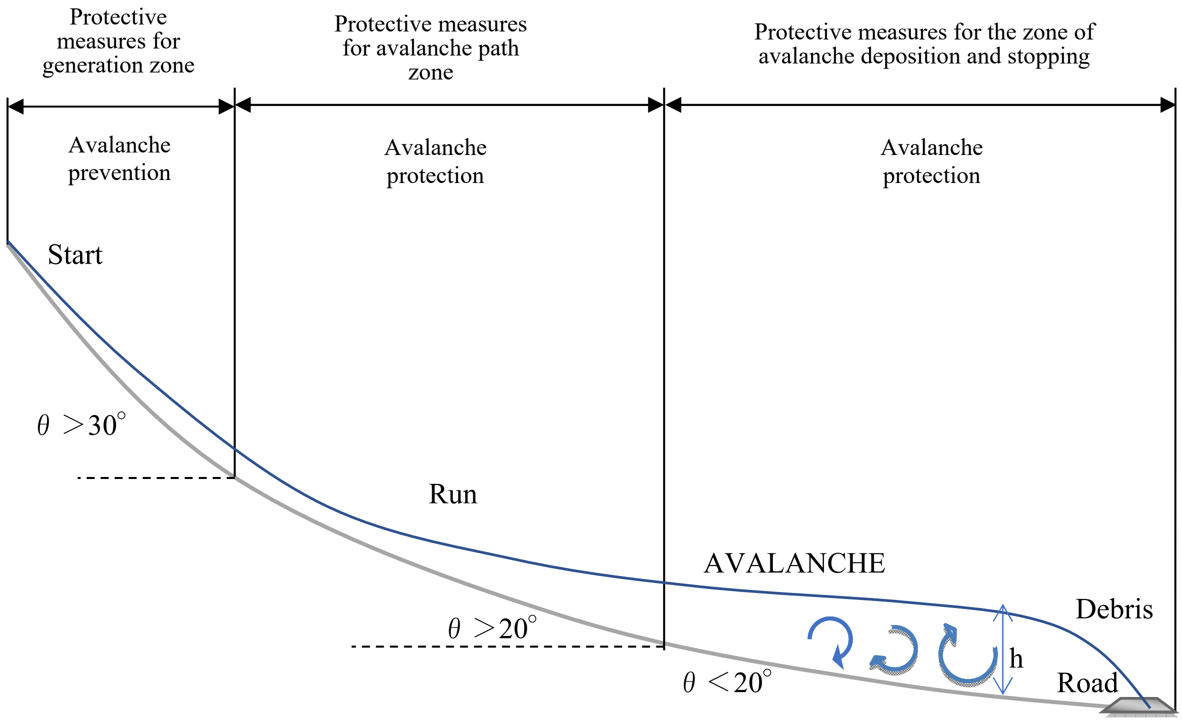


Figure 8.1-1 Section of Sediment Movement

8.2 Selection of Countermeasures

8.2.1 Classification of Countermeasures

As measures against avalanches, there are hard measures and soft measures as shown in Figure 8.2-1. Hard countermeasures are to prevent the occurrence of avalanche by various constructions and to prevent / induce the flow of the resulting avalanche. On the other hand, the soft measure predicts the occurrence of avalanche, creates a danger zone map to avoid damage, and implements road closing based on it. It is necessary to implement comprehensive countermeasures against huge numbers of avalanche dangerous places combining hard and soft measures in an appropriate balance.

Countermeasures against avalanches

Soft measures
- Road closure

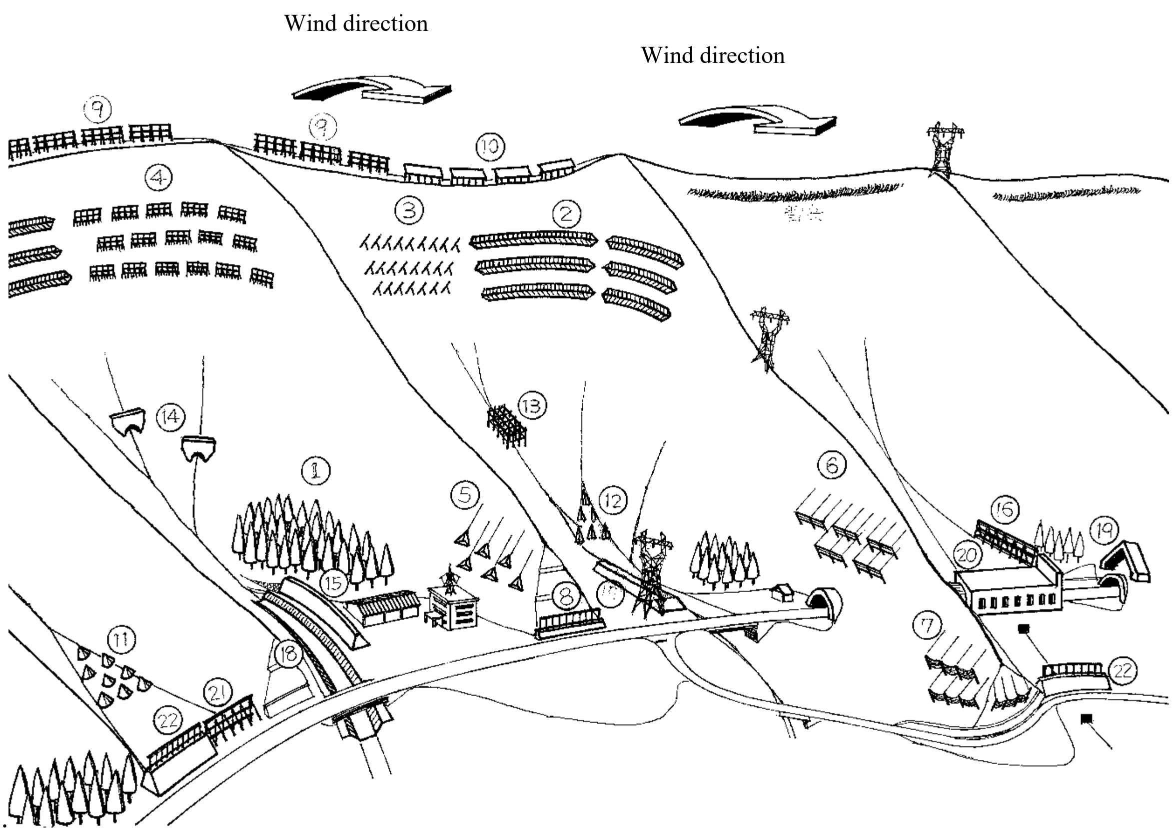
Hard measures
- Preventive constructions
- Protective constructions

Figure 8.2-1 Hard and Soft countermeasures (Source: Amendment of the 2005 Snow Removal and Snow Protection Handbook, Snow Protection publication)

As shown in Figure 8.2-2, the avalanche countermeasure facilities used in hard measures are roughly divided into preventive facilities and protective facilities from their functions. Preventive facilities are installed in avalanche generation zone and aim to prevent the occurrence of avalanche in advance. Protective facilities are installed in path and deposition zone and aim to protect roads from dangers caused by avalanches that have occurred.

The avalanche-prevention structures are of the following types: 1) preventing the onset of avalanche movement by sliding or creeping of snow cover on the slope, and thus directly preventing the formation of avalanches; 2) preventing the formation of snow cornices, which are one of the causes of the avalanche generation, and thereby indirectly preventing the formation of avalanches.

Avalanche structures can also be of various types and directions: protective structures protect the corresponding object from an impending avalanche, avalanche depressing structures reduce avalanche energy, guiding structures change the direction of the avalanche, avalanche passing constructions aim to avoid avalanche collision.



etc.

Avalanche prevention structures	Avalanche protection structures	
1. Avalanche prevention forest	9. Snow retaining fence	17. Guiding bank
2. Stepped terraces	10. Blowing off fence	18. Guiding trench
3. Avalanche preventive pile	11. Earth Bank (Earth Mound)	19. Avalanche splitter
4. Avalanche preventive fence	12. Energy reducing pile (group of piles)	20. Snow shed
5. Supported frame	13. Framework (jungle)	21. Protective fence
6. Supported fence	14. Energy reducing retaining wall	22. Protective retaining wall
7. Snow net	15. Guiding retaining wall	
8. Protection fence	16. Guiding fence	

Figure 8.2-2 Schematic layout of hard measures

(Source: Snow removal / snow protection handbook. Snow protection version. 2005)

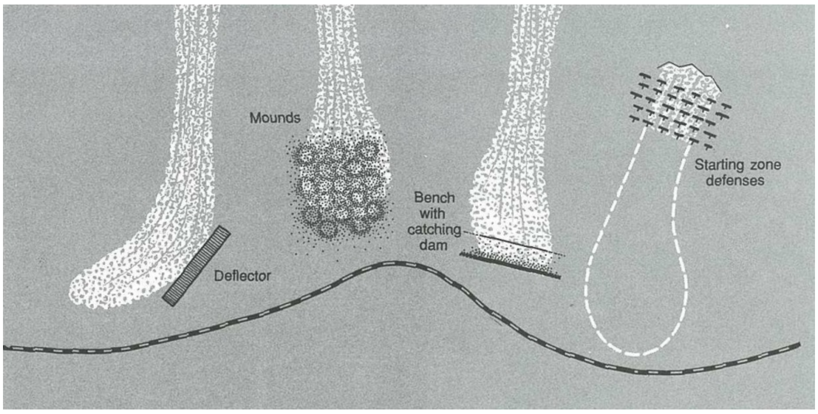


Figure 8.2-3 Defense structures for protection of mountain highways

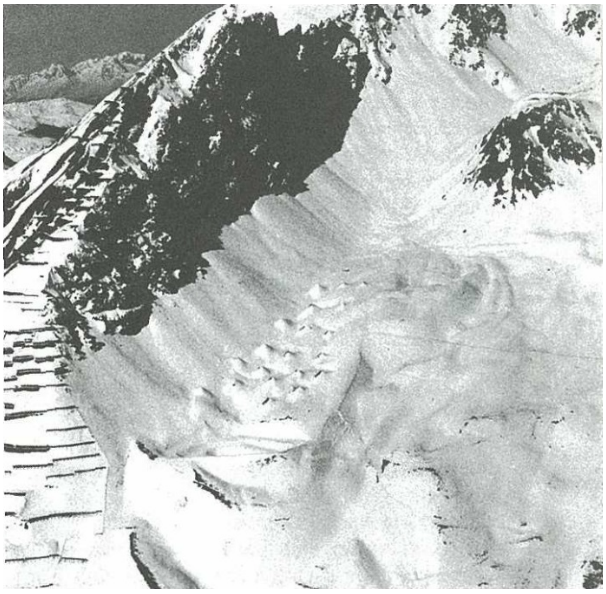


Figure 8.2-4 Avalanche countermeasure structure situation

The left side shows supporting structures in avalanche starting zones. In the center of the picture, mounds and arrester dikes are visible. (Photo by E. Wengi)

Table 8.2-1 Major Classification and Type of Countermeasures

Protective structure		Short description
Preventive structures	Avalanche prevention forest	The method involves planting appropriate tree species based on their functionality to prevent formation of avalanches.
	Stepped terraces	This engineering method prevents formation of avalanches through making terraces by cutting the slope or by other methods and mitigates the sliding of snow cover.
	Avalanche preventive pile	This method prevents formation of avalanches through installing piles instead of forests.
	Avalanche preventive fence	This method prevents formation of avalanches through installing fences. Generally they are made from steel.
	Supported pile	This engineering method prevents formation of avalanches through frame structures suspended by a cable along the slope.
	Supported fence	This engineering method prevents formation of avalanches through fences suspended by a cable along the slope.
	Snow net	This engineering method prevents formation of avalanches through a net consisting of a wire rope.
	Protruding protective fence	This engineering method prevents sliding and moving of small-scale snow shafts
	Fence to prevent the appearance of snow cornices	This method prevents formation of snow cornices through the forming vortex in front of and behind the fence and reducing the wind speed, thereby holding the snow
	Blowing off fence	This method prevents the formation of snow cornices through the collection of air flow from the holes in the lower part of the fence, and by increasing the speed of the wind thereby blowing off the snow.
Protective structures	Earth mound	This method protects the object through a cone-shaped earthen bank mounted on the avalanche path, reducing the speed of running avalanche.
	Energy reducing pile (group of piles)	This method protects the object through a piles mounted on the avalanche path, reducing the speed of running avalanche.
	Framework	This method protects the object through a framework mounted on the avalanche path, reducing the speed of running avalanche.
	Energy reducing fences	This method protects the object through a fence mounted on the avalanche path, reducing the speed of running avalanche.
	Guiding retaining wall	This method protects the object through retaining wall mounted on the avalanche path, changing running avalanche direction.
	Guiding fence	This method protects the object through a fence mounted on the avalanche path, changing running avalanche direction.
	Guiding bank	This method protects the object through earth bank mounted on the avalanche path, changing running avalanche direction.
	Guiding trench	This method protects the object through trench excavated on the avalanche path, changing running avalanche direction. Often used in combination with guiding earth bank.
	Avalanche splitter	This method protects the object through a wedge-shaped structure installed on the avalanche path, splitting an avalanche into two parts
	Snow shed	This method protects the object by passing an avalanche over a long roof installed above the road.
	Protective fence	This method protects the object through the installation of a protective fence in avalanche deposition zone, which stops descended avalanche flow.
	Protective retaining wall	This method protects the object through the installation of a retaining wall in avalanche deposition zone, which stops descended avalanche flow.
	Protective dam	This method protects the object through the installation of a dam in avalanche deposition zone, which stops descended avalanche flow.

(Source: Snow removal / snow protection handbook. Snow protection version. 2005)

Table 8.2-2 Comparison Table of Countermeasures against

Applicable Condition		Design Snow Depth: 2~4m, Foundation: Rock											
Location of Countermeasures		Generation Source Zone								Road and/or Sedimentation Zone			Remarks
Type of Countermeasures		Prevention Work								Blocking/Guiding Work			
Method of Countermeasures		Snowbreak Woods	Stepped Terraces (including Widening Berm by Cutting)	Widening Berm (Facilities Construction)	Piles	Prevention Fence (Fixed Type)	Supported Frame	Supported Fence	Snow Net	Protection Fence	Protection Wall	Snow Shed	
Outline		To prevent the occurrence of acalanche by woods	To prevent the occurrence of full-depth avalanche by separating the slope length to short length by steps.	To prevent the occurrence of avalanche by widening of road berm. (It is desirable that the road berm width is planned as 1.2 times the design snow depth.)	Pile structures, which are built almost at right angles to the slope, support a range of snow cover by the viscosity of the snow.	To prevent the avalanche caused by creep and glide phenomenon of the snow by the fence. There are 2 types fundation like a concrete type and pile type.	Supported Frame, which is pyramid-shaped and is hanged in the wire rope from the top of the slope by the anchor, can prevent the movement of the snow. It can be prevented the occurrence of the avalanche by installing them a large number.	Supported Fence, which is hanged from the top of the slope by wire rope, is applied to prevent the avalanche. (It is applied that the space for the fundation of supported fence can not be secured.)	Snow Net can be received the snow pressure by the net installed between pillars which are installed on the slope. Snow Net is more expensive a little than other countermeasures. It is effective for high snow depth area.	To prevent the avalanche by the fence. It should be installed adequate position in consideration with avalanche area.	Protection wall is concrete structure. It receives the avalanche by the behind pocket. Structure scale is larger than other countermeasures, and installed area is limited.	Snow Shed can protect from the damage of the road and road user by the avalanche by being passed through the avalanche on the concrete roof.	
													
Type of Avalanche	All Layers	○	○	○	○	○	○	○	○	○	○	○	
	Surface Layer	×	×	△	×	○	×	○	○	○	○	○	
Depth of Snow	1～4m	○	○	○	○	○	○	○	○	○	○	○	
	4～6m	×	×	×	○	○	×	×	○	△	△	○	
	6m and more	×	×	×	×	×	×	×	×	×	×	○	
Slope	20° and less	○	○	○	○	○	△	△	△	○	○	△	In case of steep slope, effect of Piles and Supported Frame is small. Protection Fence should be installed on the slope which is less than 20 degree.
	20～30°	○	○	○	○	○	○	○	○	△	△	○	
	30～40°	○	○	○	○	○	○	○	○	×	×	○	
	40～50°	×	△	○	△	○	△	○	○	×	×	○	
	50° and more	×	×	○	×	△	×	○	○	×	×	○	
Topographic Condition	Convexoconcave	×	×	×	○	○	○	×	○	○	○	○	"Convex-concave" is indicated the groove and boulder caused by flowing water and boulder.
	Stream	△	△	×	○	○	○	○	○	○	○	○	
	Flat	○	○	○	○	○	○	○	○	○	○	○	
Length of Slope	15～ 50m	○	○	○	○	○	○	○	○	○	○	○	In case of installing the protection fence, it is desirable that intervals of installation is 15m.
	50～100m	○	○	○	○	○	○	○	○	○	○	○	
	100～200m	○	○	○	×	○	×	×	○	△	○	○	
	200m and more	○	×	○	×	○	×	×	○	△	○	○	
Geotechnical Condition	Soil	○	○	○	○	○	○	○	△	○	○	○	In case that the bearing ground is deep, It is undesirable that Piles and Protection Fence is applied.
	Soft Rock	×	○	○	○	○	○	○	○	○	○	○	
	Hard Rock	×	×	○	○	○	○	○	○	○	○	○	
	Landslide	○	×	○	×	×	○	○	×	×	×	×	
Description		1).Combination with other countermeasures may be required until trees grow enough. 2).It is most preferable as permanent countermeasure.	1).Applicable to the slope of 30 ~ 40 degree. 2).Applicable to soft rocks that can be excavated easily. 3).Prevention for full-depth avalanche. 4). Applicable to snow depth of less than 3 ~ 4m. 5). Need to remove the deposition of sediment on the steps.	1).It is applied on road slope. 2).It is effective against full-depth avalanche 3).In case that width of the berm is enough, Widening by the facility is not required.	1).Applicable to less than 40 degree of the slope. 2).Applicable to soft ground that can be excavated easily. 3).Prevention for full-depth avalanche. 4).Applicable to snow depth of less than 3 ~ 4m. 5).In the concave-convex terrain, the piles and protection fence are suitable.	1).Applicable to the slope than less than 55 degre. 2).Applicable to soft ground that can be excavated easily. 3).Prevention for full-depth avalanche and surface avalanche. 4).Applicable to snow depth of less than 5 ~ 6m. 5).In the concave-convex terrain, the piles and protection fence are suitable.	1).Applicable to steep slope or soft ground. 2).Prevention for full-depth avalanche. 3).Applicable to snow depth of less than 5 ~ 6m. 4).In case that Supported Frame or Supported Fence is installed more than 3 stages, diameter of the wire rope is thick and construction become difficult.	1).Applicable to steep slope or soft ground. 2).Prevention for full-depth avalanche and surface avalanche. 3).Inapplicable to snow depth of more than 4m. 4).In case that Supported Frame or Supported Fence is installed more than 3 stages, diameter of the wire rope is thick and construction become difficult.	1).Applicable to steep slope. 2).Prevention for full-depth avalanche and surface avalanche. (Rock fall of small scale can be protected.)	1).Applicable to the slope of less than 20 degree. (In case of steep slope, fence height becomes higher.) 2).Prevention for full-depth avalanche and surface avalanche.	1).Applicable to the slope of less than 20 degree. (In case of steep slope, fence height becomes higher.) 2).Prevention for full-depth avalanche and surface avalanche.	1).It is possible to prevent from the avalanche completely. 2).Reliability is high as a protection against the avalanche. 3).Snow shed should be installed in place that other countermeasure cannot be applied.	
Adequacy of Installation		･It takes a long time to obtain the effect	･Deforestation is required. ･Large scale terrain modification is required.	･It can not be applid snow depth of more than 4.5m	･It may not be suitable depending on avalanche scale.	･Workability and economic is inferior than the Snow Net.	･It can not be applid snow depth of more than 4.0m	･It can not be applid snow depth of more than 4.5m	･In case of soft ground, foundation scale become massive.(construction cost would be high)	･Appllicable to steep slope like more than 20 degree, but fence heigh becomes higher (cost is high).	･Appllicable to steep slope like more than 20 degree, but fence heigh becomes higher (cost is high).	･Snow shed is more expensive than other countermeasures.	
Approximate Cost (Direct Cost(DC) + Indirect Cost (70% of DC)) Note: Construction cost depends upon the site condition		4,000 Thousand Yen/ha Japanese White Birch (H=4.5m) 100 trees/ha Local growth tree is applicable	170 (Thousand KGS/m)	550 (Thousand KGS/Place)	200 (Thousand KGS/Place)	2,400 (Thousand KGS/Place)	380 (Thousand KGS/Place)	680 (Thousand KGS/Place)	1,000 (Thousand KGS/m)	400 (Thousand KGS/m)	1,700 (Thousand KGS/m)	3,400 (Thousand KGS/m)	Construction cost is different depending on construction are, terrain, condition and etc. The construction cost described in this table is sample cost under the slope of the same conditions.
										○ : Applicable	△ : Requires Consideration	× : Not Applicable	

8.2.2 Earthworks as protective measures

8.2.2.1 Basic idea

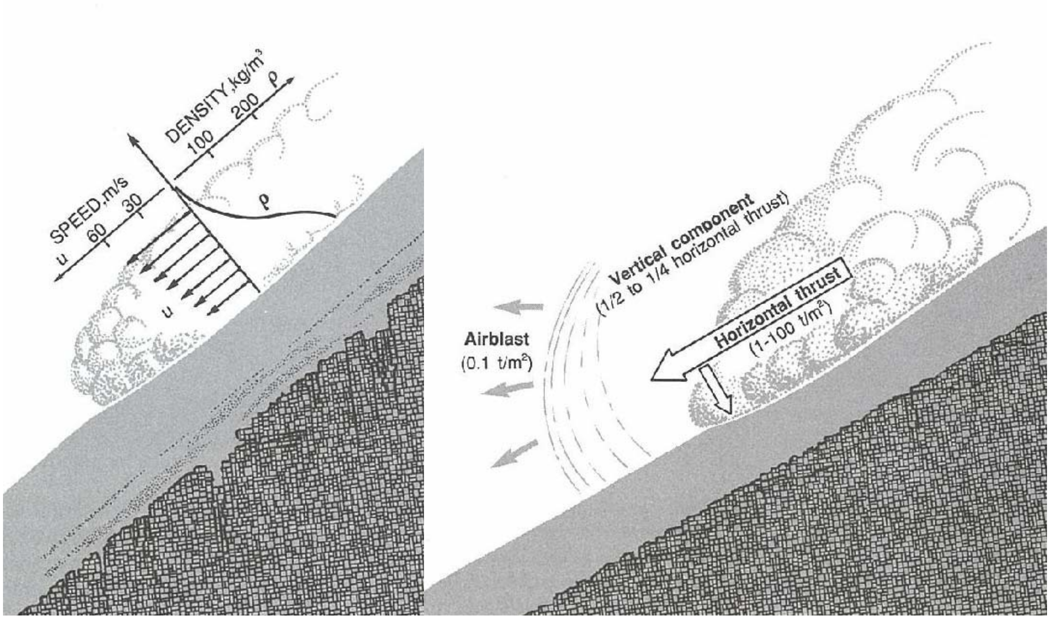
Permanent avalanche countermeasures as shown in Table 8.2.2 are very expensive and sometimes cannot be implemented. Table 8.2-4 shows a countermeasures centering on earthworks, which are cost efficient in comparison with Table 8.2.2.

Earthwork based protective measures do not have sufficient strength against the load during collision with large-scale avalanches with pathway more than 1 km. In this regard, dumping and destruction are possible during a collision with an avalanche. When planning the placement of a structure, one should take an extra distance from the road equal to twice the height of the structure, so that even if the structure is dumped, there will be less damage to the road.

Table 8.2-3 Correlation between Impact Pressure and Potential Damage

Impact Pressure(N/m^2)	Potential Damage
1	Break windows
5	Push in doors
30	Destroy wood frame structures
100	Uproot mature spruce
1000	Move reinforced-concrete structures

Source：The avalanche handbook (David Mcclung and Peter Shearer (1993))



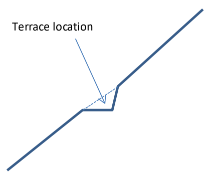
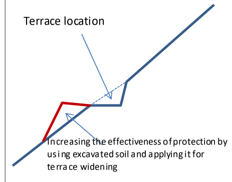
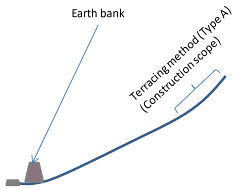
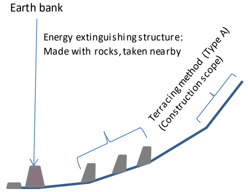
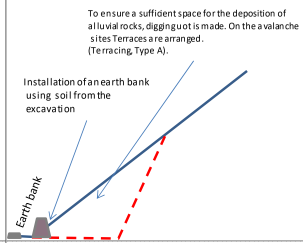
Avalanche velocity u and inner density ρ distribution example of avalanche vertical to the slope

Schematic diagram of impact force and blast of the tip of avalanche (example)

Figure 8.2-5 Schematic diagram of avalanche impact force (from The Avalanche Handbook）

Table 8.2-4 Comparison Table of Countermeasures against

Comparative table of structural methods against avalanches

	Form of construction				
	①Terracing method (Type A)	②Terracing method (Type B)	③Terracing method (Type A) + Earth bank	④Terracing method (Type A) + Energy extinguishing structure + Earth bank	⑤Terracing method (Type A) + Earth bank
Slope		Cold Regions Sience and Engineering PartⅢ, Malcom Mellor, 1968, U.S.ARMY MATERIEL COMMAND 		Earth bank building using the soil from an excavation 	
Parameters	This method involves the construction of terraces vertically along the slope at a certain interval, which keep the snow cover and prevent full depth avalanches formed due to slipping.	This method involves the construction of terraces vertically along the slope at a certain interval, which keep the snow cover and prevent full depth avalanches formed due to slipping. Also, it is supposed to build embankments for the expansion of terraces	This method involves the construction of terraces vertically along the slope at a certain interval, which keep the snow cover and prevent full depth avalanches formed due to slipping. Also, earth bank is built near the road to prevent disaster, caused by avalanche that crossed terrace.	This method involves the construction of terraces vertically along the slope at a certain interval, which keep the snow cover and prevent full depth avalanches formed due to slipping. Also, earth bank and avalanche energy extinguishing structures are built near the road to prevent disaster, caused by avalanche that crossed terrace.	If the slope is steep near the road, even with using terraces, it is likely that the snow mass will fall on the road. Therefore, it is necessary to provide a place for avalanche deposit by digging a pocket on the slope before earth bank.
Scope of application	To a certain extent, it is effective against avalanches of full depth. However, the terraces, gradually smoothed out due to the snow cover and losing the surface heterogeneity, lose the effect of protection from surface avalanches. Consequently, with the increase of snow cover it is necessary to broaden the terraces themselves.	To a certain extent, it is effective against avalanches of full depth. However, the terraces, gradually smoothed out due to the snow cover and losing the surface heterogeneity, lose the effect of protection from surface avalanches. Consequently, with the increase of snow cover it is necessary to broaden the terraces themselves.	To a certain extent, it is effective against avalanches of full depth. However, the terraces, gradually smoothed out due to the snow cover and losing the surface heterogeneity, lose the effect of protection from surface avalanches. Consequently, with the increase of snow cover it is necessary to broaden the terraces themselves. The height of the dam in terms of the engineering efficiency of the structure is maximum 5 m.	To a certain extent, it is effective against avalanches of full depth. However, the terraces, gradually smoothed out due to the snow cover and losing the surface heterogeneity, lose the effect of protection from surface avalanches. Consequently, with the increase of snow cover it is necessary to broaden the terraces themselves. The height of the dam in terms of the engineering efficiency of the structure is maximum 5 m.	To a certain extent, it is effective against avalanches of full depth. However, the terraces, gradually smoothed out due to the snow cover and losing the surface heterogeneity, lose the effect of protection from surface avalanches. Consequently, with the increase of snow cover it is necessary to broaden the terraces themselves. The height of the dam in terms of the engineering efficiency of the structure is maximum 5 m. Also, when digging a pocket, it is necessary to ensure the stability of the slope in terms of soil quality.
Usage scale (snow cover depth, slope angle, etc.)	Snow cover depth 1-2 m Avalanche generation slopes angle 30～45°	Snow cover depth 1-2 m Avalanche generation slopes angle 30～45°	Snow cover depth 1-2 m Avalanche generation slopes angle 30～45°	Snow cover depth 1-2 m Avalanche generation slopes angle 30～45°	Snow cover depth 1-2 m Avalanche generation slopes angle 30～45°
Merits and demerits	Merits: Does not require special materials, enough excavation work. The extracted soil from the digging of the shelves can be effectively applied to their broadening. Demerits: Due to the load of the snow cover or other external influences, the shelves are often destroyed, therefore, to the beginning of snowfalls it is necessary to restore their shape. Moreover, in view of the need to follow the slope form, when colliding with cloughs or with mountain streams, it is imperative to think about engineering ways of solving such problems. The soil mound is easily destroyed, therefore, it requires some strengthening protective agent.	Merits: Does not require special materials, enough excavation work. The extracted soil from the digging of the shelves can be effectively applied to their broadening. Demerits: Due to the load of the snow cover or other external influences, the shelves are often destroyed, therefore, to the beginning of snowfalls it is necessary to restore their shape. Moreover, in view of the need to follow the slope form, when colliding with cloughs or with mountain streams, it is imperative to think about engineering ways of solving such problems. The soil mound is easily destroyed, therefore, it requires some strengthening protective agent.	The design of the terrace is similar to that described in the left column. Merits: earth bank can be built from excavated soil during construction of terraces. Demerits: the earth bank is easily destroyed, therefore it requires surface protection. In addition, too much height is inadmissible in terms of efficiency, a maximum of 5 m.	The design of the terrace is similar to that described in the left column. Merits: earth bank can be built from excavated soil during construction of terraces. Demerits: the earth bank and energy extinguishers can be easily destroyed, therefore it requires surface protection. In addition, too much height is inadmissible in terms of efficiency, a maximum of 5 m.	The design of the terrace is similar to that described in the left column. Merits: earth bank can be built from excavated soil during construction of terraces. Demerits: the earth bank is easily destroyed, therefore it requires surface protection. In addition, too much height is inadmissible in terms of efficiency, a maximum of 5 m.
Terrace width, Interval between terraces, Earth bank	Terrace width: 1-2 m Interval: 10～20 m	Terrace width: 1-2 m Interval: 10～20 m	Terrace width: 1-2 m Interval: 10～20 m Earth bank :masonry or earth construction (h=5m)	Terrace width: 1-2 m Interval: 10～20 m Earth bank :masonry or earth construction (h=5m)	Terrace width: 1-2 m Interval: 10～20 m Earth bank :masonry or earth construction (h=5m) Snow load: as needed

8.2.2.2 Types and effects of earthworks as protective measures

Types of earthworks as protective measures are shown in Table 8.2-5

Table 8.2-5 Types and purposes of avalanche countermeasures based on earthworks

Type	Countermeasure type	Purpose
Preventive	Terracing	They are set in generation zone to prevent the occurrence of avalanches
Energy reducing	Earth bank (Earth dam)	They are set on the avalanche pathway to reduce the avalanche speed
	Terracing	They are set on the avalanche pathway to reduce the avalanche speed. In Japan, Europe and North America, terraces are set for preventive purposes, but in Kyrgyzstan the effect of reducing avalanche speed empirically has been confirmed.
Guiding	Guiding earth banks (dams)	They are set in avalanche path zone or its end and change avalanche route to prevent reaching the road
Protective	Earth dam	They are set in zone of avalanche deposition and stopping. When the slope is steep and deposit capacity cannot be secured, excavation of the slope is also used to ensure the deposition capacity.

8.2.2.3 Selection flow of countermeasures based on earthworks

Figure 8.2-6 shows the selection flow of the countermeasures. The scheme does not include guiding types of countermeasures. Such measures are taken when there is space near the road and when changing the avalanche direction is extremely effective.

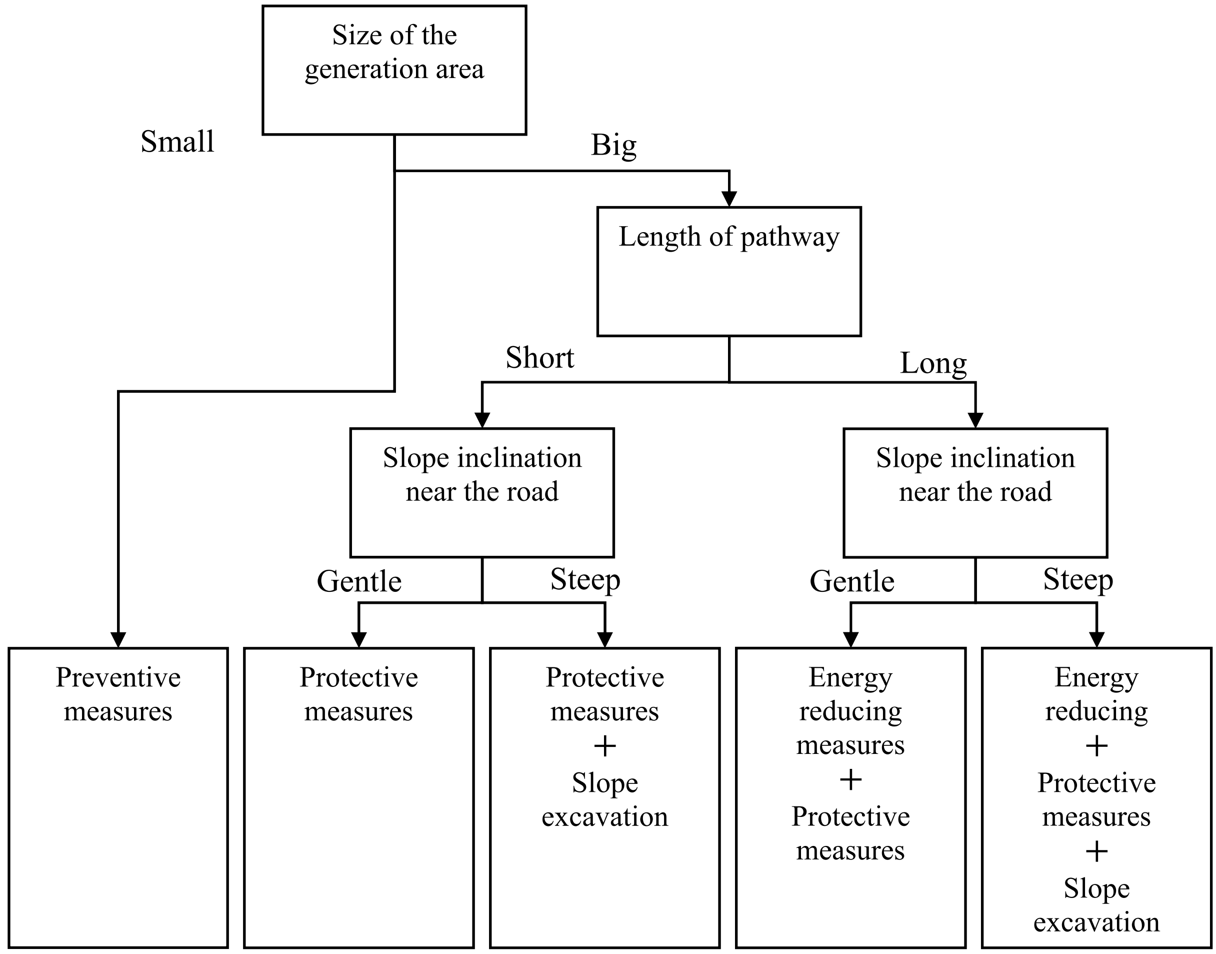
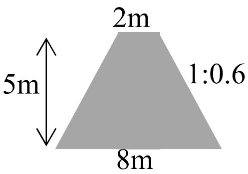
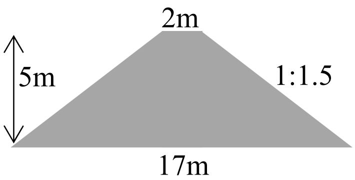


Figure 8.2-6 Selection flow of countermeasures

8.2.2.4 Cost of earthworks

The approximate costs of protective measures, mainly based on earthworks, are shown in Table 8.2-6 By multiplying these unit prices by the expected amount of soil and length of countermeasure structure, it is possible to calculate the approximate cost of the protective method. Regarding the embankment, the cost of several materials and shapes are shown below. It is necessary to set the structure, taking into account the availability of the site and materials for construction on site.

Table 8.2-6 Cost of countermeasures based on earthworks

Work type		Approximate cost	Remarks
Terracing		10 Thousand KGS/m^3	Construction by a high altitude surface excavator (rock climbing machine) http://www.taisho-kk.com/technical/methodtop.html
Embankment Reinforced earth wall		620 Thousand KGS/m	Height 5 m and width 3 m (Pictures : http://georock.jp/)
Embankment Reinforced earth wall Soil cement		140 Thousand KGS/m	Height 5 m and width 8 m Soil stabilization by soil cement method When side slope 1: 0.6
Earth dam, Embankment		100 Thousand KGS/m	Height 5 m and width 17 m, When side slope 1: 1.5

8.3 Structural Detail of Main Countermeasures

8.3.1 Terracing

8.3.1.1 Outline of terracing

Terracing is a countermeasure work that prevents the movement of snow cover on the slope, thereby prevents the occurrence of an avalanche by cutting and banking the slope. It has been practiced in Europe since the 19th century. From the results of Japan and Europe, the terracing work has been shown to be effective in the following situations:

・Suppression of full-layer avalanche due to snow glide
・Slope incline less than 35°
・Snow depth does not exceed 1.5 m
・Slopes with low snow inflow rates
・Terrace width W is at least 1.5 times bigger than depth H of snow cover

The construction of terraces includes excavation works in the middle or in the upper part of the slope with the help of mountain climbing excavator or by human forces.

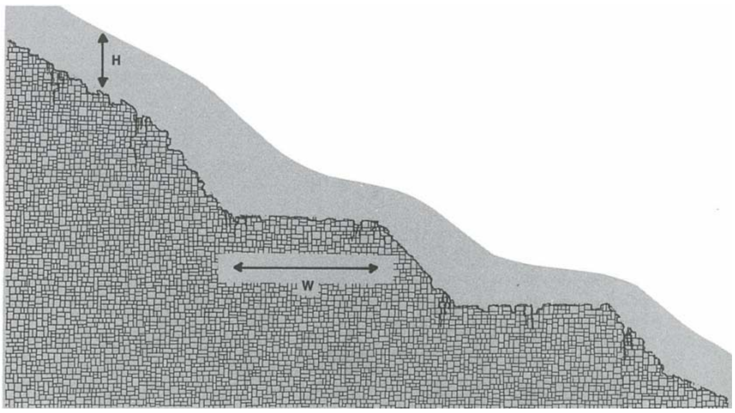
	
Terraces in starting zone. The terrace width W, is at least 1.5 times the snow depth, H.	Terraces in avalanche starting zone. (Photo by H.Frutiger)

Figure 8.3-1 Components of Supporting Structures Terraces
(from THE Avalanche HANDBOOK)

In Kyrgyzstan, the terraces are set in the middle part of the slope, and are aimed at reducing the power of the avalanche. In Japan, it is not uncommon when snow cover reaches 4 ~ 5 m. Thus, with a large accumulation of snow, the terraces are covered with snow and the energy reducing function does not work or it is too insignificant. In Kyrgyzstan, due to the continental climate, the depth of snow cover is 1 ～ 2 m, and the terraces do not remain under the snow cover. Perhaps therefore, the terraces here are aimed at energy reducing, while in other countries, this method is used to prevent occurrence of avalanches.

8.3.1.2 Placement of terraces

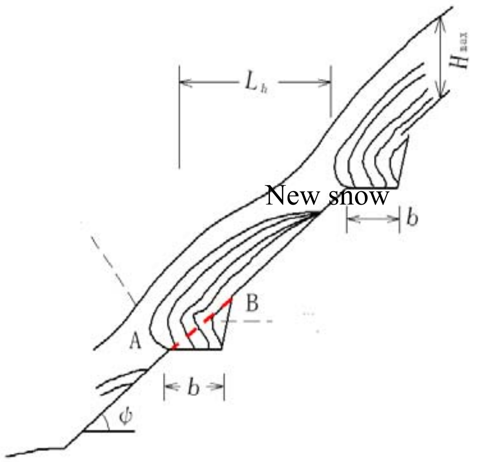
(1) Terraces width

Terraces width is as follows.

b＝0.8×Hmax

Hmax ; The maximum depth of snow cover over the years, where the countermeasure is supposed to be implemented.

However, the wider the terrace, the higher the effect of suppressing the moving of snow. The width of terraces installed on BO road is about 2 m, and this terrace width 2 m can be used as one criterion.



Space

Figure 8.3-2 Schematic diagram of snow cover on the terrace

(2) Interval between rows of terraces

1) Column interval calculation formula

The interval between rows during terracing can be calculated by the following formula.

$$L_h = \frac{\alpha \times sec\psi \times b \times S_R}{W_s(sin\psi - \mu cos\psi)}$$

L_h	: Horizontal distance between upper and lower terraces（m）
α	: Constant（=0.5）
ϕ	: Inclination angle of slope
b	: The width at the bottom of the carved terrace（m）、$b=0.8H_{max}$
	H_{max} : The maximum depth of snow cover over the years in implementation area (m)
S_R	: Effective shear force of snow under line A - B in Figure 8.3-2（kN/m^2）
W_S	: The expected yearly maximum snow weight at that point（kN/m^2）
μ	: Coefficient of friction（used as $\mu \cos\phi = 0.2$）

On the other hand, the terraces in the vicinity of 223 km of BO road are set at oblique distance of 12 to 15 m and altitude difference of 5 to 8 m, and they were effective against avalanche in the past. Therefore, this interval can be used as one criterion.

Regarding α, ϕ, μ:

These coefficients are adapted to the zone with the maximum snow depth of 3 to 4 m in Japan, so it is desirable to set these coefficients to suitable values for Kyrgyzstan.

The above equation expresses, through sec ψ · b, how many times the width of the terrace it is necessary to set the interval L_h between rows in the horizontal direction. The ratio to the width b depends on the shear strength $\alpha \cdot S_R$ and the driving force $W_S \cdot (\sin\psi - \mu\cos\psi)$. In other words, since $\alpha \cdot S_R$ and $W_S \cdot (\sin\psi - \mu\cos\psi)$ are balanced by the terrace width b, and the snow on the slope is stable, the distance to the terrace above and below it should be taken as L_h.

2) Other calculation formula

Other examples studied in the past are described below.

(a) Calculation formula used in Savoie region of France（by Shidei (1950)[*1]）

$$d = K\ell\cot(\alpha - \beta)$$

$$K = \frac{D/\ell}{\cot\alpha}$$

here、

d ; Distance between the axles of the upper and lower terraces

ℓ ; Terrace width

α ; Slope angle

β ; The minimum angle of slope at which avalanches are formed (24°)

D ; Distance between axles with continuous terraces

3) Empirical formula in Japan（by Shidei (1950)[*1]）

$$\ell = \frac{1}{7}h$$

here、

ℓ ; Terrace width

h ; Vertical distance between the upper and lower terraces

*1 Shidei, Proposal of formula for terraces against avalanches. Japan Snow and Ice Society magazine “Snow and ice” 12 vol. 5, p.22 - 25, 1950

8.3.2 Earth embankment (protection structure)

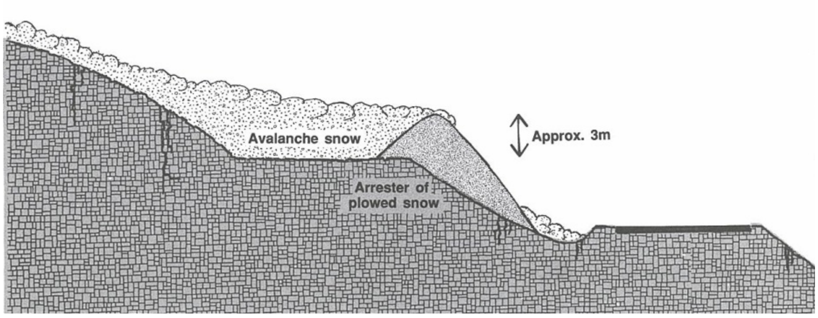
8.3.2.1 Outline of protective structures

Protection measures against avalanches are structures that do not allow an avalanche to reach the road by stopping it and holding the avalanche deposit. It is extremely important that these measures have sufficient height to stop the avalanche and the capacity for its deposition.

Because of the cutting of shelves on the slope, an extra soil appears that can be used on the side of the road as an earthen dam with a protective function. The method of terracing can be effective with avalanches of full depth, and with surface ones it is ineffective. Avalanche-prone areas in the Kyrgyz Republic are at an altitude of more than 2500 m, meteorological conditions are prone to the appearance of snow crusts due to a small snow cover of 1-2 m, solar radiation, snowfall and strong wind. Consequently, when the upper and lower shelves are connected to the new snow, there is a danger of the formation of a sliding layer of fresh snow and the onset of surface avalanche. For this reason, it is effective to construct the earth dam near the road, taking into account the case where it was not possible to suppress the occurrence of the surface avalanche by terracing.

The greater the avalanche velocity, the higher the retaining wall becomes. Therefore, it is desirable to install protective walls in case of small-scale avalanches or close to the avalanche deposition and stopping zone. It is also effective to reduce the speed of the avalanche by installing energy suppressing structures in front of the protective retaining wall.

There is also an effect of reducing the amount of snow in the sediment section, thereby increasing capacity for avalanche deposit. It is possible by constructing wide ditches along the road. In winter, you can build snow dams as emergency measures.



(a) Bench with snow arrester

(b) Combined catching dam (Photo by S.Margreth,SLF) Dam height=17m, retention volume=260,000m^3

(c) Arrester. (Photo by H. Frutiger)

(d) (Reinforced) Arrester in Japan.

Figure 8.3-3 Arrester (from THE Avalanche HANDBOOK)

8.3.2.2 Installation and design of earth dams

(1) Structure

Earth dams, due to structural features, cannot have a large effective height, so they are limited to 5 meters. Depending on the soil used, if it is impossible to provide an earth dam with a gradient of stability due to the quality of the soil, it becomes necessary to secure the surface and give the dam stability by concrete or other material. Of course, depending on the scale of the avalanche, the structure will not be able to stop the entire volume, but it will be able to keep some part from reaching the road, which will significantly reduce the volume of snow removal works.
The height of the protective construction is approximately calculated by the formula below. If such a calculation is difficult to perform, then it is necessary to focus on the maximum height in the history of avalanches on this site, or as was said earlier, due to structural problems, to set the height to 5 m.

$Hd = Hs + Ha + Hv$

here、

Hs : Depth of snow accumulated by snowfall and earlier avalanches

Ha : Estimated depth of avalanche flow

$Hv = Va^2 / 2g$

Va : Approach speed of avalanche

$g = 9.81 m / s^2$

Since this calculation formula is the height calculated from a simple dynamic model, it may be underestimated.

The steepness of the mountain side of the embankment should be as steep as possible. It is because there is a high possibility that an avalanche will ride over the embankment if it is too gentle.

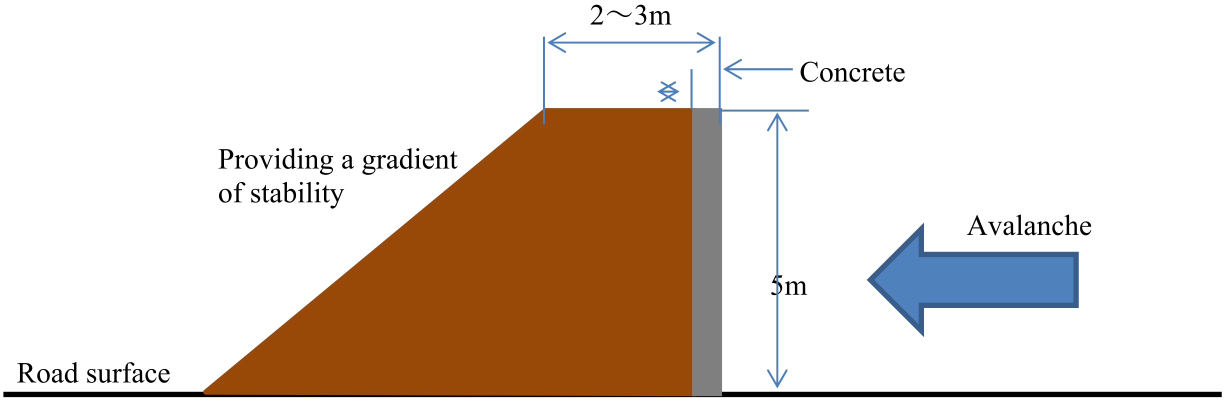


Figure 8.3-4 Cross-section of schematic structure of a bank at a road shoulder (draft)

Construction works for reinforcing earth embankment allow you to have a structure with a steep slope angle. Such constructions are described below (Table 8.2-6).

- Geotextile reinforced earth wall construction method (slim earth type). It is sold as a product in Japan.
- In the case of using modified soil (soil cement) mixed cement without using geotextile particles, the sidewall gradient 1:0.6 is possible.
- In the case of using materials other than cement, the construction method is also considered in form with large sand bags that are resistant to weather conditions.
- When building an embankment of earth and sand only (slope of the embankment on the sides 1: 1.5), if the height is 5m, then the width should be 17m.

As an urgent measure, where there is a fear of avalanches and there are no earthen dams, you can build a snow bank temporarily replacing the earthen dam. And if there is water source nearby, it is considered that it is possible to raise the level of its strength by sprinkling with water and freezing the entire surface.

(2) Locating

If the avalanche pathway is long, starting from the zone of the avalanche generation and up to the road, then it is desirable to build an earthen dam not at the wayside, but on the shallow part of the slope at the end of the avalanche pathway (less than 20°). Because if the avalanche crosses the dam, the avalanche deposit will remain between the road and the earth dam.
The items to consider in this case are as follows:

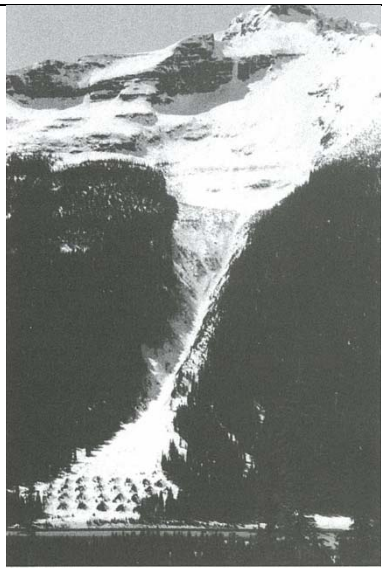
- Comparison of the volume of the avalanche and avalanche deposit retained by the earthen dam.
- Load on the dam when an avalanche strikes.
- The volume of avalanche deposit that reached the road when the avalanche passes through the earthen dam.

8.3.3 Avalanche retarders

8.3.3.1 Effects of avalanche retarders

Avalanche retarders reduce the speed of avalanches, thereby reducing reached distance and therefore are installed in the zone of avalanche path. There are retarders in the form of structures or in the form of earthworks.

(a) Flow retarders of steel in Japan. (Photo by R. Decker)



(b) Earth mounds to retard flowing snow at the end of a runout zone. (Photo by P. Schaerer)

(c) Earth mounds in a runout zone. (Photo by H. Frutiger)

Figure 8.3-5 Retarders (from THE Avalanche HANDBOOK)

8.3.3.2 Structure and arrangement of retarders

(1) Structure

Mainly earth dams are used as in Figure 8.3-4, however, in order for the structures to spread out on the avalanche pathway, not such structures as dams of walls, but individual disjoint structures (hereinafter referred to as “earthen band”) are suitable.

The angle of the forward slope side of the earthen bank is better to be steep, but it depends on local soil’s quality conditions. The height of the bank D_k is taken twice as deep as the depth of the snow cover *H,* and ½ of the diameter *d.*

$$D_k = \frac{d}{2} = 2H, \qquad d = 4H, \qquad L = 2d = 8H$$

To protect the slope of the earth bank from damage caused by rain, it should be strengthened by planting plants and herbs. It is also possible to ensure the protection of the slope by masonry of the front side.

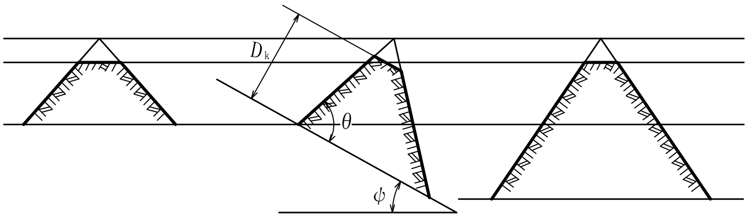
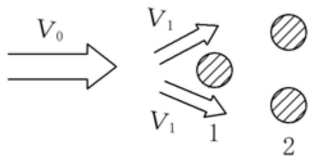
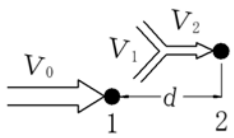


Figure 8.3-6 Earth bank configurations（Source: Snow removal / snow protection handbook / Snow protection version, 2005）

Considering the fact that there are no directions about earth bank design, here are the main ideas and design policy. Suppose that on the slope, as in scheme below earth banks were made in 1,2,…, n number of rows. In other words, the descending avalanche flow is divided into 2 parts on the earth bank 1. Further, the earth banks 2, 3, 4 one by one separates the avalanche flow and it loses power and speed until it completely stops to the nth row.



Earth banks and speed



Change in avalanche speed

Figure 8.3-7 Scheme of earth banks and avalanche speed changes (Source: Snow removal / snow protection handbook / Snow protection version, 2005)

The avalanche, coming off at a speed V0, and colliding into the first earth bank, is divided into 2 parts. The change in velocity after separation can be approximately determined by the following formula, assuming that the velocity after collision is V1, and the angle of change in directions is α.

$$\frac{V_1}{V_0} = 1 - \mu \sin \alpha$$

V_0 : Avalanche speed before collision with the first earth bank (m/s) ;
V_1 : Avalanche speed after collision with the first earth bank (m/s) ;
μ : Avalanche flow speed attenuation coefficient due to a collision with the earthen bank;
α : Angle of change of avalanche direction

Regarding the index μ, according to the experiment on the force of action of the snow mass, there is actually a measured index μ=0.3.

$$\therefore \frac{V_1}{V_0} = 1 - 0.3 \sin \alpha$$

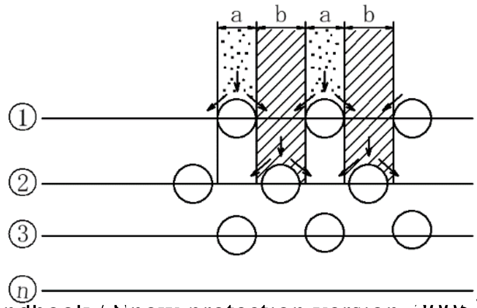
If α = 45 °:

$$\frac{V_1}{V_0} = 1 - 0.3 \sin 45° = 0.79$$

Therefore, with a single change in direction, the velocity is 79% of the original one. This data is shown in the table below. The avalanche speed is 56% at n = 2, 40% at n = 3, and 25% at n = 4. n is the number of rows of earth banks. In this way, the avalanche gradually decreases the speed while colliding with earthen banks, but in practice the damage will be almost eliminated if it is about 20% of the initial speed, so it seems that 3 to 4 rows of earth are enough. It is desirable to determine the number of rows in consideration of the situation of the avalanche slope.

Table 8.3-1 Avalanche speed at each row

		a		b
n	Number of clashes	V	Number of clashes	V
①Front	1	V	0	V
①Top	2	νV	0	V
②Front	3	ν^2V	1	V
②Top	4	ν^3V	2	νV
…	…	…	…	…
n Front	2n-1	ν^{2n-2}V	2n-3	ν^{2n-4}V
n Top	2n	ν^{2n-1}V	2n-2	ν^{2n-3}V



（Source: Snow removal / snow protection handbook / Snow protection version, 2005）

(2) Arrangement

If the avalanche pathway is long, starting from the zone of avalanche generation and up to the road, then it is desirable to place avalanche-deflecting structures between the avalanche pathway and the sediment zone on the shallow part of the slope (less than 20° ,Figure 8.3-8

Earth banks, as a rule, are arranged in stages. As shown in Figure 8.3-9 they are arranged so that the straight lines connecting their centers form an equilateral triangle. The center-to-center distance *L* is twice as many as the diameter *d* of the earth bank. In other words, $L=2d$.

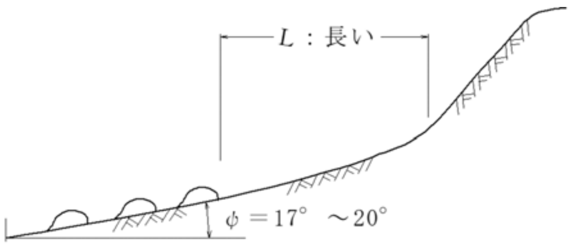


Figure 8.3-8 Earth banks arrangement. Side view

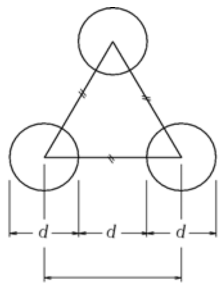


Figure 8.3-9 Earth banks arrangement. Plan view

(Source: Snow removal / snow protection handbook / Snow protection version, 2005)

It should be noted that in Figure 8.3-8 there is a designation $\psi=17\sim20°$ (Snow removal / snow protection handbook / Snow protection version, 2005)), however, to eliminate the power of the avalanche, it is not necessary to adhere to 17°, because the more shallow the slope, the more effect is given by the earth bank.

The optimum height is 5 to 6 m, but there are examples of construction of earth bank of 8 m in height in snowy areas and in areas where multiple avalanches are expected.

(3) Energy reducing effect of terracing method

According to local engineers in Kyrgyzstan, even those terraces installed in the middle of the avalanche generation area and relatively close to the road have effect of suppressing the avalanche coming down from the top of the slope (the effect of energy extinguishment in the hilly zone a). The method of terracing is full-depth avalanches preventing method, therefore it is believed that this method cannot prevent avalanches formed above the cutout of the terraces in the upper part of the slope. If the method of terracing can have such extinguishing energy effect, then terraces can be arranged on a relatively wide and flat surface, and one can expect the absorption of avalanche energy and velocity decrease in avalanche deposit area b. Here are the factors that influence on the energy extinguishment effect, which can be obtained from the method of terracing in a hilly zone a. From these, it seems reasonable to think that the unevenness of the snow cover caused by the terraces on the slope plays an energy extinguishing effect.

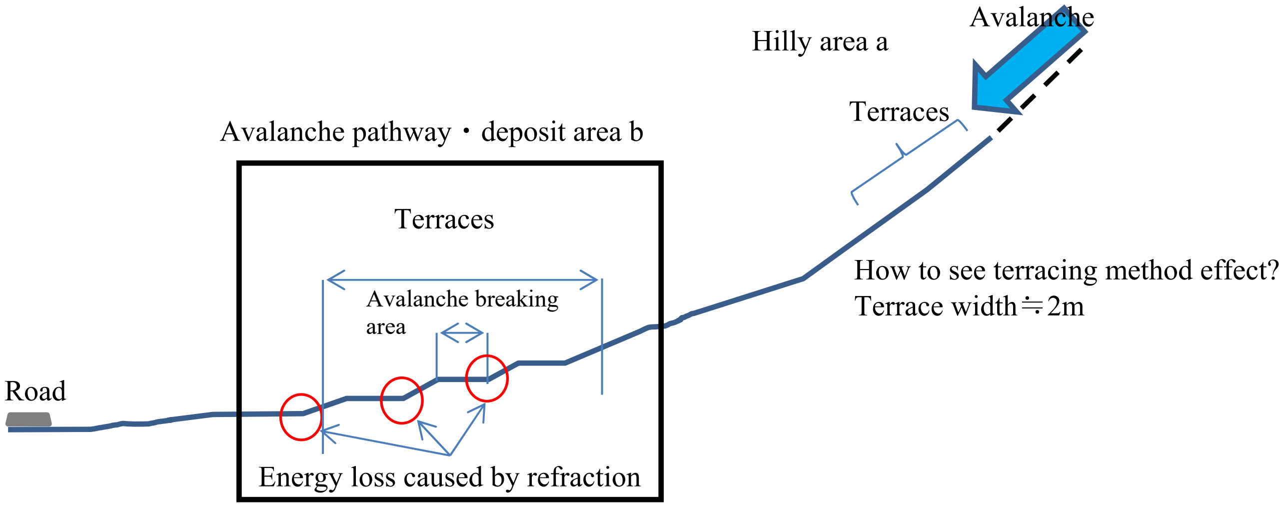


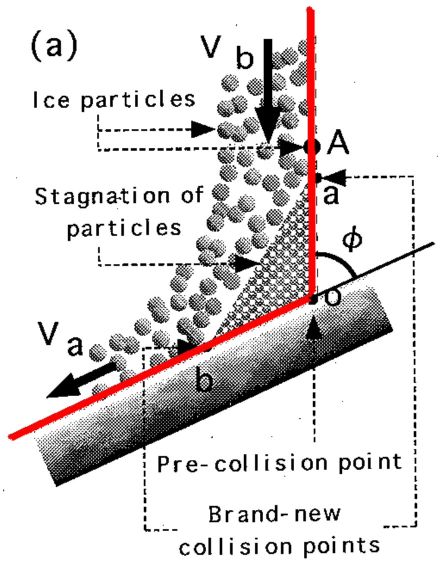
Figure 8.3-10 Schematic view of idea of terracing reduction effect

1) Avalanche speed decelerates due to irregularities on the slope

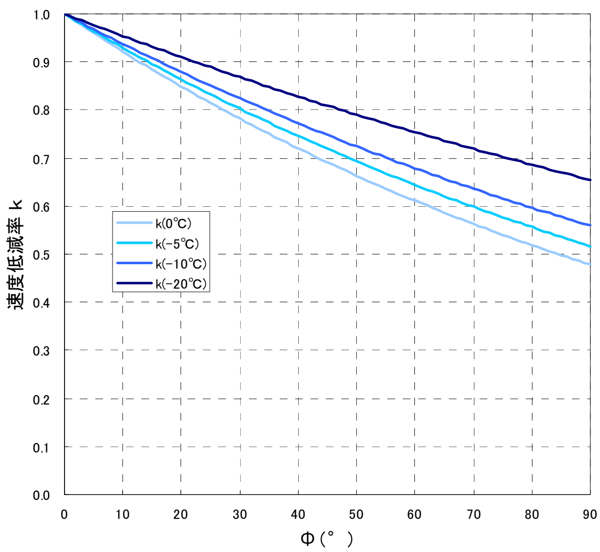
Consider the braking effect caused by the effect of softening the gradient due to the refraction of avalanche pathway. Speed deceleration coefficient k depends on the pathway refraction angle φ and air temperature T.

$$k = \exp(-\phi \cdot \mu_s)$$
$$\mu_s = 0.47 + 0.01T$$

μ_s is the coefficient of dynamic friction between the stagnant mass (fragment type) and the avalanche. The more the air temperature increases, the more stagnant effect of the fragment mass appears. It leads to a decrease in avalanche velocity due to the refraction effect. Conversely, when the temperature is lowered, the stagnant effect of the fragmentation mass decreases, as does the refraction effect, and the avalanche velocity increases.



Explanation of refraction angle Φ when avalanches collide with obstacles



The model of braking coefficient due to refraction effect

Figure 8.3-11 Conceptual diagram of reducing avalanche speed due to unevenness of slope

2) Due to irregularities on the slope, the thickness of the avalanche flow changes and the avalanche velocity decreases.

The following equation is a formula showing the change in thickness of avalanche layer when colliding with the roof of snow shed. The symbols are as shown below.

$$h_2 = h_1 \sqrt[3]{\left(\frac{\sin\theta_2}{\sin\theta_1}\right)}$$

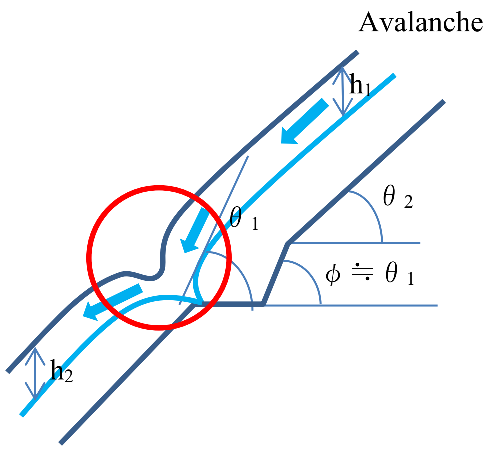


Figure 8.3-12 Extinguishing by terracing method effect

The avalanche speed in the form of a flow is expressed by the following equation.

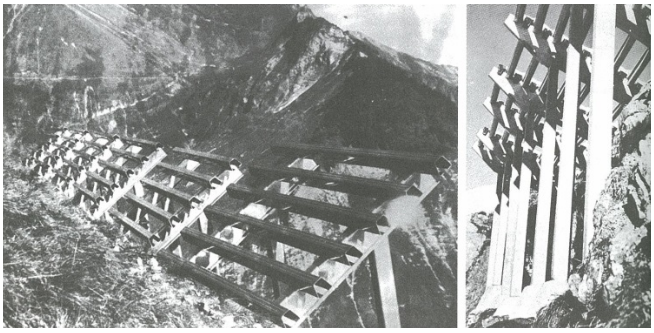
$$V = \sqrt{\xi h(\sin\phi_0 - \mu\cos\phi_0)}$$

As the avalanche layer thickness *h* increases, the avalanche speed also increases, so that the terracing method gives an extinguishing effect if $\theta_1 > \theta_2$. In addition, ξ is the turbulent damping coefficient (about 500m/s^2 in full-depth avalanche), μ is the dynamic friction coefficient, and φ_0 is the slope inclination.

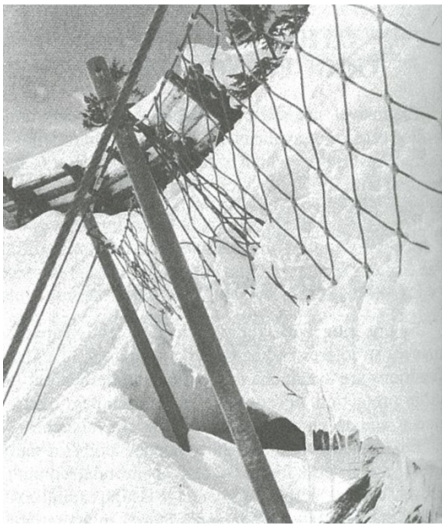
8.3.4 Other measures

8.3.4.1 Preventive measures

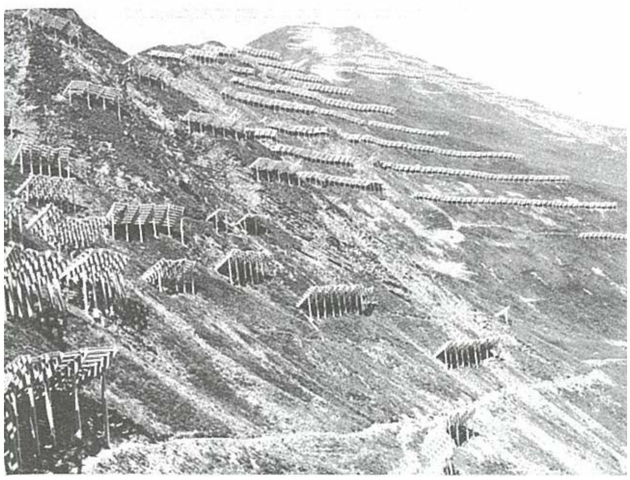
Preventive measures are measures that with the help of certain structures suppress the movement of snow cover on the slope, thereby preventing the emergence of avalanches. Often, structures in the form of fences/shields, but there are also structures as grids of wire ropes, called snow protection nets. Usually these are installed perpendicular to the ground, but can be built in the vertical direction, too. Nowadays, steel structures are mainly used, but earlier structures were made of wood, aluminum, concrete, etc. The main goal is to prevent the snow cover from moving on the slope. If sufficient force is provided against the snow cover, the effect will be ensured regardless of the material.



Snow bridges



Snow net used as supporting structure



Older inadequate supporting structures in the foreground. Modern ones in continuous rows at the back. St.Antonien, Switzerland. (Photo by A. Roch)

Figure 8.3-13 Components of Supporting Structures
(from THE Avalanche HANDBOOK)

8.3.4.2 Guiding structures

Guiding facilities (deflectors) are measures that change the direction of the avalanche to prevent it from directly descending onto the road. Soil dams are also suitable to serve as similar structures, however, reinforced soil walls as well as gabion nets are more common. There are examples from North America where such structures with a height of 6 - 12 m, at most 20 m, were installed. Using local soil, this option could prove an effective structure at an optimal cost.

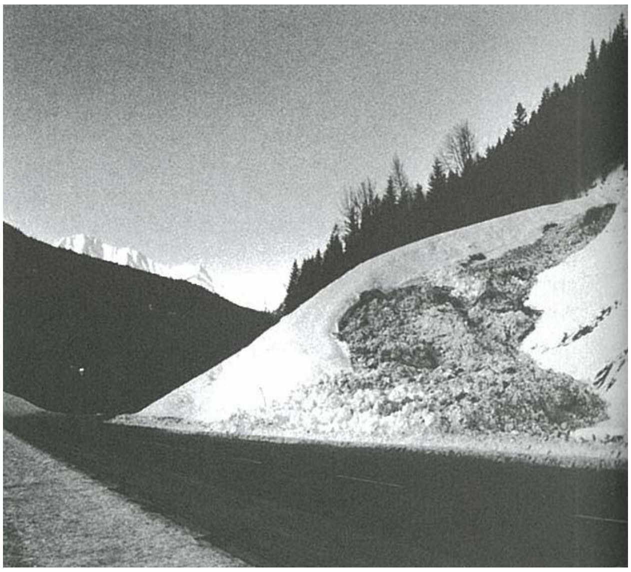
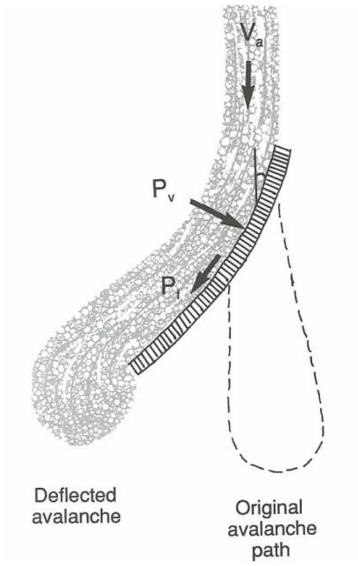
	
(a) Deflector built of earth materials. (Photo by P. Schaerer)	(b) Location and forces on a deflector. The initial deflection angle should be less than 20° if possible.

Figure 8.3-14 Deflector
(from THE Avalanche HANDBOOK)

Principal considerations for the location and design of deflectors are as follows:

- The deflected avalanche must have enough space to run out harmlessly
- Preferably, the angle α between the direction of an avalanche and the deflector should not exceed 20° (30°maximum).
- The design height H_d of the deflector can be calculated roughly by the relationship

  Hd = Hs + Ha + Hv

  Where:

  Hs : depth of snow deposited by snowfall and previous avalanches

  Ha : flow depth of the design avalanche

  $H_v = (V_a \sin\alpha)^2 / 2g$ = minimum runup height from flowing snow. Since H_v is derived only from simple energy considerations based on the assumption that the avalanche moves as a point mass, the expression given here must be regarded as a minimum estimate only（Hungr and McClung、1987）

  V_a : approach speed of the design avalanche

  α : deflection angle

  $g = 9.81 m / s^2$

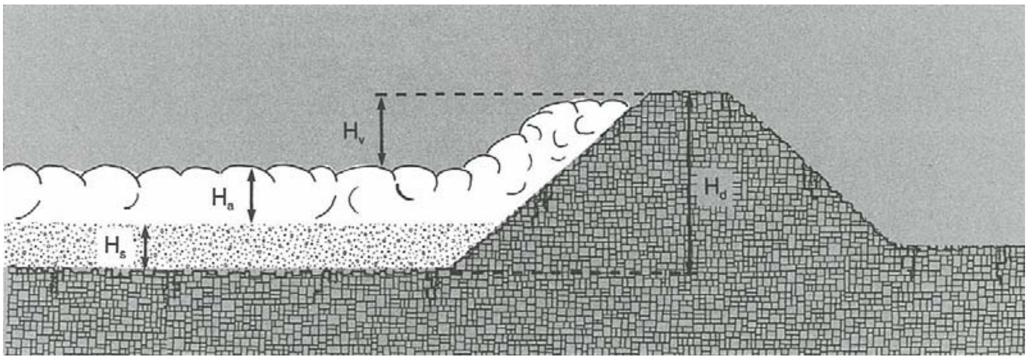


Figure 8.3-15 Schematic for calculating height of deflectors.
(from THE Avalanche HANDBOOK)

- Deflector height H_d can be increased by excavating the front of the dam.
- Sometimes snow dams are constructed as temporary countermeasure.

8.3.4.3 Snow Sheds

Snow sheds are structures that allow avalanches to pass through their roof and protect the road from any damage. Usually built from concrete and steel materials. Snow sheds should be of sufficient length to cover the width of the avalanche path. The length can sometimes be reduced by setting the guiding dams on top of both sides of the snow shed to prevent spreading of avalanche. When several avalanche paths are closely located to each other, it is better to construct one continuous shed, which is more economical and practical for later maintenance, rather than several short ones.

When designing a snow shed, the following design forces should be considered:

- Snow load
- Avalanche load （The driving force when an avalanche passes through the roof of the gallery depends on the thickness of the avalanche layer）
- Avalanche load
- Wind load （explosive force against the roof of the gallery from the side of the road; usually not considered）
- Fragment mass loading (amount, density)
- Cornice (load of hanging snow from the roof of the gallery)
- Sedimentation strength
- Surcharge from shock load
- Buoyancy
- Power of sedimentation
- Load from soil-stone mass brought by avalanche
- Consideration of a structure different from the type of portal and the reverse type L
- Earthquake inertial force

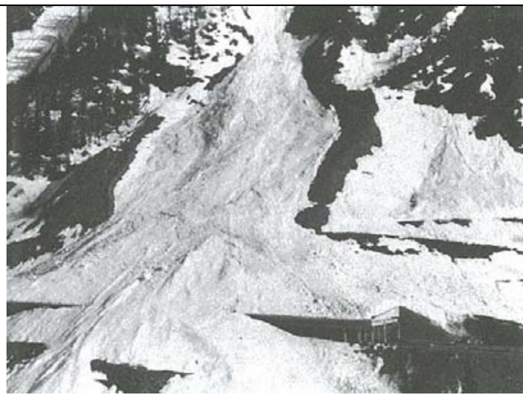
	
Snow shed used to protect highway traffic. (Photo by P. Schaerer)	now shed with dikes that prevent spreading of avalanches. (Photo by P. Schaerer)

Figure 8.3-16 Snow shed

(from THE Avalanche HANDBOOK)

8.3.4.4 Nonstructural measures

(1) Artificial avalanche

These are measures for the artificial removal of snow from a slope before avalanche formation. This is done by shooting the slope by methods described below.

It is not always that avalanche is formed during shelling. It is important that the condition of the snow cover is unstable and, as such, can cause avalanche activity at any time.

Table 8.3-2 Artificial avalanche methods

Method	Description
Artillery	Under high level of avalanche danger, artificial avalanche is carried out by method of shelling. This method can be applied even if avalanche starting zone is at aa inaccessible distance. It is necessary that the slope is under a certain position and suitable for firing.
Helicopter bombing	Forced descent of avalanches is carried out through the discharge of charges from a helicopter. It is effective in places where shelling from the ground is impossible, as well as at close proximity of an avalanche-prone slope. Helicopter flights and the transport of explosives are always dangerous, so it is imperative that you carefully plan your security measures.
Installation of explosives on the slope	Forced avalanche descent through the installation of explosives on the slope. There is no danger of undermining, but implementation on large slopes is very difficult to install explosives.
Means of forced descent of avalanches that do not use explosives (gas firing, etc.)	Without using explosives, the avalanche is forcibly descended through such means as an air gun. In North America, pneumatic guns called Avalauncher (Avalauncher) are often used. It is considered much safer than shelling, but it is under the influence of strong wind, and the shelling distance is short and the accuracy is low.

Carrying out artifical avalanche on the Bishkek-Osh road

Sighting for firing artillery (From Avalanche Handbook)

The Avalauncher is a control weapon with limited range utilizing compressed gas. (Photo by P. Schaerer From Avalanche Handbook)

Helicopter with bombardier dropping a bomb. (Photo by T. Auger, From Avalanche Handbook)

Figure 8.3-17 Artillery

Table 8.3-3 Approximate Ranges of Avalanche Control Weapons Using High Explosive Rounds (after Perla and Martinelli,1976)

Weapon	Maximum Range(m)	Payload (kg TNT)
75-mm howitzer	8,800	2.3
105-mm howitzer	11,300	0.7
75-mm recoilless rifle	6,350	0.7
105-mm recoilless rifle	8,600	2.0
Avalauncher	1,000	1.0

(2) Pre-traffic control

Measures such as stopping traffic are taken at an increased level of danger in order to avoid damage from avalanches to vehicles. It is necessary to determine the meteorological factors, the possible causes of avalanche formation and the high accuracy of the weather forecast.

(3) Avalanche Detection

Early detection of avalanche danger ensures safety while limiting and removing restrictions on the movement of vehicles. Table 8.3-4 presents items of which not all are practically used, but are typical when detecting an avalanche hazard. Many of these are being studied in Europe, North America and Japan, which are advanced countries in the study of avalanche prevention. By identifying the features of the weather when an avalanche hazard is detected, it will be possible to determine a set of meteorological factors to more effectively carry out a prior movement restriction.

Table 8.3-4 Instruments for avalanche detection

Type of sensor	General description
Measurement of atmospheric pressure and aerodynamics	A method of detecting avalanche pressure fluctuations in the low frequency range. It also proposes determining the location of the difference in time signals from a variety of sensors. There is a probability of detecting an avalanche at a great distance, about 100 km. Since avalanches in Kyrgyzstan are large in scale and the S / N ratio is large, it is possible to detect avalanches through several sensors covering the broadband avalanche danger with high accuracy.
Microphone / Acoustic Sensor	The method of detecting the sound, the starting point of the avalanche. In case of avalanches from a large-scale slope, as in Kyrgyzstan, it is assumed that there is a certain amount of time from the point of origin of the avalanche to the road, which can be used to ensure the safety of traffic control operations.
Identification bar meter	The method of sharing an inclinometer with a vibration sensor and determining the position of a column, somehow modified by an avalanche.
Seismograph / Vibration Sensor	The avalanche hazard detection method by a seismograph, transmitting signals of seismic vibration of the soil due to the avalanche flow. Currently, studies are underway to determine the location from the signals of several seismographs.
Acoustic emission sensor (AE)	AE is a phenomenon that, when a substance is deformed or destroyed, releases the energy of an elastic wave stored inside as a sound wave. Prediction of avalanche formation using the AE sensor through the detection of AE snow cover accumulated by the avalanche.

Other non-structural measures are described in Chapter 10.

CHAPTER 9 COUNTERMEASURES AGAINST SNOWDRIFT

9.1 General

The countermeasures for snow drifting are generally selected in view of the following items: (1) purpose and objective, (2) meteorological condition, (3) road structure and width, (4) land condition, (5) construction cost and maintenance, (6) impact on the environment. General information about each item is listed below.

(1) Purpose and Objective

The purpose and objective for the development of facilities against snow drifting should be clarified. For example, is the purpose of countermeasures for snowdrift or obstruction to visibility? Is the target area embankment section or cut earth section?

(2) Meteorological Condition

The adequacy of countermeasures does not largely depend on the transport rate of drifting snow. However, the cut earth and embankment are not applicable to the place where transport rate of drifting snow is low on a cost-benefit basis.

There is a high possibility that the typical narrow-band woods are not applicable at the section where transport rate of drifting snow is high because the function of typical narrow-band woods to prevent snowdrift much remains unknown.

(3) Road Structure and Width

The road structure of drift-free cut and fill for snowdrift control are confined. The applicability of road snowbreak woods and snow fence rely on the terrain condition and road structure. However, the applicable condition for collector snow fence and standard-width woods are comparatively wide. In general, blower snow fence is applicable to two lane roadways and under. Other countermeasures are applicable to multilane roadway.

(4) Land Condition

Drift-free cut and low-gradient embankment is required a large road site. The required area to install snow fence is determined in the following order: traditional collector snow fence>collector snow fence>blower snow fence. The required width to install standard-width woods is generally up to 40m from road shoulder.

(5) Construction Cost and Maintenance

Considering land acquisition cost, countermeasures priority is determined. In all cases, initial cost is inevitable like earth work cost for cut earth/embankment, material cost and foundation work cost for snow fence. Maintenance cost for growth management of road snowbreak woods after planting accounts for a large percentage of total cost.

(6) Impact on the environment

It is necessary for environmental protection to consider the driving environment, landscape and roadside environment.

Considering driving environment, blower snow fence, which is installed near the road, obscures driver’s visibility and traditional collector snow fence, which is installed away from the road, creates the danger of snowdrift near the roadside.

In landscape respect, cut earth, embankment and road snowbreak woods have advantage. Snow drifting countermeasures by road structure conserve landscape and do not require ancillary facilities.

Road snowbreak woods is used for highway planting and has a beneficial effect on the environment. However, it is necessary to be careful if there is section, which has originally good landscape, so that the installation of road snowbreak woods will not spoil the good landscape.

Likewise, it is necessary to consider the retractable snow fence (especially blower snow fence) if there is section which needs to consider the good landscape so that the good landscape will not be spoiled.

In roadside environment respect, traditional collector snow fence and other snow fence have a potentially detrimental effect on the road due to snowdrift and snow pile. On the other hand, road snowbreak woods have a potentially detrimental effect on the road due to sunshine obstacle and fallen leaves.

9.2 Selection of Countermeasures

9.2.1 Classification of Countermeasures

Snow drifting countermeasures (related to road structure, ancillary facilities and large-scale structure) depending on their functions are divided into countermeasures against snow pile, obstruction to visibility and road signs. Countermeasures types against snow drifting will be considered in detail in accordance with countermeasures Manual against snow drifting (Hokkaido Development Department).

The classification of countermeasures against snow drifting is given in Table 9.2-1. It is divided into three types of countermeasures, changing Road Structure and making it more resistant to snowdrifts, Ancillary Facilities installed roadside (including visual facilities, indicating road profile, for safety and unhindered traffic) and Large Scale Structure. The delineation/ visual guidance facilities do not directly prevent snow drifting but improve the visibility of drivers. These three types of countermeasures can be used in combination because of the different replacement and point of its observation.

Table 9.2-1 Major Classification and Type of Countermeasures

Classification	Type	Measures	Major Purpose of Measures
Road Structure	Cut earth	Drift-Free Cut	Snowdrift
	Embankment	Fill for Snowdrift Control	Snowdrift
		Low-Gradient Embankment	Snowdrift, obstruction to visibility
Ancillary Facilities	Road Snowbreak Woods	Standard-Width Woods	Snowdrift, obstruction to visibility
		Typical Narrow-band Woods	Obstruction to visibility
	Snow Fence	Traditional Collector Snow Fence	Snowdrift
		Collector Snow Fence	Snowdrift, obstruction to visibility
		Blower Snow Fence	Obstruction to visibility
		Solid Barrier	Snowdrift, obstruction to visibility
	Delineation/ Visual Guidance Facilities	Fixed-Post Delineator	Indication of width of snow removal, Visual Guidance
		Snow Pole	Indication of width of snow removal, Visual Guidance
		Delineator	Visual Guidance
		Visual Guidance Trees	Visual Guidance
		Roadway Lighting	Traffic Safety, Visual Guidance
Large Scale Structure		Snow Shelter	Snowdrift, obstruction to visibility

9.2.1.1 Snow Drifting Countermeasures by Road Structure

Snow drifting countermeasures by road structure is indicated, for example, altering slope gradient and length of embankment and cut earth and height of embankment prevent snowdrift on the road and mitigate obstruction to visibility of the drivers.

Snow drifting countermeasures by road structure is classified into three types. The applicability of these countermeasures is determined by landscape environmental conditions for planning of construction new road and their drawings, or current situation for the existing road. Moreover, it is also necessary to take into account meteorological conditions and condition of snow drifting on the site.

(1) Drift-Free Cut

The slope gradient of drift-free cut at the windward side shall be gentler than 1:3.0 along the section of cut earth in the snow drifting prone area. Furthermore, snow-disposal space is required to lower the height of the snow pile along the roadside. Drift-free cut generates stable snow cornice and snowdrift on the cut slope, which contributes to prevent snowdrift on the road and to mitigate obstruction to visibility of the drivers.

(2) Fill for Snowdrift Control

The fill for snowdrift control contributes to prevent generating snowdrift on the slope and to mitigate obstruction to visibility of the drivers by lowering the height of the snow piles along the roadside.

(3) Low-Gradient Embankment

The slope gradient of low-gradient embankment is gentler than 1:4.0, which is promising the following two things.

1) Low-gradient embankment contributes to prevent exfoliation of wind at the top of slope and blowing upward, which avoid generating snowdrift.

2) Low-gradient embankment is not required guard fence and prevents the flying snow from snow piles by lowering the height of the snow piles along the roadside.

9.2.1.2 Snow Fence

Snow fence is generally made of steel plate which is called snowbreak fin. The fins are installed on the both side of fence (windward and leeward side). The purpose is to control the wind currents/velocity, prevent snowdrift and mitigate obstruction to visibility.

Horizontally and vertically attached snowbreak fins are made of steel and wooden and have different types and shapes. Depending on the structure and function, snow fence is classified into the following four types. These four types snow fences are used selectively corresponding to the road structure, meteorology, terrain, land use and roadside environment.

(1) Traditional Collector Snow Fence

Traditional collector snow fence is installed on the windward side of road. This snow fence deposit snowdrift at the both side of the fence (windward and leeward), which prevents the blowing snow and snowdrift on the road. The function of this snow fence is to prevent snowdrift and to mitigate obstruction to visibility.

(2) Collector Snow Fence

Collector snow fence is different from traditional collector snow fence in that the space at lower portion of snow fence is closed. Because of this feature, collector snow fence captures more snow at windward than leeward. Likewise, collector snow fence is higher and smaller void ratio than the traditional collector snow fence. The function of this snow fence is to prevent snowdrift and to mitigate obstruction to visibility.

(3) Blower Snow Fence

Snowbreak fin at upper part of snow fence blocks the blowing snow. The strong wind through the opening space at lower portion of snow fence blows off the snow on the road. This snow fence has large effect to mitigate obstruction to visibility because blowing snow pass through the immediately above road surface.

(4) Solid Barrier

Solid barrier has been developed to prevent snowdrift and obstruction to visibility on the mountain road due to the wind blowing up from valley. Solid barrier captures more snow at windward than leeward and mitigate the wind velocity on the road. This is a type of the collector snow fence.

9.2.1.3 Road Snowbreak Woods

The purpose of road snowbreak woods is to prevent snowdrift by windbreak function of woods, and to mitigate obstruction to visibility.

There are two types of road snowbreak woods: “Standard-Width Woods” which width is more than 10m and “Typical Narrow-Band Woods” which width is less than 10m

Road snowbreak woods cause secondary effects of environment preservation, like roadway planting, landscape improvement, emission gas purification, noise abatement, and so on.

The other countermeasures are fungible for snow drifting but road snowbreak woods have other functioning as a plant, which is the most distinctive feature. The effect at the growing stage of woods is insufficient, but the woods at maturation stage have a great effect since the road snowbreak woods are higher than other countermeasures. The disadvantages of road snowbreak woods include the necessity of large space, cost of growth management and duration until exerting the effect. On the other hand, the road snowbreak woods have many advantages, like beneficial effect on snow drifting after growth, above-mentioned environment preservation, etc. Thus, the plan of countermeasures against snow drifting should be formulated from the long-term viewpoints after understanding the feature of road snowbreak woods.

(1) Standard-Width Woods

There is enough space of woods for transport rate of drifting snow. This countermeasure has functions to prevent snowdrift and mitigate obstruction to visibility. The width of woods is more than 10m.

(2) Typical Narrow-Band Woods

The main purpose of this countermeasure is to mitigate the obstruction to visibility. There is almost not space for snowdrift and the width of the woods is less than 10 m.

9.2.1.4 Delineation/ Visual Guidance Facilities

Delineation/ visual guidance facilities are one of the countermeasures against snow drifting to indicate the position of roadside and road alignment, to guide the visibility of road user and secure the safety and efficiency of snow removal work.

Drivers take the wheel while looking and judging the circumstances of road and road alignment to secure the safety. The safety driving relies on the recognition of a correct distance and speed adjustment based on the driver’s experiences. During snow drifting, the drivers do not only reduce the visibility, but also lose a sense of distance. Thus, the recognition of a correct distance is important for the drivers.

Delineation/ visual guidance facilities have the following three functions as a countermeasure against snow drifting.

① Indication of Road Alignment: Guidance of visibility adjusting road alignment
② Recognition of visual distance: Function to recognize visual distance
③ Recognition of position of roadside: Function to recognize position of roadside including lane

As countermeasures for snow drifting, the road snowbreak woods and snow fence is prioritized because these measures directly work on the snow. However, these countermeasures are not able to prevent from snow drifting, perfectly. Therefore, it is important to be secured a safety driving by supplementarily utilizing the delineation/ visual guidance facilities to enhance the mentioned above three functions.

The specific four facilities for delineation/ visual guidance are presented below.

(1) Delineator

Delineator is continuously placed along the side of road to clarify the road alignment and to guide the visibility of the driver.

Delineator is a facility to indicate the width of removal snow and to improve the visibility of roadway during snow drifting at snowy cold region, and including self-luminous type.

(2) Snow Pole

Snow pole is a facility at side of road to give a landmark object for snow removal work and to guide the visibility of the road user, and including self-luminous type.

(3) Fixed-Post Delineator

Fixed-post delineator is continuously placed along the side of road to indicate the width of removal snow and to work on the countermeasure against the obstruction to visibility of the road users. This facility is a facility to guide the visibility of the road user, and including self-luminous type.

(4) Visual Guidance Trees

Visual guidance tree is continuously placed along the side of road to guide and improve the visibility of the road user during the blowing snow and snowfall. The young growth is generally installed and the thinned tree is also utilized.

9.2.1.5 Snow Shelter

This is the most effective countermeasure against snow drifting because the road is perfectly intercepted from the snow by the snow shelter.

Snow shelter is generally applicable in case of followings: transport rate of drifting snow is extremely high, there is no interrupt wind along the road, wind direction is irregularity due to the complicate terrain around the road, other countermeasures are not applicable because the road runs on the mountain path and canyon, the important degree of road is high.

9.2.2 Criteria for Selection of Countermeasures

Selection of Countermeasures will be determined mainly by following Table 9.2-2, based on such conditions as snow protection, weather conditions, road construction, land use, etc., however, final decision should be made in accordance with Table 9.2-3, which shows applicable conditions of snowbreak facilities and detailed terrain conditions.

Table 9.2-2 Selection Table of Countermeasures

Selection criteria: Cross-sectional profile	Target of countermeasure	Prevailing wind direction	Land available	Number of lanes ※2	Road Structure: Low-Gradient Embankment	Road Structure: Embankment	Road Structure: Drift-free cut	Snowbreak Woods: Standard Woods	Snowbreak Woods: Narrow-Band Woods	Snow Fence: Traditional Collector Snow Fence	Snow Fence: Collector Snow Fence	Snow Fence: Blower Snow Fence ※3	Delineation Facilities	Large-scale facility
Fill	Snowdrifts countermeasures against snow pile	rectangular	yes	Multiple lanes・one lane	○	○	—	◎	×	○	○	×	△	○
			no	Multiple lanes・one lane	×	◎	—	×	×	×	○	×	△	
		acute angle	yes	Multiple lanes・one lane	○	○	—	◎	×	○	○	×	△	
			no	Multiple lanes・one lane	×	◎	—	×	×	×	○	×	△	
	Snowdrifts countermeasures against snow pile and obstruction to visibility	rectangular	yes	Multiple lanes・one lane	○	○	—	◎	×	○	○	×	△	○
			no	Multiple lanes・one lane	×	○	—	×	×	×	◎	×	△	
		acute angle	yes	Multiple lanes・one lane	○	○	—	◎	×	○	○	×	△	
			no	Multiple lanes・one lane	×	○	—	×	×	×	◎	×	△	
	Snowdrifts countermeasures against obstruction to visibility	rectangular	yes	Multiple lanes	○	○	—	○	◎	○	○	×	○	○
				One lane	○	○	—	○	◎	○	○	○	○	
			no	Multiple lanes	×	○	—	×	◎	×	○	×	○	
				One lane	×	○	—	×	◎	×	○	○	○	
		acute angle	yes	Multiple lanes・one lane	○	○	—	○	◎	○	○	×	○	
			no	Multiple lanes・one lane	×	○	—	×	◎	×	○	×	○	
Flat	Snowdrifts countermeasures against snow pile	rectangular	yes	Multiple lanes・one lane	—	○	—	◎	×	○	○	×	△	○
			no	Multiple lanes・one lane	—	◎	—	×	×	×	○	×	△	
		acute angle	yes	Multiple lanes・one lane	—	○	—	◎	×	○	○	×	△	
			no	Multiple lanes・one lane	—	◎	—	×	×	×	○	×	△	
	Snowdrifts countermeasures against snow pile and obstruction to visibility	rectangular	yes	Multiple lanes・one lane	—	○	—	◎	×	○	○	×	△	○
			no	Multiple lanes・one lane	—	○	—	×	×	×	◎	×	△	
		acute angle	yes	Multiple lanes・one lane	—	○	—	◎	×	○	○	×	△	
			no	Multiple lanes・one lane	—	○	—	×	×	×	◎	×	△	
	Snowdrifts countermeasures against obstruction to visibility	rectangular	yes	Multiple lanes	—	○	—	○	◎	○	○	×	○	○
				One lane	—	○	—	○	◎	○	○	○	○	
			no	Multiple lanes	—	○	—	×	◎	×	○	×	○	
				One lane	—	○	—	×	◎	×	○	○	○	
		acute angle	yes	Multiple lanes・one lane	—	○	—	○	◎	○	○	×	○	
			no	Multiple lanes・one lane	—	○	—	×	◎	×	○	×	○	
Cut	Snowdrifts	rectangular	yes	Multiple lanes・one lane	—	—	○	◎	×	○	○	×	△	○

Selection criteria: Cross-sectional profile	Target of countermeasure	Prevailing wind direction	Land available	Countermeasures: Number of lanes ※2	Road Structure: Low-Gradient Embankment	Road Structure: Embankment	Road Structure: Drift-free cut	Snowbreak Woods: Standard Woods	Snowbreak Woods: Narrow-Band Woods	Snow Fence: Traditional Collector Snow Fence	Snow Fence: Collector Snow Fence	Snow Fence: Blower Snow Fence ※3	Delineation Facilities	Large-scale facility
	countermeasures against snow pile		no	Multiple lanes・one lane	—	—	×	×	×	×	◎	×	△	
		acute angle	yes	Multiple lanes・one lane	—	—	○	◎	×	×	○	×	△	
			no	Multiple lanes・one lane	—	—	×	×	×	×	◎	×	△	
	Snowdrifts countermeasures against snow pile and obstruction to visibility	rectangular	yes	Multiple lanes・one lane	—	—	○	◎	×	○	○	×	△	○
			no	Multiple lanes・one lane	—	—	×	×	×	×	◎	×	△	
		acute angle	yes	Multiple lanes・one lane	—	—	○	◎	×	×	○	×	△	
			no	Multiple lanes・one lane	—	—	×	×	×	×	◎	×	△	
	Snowdrifts countermeasures against obstruction to visibility	rectangular	yes	Multiple lanes・one lane	—	—	○	○	×	○	○	×	◎	○
			no	Multiple lanes・one lane	—	—	×	×	×	×	○	×	◎	
		acute angle	yes	Multiple lanes・one lane	—	—	○	○	×	×	○	×	◎	
			no	Multiple lanes・one lane	—	—	×	×	×	×	○	×	◎	

Legend ◎ : Facility which has advantages in general selection
○ : Facility which might be chosen, but detailed condition of terrain should be considered
× : Facility which should not be selected
△ : Can be chosen together with snow drifting countermeasures ◎ or ○
— : Facility which is impossible to select

※1 This table is a standard selection of countermeasures
※2 Besides number of lanes, road width and lane line should be taken into account
※3 In addition to the above selection criteria, maintenance and management at the bottom side are essential conditions.

Table 9.2-3 Comparison Table of Countermeasures

Type of Countermeasures		Photos	Weather Condition: Amount of Snow at Snowdrifts* Small	Medium	Large	Main wind direction forms an acute angle with road direction	Road Structure/Width: Transected Structure	Adaptation to Multilaned	Site Condition: Required Land Area	Approximate Cost: Construction Cost	Maintenance Cost	Environmental Impact: Driving Condition	Landscape	Impact on Roadside	Remarks
Drift-Free Cut	Drift-Free Cut		○	○	○	△ It is difficult to form for stable snowdrift on the slope	High Embankment × Low Embankment × Flat × Cutting ○ Deep Cutting △	○	Large	Earth Work 100 (Thousand KGS/m)	Maintenance of Slope	○ Oppressing feeling due to cutting is alleviated	○ It is possible to plant on the excavated gradual slope and blend in with the scenery	○ Snow is drifted on the slope. Therefore, the snowdrift have less influence on adjacent area	1) Snow control effects depend on the length and gradient of slope 2) Combination of snow fence and snowbreak wood shall be considered in case of lack of snow controll capacities
Fill for Snowdrift Control	Fill for Snowdrift Control		○	○	○	○	High Embankment ○ Low Embankment ○ Flat △ Cutting × Deep Cutting ×	○	Small	Earth Work 210 (Thousand KGS/m)	Maintenance of Slope	○	○ This type does not use a fence and wall. Hence, opened distant landscape is spread	△ High embankment might cause the snowdrift and shading at the adjacent area	1) Countermeasures against snowdrift on the road is focused on 2) Strong snowdrift might cause obstruction to visibility when snowbank has been generated at road side 3) Visual targets for the drivers are extremely reduced in case of high embankment
Fill for Snowdrift Control	Low-Gradient Embankment		○	○	○	○	High Embankment ○ Low Embankment × Flat × Cutting × Deep Cutting ×	○	Large Land acquisition is required up to foot of slope	Earth Work 260 (Thousand KGS/m)	Maintenance of Slope	○	○	○	1) Guard fences/handrails are not required and snowbank might be controlled lower 2) Vehicles seldom fall/overturn due to the gradient slope
Snow Fence	Traditional Collector Snow Fence		○	○	○	△	High Embankment × Low Embankment △ Flat ○ Cutting △ Deep Cutting ×	○	Large The length between snow fence and roadside is longer	Installation 40 (Thousand KGS/m)	(Installation and removal cost, and land rent)	○ Driving condition of this fense is better than others snow fense due to distance from road	○ Among snow fence type, this fence does not comparatively spoil the sight	× Adjacent area might be rented. Snowdrift is formed at the both side of snow fence, which causes sunshine obstacles	1) Snowdrift is formed at the both side of snow fence and adjacent area might be affected 2) Adjacent area is usually required to rent during winter season. Installation and removal of fences are annually required
Snow Fence	Collector Snow Fence		○	○	△	△ It is comparatively applicable among snow fence type	High Embankment ○ Low Embankment ○ Flat ○ Cutting △ Deep Cutting ×	○	Medium	Facilities including Foundation 100 (Thousand KGS/m)	Maintenance Cost (Cost of assembling and storage)	△ It is necessary to consider the oppressing feeling for driver	△ The sight is slightly spoiled due to the height of fence	△ Snowdrift is formed on the windward of the snow fence, which causes sunshine obstacles	1) Snowdrift is formed on the windward of the snow fence and adjacent area might be affected 2) Obstruction to visibility (end effect) at end of fence shall be considered 3) It is possible to be considered landscope during non-snow season by using retractable fence
Snow Fence	Blower Snow Fence		○	△	×	× It is effective if the wind direction is approximately perpendicular to fence	High Embankment ○ Low Embankment ○ Flat ○ Cutting × Deep Cutting ×	× This fence is applicable to two and less lane road	Small Required land is smaller because the snow fence can be installed beside roadside	Facilities including Foundation 100 (Thousand KGS/m)	Maintenance Cost (Cost of assembling and storage)	△ There is a high possibility to narrow driver's eyesight at the intersection and so on.	△ Retractable fence is applicable at the place where landscape conservation is required	○ Among snow fence type, this fence does not comparatively cause snowdrift at the adjacent area	1) The improvement of visibilities should be considered since there is a possibility for drivers to lose lateral visibility and sight distance 2) The removal of snowbank at the bottom of fence is essential for functional maintenance of snow fence 3) It is possible to be considered landscope during non-snow season by using retractable fence
Road Snowbreak Woods	Standard-Width Woods		○	○	○	○	High Embankment ○ Low Embankment ○ Flat ○ Cutting ○ Deep Cutting △	○	Large The required width of land acquisition is at most 40 m	Planting Work 14 (Thousand KGS/m)	Maintenance of Plant	○	○	○ It is possible to cause sunshine obstacles and a lot of leaf drop with tree growth	1) Width of woods are calculated by the amount of snow at snowdrifts at the site 2) It takes time to fulfill a function of snow protection 3) It is necessary to consider so as not to spoil the good landscope
Road Snowbreak Woods	Typical Narrow-Band Woods		○	△	×	△	High Embankment × Low Embankment ○ Flat ○ Cutting × Deep Cutting ×	△	Medium	Planting Work 4 (Thousand KGS/m)	Maintenance of Plant	○	○	○ It is possible to cause sunshine obstacles and a lot of leaf drop with tree growth	1) There is a possibility not to apply this countermeasurees at the place of high transport rate of drifting snow 2) It takes time to fulfill a function of snow protection
Important Structure	Snow Shelter		○	○	○	○	High Embankment ○ Low Embankment ○ Flat ○ Cutting ○ Deep Cutting ○	○ Large increase of construction cost	Small Required land is smaller because the snow shelter can be constructed beside roadside	Facilities including Foundation 2,000 (Thousand KGS/m)	In case of steel material, corrosion prevention is required as a maintenance cost	△ There is a possibility of security violation for driving at the entrance of shelter	× The landscape is spoiled due to the shelter	△ Snowdrift may be generated around the shelter	It is difficult to manufacture the member of steel/concrete shelter at the site. The cement and aggregate is procurable but the manufacture of of PC member is difficult at the site.

* Amount of Snow at Snowdrifts   Small : $40m^3/m$ below   Medium : 40～$60m^3/m$ Large : $60m^3/m$ and more

○ : Applicable   △ : Requires Consideration   × : Not Applicable

Table 9.2-2 Countermeasures Selection Criteria as follows

(1) Cross-sectional profile

The applicability of countermeasures for snow drifting depends on road structure, drift-free cut and embankment. There are countermeasures that are not applicable to road structure.

(2) Target of countermeasure

Depending on the evaluation of danger degree of snowdrifts, snowdrift factors are formulated, snow pile factors and poor visibility factors. Countermeasures for each target differ from each other.

(3) Prevailing wind direction

In the case of rectangular or close to a rectangular wind direction to the road, degree of danger of snow drifting increases. However, it has been verified that in this case, road snowbreak woods and snow fences are effective. In case of diagonal wind direction, road snowbreak woods prevents snowdrift and snow fences is less effective.

(4) Land provision

Land provision assumes land for road snowbreak woods (standard) and snow drifting countermeasures by road structure (drift-free cut and fill).

(5) Number of lanes

If the road is multilane and wide, blower snow fence is less effective. In addition to the number of lanes, it is necessary to consider road width and road side, presence or absence of traffic marker.

Table 9.2-3 is summary table and shows applicability of each type of snow drifting structure according to highway location, road structure, meteorological conditions etc. In the case of selection of several options on Table 9.2-2, final decision should be made according with this table. Each factor of Table 9.2-3 is shown below:

1) Purpose and Objective

It is necessary to find out the purpose and objective of countermeasures against snow drifting. For example, is the purpose of countermeasures for snowdrift or obstruction to visibility? Is the target area embankment section or cut earth section?

2) Meteorological Condition

Applicability or impossibility of countermeasures against snow drifting does not largely depend on the amount of snow storm/drifting. However, cut earth and embankment are not applicable to the place where volume of drifting snow is low on a cost-benefit basis. Conversely, in the case of constant snow pile or obstruction to visibility joint use of snow fences and road sign (barrier poles etc.) sometimes is not sufficient to ensure road safety. It is necessary to consider the importance degree of road and definite section.

There is a high possibility that the typical narrow-band woods are not applicable at the section where transport rate of drifting snow is high because the function of typical narrow-band woods to prevent snowdrift much remains unknown.

3) Road Structure and Width

Earth bank and drift-free cut restricts the road structure due to the countermeasures feature. The applicability of road snowbreak woods and snow fence rely on the terrain condition and road structure. However, the applicable condition for collector snow fence and standard road snowbreak woods are comparatively wide.

In general, blower snow fence is applicable to two lane roadways and under. Other countermeasures are applicable to multilane roadway.

4) Land Condition

Drift-free cut and low-gradient embankment is required a large road site. The required area to install snow fence is determined in the following order: traditional collector snow fence>collector snow fence>blower snow fence. The required width to install standard road snowbreak woods is generally up to 40m from road shoulder.

5) Construction Cost and Maintenance

Considering land acquisition cost, countermeasures priority is determined. In all cases, initial cost will be inevitable like earth work cost for cut earth/embankment, material cost and foundation work cost for snow fence. Maintenance cost for growth management of road snow-break woods after planting accounts for a large percentage of total cost.

6) Impact on the environment

It is necessary for environmental protection to consider the driving environment, landscape and roadside environment. Considering driving environment, blower snow fence, which is installed near the road, obscures driver's visibility and traditional collector snow fence, which is installed away from the road, creates the danger of snowdrift near the roadside.

In landscape respect, cut earth, embankment and road snow-break woods have advantage. Snow drifting countermeasures by road structure conserve landscape and do not require ancillary facilities.

Road snowbreak woods is used for highway planting and has a beneficial effect on the environment. However, it is necessary to be careful if there is section, which has originally good landscape, so that the installation of road snow-break woods will not spoil the good landscape.

Likewise, it is necessary to consider the retractable snow fence (especially blower snow fence) if there is section, which needs to consider the good landscape so that the good landscape will not be spoiled.

In roadside environment respect, traditional collector snow fence and other snow fence have a potentially detrimental effect on the road due to snowdrift and snow pile. On the other hand, road snow-break woods have a potentially detrimental effect on the road due to sunshine obstacle and fallen leaves.

9.3 Structural Detail of Main Countermeasures

Main countermeasures such as road snowbreak woods, snow fence, snow shelter and their details will be considered in this section. The purpose of countermeasures is to prevent snowdrift by obstructing them to reach the road and reducing the level of damage (snow pile and poor visibility).

9.3.1 Standard Woods

The function of standard woods is to prevent snowdrift and mitigate poor visibility. The width of woods is 10 m or more.

Standard woods consist of base woods, the main purpose of which is to prevent snowdrift and advance-growth trees, the function of which is to protect base woods during initial growth（Figure 9.3-1）

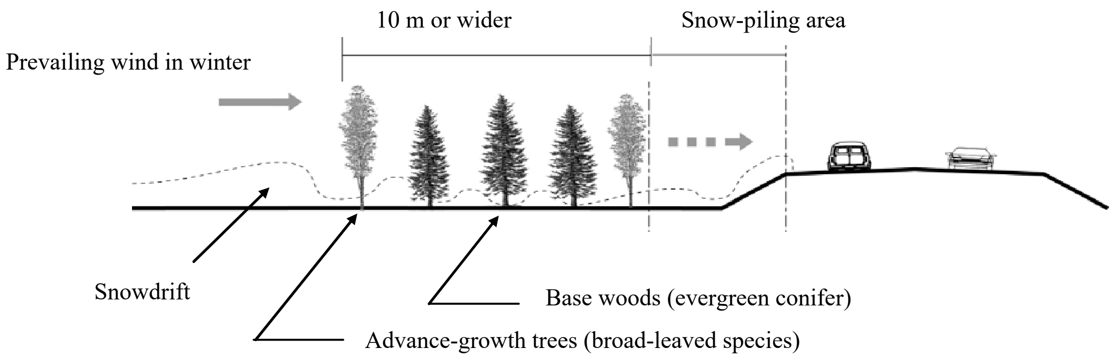


Figure 9.3-1 Cross-section of Standard Woods

Photo 9.3-1 Standard Woods

9.3.2 Narrow-Band Woods

The purpose of narrow-band woods is to prevent snowdrifts and mitigate poor visibility. There is no space for snowdrift and width of woods is less than 10 m (Figure 9.3-2).

Narrow-band woods consist only of base woods, the main purpose of which is to prevent snowdrifts.

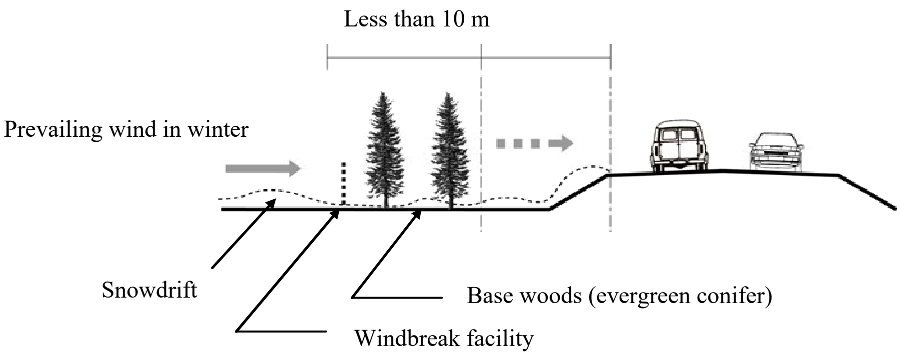


Figure 9.3-2 Cross-section of Narrow-band Woods

Photo 9.3-2 Narrow-Band Woods

9.3.3 Traditional Collector Snow Fence

Traditional collector snow fence is installed on the windward side of road. This snow fence deposit snowdrift at the both side of the fence (windward and leeward), which prevents drifting snow from blowing onto the road and snowdrifts from forming on the road.

The function of this snow fence is to prevent snowdrift, but the main purpose is to mitigate obstruction to visibility. As shown in Figure 9.3-3and Photo 9.3-3, such fences are constructed from bearing pile and extended lengthwise and crosswise snow fences. The gap is left every few fences and void ratio is adjusted by density of rows. Between fence and land surface remains void equal to one part of fence height. This is called lower void, which due to the wind blows the snow and prevents fence from snow pile and from being damaged by snow deposits

On windward side of snow fence, snowdrift decreases wind speed as it approaches fence and snow pile is accumulated. On leeward side of snow fence, edding motions are formed and transport rate of snow decreases. Therefore, snow passing through lower void of fence or through over the fence falls and forms snowdrift on leeward side. There are different designs of snow fences and they are made of various materials, and functions against snow drifting (shape and volume of snowdrift in front of and behind the fence) are determined corresponding to snowdrift volume and other meteorological indicators, height, density, lower void of fence.

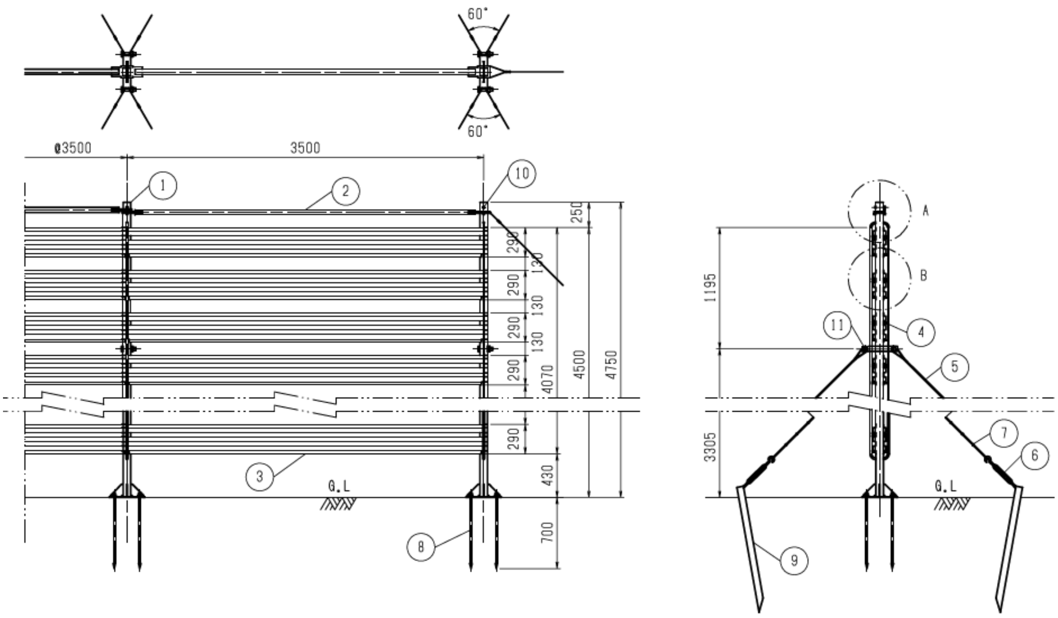


Figure 9.3-3 Standard Scheme of Traditional Collector Snow Fence

Photo 9.3-3 Traditional Collector Snow Fence

Snow fences should be installed at a distance from the road so that snowdrift on leeward side does not reach the road. If the site for installation fence is located outside the land, which is allocated for road, it is necessary to lease the site. And in case of using land for other purposes other than winter period, every year installation and dismantling works are required, as well as a storage place for fences. In order to maximize the effectiveness of snow fence, both standards and installation site are extremely important to prevent snowdrift.

9.3.4 Collector Snow Fence

Collector snow fence is similar to the traditional snow fence, but it has some differences. In particular, collector snow fence is taller and has a smaller void ratio. Moreover, it has no gap in the bottom part and it captures more snow at windward side. Because of this feature, collector snow fence captures snow on windward side and its leeward drifts are small. It can be built near the road, which prevents snowdrift on the road. It shows synergistic effect of snow control and windbreak, and thus it mitigates visibility hindrance.

Since snow fences are installed remotely from the road, road on the leeward side is poorly protected, as well as visibility obstruction mitigation effect is low. Collector snow fence （Figure 9.3-4、Photo 9.3-4）is located on road section and designed to prevent snowdrift of multiple lane that cannot be fully protected by blower snow fence. Collector snow fence installed on roadside prevents not only snowdrift and windbreak, but also serves as guide sign on the road. Collector snow fence function is determined by maximum volume of snowdrift on windward side. Most of these snow fences as shown in figure have a height of 5 m and do not have lower void. Void ratio at lower portion of snow fence is zero, at upper portion is about 30～40%. At the top, there is shroud with a slope to windward side. Meshy plate gives possibility to see side view and cars from crossroads and shroud installed at the top of high fence, which is intended to ease oppressive feeling of drivers. The effect of this type of fence is mainly determined by its height and void, but the presence or absence of shroud does not have a big influence on windbreak / snowdrift preventing effect. In cases of installing snow fence on the embankment, it is not necessary to provide shroud, especially when actual height of fence from the road surface is low and side view of driver is hard to see.

Collector snow fence has a history about 30 years since its development in Japan. Almost all results of applying 5 m fence are satisfied and problems suspecting the function have not occurred. When snow drift prevention capacity decreases due to terrain modification, or in area where the amount of drifts is very high, as a countermeasure increasing the fence height is necessary.

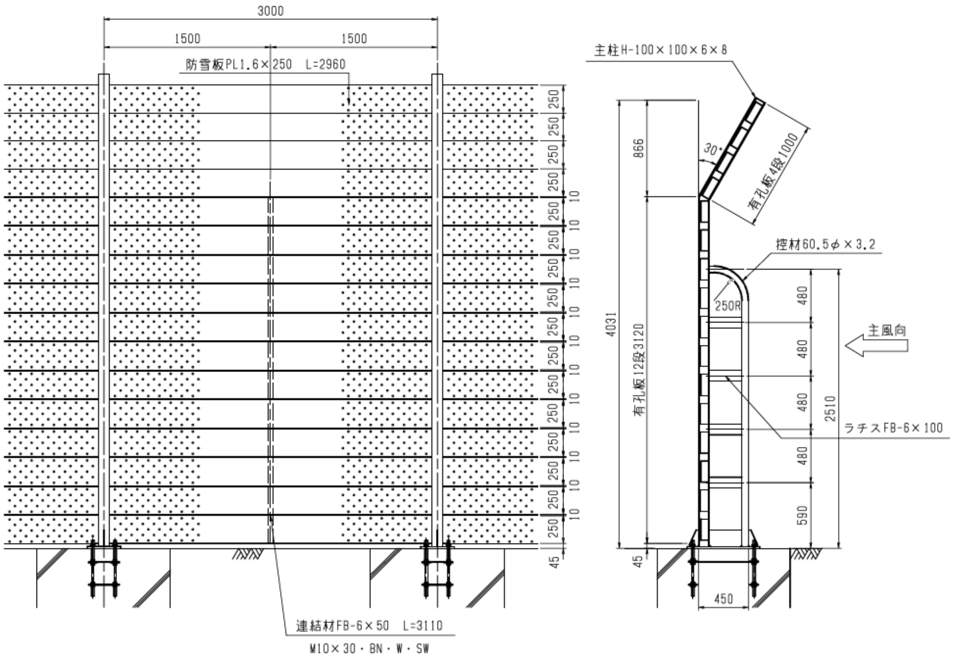


Figure 9.3-4 Standard Scheme of Collector Snow Fence

Photo 9.3-4 Collector Snow Fence

9.3.5 Blower Snow Fence

Blower snow fence fins retard the wind and snow on the roadside and the surface blown away by strong wind that is accelerated after passing through gaps in the bottom of fence. This fence mitigates obstruction to visibility.

Fence where strong wind coming through bottom clearance blows snow onto the road surface and off the road is blowing fence (Photo 9.3-5). Strong wind blows off the snow on roadbed and snow from windward transports on road surface, so it mitigates poor visibility. This structure was developed in Japan as countermeasure for snowdrift on road site（Photo 9.3-5）

Fence is designed so that the fence itself or its blocks are tilted to the leeward side to increase wind velocity on roadway to maximize blow-off functionality. If the angle from the vertical plane is small, wind velocity and force of blowing snow increases. On the other hand, if angle of wind reaching the road surface is large, the wind velocity becomes easily destructible, which reduces blowing coverage. Therefore, in most cases fence is installed with a slope of 30° vertically.

Coverage area of blowing fence is proportional to the height of fence of similar type. In the case of multi-board type blower snow fences, which are most frequently used, when the road surface is cleaned, the fence height is 2 to 3 times higher. Therefore, the fence height is 3.5 to 4.0 m.

Since coverage area of blower snow fence is limited, generally it is installed in the upper and lower of two lane roads. It is likelihood of snow accumulation on wide roads. It is also formed if there are fences on the road, or median preventing wind stream.

Blower snow fence is effective only if it is not installed at rectangular angle to prevailing wind, and in the case of head wind, it forms snowdrift, so careful attention should be paid to meteorological conditions during installation.

In order to maintain functionality of fence, it is extremely important to keep always bottom clearance open. In areas with heavy snowfall, bottom clearance often is clogged and snow accumulates on roads. Therefore, if there is more snow, more clearance and more effort is made for its functionality, preferably by snow removal in leeward direction.

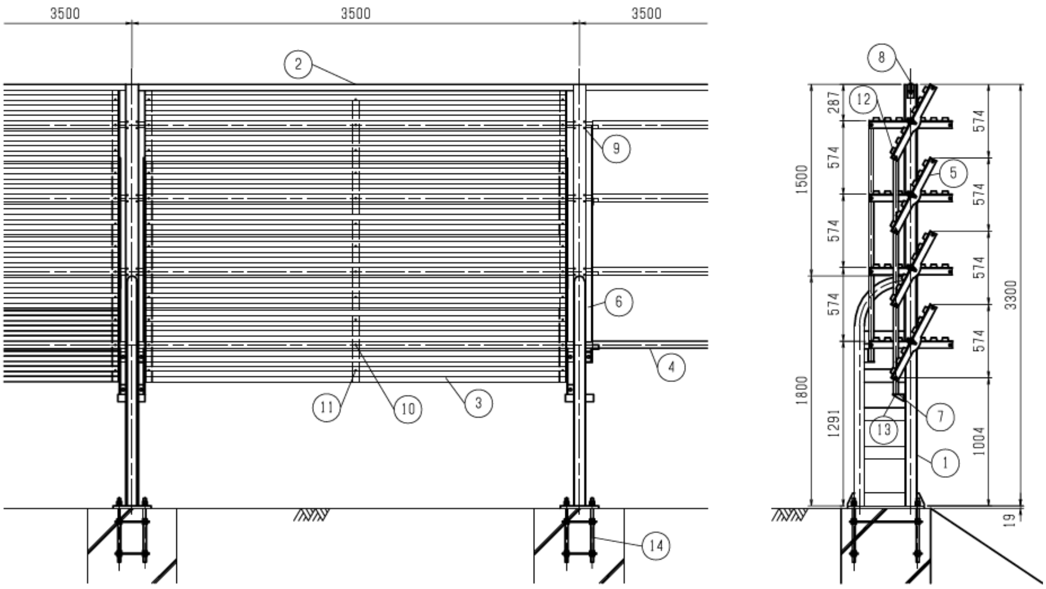


Figure 9.3-5 Transverse Scheme of Blower Snow Fence

Photo 9.3-5 Blower Snow Fence

9.3.6 Solid Barrier

Solid barrier has been developed to prevent snowdrifts and mitigate visibility hindrance caused by winds blowing up slopes in mountainous areas. It is a kind of snow fence that holds drifting snow on the windward side and reduces the wind velocity on roads.

Snowdrifts caused by winds blowing up slopes in mountainous area can cause poor visibility and snowdrifts. As a countermeasure solid barrier has been developed (Photo 9.3-6). This type of fence holds snow on the windward side, therefore it does not have a lower clearance, with 0 clearance and board with an elevation angle of about 20 ° (usually 5m wide) and a supporting pile（Figure 9.3-6）. It is installed 2 to 3 m lower than road surface not to hinder the view of the driver. Construction type as well as the function of capturing snow on windward side, allows the fence to be positioned as a modified type of snow fence.

The fence reduces the wind velocity on windward side so that snow flying from the bottom upwards is trapped and deposited on the windward side. Synergistic effect of reduction of amount of snowfall and wind velocity on leeward side mitigates poor visibility.

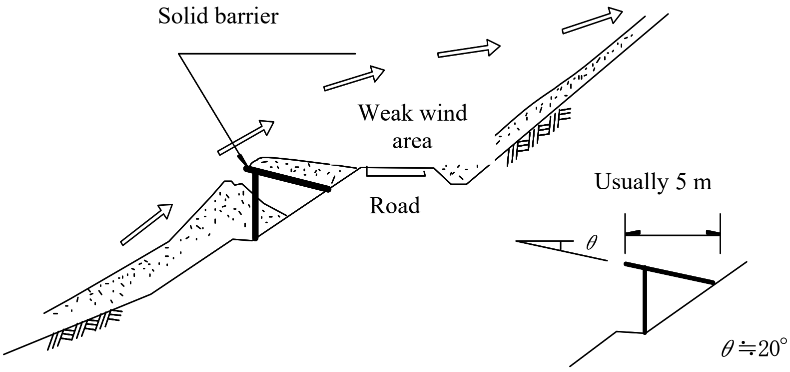


Figure 9.3-6 Transverse Scheme of Solid Barrier

Photo 9.3-6 Solid Barrier

9.3.7 Snow Shelter

This is the most effective countermeasure against snow drifting because the road is perfectly intercepted from the snow by the snow shelter. On the other hand, this facility is the highest construction cost, and the worst landscape and feeling of pressure to the road users.

Snow shelter is generally applicable in case of the followings: transport rate of drifting snow is extremely high and there is no obstacle to wind flow, chaotic changes of wind direction due to the complicate terrain, on mountain passes and valleys of mountainous areas, the importance degree of road is high and where other countermeasures are not applicable.

Snow shelter is near-perfect facility against snow drifting. However, snow shelter has problems due to closed space, such as road surface freezing in the shelter, rapid change of lightness and visibility at the mouth of shelter. These problems must be paid attention after the construction as an operation and maintenance work. The length of shelter should be determined based on the detailed investigations of terrain and meteorological condition like wind direction/velocity so that snow will not blow into the shelter. Besides, the other countermeasures at the mouth of shelter will be considered since the rapid change of visibility due to snow drifting at the mouth might cause a traffic accident.

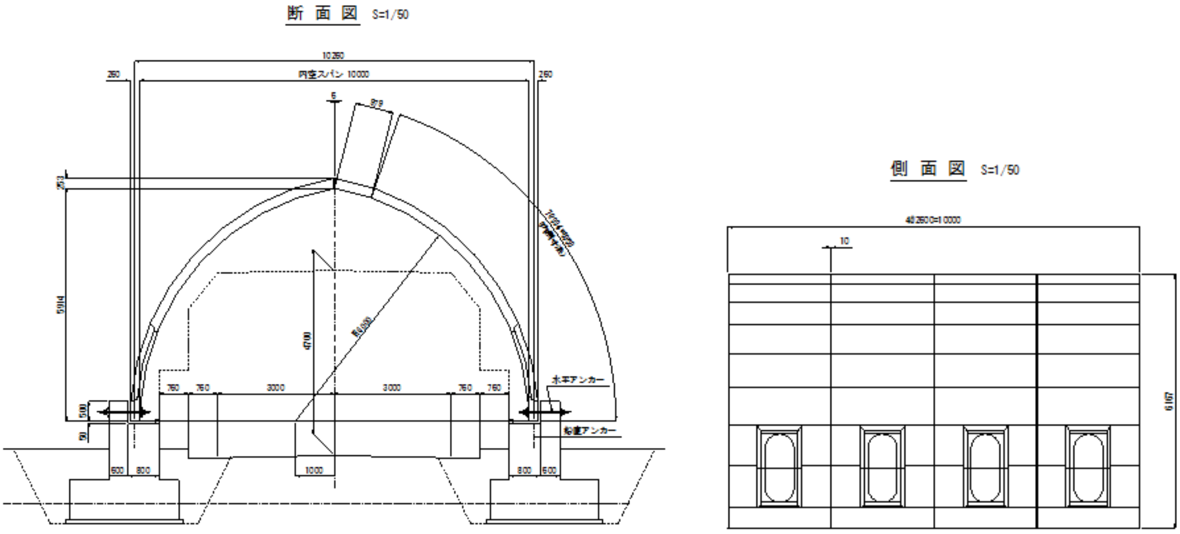


Figure 9.3-7 Standard Scheme of Snow Shelter

Photo 9.3-7 Snow Shelter

9.4 Applicable countermeasures in Kyrgyz Republic

We have provided broad overview of countermeasures against snow drifting, and described structures of the most basic types. Here we consider the most suitable countermeasures for the KR, their designs and parameters.

9.4.1 Applicability of countermeasures

Below we consider the applicability of countermeasures, depending on conditions of the KR.

【Drift-free cut△】Drift-free cut is applicable under the severe condition of snowdrift. In case of this, the applicable section is limited because the slope should be long and low-gradient like 1:3.0, length of slope should be longer, not everywhere it can be applied.

【Fill for snowdrift control×】There are a few embankment and plain terrain. The embankment work is not applicable.

【Low-gradient embankment 土×】There are a few embankment and plain terrain. The embankment work is not applicable.

【Traditional collector snow fence ○】It is effective if there is a guarantee of providing required area to install fence, as well as with the correct determination of location and technical characteristics. This countermeasure is not generally applicable to deep cut earth, but there is no section of deep cut earth. Moreover, due to the remote location from road, even if fence is tilted, the road will be not damaged. This countermeasure sufficiently exerts its effectiveness by provision of adequate specification and distance from the road, even saving on materials or foundation, which are not crucial importance here. In connection with the above, it can be said that this method is appropriate for the KR.

【Collector snow fence △】The effectiveness is the same as traditional collector snow fence. However, the effectiveness will be reduced if the back of fence is filled by huge amount of snowdrift. This countermeasure will not be applied if the traditional collector snow fence is applicable at the site since the cost of collector snow fence is higher than traditional collector snow fence.

【Blower snow fence×】Blower snow fence is installed at road shoulder. Fence blows the snow and mitigates obstruction to visibility by adjusting direction of fence and utilizing the space at lower portion of fence. However, the blower snow fence is installed at the top of cut slope, which may cause the snowdrift on the main road. It requires minor maintenance. For instance, even after installation on level ground or on an embankment, it is necessary to monitor bottom clearance. Often it is clogged / filled up with snow. Or parapets and snow banks from snow clearing should be installed on the opposite side etc. Thus, this countermeasure is not applicable.

【Standard width woods×】Elevation of target sections is higher than forest line limit, it is extremely difficult to arrange a forest there. Even in flat terrain, the planting of coniferous forests is complicated, and even if the forest grows well, it will take about 10-20 years until exerting the effect. Even after planting, constant growth management is necessary until forest grows.

【Narrow-band woods ×】The same as Standard width woods.

【Snow shelter 】Currently it is considered impossible to construct this by local engineers. However, as a result of future field survey, it has been found that the scale of snow drifts is large and wind direction is irregular and ordinary snow fences are not very effective, careful measures should be taken on such sites by building snow shelter.

Based on the above result, Traditional Collector Snow Fence is basically applicable countermeasure for snow drifting disaster along the target section in KR. Moreover, delineation facilities are desirably applied as an ancillary measure, which is enhanced the safety.

9.4.2 Design of Traditional Collector Snow Fence

Consider next methods for determining the characteristics function of traditional collector snow fence. Figure 9.3-8 shows its characteristics.

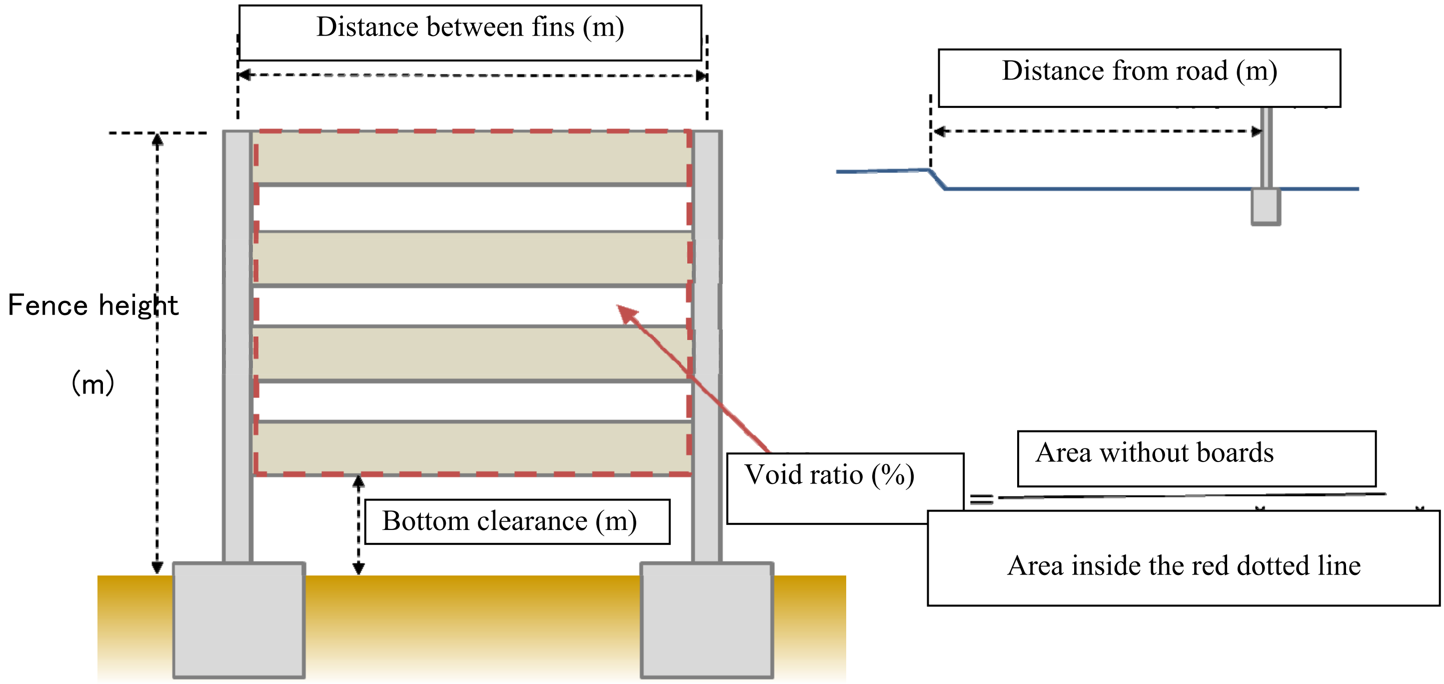


Figure 9.3-8 Traditional Collector Snow Fence characteristic

①Void ratio (%): within 25-50%.

②Fence height H (m) can be calculated using the following formula. The standard height should be above 3 m.

$$H=\sqrt{\frac{Vs}{45.5-0.31\cdot(100-P)}}+Hs$$

Vs : Snowdrift volume (m³/m), H : Fence height (m)
Hs : Snow depth (m) P : Void ratio (%)

③Distance from road L (m) can be calculated using the following formula. It should be less than 80m.

$$L=(9+0.46\cdot P)\cdot(H-Hs)$$

P : Void ratio (%) H : Fence height (m) H : Snow depth (m)

④Bottom clearance (m) is about: 0.5～0.6 m.

⑤ Distance between fins (m): It is determined according with safety construction parameters and cost saving (in Japan it is often about 3 ～ 4 m).

9.4.3 Traditional Collector Snow Fence that can be constructed in the Kyrgyz Republic

In this section, based on discussions with counter party, we made an estimation fence that can be constructed in the Kyrgyz Republic. However, this is only rough estimate. Therefore, in future, it is necessary to adjust technologies and design recommendations, while developing countermeasures against snow drifting, designing and constructing traditional collector snow fence.

Table 9.3-1 Estimation of construction works of Traditional Collector Snow Fence(for 1 span/distance between fins)

Items	Unit of measure	Price (som)	Remarks
Pipe	5m	1,000	On one side
Board	18m	4,000	Wooden board
Component parts	1 set	1,000	
Concrete	1 foundation	75	Foundation
Work	1 set	2,000	
Subtotal		8,075	
Overhead expenses		1,960	
Total		10,035	Fence height ×3.5 m span

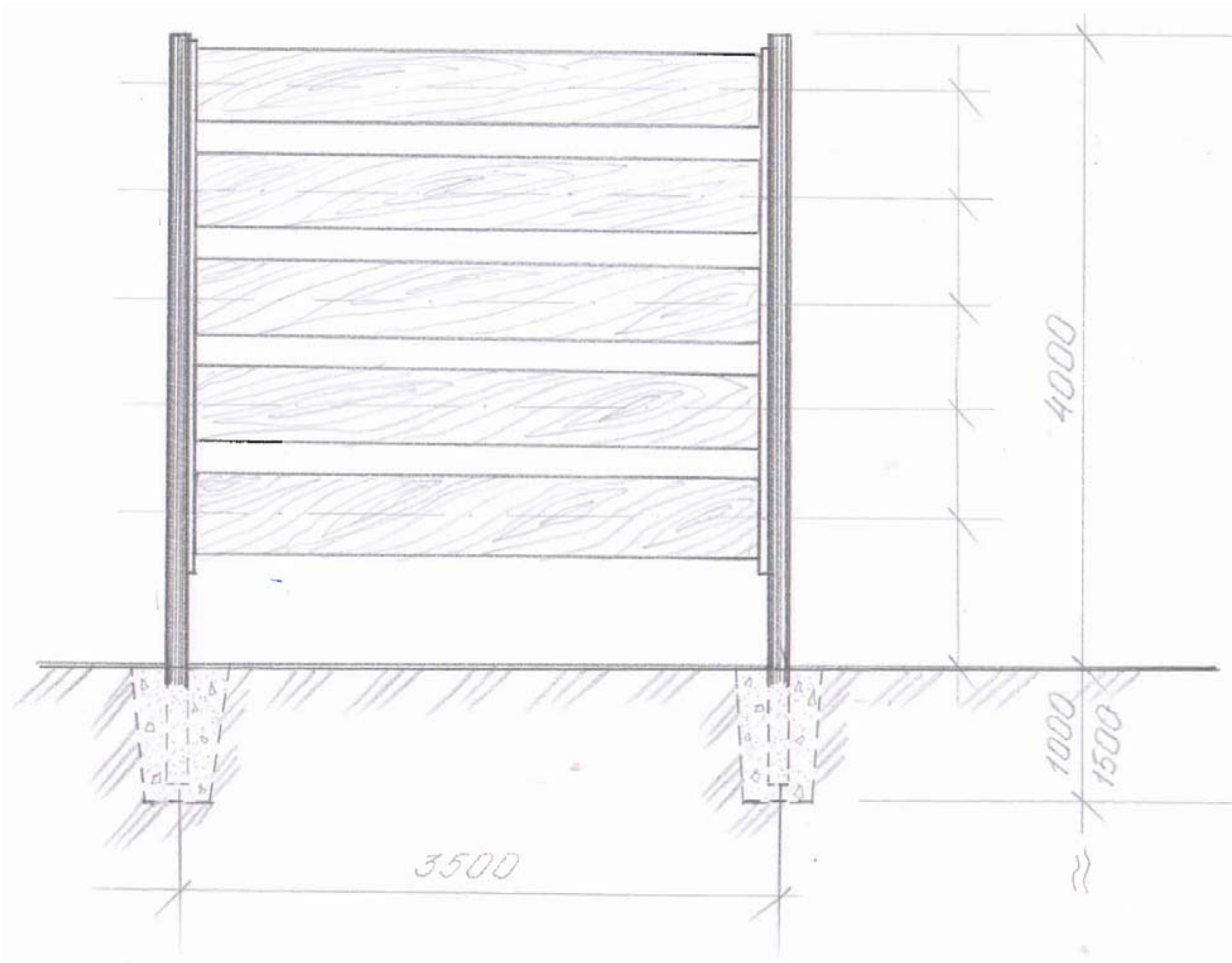


Figure 9.3-9 Overview of Traditional Collector Snow Fence prepared by Counter Party (Applicability of wooden boards for costs reasons)

CHAPTER 10 NON-STRUCTURAL MEASURES AGAINST ROAD DISASTER

10.1 General

Road shall be protected physically in principle, however, it requires quite high cost and that is not realistic in some cases, and the Basic Concept of the road disaster prevention is to reduce vulnerability against hazards by road disasters, non-structural measures(NSM) could be effective in many cases even this method could not protect the road physically.
NSM usually operates the targets blow;

I. Avoidance of the direct damage to Users
II. Minimizing the impact on social activities
III. Reduction of disaster by natural phenomena

I Avoidance of the direct damage to users

Even though the road could not be protected from natural disasters, it is possible to avoid direct damage to road uses by the announcement of the detail of the disaster to be happened or by the block the road until the disasters are gone.

II Minimizing the impact on Social activities

Road disaster causes some grave impacts to the social activities during it closed, it is better to minimize those influences by NSM. For example, if some alert information could be announced in advance people could avoid being influenced by changing their activity, and could use their time another purpose instead of being captured on the road.
And more, however, even if some of the drivers might captured by the road close, it would be able to minimize the impact, if the road cleaning work has been prepared to minimize the duration of the closing period by DEU. It requires the both, the sufficient human resources and equipment of DEU and the adequate preparedness of DEU.

III Reduction of disaster by natural phenomena

According to the monitoring data and inspection, disaster by natural phenomena could be studied precisely, disaster body could be taken or be reduced by artificial techniques or emergency measures.

The road disaster has a character of the disaster cycle shown in Figure 10.1-1. NSM could be categorized in each category of the cycle.

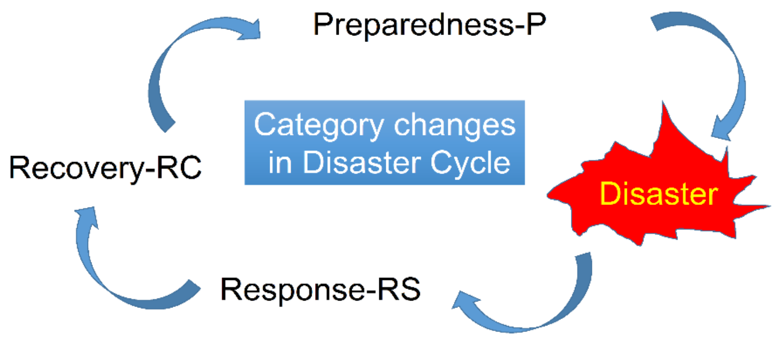


Figure 10.1-1 The category of the road disaster measures

On the other hand, NSM is usually planned to target those 4 purposes;

1- establishment of basic information collection (such as meteorological data and disaster record data)
2- tentative measures until structural measures completion
3- alternative solution where the structural measures are difficult to be installed
4- publicity and education in public about the road disaster prevention

NSM could be more effective and economical with the combination of structural measures and another kind of NSMs. It is important to assess the combination of the NSMs and structural measures, and select the suitable measures as the road condition and the road management ability.
Shows the typical flow to select measures. To develop the plan of measures for the road disaster, it is better to assess the collection the entire road disaster records and study them at first to evaluate the suitability of the NSMs. To select the NSM plan it is important to consider the structural measures plan and the road type classification in the targeting area. After the selection of NSM plan, to arrange the demarcation of NSM plan is also important to implement them effectively.

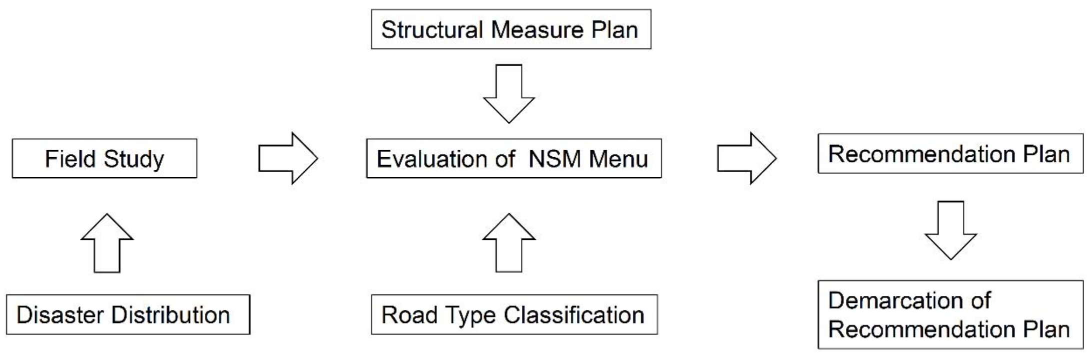


Figure 10.1-2 Typical flow chart of the NSM selection

Shows the road disaster distribution sample collected by the 2016-2019 JICA road Project. There are more than 200 hundreds disaster points distributes at the roads in 6 DEPs' jurisdictions. If all of them would be protected by structural measures, it needs tremendous budgets and times. In this situation, it is recommended to improve the safety of roads gradually with utilizable NSM.
Road classification usually is evaluated by the importance, dominant road users and the traffic volume.

Table 10.1-1 Road disaster distribution along BO road and other related roads of 2016-2019 JICA road Project

Assumption Data from DEPs,BOUADs, RMD, MES and Inspection result of Japanese experts

Disaster Classification	DEP-9	DEP-23	DEP-26	DEP-30	DEP-50	DEP-959	Total
rock fall	15	0	12	20	1	5	53
landslide	4	2	2	3	2	12	25
debris flow	4	2	9	8	7	38	68
avalanche	14	26	3	0	0	2	45
snow drift	11	2	0	0	0	1	14
erosion	0	0	5	1	4	0	10

Total	48	32	31	31	14	58	214

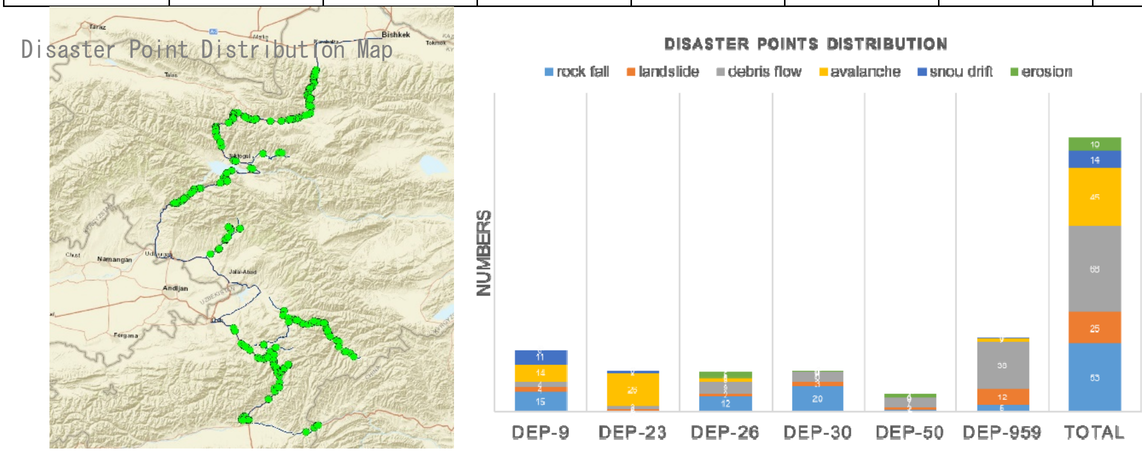


Figure 10.1-3 Disaster Point Distribution Map

10.2 Selection of Countermeasures

10.2.1 Classification of Countermeasures

NSM in general denotes Preventive Road Regulation. It is the most effective NSM to prevent involvements by road disasters, but it is difficult to implement precisely in several aspects both in technically and in ministerial.

This chapter explains some kind of NSMs alongside of Preventive Road Regulation, which are suitable to the current road condition of Kyrgyz country in terms of engineering and financial aspect.

There are many kinds of NSM as targeting purpose and methodologies and activities of NSM are in the diverse fields. NSM should be selected and arranged suitable for their road management condition, and should be reflected from the feed backs of implementation process, monitoring data and evaluation results. Because those processes of NSM are closely related and conditions of the nature and the social are ever-changing. Table 10.2-1 shows the type of NSM classified by its effect.

Table 10.2-1 Major Classification and Type of NSM

Effect Classification	Type of NSM
Mitigation	Artificial Avalanche, Artificial Rock fall
Monitoring	Meteorological Data collection and analysis, Landslide movement monitoring, (Inspection)
Identification	Disaster Distribution Map / Hazard Map, Inspection (Daily, Seasonal, Annual Activity), Alert to Road Users
Notification	Hazard Map / Pamphlet, Road Sign and Sign Board
Avoidance	Preventive Road Regulation, Bypass
Response Improvement	Heavy Equipment Management by GPS, Emergency Measure

Monitoring targets to reduce impact by Natural Phenomena such avalanche and slope failure.

Monitoring targets to predict the disaster by studying the character of the disaster along the roads.

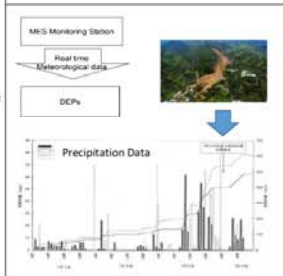
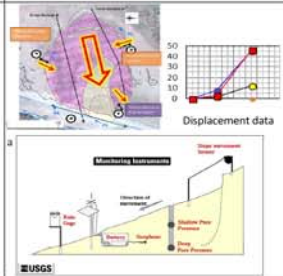
Identification targets to figure out the disaster distribution and detailed condition of the disaster.

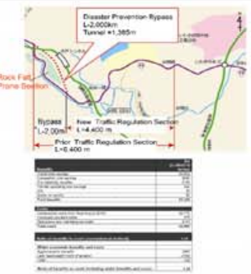
Notification targets to notify the dangerous situation along the road to road users and to educate people to understand the road disaster prevention activities.

Avoidance targets to avoid road users from the dangerous of disasters by constructing safety new road, closing the road during the dangerous situation to be predicted.

Response improvement targets to minimize the road closing period by disasters.

Table 10.2-2 Comparison Table of Non-structural Measures

Category	Preparedness	Preparedness	Preparedness	Preparedness	Preparedness	Preparedness
	Monitoring	Identification of disasters	Notification of disaster	Identification of disasters	Monitoring	Avoidance of disaster
Name	Meteorological Data collection and analysis	Disaster Distribution Map / Hazard Map	Hazard Map / Pamphlet	Inspection (Daily , Seasonal, Annual Activity)	Landslide movement monitoring	Preventive Road Regulation
purpose	establishment of disaster precast	Identification of disaster position, area(volume), frequency	Education for Public	To identify the current situation of Disasters	To clarify the scale and behavior of sliding and not sliding body and to assess urgency.	Hazard prevention during Excessive Weather Avoidance of the Direct damage to Users
Outline	Weather condition strongly influences slope stability. It is necessary for collecting the weather data as long as possible. The collected data is used for disaster prediction analysis.	The hazard map is a map integrated results of road facility comprehensive inspection, daily patrol and disaster records into a large scale map. The hazard map shows weakness correlated with inside factors causing landslides, rock-fall, slope failure, rock-mass failure, debris flows. Snow disasters could also be indicated in the map. The hazard map is a basic data to develop the disaster prevention plan.	The hazard map could be modified for easily understandable materials for the common people. This kind of hazard map is useful to notify the road disasters and necessity of disaster prevention in several kind of situations, such education program in school and community meeting, distribution to road users.	Inspection is the most important and basic activity for the road disaster prevention. There are many kind of inspection method according to frequency and level of detail but all inspections are targeting to predict the disasters in advance. Inspection usually use its specified data sheets or style to unify the results even if anyone else might implement. The result of inspection is used to assess the dangerousness of the site and shall be stored as the data base for disaster prevention.	Landslide movement is rather slower than other kind of disasters so it can be monitored by the measurement methods of installed targets such stake, paint, gauge etc.. Result of measurement is analyzed to identify the scale of sliding body and urgency of the movement. In many cases, acceleration of the movement could be predicted and measures to stop the movement could be planned and implemented.	Some lager scale disasters are too big to stop by structural measures, so Preventive Road Regulation method is chosen to protect road users. Preventive Road Regulation is the method that traffic of the road is regulated by the judgement of experimental theory. The judgement of the regulation is based on the threshold that is analyzed by the relationship of prior disaster records and weather conditions. There are several theories about threshold analysis and the Preventive Road Regulation of Japan uses the total amount of a continuous rainfall for its parameter.
Example of Specific Methodology	Real time Meteorological Data Monitoring system Threshold analysis of disaster occurrence Install monitoring equipment at necessary points	Hazard Map for Disaster Monitoring and disaster prevention plan	Hazard Map and leaflet for Road users and public person	Disaster occurrence record by daily inspection Detailed disaster inspection by seasonal or specific Inspection	Measurement of stakes, painted marks on surface Measurement of pipes or deformation gauge install in borehole	Preventive Road Regulation anouncement system Threshold anaysis
						
Availability	effective for rainfall triggered disasters and snow disasters	Availability for disaster records, large scale map(1/5,000), geological information for same scale , well trained staffs	the type and volume of the targeting disaster is already clarified to some extend	the engineer shold be trained to ipmlement any kind of inspections.	effective for relatively slow movement disasters	based on the developed study of disaster occurance of targetting area anaoucement system to road users consensus of every stake holders and understandings for disaster prevention activity by the sociaty
Cost (1,000 soms)	FTP client soft wear :	personeral cost (Engineer 10 days) :	Hazard map print (10,000 pieces) : 50	Detailed inspection personeral cost (Engineer 5 days with travel cost) :	Detailed inspection personeral cost (Engineer 2 days with travel cost) :	personeral cost (Engineer 2 days) :

Category	Preparedness	Preparedness	Preparedness	Response / Preparedness	Response	Response
	Avoidance of disaster	Mitigate disaster	Notification of disaster			
Name	Bypass	Artificial Avalanche / Rock Fall technic	Road Sign and Sign Board	Alert to Road Users	Heavy Equipment Management by GPS	Emergency Measure
purpose	Avoidance of the Direct damage to Users and economy		Prevent public people from	Real time information to Road Users		To protect road from occurred disaster
Outline	To keep the traffic even under the critical weather conditions, bypass is planned against large scale road disasters. This is a new road construction so the safty of the road is almost perfect but this requires vast funds and a long construction period. The plan of Bypass should be reviewed not only by safty aspect but also economic evaluation usually.	Artificial Avalanche / Rock Fall technic are useful to remove the dengerous body of disasters. There are some difficulties in those techniques , such as the judgement about when and where to implement in Artificial Avalanche, the way of breaking and safty of remaining walls in lage scale Artificial Rock Fall. Those methods require the traffic regulation during the implementation.	Road sign is a basic information tool for road disaster prevention. To install road signs it is important to select the suitable design and place. This is also useful to prevent traffic accidents. Sign boards could tell more specified information to the road users by discribing the detailed danger of disasters.	Real time information to Road Users is quite effective to prevent traffic accidents and to save loss of socisl activities. There are several kind of tools to inform alert such as Electrical sign board , Internet , direct oral communications. To inform alert public person effectively, tools and its content should be studied by coverage, location and timing.	Once disaster occurs, length of closing period depends on the response activity by the road manegement section. Scince the asset for respond is limitted generally, to make the most use of assets is important. Mnagement of Heavy equipment by installing GPS to them is tagetting the effective formation for the response act to disasters.	During response activities of landslide, rockfall, erosion and avalanche, road manegement section could make measures against the outspread disasters. The tools for this act is limited under the critical situation, emargency measures are mainly organaized by the materials procured near the site, for example large sandbags and embankment by soils or snow.
Example of Specific Methodology	Bypass plan B/C analysis	Artificial Avalanche Rock Fall technic	Road sign Massage board	Electrical Sign Board Internet Alert distribution System	Global GPS vehicle management system	Embankment (counter weight for landslide) Large sandbag wall
						
Availability	complehensive dicision based on technical, economical and social aspect	In case of dangerous body is already clarified Rock body is not so big and easy to be disconnected			within the mobile network accessible area	nesseccity of prepairation of construction materials
Cost (1,000 soms)	tunnel project (700m) : 300.000	Artificial Avalanche 1 site : 1,300 Artificial Rockfall (static blast 10 m^3) : 150	1 massage board : 60	2 units of Electrical Sign Board : 540 Internet alert distribution System plan (engineer 5 days) :	GPS management system with 100 GPS devices :920	Embankment (1000 m^3) : 500

10.2.2 Criteria for Selection of Countermeasures

Figure 10.2-1 shows the flow of NSM selection.

As prior mentioned, NSM is not a measures to protect the road by structures, and the effectiveness of NSM depends on the activity of both the road management sector and the road users. It is important to assess the current situation of jurisdictive roads so that to realize the objectives. NSM method shall be generally implemented with several methods in parallel, and it requires to work together with another Ministries and local governments or local societies to pervade NSM's effecting societies. Most of NSMs would not bring their effects immediately, however, NSMs should be implemented ongoingly and revised them time to time.

Most of NSMs are categorized in preparedness, and only response improvement and notification (of disaster occurrence) are categorized in Response.

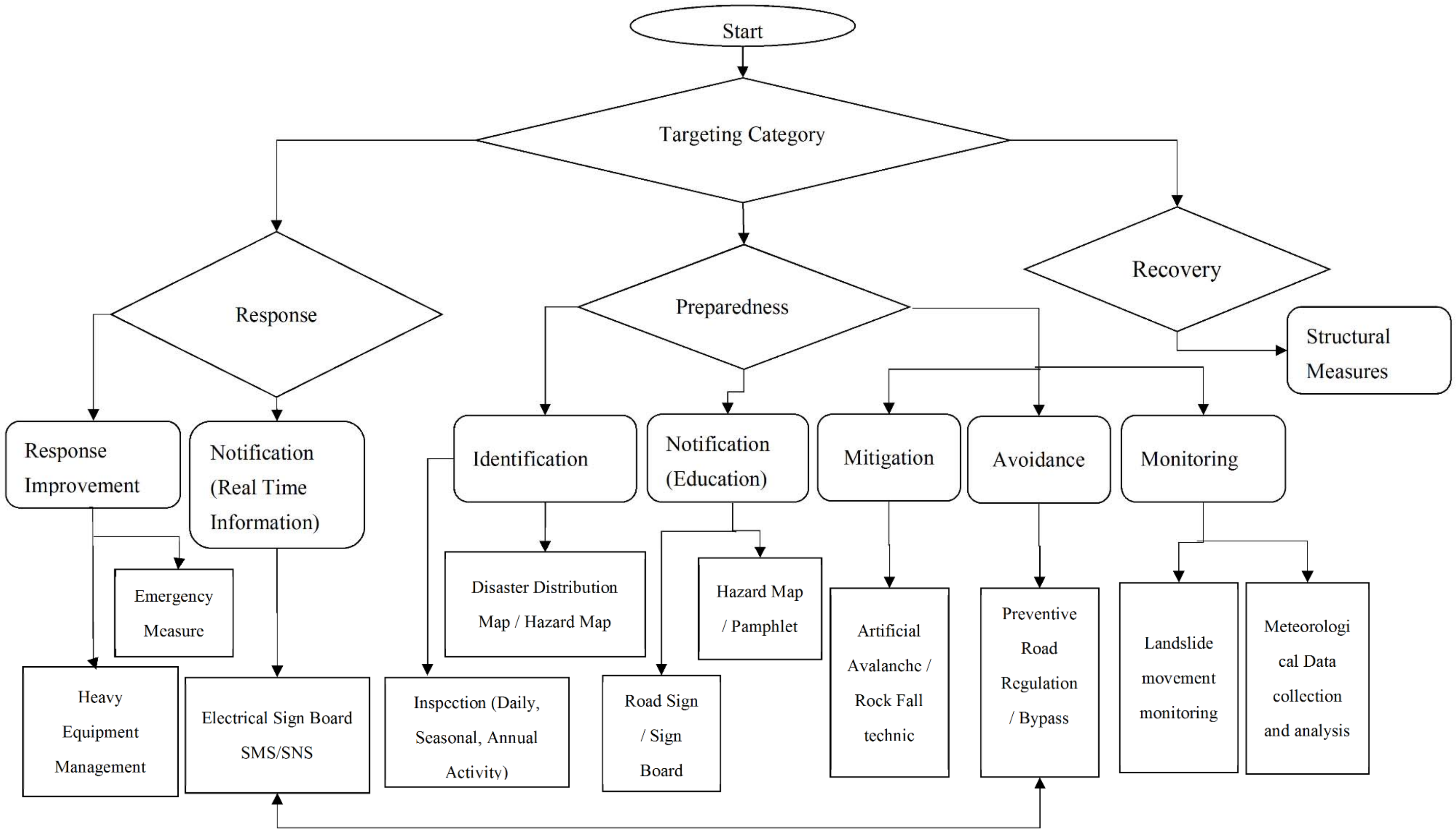


Figure 10.2-1 Selection Flowchart of Countermeasures

10.3 Detail of Main Non-structural Measures

10.3.1 Preparedness

10.3.1.1 Meteorological Data collection and analysis

[Purpose] Establishment of disaster precast

[Outline]Weather condition strongly influences slope stability. The meteorological data is quite basic for disaster prevention activities, so it is necessary to collect and store the weather data as much as possible to utilize them for road disaster prevention in MOTR. In many cases, meteorological data is collected and stored in Meteorological organizations, it is rational to share those data in MOTR.

The meteorological monitoring is implemented under the standard method, so the road management authority should understand the quality of those data and respond flexibly to utilize them. For example, the meteorological data shall be collected separately in the area sectioned by the identical property generally, but it is difficult to achieve in practice. Shows the distribution of the utilizable meteorological and hydrological monitoring stations in Kyrgyz. The meteorological monitoring station could be installed by MOTR as necessary.

The main parameters of meteorological data related with road disasters are rainfall, temperature, wind, and snow depth. The road management authority should establish the standard system for data browsing f and storage. The collected data could be used for the disaster precast analysis.

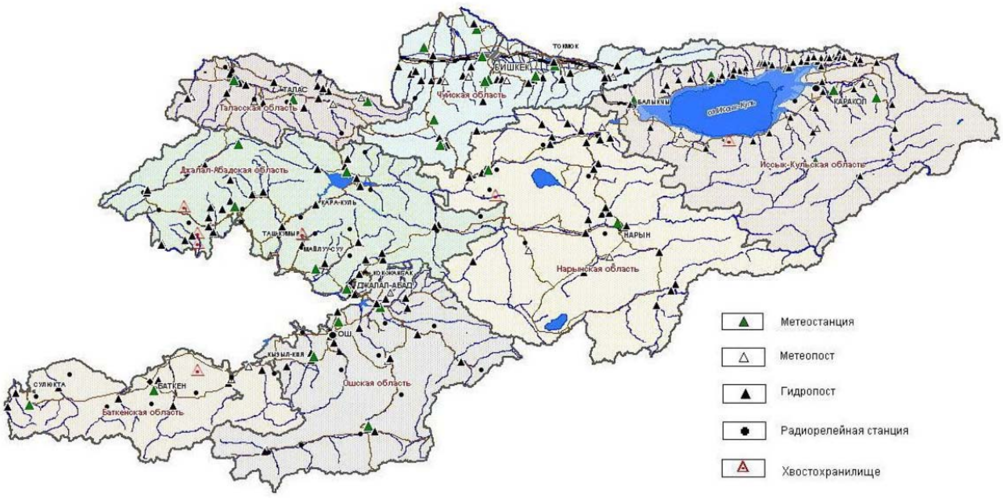


Рис. 1.1 Карта-схема административно-территориального деления и мониторинговая система слежения МЧС КР за развитием природных и техногенных процессов на территории Кыргызской Республики

Figure 10.3-1 Distribution of MES meteorological monitoring station (2015 disaster almanac, MES)

10.3.1.2 Disaster Distribution Map / Hazard Map

[Purpose]Identification of disaster characters such as position, area, scale, frequency

[Outline]The hazard map is a map integrated results of road facility comprehensive inspection, daily patrol and disaster records into a large scale map. Shows the structure of the road hazard map and there are many kinds of materials which consists the road hazard map. To elaborate the road hazard, map those materials should be collected and studied as the targeting map level. Figure 10.3-2 right shows typical hazard map targeting to clarify the detailed distribution of hazards and to monitor the hazardous phenomenon to prevent disasters in advance. This map has characters shown in as follows;

- Base map is 1/5,000 scale and it covers the area to the watershed
- Slope is colored by risk classification
- disaster type and scale is assessed from disaster record, existing inspection data, and topographical analysis
- derailed assessment of disaster area (such as rupture, float, etc.) and impact area are described
- Detailed disaster record, countermeasures and result of safety assessment are shown

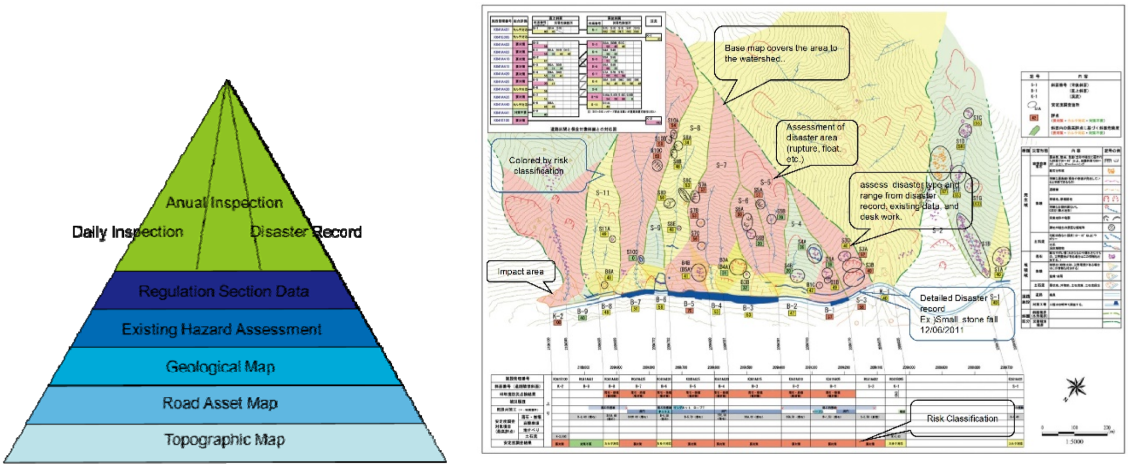


Figure 10.3-2 Stricture of the road hazard map(left) and typical Hazard map of slope disaster (right)

The hazard map has several types and Figure 10.3-3 shows the sample of the simple type hazard map which shows the disaster point distribution on the free usable GIS topographical map. However, this kind of map is easy to elaborate, fulfills a function in some situation.

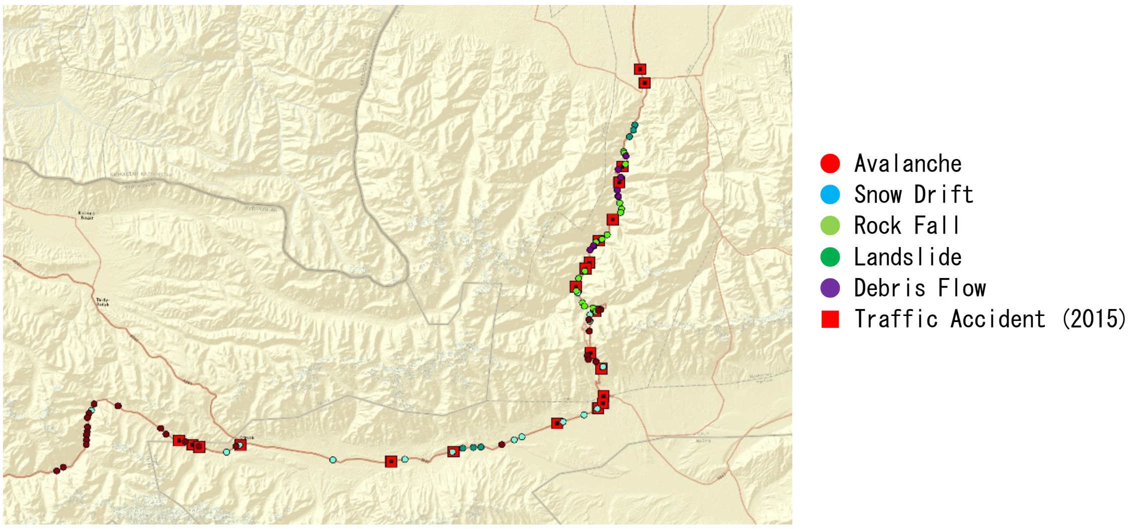


Figure 10.3-3 Hazard distribution map of BO road (northern part)

10.3.1.3 Educational Hazard Map / Pamphlet

[Purpose]Education for Public

[Outline]The hazard map could be modified for easily understandable materials for the common people.

This kind of hazard map is useful to notify the road disasters and necessity of disaster prevention in several kind of situations, such education program in school and community meeting, or directly distributed to road users.

Educational materials of the disaster prevention generally contain massages about the perception of current state, activities of the road authority staffs and road users' regulation to be hewed. It is important to simplify the expression so that readers might become interesting with the massages.

Figure 10.3-4 shows the sample of the disaster prevention pamphlet for metropolitan area and the dangerous point map of the mountain road.

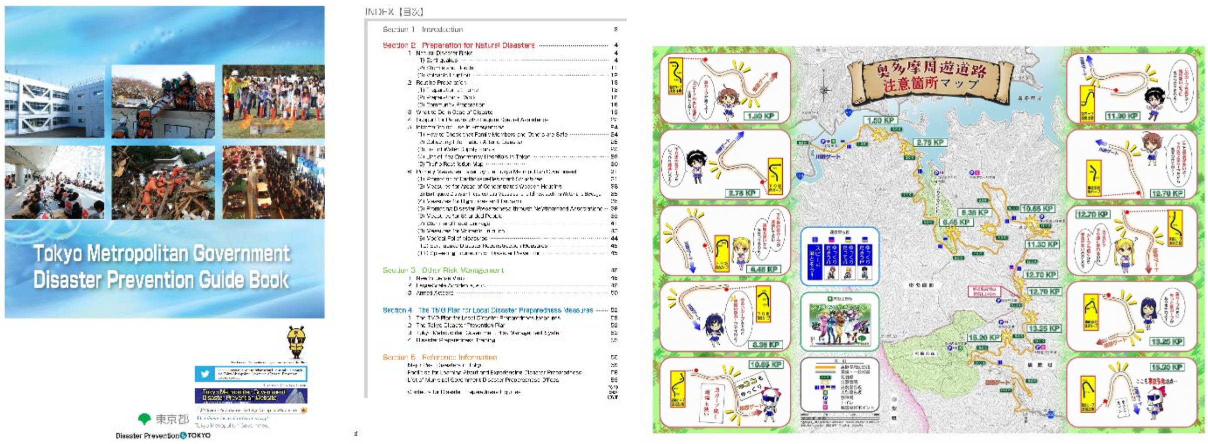
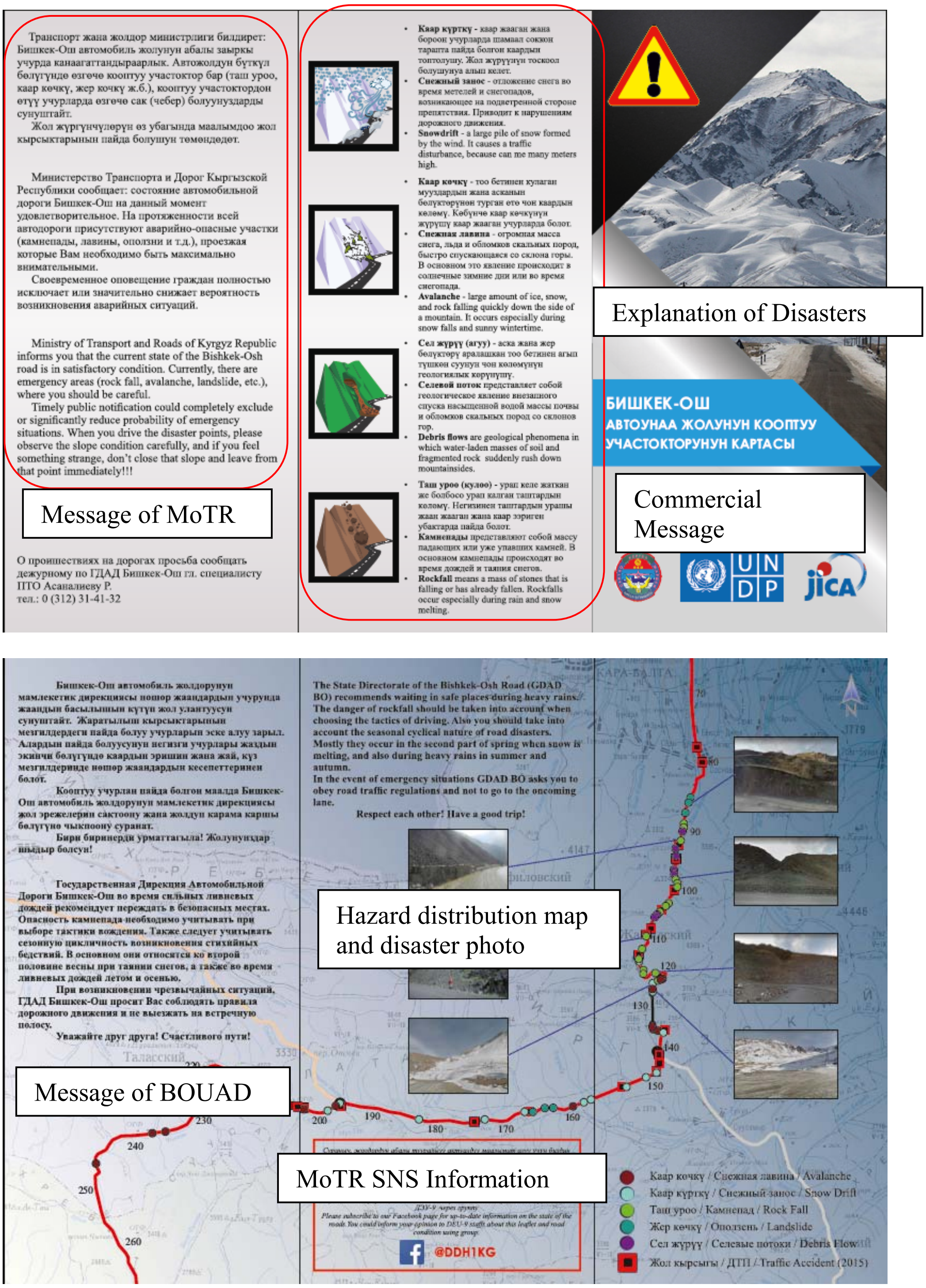


Figure 10.3-4 Contents of disaster prevention pamphlet in metropolitan area (left) and the dangerous point map of the mountain road (right)

In 2018, RMD (AMS) and BOUAD cooperated to distribute the brochures to road users shown in. The contents of these are as follows ;

- Hazard distribution map : Disaster points collected by RMD, MES and JICA study team and the 2015 traffic accident points plotted on the nationwide map elaborated during the Soviet Union regium
- Hazard phenomena explanation : avalanche, snow drift, rockfall and debris flow is simply described with original illustration
- Message from RMD and BOUAD : safety guidance by road engineers
- Introduction of MoTR's Face Book page
- Emergency Contact Number : MES's 112 and MoTR general contact number
- Sponsor's message : Logo mark of UNDP and JICA which donated for the printing brochures

The working group for brochures consisted by AMS, BOUAD and DEUs Engineers designed and edited them through their discussion and finalized its layout and outsourced printing work to the print house. The cost of printing was less than 2 com per 1 piece. It is possible to reduce the printing cost if it could be printed in MoTR.



Draft Design of DEU-9 Hazard Map for Road Users

10.3.1.4 Inspection (Daily, Seasonal, Annual Activity)

[Purpose]To identify the current situation of Disasters

[Outline]Inspection is the most important and basic activity for the road disaster prevention. There are many kind of inspection method according to frequency and level of detail. The inspection techniques should be trained to achieve the following targets.

① The technique which assesses the risks in the vast road side slopes precisely

② The technique which figures out the character of the dangerous points and the conditions surrounding the road and gives a reaction immediately against them

Inspection usually use its specified data sheets or style to unify the results even if anyone else might implement. The result of inspection is used to assess the dangerousness of the site and shall be stored as the data base for disaster prevention.

The detail of the inspection technique shall be referred to the inspection manuals. The daily inspection which could be implemented in the patrol activities by DEP's staffs is important to collect the small scale disasters which is used for the disaster precast analysis.

10.3.1.5 Landslide movement monitoring

[Purpose]To clarify the scale and behavior of sliding and not sliding body and to assess urgency.

[Outline]Landslide movement is rather slower than other kind of disaster so it can be monitored by the measurement methods of installed targets such stakes, painted marks, gauge etc.

To implement the land slide monitoring, the monitoring plan should be developed that contains the procedure and the division of roles and it is better that the plan is reviewed by the geological engineer.

The land slide movement become active with the rise of the groundwater table which is generally resulted by the rainfall and the snow melting. It is important to consider this character of landslide and take account of them for the plan. When the movement is suspected to become active, the frequency of the measurement shall be increased.

Result of measurement is analyzed to identify the scale of sliding body and urgency of the movement. In many cases, acceleration of the movement could be predicted and emergency measures to stop the movement could be planned and implemented.

There is a famous landslide known in RMD and BOUAD at 85.5 kp on BO road which deforms the road structures by the degree the pavements has not been made up. BOUAD decided to start monitoring the movement by cooperated with JICA study team from 2016. Figure 10.3-6 shows the on-going monitoring data of this site collected by BOUAD. After the rainy and winter season of 2016 to 2017 the movement was found which is far exceeded the regulation for emergency countermeasures in Japan, BOUAD budgeted for the emergency countermeasures as 2018 annual budget.

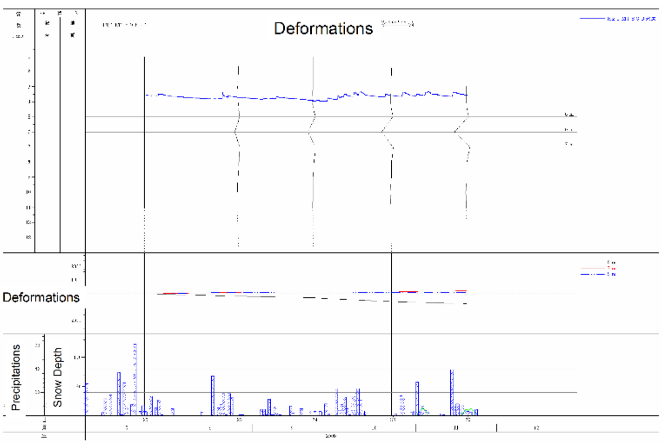
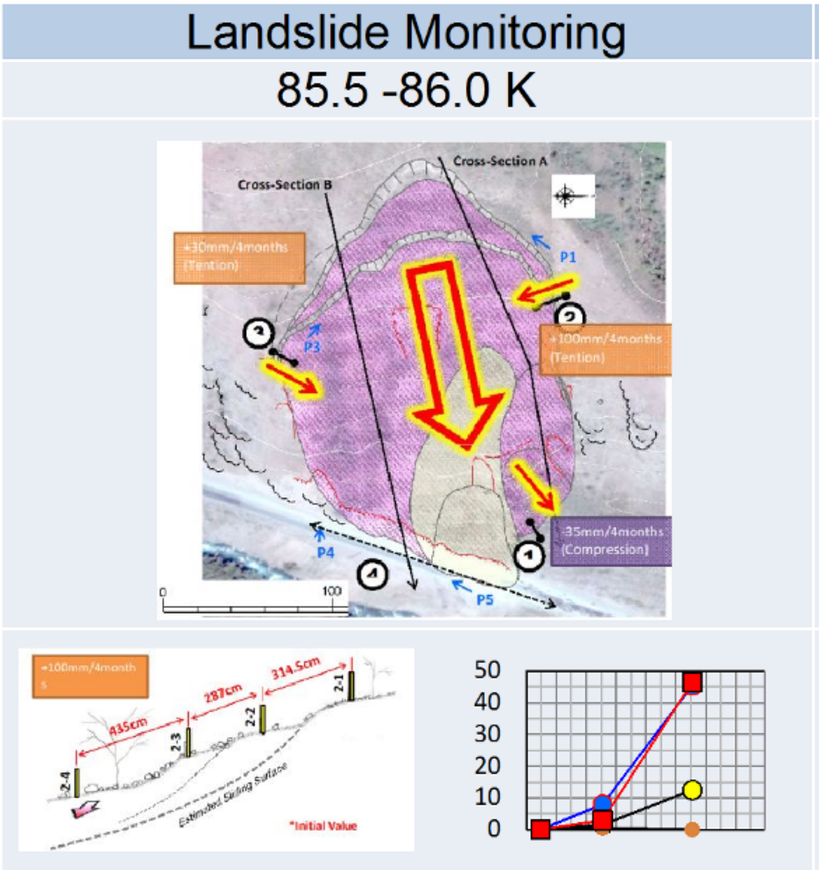


Figure 10.3-5 Sample of the lans slide monitoring data correlated with precipitations and snow depth


Landslide Monitoring
85.5 -86.0 K
Cross-Section A
Cross-Section B
+30mm/4months
(Tention)
P1
P3
+100mm/4months
(Tention)
-35mm/4months
(Compression)
P4
P5
0
100
+100mm/4months
435cm
287cm
314.5cm
2-1
2-2
2-3
2-4
Estimated Sliding Surface
*Initial Value
50
40
30
20
10
0


Мониторинг оползня
Км 85.5 - 86.0
Cross-Section A
Cross-Section B
+30mm/4months
(Tention)
P1
P3
+100mm/4months
(Tention)
-35mm/4months
(Compression)
P4
P5
0
100
+100mm/4months
435cm
287cm
314.5cm
2-1
2-2
2-3
2-4
Estimated Sliding Surface
*Initial Value
50
40
30
20
10
0

Figure 10.3-6 Landslide monitoring result at 85.5 kp BO road installed by BOUAD

Map shows the monitoring points and installed monitoring system and graph of collected deformation are illustrated in below.

10.3.1.6 Preventive Road Regulation

[Purpose]Hazard prevention during Excessive Weather

[Outline] Some larger scale disasters are too big to stop by structural measures, so the preventive road regulation method is chosen to protect road users. The preventative road regulation is the method to prevent direct impacts of the disaster to road users by regulating the traffic during the dangerous period which is configured by the study of relationship between disasters and weather parameters.

The regulated section should be informed and put forward to the road users, and is closed by the gates set at each side of the section (shown in Figure 10.3-7).

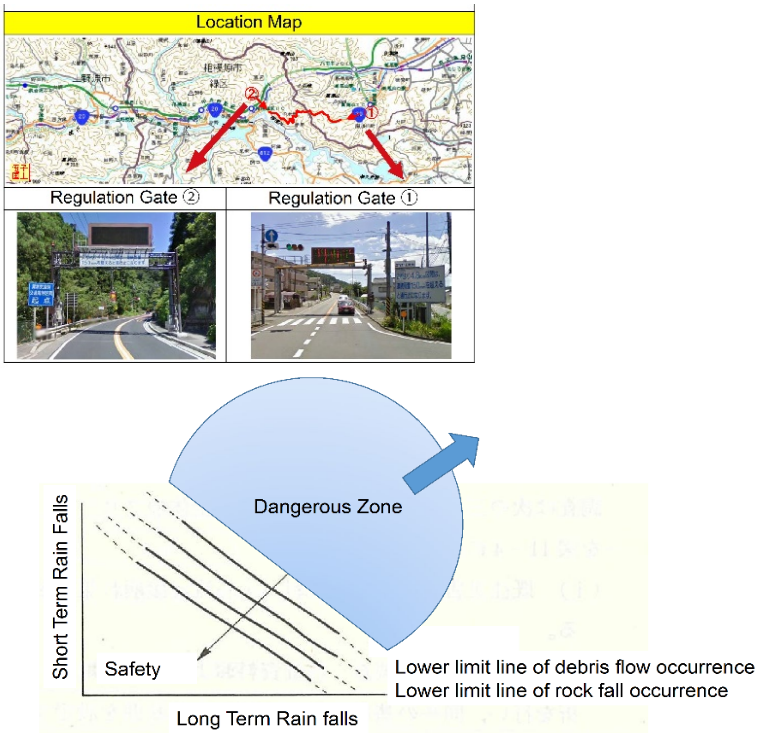


Figure 10.3-7 Preventative road regulation section and closing information message boards (left) and threshold analysis using relationship between precipitation and disaster occurrence (right)

Preventive road regulation shall be implemented under the sectional defined regulation with the judgement of experimental theory. The judgement of the regulation is based on the threshold that is analyzed by the relationship of prior disaster records and weather conditions. There are several theories about threshold analysis, which is classified the physical model and the statistic model, and the preventive road regulation of Japan uses the total amount of a continuous rainfall for its parameter. Example of preventative traffic regulation analysis is shown in Table 10.3-1. Generally, disasters have an occurrence timing, debris flow tends to occur at the peak of the accumulate rainfall and land slide tends to occur after the intense rainfall.

This method needs the consensus of every stake holders and understandings for disaster prevention activity by the society. And there are some problems as shown in follows in Japanese system.

- Disaster occurrence outside the regulation section
- Missed regulation without disaster occurrence
- Necessity for re-evaluation of the study of relationship between precipitation and disaster
- Increase of the ratio of the disasters occurred at outside the regulation section caused by the small precipitation

Table 10.3-1 Example of preventative traffic regulation analysis

Example of data collection and analysis for preventative traffic regulation

1- Disaster record collection and distribution Map

Where, When, How (volume and type)

2-Rainfall record, Topographic data, Geological data, Vegetation data collection
and Area classification of Precipitation Index

Monitoring data blank area is unified by the similarity of geology and topography

probable rainfall analysis
Precipitation Difference between location

3-Hourly Rain/ and Effective Rain plot in graph form
Configure Threshold (Critical Line, Warning Line, Evacuation Line) using snake curve
and analyze Failure rate

10.3.1.7 Bypass

[Purpose]Avoidance of the direct damage to users and economy

[Outline]To keep the traffic even under the critical weather conditions, bypass is planned against large scale road disasters. This is a new road construction, so the safety of the road is almost perfect, but this requires vast funds and a long construction period. The plan of Bypass should be usually reviewed not only by safety aspect but also economic evaluation. Figure 10.3-8 shows the example of disaster avoidance bypass plan.

Figure 10.3-8 example of disaster avoidance bypass plan

10.3.1.8 Artificial Avalanche / Rock Fall technic

[Purpose] To remove the occurrence factor of disaster

[Outline]Artificial Avalanche / Rock Fall technic are useful to remove the dangerous body of disasters.

There are some difficulties about when and where to implement in artificial avalanche, the way of blasting and safety of remaining walls in large scale artificial rock Fall. Those methods require the traffic regulation during the implementation.

These techniques could be improved by following aspects;

- To increase snow condition monitoring points for the judgement of artificial avalanche
- Triggering by very own method like "snow arrow" for avalanche
- Way of blasting rock body using static method (without "dynamite")

About artificial rock fall, it needs that dangerous body is clearly clarified and rock body is not so big and easy to be disconnected. If it is not so, the cost of artificial rock fall becomes quite expensive in some cases.

10.3.1.9 Road Sign and Sign Board

[Purpose] To notify message to road users

[Outline]Road sign is a basic information tool for road disaster prevention. To install road signs, it is important to select the suitable design and place. This is also useful to prevent traffic accidents, so the design and installation points shall be planned by disaster records and the traffic accident data.

Sign boards could tell more specified information to the road users by describing the detailed danger of disasters. For example, if there is a section where the debris flow occurs repeatedly, it is effective to install the massage board as shown in Figure 10.3-9 to notify the danger to road users.

Figure 10.3-9 Installation image of sign board to prevent involvement in debris flow

10.3.1.10 Alert to Road Users

[Purpose]Real time information to Road Users

[Outline]Real time information to Road Users is effective to prevent traffic accidents and to save loss of social activities.

There are several kinds of tools to inform alert such as electrical sign board, internet system and direct oral communications. To inform alert public person effectively, tools and its content should be studied by coverage, location and timing. According to the information about occurrence of disasters in mountain area, if the information announced or displayed in the city or entrances of the road, road users could avoid being involved the traffic hindrance.

There are two types of electrical sign board, one is fixed at the site and the other is mobile type. It is effective to handle this device remotely so that the road management staffs could change the massages promptly. Figure 10.3-10 shows the image of electrical sign board remote control system.

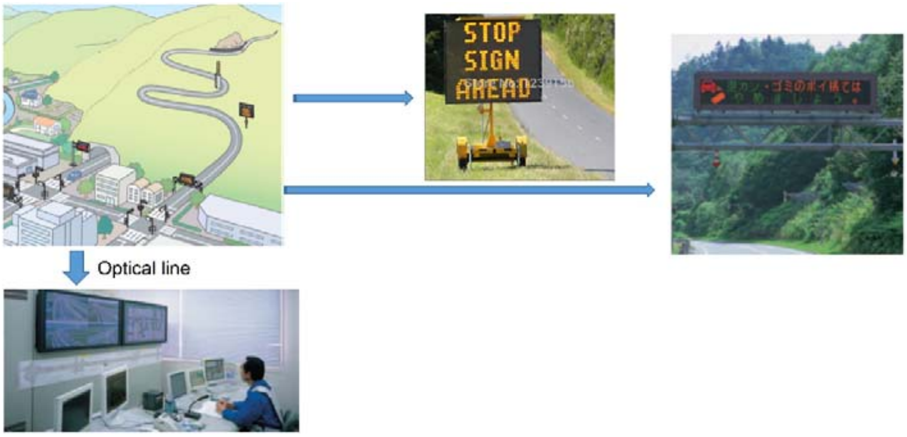


Figure 10.3-10 On line electrical sign board system image

MES has already installed SMS information system to announce alert massage to mobile phone users. It is effective too if MOTR might install their own alert provide system to announce disaster information. There are several methods to provide information to road users by internet, Figure 10.3-11 shows a system image of disaster alert by SNS (social networking service). It is necessary to develop the time line plan for smooth implementation.

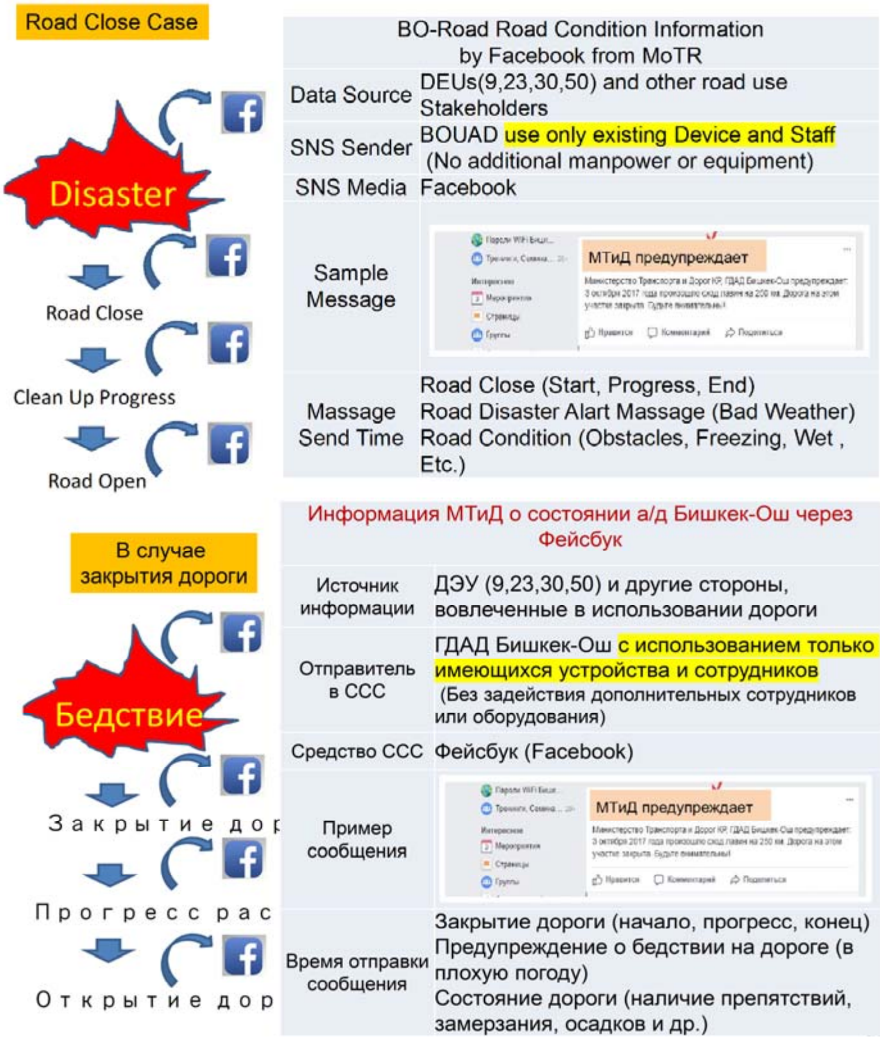


Figure 10.3-11 SNS alert information system image by MOTR

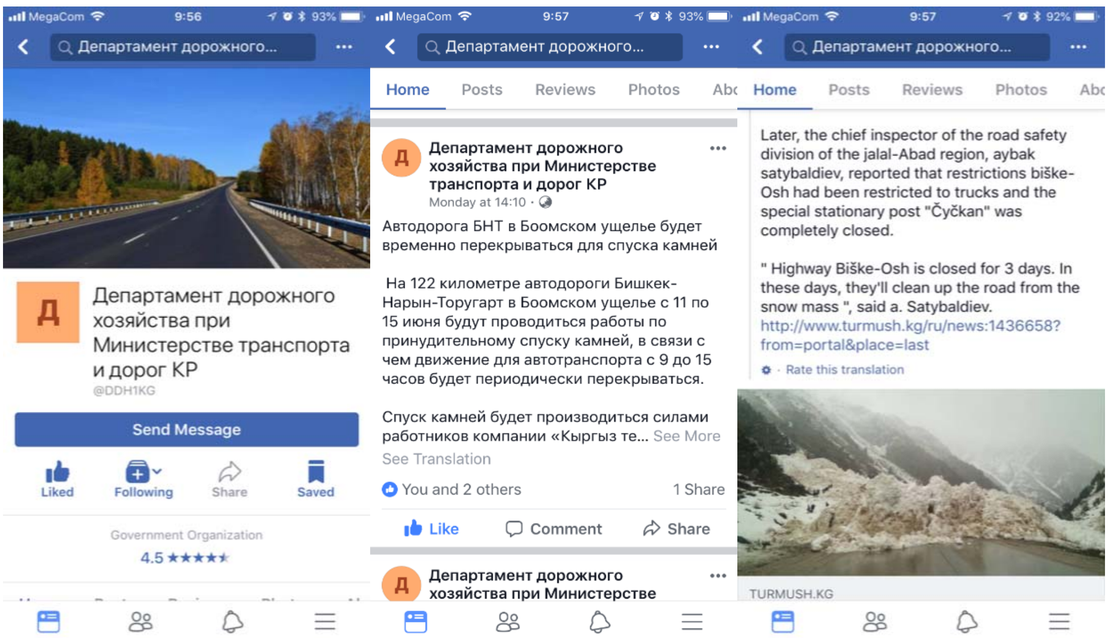


Figure 10.3-12 MOTR (BOUAD) 's Facebook Page

In 2018, RMD instructed to AMS and BOUAD to install SNS information system by Facebook to share the road disaster information with road users as well as the brochures distribution. The instruction document is shown in Figure 10.3-13 .
After installation, it is important to keep on boosting the MOTR SNS users (followers) , for this reason, these points shall be considered.

- Contents shall be reviewed and revised on a periodic basis
- Promote Facebook page by using everything in MOTR's power
- Provide accurate / precise (evidence based), in good time and readable information

КЫРГЫЗ РЕСПУБЛИКАСЫНЫН ТРАНСПОРТ ЖАНА ЖОЛ МИНИСТРЛИГИНИН АЛДЫНДАГЫ ЖОЛ ЧАРБА ДЕПАРТАМЕНТИ

ДЕПАРТАМЕНТ ДОРОЖНОГО ХОЗЯЙСТВА ПРИ МИНИСТЕРСТВЕ ТРАНСПОРТА И ДОРОГ КЫРГЫЗСКОЙ РЕСПУБЛИКИ

БУЙРУК **ПРИКАЗ**

Чыгыш № 06-09 Дата «09» 01 2018г

«Об использовании информационных брошюр и информировании населения через социальные сети»

В рамках проекта «Укрепление потенциала в управлении предотвращением бедствий на автомобильных дорогах Кыргызской Республики» в целях повышения безопасности всех пользователей автодороги Бишкек-Ош, а также для распространения информационных брошюр с содержанием карты опасных участков и системы оповещения через социальные сети,

ПРИКАЗЫВАЮ:

1. Сейитбекову И. – начальнику ОУА принять на использование страницу **«Департамент дорожного хозяйства при Министерстве транспорта и дорог КР»** в социальной сети «Facebook» для информирования пользователей дорог и населения.

2. Шекеева А. – ведущего специалиста ОУА ДДХ назначить ответственным за управлением страницей **«Департамент дорожного хозяйства при Министерстве транспорта и дорог КР»** в социальной сети «Facebook»:

- в дальнейшем осуществлять работоспособность страницы, набрать подписчиков, безотлагательно выкладывать различного рода информацию возникающих на автодороге Бишкек-Ош (сход лавин, оползней, камнепады и т.д.).

3. Генеральному директору ГДАД Бишкек-Ош Кадырбаеву Т.Т. закрепить приказом использование информационных брошюр с содержанием карты опасных участков.

4. Начальникам ДЭУ № 9, 23, 30 обеспечить распространение информационных брошюр на пропускных пунктах «Сосновка» и «Каракуль».

5. Контроль за исполнением настоящего приказа оставляю за собой.

Директор **А.Ибраев**

ROAD MAINTENANCE DEPARTMENT
UNDER THE
MINISTRY OF TRANSPORT AND ROADS OF THE KYRGYZ REPUBLIC

Outgoing No. 06-OD

Date: 9 January 2018

ORDER
on the utilization of informative brochures and on the notification of the population through the social networking systems

Within the framework of the "Project for capacity development for road disaster prevention management in the Kyrgyz Republic", to ensure the safety of all the users of the Bishkek-Osh automobile road, as well as to distribute informative brochures containing hazard map and the Social Networking System,

I hereby order:

1. to Istanbek Seyitbekov, Head of AMS/RMD, to take for usage the Facebook page "Road Maintenance Department under the Ministry of Transport and Roads of the Kyrgyz Republic" [*«Департамент дорожного хозяйства при Министерстве транспорта и дорог КР»*] for notifying the road users and the population;
2. to appoint Azat Shekeev, Leading Specialist of AMS/RMD, responsible for the operation of the Facebook page; and for further management of the page to ensure its activeness, boost the number of subscribers, promptly post information regarding various kinds of situations on the Bishkek-Osh road (avalanche, landslides, rockfalls, etc.);
3. to T. Kadyrbaev, General Director of the General Directorate of the Bishkek-Osh road/RMD, to approve the informative brochures with the hazard map by official order for further utilization;
4. to the Heads of DEU 9, DEU 23 and DEU 30 to ensure the distribution of the information leflets at "Sosnovka"and "Kara-Kul" toll gates.
5. I reserve the control over the execution of this order.

Figure 10.3-13 Order from RMD Director about SNS and Hazard Map

10.3.1.11 Heavy Equipment Management by GPS

[Purpose] To control equipment precisely for disaster recovery

[Outline]Once disaster occurs, length of closing period depends on the response activity by the road management section. Since the asset for respond is limited generally, to make the most use of assets is important.

Management system of Heavy equipment by GPS is already installed in BO-UAD, however, this system had not been used for improvement of disaster recovery. There is a possibility to control them for the effective formation at the response act against disasters. There is a connection system which can operate without mobile phone network suitable for the mountain region.

Figure 10.3-14 Heavy equipment management by GPS image

10.3.1.12 Emergency Measure

[Purpose]To protect road from secondary disaster

[Outline]During response activities of landslide, rock fall, erosion and avalanche, the road management section could set measures against the outspread disasters.

The emergency measure is prepared for the suspected scale of disaster as the follow chart shown in. The road management sector shall line up the system, equipment and materials to minimize the influence of the disaster. The measures are planned and implemented as the result of the inspection and monitoring after the disaster.

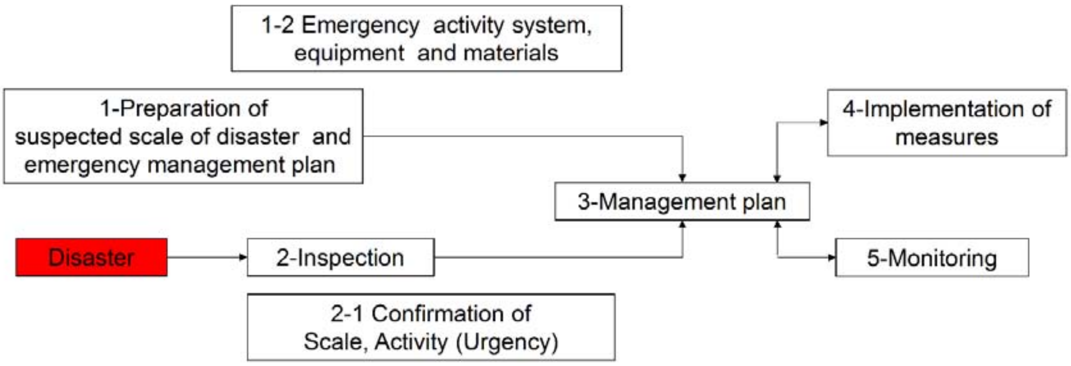


Figure 10.3-15 The follow chart of emergency measures activity

The act shall be controlled by the inspection result and monitoring by the road management sector without the influences from the external organization.

The tools for emergency measures are limited under the critical situation, these are mainly organized by the materials procured near the site, for example large sandbags and embankment by soils or snow. The materials for emergency measures shall be stored at the specified place and se to be able to use anytime in need.

Large sandbag is about 1.0 ton weight and easy to bank up even in narrow space so that it is possible to protect traffic along the road side.

Figure 10.3-16 Banked up large sandbags