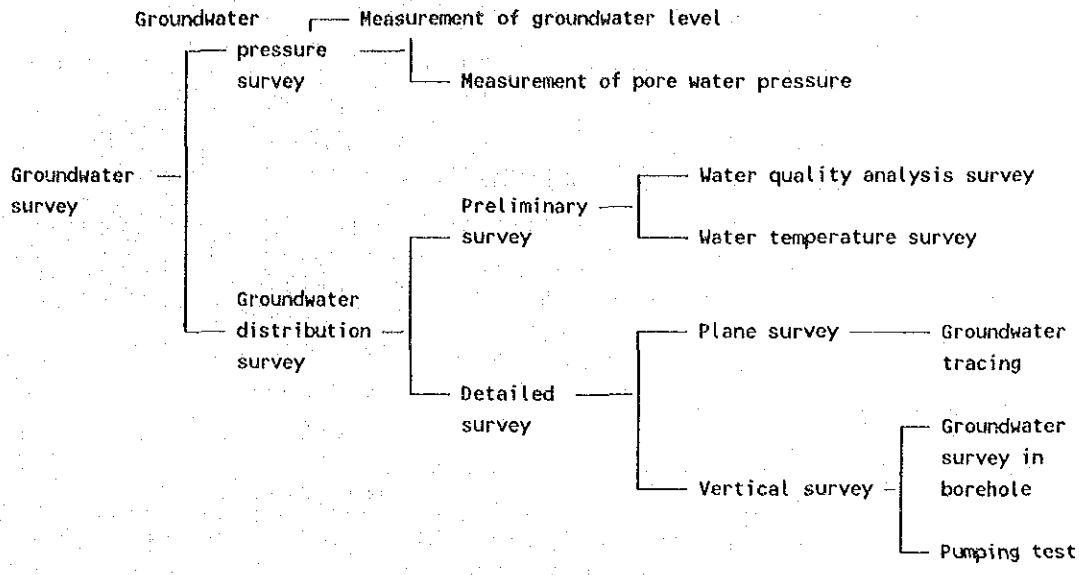


FIGURE 4.2-1 GROUNDWATER SURVEY

To analyze the mechanism of landslide, it is necessary to examine the correlationships between fluctuation of groundwater and movement of landslide and between fluctuation of groundwater and rainfall.

- Movement Survey

  This survey is carried out to determine the direction and speed of movement of landslide by measurement with instruments such as extensometers, slant-rules, displacement plies and displacements plates. From the measurements, changes of strain at slide plane as well as changes of expansion and slant at the ground surface accompanied with landslide movement can be determined.

5) Survey for Debris Flow (D-FL)

The following surveys are required:

- Topographis Survey

  Longitudinal levelling and cross section survey of stream to investigate gradient and cross section of the stream and condition of deposits;

- Geotechnical Survey

  Thickness and properties of deposits; and

- Hydrological Survey/Analysis

  Discharge velocity, tractive force, etc.

6) Survey for Scour/Washout of Roadbed (Rd-D)

- Gradient and cross section of the stream, and landuse and significant physical features in the vicinity of the stream should be surveyed.
- Data necessary for hydrologic analysis should be collected, including:
  - Flood flow data and stream flow records;
  - Basin characteristics including drainage area, main channel slope, stream length, surface storage, geology, soil-infiltration index, basin shape, stream density, basin elevation, cover, basin slope, landuse and basin orientation; and
  - Precipitation.
- Properties of roadbed material should be examined.

7) Survey for Flooded/Muddy Road Surface (FM-Rd)

- Data for hydrologic analysis covering whole drainage area where the flooded/muddy portion is situated should be collected including topographic features, drainage area, channel characteristics, precipitation, flood information, etc.
- Conditions of drainage facilities should be examined on their location, size, material, damage, siltation, clogging, etc.
- Properties of road surface and roadbed materials should be investigated.

8) Survey for Permanent Bridge Washout (PBr-W) and Temporary Bridge Washout (TBr-W)

- Hydrologic data should be collected/surveyed including:
  - Channel characteristics including cross section of the stream channel and flood plains, streambed material and slope, vegetal cover, etc.;
  - Flood flow data and stream flow records;
  - Basin characteristics including drainage area and topographic features;
  - Precipitation;
  - History of change in alignment of channel; and
  - History of stream degradation or aggradation.
- Soil investigation should be done where substructures are planned to be located.

9) Survey for Permanent Bridge Approach Washout (PBr-A) and Temporary Bridge Approach Washout (TBr-A)

Refer to 6) Survey for Scour/Washout of Roadbed (Rd-D).

10) Survey for Permanent Bridge Other Damage (PBr-D), Temporary Bridge Other Damage (TBr-D) and Spillway Damage (SPW-D)

Refer to 8) Survey for Permanent Bridge Washout (PBr-W) and Temporary Bridge Washout (TBr-W).

11) Survey for Culvert Damage (CLV-D)

- Hydrologic data should be collected/surveyed including:
  - Topographic features in the vicinity of the culvert site;
  - Drainage area;
  - Characteristics of the stream channel upstream and downstream of the culvert;
  - Highwater information; and
  - Precipitation.
- Conditions of the culvert should be examined on its location, size, material, damage, siltation, clogging, etc., especially at the inlet and outlet portions.
- Conditions of the area around the culvert should be carefully inspected. If embankment slope is damaged, the surveys mentioned in 2) above are required.

12) Survey for Seawall Damage (SW-D)

- Data necessary to analyze wave run-up height and wave pressure should be collected/surveyed, including:
  - Coastal topography;
  - Meteorological data (precipitation, wind, storm surge);
  - Wave measurement data; and
  - Characteristics of seabed sediment.
- Soil investigation should be carried out at the location of the seawall.

CHAPTER 5
RESTORATION MEASURES

CHAPTER 5
RESTORATION MEASURES

A restoration is generally classified into the following two types:

- Urgent Restoration

  This is a measure which is taken immediately after occurrence of disaster with the main objective of reopening the road which has been closed to traffic caused by the disaster.

- Permanent Restoration

  This is a measure which is taken after the urgent restoration to restore the road completely and to prevent the recurrence of disaster.

5.1 URGENT RESTORATION MEASURES

The purposes of urgent restoration are generally as follows:

- To secure urgently and temporarily at least one lane traffic by removing obstacles or by refilling eroded portion.
- To remove materials suspended to endanger traffic like unstable rocks on a slope.
- To check the progress of damage until permanent measures are taken.

The requirements for urgent restoration measures are as follows:

- To be able to be implemented immediately after occurrence of disaster and completed in a short period.
- To require no special equipment, material and expertise.
- To be low-cost.

Urgent restoration measures selected in view of the above and included in the Manual are as follows:

U1: Earth Work	U1-1: Removal of Deposit Materials
	U1-2: Removal of Unstable Materials
	U1-3: Removal of Head
	U1-4: Refilling/Embankment
	U1-5: Selected Material Fill

U2: Surface Drainage	U2-1: Temporary Slope Ditch U2-2: Temporary Side Ditch U2-3: Sand Bag Setting
U3: Slope Protection	U3-1: Sheet Covering U3-2: Sand Bag Covering
U4: Retaining Work	U4-1: Sand Bag Wall U4-2: Gabion Wall U4-3: Wooden Fence
U5: Foot Protection	U5-1: Gabion Foot Protection
U6: Bridge	U6-1: Wooden Pile Bent U6-2: H-Pile Bent U6-3: Bailey Bridge
U7: Pavement Work	U7-1: Gravel Surfacing

Urgent restoration measures are summarized in Table 5.1-1 (1) to (4).

TABLE 5.1-1 (1) TYPE OF URGENT RESTORATION MEASURES

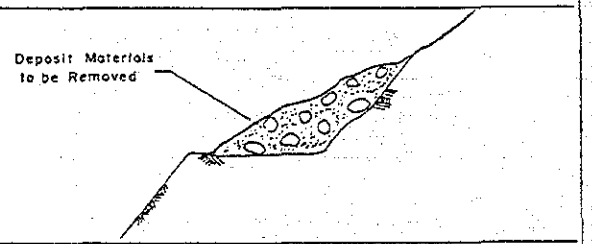
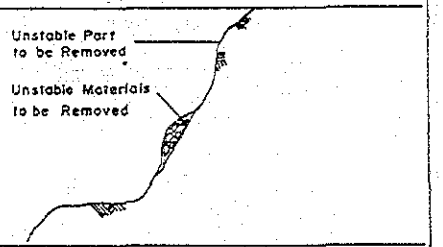
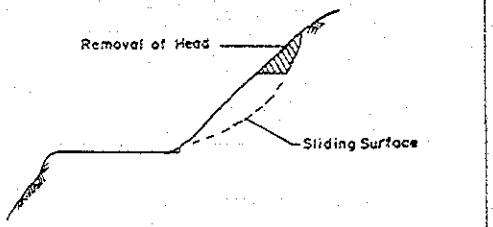
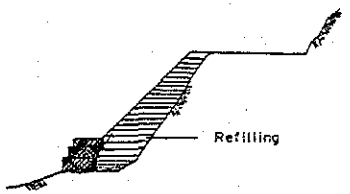
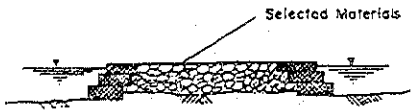
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
U1: Earth Work	U1-1: Removal of Deposit Materials	To open road for traffic by removing failed or moved materials deposited on the road.	C-F FALL L-SL D-FL	
	U1-2: Removal of Unstable Materials	To ensure traffic safety by removing unstable parts or materials on the slope	C-F FALL	
	U1-3: Removal of Head	To reduce motivating force by removing head portion of cut slope failure or landslide	C-F L-S Usually applied to landslide (L-S)	
	U1-4: Refilling/ Embankment	To open road for traffic by filling failure portions of the road with soil etc.	E-F PBr-A TBr-A CLV-D SW-D Usually applied with slope protection work or retaining work.	
	U1-5: Selected Material Fill	To fill portions influenced by water with selected materials such as sand and gravel, cobbles, etc.	E-F PBr-A TBr-A SPW-D CLV-D SW-D	

TABLE 5.1-1 (2) TYPE OF URGENT RESTORATION MEASURES

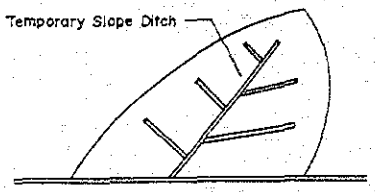
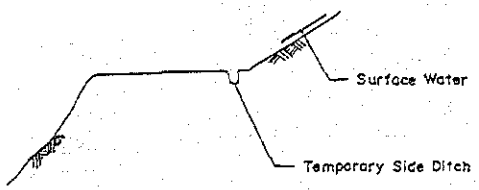
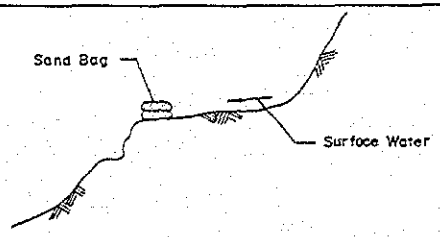
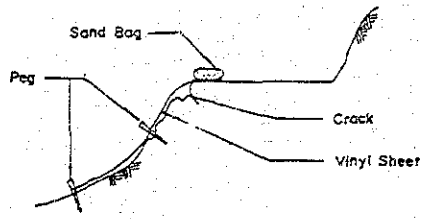
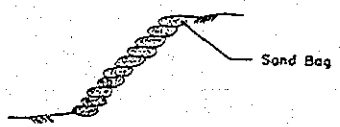
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
U2: Surface Drainage	U2-1: Temporary Slope Ditch	To collect and drain surface water on slope by providing slope ditch for preventing slope surface from erosion/scour.	C-F FALL	
	U2-2: Temporary Side Ditch	To drain surface water on the road for preventing water from flowing onto embankment slope.	E-F	
	U2-3: Sand Bag Setting	To prevent the surface water from flowing onto the collapsed slope by setting sand bags.	E-F Instead of sand bags, there is a case in which small bank is constructed.	
U3: Slope Protection	U3-1: Sheet Covering	To protect slope from erosion and scour by covering the slope surface with vinyl sheets, etc.	C-F E-F Usually applied to small area of the slope.	
	U3-2: Sand Bag Covering	To protect slope from erosion and scour by covering the slope with sand bags.	E-F Can be applied to fairly steep slope (up to 0.5:1)	

TABLE 5.1-1 (3) TYPE OF URGENT RESTORATION MEASURES

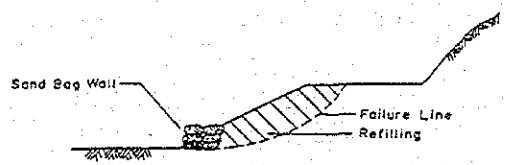
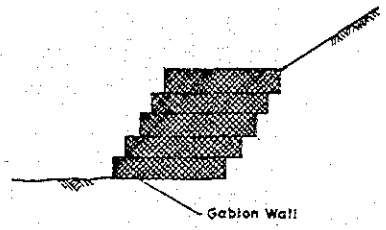
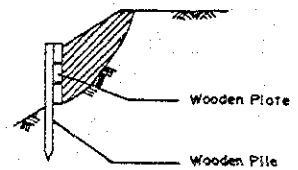
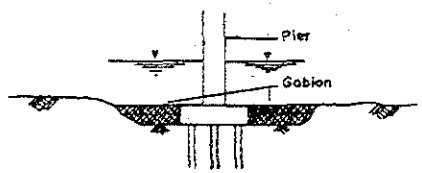
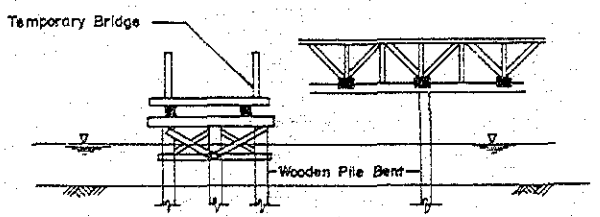
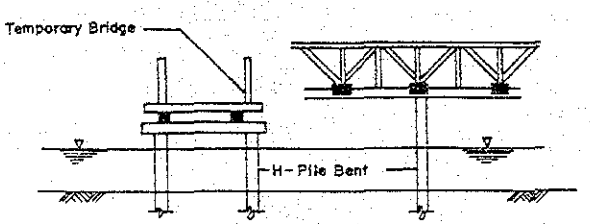
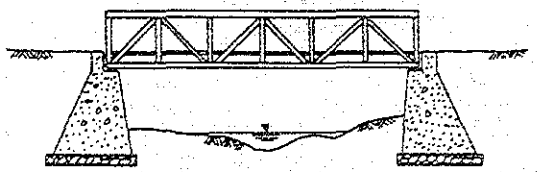
CLASSIFICTION	TYPE OF WORK	D E S C R I P T I O N	A P P L I C A T I O N (Type of Disaster)	I L L U S T R A T I O N
U4: Retaining Work	U4-1: Sand Bag Wall	To resist earth pressure by stacking sand bags.	C-F E-F L-S	
	U4-2: Gabion Wall	To resist earth pressure by stacking gabions.	C-F E-F L-S PBr-A TBr-A SW-D Effective for slope with water seepage.	
	U4-3: Wooden Fence	To resist earth pressure by wooden fence.	E-F SW-D Mainly applied to embankment slope failure (E-F).	
U5: Foot Protection	U5-1: Gabion Foot Protection	To protect foot of revetment, retaining wall, pier, etc. from scour by placing gabion.	E-F PBr-A PBr-D TBr-A TBr-D CLV-D	

TABLE 5.1-1 (4) TYPE OF URGENT RESTORATION MEASURES

CLASSIFICTION	TYPE OF WORK	D E S C R I P T I O N	A P P L I C A T I O N (Type of Disaster)	I L L U S T R A T I O N
U6: Bridge	U6-1: Wooden Pile Bent	To support a temporary bridge.	PBr-W PBr-A TBr-W TBr-A	
	U6-2: H-Pile Bent	To support a temporary bridge.	PBr-W PBr-A TBr-W TBr-A	
	U6-3: Bailey Bridge	To provide a temporary bridge.	PBr-W PBr-A TBr-W TBr-A	
U7: Pavement Work	U7-1: Gravel Surfacing	To restore deteriorated road surface.	Applied to all types of disaster except the following: PBr-W PBr-D TBr-W TBr-D	

5.1.1 U1: Earthwork

1) U1-1: Removal of Deposit Materials

This work is to reopen the road for traffic by removing materials depositing on the road surface and obstructing traffic.

The situation which requires this work is illustrated in Figure 5.1-1.

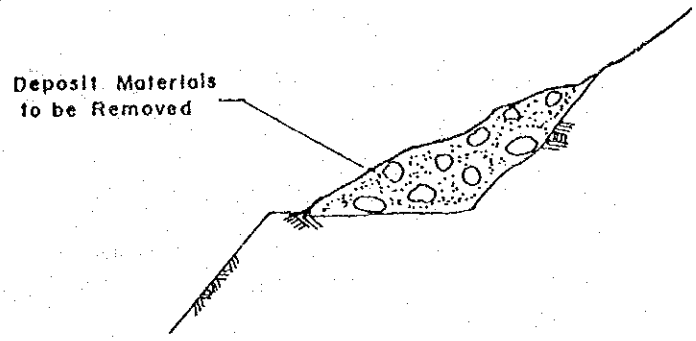


FIGURE 5.1-1 REMOVAL OF DEPOSIT MATERIALS

In order to reopen the road as soon as possible, only one lane is usually planned to be opened.

There are many cases where only this work is applied as the urgent restoration measure.

When a large volume of materials is deposited on the road surface, wheel loaders and dump trucks are required. Fast arrangement and delivery of these equipment to the disaster spot are very important.

When the deposit materials are small in volume, the removal shall be done by manpower until arrival of the equipment.

From environmental aspects, such a work as pushing the deposit materials down to the valley side is not appropriate. The deposit materials shall be hauled and dumped at proper area.

2) U1-2: Removal of Unstable Materials

This work is to remove unstable rocks, materials or portions of collapsed slope suspectable to fall down, in order to keep safety of reopened traffic.

This situation which requires this work is illustrated in Figure 5.1-2.

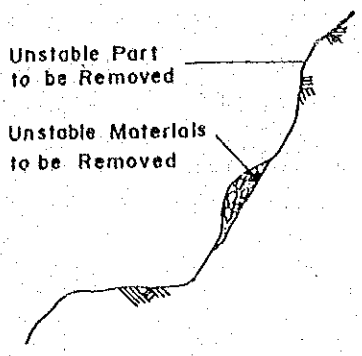


FIGURE 5.1-2 REMOVAL OF UNSTABLE MATERIALS

The removal of unstable materials on the slope is mainly done by manpower, but materials removed from the slope and deposited on the road surface are excluded by wheel loaders and dump trucks.

There are few experiences of this work applied as the urgent restoration measures in the Philippines. However, this work is highly recommended from the viewpoint of traffic safety.

3) U1-3: Removal of Head

This work is to remove the head portion of cut slope failure or landslide to reduce the motivating force.

Since this work is applied as the permanent restoration measure too, the detailed descriptions are presented in Section 5.2.

4) U1-4: Refilling/Embankment

This work is to refill collapsed portions of the embankment in order to reopen the road for traffic.

(Refer to Section 5.2)

5) U1-5: Selected Material Fill

This work is to refill collapsed portions influenced by water with selected materials such as sand and gravel, crushed stone, cobble, etc.

(Refer to Section 5.2)

5.1.2 U2: Surface Drainage

Surface drainage is provided to prevent erosion/scour by collecting and draining surface water.

1) U2-1: Temporary Slope Ditch

This is a ditch temporarily provided on collapsed slope to protect the slope surface from erosion/scour.

The ditch is usually naked or made with simple and cheap materials, e.g. soil cement or brushwood.

These are shown in Figure 5.1-3.

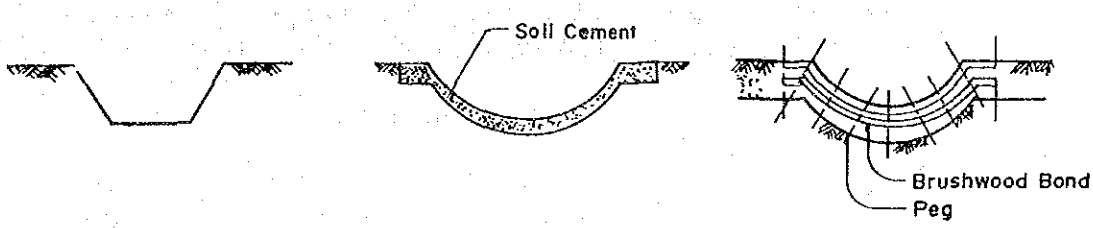


FIGURE 5.1-3 TYPES OF TEMPORARY SLOPE DITCH

Ditches are arranged on the slope as shown in Figure 5.1-4.

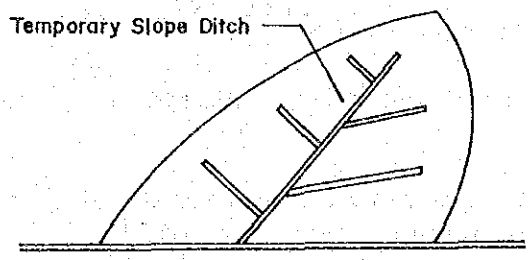


FIGURE 5.1-4 ARRANGEMENT OF TEMPORARY SLOPE DITCH

Since this work can be done by manpower, no special equipment is required.

2) U2-2: Temporary Side Ditch

This is a ditch temporarily provided on the road side to protect embankment slope from erosion by collecting and draining surface water flowing on the road surface.

The ditch is naked or made with soil cement or brushwood and is located as shown in Figure 5.1-5.

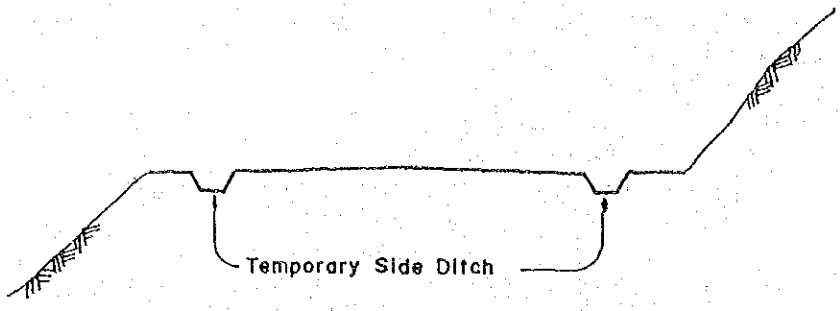


FIGURE 5.1-5 TEMPORARY SIDE DITCH

3) U2-3: Sand Bag Setting

This is to set sand bags to protect the embankment slope from erosion/scour by preventing surface water from flowing down on the slope.

The location of sand bag is illustrated in Figure 5.1-6.

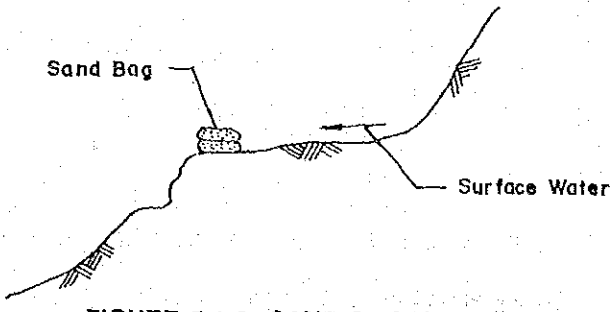


FIGURE 5.1-6 SAND BAG SETTING

Main materials for this work are vinyl or linen bags.

Since the work is to fill earth into sand bags and set them, no special equipment are required.

This work is often applied in Japan as an effective urgent restoration measure. The application of this work is strongly recommended.

5.1.3 U3: Slope Protection

A collapsed slope is easily eroded or scoured by the surface water flowing down on the slope surface during rain, and consequently the failure of slope promptly expands.

In order to prevent the expansion of the failure due to erosion/scour, the slope shall be covered by suitable materials.

The following types of work are applicable as urgent restoration measures:

1) U3-1: Sheet Covering
2) U3-2: Sand Bag Covering

These works are usually used for covering small or medium size of slopes.

The slope is covered with vinyl sheet, synthetic fiber net, straw mat, paper products etc. in such a manner as shown in Figure 5.1- 7.

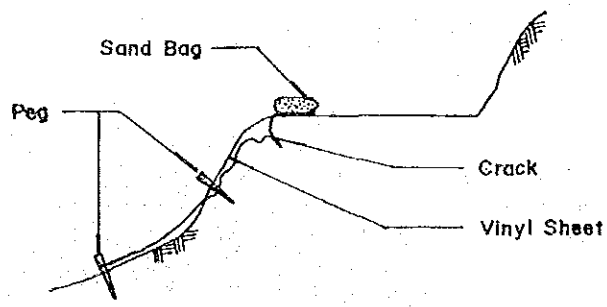


FIGURE 5.1-7 SHEET COVERING

Sand bag covering is also carried out in a manner shown in Figure 5.1-8.

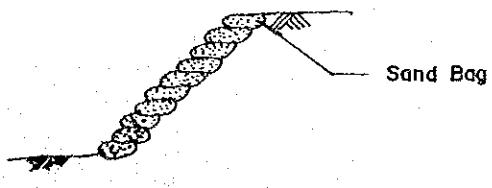


FIGURE 5.1-8 SAND BAG COVERING

As shown in Figure 5.1-7, sand bag covering is useful not only to protect the slope but also to stabilize the steep slope.

There are few experiences of these slope protection works in the Philippines. However, the introduction of these works is desirable, since they are very cheap and effective.

Since these works are carried out mainly by manpower, no special equipment is required.

5.1.4 U4: Retaining Work

This is to prevent slope failure by supporting and resisting motivating force with wall.

There are many kinds of retaining wall, most of which are used as permanent restoration measures. Described in this section are only those that are used as urgent restoration measures.

1) U4-1: Sand Bag Wall

Figure 5.1-9 shows an example of sand bag wall.

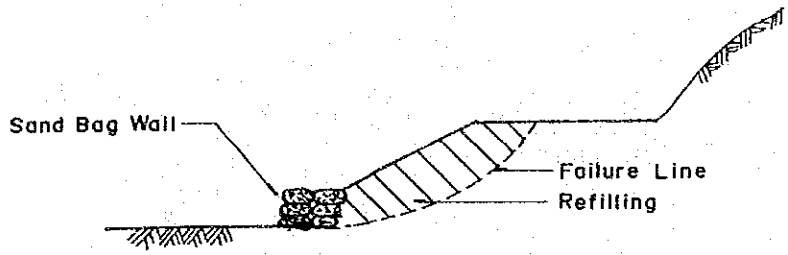


FIGURE 5.1-9 SAND BAG WALL

This work can simply be done only by manpower in a short period.

2) U4-2: Gabion Wall

Figure 5.1-10 shows an example of gabion wall.

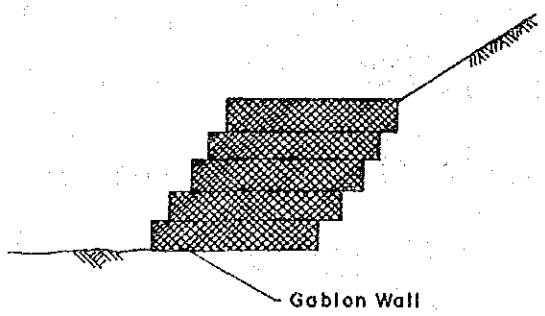


FIGURE 5.1-10 GABION WALL

Gabions are generally divided into two types, i.e. a cylinder gabion and a mat gabion. Gabion wall is mainly made with mat gabions.

In the Philippines, there are few experiences of the gabion wall. However, since this is a simple and reliable restoration measure, prompt introduction is desirable.

3) U4-3: Wooden Fence

Wooden fence to temporarily support earth pressure is made up by wooden piles driven at intervals of 0.6 m to 1.2 m and wooden plates set between these piles, as illustrated in Figure 5.1-11.

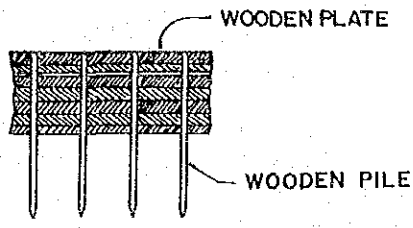


FIGURE 5.1-11 WOODEN FENCE

This work is effectively applied to restore the embankment at steep mountainous areas as shown in Figure 5.1-12.

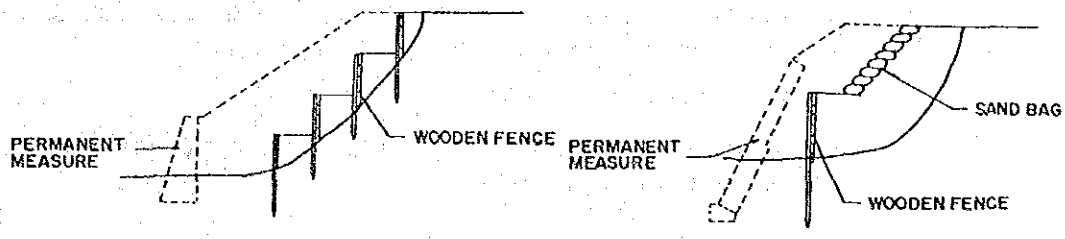


FIGURE 5.1-12 APPLICATION EXAMPLES OF WOODEN FENCE

A small scale of wooden fence can be constructed only by manpower by using such tools as saw and hand hammer. However, for a big scale of wooden fence, a pile driving machine is required.

Wooden fence is usually designed by practical experiences. However, when a high wooden fence is planned, it must be designed based on the stability analysis.

5.1.5 U5: Foot Protection

This is to protect the toe of revetment of river bank or pier of bridge from scour by river current.

There are many types of foot protection work and gabion foot protection is commonly used as urgent restoration measures.

1) U5-1: Gabion Foot Protection

   (Refer to Section 5.2)

5.1.6 U6: Bridge

1) U6-1: Wooden Pile Bent
2) U6-2: H-pile Bent
3) U6-3: Bailey Bridge

   Bailey bridge with wooden pile bent or H-pile bent is applied as urgent restoration measure for bridge or its approach washout because of the constructability in a short period. The choice between wooden pile and H-pile is made depending on load to be supported and availability of material.

   H-piles and bailey bridge panels will be evacuated after completion of the permanent bridge. They are re-used in other disaster spots or stocked in regional/district offices for future use. Therefore, only depreciation costs are involved in the urgent restoration work.

5.1.7 U7: Pavement Work

This is to restore road surface deteriorated by disaster, applied to various types of disaster as a cooperative measure with other restoration work.

1) U7-1: Gravel Surfacing

   Gravel surfacing is a commonly used pavement work as urgent measure. Standard thickness of gravel surfacing is 20 cm.

5.2 PERMANENT RESTORATION MEASURES

Permanent restoration measures are usually taken after urgent measures for the following purposes:

- To restore the road completely to its original condition or upgrade it when necessary.
- To prevent the recurrence of disaster.

Major considerations in selecting permanent restoration measures are as follows:

- To be technically and practically applicable in the Philippines using available equipment, materials and expertise.
- To introduce new or uncommon techniques in the Philippine as far as practically acceptable.
- To be harmonized with natural environment.

Permanent restoration measures selected in view of the above and included in the Manual are as follows:

P1: Earthwork	P1-1: Recutting P1-2: Removal of Head P1-3: Refilling/Embankment P1-4: Counterweight Fill P1-5: Selected Material Fill
P2: Surface Drainage	P2-1: Slope Ditch P2-2: Side Ditch P2-3: Water Channel P2-4: Culvert P2-5: Catch Basin
P3: Subsurface Drainage	P3-1: Subsurface Drainer P3-2: Horizontal Drain Hole P3-3: Deep Well P3-4: Drain Tunnel
P4: Slope Protection by Vegetation	P4-1: Hand Seeding P4-2: Hand Seeding With Mat P4-3: Sodding P4-4: Strip Sodding P4-5: Seed Spraying P4-6: Pick Hole Seeding P4-7: Seed Packet P4-8: Wattling

P5: Slope Protection by Structure	P5-1: Mortar Spraying P5-2: Concrete Spraying P5-3: Stone Pitching P5-4: Concrete Pitching P5-5: Gabion Pitching P5-6: Concrete Block Crib P5-7: Cast-in-place Concrete Crib P5-8: Sprayed Concrete Crib
P6: Retaining Wall	P6-1: Riprap P6-2: Grouted Riprap P6-3: Concrete Block Wall P6-4: Gravity Type Stone Masonry Wall P6-5: Gravity Type Concrete Wall P6-6: Supported Type Concrete Wall P6-7: Cantilever Type Concrete Wall P6-8: Buttressed Type Concrete Wall P6-9: Gabion Wall P6-10: Sheet Pile Wall
P7: Anchoring	P7-1: Rock Bolt P7-2: PC-Anchor
P8: Catch Work	P8-1: Catch Fill and Ditch P8-2: Catch Gabion Wall P8-3: Catch Concrete Wall P8-4: Catch Fence P8-5: Catch Wire Net
P9: Supporting Work	P9-1: Concrete Supporting
P10: Rock Shed	P10-1: Concrete Rock Shed
P11: Prevention Pile	P11-1: Steel Prevention Pile
P12: Slope Breasting	P12-1: Stone Breasting P12-2: Gabion Breasting
P13: Sabo Dam	P13-1: Concrete Sabo Dam P13-2: Gabion Sabo Dam P13-3: Steel Sabo Dam
P14: Consolidation	P14-1: Concrete Consolidation P14-2: Gabion Consolidation
P15: Bridge	P15-1: Concrete Bridge P15-2: Steel Bridge
P16: Foot Protection including Apron	P16-1: Concrete Foot Protection P16-2: Gabion Foot Protection P16-3: Grouted Riprap Apron
P17: Spurdike	P17-1: Stone Spurdike P17-2: Gabion Spurdike

P18: Spillway	P18-1: Concrete Spillway
P19: Pavement Work	P19-1: Gravel Surfacing P19-2: Bituminous Pavement P19-3: Concrete Pavement
P20: Reinforced Earth	P20-1: Reinforced Earth Wall P20-2 Inserting of Reinforcing Bar

Permanent restoration works are summarized in Table 5.2-1 (1) to (16).

TABLE 5.2-1 (1) TYPE OF PERMANENT RESTORATION MEASURES

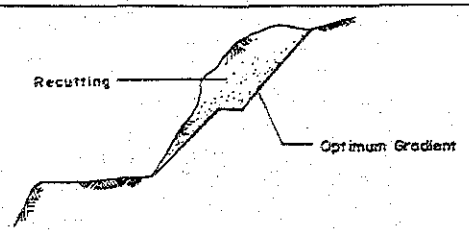
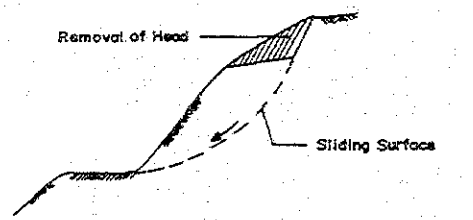
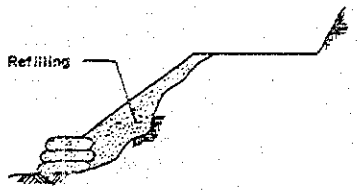
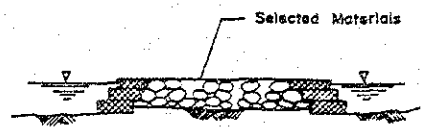
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P1: Earth Work	P1-1: Recutting	To stabilize slope by cutting it to optimum gradient.	C-F FALL Usually applied with drainage work and slope protection work.	
	P1-2: Removal of Head	To reduce sliding force by removing head portion of slope.	C-F L-SL Usually applied to landslide. (L-SL).	
	P1:3: Refilling/ Embankment	To recover failed portion of road by refilling with soil.	E-F PBr-A TBr-A CLV-D Usually applied with drainage work, slope protection work or retaining wall.	
	P1-4: Counterweight Fill	To resist sliding force by filling at foot portion of slope.	C-F E-F L-SL Usually applied to landslide (L-SL).	
	P1-5: Selected Material Fill	To fill portions influenced by water with selected materials such as sand and gravel, cobbles, etc.	E-F PBr-A TBr-A SPW-D CLV-D SW-D	

TABLE 5.2-1 (2) TYPE OF PERMANENT RESTORATION MEASURES

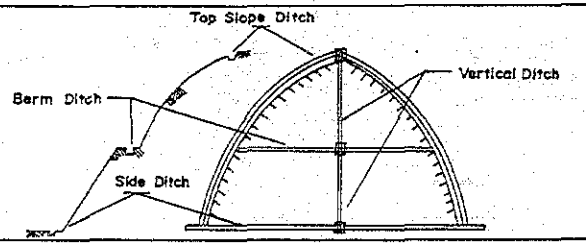
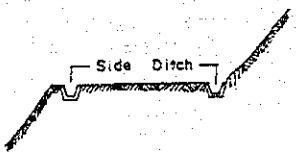
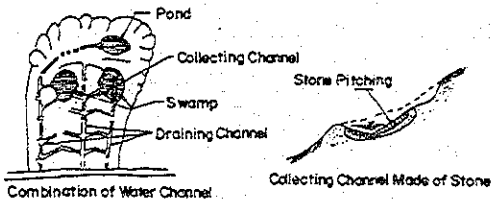
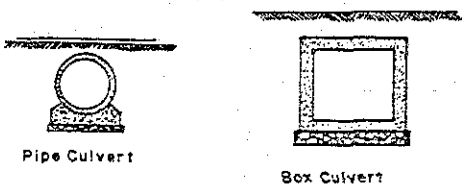
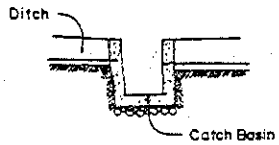
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P2: Surface Drainage	P2-1: Slope Ditch	To prevent erosion and scour of slope surface by collecting surface water running down on slope surface.	C-F FALL	
	P2-2: Side Ditch	To prevent erosion and scour of road and embankment surface by collecting surface water on road surface.	E-F PBr-A TBr-A	
	P2-3: Water Channel	To reduce sliding force by collecting and draining surface water in landslide area.	L-SL	
	P2-4: Culvert	To collect and drain water crossing road.	E-F SPW-D CLV-D	
	P2-5: Catch Basin	To connect different types of drainage facilities, reducing energy of flowing water.	Applied with other drainage works.	

TABLE 5.2-1 (3) TYPE OF PERMANENT RESTORATION MEASURES

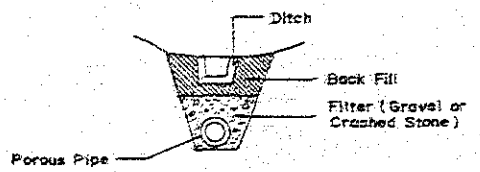
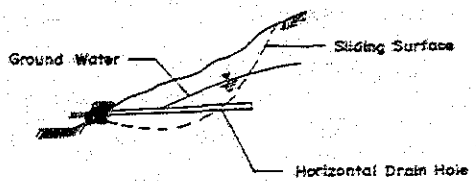
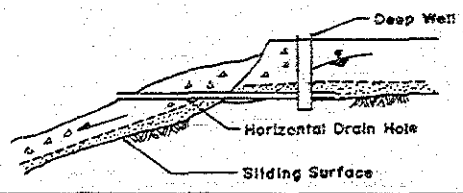
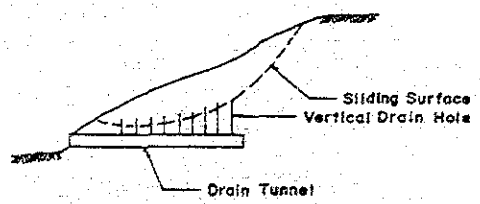
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P3: Subsurface Drainage	P3-1: Subsurface Drainer	To drain shallow groundwater and thus stabilize slope.	C-F L-SL Usually used in combination with surface drainage.	
	P3-2: Horizontal Drain Hole	To stabilize landslide-prone slope by draining groundwater in deep portion.	L-SL	
	P3-3: Deep Well	To stabilize landslide-prone slope by draining groundwater in deep portion.	L-SL Applied when horizontal drain hole is too long or crowdedly placed.	
	P3-4: Drain Tunnel	To stabilize landslide-prone slope by draining groundwater in deep portion.	L-SL Usually applied to large-scaled landslide with rich groundwater.	

TABLE 5.2-1 (4) TYPE OF PERMANENT RESTORATION MEASURES

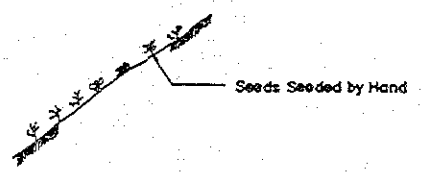
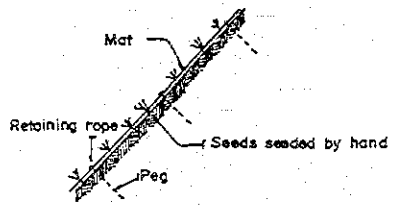
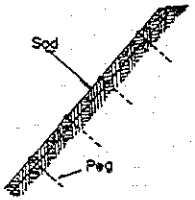
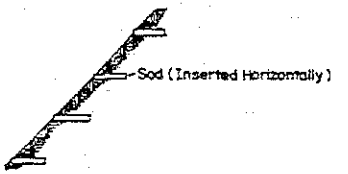
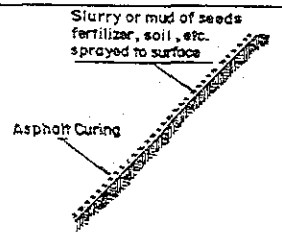
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P4: Slope Protection by Vegetation	P4-1: Hand Seeding	To prevent erosion, scour and weathering of slope by covering it with vegetation. Seeds are susceptible to be washed out by rain.	C-F E-F FALL L-SL Mainly applied to slope of soil or strongly weathered rock. Slope with gradient of greather than 0.8:1 is not applicable.	
	P4-2: Hand Seeding with Mat	To prevent erosion, scour and weathering of slope by covering it with vegetation. Slope is covered with mat after seeding to prevent washing out of seeds.	C-F E-F FALL L-SL	
	P4-3: Sodding	To prevent erosion, scour and weathering of slope by covering it with vegetation. Certain size of sod is directly laid on slope. Protection effect is immediately expected.	C-F E-F Usually applied to small area of slope.	
	P4-4: Strip Sodding	To prevent erosion, scour and weathering of slope by covering it with vegetation. Strip shaped sod is inserted on slope at some intervals.	E-F Only applied to embankment slope.	
	P4-5: Seed Spraying	To prevent erosion, scour and weathering of slope by covering it with vegetation. Mixed slurry or mud composed of seeds, water, fertilizer, soil, etc, are sprayed by pump or spray gun. Slope is covered with asphalt emulsion for curing after spraying.	C-F E-F FALL L-SL Applied to large area of slope.	

TABLE 5.2-1 (5) TYPE OF PERMANENT RESTORATION MEASURES

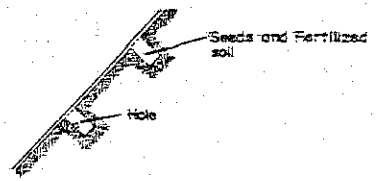
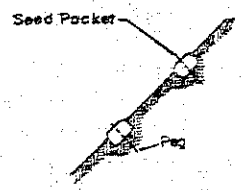
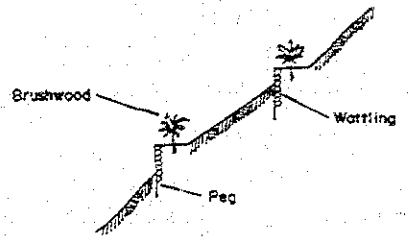
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P4: Slope Protection by Vegetation (Continued)	P4-6: Pick Hole Seeding	To prevent erosion, scour and weathering of slope by covering it with vegetation. Seeds and fertilized soil are filled into holes dug on slope.	C-F FALL Applied to slope relatively unsuitable to grow grass.	
	P4-7: Seed Packet	To prevent erosion, scour and weathering of slope by covering it with vegetation. Bags filled with seeds and fertilized soil are set on slope.	C-F FALL Applied to slope relatively unsuitable to grow grass.	
	P4-8: Wattling	To prevent erosion, scour and weathering of slope by covering it with vegetation. Interwoven fences of brushwood are made in shallow trenches on slope.	C-F FALL Mainly applied to eroded natural slope.	

TABLE 5.2-1 (6) TYPE OF PERMANENT RESTORATION MEASURES

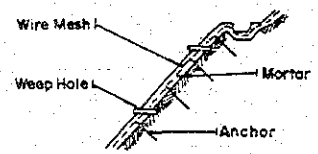
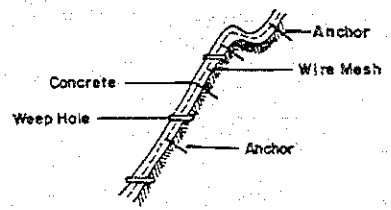
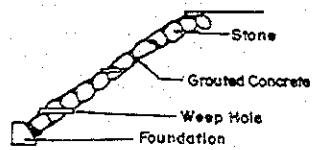
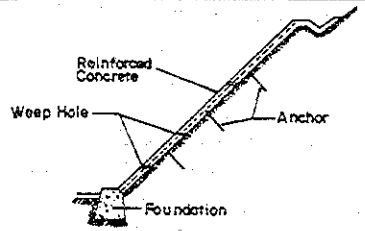
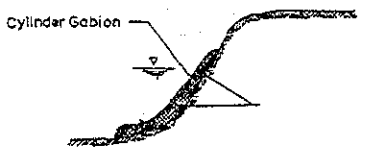
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P5: Slope Protection by Structure	P5-1: Mortar Spraying	To protect slope by covering it with sprayed mortar.	C-F FALL Applied to slope of weathered rock unsuitable to grow grass. Not applicable to slope with rich seepage water.	
	P5-2: Concrete Spraying	To protect slope by covering it with sprayed concrete.	C-F FALL Applied to slope of weathered rock unsuitable to grow grass. Not applicable to slope with rich seepage water.	
	P5-3: Stone Pitching	To protect slope by covering it with slope.	C-F E-F FALL Usually applied to slope gentler than 45°.	
	P5-4: Concrete Pitching	To protect slope by covering it with cast-in-place concrete.	C-F FALL Usually applied to slope gentler than 45°.	
	P5-5: Gabion Pitching	To protect slope by covering it with gabion.	C-F E-F PBr-A TBr-A CLV-D Usually applied to slope with seepage water or revetment of dike.	

TABLE 5.2-1 (7) TYPE OF PERMANENT RESTORATION MEASURES

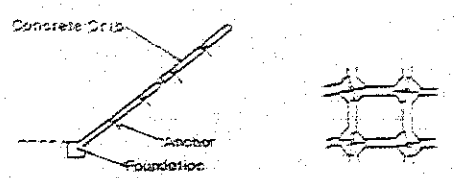
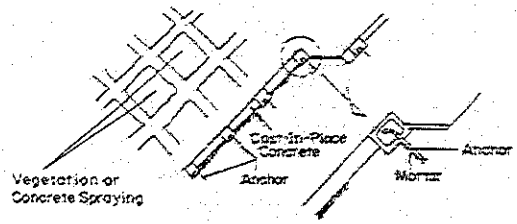
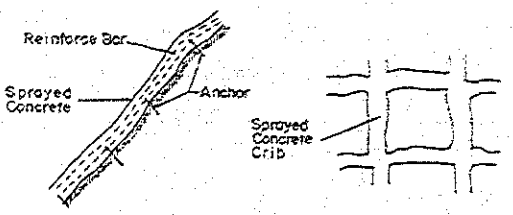
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P5: Slope Protection by Structure (Continued)	P5-6: Concrete Block Crib	To protect slope by covering it with precast concrete block crib.	C-F E-F FALL Usually applied to slope gentler than 45°.	
	P5-7: Cast-in-Place Concrete Crib	To protect slope by covering it with cast-in-place concrete crib. Resisting force against earth pressure may be expected when large size is applied.	C-F E-F FALL PBr-A TBr-A Applicable to slope steeper than 45°.	
	P5-8: Sprayed Concrete Crib	To protect slope by covering it with crib made by spraying concrete through gun. Resisting force against earth pressure may be expected when large size is applied.	C-F FALL Applicable to slope steeper than 45°. Irregularity of slope surface is not necessary to correct.	

TABLE 5.2-1 (8) TYPE OF PERMANENT RESTORATION MEASURES

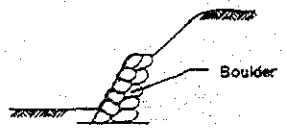
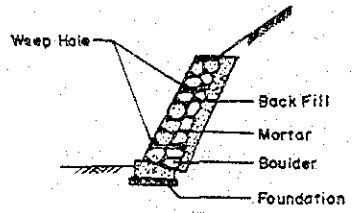
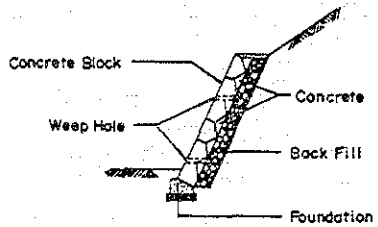
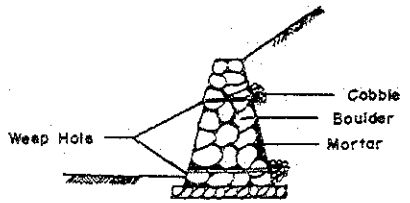
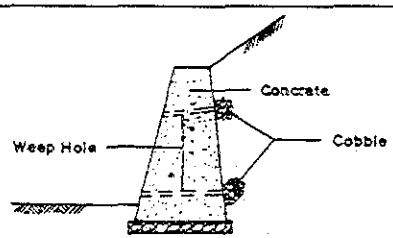
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P6: Retaining Wall	P6-1: Riprap	To protect slope from failure, resisting earth pressure. Resistant force is very small.	C-F E-F FALL Applicable to wall less than 3 m high.	
	P6-2: Grouted Riprap	To protect slope from failure, resisting earth pressure. Resistant force is small.	C-F E-F FALL PBr-A TBr-A CLV-D Applicable to wall less than 5 m high.	
	P6-3: Concrete Block Wall	To protect slope from failure, resisting earth pressure. Resistant force is small.	C-F E-F FALL PBr-A TBr-A CLV-D Applicable to wall less than 5 m high.	
	P6-4: Gravity Type Stone Masonry Wall	To protect slope from failure, resisting earth pressure.	C-F E-F FALL PBr-A TBr-A CLV-D Applicable to wall less than 5 m high.	
	P6-5: Gravity Type Concrete Wall	To protect slope from failure, resisting earth pressure.	C-F E-F FALL PBr-A TBr-A CLV-D Applicable to wall less than 5 m high.	

TABLE 5.2-1 (9) TYPE OF PERMANENT RESTORATION MEASURES

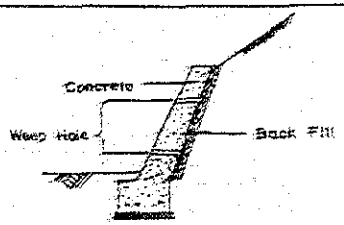
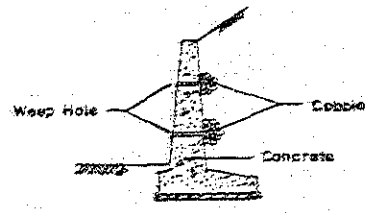
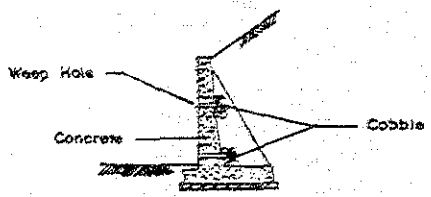
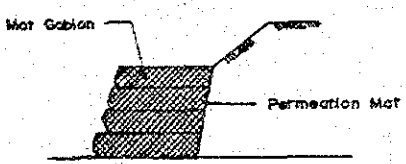
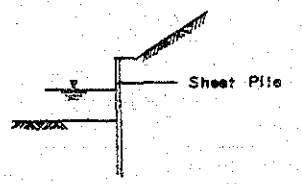
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P6: Retaining Wall (Continued)	P6-6: Supported Type Concrete Wall	To protect slope from failure, resisting earth pressure.	C-F FALL Mainly applied to cut slope. Applicable to wall less than 10 m high.	
P6-7: Cantilever Type Concrete Wall	To protect slope from failure, resisting earth pressure.	E-F TBr-A PBr-A Usually applied to wall 3 to 10 m high.	
P6-8: Buttressed Type Concrete Wall	To protect slope from failure, resisting earth pressure.	E-F TBr-A PBr-A Usually applied to wall more than 6 m high.	
P6-9: Gabion Wall	To protect slope from failure, resisting earth pressure.	E-F TBr-A PBr-A Mainly applied to embankment slope with seepage water.	
P6-10: Sheet Pile Wall	To protect slope from failure, resisting earth pressure.	E-F TBr-A PBr-A Mainly applied to bridge approach and revetment of dike.	

TABLE 5.2-1 (10) TYPE OF PERMANENT RESTORATION MEASURES

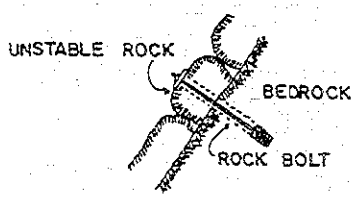
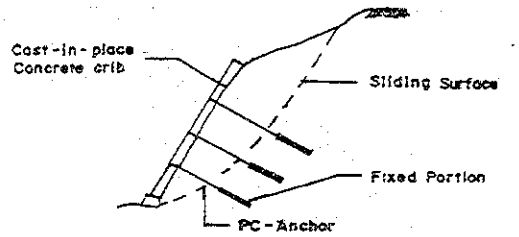
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P7: Anchoring	P7-1: Rock Bolt	To prevent unstable rocks on slope surface from falling down, by tying them to bedrock with rock bolt.	C-F FALL Usable also as supplemental measure of concrete crib.	
	P7-2: PC-Anchor	To prevent collapse and separation of bedrock by directly tightening the unstable bedrock with PC-anchor.	C-F FALL Usable also as supplemental measure of other protection works such as concrete crib, concrete pitching and retaining wall.	

TABLE 5.2-1 (11) TYPE OF PERMANENT RESTORATION MEASURES

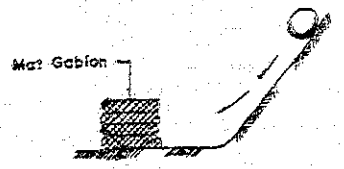
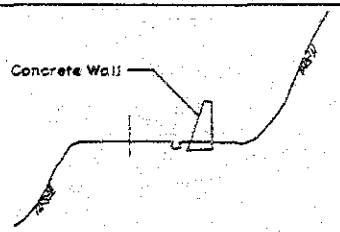
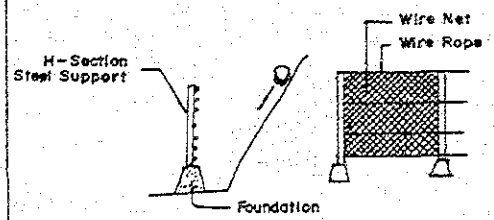
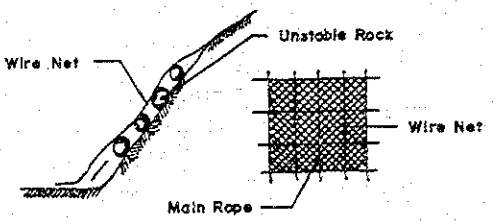
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P8: Catch Work	P8-1: Catch Fill and Ditch	To prevent falling rocks from extending to road by providing fill and ditch.	C-F D-FL FALL Wide space for deposit is required between road edge and toe of slope Applicable where wide space is available on roadside to provide space for deposite.	
	P8-2: Catch Gabion Wall	To prevent falling rocks from extending to road by providing catch gabion wall.	C-F D-FL FALL Applicable where enough space for deposit is available on roadside.	
	P8-3: Catch Concrete Wall	To prevent falling rocks from extending to road by providing catch concrete wall.	C-F D-FL FALL Applicable where enough space for deposit is available on roadside.	
	P8-4: Catch Fence	To prevent falling rocks from extending to road by providing catch fence.	FALL Applicable where enough space for deposit is available on roadside.	
	P8-5: Catch Wire Net	To prevent falling rocks from extending road by providing catch wire net.	FALL Applied where no space on roadside Unsuitable to slope of easily weathered materials.	

TABLE 5.2-1 (12) TYPE OF PERMANENT RESTORATION MEASURES

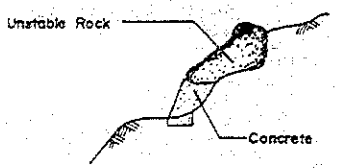
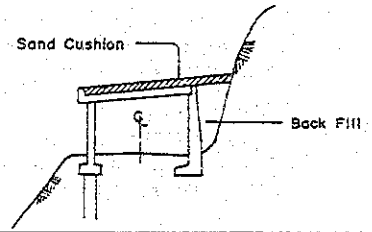
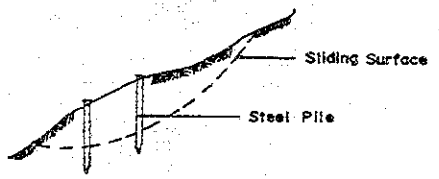
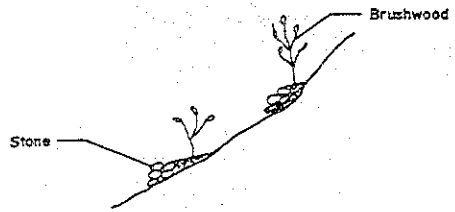
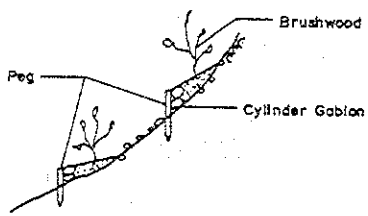
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P9: Supporting Work	P9-1: Concrete Supporting	To prevent unstable rock from falling down by supporting it with concrete.	FALL Mainly applied to supportless rocks which are big and difficult to remove.	
P10: Rock Shed	P10-1: Concrete Rock Shed	To avoid rock fall damage by covering road with shed.	C-F FALL Mainly applied to large-scaled fall.	
P11: Prevention Pile	P11-1: Steel Prevention Pile	To resist movement force of landslide by bending strength and shearing strength of pile.	L-SL Usually applied to landslide where sliding plane is deep.	
P12: Slope Breasting	P12-1: Stone Breasting	To stabilize cut slope with rocky deposit by providing riprap wall.	C-F FALL	
	P12-2: Gabion Breasting	To stabilize cut slope with rocky deposit by providing gabion wall.	C-F FALL	

TABLE 5.2-1 (13) TYPE OF PERMANENT RESTORATION MEASURES

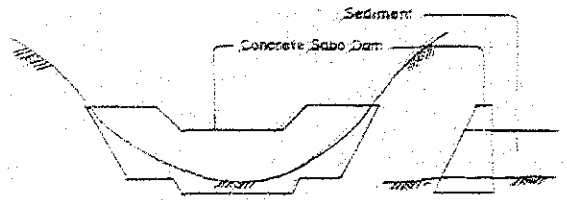
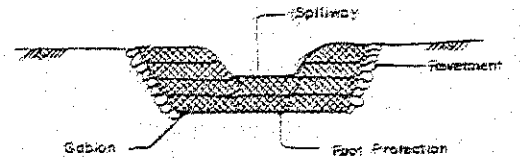
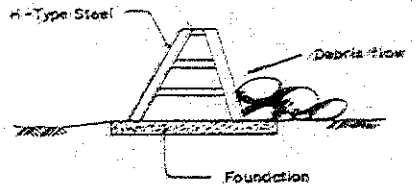
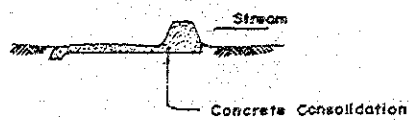
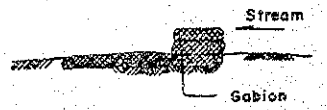
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P13: Sabo Dam	P13-1: Concrete Sabo Dam	To prevent debris flow by constructing concrete sabo dam.	D-FL Mainly applied to large-scaled debris flow.	
	P13-2: Gabion Sabo Dam	To prevent debris flow by constructing gabion sabo dam.	D-FL Mainly applied to large-scaled debris flow.	
	P13-3: Steel Sabo Dam	To prevent big rocks or trees from flowing down by providing steel sabo dam. Small-sized debris can pass through dam.	D-FL Mainly applied to large-scaled debris flow.	
P14: Consolidation	P14-1: Concrete Consolidation	To prevent scour of river bed by providing concrete consolidation like small-scaled sabo dam.	D-FL PBr-D	
	P14-2: Gabion Consolidation	To prevent scour of river bed by providing gabion consolidation like small-scaled sabo dam.	D-FL PBr-D	

TABLE 5.2-1 (14) TYPE OF PERMANENT RESTORATION MEASURES

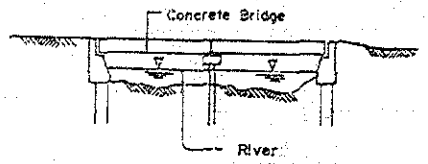
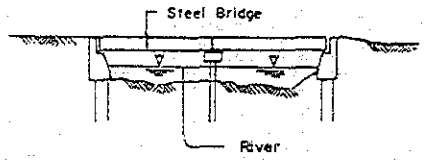
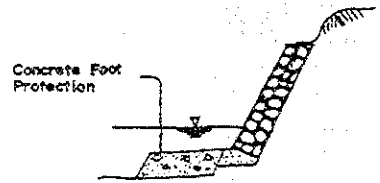
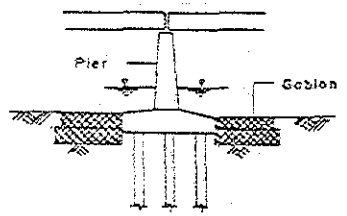
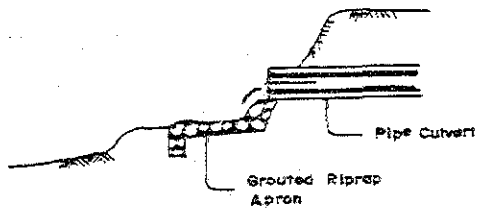
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P15: Bridge	P15-1: Concrete Bridge	To provide stream crossing facility.	D-FL, PBr-W, PBr-A, TBr-W, TBr-A, SPW-D Applied to bridge and/or bridge approach washout. Applied sometimes to debris flow to avoid damage when other counter measures are difficult and costly.	
	P15-2: Steel Bridge	To provide stream crossing facility	D-FL, PBr-W, PBr-A, TBr-W, TBr-A, SPW-D Applied to bridge and/or bridge approach washout. Applied sometimes to debris flow to avoid damage when other counter measures are difficult and costly.	
P16: Foot Protection including Apron	P16-1: Concrete Foot Protection	To prevent foot portion of structure from being scoured by stream of water by placing concrete.	E-F, PBr-A, PBr-D, TBr-A, TBr-D, CLV-D	
	P16-2: Gabion Foot Protection	To protect foot portion of structure from being scoured by stream of water by placing gabion.	E-F, PBr-A, PBr-D, TBr-A, TBr-D, CLV-D	
	P16-3: Grouted Riprap Apron	To protect foot portion of structure and/or frontage ground from being scoured by dropping water by placing grouted riprap apron.	CLV-D	

TABLE 5.2-1 (15) TYPE OF PERMANENT RESTORATION MEASURES

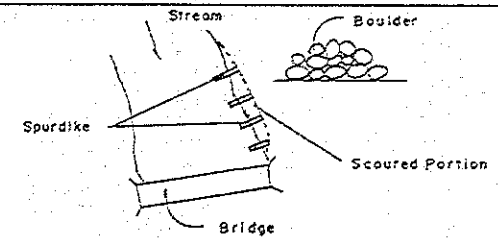
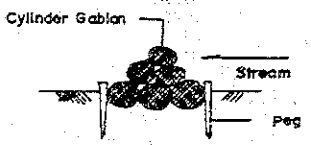
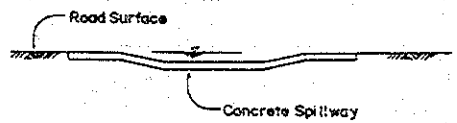
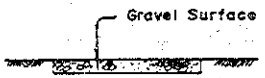
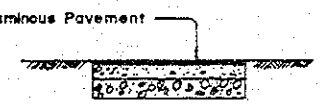
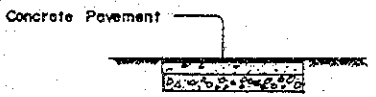
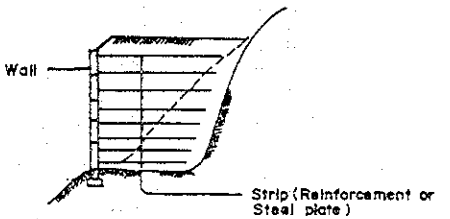
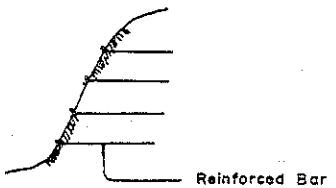
CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P17: Spurdike	P17-1: Stone Spurdike	To protect river bank and bridge approach by changing direction of stream with spurdike made of stone	E-F TBr-A PBr-A	
	P17-2: Gabion Spurdike	To protect river bank and bridge approach by changing direction of stream with spurdike made of gabion.	E-F TBr-A PBr-A	
P18: Spillway	P18-1: Concrete Spillway	To cross small stream by placing concrete spillway insted of culvert.	C-F D-FL E-F Applied only to small stream on mountainside.	

TABLE 5.2-1 (16) TYPE OF PERMANENT RESTORATION MEASURES

CLASSIFICATION	TYPE OF WORK	DESCRIPTION	APPLICATION (Type of Disaster)	ILLUSTRATION
P19: Pavement Work	P19-1: Gravel Surfacing	To reconstruct washed-out or deteriorated gravel surface.	Applied to various types of disaster of gravel surfaced road.	
	P19-2: Bituminous Pavement	To reconstruct washed-out or deteriorated bituminous pavement.	Applied to various types of disaster of bituminous pavement road.	
	P19-3: Concrete Pavement	To reconstruct washed-out or deteriorated concrete pavement.	Applied to various types of concrete pavement road.	
P20: Reinforced Earth	P20-1: Reinforced Earth Wall	To construct stable earth structure by placing reinforcing materials therein.	E-F Applied to embankment which requires perpendicular slope because of limitation of construction condition.	
	P20-2: Inserting of Reinforcing Bar	To stabilize steep slope by strengthening it with inserted reinforcing bar.	C-F	

5.2.1 P1: Earth Work

1) P1-1: Recutting

Refer to	APPENDIX I	ANALYSIS METHODS	1. Slope Stability
	APPENDIX II	STANDARD DRAWINGS	1. Cut Slope, Embankment Slope

This is to stabilize the cut slope by recutting with appropriate and stable gradient in the spot where the collapsed slope is unstable due to its steep gradient.

Application

Recutting is one of the basic measures for restoration of cut slope failure. However, recutting of the large slope is not recommendable for restoration of rural roads, because it is very difficult and costly for construction.

Recutting is useful to prevent deep failure but it is not so effective to prevent surface failure. Therefore, appropriate drainage and slope protection works should be applied to recut slopes.

Gradient of Cut Slope

It is very difficult to determine the gradient of slope by stability analysis alone because geological and soil characteristics composed of the slope are inhomogeneous and very complicated.

Therefore, the recutting gradient is generally designed by standard gradient empirically established based on past experiences of road construction at the adjacent area.

Recommendable standard gradients of the recutting are shown in Table 5.2-1.

TABLE 5.2-1 STANDARD GRADIENTS OF RECUTTING

SOIL OR ROCKS		HEIGHT OF CUT	G R A D I E N T
Hard Rock			0.5:1 to 0.8:1
Soft Rock			0.5:1 to 1.2:1
Sand	Not dense, or poorly graded		1.5:1 or above
Sandy Soil	Dense	Less than 5 m 5 to 10 m	0.8:1 to 1.0:1 1.0:1 to 1.2:1
	Not dense	Less than 5 m 5 to 10 m	1.0:1 to 1.2:1 1.2:1 to 1.5:1
Sandy Soil mixed with gravel or rock masses	Dense, or well graded	Less than 10 m 10 to 15 m	0.8:1 to 1.0:1 1.0:1 to 1.2:1
	Not dense, or poorly graded	Less than 10 m 10 to 15 m	1.0:1 to 1.2:1 1.2:1 to 1.5:1
Cohesive Soil		0 to 10 m	0.8:1 to 1.2:1
Cohesive Soil mixed with rock masses or cobble stones		Less than 5 m	1.0:1 to 1.2:1
		5 to 10 m	1.2:1 to 1.5:1

Where the slope is composed of one kind of soil or rock, recutting with uniform gradient is recommended. On the other hand, where the slope is composed of different kinds of soil and rocks, different gradient for each soil and rock layer is adopted as shown in Figure 5.2-1.

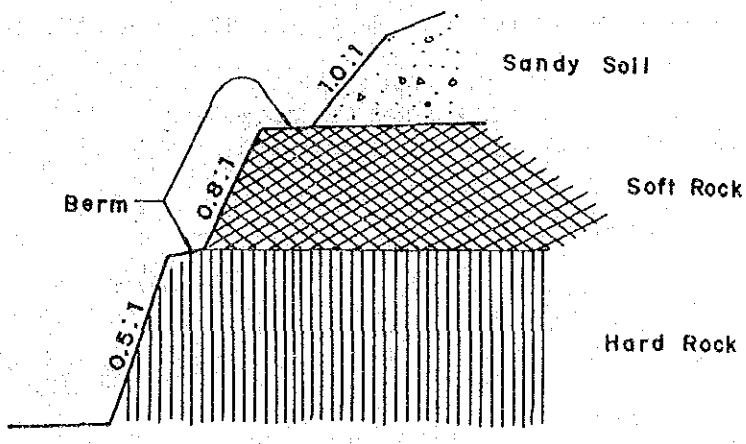


FIGURE 5.2-1 DIFERRENT GRADIENT OF CUT SLOPE

Berm

The berm shall be provided at every 5 to 10 m in height of a slope which layer is composed of uniform soil or rock layer. In case where the slope is composed of different kinds of soil or rock layers, the berm is provided at the boundary between permeable and non-permeable layer, as shown in Figure 5.2-2.

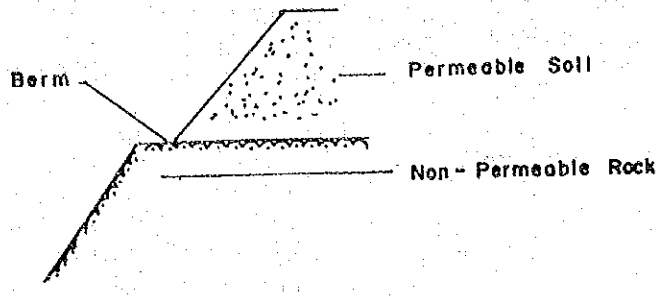


FIGURE 5.2-2 LOCATION OF BERM

The berm prevents erosion of the slope surface by intercepting speed and concentration of the surface water flowing down on the slope. It can also be used as a sidewalk for inspection purpose.

Where the slope is composed of stable soil or rock layer against erosion, the berm is usually made at 5 to 10% of gradient toward the bottom of slope as shown in Figure 5.2-3.

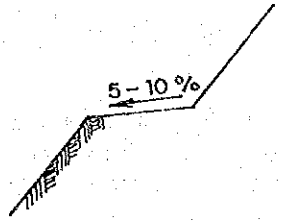


FIGURE 5.2-3 GRADIENT OF BERM WITHOUT BERM DITCH

On the other hand, where the slope is composed of soil or erosive rock layer, the gradient of the berm is made in the reverse direction and a ditch is constructed to drain the surface water, as shown in Figure 5.2-4.

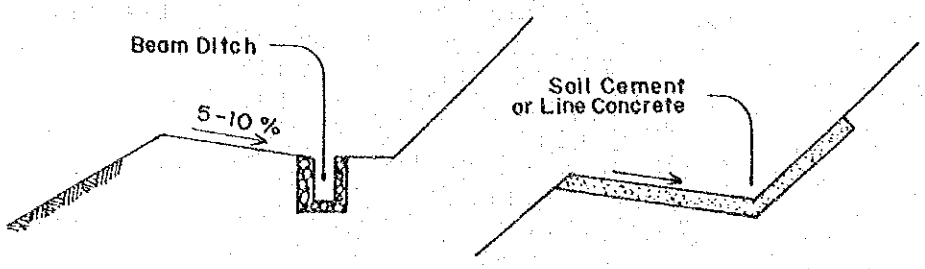


FIGURE 5.2-4 GRADIENT OF BERM WITH DITCH

Construction

A small size of recutting is usually done by hand works.

For medium or large recutting work for common soil or soft rock slopes, such a machine as bulldozer or backhoe can be used under the site condition which has enough space to operate it.

Stable hard rock which require blasting for excavation must be excluded from an object of the recutting.

At the start, finishing stake must be properly placed in order to guide and show the planned line of slope as shown in Figure 5.2-5.

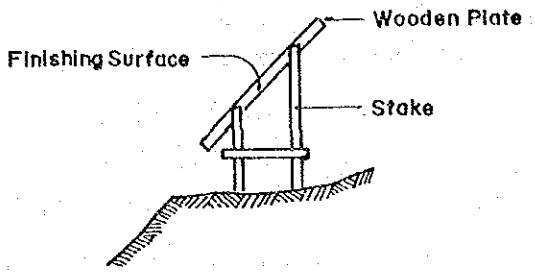


FIGURE 5.2-5 FINISHING STAKE

To shave off rocks up to the planned line of slope, pickage or coal pick hammer is used in case of soft rock.

After shaving off rocks, remaining unstable materials shall be carefully removed with pick hammers or bars.

For common soil slope, the main portion is excavated with machines at the start, leaving the soil with 20 to 30 cm in thickness from the planned line of a slope. Then, shaving off the common soil is carried out with picks or hoes following the finished surface indicated by the finishing stakes.

2) P1-2: Removal of Head

This is to remove the head portion of cut slope failure or landslide to reduce the sliding force. The situation which requires removal of head is illustrated in Figure 5.2-6.

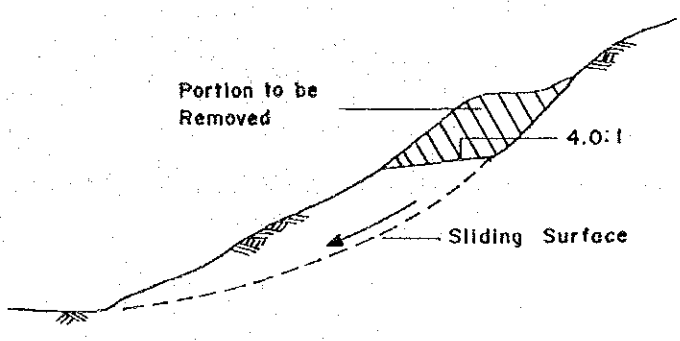


FIGURE 5.2-6 REMOVAL OF HEAD

Removed portions is graded at a gentler gradient than 4.0:1 and is protected by vegetation. Ditches to drain surface water are generally provided on the graded slope.

Removing work should be carried out from the upper part to the lower part so as not to disturb the stability of the slope during construction.

Construction is carried out in the same way as mentioned in recutting. Removal of head is one of effective measures for small to medium size of landslide. However, this is commonly applied together with subsurface drainage, prevention pile, etc.

3) P1-3: Refilling/Embankment

This is to refill collapsed portions of embankment in order to reopen the road for traffic.

Important notes in design and construction of the refilling are as follows :

- To apply appropriate gradient of slope
- To construct with sufficient compaction

Application

Refilling is carried out for almost all embankment related disasters. In most cases, it is incorporated with drainage work and slope protection work.

Gradient

The gradient and shape of refilling can be determined through a stability analysis.

In general, however, they are given by referring standard gradients empirically established depending on height and materials of refilling. Recommendable standard gradients are shown in Table 5.2-2.

TABLE 5.2-2 STANDARD GRADIENT OF REFILLING

Filling Materials	Height of Fill (m)	Gradient
Well grading sand, gravel, or sand mixed with gravel	Less than 5 m.	1.5:1 to 1.8:1
	5 to 15 m.	1.8:1 to 2.0:1
Poor grading sand	Less than 10 m.	1.8:1 tO 2.0:1
Rock masses	Less than 10 m.	1.5:1 to 1.8:1
	10 to 20 m.	1.8:1 to 2.0:1
Sandy soil, hard clayey soil, or hard clay	Less than 5 m.	1.5:1 to 1.8:1
	5 to 10 m.	1.8:1 to 2.0:1
Soft clayey soil	Less than 5 m.	1.8:1 to 2.0:1

Berm

A berm of 1.0 to 2.0 m in width should be provided every 5.0 to 7.0 m in height from top of refilling.

The berm is provided to prevent erosion on the slope surface by concentration of the surface water flowing down on the slope. It can be also used as a sidewalk for inspection purpose.

Protection of Slope Surface

The slope of refilling is usually protected with vegetation. Where refilling materials is unsuitable for vegetation such as gravel and sand, the surface of refilling should be covered with fertile clayey soil as shown in Figure 5.2-7. This is called as a Blanket Soil.

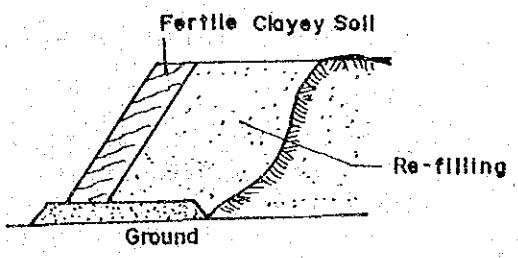


FIGURE 5.2-7 COVER OF SLOPE (BLANKET SOIL)

In such cases, stone, concrete or riprap pitching can also be applied as slope protection, a little steeper gradient up to 0.8:1 can be adopted, together with pitching works where the height of refilling is not so high. This is shown in Figure 5.2-8.

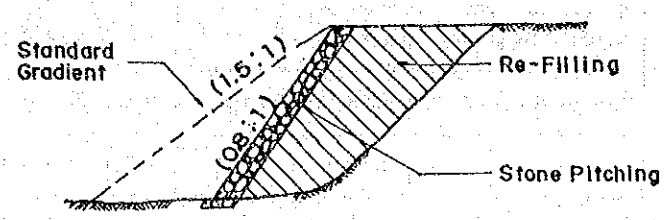


FIGURE 5.2-8 ALLOWABLE GRADIENT IN CASE THAT PITCHING WORK IS APPLIED

Refilling with High Potential of Failure

- Refilling on Slant Ground

  Refilling constructed on slant ground is always face to danger of collapse by seepage water from the ground.

  In this case, drainage layer should be designed to drain groundwater as shown in Figure 5.2-9.

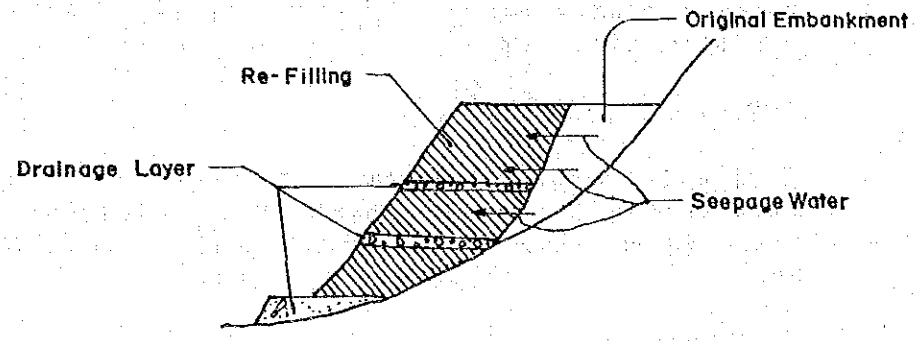


FIGURE 5.2-9 DRAINAGE LAYER FOR REFILLING

- Refilling on Soft Ground

  Refilling on soft ground is unstable and also causes settlement during filling work and sometimes after completion. As the measure for unstability and settlement, sand mat, brushwoods or geotextile should be spreaded on the foundation ground of refilling as shown in Figure 5.2-10.

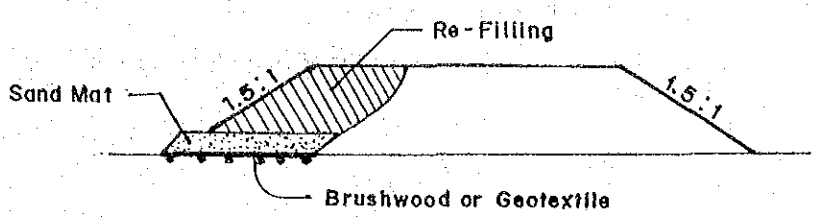


FIGURE 5.2-10 MEASURE OF REFILLING ON SOFT GROUND

Construction

One of main causes of embankment failure is the infiltration of rain water into the fill. This is mainly brought by insufficient compaction of the fill.

As an effective compaction method, horizontal thin layer compaction method is usual applied. This method to compact every horizontal layer with 20 to 30 cm in thickness by compaction equipment such as tire roller and vibrating roller.

However, refilling is generally required at narrow and steep places where the common compaction equipment is inapplicable. In such condition, filling material should be compacted at every thin layer using vibratory plate compactor or rammer as shown in Figure 5.2-11.

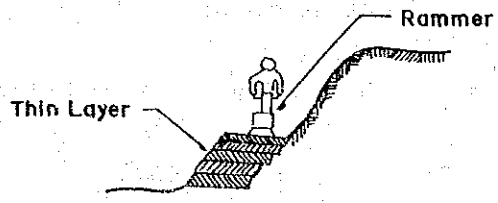


FIGURE 5.2-11 COMPACTION FOR REFILLING

The slope can also be compacted by using the compaction equipments as shown in Figure 5.2-12.

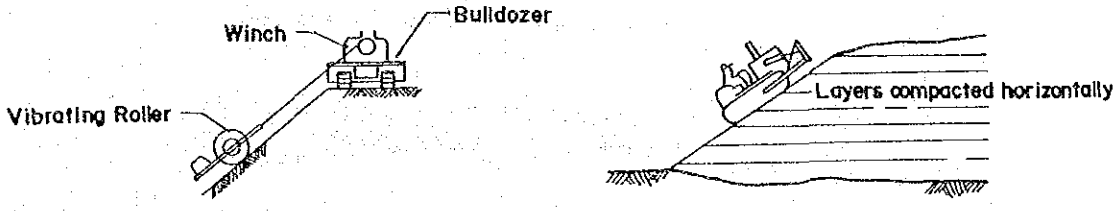


FIGURE 5.2-12 COMPACTION OF SLOPE BY VIBRATING ROLLER AND BULLDOZER

4) P1-4: Counterweight Fill

This is to fill at the toe of slope to resist the sliding force, as a measure for cut slope failure or landslide.

This is illustrated in Figure 5.2-13.

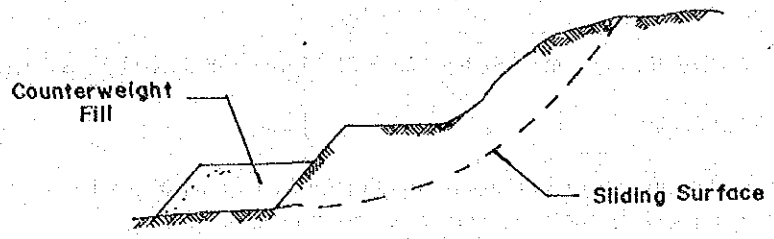


FIGURE5.2-13 COUNTERWEIGHT FILL

This work can be applied only at the place where there is enough space for construction of fill at the toe of the slope.

At the toe of the slope, there is usually seepage of ground water. The counterweight fill, therefore, should be constructed with permeable materials such as sand and gravel, or rock masses.

Construction should be carried out following the methods mentioned in 3) P1-3: Refilling/Embankment.

5) P1-5: Selected Material Fill

Refilling at the place affected by water should be done with selected good material such as sand and gravel, crushed stone, cobble, etc.

For example, this method is applied to such a case as inner fill of the collapsed spillway.

This is shown in Figure 5.2-14.

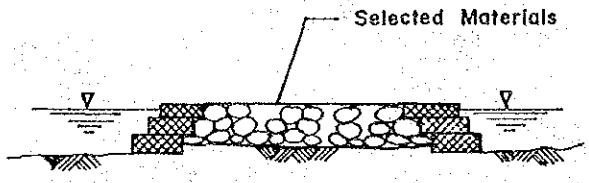


FIGURE 5.2-14 SELECTED MATERIAL FILL FOR SPILLWAY RESTORATION

Wheel loader, dump truck and compaction equipment are required for construction.

5.2.2 P2: Surface Drainage

Refer to APPENDIX I	ANALYSIS METHODS	2. DRAINAGE
APPENDIX II	STANDARD DRAWINGS	2. SIDE DITCH, DITCH BASIN

This is to collect and drain surface water in order to prevent road slopes from erosion and/or scour.

The facilities for this purpose are as follows:

P2-1: Slope Ditch
P2-2: Side Ditch
P2-3: Water Channel
P2-4: Catch Basin

Besides the above facilities, pipe or box culvert is used as a cross drainage facility.

These drainage facilities are usually designed in new construction stage. However, they should be considered as one of important restoration measures in order to prevent recurrence of the disaster.

1) P2-1: Slope Ditch

This is to provide ditches on the slope to drain and collect surface water flowing down on the slope surface.

Slope ditches are classified as follows :

- Top Slope Ditch

  Top slope ditch is designed based on the volume of discharge with some allowances considering terrain, slant and soil. It is provided along the entire length of the top of slope to avoid down-flow of surface water from the surrounding area. Every end of ditch is connected with existing drainage system.

- Berm Ditch

  Berm ditch provided on the berm is to drain surface water on the slope to prevent the slope from erosion.

– Vertical Ditch

Vertical ditch is to drain the water from top to the side ditch at the toe of the slope.

The location of these ditches is shown in Figure 5.2-15.

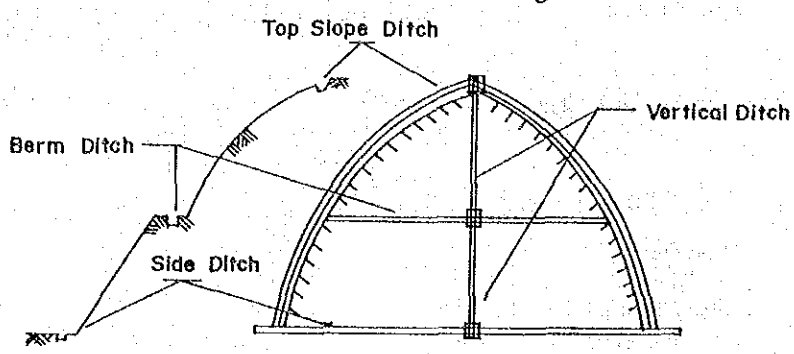


FIGURE 5.2-15 LOCATION OF SLOPE DITCH

The following types of ditches are usually applied :

– Naked Ditch (Figure 5.2-16)

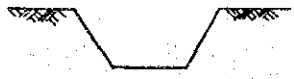


FIGURE 5.2-16 NAKED DITCH

This is suitable for impermeable soil ground.

– Soil Cement Ditch (Figure 5.2-17)

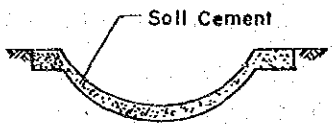


FIGURE 5.2-17 SOIL CEMENT DITCH

Mixed ratio of the cement is about 6% in dry weight.

– Grouted Riprap Ditch (Figure 5.2-18)

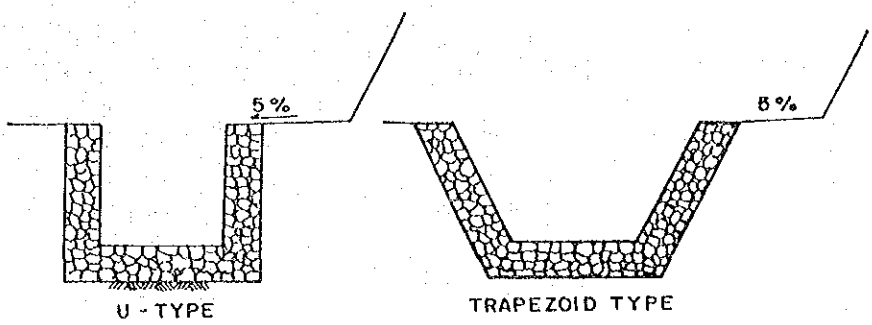


FIGURE 5.2-18 GROUTED RIPRAP DITCH

This can be used for all types of ditches.

– Concrete U-Type Ditch (Figure 5.2-19)

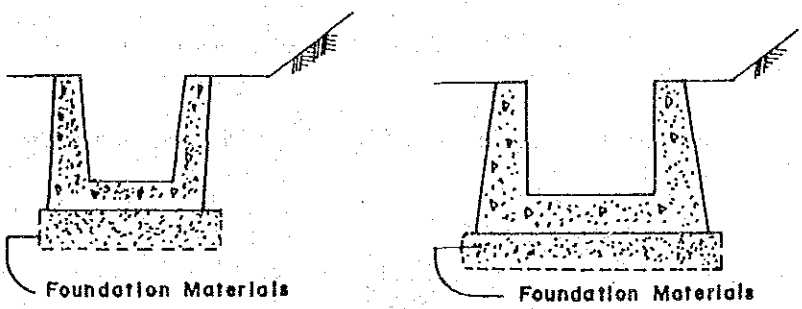


FIGURE 5.2-19 CONCRETE U-TYPE DITCH

This can be used for all types of ditches.

For the case that the concrete U-Type ditch is applied to the vertical ditch, an example of the arrangement is shown in Figure 5.2-20.

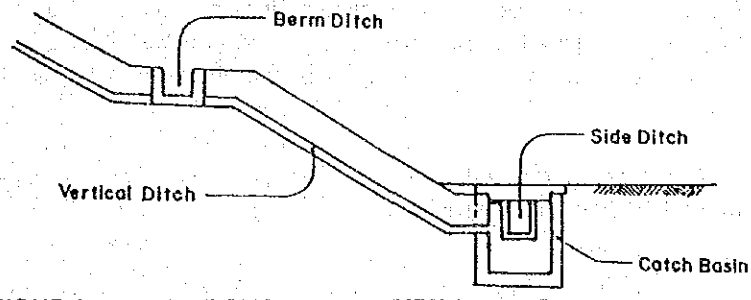


FIGURE 5.2-20 CONCRETE U-TYPE VERTICAL DITCH

When the gradient of the slope is steeper than 1.0:1, the vertical ditch is usually covered with a lid.

2) P2-2: Side Ditch

The side ditch is mainly constructed at a toe of the cut slope. However, surface water concentrates at the inner curve portion and flows down on the slope surface of embankment causing erosion/scour thereof. For this portion, the side ditch is also provided on the shoulder on the embankment side as shown in Figure 5.2-21.

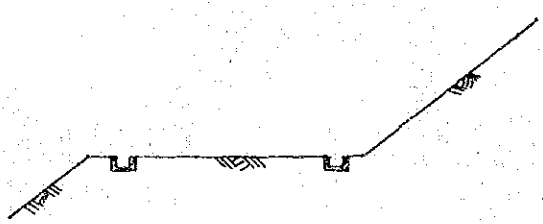


FIGURE 5.2-21 LOCATION OF SIDE DITCHES AT INNER CURVE PORTION

All types of ditches applied to the slope ditch can also be used as the side ditch.

3) P2-3: Water Channel

For the landslide, water channels are usually arranged to drain surface water from the landslide area to outside.

Stone pitching channel as shown in Figure 5.2-22 is a commonly used type.

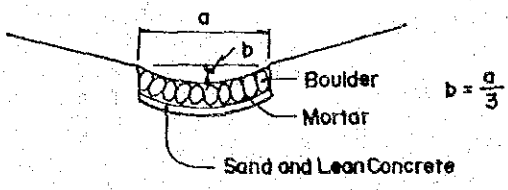


FIGURE 5.2-22 STONE PITCHING WATER CHANNEL

4) P2-4: Culvert

Culverts are classified into three types; pipe, box and arch culvert. It is economical that the pipe culvert is applied for small discharge and box culvert for relatively large discharge. Arch culvert is applied to a high embankment where load on the culvert is large.

Even if small volume of discharge is estimated, the diameter of pipe culvert should be more than 60 cm to the maintenance purpose.

The culvert should be set at the same gradient of the existing stream as a general rule. However, gradient steeper than 10% is not preferable because of difficulty in construction and danger of sliding.

Since the inlet and outlet of the culvert are easily scoured in general, the appropriate protection such as wing, revetment and foot protection should be incorporated.

5) P2-5: Catch Basin

At places where the length or the gradient of drainage flow are large, catch basins are installed to reduce the energy of running water.

An example of catch basin is shown in Figure 5.2-23.

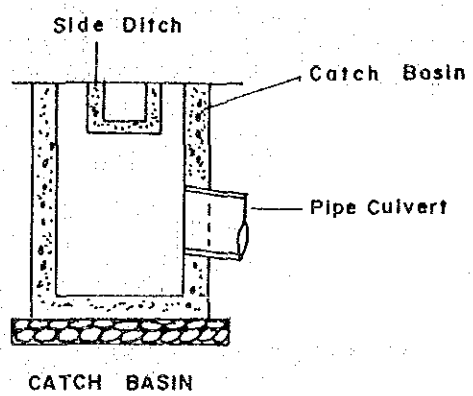


FIGURE 5.2-23 CATCH BASIN

5.2.3 P3: Subsurface Drainage

Refer to APPENDIX II STANDARD DRAWINGS 3. SUBSURFACE DRAINER

Groundwater, spring water and seepage water under the surface of slope should be drained to keep stability of the slope.

Subsurface drainage facilities are generally classified according to the depth of ground water existing, as follows:

- For shallow ground water

  P3-1: Subsurface Drainer

- For deep ground water

  P3-2: Horizontal Drain Hole
  P3-3: Deep Well
  P3-4: Drain Tunnel

1) P3-1: Subsurface Drainer

Closed Conduit

Closed conduit and closed conduit with open ditch are most suitable to collect and drain shallow groundwater, existing about 3 m below ground surface.

They are effective measures particularly to groundwater in soils with small coefficient of permeability.

These conduits are constructed in such a way that a fascine or gabion is installed in the ditch excavated to a predetermined depth as shown in Figure 5.2-24. Vinyl cloth or asphalt board is laid below them to prevent any leakage. Gravel is placed with filter around and above them to prevent clogging. Where the amount of collected water is large, perforated pipes are sometimes used. Catch basins or manholes are normally installed at every 20 to 30 m of conduit and are connected to surface water ditch.

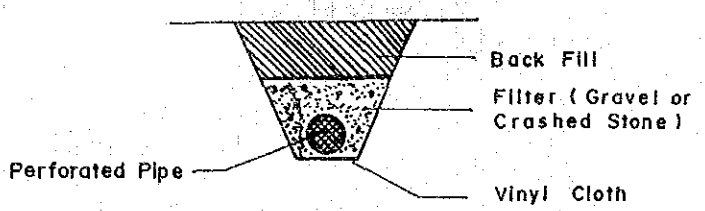


FIGURE 5.2-24 CLOSED CONDUIT

The flow of shallow groundwater, which is similar to surface water, is changed by terrain and is concentrated to valley or concaves. Closed conduit with open ditch is used in these cases to collect groundwater and surface water at the same time. A typical structure is shown in Figure 5.2-25.

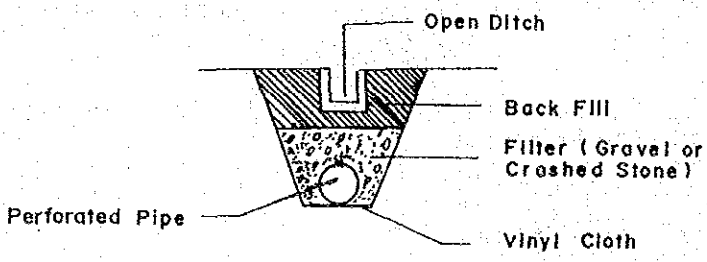


FIGURE 5.2-25 CLOSED CONDUIT WITH OPEN DITCH

Gabion Subsurface Drainer

For a slope with extensive spring water, gabion is laid near the toe of slope as shown in Figure 5.2-26. Gabion is useful not only for drainage but also for preventing failure at the toe of slope.

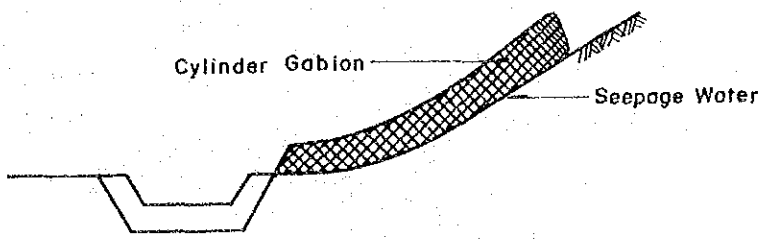


FIGURE 5.2-26 GABION SUBSURFACE DRAINER

Subsurface Drainage System for Shallow Groundwater

To collect and drain groundwater permeating into the slope and seepaging near the ground surface, groundwater drainage system should be designed as shown in Figure 5.2-27.

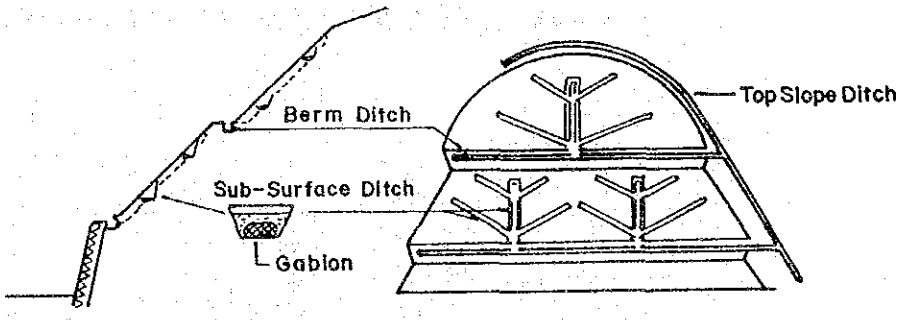


FIGURE 5.2-27 SUBSURFACE DRAINAGE SYSTEM

Subsurface drainage facilities are laid in the form of U-shape or Y-shape depending upon the conditions of seepage in the slope. Catch basins or perforated pipes embedded in ditches are preferable at places where large seepage water exists or where several ditches meet each other.

2) P3-2: Horizontal Drain Hole

Where spring water comes out to the surface of slope, holes are drilled and perforated pipes are inserted to the drilled holes to drain water as shown in Figure 5.2-28.

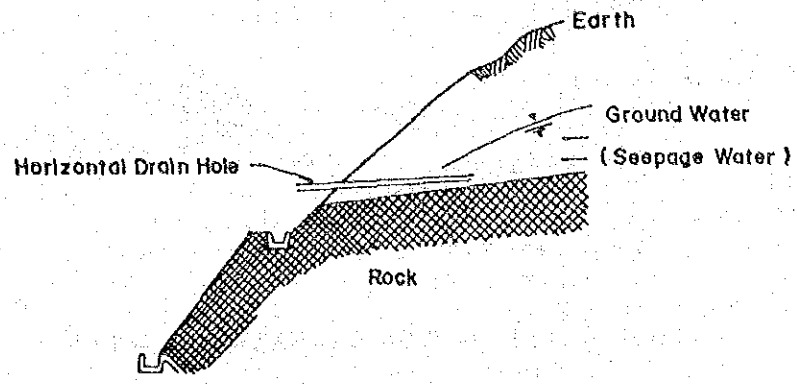


FIGURE 5.2-28 HORIZONTAL DRAIN HOLE

Where stability of a slope is likely to decrease due to seepage water, horizontal drain hole drilled by boring should be planned.

The location of horizontal drain holes should be spread as shown in Figure 5.2-29, and a pipe with strainer should be inserted. The end of hole may sometimes be scoured due to discharge, thus it should be protected by gabions or concrete wall.

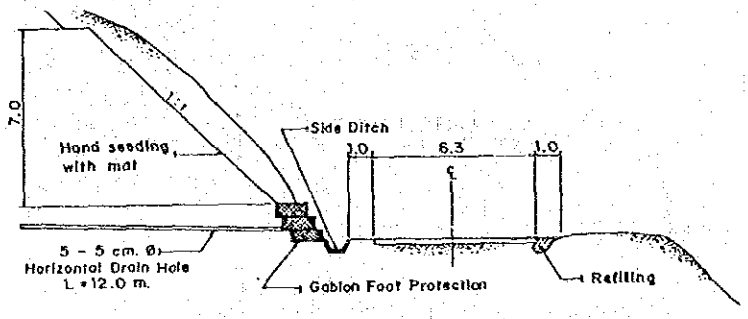


FIGURE 5.2-29 HORIZONTAL DRAIN HOLE

3) P3-3: Deep Well

Deep well is used where horizontal drain hole is too long or groundwater is concentrated at some place.

Groundwater is usually collected through the well and horizontal drain holes extend from the well. A diameter of the well is required to be 2.5 to 4.0 m so that the boring work can be done in the well.

Deep well is made by reinforced concrete or corrugated pipe and 3 to 4 inches pipe in diameter is usually used as drain pipe.

An example of deep well is illustrated in Figure 5.2-30.

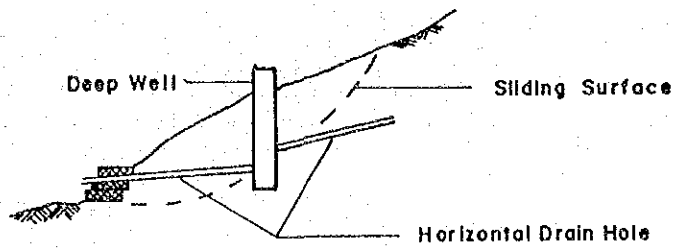


FIGURE 5.2-30 DEEP WELL

4) P3-4: Drain Tunnel

This is applied to a large-scaled landslide where sliding surface reaches groundwater level.

Drain tunnel is the most effective measure to drain groundwater although costly.

An example of the drain tunnel is illustrated in Figure 5.2-31.

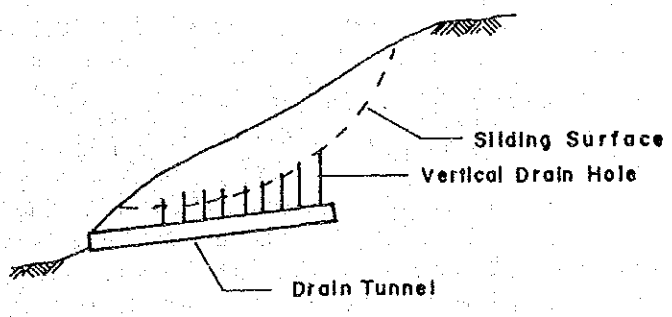


FIGURE 5.2-31 DRAIN TUNNEL

5.2.4 P4: Slope Protection By Vegetation

Refer to APPENDIX II STANDARD DRAWINGS 4. VEGETATION

Slope protection by vegetation (vegetation work) is designed to prevent erosion due to rain water by means of plants growing on the slope and roots of the plants firmly binding materials at the slope surface.

Vegetation is the most recommendable measure to protect the slope, since the construction cost are relatively low in most cases and the vegetation creates a beautiful view.

Survey for Vegetation Work

For successful vegetation work, weather and soil conditions of the site should be surveyed and the species of grasses to assure the complete growth should be selected based on the results of soil survey.

- Area, Height, etc. of Slope

  Machinery work is suitable, when the slope is large and located closely to each other. However, handwork is more economical, when the area is small and the places of work are scattered. Selection of the type of work depends on the maximum height of slope.

- Conditions of Adjacent Land

  Sprayed materials may sometimes scatter and pollute houses or structures, therefore, surveys for scattering and pollution must be made in advance.

- Soil Conditions (physical and chemical composition, water content and hardness of soil, presence of spring water, evenness, etc.)

  Surveys should be carried out to check whether the soil is easily eroded such as sandy soil, whether the rooting of plants is difficult such as clay and mudstone, whether the growth of plants is difficult because of strong acidic soil, etc, and whether there is much spring water. The finishing requirements of the slope depends upon the kind of work. For example, a certain irregularity is rather desirable for seed spraying, while the smooth surface is needed for sodding mats. The degree of finish of slope surface, therefore, should be determined before seeding work.

- Weather Conditions (air temperature, rainfall, slope direction, degree of sunniness)

  Yearly mean air temperature should be checked to determine what types of plant will grow, and daily mean air temperature to determine what season is suited to seeding work. The slope direction and degree of sunniness should also be checked to judge which is better, the sun-tolerance grasses or the shade-tolerance grasses.

  The weather and possible heavy rains during scheduled period of work should be examined to select the type of work and the curing method suitable to these conditions.

- Availability of Materials and Equipment

  Availability of materials used for vegetation in the region or the country, especially for seeds, grasses or plants, is one of the most important survey items for the selection of the type of work.

  If the mechanical vegetation works are not popular and labor intensive works are desirable in the country, the types of work by manpower should be selected.

Plants for Slope Protection

In the Manual of Restoration and Erosion Control for the Philippines, H.J. Weidelt, 1976, some promising species growing in the Philippines are listed. Many of them have been tested successfully in slope and bank protection.

Trees are considered to be unsuitable for slope protection because they grow high. Therefore, those except trees are quoted from the above Manual as follows:

- Grasses:
  - Weeping Love Grass (Eragrostis curvula): This specie has been introduced from Southern Africa to other tropical countries with a well balanced wet and dry seasons. It is widely used for erosion control in Japan and Taiwan, particularly for hydro- seeding. An advantage is that this grass does not completely dry up during the dry season.
  - Bermuda Grass (Cynodon dactylon): Equally suitable for dry and moist sites; stolon-forming, excellent soil cover particularly for banks and waterways; propagation usually by planting stolons or by sodding.
  - Kikuyu Grass (Pennisetum clandestinum): As a native of the highlands of East Africa, this stolon-forming grass can only thrive under somewhat moist conditions; the specie has a dense root system and be propagated by planting stolons or small sods; widely used for erosion control in Taiwan.

- Vines:
  - Kudzu (Pueraria thunbergiana, syn. P. hirsuta): For erosion control, this specie is considered the best of all the kudzus; propagation mainly by cuttings, because seed production is generally low; perennial.
  - Pueraria phaseoloides (syn. P. javanica): This is more used as a fodder plant and for lower elevations; perennial.
  - Centrosema (C. pubescens): A fast growing vine; shade resistant, perennial and quite tolerant of dry sites.
  - Perennial lespedeza (Lespedeza cuneata): An excellent cover plant, even on badly eroded sites; draught resistant.
  - Lipai (Mucuna nigricans): A perennial vine thriving well on dry sites; seed can be collected in February/March; the leaves are very itchy.
- Shrubs
  - Guava (Psidium guava): Very modest soil requirements; able to grow on practically all sites; very dense and widespread root system.
  - Lantana camara: Quite adaptable even to poor sites; deep root system: propagation by cuttings.
  - Nauclea spp: A shrub growing on the driest sites, even in clefts of rocks on southern slopes; seed ripens in March/April; frequent in the Binga/Ambuklao area.
  - Trompet Tree (Datura alba): More of a shrub than a tree; fast growing, poisonous; propagation by cuttings; for medium and high elevations only.
  - Mexican Sunflower (Helianthus tuberosus): Forms shrubs with lignified stems; sprouts easily and grows rapidly; most useful brush species for biological engineering in the medium and higher elevations.
  - Dumanay (Homonoia riparia): A medium-sized shrub found in the beds of creeks and streams or along their banks; useful for river bank stabilization, survives flooding; slow growth; propagation by cuttings.

- Maguey (Agave cantala): Very draught resistant; provides cover for degraded soils; propagation by suckers or the viviparous embryos of the inflorescence (bulbils).

1) P4-1: Hand Seeding

Seeds of desirable grass and vine species are directly sowed by hand in horizontal grooves made on the slope.

The horizontal grooves are made at intervals of 10 cm to prevent sowed seeds from washing out by rain as shown in Figure 5.2-32.

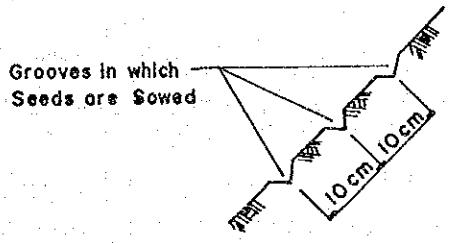


FIGURE 5.2-32 GROOVES MADE ON SLOPE

According to an experience done by DENR (Department of Environment and Natural Resources) and JICA in the Philippines, seeds of centrosema and colopogonium showed a good result. Seeds were sowed at average of 1 gram/m^2. (Refer to Manual for Erosion Control Works, 1988).

2) P4-2: Hand Seeding with Mat

This is to cover the slope on which seeds directly sowed with mats. The slope is protected by the mat until germination.

Material of mat is roughly woven cloth, paper, straw blind, straw mats and cut-straw felt. Some mats are reinforced with nets.

In the RP-Japan Forestry Development Project being conducted by DENR and JICA, the mat was made with cogon and applied as a erosion control work of the slope.

The procedures are as follows:

- Cogon mats are prepared by using "matting frame" shown in Figure 5.2-33.

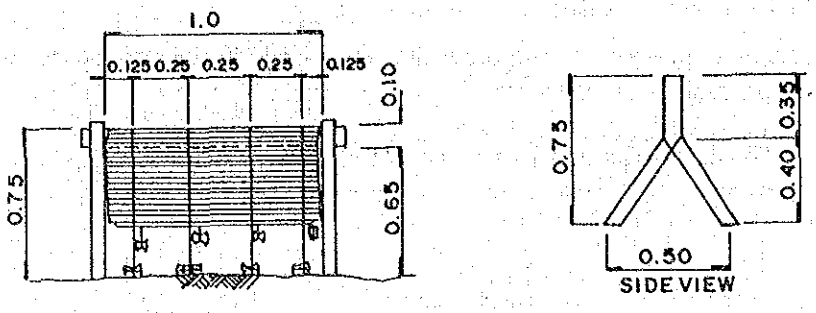


FIGURE 5.2-33 MATTING FRAME

- Seeds of centrosema and colopogonium are sowed by hand in horizontal grooves made at intervals of 10 cm on the slope. Seeds to be sowed are about 1 gram/m^2.
- Cogon mats are set on the slope on which seeds are sowed with small pegs in all corners as shown in Figure 5.2-34. Pegs are preferred to be brushwoods with sprouting ability like kakawate.

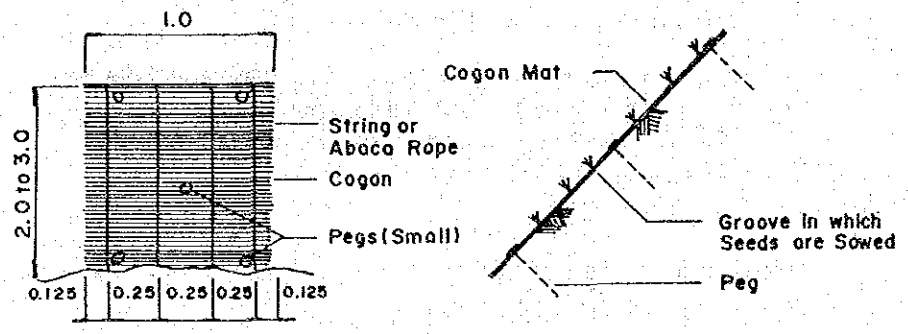


FIGURE 5.2-34 SETTING OF COGON MAT

3) P4-3: Sodding

This is the conventional method in which sods are directly laid on the slope surface. Therefore, protection effects can be realized immediately after the placement of sods.

For this work, the standard size of the field sod is 36 x 28 cm, and ten units of sods are good for 1 square meter.

When laying the sods, they are laid flat directly on the slope surface with long side of sod put horizontally. No joints are provided to prevent scour starting from the joints. Each sod shall be tightly contacted the slope surface by hitting it with a tamping board. More than two pegs are used per sod unit (Figure 5.2-35).

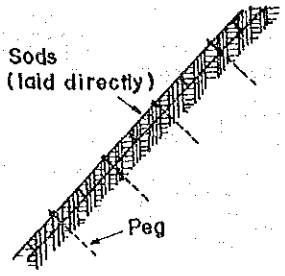


FIGURE 5.2-35 SODDING

4) P4-4: Strip Sodding

This is the coventional method for the embankment slope in which sods are inserted horizontally in the form of streak into the slope when tamping the slope. The sod grows slowly and many years are required until the whole surface is covered. Therefore, the growth of grasses should be accelerated by fertilization and the slope should be fully compacted.

When using the standard size of 36 x 28 cm sod, each sod is cut into the strip-shaped sod of 14 cm in width and then cut sods are horizontally inserted into the slope at the interval of 30 cm (Figure 5.2-36).

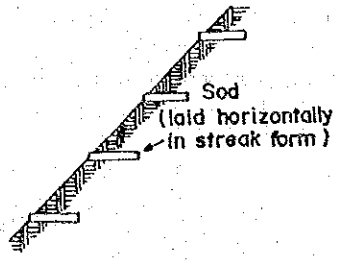


FIGURE 5.5-36 STRIP SODDING

5) P4-5: Seed Spraying

The seed spraying is classified into two types; a seed-slurry spraying and a seed-mud spraying.

Seed-Slurry Spraying

A mixed slurry composed of seed, water fertilizer, cohesive agent and fibers are sprayed with a pump to the face of either cut or embankment slope. This work is suited to relatively low gradient slope.

Green-colored ligneous fibers are often used as fibers for a fine sight. In the typhoon or heavy rain season, the curing should be performed after execution of the work by using asphalt emulsion or the like.

For the execution, pump and tank with an agitator are required. However, the seed slurry can be made and sprayed manually without above-mentioned equipment disregarding the work speed.

Seed-mud Spraying

Seed, soil, fertilizer and water are mixed together to form a mud-like mixture and then sprayed to the slope. This is suited to high and steep cut slopes. A spray gun is employed in combination with an air compressor. Asphalt emulsion is sprayed for curing.

Amount of the mud-like mixture to be sprayed is about 0.01 m^3/m^2 and its stable water content is about 30 to 40% of the total amount.

In the execution, the spraying distance and angle of nozzle should be adjusted in response to the hardness of the slope so as not to roughen the slope surface.

Curing by asphalt film can prevent erosion due to heavy rain during rainy season. Doubled solution of cationic type is generally used at a rate of 1 liter $/m^2$ asphalt emulsion.

This seed mud spraying can also be carried out by manpower taking no account of the efficiency like the seed spraying.

6) P4-6: Pick Hole Seeding

Holes are dug on the slope surface by pick work and then seed and fertilized soil is filled into the dug holes.

Normally, the hole with 6 to 10 cm in diameter and 15 cm in depth at the rate of 15 to 20 holes per square meter.

Solid fertilizer is filled into the bottom of the hole and the good quality soil with seed over the fertilizer. Then the hole is covered with asphalt emulsion for curing.

This is suitable to protect cut slope being relatively unsuitable to grow grasses (Figure 5.2-37).

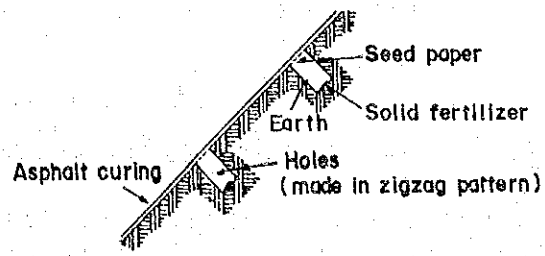


FIGURE 5.2-37 PICK HOLE SEEDING

7) P4-7: Seed Packet

This is mainly applied to cut slope being relatively unsuitable for vegetation. Net packets filled with seed and fertilized soil are laid in horizontal grooves made in the slope surface.

Synthetic resin net is generally used as the seed packet and seed and fertilized soil can be filled into the packet either on the site or in factory.

The depth of the groove in which the seed packet is set is determined so that the top of packet is slightly projected out from the slope surface. The normal spacing between grooves is 50 cm (Figure 5.2-38).

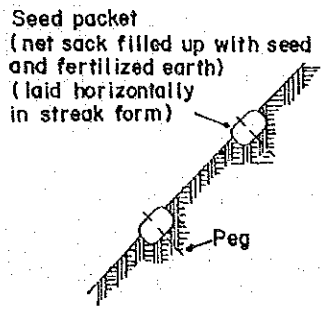


FIGURE 5.2-38 SEED PACKET

8) P4-8: Wattling

This is to form steps on the slope by a small fence commonly made with brushwood, bamboo, fascine, etc.

Steps formed with wooden fence protect the slope from erosion and/or scour during the period until seeded plants will grow enough to stabilize the slope.

The wattling is made as follows :

- To dig trenches of about 30 cm in depth following the contour of the slope.
- To drive pegs. At least 1/2 of the peg length should be penetrated into the ground. An average interval between pegs is 30 to 50 cm.
- To interweave brushwood, bamboo or fascine, etc. on the driven pegs in such a way that the butt ends are bent down into the ground for root development.
- To fill the trenches with excavated soil to provide 30 cm space for planting.

An example of the wattling is illustrated in Figure 5.2-39.

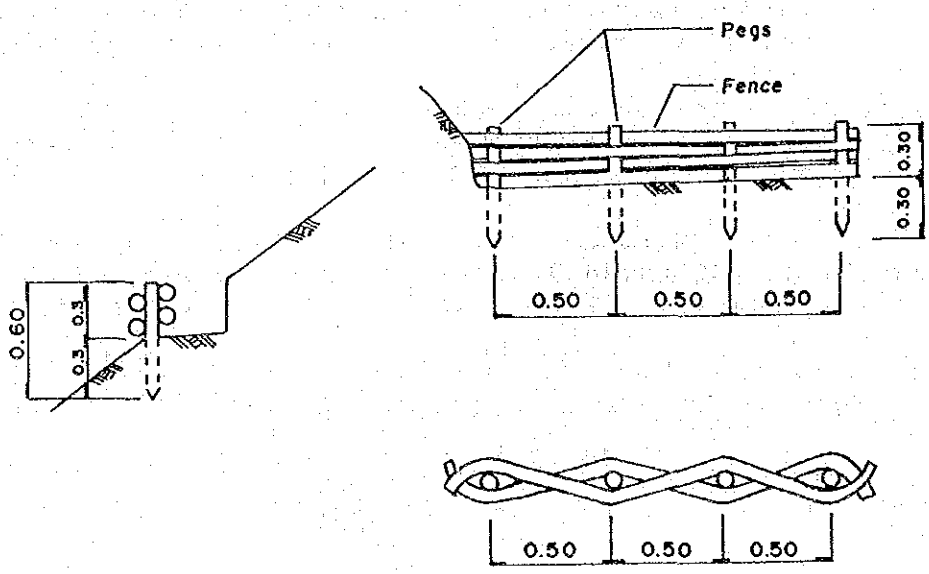


FIGURE 5.2-39 WATTLING

DENR and JICA constructed wattling with the following materials and obtained a good result.

Fence = Alibangbang branches (2 to 3 m long)
Cogon band
Napier band

Peg = Alibangbang peg (4 to 6 cm in diameter and 80 to 100 cm in length).

5.2.5 P5: Slope Protection by Structure

Refer to APPENDIX II STANDARD DRAWINGS

5. CONCRETE SPRAYING, MORTAR SPRAYING
6. CAST-IN-PLACE CONCRETE CRIB
7. SPRAYED CONCRETE CRIB

Slope protection works by structure are classified into 8 types according to their work methods and materials as follows :

P5-1: Mortar Spraying
P5-2: Concrete Spraying
P5-3: Stone Pitching
P5-4: Concrete Pitching
P5-5: Gabion Pitching
P5-6: Concrete Block Crib
P5-7: Cast-in-place Concrete Crib
P5-8: Sprayed Concrete Crib

A suitable work type is selected based on the integrated considerations from engineering aspects i.e. kind of structure and soil to be protected, conditions of slope surface, slope gradient, workability etc. and also from environmental and economical aspects.

1) P5-1: Mortar Spraying

2) P5-2: Concrete Spraying

Application

Mortar or concrete spraying is suitable to protect the cut slope surface where soil conditions are as follows :

- Easily weatherable rock with no seepage water and no danger of further movement.
- Weathered rock which may be stripped off.
- Soils not suited for vegetation such as mudstone.

The standard thickness of spraying is 8 to 10 cm and 10 to 20 cm for mortar and concrete spraying, respectively, since thinly sprayed mortar structure can not be recognized as permanent structure.

Where seepage water is anticipated, proper facilities such as horizontal drain hole or stone-filled drain are provided prior to spraying works. Otherwise, the sprayed layer will be damaged by water pressure.

Typical Example

A typical example of spraying is shown in Figure 5.2-40.

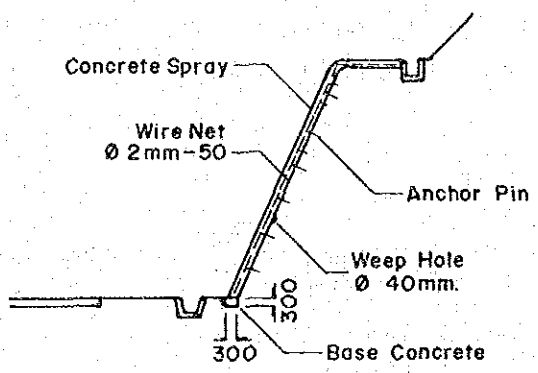


FIGURE 5.2-40 MORTAR AND CONCRETE SPRAYING

Thickness of Spraying

The thickness of spraying is determined taking account the kind of rock, and slope and weather conditions. A minimum thickness of 10 cm is required in areas in bad weather condition.

Mortar spraying of 5 to 10 cm in thickness is generally adopted for the slope of hard rock with gradient of 0.3:1, while concrete spraying of 10 to 15 cm is used for the slope of soft rock with 0.5:1 gradient.

Mix Proportion for Mortar and Concrete Spraying

The standard mix proportion by weight of cement and aggregates is 1:3 to 1:4 (C:S) for mortar spraying and 1:3:1 to 1:5:2 (C:S:G) for concrete spraying. Water cement ratio is 45 to 50% for mortar spraying and about 40 to 45% for concrete spraying. Table 5.2-3 presents an example of a mixed proportion for mortar and concrete spraying.

TABLE 5.2-3 MIXED PROPORTION FOR MORTAR AND CONCRETE SPRAYING

	Weight Ratio	W/C (%)	Cement (kg)	Sand (kg)	Gravel (kg)	Max. Size (mm)
Mortar Spraying	1:4	45	430	1742	-	-
Concrete Spraying	1:4:2	45	310	1321	660	15

Construction

Prior to spraying, supportless stones and dust on the surface of slope are removed with pressured water or compressed air and then wire mesh is placed and anchored over the surface of slope. Diamond shape wire mesh is used for irregular slope surface, and welded wire mesh for slightly irregular slope. The standard number of anchors is 1 to 2 per square meter.

Weep holes are required for spraying. At least one weep hole is needed per 2 to 4 square meters.

Spraying can be constructed either by dry or wet method, nevertheless wet method is more common. In dry method, water and other materials are separately conveyed with compressed air through different hoses and then sprayed from the same nozzle.

In wet method, firstly, all materials are mixed together in a mixer, as a slurry. Secondary, the slurry is conveyed to a discharging nozzle by compressed air, and finally sprayed to the surface of the slope.

Spraying is normally constructed from top to bottom of the slope and repeated until the specified thickness is attained. The tip of nozzle is held at right angle to the surface and moved slowly in a circular motion so as to acheive uniform spraying.

The timing and place for stopping the spraying operation is at a proper place such as a construction joint.

The distance between the tip of nozzle and the surface to be sprayed is about 1 m. The thickness of a single spraying is depending on the cohesion and the setting rate of mortar slurry.

Setting time can be shortened by adding accelerating agent of either powder or liquid type. The appropriate weight ratio of agent is about 3% of cement for the powder and about 2 to 4% for the liquid.

Loss amount of mortar or concrete slurry is one of important factors for estimating the material volume and construction cost. Loss is produced by filling into concave portions and rebound during spraying work. Rebound ratio (ratio between rebound and total amount) is governed by the mixed proportion of materials, characteristics of aggregates, amount of accelerating agent, gradient of surface and skill of the operator. Rebound ratio is generally about 10 to 15%. Re-use of dropped aggregates is not permitted.

The end portion of sprayed concrete at the top of slope is completely embedded into the ground or firmly connected with a ditch to prevent seepage of surface water as shown in Figure 5.2- 41.

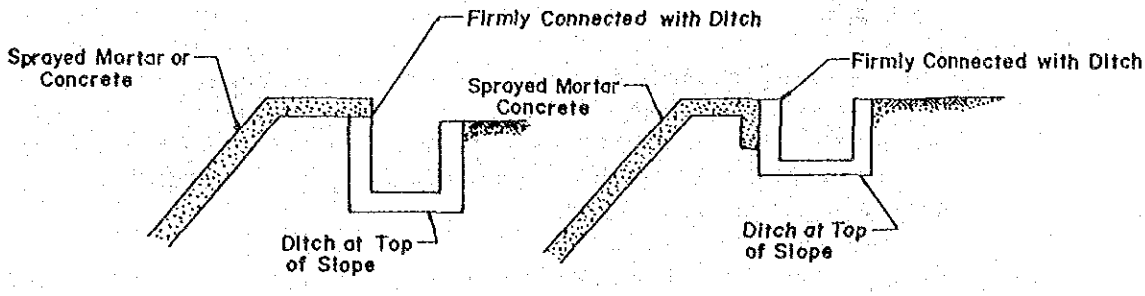


FIGURE 5.2-41 CONNECTION OF SPRAYED CONCRETE WITH DITCH

Longitudinal construction joint is provided every 10 to 20 m for relatively flat surface, while it may be unnecessary for remarkably irregular surface. An example of construction joint is shown in Figure 5.2-42.

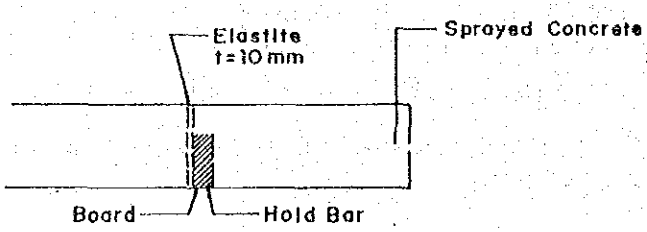


FIGURE 5.2-42 CONSTRUCTION JOINT OF CONCRETE SPRAYING

3) P5-3: Stone Pitching

Application

Stone pitching (or block pitching) is constructed to protect the slope from weathering and erosion. This work is applicable to the slope in the following conditions; i) slope gradient is gentler than 1:1, ii) surface soil is non-cohesive sediment, mud stone or fragile clay, and iii) height of slope is less than 5m.

As for dry pitching, however, the maximum applicable height of slope is less than 3m.

Typical Example

A typical example of stone or block pitching is shown in Figure 5.2-43.

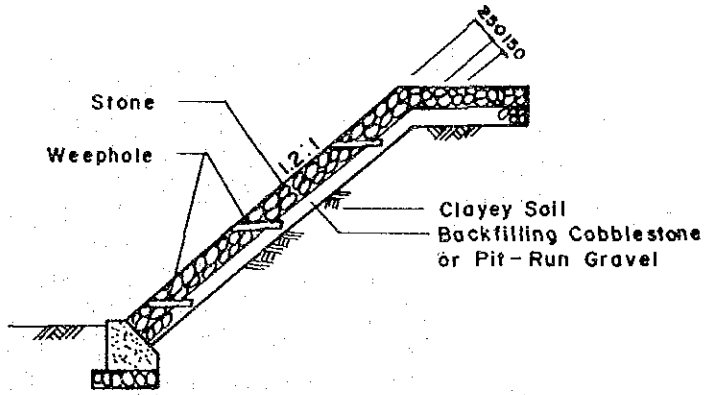


FIGURE 5.2-43 STONE PITCHING

Construction

Where rich seepage water exists, backfilling with cobblestones or pit-run gravel is constructed to provide better drainage from the rear of the structure. Filter layer is required when the fine- grained portion of surface soil is likely to run off together with water. In this case, the thickness of backfilling is about 20 cm.

Weep holes with diameter of about 50 mm is also required for smooth drainage. The standard number of weep holes is 1 (one) per 2 to 4 m^2, but this rate is increased where seepage water is rich. If a large amount of seepage water is present, stone pitching is performed after installing sufficient drainage facilities. The foundation is built first and stones are fixed with ties, and backfilling is made with any vacant space carefully filled up without creating large gap near the crown. The foundation may be made of cobblestones, concrete, piles or ladder type footing. Joints are required every 10 to 20 m to cope with differential settlement.

4) P5-4: Concrete Pitching

Application

Concrete pitching is used for slope of bedrock with many joints or loose talus cone layer, where concrete block crib work or concrete spraying may be insufficient to protect the slope.

Plain concrete pitching (without reinforcing bar) is used for slope with gradient gentler than 1:1 while reinforced concrete pitching is used for a slope with gradient of 0.5:1.

Typical Example and Details

A typical example of concrete pitching is shown in Figure 5.2-44.

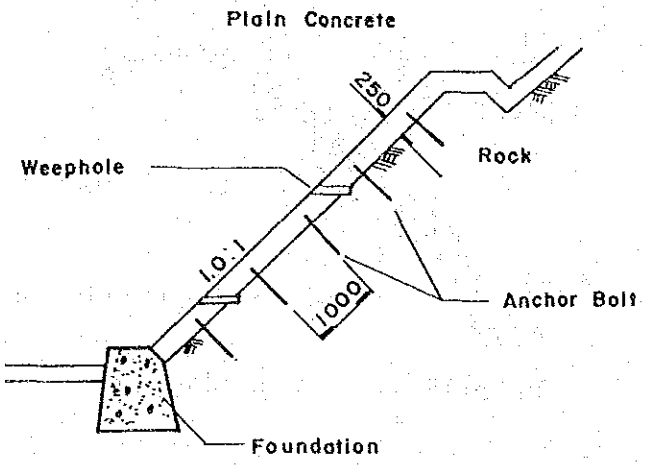


FIGURE 5.2-44 CONCRETE PITCHING

Plain concrete pitching requires a minimum thickness of about 20cm. Non-slip legs or anchor bolts are placed at a rate of one anchor per 1 to 2 m^2, and the standard depth of embedment is 1.5 to 2.0 times of the concrete thickness.

Construction

During the construction, it is required i) to prevent the permeation of groundwater into bedrock, ii) to place concrete on whole surface of slope without any running portion, iii) to completely dispose of seepage water by means of weep holes, and iv) to properly embed the upper end of concrete pitching into the ground.

The surface of slope has to be properly prepared prior to the placement of concrete. Otherwise air gap may be created between placed concrete and ground, and grasses or trees may germinate through the joints. It results the failure of concrete due to the penetration of rain water into the air gap.

The construction joint must be constructed at right angle to the surface or by means of half-lap joint as shown in Figure 5.2-45.

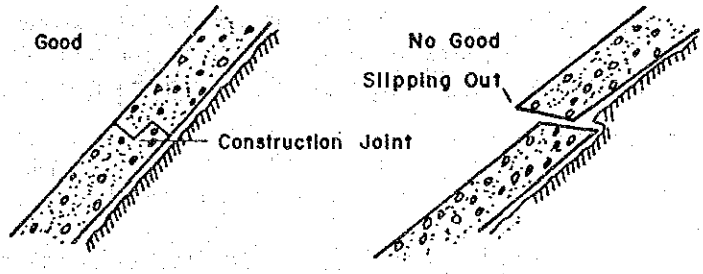


FIGURE 5.2-45 CONSTRUCTION JOINT OF CONCRETE PITCHING

5) P5-5: Gabion Pitching

Application

Gabion is used for slope protection where the slope material may run off due to spring water or the collapsed portion is to be restored.

There are several types of gabions such as cylinder, mat, free and flat.

Cylinder gabion is mainly used for disposing of spring water in the surface layer of the slope and for draining surface water.

Typical Example

A typical example of gabion pitching is shown in Figure 5.2-46.

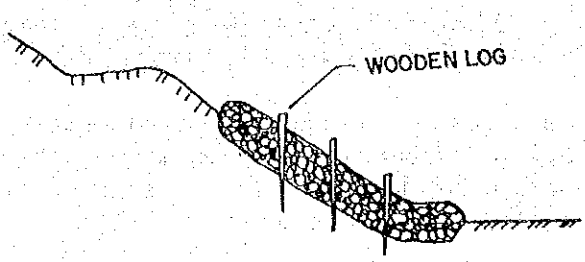


FIGURE 5.2-46 GABION PITCHING

Construction

In case of very extensive spring water, water collected by gabions must be quickly drained. If gabions are likely to be clogged due to the run-off of sediment from the slope, the surrounding area of the gabions should be protected by gravel.

6) P5-6: Concrete Block Crib

Application

Concrete block crib is usually applied to the slope i) with gradient of gentler than 1:1, ii) with seepage water, iii) where vegetation works is unapplicable and iv) where earth pressure is unexpected.

Typical Example and Details

A typical example of concrete block crib is shown in Figure 5.2- 47.

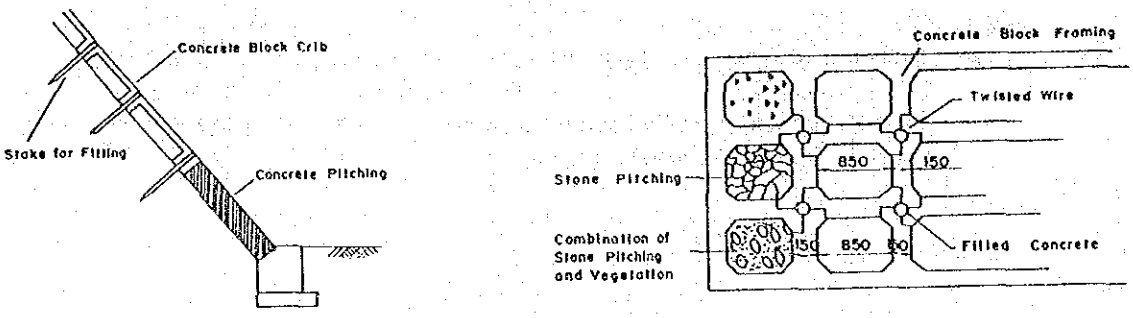


FIGURE 5.2-47 CONCRETE BLOCK CRIB

Spaces inside the frame must be filled up with good quality soil to protect the surface of slope with vegetation except in the following cases which may require stone or concrete block pitching.

- Gradient of slope is steeper than 1.2:1.
- Considerable amount of seepage water exists.
- Good quality soil is not available.
- Vegetation may flow out.

Construction

The surface of slope must be finished to be flat so that members of the crib are fixed to the slope. Wire from each member is tied with a stake or anchor bolt driven at each intersection of members and each hole is filled up with mortar for fixing. The stake or anchor bolt is 50 to 100 cm in length.

Special precautions are required to prevent the sediment to run off from the rear of frame due to improper handling of seepage water, and the disengagement of filled materials in the space of frame due to insufficient compaction.

When dry cobblestone pitching is constructed inside the crib frame on a slope with sand or on a slope with rich seepage water, it is recommended to place the frame after suppressing sediment run off by installing stone-filled drains in the manner of branches of trees or by laying water permeable mats.

Cobblestones are laid on its butt end and be fully interlocked with other cobblestones. Usage of weathered stone or stone with small grain size is not desirable.

When filling materials, complete compaction is necessary to prevent the materials from slipping down with rainfall run off.

7) P5-7: Cast-in-place Concrete Crib

Application

Cast-in-place concrete crib is used for slope with the following conditions.

- Future stability of the slope is questionable such as weathered rock with spring water and large-size slope with spring water.
- There is a fear that concrete block crib work may collapse.

– Supportless stones and rocks cannot be fixed by concrete spraying on bedrock with many joints and cracks.

Typical Example

A typical example of cast-in-place concrete crib is shown in Figure 5.2-48.

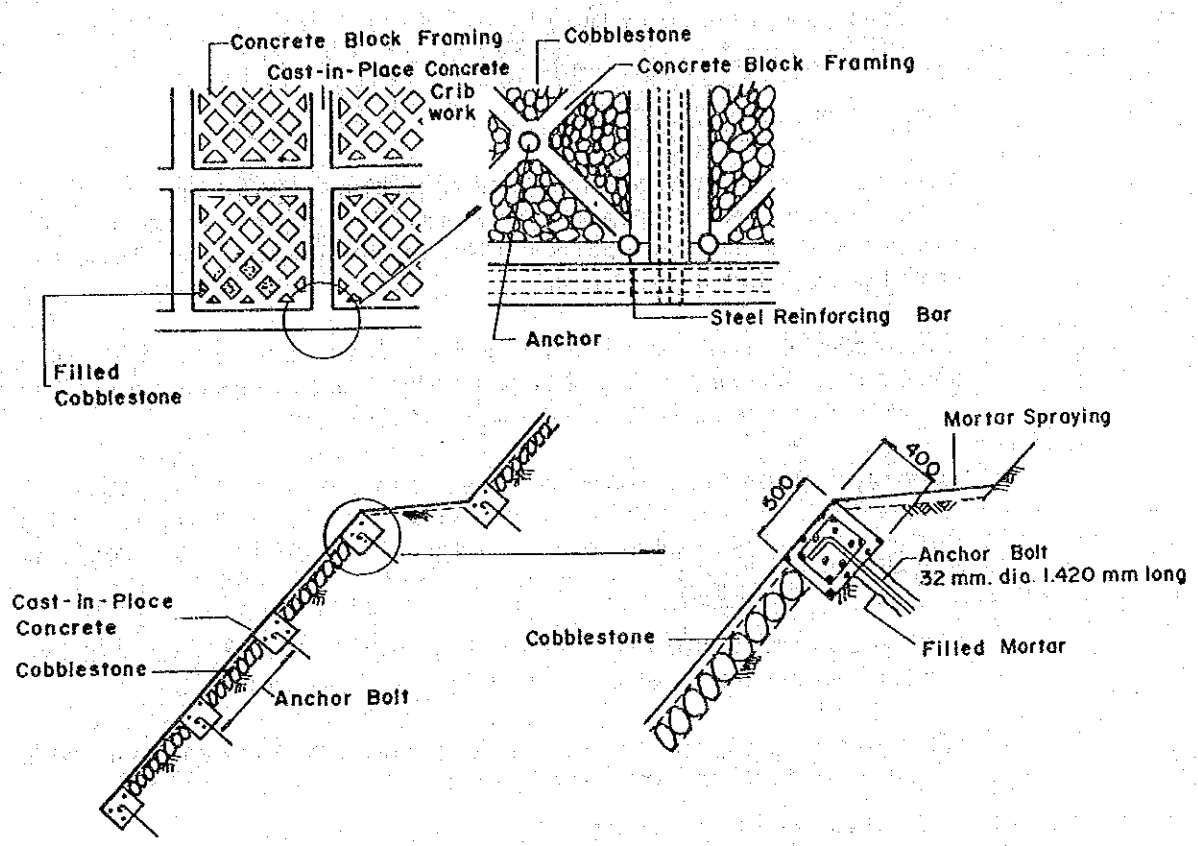


FIGURE 5.2-48 CAST-IN-PLACE CONCRETE CRIB

Construction

Frames of crib are made of cast-in-place reinforced concrete, and the spaces inside the frames are filled with and protected by stone pitching, block pitching, concrete pitching, mortar spraying or sodding depending upon the conditions of the slope.

Joints of the frames must be anchored with stakes or prestressed steel bars for fixing. Frames may be partly embedded in or just laid on the slope.

8) *P5-8: Sprayed Concrete Crib*

Application

Sprayed concrete crib is used under the same conditions as in cast-in-place concrete crib. The main advantage of this work is to be able to construct the concrete crib in conformity with the irregularity of the surface of slope.

Typical Example

The plan shape of this work is the same as in cast-in-place concrete crib. In Figure 5.2-49, the side views of different cases are presented.

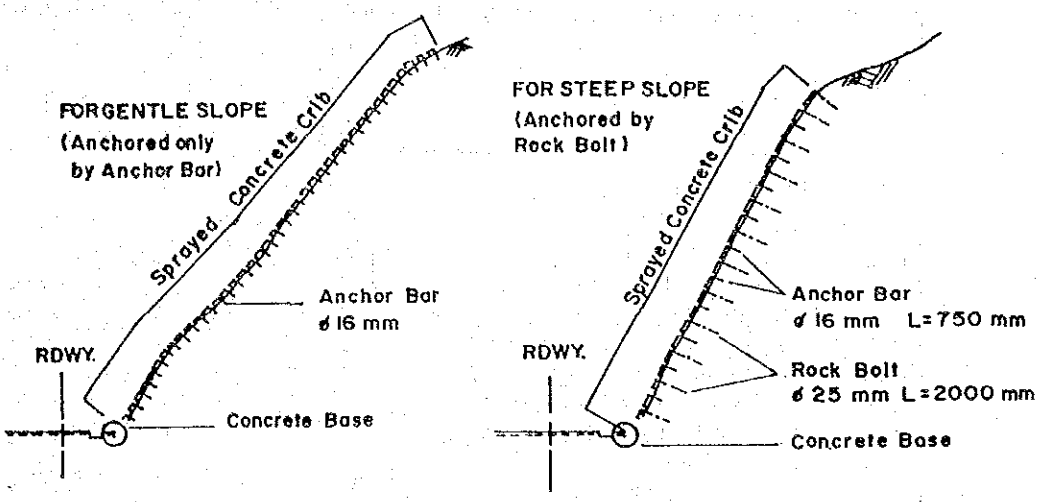


FIGURE 5.2-49 SPRAYED CONCRETE CRIB

Construction

Wire mesh and reinforcing bar to make cribs are placed on the face of the slope in conformity with the irregularity of the surface of the slope, and then concreting is done by concrete spraying.

In this method, works to place concrete and remove forms are not necessary. Therefore, this method is efficient for large and steep slope in mountainous area.

5.2.6 P6: Retaining Wall

Refer to	APPENDIX I	ANALYSIS METHODS	3. CONCRETE RETAINING WALL 4. GROUTED RIPRAP RETAINING WALL 5. MAT GABION WALL
	APPENDIX II	STANDARD DRAWINGS	8. GROUTED RIPRAP 9. FOUNDATION FOR GROUTED RIPRAP 10. GRAVITY WALL, GRAVITY TYPE STONE MASONRY WALL 11. RC STEEL PILE, GRAVITY TYPE SEA WALL 12. MAT GABION, CYLINDER GABION

Retaining walls are structures to support and retain earth in the places where stability of slope can not be assured by earth slope alone or other slope protection works.

Type of Retaining Walls

Retaining walls are classified into the following types in accordance with their materials and shapes:

P6- 1: Riprap
P6- 2: Grouted Riprap
P6- 3: Concrete Block Wall
P6- 4: Gravity Type Stone Masonry Wall
P6- 5: Gravity Type Concrete Wall
P6- 6: Supported Type Concrete Wall
P6- 7: Cantilever Type Concrete Wall
P6- 8: Buttressed Type Concrete Wall
P6- 9: Gabion Wall
P6-10: Sheet Pile Wall

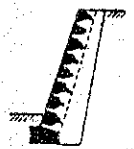
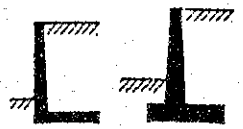
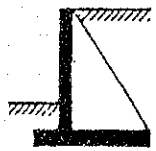
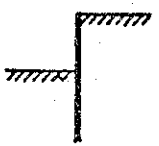
Table 5.2-4 presents the comparison of retaining wall types.

Construction Requirements

Retaining wall should be carefully constructed since this structure is designed to retain the extensive earth pressure and therefore the failure of this structure may result in the severe damage not only to the road structure but to the users as well.

Construction requirements are presented here, while design methods are discussed in Appendix-1.

TABLE 5.2-4 TYPE OF RETAINING WALL

TYPE	SHAPE	RECOMMENDABLE HEIGHT	CHARACTERISTICS	SUITABLE APPLICATION TO:	ECONOMIC ASPECT
P6- 1: Riprap P6- 2: Grouted Riprap P6- 3: Concrete Block Wall		· Less than 3 m for riprap · Less than 5 m for grouted riprap · Less than 7 m for concrete block wall with backfill concrete	· Easily conformable to the shape of construction site	· Slope protection · Where the earth pressure is small	· Economical
P6- 4: Gravity Type Stone Masonry Wall P6- 5: Gravity Type Concrete Wall P6- 9: Gabion Wall		· Less than app. 5 m	· Easy of construction	· Where the foundation ground is stiff, not needing pile foundation	· Economical in case of low height · Uneconomical in case of more than 4 m height
P6- 6: Supported Type Concrete Wall		· Less than app. 10 m	· Not self-standing gravity type	· Where the foundation ground is stiff · Back side excavation can be minimized	· Economical
P6- 7: Cantilever Type Concrete Wall		· 3 m - 10 m	· Applicable to high structure taking advantage of earth on footing for stability	· Where the foundation ground is poor	· Economical
P6- 8: Buttressed Type Concrete Wall		· More than app. 6 m	· Less concrete volume but more complicated in construction in comparison with cantilever type	· Where the foundation ground is poor	· Depending on height and ground conditions
P6-10: Sheet Pile Wall		· 3 m - 5 m	· Easy of construction but needing heavy equipment	· Where the foundation ground is medium stiff · Mainly applied to river side embankment	· Uneconomical

Where the bearing ground is a bedrock, the bedrock should be cut to a depth required for placing a footing. The cut surface of the bedrock should be cleaned and then the spread footing may be placed. See Figure 5.2-50 (a).

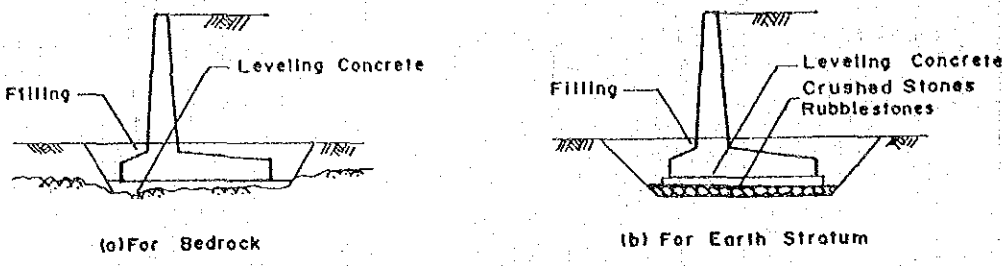


FIGURE 5.2-50 SPREAD FOOTING FOUNDATION

Where the bearing ground is earth or gravel, rubblestones should be laid over the excavated surface and rolled fully and uniformly. Leveling concrete mix should be poured over the rubblestones, and then the spread foundation may be placed over it. See Figure 5.2-50 (b).

Where the bearing ground surface is slanted, the portion at the valley side should be cut in the form of steps and replaced with concrete to the bedrock line to form a horizontal, uniform foundation. The body of the retaining wall should then be directly built over the foundation. See Figure 5.2-51.

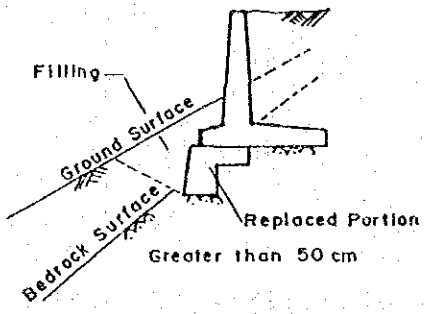


FIGURE 5.2-51 GROUND STEPPING METHOD

Where the bearing ground is made up of poor materials, a pile foundation is generally adopted. However, if the poor stratum is thin, it is recommended to replace this with a better material such as good quality gravelly soil or the like, to provide a uniform bearing ability so that the retaining wall may be built directly over the replaced material. See Figure 5.2-52.

Replaced Soil: Crusher run on good material with sufficient bearing capacity

Angle of load distribution: $=30^{o}$

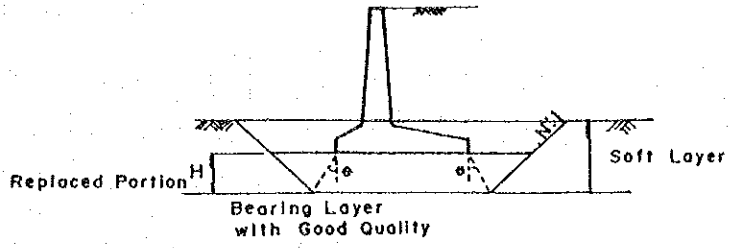


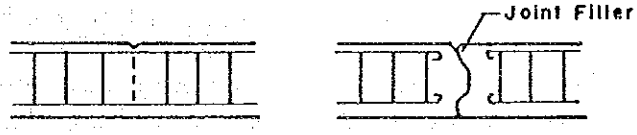
FIGURE 5.2-52 GROUND REPLACING METHOD

- Concrete Work

Concreting work for both the footing and wall should be done as monolithically as practicable. If this is not possible, groove, tenon or half-lap construction joint should be provided or steel dowels should be inserted at the joints.

Construction joint of wall should be provided at every 10 m or less as shown in Figure 5.2-53 (a). Reinforcing bar shall not be cut at the joint.

Expansion joint of wall should be provided at every 10 m or less for gravity type and at every 15 to 20 m for cantilever type retaining wall. See Figure 5.2-53 (b).



(a) CONSTRUCTION JOINT (b) EXPANSION JOINT

FIGURE 5.2-53 JOINT OF WALL

- Backfill Work

Backfilling should not be allowed until the structure become stable and strong enough to resist the earth pressure.

Only selected quality materials should be used to backfill the retaining wall.

Where the back of the retaining wall is used as a road, the selected materials should be placed as shown in Figure 5.2-54.

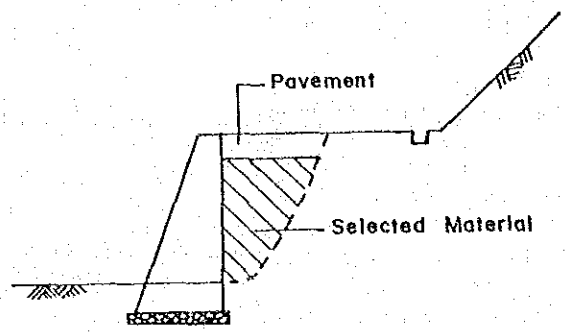


FIGURE 5.2-54 BACKFILL OF SELECTED MATERIAL

Compaction is preferably done with heavy equipment such as 0.5t vibrating compactor or vibrating roller more than 1t for the lower portion and tire roller for the upper portion of backfilling. For the narrow portions, small size compactor may be used.

The thickness of a layer for the compaction should be less than 20 cm.

Rain water should be perfectly prevented from flowing into the portion of backfilling. Drain or closed conduits should be provided in order to drain the seepage water.

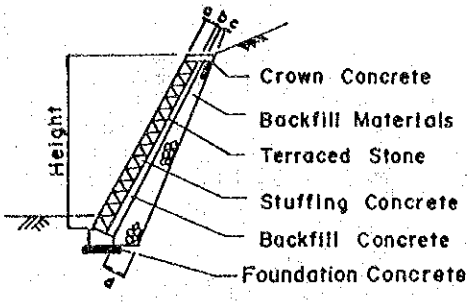
1) P6-1: Riprap
2) P6-2: Grouted Riprap
3) P6-3: Concrete Block Wall

Application

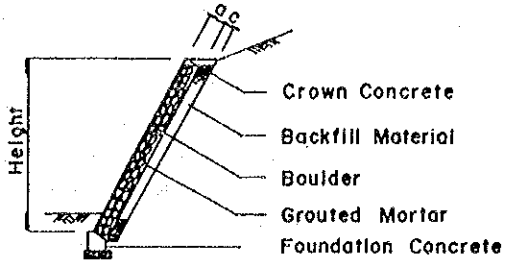
These types are applicable to the slope with small earth pressure acting on the wall. Therefore, they are used mainly for protecting a slope from small-scaled failure near the toe of the slope. The height of the structure is normally less than 7 m.

Shape

Figure 5.2-55 shows a typical section of grouted riprap/concrete block wall.



CONCRETE BLOCK WALL



GROUTED RIPRAP

(a) Rear to face Length of Terraced Stone
(b) Thickness of Backfilling Concrete (5 - 20 cm)
(c) Thickness of Backfilling Material at top
(d) Thickness of Backfilling Material at Bottom

FIGURE 5.2-55 GROUTED RIPRAP/CONCRETE BLOCK WALL

Rear to face length of terraced stone

Rear to face length of terraced stone is determined by height and gradient of a slope. Refer to the standard length shown in Table 5.2-5.

TABLE 5.2-5 REAR TO FACE LENGTH OF TERRACED STONE

Grouted Riprap					
Height (m)		0-3.0	3.0-4.0	4.0-5.0	5.0-7.0
Gradient	Embankment	0.3:1	0.4:1	0.5:1	0.6:1
	Cut	0.3:1	0.3:1	0.4:1	0.5:1
Rear to Face Length (cm)		30	50	60	80
Concrete Block Wall					
Height (m)		0-1.5	1.5-3.0	3.0-5.0	5.0-7.0
Gradient	Embankment	0.3:1	0.4:1	0.5:1	0.6:1
	Cut	0.3:1	0.3:1	0.4:1	0.5:1
Rear to Face Length (cm)	Stuffing Concrete only	35	35	35	-
	Stuffing Concrete and Backfilling Concrete	35+5* = 40	35+10* = 45	35+15* = 50	35+20* = 55

Note:

* thickness of backfilling concrete
\- not applicable

Backfilling

Backfilling is constructed to reduce pressure acting on the retaining wall by draining water and thus reducing water pressure.

For riprap and grouted riprap, uniform thickness of backfilling of 30 cm from top to bottom is recommended.

Standard thickness of backfilling for concrete block wall to be used for embankment slope is shown in Table 5.2-6.

TABLE 5.2-6 THICKNESS OF BACKFILLING FOR CONCRETE BLOCK WALL FOR EMBANKMENT SLOPE

Height (m)		0-1.5	1.5-3.0	3.0-5.0	5.0-7.0
Thickness (cm)	Top	20-40	20-40	20- 40	20- 40
	Bottom	30-60	45-75	60-100	80-120

For cut slope of firm soil, uniform thickness of 30 to 40 cm from top to bottom is recommended, while the thickness shown in Table 5.2-6 can be applied for cut slope of loose soil.

Construction

Cobblestone or crushed stone are well placed to support the concrete foundation. In case of rock foundation, lean concrete with 15 cm in thickness is more preferred instead of stone.

Joint shoud be provided every 20 m. However, it may vary depending on the soil condition.

Weep hole must be provided at least 1 per 2 m^2.

When high retaining wall is required, separated walls may be constructed as shown in Figure 5.2-56.

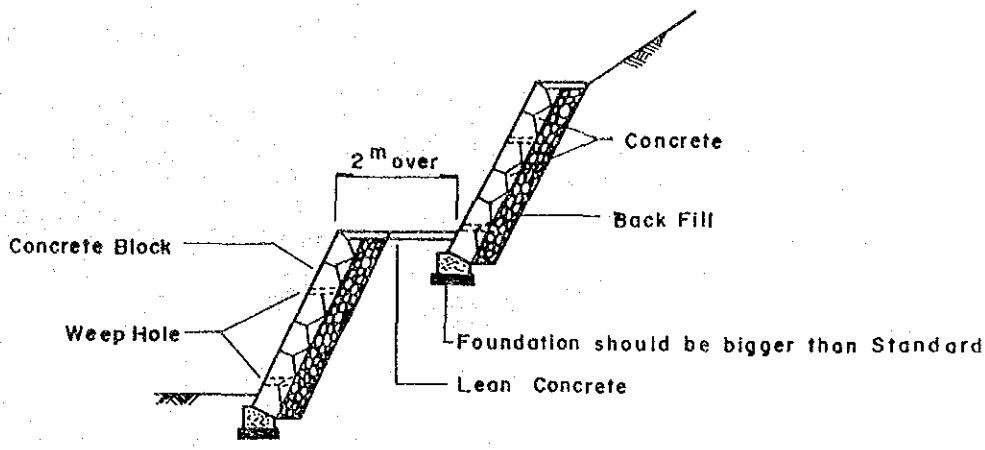


FIGURE 5.2-56 SEPARATED WALL

4) P6-4: Gravity Type Stone Masonry Wall

5) P6-5: Gravity Type Concrete Wall

Application

Gravity type retaining wall is mainly used as a direct restraint work for slope failure or as a foundation of other slope protection work. This type is often adopted when the height is relatively low (less than 5 m) and strong bearing stratum is assured for a foundation ground.

This type is designed so as to counter against earth pressure by its own weight, in such a way that the resultant force of earth pressure and dead load may not create tensile stress in the wall.

In case that tensile stress is created, semi-gravity type may be applied providing reinforcing bar to cover tensile stress in concrete.

Shape

The width of the bottom slab is, in general, about 0.5 to 0.7 times the height of retaining wall, and the width of the crown is more than 35 cm to provide enough space for protection fence. See Figure 5.2-57.

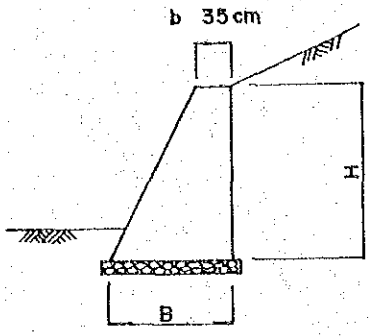


FIGURE 5.2-57 GRAVITY TYPE RETAINING WALL

6) P6-6: Supported Type Concrete Wall

Application

Supported type concrete wall is designed as a gravity type structure although it can not stand by itself. It is supported by the earth at the rear of the wall. This type can counter by its own dead load against earth pressure. This type is often used as a countermeasure to stabilize a slope in mountainous area.

Shape

Generally, slope ratio at front of wall is 0.3:1 to 0.6:1 and height of wall is about 3 to 10 m. But, as the special case, the wall with a height of 14 m is sometimes designed in Japan. See Figure 5.2-58.

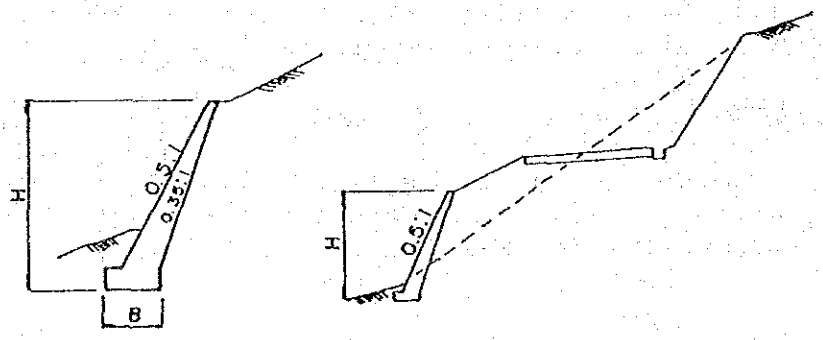


FIGURE 5.2-58 SUPPORTED TYPE CONCRETE WALL

7) P6-7: Cantilever Type Concrete Wall

Application

Cantilever type concrete wall is used in places where a high wall is required and gravity type or other type is not economical. Where the required height is 3-10 m, the volume of concrete is smaller than that of a gravity type.

A cantilever type concrete wall consists of a vertical wall and bottom slab which can resist external force as a cantilever beam. According to the location of a vertical wall in relation to a bottom slab, this type is sub-classified into inverted T type and L type.

Shape

Standard section of cantilever type concrete wall is shown in Figure 5.2-59.

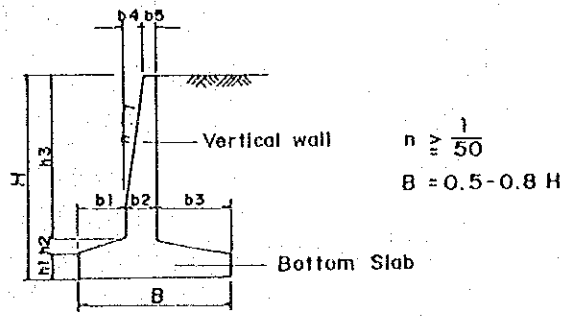


FIGURE 5.2-59 CANTILEVER TYPE CONCRETE WALL

Table 5.2-7 shows the standard dimension of inverted T type wall.

TABLE 5.2-7 STANDARD DIMENSION OF INVERTED T-TYPE WALL

Dimension (m)	Wall Height H (m)				
	3.0	4.0	5.0	6.0	7.0
H	3.000	4.000	5.000	6.000	7.000
h1	0.400	0.450	0.500	0.550	0.600
h2	0.150	0.150	0.150	0.200	0.200
h3	2.450	3.400	4.350	5.250	6.200
B	2.000	2.700	3.500	4.250	5.000
b1	0.400	0.550	0.700	0.850	1.000
b2	0.550	0.600	0.650	0.700	0.750
b3	1.050	1.550	2.150	2.700	3.250
b4	0.200	0.250	0.300	0.350	0.400
b5	0.350	0.350	0.350	0.350	0.350

8) P6-8: Buttressed Type Concrete Wall

Application

Buttressed type concrete wall is used for the purpose of reducing the thickness of the vertical wall and bottom slab as compared with those of cantilever type concrete wall. The wall and slab are designed as a continous plate or beam supported by buttressed walls which are designed as web plate of a T-Type cantilever wall. This type is generally applied to more than 6 m high walls.

Shape

Standard type of buttressed type concrete wall is shown in Figure 5.2-60.

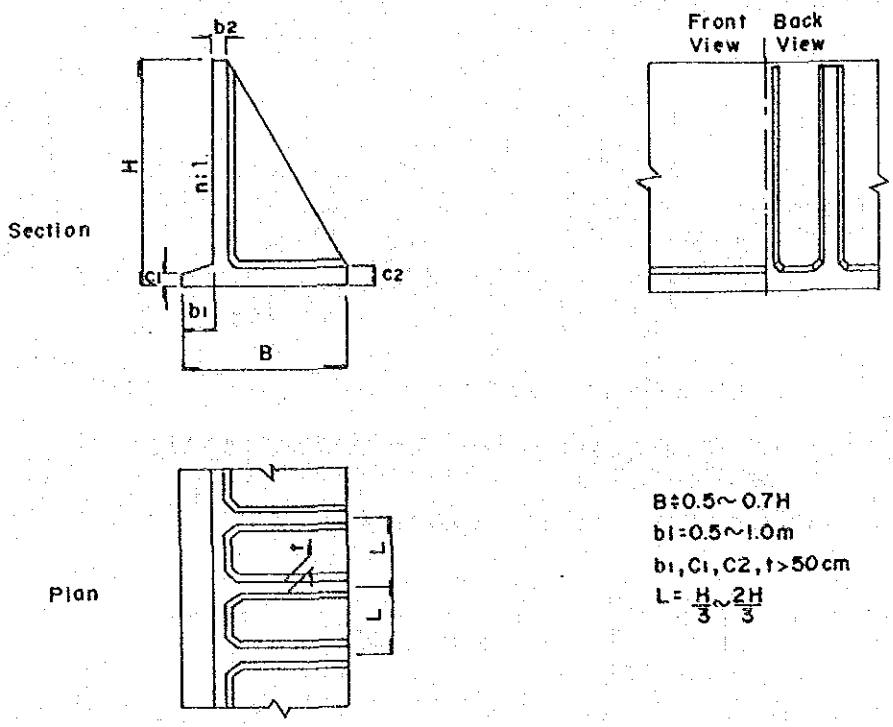


FIGURE 5.2-60 BUTTRESSED TYPE CONCRETE WALL

9) P6-9: Gabion Wall

Application

Gabion wall is used to prevent small size failure at the toe of slope, especially where seepage water exists.

Gabion is commonly used as a protection work rather than as a retaining wall, since this can resist only small earth pressure.

Shape

Mat gabion is generally used for retaining wall as shown in Figure 5.2-61.

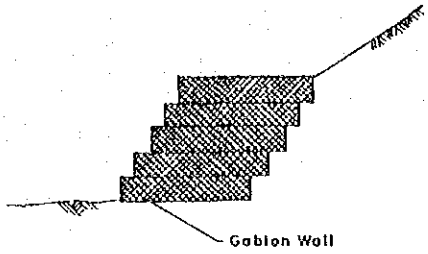


FIGURE 5.2-61 GABION WALL

10) P6-10: Sheet Pile Wall

Sheet piles are made of wood, steel, or precast concrete. For the restoration purpose, the use of steel sheet piles is recommended because of their strength and easiness in driving.

Self-supporting sheet pile wall is too support the lateral pressure such as earth pressure by means of the lateral resistance force along its penetration depth and the bending rigidity of sheet pile.

Recommendable height for this work between crest and excavated surface is 3 to 5 m, and higher wall requires tie rod or inclined pile, which is unsuitable for the restoration work due to its costly and difficult construction (Figure 5.2-62).

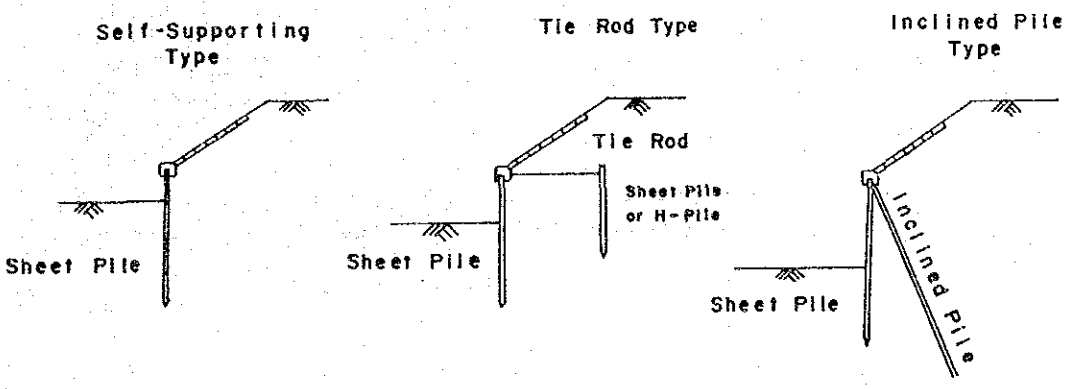


FIGURE 5.2-62 SHEET PILE WALL

However, in such a special case as both sides of embankment are washed away or failed, double sheet pile walls tied with each other by tierod is often used for either temporary or permanent measure, as shown in Figure 5.2-63.

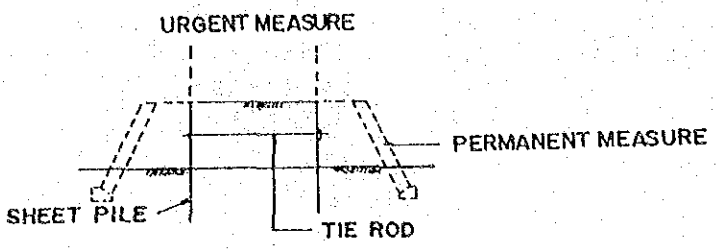


FIGURE 5.2-63 DOUBLE WALL SYSTEM

Driving of sheet pile is carried out by using general equipment; i.e. steam-, hydraulic- or vibro-hammer mounted on a crawler crane, or mechanical-hammer. Construction of sheet pile wall, including driving, is carried out in accordance with general practice in the Philippines.

Since sheet piles are widely used for restoration works and can be reused several times, it is recommended to stock reasonable amount of them in regional or district offices for quick and appropriate response to disaster.

5.2.7 P7: Anchoring

Refer to APPENDIX I ANALYSIS METHODS 6. ANCHORING
APPENDIX II STANDARD DRAWINGS 7. P.C. ANCHOR

1) P7-1: Rock Bolt

Application

Rock bolt is used to prevent unstable rocks on slope surface from falling down, by tying them to bedrock as shown in Figure 5.2- 64.

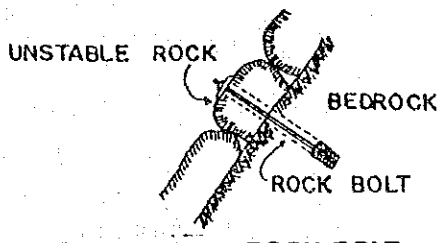


FIGURE 5.2-64 ROCK BOLT

Construction

Both the unstable rock and bedrock should be drilled with a rock drill at the same time and then a rock bolt should be inserted to the drilled hole.

The tip of the rock bolt is split longitudinally and the rock bolt can be anchored by inserting a wedge to the split and by driving the bolt into the hole. Mortar is then filled into the hole and the bolt is tightened from the outside for anchoring.

2) P7-2: PC-Anchor

Application

PC-anchor is used in case where there are joints or cracks in the bedrock slope of hard or soft rocks and the slope is likely to collapse or fall down. This work aims to prevent the collapse and separation of bedrock by directly tightening the unstable bedrock.

PC-anchor is also employed for increasing the stability of other works such as cast-in-place concrete crib, concrete pitching and retaining wall (refer to Figure 5.2-65).

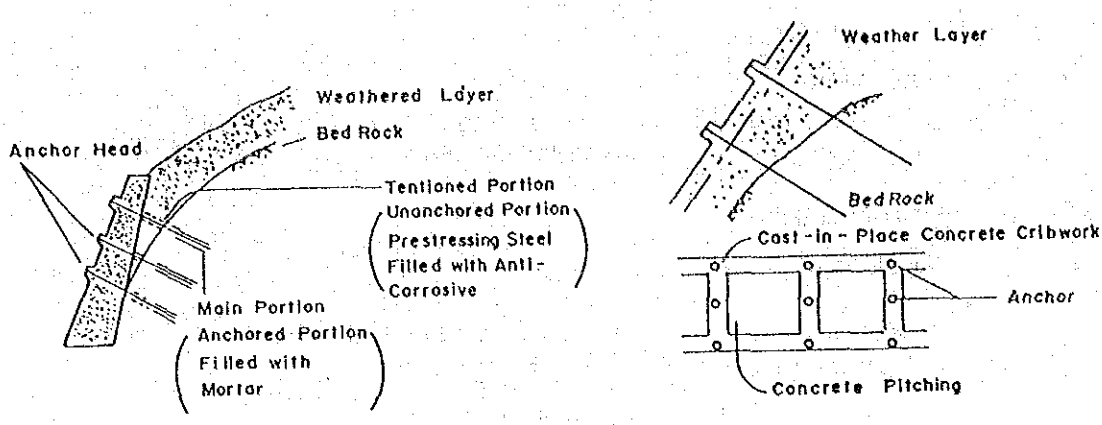


FIGURE 5.2-65 PC-ANCHOR

Type of Anchoring

PC-anchor is composed of three parts; main portion, tension member, and anchor head.

PC-anchor is classified into the following three types according to the method of anchoring the main portion of anchor to the bedrock (Figure 5.2-66):

- Friction type anchor: This transfer the pull-out force of anchor to the bedrock by means of frictional resistance between the bedrock and the periphery of the main portion of anchor.
- Bearing type anchor: A part of the main portion of anchor is enlarged and the pull-out force of anchor is resisted by passive earth pressure.
- Combination type anchor: Combination of the two above.

Friction type anchor is most commonly used.

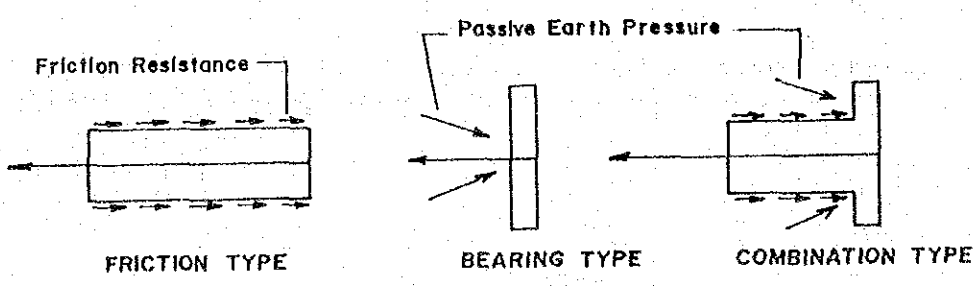


FIGURE 5.2-66 ANCHORING METHODS

Structural Detail

Structural detail of PC-anchor is shown in Figure 5.2-67.

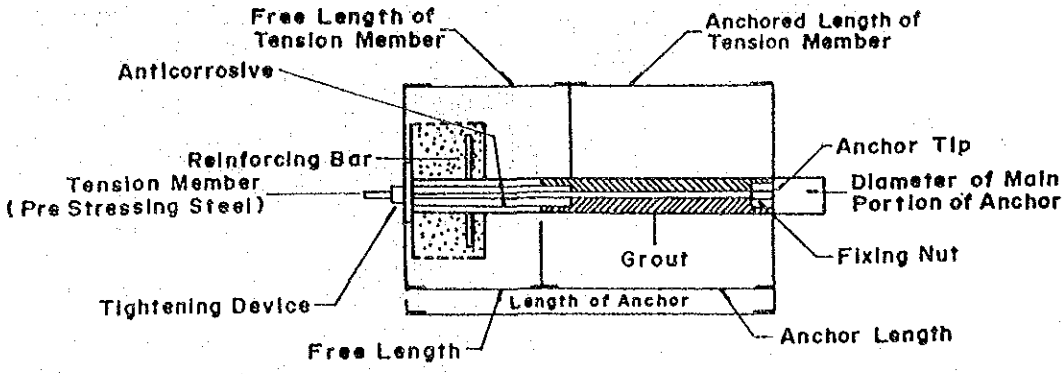


FIGURE 5.2-67 STRUCTURAL DETAIL OF PC-ANCHOR

Because of high tension acting on tension member, prestressed steel such as prestressed steel rod, prestressed steel strand and prestressed steel wire are generally used as materials for main portion and tension member.

Construction

The main portion of anchor should be anchored to bedrock which has not been weathered. In addition, the main portion of anchor should be installed deeper than the anticipated sliding surface. Since the factors in the actual ground are complicated, the results of ground survey should be fully examined and the most effective layout of anchors should be made.

When using anchors as semi-permanent structure, steel tension members should be properly treated to prevent corrosion. For this purpose, grouting is performed to the portion of free length of tension member after anchoring, or sheaths are placed to cover steel members and anticorrosive is filled into the gaps between the sheath and steel members. Otherwise, anticorrosive is applied to the portion of free length. See Figure 5.2-68.

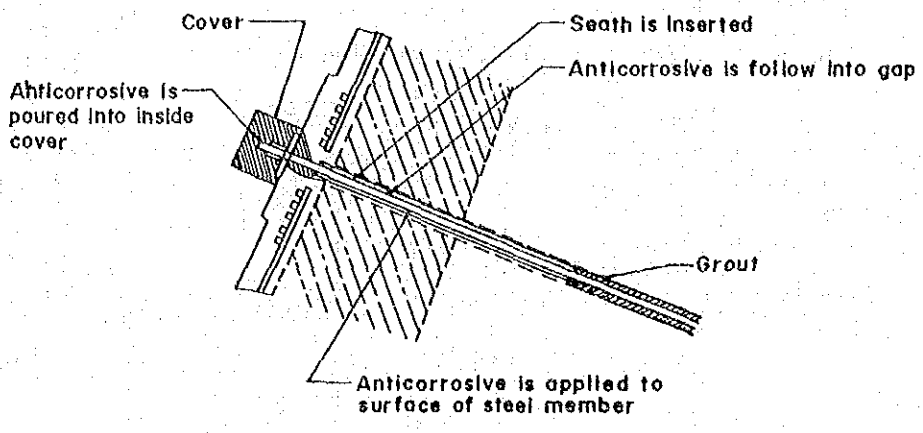


FIGURE 5.2-68 ANTICORROSIVE OF PC-ANCHOR

After grout of the main portion of anchor gains the designed strength, tension test is conducted for more than three anchors or more than 5% of the total number of anchors and then confirmation test is conducted for all other remaining anchors. A load of 1.2 to 1.3 times the design anchor force is used as the maximum load for the tension test, and a load of 1.0 to 1.2 times for the confirmation test.

An example of mix proportion for grout is shown in Table 5.2-8.

TABLE 5.2-8 EXAMPLE OF MIX PROPORTION FOR GROUT

	Cement	Water	Sand
Cement Mortar	1	0.5	0.6
Cement Milk	1	0.5 - 0.55	-

5.2.8 P8: Catch Work

Refer to APPENDIX II STANDARD DRAWINGS 13. CATCH FENCE
14. CATCH WIRE NET

Catch work is a countermeasure against fall by preventing the falling materials from extending to the road. It is classified into the following:

- P8-1: Catch Fill and Ditch
- P8-2: Catch Gabion Wall
- P8-3: Catch Concrete Wall
- P8-4: Catch Fence
- P8-5: Catch Wire Net

1) P8-1: Catch Fill and Ditch

Catch fill and ditch are usually used at the place where roadside is wide enough to provide a flat pocket for falling rock. The advantage of this type is that it can be constructed easily and economically since expensive materials such as concrete and steel are not required. See Figure 5.2-69 below.

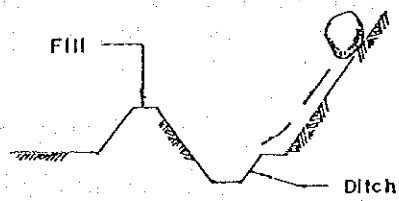


FIGURE 5.2-69 CATCH FILL AND CATCH DITCH

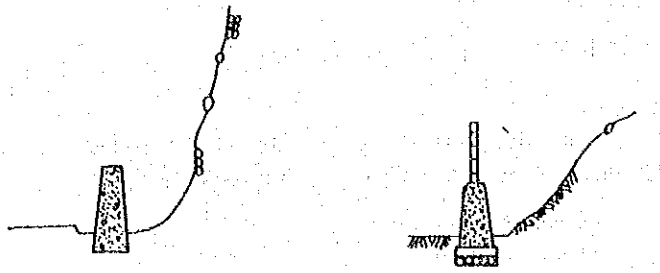
Height and width of catch fill and ditch are designed in consideration of velocity and jumping height of falling rock.

2) P8-2: Catch Gabion Wall

3) P8-3: Catch Concrete Wall

Catch wall is used to prevent rocks from falling onto road, and usually constructed at roadside.

A space (pocket) is provided at the back of catch wall so that fallen rocks and collapsed earth can be piled up. Catch wall is set up at the place where road shoulder is wide or slope is gentle. Catch wall is sometimes used jointly with catch fence. See Figure 5.2-70.

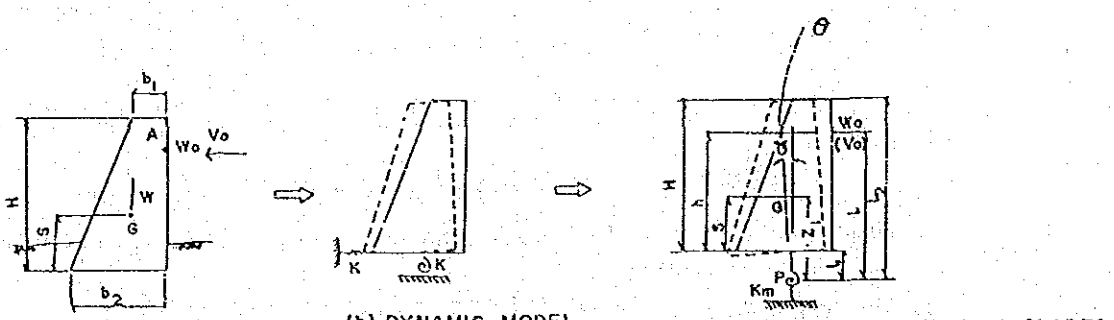


CATCH WALL　　CATCH WALL WITH FENCE

FIGURE 5.2-70 CATCH WALL

Design

Catch wall is a kind of gravity type retaining wall and is designed in such a way that kinetic energy of falling rock or collapsing earth can be retained by displaced energy of concrete body and foundation, as shown in Figure 5.2-71.



A; POINT OF CLASH
G; CENTER OF GRAVITY
(a) ACTUAL CONDITION

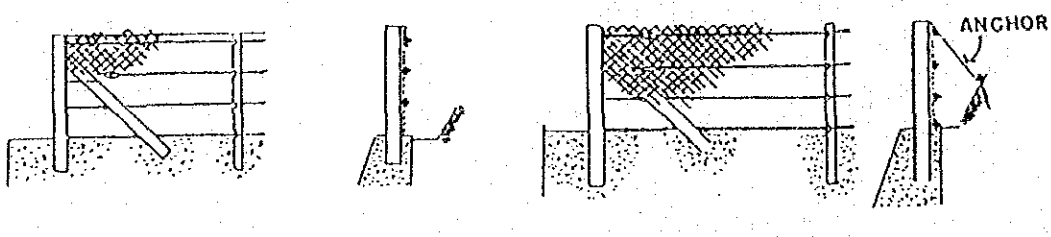
(b) DYNAMIC MODEL SYMBOLIZED BY SHEARING AND ROTATIONAL SPRINGS

(c) DYNAMIC MODEL SYMBOLIZED BY ROTATIONAL SPRING

FIGURE 5.2-71 CONCEPTIONAL MODEL FOR DESIGN OF CATCH WALL

4) P8-4: Catch Fence

Catch fence is useful only against small size rock fall. Examples of rock fence are shown in Figure 5.2-72.



(a) STRAIGHT POST　　(b) POST WITH ANCHOR

FIGURE 5.2-72 ROCK FENCE

Usually, rock fence is set up at the road shoulder or at the lowest berm, but it is also advisable to set the upper berm to absorb energy of falling rock for large scale slope, as shown in Figure 5.2-73.

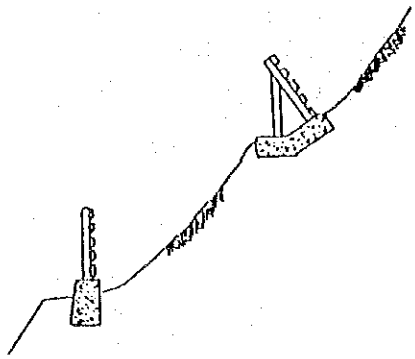


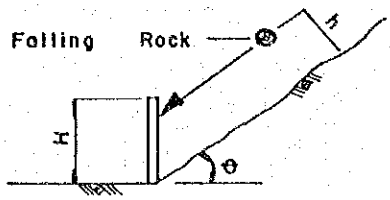
FIGURE 5.2-73 DOUBLE LINES OF ROCK FENCE

Height of Fence

Height of fence should be decided based on jumping height of falling rock. Jumping height is usually less than 2 m.

The guideline for deciding the height of fence is given in Figure 5.2-74.

1) Without flat space



$H > h \cdot \sec \theta$

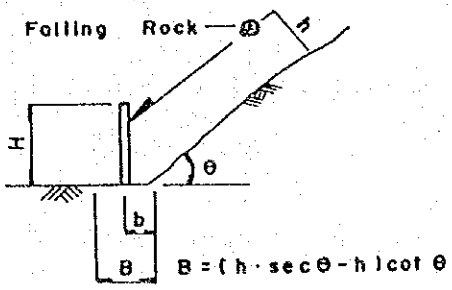
Example

h = 2m

θ = 60°

H > 4.0m

2) 0 <b <B



$H > h \sec \theta - b \tan \theta$

Example

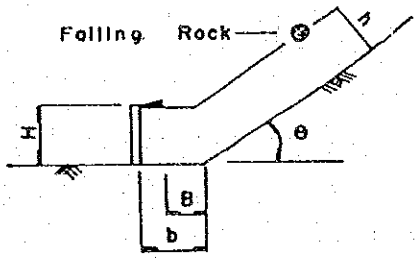
h = 2m

θ = 60°

b = 0.7

H > 2.8m

3) b ≥ B



H > h

h = 2m

θ = 60°

b = 1.5m

H = 2m

FIGURE 5.2-74 HEIGHT OF CATCH FENCE

5) P8-5: Catch Wire Net

Catch wire net aims to prevent spread of damage by covering a slope with wire net. This type is installed in such a way that the upper end portion of the net is separated from the surface of the slope. Falling stones from the upper portion of slope are caught by the gap between the net and slope, and the energy of the falling rock is absorbed when the stone crashes against it. See Figure 5.2-75.

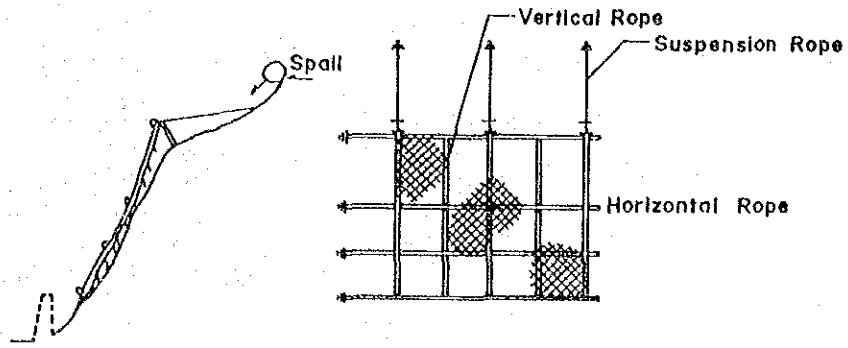


FIGURE 5.2-75 CATCH WIRE NET

Design

Catch wire net is designed with the following considerations:

- Energy of the falling rock
- Energy absorbable by the net
- Strength and stability of anchor on the assumption that ultimate strenth of the rope will act on the anchor.

5.2.9 P9: Supporting Work

1) P9-1: Concrete Supporting

Unstable rock is fixed by supporting it with concrete at the lower and surrounding portion of the rock. Sometimes, stone masonry work is also used instead of concrete work. This method is effective for the gentle slope where there are many unstable rocks which can not be easily removed. See Figure 5.2-76.

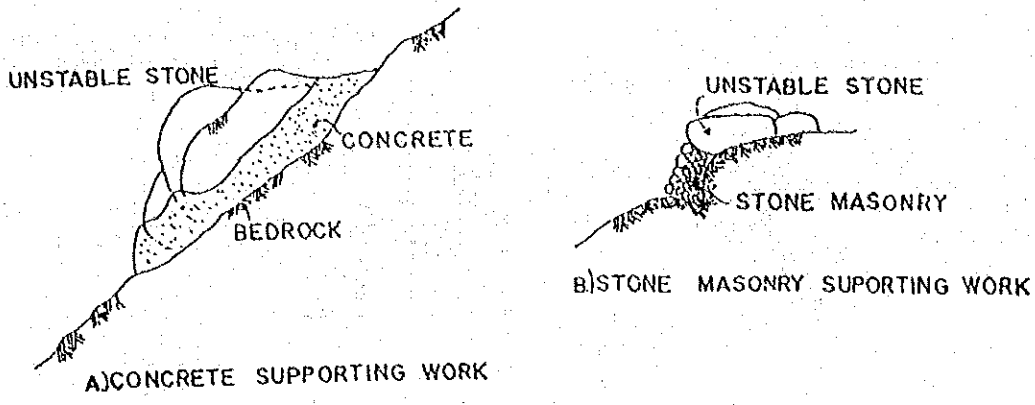


FIGURE 5.2-76 SUPPORTING WORK

5.2.10 P10: ROCK SHED

Refer to APPENDIX I ANALYSIS METHODS 7. ROCK SHED
APPENDIX II STANDARD DRAWINGS 15. ROCK SHED

1) P10-1: Concrete Rock Shed

Rock shed is constructed to cover the whole width of a road to prevent rocks from falling into the road. Rock shed is used in the following cases.

- Large and steep slope where rocks are prone to fall is continued and roadside space is narrow.
- Falling rocks are big and falling area is so wide that rock fence may not prevent them.
- Falling height is so high that falling rock may jump over a fence.

Rock sheds are classified according to the shape into form types; portal, retaining wall, arch and pocket types; as shown in Figure 5.2-77. Rock sheds are made of steel, reinforced concrete or prestressed concrete, among which reinforced concrete is the most common.

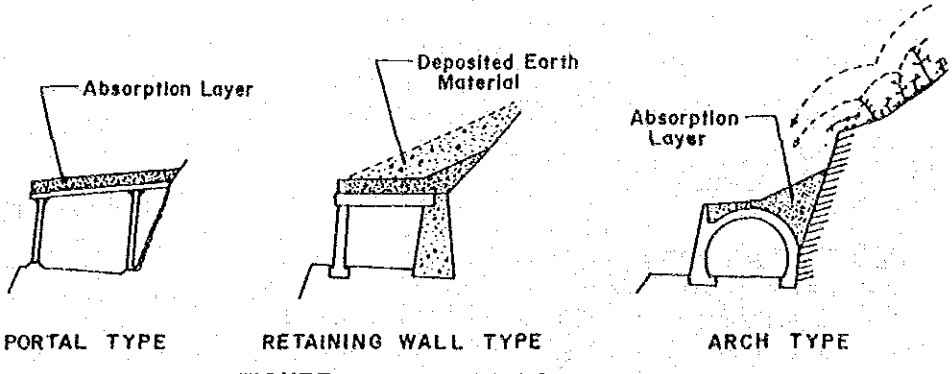


FIGURE 5.2-77 ROCK SHED

Where a road is situated on a mountainside, i.e. mountain on one side and valley on the other side, the following type is recommended. See Figure 5.2-78.

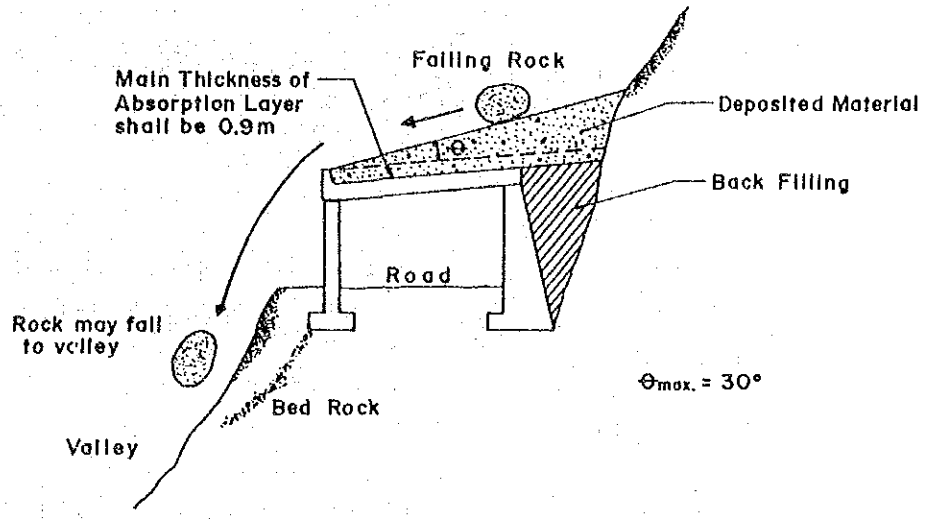


FIGURE 5.2-78 ROCK SHED ON A ROAD IN BETWEEN MOUNTAIN AND VALLEY

5.2.11 P11: Prevention Pile

1) P11-1: Steel Prevention Pile

Prevention pile is a countermeasure for landslide, controlling a movement force of sliding mass by bending strength and shearing strength of pile. Anchoring is sometimes used with pile to increase the resisting force of pile against thrust of sliding mass (Figure 5.2-79).

Piling is usually applied at a place where the bedrock is strong so that pile can withstand a sliding mass. This type is also effecitve in case where the sliding plane is deep. However, if the motion of a landslide is vigorous and exceeds 1 mm per day, piling may not be effective because each pile may act individually unless all piles are placed at the same time.

Pre-cast concrete piles, cast-in-place concrete piles, H-section steel piles and steel pipe piles are used as prevention piles. The most commonly used method is as follows: 1) a bore hole with a large diameter (about 35 to 40 cm) is driven, 2) a steel pipe with a diameter of about 30 cm is inserted to the hole, 3) the inner space of the pipe is filled up with concrete, and 4) the gap between the pipe and wall of bore hole is filled with grout.

Piles are designed following the well-known Chang's Formula.

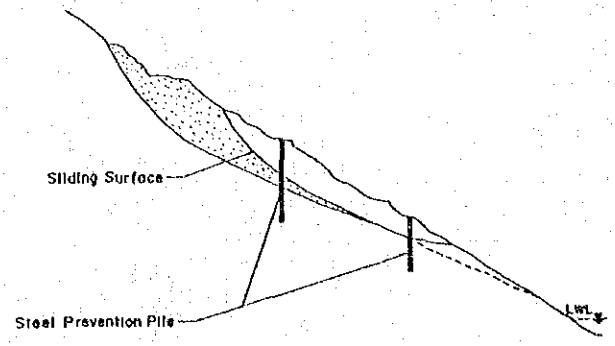


FIGURE 5.2-79 STEEL PREVENTION PILE

5.2.12 P12: *Slope Breasting*

1) P12-1: Stone Breasting

2) P12-2: Gabion Breasting

Breasting is constructed on the cut slope with stones or gabions as shown in Figure 5.2-80.

The same effect as wattling work (P4-8) is expected by this work.

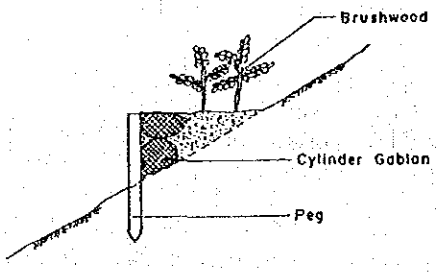


FIGURE 5.2-80 GABION BREASTING

5.2.13 P13: Sabo Dam

Refer to APPENDIX I ANALYSIS METHOD 8. SABO DAM.

Sabo dam is a countermeasure for debris flow with the following purposes:

- To catch and collect debris and sediment
- To control flow of debris and sediment
- To make gradient of stream bed gentler to prevent stream bed and bank from scouring.
- To control turbulent flow and thus prevent stream bank from scouring.

Sabo Dam is classified into several types such as concrete, gabion, steel, etc. depending on the meterial used.

1) P13-1: Concrete Sabo Dam
2) P13-2: Gabion Sabo Dam
3) P13-3: Steel Sabo Dam

Sabo dam work is classified in accordance with the purpose as follows :

- Debris flow prevention dam is used to catch and collect debris and sediment.
- Control dam is to control flow of debris and sediment.
- Scour prevention dam is to prevent stream bed and bank from scouring.
- Hillside dam is to protect stream bank and hillside from scouring

The location of sabo dam must be carefully selected according to its purpose. The following are general guidelines in determining the location of sabo dam:

- Firm Bedrock is preferable so that a stable foundation may be constructed. Where foundation is gravel, a height of sabo dam should be less than 15 m.
- Downstream just after the place where debris are stored/deposited is suitable.
- Upstream just before the width of torrent becomes wider is suitable.
- A curbed portion of torrent is not suitable.

In case the torrent is long and the volume of debris is estimated to be extensive, a series of sabo dams is arranged in a step-like manner as shown in Figure 5.2-81.

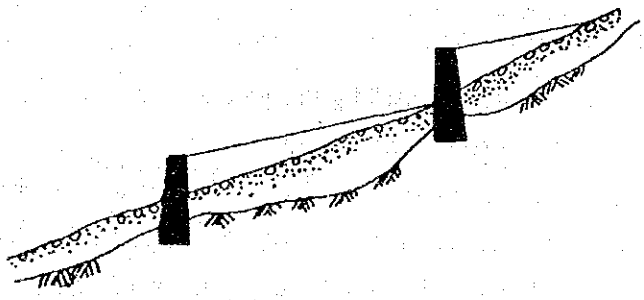


FIGURE 5.2-81 SERIES OF SABO DAM

An example of gabion sabo dam is shown in Figure 5.2-82.

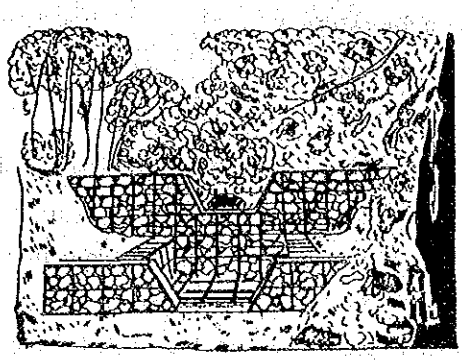


FIGURE 5.2-82 GABION SABO DAM

5.2.14 P14: Consolidation

Consolidation is to prevent a river bed from scour by making a gradient of the river bed gentle. Thus, movement of sediment on the river bed can be controlled and at the same time the river bank is also protected. It is sometimes applied for the protection of the foundation of structures along the river bank.

The materials commonly used for consolidation are concrete and gabion.

1) P14-1: Concrete Consolidation
2) P14-2: Gabion Consolidation

The locations where consolidations are constructed are as follows:

- Where river bed may be scoured
- At a downstream just after a confluence (a meeting point of flows)
- At a downstream after a failure of river bank
- At a downstream just after the curved portion of stream
- Where river stream is swift or turbulent

Figure 5.2-83 shows a typical shape of consolidation structure.

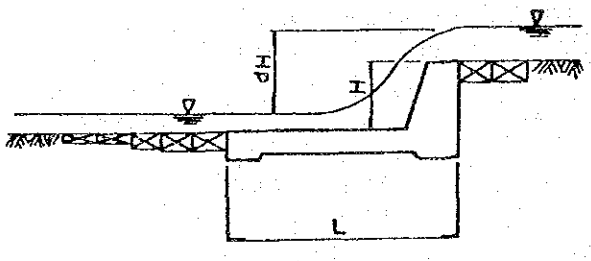


FIGURE 5.2-83 TYPICAL SHAPE OF CONSOLIDATION STRUCTURE