10.2.5 Coastal Erosion－Ginatilan-Alegria Road, Km 172 (Region VII)

(1) Background of Existing Countermeasure

The costal revetment at Ginatilan-Alegria Road, Km 172 was damaged over a 60 m length due to costal erosion. Based on the boring investigation and site damage assessment, the following factors were assumed to cause the said damage;

- The road section was constructed on stiff weathered shale ground (N>40) as shown in Figure 10.45. Groundwater level under the road was observed to be the same as the sea water level at the survey time, however, there were possibilities that the groundwater increases during the rainy season and the water pressure affects the riprap revetment.
- The elevation of the foundation of the existing revetment is approximately +1.0 m above sea level, and the foundation is not embedded. Water level at high tide is supposed to range between approximately +1.0 m to +1.7 m, therefore, the foundation of the existing revetment is deemed to have been scoured.
- Signs of holes formed by seepage water on the road shoulder portion were observed. The groundwater level under the road pavement on the mountain side was the same as the sea water level on the boring survey, which indicates that the seepage water holes were caused by overtopping of waves from the sea side.

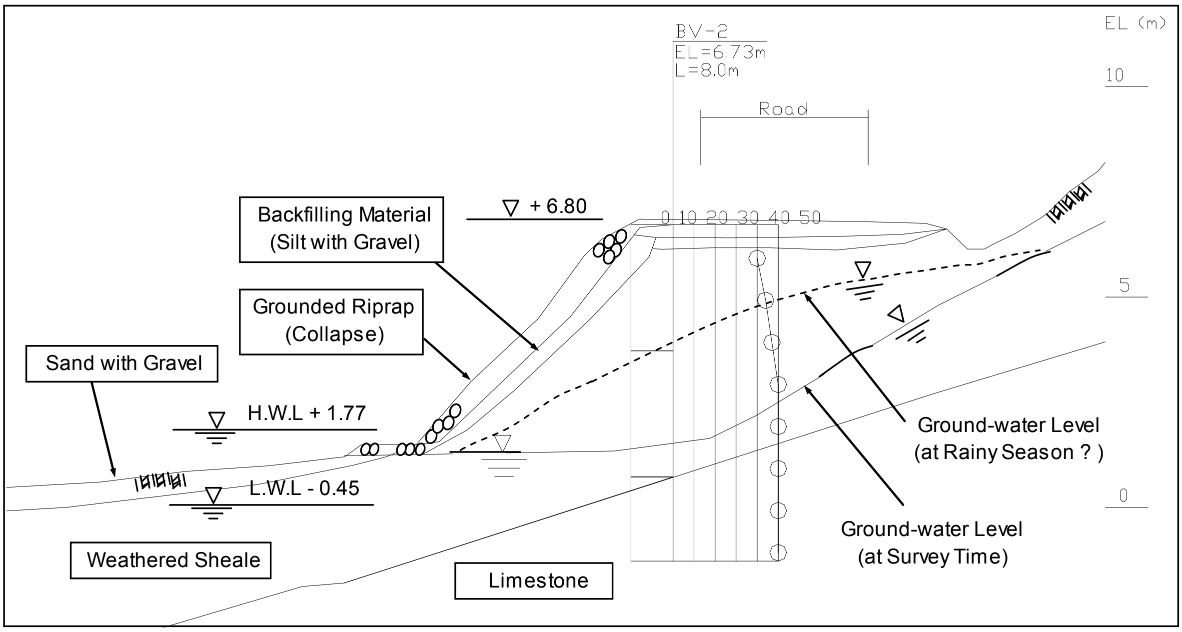


Figure 10.45 Engineering Geological Profile at Ginatilan-Alegria Road Km 171

(2) Design Procedure for the Countermeasure

The structure for the countermeasure design is a coastal revetment of gravity concrete type with a curbed parapet wall as illustrated in Figure 10.46. The shape and dimensions of the retaining structure are as follows;

Wall Type : Leaning Concrete Wall

Sea Water Level = H.W.L = +1.77 m, L.W.L = -0.45 m

Wave Height = 5.0 m

Design Crest Elevation = Design Tide Level + Design Wave Height + Free Board

= +1.77 m + 5.0 m + 0.5 m = +7.27 m → +7.80 m

Height of Wall = H = 6.5 m (including 1.0 m of curbed parapet wall)

Gradient of Wall = 1:0.45 (front slope), 1:0.25 (rear slope)

Foundation Type : Concrete Embedment (H = 0.5 m) + Sheet pile (L=2.0 m)

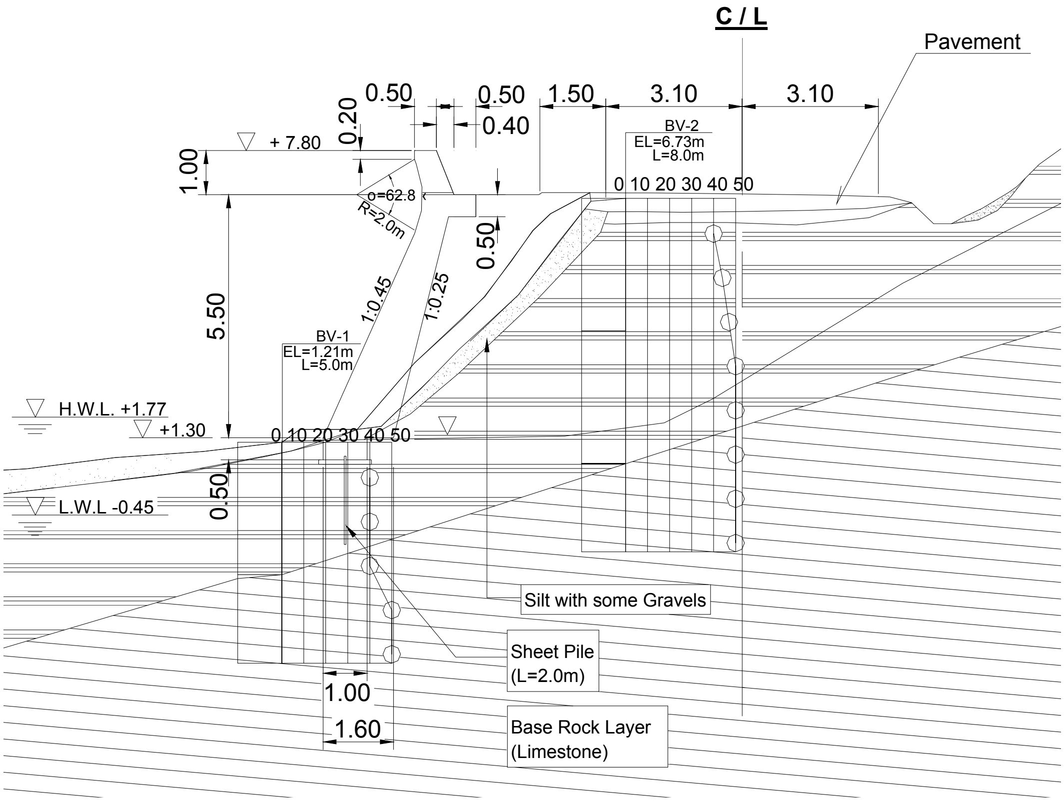


Figure 10.46 Typical Cross Section for Gravity Type Revetment

Figure 10.47 shows the design procedure for the above structure. The revetment type shown in Figure 10.46 is determined from the point of view that that the foundation work should not be executed under water. Thus water a cut-off wall is to be installed to prevent leakage of backfill material, boiling and piping to avoid damage to the revetment. Hereafter, the design method for the water cut-off will be described;

Determination of Soil Design

↓

Determination of Design Water Level : - Sea Water Level (H.W.L., L.W.L.), Wave Height

↓

Determination of Revetment Height

↓

Determination of Design External Forces : Dead Loads, Earth Pressure, Water

↓

Stability Design Calculation of Wall Body : 1) Tumble, 2) Slip, 3) Bearing Capacity

↓

Design of Cut-off Wall on Foundation

↓

End

Figure 10.47 Design Procedure for Coastal Gravity Type Concrete Revetment

(3) Design Method for Water Cut-off Wall

(a) Design Condition of Water Level

Figure 10.48 shows the design condition of the water level for the water cut-off wall.

- Ground water elevation at the back side of the revetment =+2.80 m
  (One third of the height between the ground water level at the mountain side and the elevation of the revetment bottom during the rainy season is assumed.)
- Sea water level = + 1.30 m (at the bottom of the revetment)

(b) Design Criteria and Design Calculations

[Judgment of Impermeability Effectiveness]

Impermeability effectiveness of the cut-off wall is judged from the length of the infiltration route as follows;

$$F = \frac{L}{H_D}$$

where, F = Safety Factor (sandy soil : 3.5 , cohesive soil : 3.0)

L = Length of infiltration route (m)

H_D = Water head deference (m)

In Figure 10.48, the safety factor for the impermeability effectiveness may be satisfied with the requirement;

$$F = \frac{1.6 + 2.5\,x\,2}{1.5} = 4.44 > 3.5 \quad \text{(-O.K.-)}$$

[Judgment of Boiling]

Boiling is checked by Terzagi's method as follows;

$$F = \frac{2 \cdot D(\gamma - \gamma_w)}{H_D \cdot \gamma_w}$$

where, F = Safety Factor (= 2.0)

γ = Unit weight of sandy soil (kN/m^3)

γ_W = Unit weight of water (kN/m^3)

D = Embedment depth (m)

Safety factor for boiling may be satisfied with the requirement as follows;

$$F = \frac{2\,x\,2.5\,x\,(1.9 - 1.0)}{1.5\,x\,1.0} = 3.00 > 2.0 \quad \text{(-O.K.-)}$$

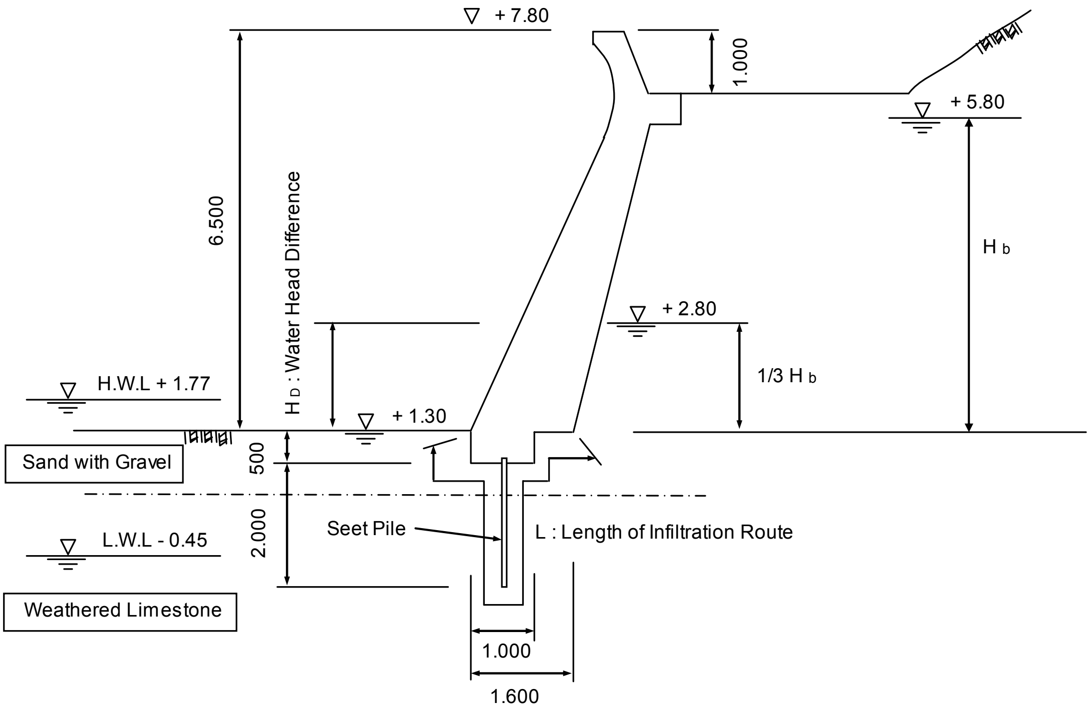


Figure 10.48 Design Condition for Water Cut-off Wall under Foundation

10.2.6 River erosion－Naga-Toledo Road No.2, Sta. 2+600 ~ 2+890

This design example was collected from The Naga-Toledo Road Project under the Arterial Road Links Development Project Phase IV (JBIC Loan No. PH-P204), which started on November 11, 2004 and ended on December 26, 2006.

(1) Damage situation

In November 2001, typhoon "Nanang" generated a heavy downpour in the Central Visayas for several days, resulting in a flood on the river along the project road. Pavements, embankments, slope protections and other structures were seriously damaged by the typhoon.

The damaged Area No.2, Sta. 2+600 ~ 2+890 is one of the areas heavily damaged by the typhoon. The main damage is river erosion due to the inadequate embankment slope protection and river training works, as shown in Photo 10.4.

Photo 10.4 Damage Conditions at Naga-Toledo Road No.2, Sta. 2+600 ~ 2+890

Moreover, the road section is prone to rock fall due to the existence of overhanging rocks above the road.

The geology is mainly sandstone and mudstone and locally contains conglomerate and limestone lenses.

(2) Selection and Design of countermeasure works

On the basis of the site reconnaissance, the recommended countermeasure was as follows:

- Refilling work to provide the necessary width of the road

- Revetment work (steel sheet piling work and riprap) to prevent the embankment slope from river scouring
- A lined ditch canal on the mountain side to prevent erosion of the roadway by surface runoff
- Widening a bottleneck in the river channel (river training) to decrease flow speed and reduce scouring energy
- Removal of overhanging rocks by controlled blasting

Photo 10.5 shows the condition after completion of the restoration works.

Photo 10.5 Restoration of Damaged Area No.2, Sta. 2+600 ~ 2+890

(3) Quantity of restoration works

The total quantity of restoration works is summarized below

- Clearing and grubbing: 0.433 ha
- Structural excavation (common): 2,906.9 m^3
- Foundation fill: 82.44 m^3
- Dredging of riverbed (common): 4,866.7 m^3
- Dredging of riverbed (hard material): 2,143.1 m^3

- Backfill/embankment: 3,947.4 m^3
- Grouted riprap (class A): 617.6 m^3
- Stone masonry: 797.9 m^3
- Steel Reinforcing bars (grade 40): 6,243.4 kg
- Concrete (class A): 138.9 m^3
- Concrete (class b): 50.9 m^3
- Lean concrete : 11.4 m^3
- Gabion mattresses: 968.9 m^3
- Geotextile filter fabric: 1,937.4 m^2
- Steel sheet piles: 4,266 l.m

10.3 Examples of Countermeasure Design in Japan

10.3.1 Soil Slope Collapse

This design example is a modification of a case study of countermeasure designs collected in the Road Slope and Restoration Works for Road Slope Disasters.

(1) Road slope situation

(a) Geology and topography

The soil slope collapse occurred on the north slope of the ridge that extends east and west. The collapsed area and its surroundings had a slope of 40 to 50 degrees.

The bedrock consists mainly of sandstone and shale and contains some intercalated thin shale bed. The overlying material is mainly river terrace and talus deposits.

(b) Disaster situation

This soil slope collapse occurred on cut slope due mainly to heavy precipitation during the period from the 31st of March to the 1st of April, 1980. The cut slope was protected mainly by vegetation and locally by natural stone pitching.

The soil slope collapse damaged the road slope including some slope protection structures, leading to a collapse area of about 2400 m^2. The collapse debris, estimated at about 4,700 m^3 in volume, completely blocked the road and partially blocked the channel of the river.

(2) Design of restoration works

(a) Site reconnaissance

Site reconnaissance of the collapsed area and its surroundings showed that the bedrock is sandstone and shale. The bedrock exposed on the collapsed area, brown and grayish brown, is strongly jointed by some structural discontinuities, including bedding and several sets of cracks perpendicular or oblique to the bedding plane.

The overlying material consists mainly of river terrace, talus and river bed sediment. The river terrace spreads smoothly on the head portion of the collapse. Spring water was observed along the foot of the terrace surface indicating that the river terrace is high water bearing.

The collapse surface was formed between the strongly weathered rock and the fresh rock, having an average thickness of about 5 to 6 meters.

Intense rainfall resulting in high pore water pressures in the thin overlying deposit and strongly weathered rock was a major factor in triggering the soil slope collapse.

(b) Selection and design of countermeasures

The selection of countermeasures against soil slope collapse should not considerably change the existing topography as it was after the collapse to ensure its conformity with its surrounding natural conditions. The basic policies for selecting countermeasures were as follows:

- Debris and rock blocks above the collapse surface should be removed as completely as possible.
- Loose river terrace distributed on the head portion of the soil slope collapse should be smoothed consistently up to its upper slope at a stable gradient.
- After shaping and resloping, the cut slope should be protected against weathering and erosion.
- Draining works should be provided between the bedrock and the river terrace on the head portion of the soil slope collapse in order to remove groundwater in the river terrace during rainfall.

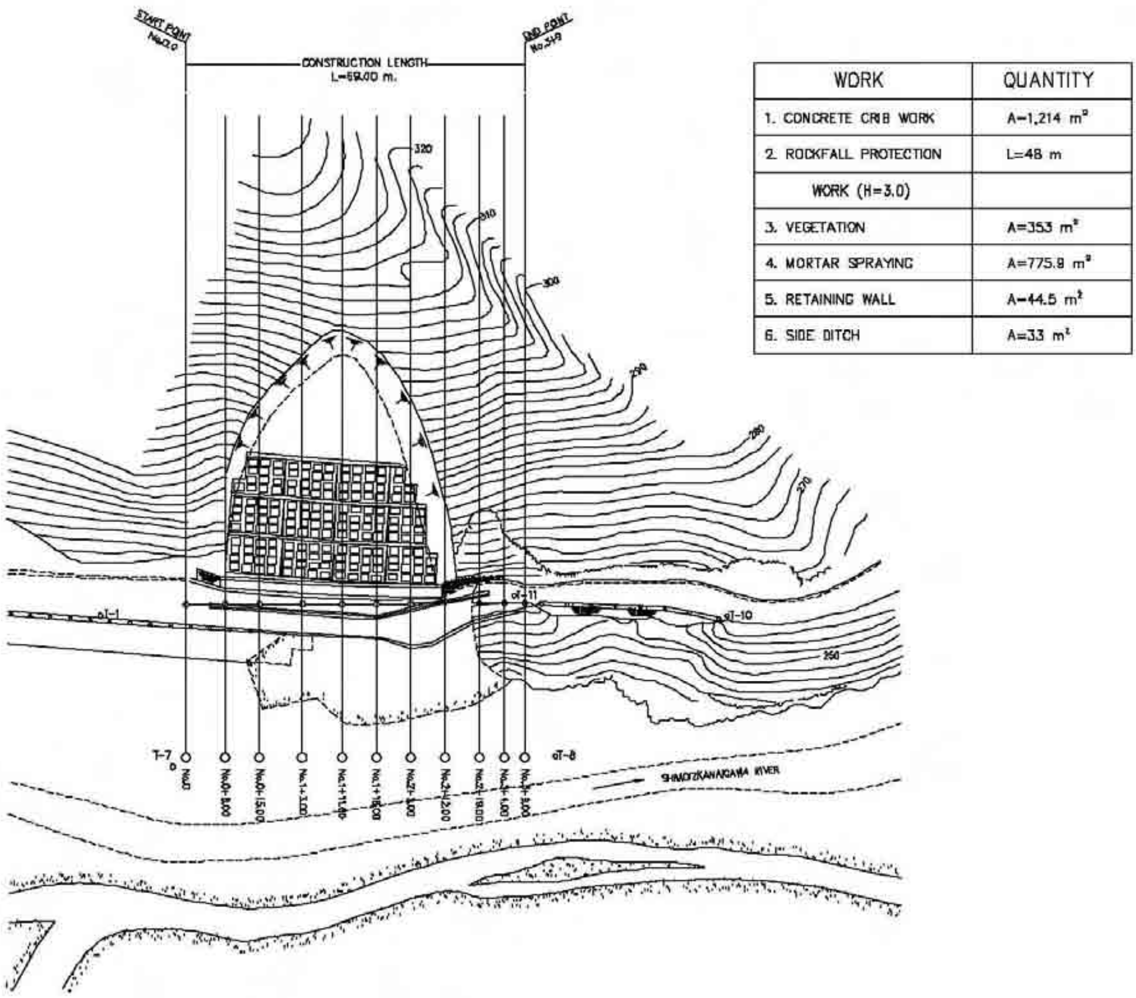
The following countermeasures for the soil slope collapse were determined on the basis of the above-mentioned basic policies:

- The gradient of cut slope was determined to be 1:1.0 (V:H), considering 1) Its conformity with the surrounding natural slopes after the removal of the loose debris and rock blocks, 2) The ease of construction of cast-in-place concrete crib work, and

3) The relationship between the height of the retaining wall and the volume of excavated soil.

- The protection of the cut slope from the lower to the upper portions were 1) a concrete retaining wall, 2) three steps of cast-in-place concrete crib work, 3) mortar spraying and 4) seed spraying. Some loose rock blocks remained on the cut slope, especially at the lower portion after resloping. Cast-in-place concrete crib work was thus provided to stabilize the loosened material. The weathered rock exposed on the upper portion of the cut slope was covered by mortar spraying. Seed spraying was carried out on the river terrace.

The general plans and typical sections for the above-mentioned plans are shown in Figures 10.49 and 10.51.



WORK	QUANTITY
1. CONCRETE CRIB WORK	A=1,214 m²
2. ROCKFALL PROTECTION	L=48 m
WORK (H=3.0)	
3. VEGETATION	A=353 m²
4. MORTAR SPRAYING	A=775.9 m²
5. RETAINING WALL	A=44.5 m²
6. SIDE DITCH	A=33 m²

Figure 10.49 Plane Layout of Countermeasure for Soil Collapse

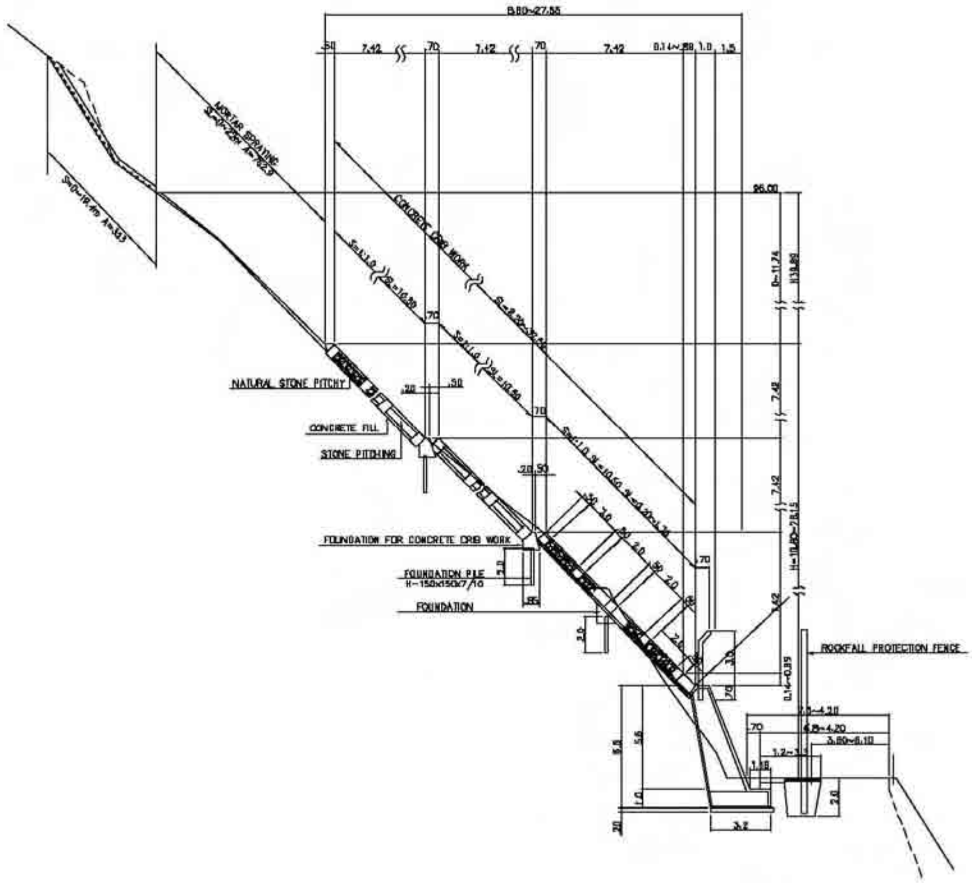


Figure 10.50 Section Layout of Countermeasure for Soil Collapse

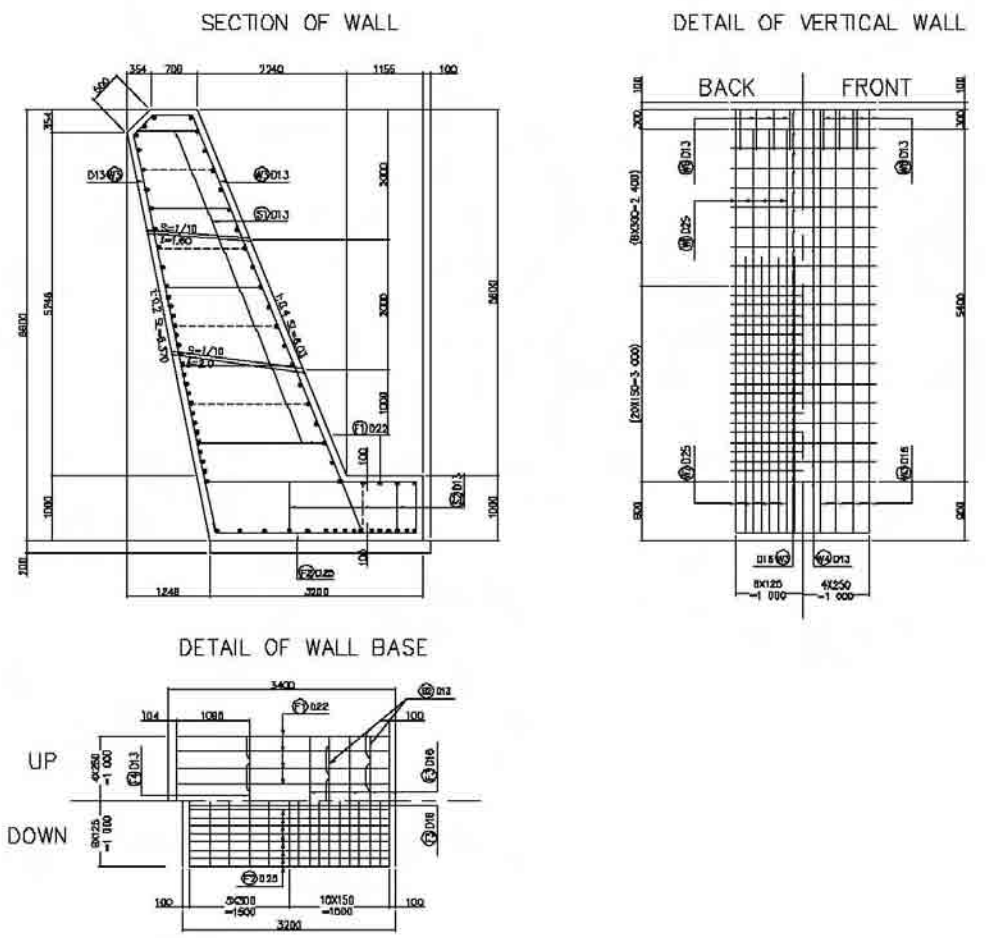


Figure 10.51 Structural Detail of Countermeasure for Soil Collapse

(3) Quantities and construction cost of restoration works

The total quantities and construction cost of restoration works is outlined below.

Construction cost: 113,219,000 Japanese Yen

- Restoration length: 69.0 m
- Excavation: 4,710 m^3
- Temporary protection fence: 57.0 m
- Concrete retaining wall: 44.5 m
- Cast-in-place concrete crib work: 5,632 m^2
- Mortar Spraying (t=100mm): 775.9 m^2
- Vegetation: 1,201 m^2
- Roadside concrete wall (H=2.0 m to 5.0 m): 33 m

10.3.2 Landslide

This design example is a modification of a case study of countermeasure designs collected in Road Slope and Restoration Works for Road Slope Disasters, 1980.

(1) Road slope Situation

(a) Geology and Topography

The road slope where the landslide occurred has a gradient of 30 to 40 degrees; and the height from the riverbed to the ridge is 80 to 90 m. The road is at the height of 25 m above the riverbed.

The landslide slope is geologically composed of mudstone of Middle to Late Miocene and intercalated partially with siltstone and tuffaceous sandstone. The mudstone is strongly weathered and highly fractured.

(b) Disaster situation

The landslide was initially triggered by a heavy precipitation of 400 mm during the 17th to 19th February, 1981, with a small-scale collapse of 50 m by 50 m above the road. The landslide debris completely blocked the road and dammed the river below the road.

The initial landslide debris was estimated at about 3,000 m^3 in volume. Later, because of a typhoon in October of the same year, the landslide was reactivated and considerably enlarged in size, leading to a final scale of 150 m in width, 70 m in length and about 40,000 m^3 in volume.

The landslide damaged the pavement of the road surface (5.5 m wide and 130 m long), a rock fall catch fence (130 m long) on the mountain side and a concrete retaining wall (4 m high and 27 m long) on the valley side.

(2) Design of Restoration Works

(a) Landslide investigation

After the occurrence of the landslide, a site reconnaissance was conducted. The site reconnaissance results showed that a main scarp near the top of the ridge at an elevation of about 150 m above sea level was connected with a continuous crack in its north slope and two small scarps in its south slopes. Therefore, the landslide was divided into three movement blocks on the basis of the topographical characteristics and the distribution of landslide scarps and cracking conditions.

Furthermore, the following investigations and monitoring were carried out to observe the sliding surface and movement conditions of the landslide.

- 8 borings with a total drilling length of 135 meters.
- 8 boreholes for groundwater level observation.
- 2 ground extensometers (installed respectively at the heads of the movement blocks A and C).

The landslide investigation results are summarized as follows:

- the movement blocks A and B both had a boat-shaped sliding surface. The sliding surface was developed below the strongly weathered mudstone, about 10 m below the ground surface. The two movement blocks moved 80 mm a day on average.
- The movement block C had a chair-shaped sliding surface, which was situated below the strongly weathered mudstone, about 12 m below the ground surface. The movement block C was triggered by with the movement of the movement blocks A and B. The block moved slowly at a mean movement speed of 2.6 mm/day.
- Groundwater was present below the sliding surface in every borehole in weakly weathered mudstone.

(b) Selection and design of countermeasures

The conceivable countermeasures for the prevention of a landslide were mainly 1) Cutting work, 2) Filling work, 3) Drainage work, and 4) Pilling work. Because the landslides occurred on a steep slope and extended onto the road at its toe, filling work and pilling work were considered to be unsuitable. In addition, because the groundwater level was already below the sliding surface, drainage work would thus be ineffective. Accordingly, cutting work was selected as the main countermeasure for these landslides.

Moreover, regarding the small-scale collapse on the valley side of the road, two alternatives were conceivable as preventive measures: 1) Repairing the existing road by constructing a cantilever concrete retaining wall and 2) shifting the road into the mountain side by recutting.

The general plan and typical sections for each movement block are shown in Figures 10.52 and 10.53. Figure 10.54 shows the details of the concrete crib work.

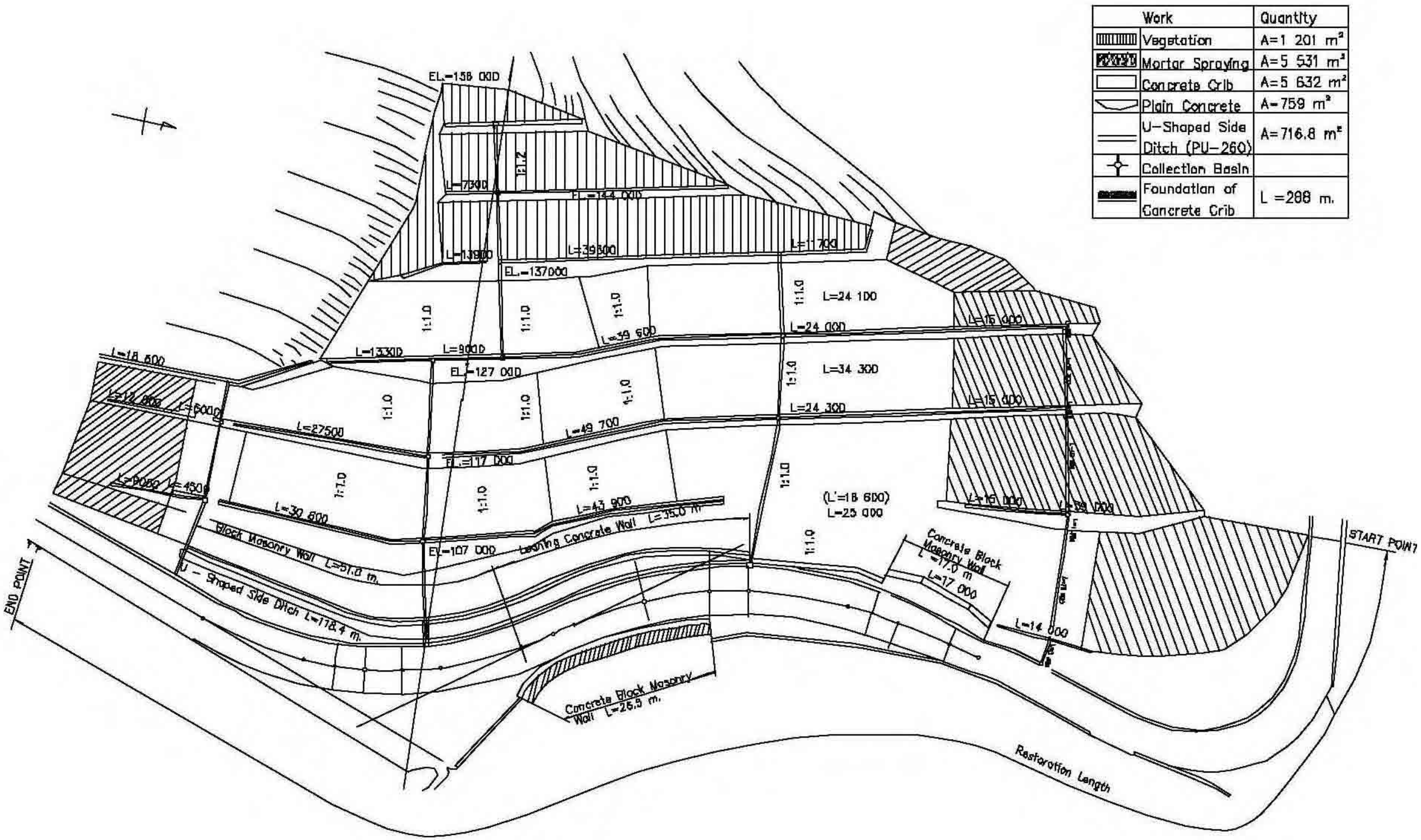


Figure 10.52 General Plane Layout of Countermeasure for Landslide

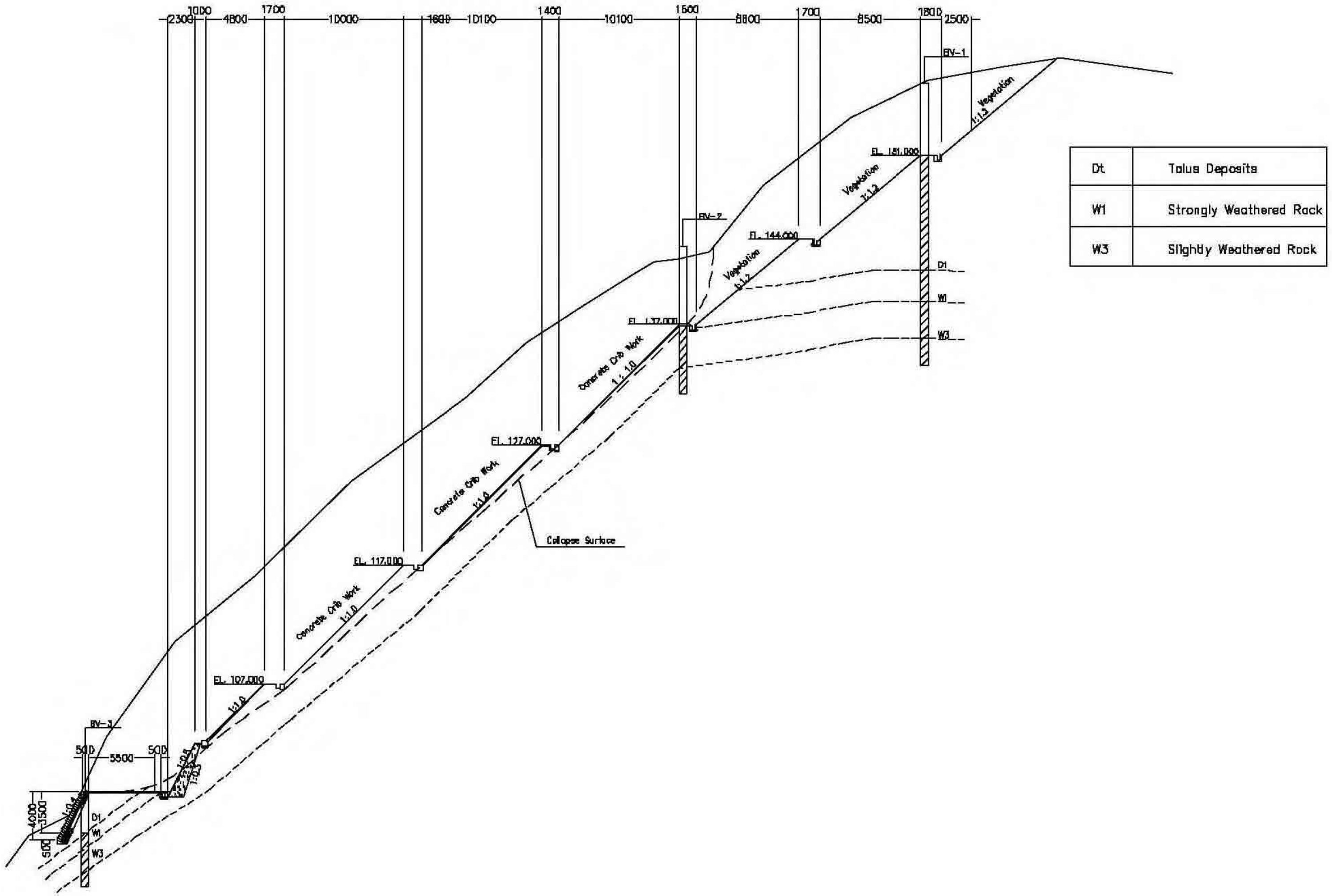


Figure 10.53 General Plane Layout of Countermeasure for Landslide

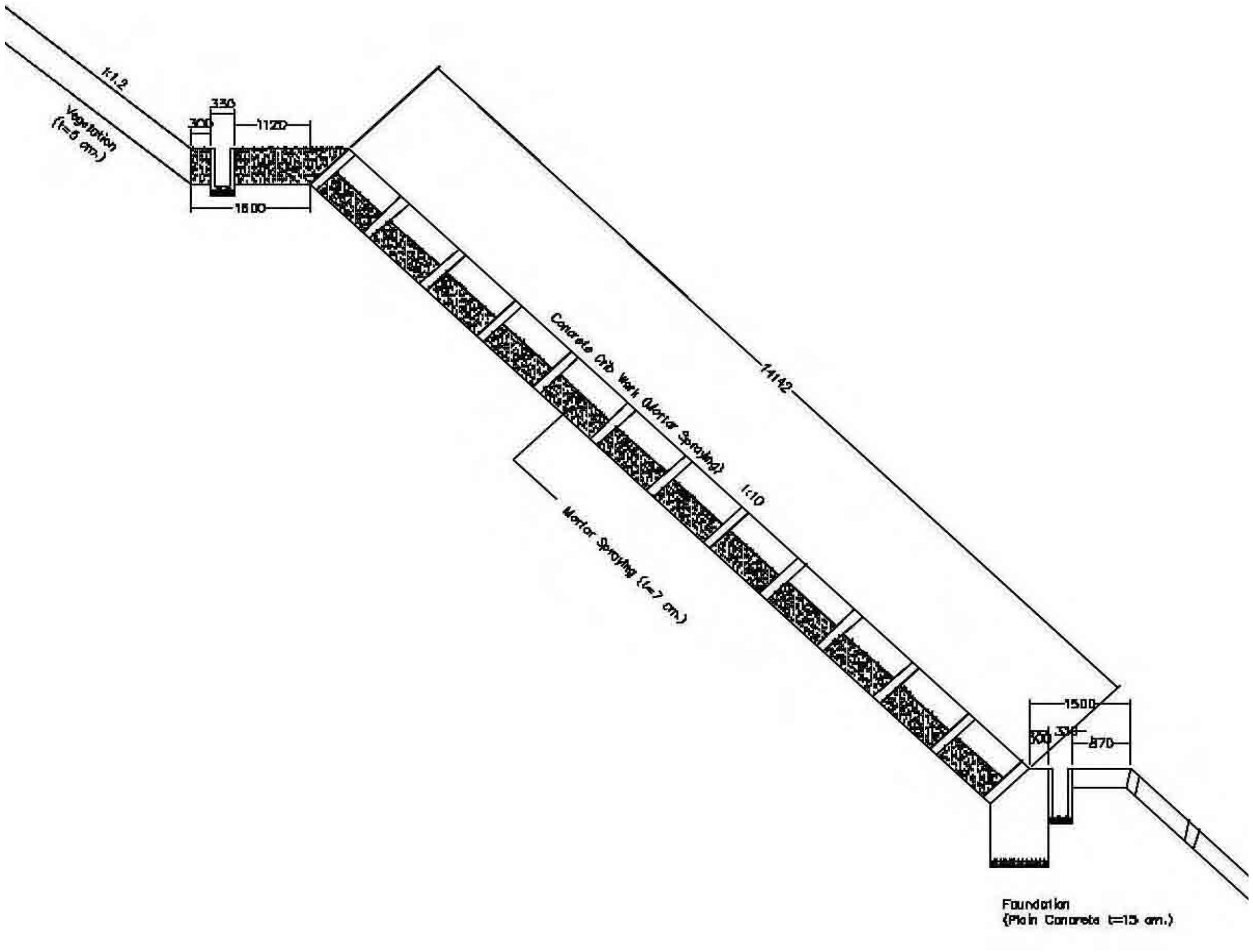


Figure 10.54 Details of Concrete Crib Work

On the basis of technical and economic comparisons, the final countermeasures for each movement block were selected as follows:

- In the cases of movement blocks A and B, the unstable landslide mass above the sliding surface and the potential unstable material were removed as completely as possible. In addition, because the toe of movement block A was deeply cut, a leaning concrete retaining wall was provided to stabilize the foot of the cut slope.
-
- For movement block C, the partial removal of unstable landslide mass was determined on the basis of the stability analysis of cut the slope. Moreover, a concrete block masonry retaining wall was provided to stabilize the foot of the cut slope.
- In order to prevent surface weathering and rock fall on the cut slope, the lower four steps of the cut slopes, which were underlain by weathered mudstone, were covered with concrete crib work, while the upper three steps of the cut slopes consisting of colluvial deposit were protected with vegetation. Moreover, mortar spraying work was carried out on both sides of movement blocks B and C for the protection of their adjacent stable areas.
- The existing retaining walls on the mountain and valley sides of the road would be difficult to repair, therefore, after realigning the road into the mountain side; a new concrete block retaining wall was provided on the valley side of the road to protect against further road slip.

(c) Stability analysis after cutting

A stability analysis of the cut slopes was carried out solely for movement block C because the landslide masses in movement blocks A and B were completely removed. The results of the stability analysis were summarized as follows:

- Ground extensometer monitoring showed that movement block C was moving, therefore its initial safety factor, Fs was determined to be 0.95.
- The maximum vertical thickness of sliding mass was about 10 m, therefore, the cohesion, C was determined to be 10 kN/m^2).
- The internal friction angle of the sliding surface was obtained (ϕ =43.2 degrees) using the back calculation method.
- The proposed safety factor, PFs was determined to be 1.2 in consideration of the

importance of the road to be protected and the degree of damage to be caused by a landslide. The safety factor of the cut slope in movement block C was calculated to be 2.10, which is greater than PFs=1.2. In conducting the stability analysis, the pore pressure acting on the sliding surface was assumed to be zero because the groundwater level was observed to be below the sliding surface.

(3) Quantities and construction cost of the restoration works

The total quantities and construction costs of restoration works are outlined below.

- Construction cost: 177,833,000 Japanese yen
- Restoration length: 238 m
- Excavation: 50,800 m^3
- Clearance of cut slope: 9,240 m^2
- Concrete block masonry wall: 212 m^2
- Large concrete block masonry wall: 134.8 m^2
- Leaning concrete retaining wall: 97 m^3
- Concrete crib work: 5,632 m^2
- Mortar Spraying: 5,531 m^2
- Vegetation: 1,201 m^2
- Pavement: 762 m^2

10.3.3 Rock Fall on Primary Local Road

This design example is a case study of countermeasures designed for rock fall.

(1) Road slope situation

(a) Geology and topography

The slope, about 80 m wide, is a combination of ridge-type and valley-type landforms. The height between the top of the ridge and the road is about 60 m. The gradient of the slope is 60 to 70 degrees for exposed rocks, and 30 to 40 degrees for talus slope.

The bedrock is mainly shale with highly developed exfoliations, forming a dip slope. The shale is covered by talus deposits chiefly along valleys.

The slope was subdivided into the following three slope blocks on the basis of geological and topographical characteristics, as summarized in Table 10.30.

Table 10.30 Summary of Slope Conditions

Block	Distance	Item	Characteristics
A	No.0'～ No.0	Geology and topography	• Gentle valley-type slope, with a slope of 30 to 40 degrees. • Rock out crops locally on steeper slopes, the slope is covered completely by talus of gravely soils.
		Collapse	• Small collapses are distributed around the springs (at the head of the valley).
		Surface water and springs	• Surface water runs at a flow rate of 30 to 40 l/min, starting from the height of 50 m above the road.
		Deformation	• No structures.
B	No.0～ No.1	Geology and topography	• Straight-type slope, with a slope of 40 to 50 degrees. • Rock out crops at the height of 30 m above the road; these are the main source of rock fall. Below the height covered is talus deposit.
		Collapse	• Collapse scars of horse-shoe shaped are observed.
		Surface water and spring	• Absent.
		Deformation	• Block masonry wall and ditches were cracked.
C	No.1～ No.1+8.0	Geology and topography	• Steep ridge-type slope, with a slope of 60 to 70 degrees. • Rock cliff is controlled by steep cracks, generating many flaking-type rock falls of 0.5 m in size.
		Collapse	• None.
		Surface water and spring	• Absence.
		Deformation	• No deformation in leaning type retaining wall.

(b) Risk of rock fall

Individual potential large rock falls, both the uprooting-type and the flaking type, were inspected one by one regarding their size and stability. A total of 54 large rock blocks were selected as potential rock falls. Of these, 47 rock blocks were at high risk and should be treated with countermeasures for rock fall.

(2) Selection of countermeasure works

(a) Policy for the selection of countermeasure works

The policy for the selection of countermeasures for the expected rock falls was as follows:

- The existing structures against rock falls should be used effectively in the planned countermeasure works.
- The expected rock falls should be prevented by rock fall protection works on the mountain side of the road as much as possible.
- For bigger rock blocks that were difficult to cope with by rock fall protection works, rock fall prevention works should be used to fix or stabilize them at the source by rock fall prevention works.

(b) Selection and alternative study of countermeasures

The following three plans are conceivable as countermeasures for rock fall according the above-mentioned policy.

Plan A: Rock fall protection work + Rock fall prevention work (Breaking work).
A standard rock fall protection fence is proposed directly behind the existing stone masonry wall at No.0 to No.1+1.0.
A concrete catch wall with rock fall protection fence is proposed on the valley side at Sta. No.0'-4.0 to No.0+5.0.
Breaking work (breaking big rock blocks to a size small enough to be treated with rock fall protection work) is used to cope with these bigger rock blocks that are beyond the capacity of the above fence.

Plan B: Rock fall protection work + Rock fall prevention work (Wire rope work).
A standard rock fall protection fence is proposed directly behind the existing stone masonry wall at Sta. No.0 to No.1+1.0.
A concrete catch wall with rock fall protection fence is proposed on the valley side at Sta. No.0'-4.0 to No.0+5.0.
Wire rope is planned to cope with the bigger rock blocks that are beyond the capacity of the above fence.

Plan C: Rock fall protection work with high energy absorption capacity.
A rock fall protection fence with high energy absorption capacity is proposed on the existing stone masonry wall at No.0 to No.1+1.0.
A concrete catch wall with rock fall protection fence of high energy absorption capacity is proposed on the valley side at Sta. No.0'-4.0 to No.0+5.0.

On the basis of the detailed comparative study, the evaluation results are summarized in Table 10.31.

Table 10.31 Study of Alternative Countermeasures

Item	**Plan A**	Plan B	Plan C
Degree of Safety	**Medium**	Medium	High
Workability	**High**	High	Low
Aesthetic Appearance and Environment	**Medium**	Medium	Medium
Construction Cost (1,000 Yen)	**9,200**	11,000	18,700
Evaluation Ranking	**1**	2	3

As a result of the evaluation, plan A is recommendable technically and economically.

(c) Calculation of kinetic energy of falling rocks

The velocity and kinetic energy of falling rocks was calculated using Equations 4.1 and 4.4 respectively, as shown before in Chapter 4 of this Guide III.

Further, in calculating the velocity and kinetic energy of falling rocks, the relevant parameters are determined as follows:

- Mass unit of falling rocks, m = 2.6 tons. (unit weight, $\gamma_t = 2.6$ ton/m^3)
- Falling height, H = 40 m
- Equivalent coefficient of friction of the slope, $\mu = 3.5$, on the basis of Table 4.1 shown in Chapter 4 of this Guide III.
- Rolling energy ratio, $\beta = 0.1$, as explained in Chapter of this Guide.

Table 10.32 shows the calculated kinetic energy of falling rocks to be inspected together with their sizes.

Table 10.32 Size and Kinetic Energy of Falling Rocks

No.	Type	Width	Height	Length	Mass	Slope height	Slope gradient	Velocity	Energy
		w	h	l	m	H	θ	V	E
		(m)	(m)	(m)	(ton)	(m)	(degree)	(m/s)	(KJ)
1	U	1.4	1.4	0.8	4.08	8	30	7.9	138.6
2	U	0.2	0.8	0.4	0.17	4	20	1.7	0.3
3	U	0.3	0.8	0.3	0.19	7	60	10.5	11.4
4	U	1.0	1.4	0.4	1.46	10	60	12.5	125.6
5	U	0.3	0.6	0.4	0.19	8	60	11.2	13.1
6	U	0.2	0.4	0.5	0.10	8	60	11.2	6.9
7	U	0.3	0.9	0.4	0.28	8	60	11.2	19.3
8	U	0.4	1.2	0.3	0.37	7	60	10.5	22.3
9	U	0.2	1.0	0.3	0.16	7	60	10.5	9.6
10	U	0.4	0.6	0.2	0.12	13	60	14.3	13.4

11	U	0.4	0.6	0.5	0.31	12	60	13.7	32.0
12	U	0.4	1.1	0.8	0.92	10	60	12.5	79.1
13	U	0.4	0.2	0.5	0.10	12	60	13.7	10.3
14	U	0.3	0.5	0.3	0.12	12	60	13.7	12.4
15	U	0.4	1.2	0.4	0.50	15	60	15.3	64.5
16	U	0.2	0.5	0.4	0.10	14	60	14.8	12.0
17	U	0.8	1.0	0.6	1.25	16	80	17.2	202.3
18	U	0.7	1.0	0.4	0.73	16	80	17.2	118.1
19	U	0.3	0.6	0.4	0.19	17	70	17.1	30.4
20	F	0.3	0.4	0.2	0.06	19	80	18.7	11.5
21	U	1.0	0.8	0.3	0.62	20	40	15.1	77.9
22	U	1.0	1.2	0.6	1.87	24	40	16.6	282.0
23	U	0.4	0.4	0.3	0.12	25	42	17.3	19.8
24	U	0.4	0.5	0.2	0.10	26	42	17.6	17.1
25	U	0.4	0.7	0.3	0.22	27	42	18.0	39.1
26	U	0.6	0.8	0.5	0.62	28	40	17.9	109.1
27	U	0.8	1.4	0.4	1.16	24	40	16.6	174.9
28	U	1.4	4.0	1.0	14.56	29	42	18.6	2782.4
29	U	1.0	1.6	1.0	4.16	28	42	18.3	767.6
30	U	0.6	0.7	0.3	0.33	21	42	15.9	45.7
31	U	0.4	0.8	0.3	0.25	24	42	17.0	39.5
32	U	0.4	0.8	0.4	0.33	26	42	17.6	56.5
33	F	0.5	0.6	0.3	0.23	32	38	18.6	43.8
34	U	0.8	1.0	0.5	1.04	32	48	20.7	245.7
35	F	0.6	0.8	0.4	0.50	33	40	19.4	103.7
36	F	0.3	0.4	0.4	0.12	31	80	23.9	37.6
37	U	0.7	1.0	0.4	0.73	32	80	24.3	236.3
38	U	0.7	1.0	0.5	0.91	33	80	24.6	303.7
39	U	0.6	0.6	0.4	0.37	34	80	25.0	127.2
40	F	0.7	0.8	0.6	0.87	34	40	19.7	185.9
41	F	1.0	1.0	0.6	1.56	37	40	20.6	362.7
42	F	0.6	1.0	0.3	0.47	39	40	21.1	115.2
43	U	0.3	0.6	0.4	0.19	40	40	21.4	47.8
44	U	0.5	0.8	0.3	0.31	38	40	20.8	74.0
45	F	0.4	0.4	0.2	0.08	40	45	22.6	22.4
46	F	0.3	0.7	0.4	0.22	40	45	22.6	61.7
47	U	0.7	0.6	0.2	0.22	39	50	23.2	65.3
48	U	0.3	0.5	0.2	0.08	38	50	22.9	23.1
49	U	0.5	0.4	0.2	0.10	30	50	20.4	22.8
50	F	0.4	0.4	0.2	0.08	26	40	17.2	13.1
51	F	0.4	0.6	0.1	0.06	11	30	9.2	2.8
52	F	0.4	0.4	0.4	0.17	19	45	15.6	22.6
53	F	0.6	0.3	0.3	0.14	12	30	9.6	7.1
54	U	0.6	0.6	0.3	0.28	25	40	16.9	44.0

Note: U = Uprooting-type rock fall, F = Flaking-type rock fall.

(3) Design of countermeasures (Plan A)

(a) Outline of selected countermeasure works

Based on the comparative study mentioned above, Plan A was finally selected as the countermeasure to be required at this site. The works are outlined as follows:

- **Sta. No.0'-4 to No.0'+5:** Concrete catch wall (gravity-type) with rock fall protection fence (having a absorption energy capacity of about 50 KJ)
- **Sta. No.0 to No.1+1.0:** Standard rock fall protection fence with underground foundation (having a absorption energy capacity of about 110 KJ)
- **Sta. No.1+1.0 to No.1+8.0:** Utilize the existing rock fall protection fence

(b) Design of concrete catch wall with rock fall protection fence

Figure 10.55 shows the details of the works to be required at this site. Table 10.33 summarizes the design conditions, parameters and criteria for the design of the concrete catch wall and rock fall protection fence; while Table 10.34 gives the specifications for the rock fall protection fence to be used.

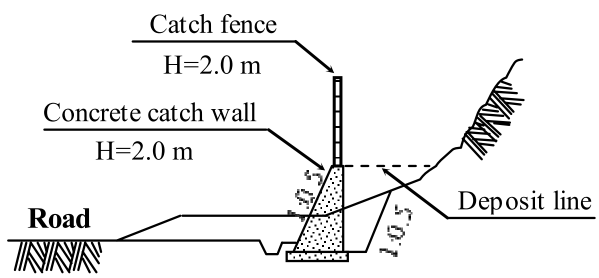


Figure 10.55 Details of These Works

Table 10.33 Summary of Design Conditions, Parameters and Criteria

Conditions, Parameters and Criteria		Remarks
1. Unit weight of backfill material (kN/m^3)	$\gamma t = 18$	Gravely and sandy soil
2. Internal friction angle of backfill material (degrees)	$\phi = 30$	
3. Cohesion of backfill material (kN/m^2)	C= 0	
4. Unit weight of concrete (kN/m^3)	$\gamma c = 23$	Plain concrete
5. Friction resistance of ground with concrete base	$\mu = 0.6$	Sandy layer
6. Bearing capacity of foundation ground (kN/m^2)	Qa = 200	Sandy layer
7. Friction angle between concrete wall and ground (degrees)	$\theta = 30$	$\theta = 0.5\ \phi$

Table 10.34 Detailed Specifications of Rock Fall Protection Fence to Be Used

Item	Specification	Remarks
1. Height of fence (m)	H = 2.0	
2. Interval of posts (m)	a = 3.0	
3. Wire rope	3×7 G/18 ϕ	Yield tensile force Ty=118
4. Intermediate posts	H-200×100×5.5×8	
5. End posts	H-150×150×7×10	
6. Wire net	3.2 ϕ 50×50	
7. Length of fence (m)	L = 9.0	

Note: 1) The allowable maximum displacement angle of the posts, ϕ = 15 degrees
2) Elastic coefficient of wire rope, Ew = 10,000 kN/cm^2.

The energy absorbable by the rock fall protection fence is calculated to check its energy absorption capacity, using Equation 4.6, as shown in Chapter 4 of this Guide III. The details of the calculation are omitted because of the difficult process. The calculated results are as follows:

$$E_T = E_R + E_P + E_N = 4.74 + 22.74 + 25.0 = 52.48 \text{ KJ}$$

According to the calculated results of the absorbable energy, the rock fall protection fence can not cope with the bigger falling rocks that have impact energy of more than 50 KJ,. These bigger rocks should be treated by breaking into manageable sizes.

The stability calculation results of the planned concrete catch wall are summarized in Table 10.35.

Table 10.35 Stability Calculation Results of the Planned Concrete Catch Wall

Item	Evaluation criteria	Calculation result	
		Normal case	Falling case
Sliding	Greater than Fs=1.5 for normal Greater than Fs=1.2 for falling	Fs = 2.818	Fs = 1.607
Overturning	Less than B/6=0.25 m for normal Less than B/3=0.50 m for normal	e = 0.108 m	e = 0.426 m
Bearing capacity	Less than qa = 200 kN/m^2 for normal Less than qa = 300 kN/m^2 for falling	qmax = 48 kN/m^2	qmax = 103 kN/m^2

The results calculated above show that the proposed concrete catch wall is safe for all cases.

(c) Design of Underground Foundation for Rock Fall Protection Fence

Table 10.36 summarizes the design conditions, parameters and sizes for the design of the underground foundation.

Table 10.36 Summary of Design Conditions, Parameters and Criteria

Conditions, Parameters and Criteria			Remarks
1. Ground condition	1.1 Unit weight (kN/m^3)	$\gamma t = 18$	
	1.2 Internal friction angle (degrees)	$\phi = 25$	
	1.3 Cohesion (kN/m^2)	C = 10	N=3
	1.4 Ground gradient (degrees)	$\beta = 0$	
2. Foundation	2.1 Width (m)	B = 0.7	
	2.2 Depth of embedment (m)	Df = 1.0	
	2.3 Unit weight (kN/m^3)	$\gamma c = 23$	Plain concrete
3. Impact of falling rock	3.1 Impact force (kN)	Fy = 25.5	
	3.2 Height of resultant force	h1= 1.67	h1=2/3h*
4. Load at the top of foundation	4.1 Horizontal force (kN)	H = 25.5	H = Fy
	4.2 Bending moment (kNm)	M = 42.5	M = H×h1

Note: h = the height from the top of foundation.

The calculation results for the Underground Foundation are shown in Table 10.37. The calculated results show that the proposed concrete foundation is safe for the installation of the rock fall protection fence.

Table 10.37 Stability Calculation Results for the Underground Foundation

Item	Evaluation criteria	Calculation result
Sliding	Greater than Fs=1.2	$Fs = M_R/M_O = 73.02/56.79 = 1.28$
Overturning	Less than Df = 1.0 m	lo = 0.560 m

(4) Quantities and construction cost of countermeasure works

The total quantity and construction cost of restoration works is outlined below.

- Construction cost: 9,200,000 Japanese Yen
- Length: 42.8 m
- Rock fall protection fence (H=2 to 2.5m) 30.0 m
- Foundation (concrete) 32.7 m^3

- Excavation: 1,400 m^3
- Backfilling: 26.7 m^3
- Removal of damaged structures: 3.2 m^3
- Breaking of big rock blocks: 2.9 m^3
- Gluing work (water wash): 8.4 m^2
- Crack filling with mortar: 0.076 m^3
- Grouting with mortar: 0.176 m^3
- Rock fall protection net (ϕ 12): 128.0 m^2
- Wire rope work: 2.0 locations
- Surface drainage (U240): 1 set

CHAPTER11 TEMPORARY TREATMENT FOR ROAD SLOPE DISASTERS AND QUALITY CONTROL OF RESTORATION WORKS

11.1 General

The road administrator should be required to maintain regular daily inspection activates to get early warning of deformation or collapse of the road sections, and when a disaster occurs such as a road slip, it is necessary to avoid the damage to road users by implementing urgent treatment, and to restore the function of the road and to prevent the road damage from getting worse. In order to be able to implement urgent treatment, the materials to be used for the urgent restoration works such as sheet piles (steel or wooden), vinyl sheet, H-section steel piles, timber piles, polyvinyl chloride pipe and covering plates should always be in a stock yard.

The planning for the temporary treatment works must take into consideration the related conditions of the road, the slope situation and weather after a disaster, and the following matters should be noted in the plans for temporary treatment works;

- The prevention measures for secondary disasters are prioritized in the temporary restoration planning, considering the possibility of secondary disasters occurring and ensuring safety in the restoration works.
- Alternative detour roads are to be considered in the plan formulation.
- The temporary work should be part of and utilized for the future permanent solution and re-doing works should be avoided.
- The temporary treatment should be formulated with a proper scale as urgent work, and the road serviceability should be ensured through the permanent restoration works.
- Material mobilization conditions also should be taken into consideration for the planning of temporary restoration works.

In case of finding the portents of a large scale landslide such cracks developing or gaps on the road surface and/or on the upper or lower slope surfaces, the ground movement should be assessed and evaluated. The following measures should be taken for the urgent treatment;

- Installing extension-meters, displacement boards or displacement stakes in order to conduct measurements of ground movement and assessment and evaluation of ground slip.

- When the ground movement is confirmed to be in the dangerous range, precautions should be taken to suspend traffic and shelter, or to suspend the construction works.
- The urgent restoration of infrastructure damaged by a landslide disaster should aim at mitigation of ground movement construction of appropriate facilities and restore traffic flow as soon as possible.

11.2 Temporary Treatment

11.2.1 Classification of Temporary Measures

Table 11.1 shows the classifications of temporary measures after slope disasters, of which measures may be combined.

Urgent restoration work will be conducted properly considering site conditions, especially the impact on road transportation, and the traffic on the damaged section should be regulated pursuant to the collapsed condition at site.

Table 11.1 Classification of Temporary Treatment Measures

Classification	Urgent Measure	Adopting Condition	Note
Water Flow Countermeasures	- Sand bags - Temporary surface drain treatment - Gabion mattresses - Blind drainage - Horizontal drain holes - Surface covering by vinyl sheet - Temporary drainage ditches	1) Excluding or intercepting surface water 2) Seepage water treatment 3) Preventing infiltration of rainfall water 4) Ending treatment of collective water	Befitting to also be used for prevention of further movement of the collapsed soil and partial stabilization.
Slope Stabilizing Countermeasures	- Cutting the slope - Counterweight embankment - Gabion mattresses - Wire mattresses - Sand bags - Piling work	1) Stabilization of the slope body 2) Stabilization for slope surface or end of slope 2') Stabilization for slope surface or end of slope	1) Used for large scale disasters. 2) for application where there is seepage water 2') for application where there is no

	- Wicker works - Copping-off collapse soil	3) Preventing loosening on slope surface 4) Surface collapse prevention.	seepage water 3) Timber pipe or round pipe is used. 4) Consider the impact to others.
Prevention of Danger to Road Traffic	- Rock fall prevention - Guard fences - Safety fences - Temporary protective fences	1) Prevent danger from rock fall and slope collapse 2) Prevent danger of road shoulder slip 3) Used for rock fall prevention or separating traffic from the restoration work	
Ensuring the flow of Road Traffic	- Temporary landing pier construction - Detour route construction	1) To be consider on road slips with steep slopes. 2) Where restoration work will be continued for a long time period and work will be carried out under difficult conditions.	

Source: Manual for Slope Protection, Japan Road Association (November 1999)

Before the slope restoration work is carried out, the following measures are to be conducted as urgent treatment;

- Removal of loosened portion of the slope or road body considering traffic safety.
- Installation of guard fences and preventive fences.
- Installation of temporary drainage ditches or surface drainage treatment in order to avoid expanding the damage caused by the disaster.

(1) Collapsed Soil Removal

The removal of collapsed soil is to be carried out to avoid an increase of damage and to ensure safe working conditions. The following matters should be noted to recover traffic flow early and to perform temporary or permanent restoration works;

- When the collapsed soil is removed from the lower slope, the slope body may become unstable and re-collapse, therefore, the situation of the upper slope should be observe while working.
- Since the cliff of the upper collapsed surface generally has a steep gradient and is unstable, the said cliff section should be stabilized while working under the collapsed portion, if necessary.

(2) Temporary Water Treatment

Surface flow treatment is an important measure to prevent an increase in the damage. Due to the fact that soil strength generally decreases with the ingress of water, unerring water treatment is required at an early stage;

- The failure surface should be covered with vinyl sheet. In this case, it should be noted that the rap of sheet portion is a weak point concern the flowing water.
- When the collapsed soil is expected to flow further, sand bags are piled at the end of the slope to minimize the impact to road traffic. In this case, if the damages slope is completely blocked, seepage water will accumulate and consequently have a negative impact on the slope stability. From this view point, a temporary open section to drain the water should be provided in the sand bag protection.
- In order to prevent infiltration of rainfall water from the upper collapsed slope, temporary drainage ditches made by excavation or sand bags is to be provided on the upper portion of the collapsed cliff.
- The damaged berm drains on the slope should be repaired, since that damage can cause further slope collapse, due to accumulation of rainfall water on the damaged section as the said water flows out on to the slope.

(3) Temporally Preventive Fence Installation

When planning emergency measures, it is necessary to consider in advance the nature of possible secondary disasters, methods of securing safety and to examine the possibility of occurrence of problems at the time of execution of the restoration works, such as affects to ordinary traffic on the road caused by out flowing of soil due to re-collapse of the slope. Temporary preventive fences can be installed to minimize the said risks as well as separating the restoration working area from the road.

Figure 11.1 presents an example of a temporary preventive fence, of which the structure has H-shape steel columns installed at appropriate intervals and the deck plate retaining walls are inserted in the H-shape steel.

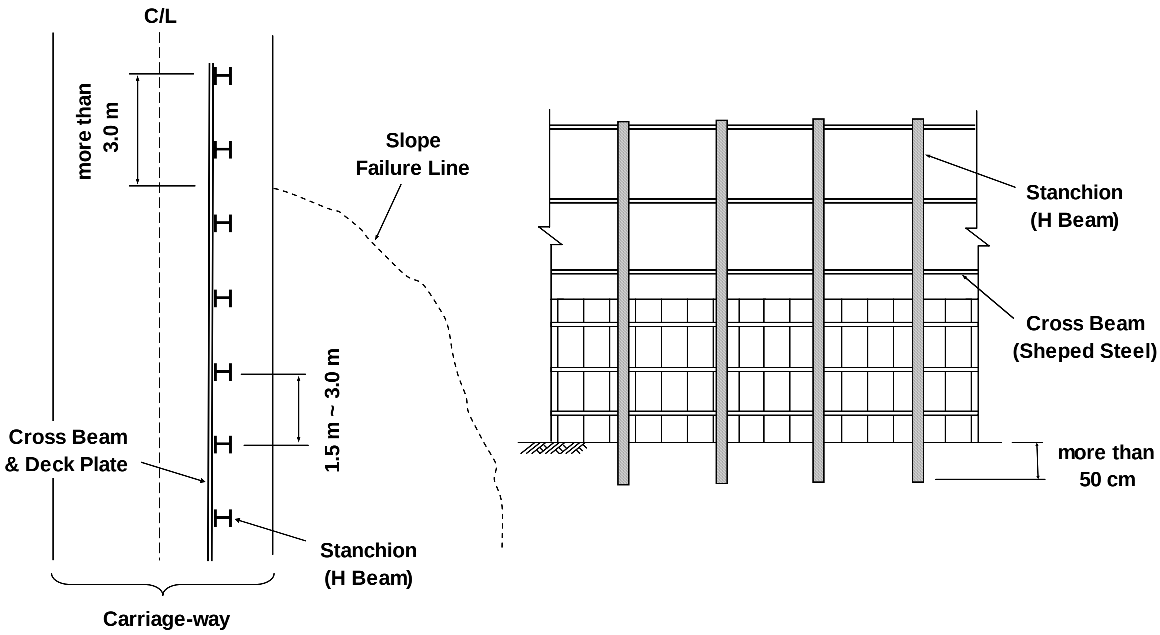


Figure 11.1 Example of Temporally Preventive Fence for Restoration Work

11.2.2 Emergency Countermeasures

(1) Cut Slope

The emergency countermeasures for collapse or deformation on a cut slope are described as follows:

(a) Cracks or Failure of the Upper Slope

If any sign of failure is found or a failure occurs, the scale and range of the failure or potential failure should be carefully examined. In case the failure has occurred only locally and there is no immediate danger of occurrence of other large-scale failures, then it is the simplest to take emergency measures by using wicker works. Besides the said situation, if the scale of the failure is large, it becomes necessary to secure the long-term stability by re-shaping the slope and providing a gentler gradient as indicated in Figure 11.2.

As emergency measures at the occurrence of a failure, the cracked portion and failed surface of the slope should be filled with soils and be covered with vinyl sheets, in order to prevent the infiltration of rain water and to prevent the progresses of damage. Furthermore, if the failure is unstable, temporary cutting to remove unstable portion should be consider in emergency measure planning.

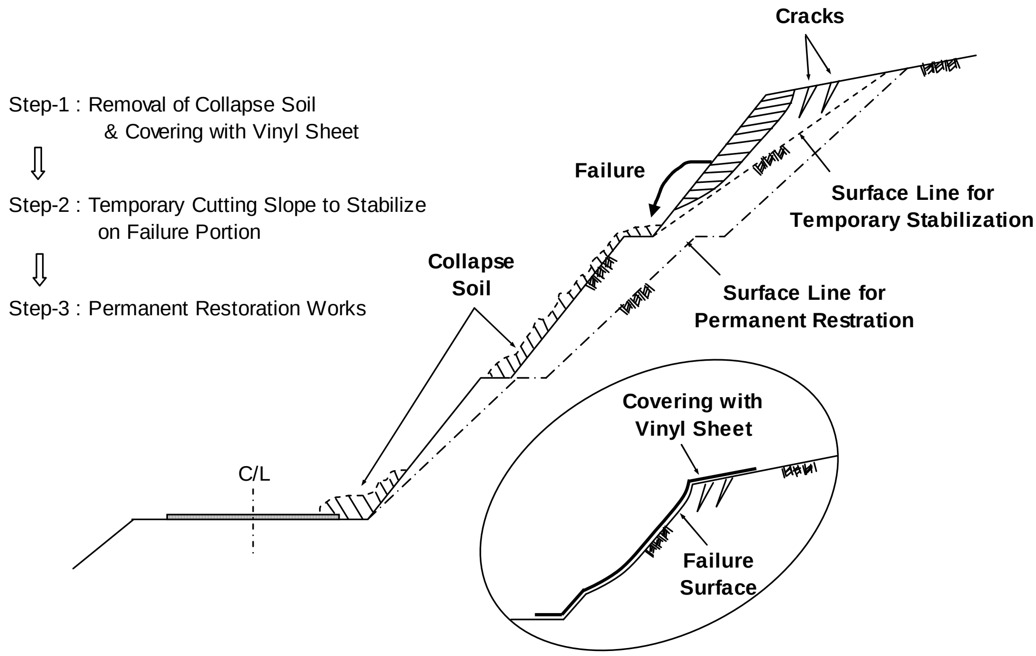


Figure 11.2 Example of Urgent Measures and Restoration after Cracks and Failure on a Cut Slope

(b) Failure on a Lower Slope

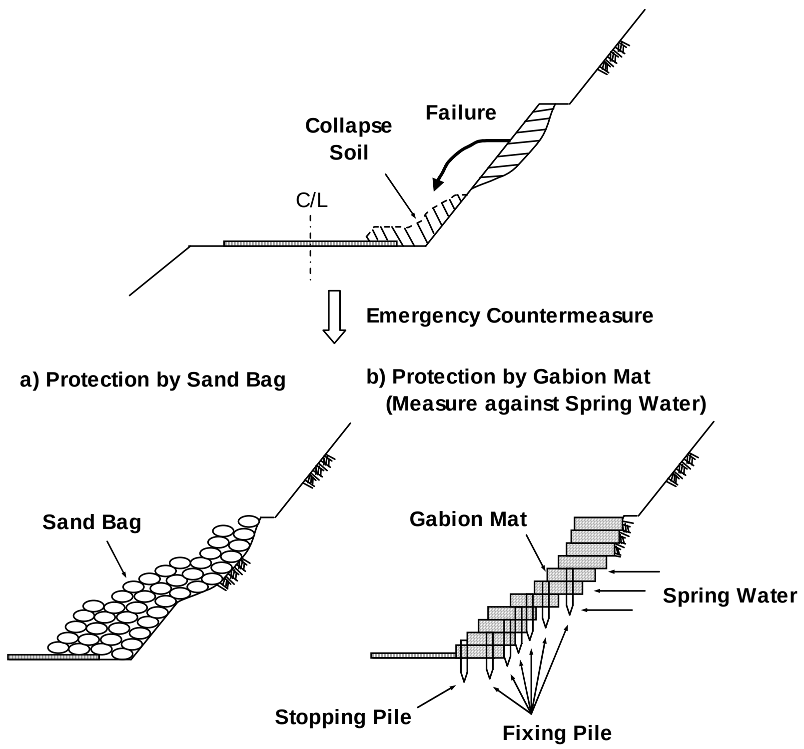
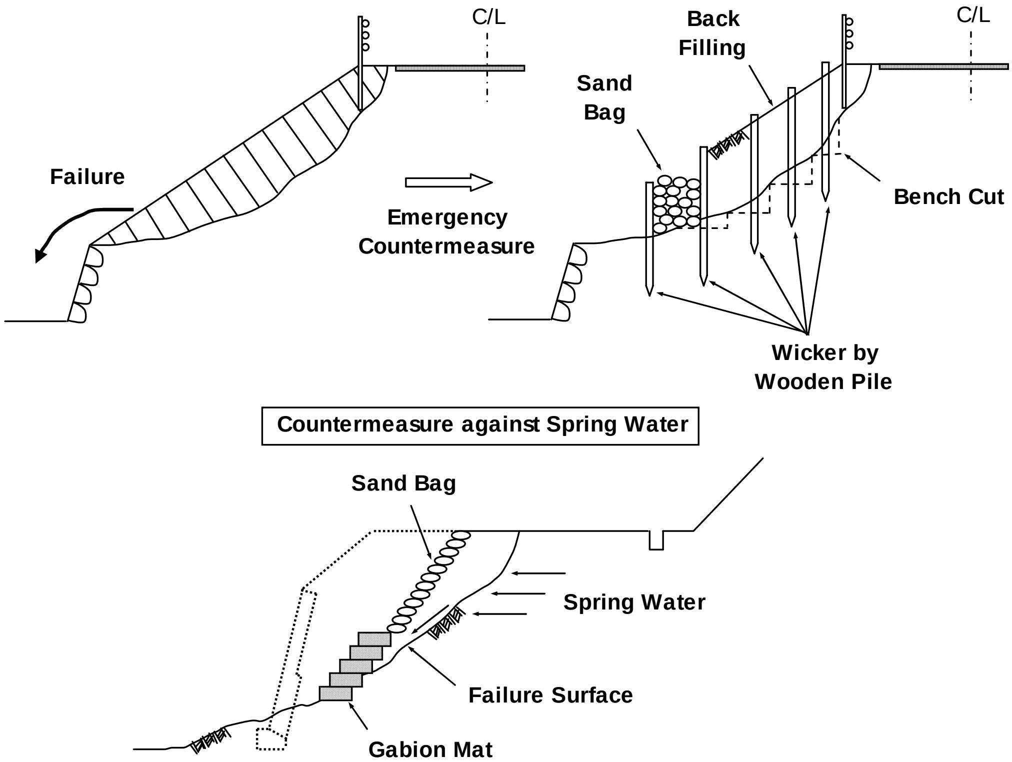


Figure 11.3 Example of Urgent Measure by Sand Bags or Gabion Mats for a Cut Slope

If the failure is only partial, the failure surface should be protected by piling sand bags as an emergency countermeasure, as illustrated in Figure 11.3. If spring water is found issuing from the failed portion, protection using gabion mats should be selected and the appropriate surface water treatment also should be required.

On the other hand, if the height of the cut slope is great and it may be forecast that a large scale failure will occur due to further infiltration of rain water, then the failed slope should be stabilized by providing a counter embankment until implementing permanent restoration. On this occasion, when it is necessary to open traffic early, a detour route should be considered. Furthermore, it should be noted that an underground water drainage facility should be provided in order to avoid filling the embankment body with water.

(2) Embankment Slope (Road Slip)



Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figure 11.4 Example of Urgent Measures by Sand Bags or Gabion Mats for an Embankment Slope

A slope failure occurs when drainage ditches are filled with rain water due to improper maintenance or a heavy local rain and the said water flow concentrates on the embankment slope. In this case, the failure section should be inspected and restored by placing and sufficiently compacting good backfilling material.

As an emergency measure for the above slope failure, use of wicker and use of drains with crushed stone to be reinforced by sand mats are effective as shown in Figure 11.4. Also installation of gabion mats at the toe of the slope is effective when spring water is observed issuing from the failure surface.

(3) Untreated Slopes

Dangerous spalls or loose soil on the slope should be removed first. However, since their removal is difficult in many cases, the following measures are also to be taken;

- Dangerous spalls or loose soil which are likely to fall are stacked using the dry or wet masonry method at a safe place on the slope, or they are fixed to the slope by means of concrete or rock bolts.
- Rock fall prevention fences or nets are installed in order to prevent danger to ordinary traffic in the incident of rock fall.

The latter measures described above may be effective against sediment failures, the re-excavation of slopes to obtain a stable gradient or slope protection using structures is often used in order to stabilize the main portion of slope.

(3) Landslides

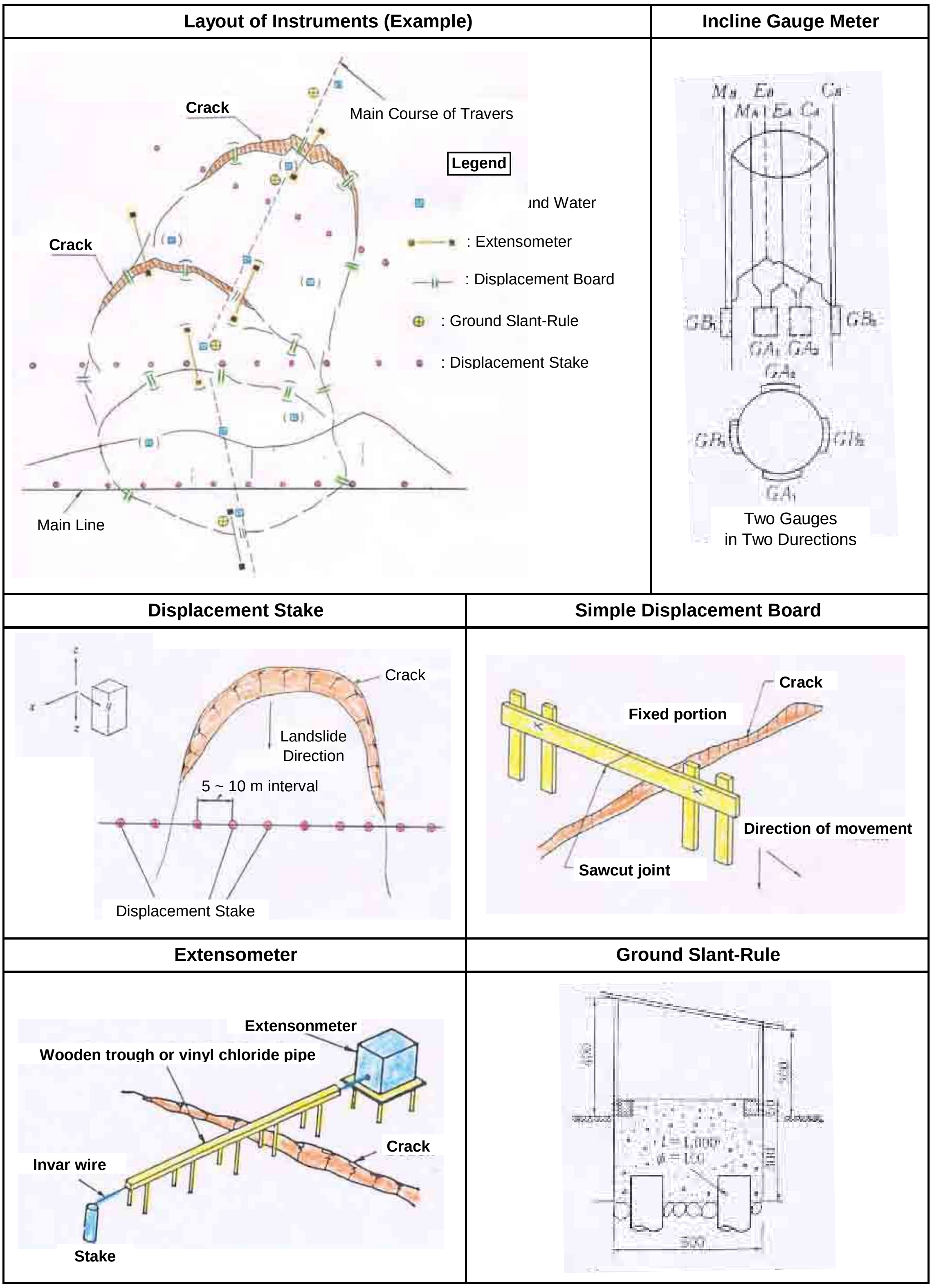
(a) Prediction of Landslides

[Establishment of Observation System]

If cracks or depressions occur on the road surface, upper slope or on a loose slope that continue to develop, it becomes necessary to predict the probability and time of a possible slip. For this purpose, extensometers, displacement stakes and/or boards and so on should be installed across the cracks or depressions to measure the velocity of expansion for a certain time. When any dangerous situations are detected, traffic or construction work shall be stopped or restricted.

The rate of expansion of cracks is related to the scale of the landslide and soil type, for example, clayey soil will slip slowly even if the strain velocity is relatively high while sandy soil and weathered rock tends to slip within a short time.

Figure 11.5 presents an example of measurement instrument arrangements for landslide observation.



Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figure 11.5 Example of Measurement Instrument Arrangements for Landslides

[Survey for Emergency Measures]

If there is a danger of landslide or if a landslide has occurred, then emergency countermeasures should be taken quickly and traffic flow restored if it found to be necessary after reviewing the degree of danger to ordinary traffic. The following surveys may be necessary in order to clarify the causes and features of landslides and proper emergency measures;

- Examine the history of landslides of the slope being considered, and distribution and characteristics of landslides in the surrounding areas.
- Examine the location and scale of cracks, the presence of tension cracks and compression cracks, presence of spring water, and the transition point of the gradient after performing an investigation of the overall surface.
- Examine the scale of the landslide and its generating mechanism and to predict the failure activities of the landslide area, the ground surface fluctuation, the distribution of groundwater, and the sliding surface.

(b) Emergency Restoration

If a landslide occurs while the road is in service, emergency restoration work should be carried out immediately. In this case, the following minimum precautions should be taken to prevent further damage due to reoccurrence of landslide activity.

- Road traffic should be detoured away from the landslide area, and emergency restoration work should be performed. In this case, the triggering of new landslides by the detoured road must be prevented as illustrated in Figure 11. 6 (a).
- If detour is not possible, emergency restoration may be carried out on the collapsed earth without removing it, though this may increase the longitudinal gradient.
- If it is unavoidable to perform emergency restoration after the removal of collapsed earth from the road, earth retaining facilities should be installed on the mountain side so as to keep the amount of earth removal to a minimum as shown in Figure 11.6 (b).
- If fill was made near the head portion of a landslide area and a landside has occurred, the fill should be removed to reduce the load on the head portion of landslide area for emergency restoration. In this case, the road traffic should be detoured outside of the landslide area, longitudinal alignment modified or a structure used.

- For the road to be urgently restored, the cut slope should be protected with flexible materials, drainage facilities to prevent infiltration into the landslide area should be urgently restored, the overall drainage system should be examined, and groundwater drainage for he fallen earth and landslide area should be urgently implemented.

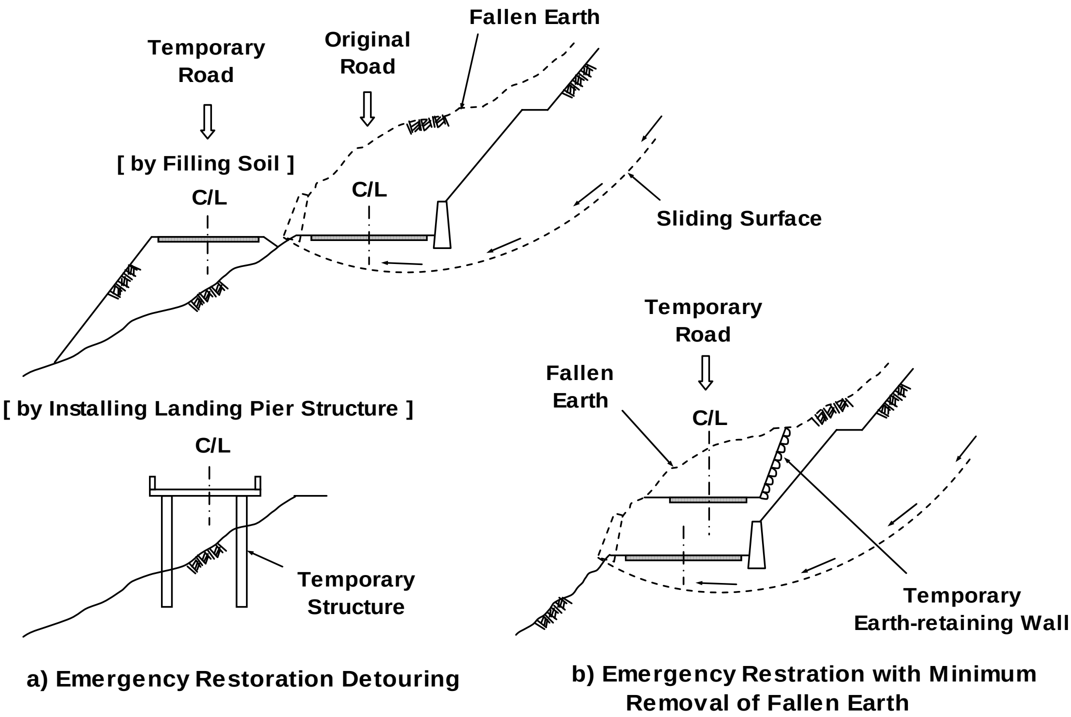


Figure 11.6 Emergency Restoration of Landside Areas

(c) Emergency Countermeasures

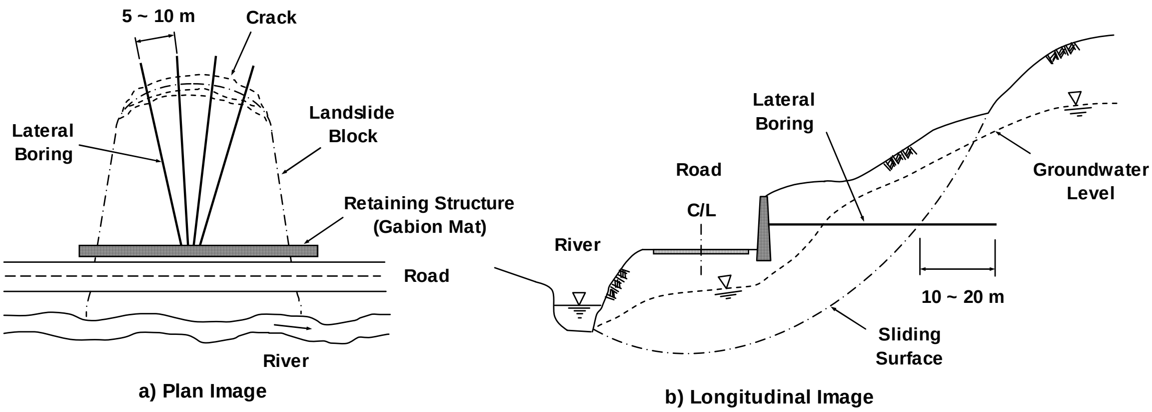
Emergency countermeasures are implemented to keep the damage to a minimum by reducing the speed of the movement of the landslide and by stabilizing the slope, however, the methods must be simple ones that may be done easily with low cost. Also, in the determination of the emergency countermeasures, the future permanent measures should be taken into account at the same time. Typical emergency countermeasures methods are described below;

[Surface Water Treatment]

Open-cuts are more desirable and any water in ponds or swamps located in the upper portion of the slope should be drained. Cracks should be covered with vinyl sheets and clay filling or the like to prevent the ingress of seepage water. Also puddles of water and water in the channel or swamp should be drained with vinyl pipe or the like to prevent infiltration.

[Subsurface Water Treatment]

If the landslide motion is still active, drainage by lateral boring should be performed. Several principal tension cracks in the slope should be selected and the several boreholes should be drilled across the cracks and approximately 10 to 20 m beyond the cracks at 5 to 10 m intervals in the direction of cracks as shown in Figure 11.7. The drainage of water near the outlet of each borehole should be done carefully.



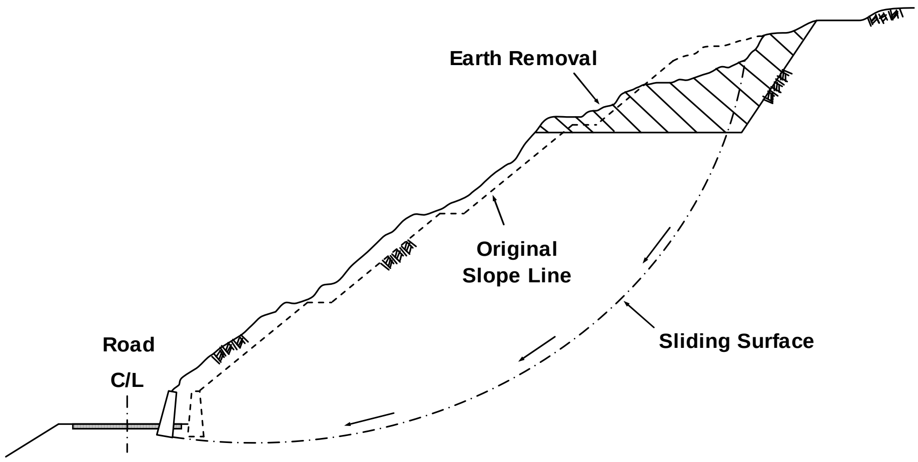
Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figure 11.7 Groundwater Drainage by Lateral Boring as an Emergency Measure

[Earth Retaining Works]

If the toe of the landslide is likely to collapse or if a failure is likely to enlarge, earth retaining works should be installed with cylinders or mat gabions at the toe.

[Earth Removal]



Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figure 11.8 Earth Removal as an Emergency Measure

It is an effective measure in many cases to perform horizontal cutting of the soil mass by several meters at the head of a landslide as shown in Figure 11.8. However, this removal should not be performed if the head portion of the cutting may become unstable, or if it is located at the tail of a secondary landslide area behind the proposed cut that may be predicted to slip.

11.3 Quality Control of Restoration Works

This clause aims to implement quality management when the restoration of a slope disaster is performed. Among the major restoration works, the following work items, that have the highest degree of success, are selected and described;

1) Slope Cutting and Flattening
2) Slope Protection : Vegetation, Mortar Spraying
3) Retaining Structures : Grouted Riprap Walls, Stone (or Concrete Block) Masonry Walls, Gabion Walls
4) Horizontal drain hole

11.3.1 Slope Cutting and Flattening Works

(1) Clearing and Grubbing

(a) Work Requirements

All surface objects and all trees, stumps, roots and other protruding objects not designated to remain should be cleared and/or grubbed, including mowing as required, except as provided below:

- Removing of undisturbed stumps and roots, and non-perishable solid objects with a minimum depth of 1.0 m below submerge or slope of embankment will not be required.
- In areas outside of the grading limits of the cut and embankment areas, stumps and non-perishable solid objects should be cut off not less than 15 cm below the ground line or low water level.
- In areas to be rounded at the top of cut slopes, stumps should be cut off flush with or below the surface of the final slope line.
- Grubbing of pits, channel changes and ditches will be required only to the depth necessitated by the proposed excavation within such areas.

- In areas covered by cogon or talahib, wide grass and other types of vegetation, top soil should be cut to a maximum depth of 15 cm below the original ground surface and disposed of outside the clearing and grubbing limits as indicated in the typical roadway section.

Except in areas to be excavated, sump holes and other holes from which obstructions are removed should be backfilled with suitable material and compacted to the required density. If perishable material is burned, it shall be burned under the constant vigil of a component watchman at such times and in such a manner that the surrounding vegetation, adjacent property, or anything designated to remain on the right of way will not be jeopardized. If permitted, burning should be done in accordance with applicable laws, ordinances, and regulations.

(b) Disposal of Cleared Material

[Nonflammable Material]

Material and debris which cannot be burned and perishable materials may be disposed of by a method and at a location as per requirements. If disposal is by burying, the debris should be placed in layers with the material disturbed so as to avoid nesting. Each layer should be covered or mixed with earth material by the land-fill method to prevent voids. The top layer of material buried is to be covered with at least 30 cm of earth or other approved material and is graded, shaped and compacted to present a pleasing appearance.

[Wooden Material]

Woody material may be disposed off by chipping. The wood chips may be used for mulch, slope erosion control or may be uniformly spread over selected areas as per the requirements. Wood chips used as mulch for slope erosion control should have a maximum thickness of 12 mm and faces not exceeding 3,900 mm^2 on any individual surface area. Wood chips not designated for use under other sections are to be spread over the designated areas in layers not to exceed 75 mm loose thickness.

Unwanted trees should be buried or disposed off as per the requirements. Low hanging branches and unsound or unsightly branches on trees or shrubs designated to remain should be trimmed as directed. Branches of trees extending above the roadbed should be removed to give a clear height of 6 m above the roadbed surface. All trimming should be done by skilled workmen and in accordance with good tree surgery practices.

(2) Open-cut Excavation

(a) Classification of Excavation

Open-cut excavations of slopes are classified as follows

- Unclassified Excavation refers to the excavation and disposal of any type of unspecified material.

- Rock Excavation refers to the excavation and disposal of igneous, sedimentary and metamorphic rock which can not be excavated without blasting or the use of rippers, and the boulders or other detached objects that each have a volume 1.0 m^3 m or more as determined by physical measurements or visually.

- Common Excavation refers to all excavation not included in the classification of "Rock Excavation".

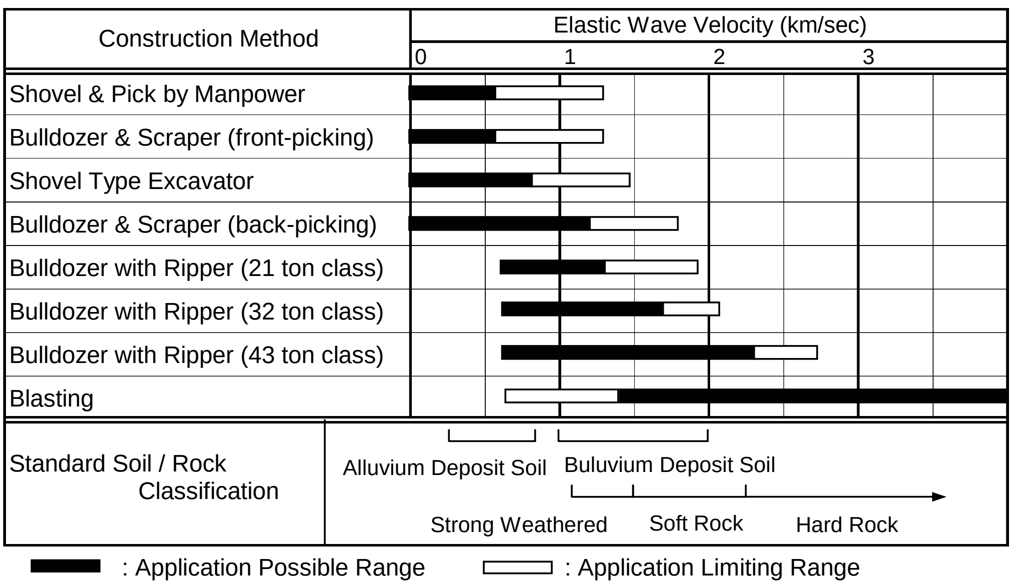
- Muck Excavation refers to the removal and disposal of saturated deposits and mixtures of soils and organic matter not suitable for foundation material regardless of moisture content.

(b) Construction Planning

The earth works are mostly executed using construction machines or construction machines combined with hand labor depending on the work category, scale of construction and site conditions. It should be necessary to select the construction method considering the hardness of the excavation material and site working space in the construction planning of the excavation work.

Table 11.2 and Figure 11.9 present standard construction methods as per hardness of ground and a flow chart for rock excavation methods, respectively.

Table 11.2 Application Range of Excavation Methods as per Material Hardness



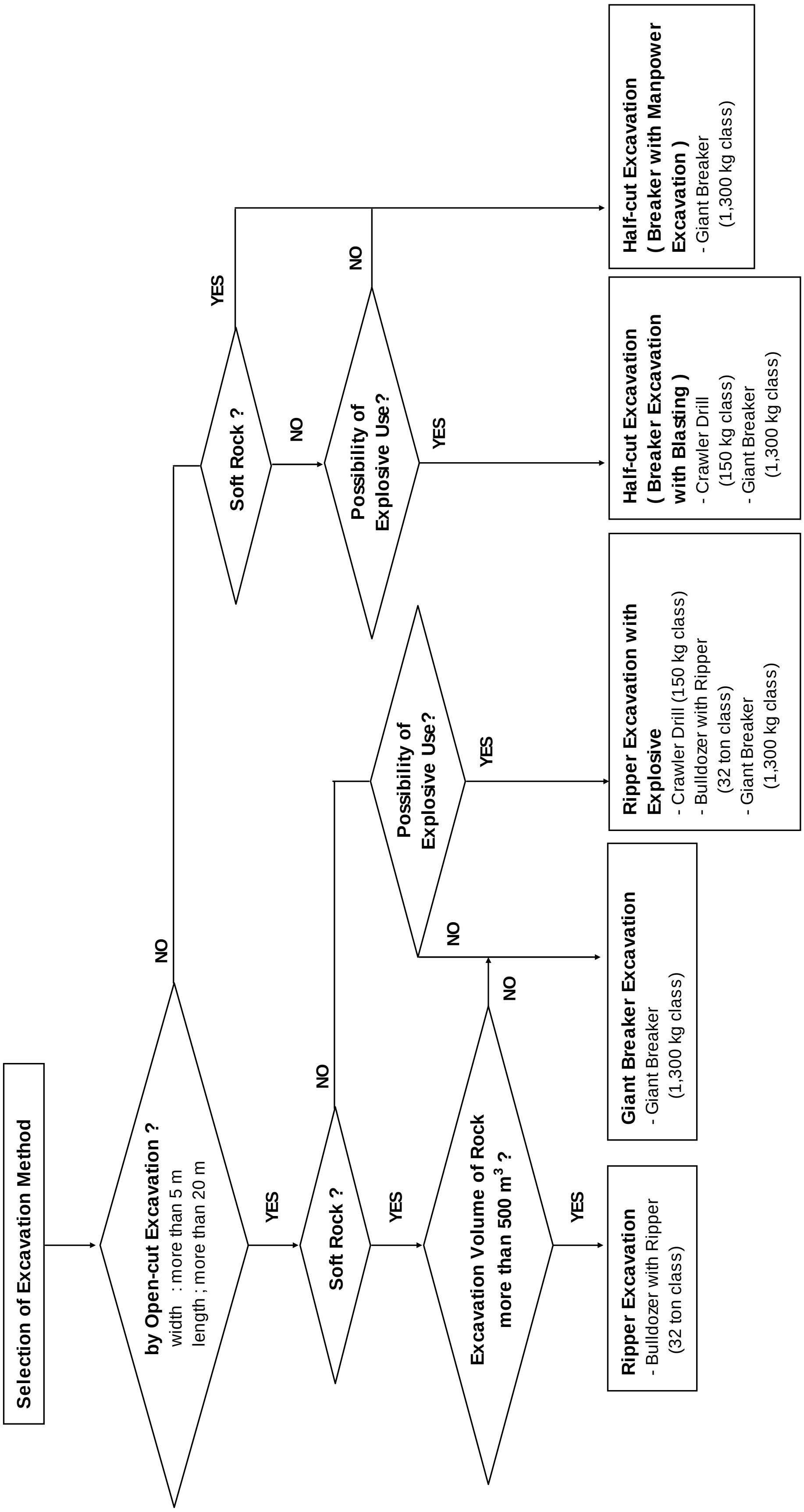


Figure 11.9 Standard Flow Chart for Selection of Excavation Method

(c) Utilization of Excavation Material

[Conservation of Topsoil]

The top soil from clearing is not suitable for embankment material due to its content of grass roots and other organic matter. However, since such top soil may be fit for vegetation on the cut slope or embankment slope, the said soil may be recommended to be utilized for blanket soil on the slope.

Suitable topsoil encountered in excavation and in areas where embankment is to be placed shall be removed to such extent as possible and to the required depth. The topsoil should be completely removed to the required depth from any designated area prior to the beginning of regular excavation or embankment work in the area and shall be kept separate from other excavated materials for later use.

[Utilization for Embankment Material]

All suitable material removed during the excavation should be used in the formation of the embankment, subgrade, shoulders, slopes, bedding and backfilling of the structures, and for other purposes shown on the plan or as directed. Unsuitable soil that can not be properly compacted in the embankment should be disposed of at a proper location and in a proper manner. Also, all excess material, including rocks and boulders that can not be used in the embankment should be disposed off as directed.

(d) Pre-watering

Excavation areas may be pre-watered before excavating the material. When pre-watering is used, the areas to be excavated should be moistened to the full depth, from the surface to the bottom of the excavation.

The water should be controlled so that the excavated material will contain the proper moisture to permit compaction to the specified density with the used of standard compacting equipment. Pre-watering should be supplemented where necessary, by truck watering units, to ensure that the embankment material contains the proper moisture at the time of compaction.

(e) Blasting

[Construction Planning]

Rock excavation which requires drilling and shooting may be pre-split. Pre-splitting to contain faces in the rock and shale formations should be performed by:

1) drilling holes at uniform intervals along the slope lines,

2) loading and stemming the holes with appropriate explosives along with stemming material, and

3) detonating the holes simultaneously.

A plan that includes an outline of the position of all drill hoes, depth of drilling, type of explosive to be used, loading pattern and sequence of firing should be submitted to the related authorities. Controlled blasting should begin with a short test section of a length to be required. The test section shall be pre-split, production drilled and blasted and sufficient material excavated whereby it may be determined if the pre-splitting methods are satisfactory.

[Surface Flattening]

The holes are to be charged with explosives of the size, kind, strength, and at the spacing suitable for the formations being pre-split, and with stemming material which passes a 9.5 mm standard sieve and which has the qualities for proper confinement of the explosives.

The finished pre-split slope should be reasonably uniform and free of loose rock. Variance from the plan of the excavated back-slope should not exceed 30 cm; however, localized irregularities or surface variations that do not constitute a safety hazard or an impairment to drainage courses or facilities will be permitted.

A maximum offset of 60 cm will be permitted for a construction working bench at the bottom of each lift for use in drilling the next lower pre-splitting pattern.

(f) Excavation to Roadbed Level

Rock is to be excavated to a depth of 15 cm below subgrade within the limits of the roadbed, and the excavation backfilled with the specified material and compacted to the required density.

Material below subgrade, other than rock shall be thoroughly scarified to a depth of 15 cm and moisture content increased or reduced, as necessary, to bring the material throughout this 15 cm layer to the moisture content suitable for maximum compaction, The said layer should then be compacted in accordance with the technical requirements.

(g) Removal of Unsuitable Material

Where the plans show the top portion of the roadbed to be selected topping, all unsuitable materials should be excavated to the depth necessary for replacement with the selected topping to the required thickness. Where excavation to the finished grade section results in a slope sub-grade of unsuitable soil, it may be required to remove the unsuitable material and backfill to the finished grade section with approved material.

The excavation of muck should be handled in a manner that will not permit the entrapment of muck within the backfill. The material used for backfilling up to the ground line or water level, whichever is higher, should be rock or other suitable granular material selected from the roadway, if available. If not available, suitable material should be obtained from other approved sources, Unsuitable material removed should be disposed of in designated areas shown on the plan or to a location as directed.

(h) Slope Stability Control

The stability of the slope and the safety of the work being undertaken must be maintained. The following site conditions on the slope and top of slope should be observed and recorded in order to monitor the stability situation;

1) Existence of cracks
2) Occurrence situation of rainfall split
3) Existence of loose rocks or boulders
4) Degree of weathering
5) Flaking of rock material
6) Direction and disturbance of joint surfaces and bedding plane in rock material
7) Location and situation of spring water

(i) Finishing and Flattening of Excavation Surfaces

The final excavated surfaces should have no abrupt changes in slope or sharp projections greater than 50 cm. Projections in excess of 50 cm will be treated where necessary by supplementary excavation to produce the desired surface of contact with the concrete, embankment, or backfill. If, during open-cut excavation work, material beyond the limits of excavation is loosened, disturbed, broken or shattered, the said portion of loosened material is to be re-compacted or removed altogether and replaced with concrete, shot-create or other compacted material. Standard construction methods of finishing and flattening slope as per slope material are as follows;

[Colluvial Deposit Slope]

In order to finish the slope as per design, the excavation should be checked by stretching a string at the proper gradient and at a known height above the subject surface and then the surface should be checked for conformity to specifications by measuring down from the string. If the excavation material is colluvial deposit, the mechanical excavation should be halted about 20 to 30 cm above the design surface, and then the finishing and flattening work is to be performed by manpower with picks and hoes.

[Rock Slopes]

If the excavation material is soft rock, finishing the slope surface is performed by manpower using picks or pick-hammers. And if the material is hard rock, the drilling along the design surface is executed using hand-hammers and then the surface finishing work is conducted by blasting with small loads so that the bedrock surface should not be loosened.

(j) Inspection and Dimensional Tolerances

Site inspections should be conducted to control work progress as shown in Table 11.3, of which, the interval is basically at every 20 m.

Table 11.3 Site Inspection Items of Slope Excavation

Category	Inspection Item
Elevation	- Road Center - Top of Slope - Toe of Slope
Distance, Width and Slope Length	[Longitudinal Direction] - Distance between Station Points - Horizontal Alignment - Distance form Change Point of Vertical Alignment - Distance from Structure - Distance from Change Point of Cut and Fill Section [Cross Sectional Direction] - Width of Road - Distance from Road Center - Width of Berm - Length of Slope
Slope Gradient	- Calculated from Measurement of Horizontal and Vertical Distances, and Slope Length

Dimensional tolerances may be established as follows:

- Elevation : less than 5.0 cm
- Width : less than 10 cm
- Slope Length : less than 20 cm when length is less than 5.0 m or less than 4 % of slope length when length is more than 5.0 m.

11.3.2 Slope Protection Works

(1) Vegetation

(a) Construction Planning

The purpose of vegetation is to prevent the erosion of the slope immediately after the completion of work, and a feature of sodding is that the face of the slope can be restored naturally. The method of vegetation may be determined depending on the site weather conditions including temperature, rainfall, slope direction, degree of sunlight and so on, and soil conditions including physical and chemical composition, water content and hardness of soil, unevenness, presence of spring water and so on.

Trial planting tests should be conducted on site preceding the vegetation work, and then the method of vegetation should be determined by assessing and evaluating the trial test. The construction plan for the vegetation work should include;

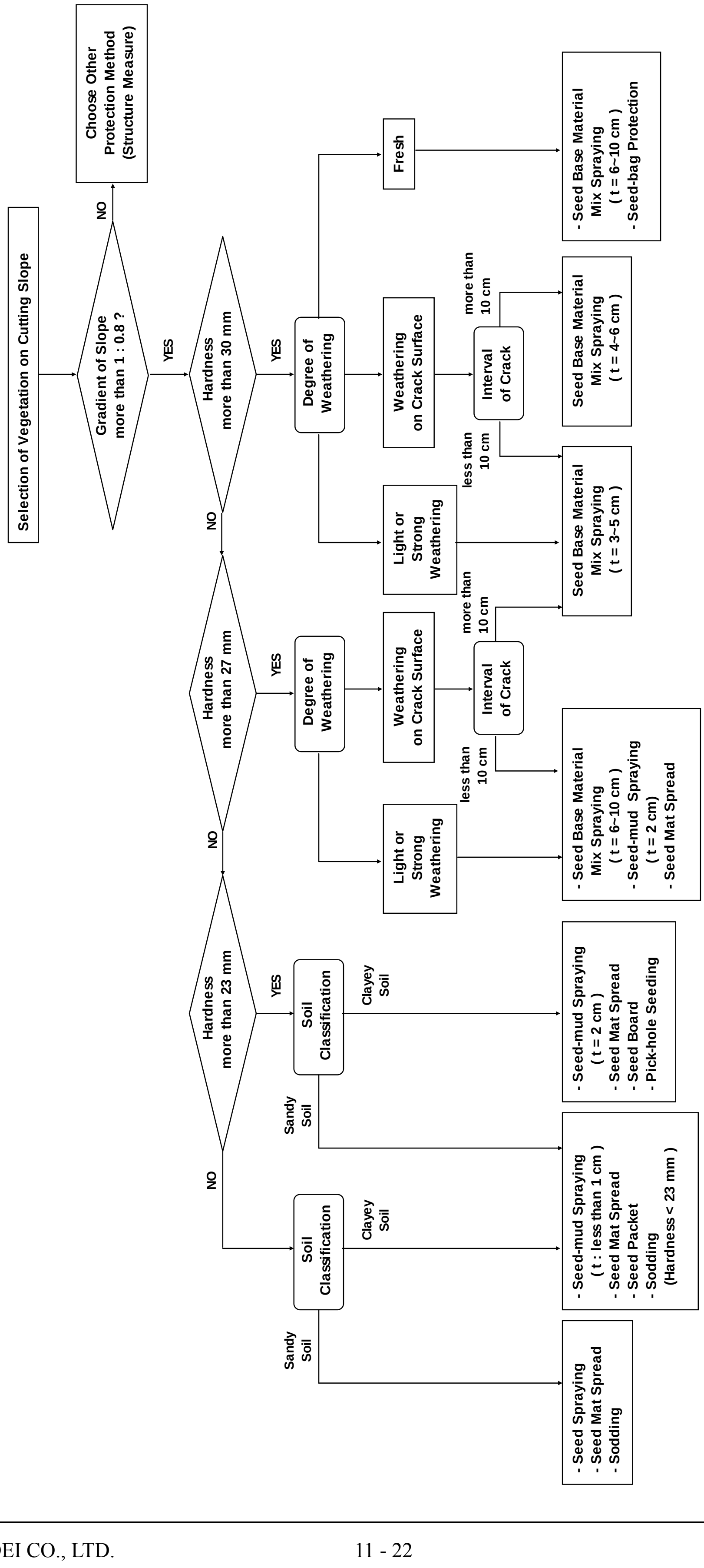
1) Materials to be used for sodding (seed, fertilizer, curing material, and covering material),
2) Detailed construction schedule and construction method, and
3) Detailed method of trial planting test.

Figure 11.10 and Figure 11.11 present a standard flow chart to select the vegetation method for cut slopes and embankment slopes respectively.

[Vegetation Work on Cut Slopes]

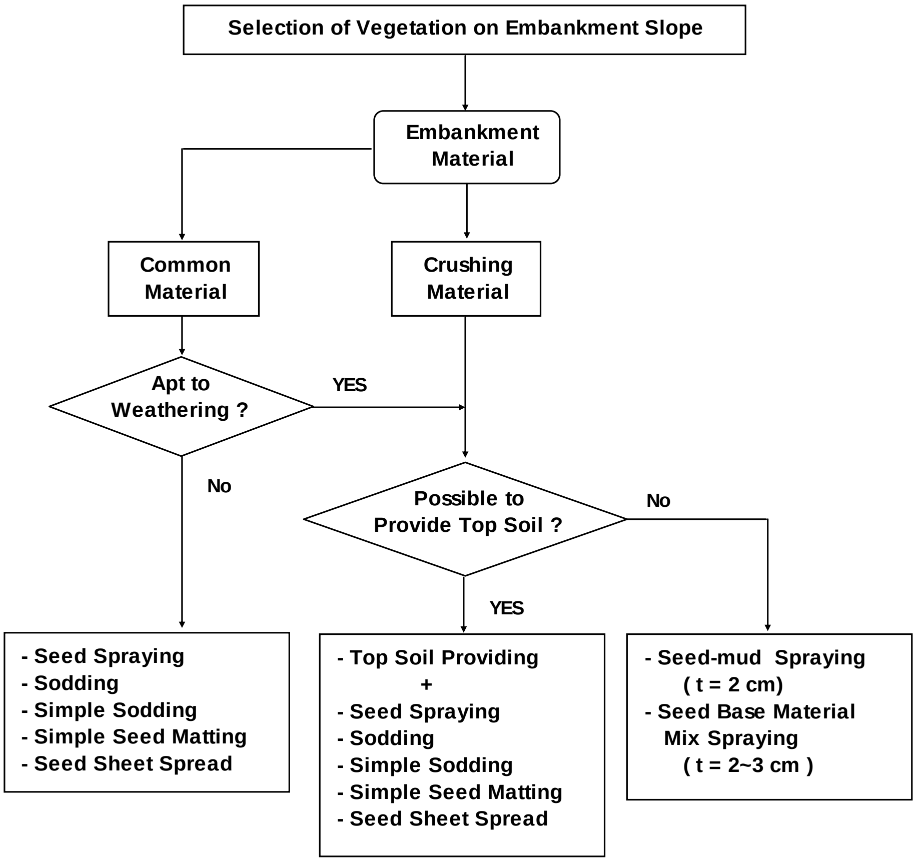
Roots of lawn grasses may penetrate sandy soils, clayey soils and clay, of which the hardness values are lower than 23 mm, so that sodding may be performed directly in these soils. Seed spraying or seed mats should be applied if simple sodding works can not be performed in a situation due to the said soil condition. If the soil hardness of the slope is greater than 23 mm but less than 27 mm, seed-mud spraying should be used. If the hardness is exceeds 27 mm, grooving and soil dressing or hoeing the soil allow the penetration of roots and then sodding work should be executed.

That is, spraying of seed and dressing soil associated with grooving and soil dressing or hoeing and soil dressing in a suitable season or, in case of work by manual labor, seed pockets or pick-hole seeding should be applied. Seed boards or pick-hole seeding are suitable to the hard clayey soils and hard clay since grooving may be possible. However, seed packets are rather ore desirable for dense gravelly soils and sandy soils in which grooves may not be formed easily.



Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figur 11.10 Standard Flow Chart for Selection of Vegetation Method on Cutting Slope



Source: Manual for Slope Protection, Japan Road Association (November 1999)

Figure 11.11 Standard Flow Chart for Selection of Vegetation Methods on Embankment Slopes

Sand tends to flow out due to spring water and create scouring if the soil of a slope is sand or sand mixed with gravel. Even if covering work is performed, the backfilling of the covering works may sometimes be excavated to result in the occurrence of a depression. If moisture conditions of the soil are suitable, soil dressing in the framing may be omitted and only sodding mats or seed-mud spraying employed. However, if much spring water is present, vegetation is not suited and then structural measure should be employed.

(b) Materials

[Seed]

Kinds and characteristics of seed, amount of seed, and optimum season for growth should be well understood. It is fundamental to select species suited to the weather and to determine the proper amount of seed and seeding season using the results of germination tests.

[Shoots]

The shoots should be healthy stems (stolons or rhizomes) with roots attached or perennial turf-forming grasses, harvested without adhering soil and obtained from the proper sources in the locality of the work where the sod is heavy and thickly matted. The presence of objectionable grasses, weeds or other material will be a caused for rejection.

[Fertilizer]

Fertilizer may be standard commercial fertilizer supplied separately or in mixture containing the percentage of total nitrogen, available phosphoric acid and water-soluble potash. It is to be furnished in standard containers with name, weight and guaranteed analysis of the contents clearly marked. The fertilizer may be supplied in the following forms;

- A dry, free-flowing fertilizer soluble in water, suitable for application by a common fertilizer spreader.
- A finely ground fertilizer, soluble in water suitable for application by power sprayer.
- A granular or pellet from suitable for application by blower equipment.

Excellent fertilizer should contain the three elements, nitrogen, phosphorus and potassium almost equally mixed with a ratio of 1:1:1. An adequate quantity of fertilizer is desirable when the planting is first done but care must be taken to ensure application of the proper amount of fertilizer since an excessive amount of fertilizer may check germination. Damage is caused when the nitrogen content exceeds 10 g/m^2 and thus the amount of fertilizer not exceeding this limit should be determined.

- Ground Limestone

Ground limestone should contain not less than 85 % in total of calcium and magnesium carbonates and should be of such fineness that 100 % should pass through 2.00 mm sieve and not less than 35 % through a 0.15 mm sieve. Granulated slag may be substituted in lieu of ground limestone with an adjusted application rate that will provided the equivalent total neutralizing power of the specified limestone.

[Curing Material]

The functions of curing materials are to protect seed from being washed away by rain or being dried out before the germination is completed and also to prevent erosion of the slope until the vegetation will cover the whole area of slope and the effect of erosion prevention will be realized.

- Chemical Curing Agents

There are many types of chemical curing agents used in seed spraying. Some of them form films over the surface layer of the slope while the others permeate into the layer to a certain depth and harden this layer. The most common type of film is a 25 % solution of asphalt emulsion (cationic), which also has the effect of erosion protection.

- Fibers

In order to fully realize the effects of erosion prevention that can be provided by fibers, the amount of fiber should be greater than 150 g/m^2. If the amount sprayed is less than this, the effects of seed protection and erosion resistance may not be obtained. It should be noted that fibers are easily affected by running water and scattered by the wind after drying.

[Top Soil]

Top soil to be applied should consist of fertile friable soil of loamy character without admixture of undesirable subsoil or refuse materials. It should be obtained from well-drained arable land and should be reasonably free from roots, hard clay, coarse gravel, stones larger than 50 mm in size, coarse sand, propagules of noxious plants, sticks, brush, litter or other deleterious substances. The following physical properties should be required for top soil;

- Organic mater content not less than 5% as determined by loss or ignition of sample oven-dried to constant weight.
- A pH range between approximately 5.5 pH and 7.6 pH.
- The material passing a 0.075 mm sieve as determined by the wash test is not less than 20 % or more than 80 %.

(c) Method of Sodding

[Seed Spraying]

Seed, fertilizer and fibers are mixed with water and sprayed with a pump to the face of either cut or fill slopes. Seed spraying is suited to relatively low land or to slopes with gentle gradients.

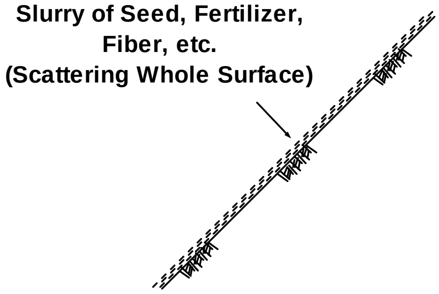


Figure 11.12 Seed Spraying

A tank car with an agitator is used for the execution of seed spraying, in which 1) water, 2) fibers, 3) cohesive agent, 4) fertilizer and 5) seed are placed in a tank in the order listed and fully agitated in order to obtain a uniform slurry. Where the covering and curing is required in the typhoon season or heavy rain season, the curing should be performed by using asphalt emulsion or like material.

[Seed-mud Spraying]

Seed, fertilizer, fibers and water are mixed together to form a slurry which is sprayed onto the surface of the slope. This method is suited to cut slopes and may be applied to places where the gradients of slopes are steep as well as high inaccessible places. A spray gun is employed in this method in combination with an air compressor; the seed, dressing soil and the other constituents are sprayed by means of compressed air and then asphalt emulsion is sprayed to perform the film curing. Wet type guns for mortar spraying are used for this method.

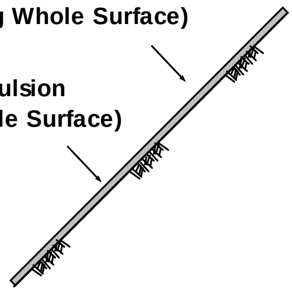


Figure 11.13 Seed-mud Spraying

The thickness of the soil to cover over the seed should be two to three times the size of the seed to assure good germination, from which the amount of soil to be used is 0.01 m^3/m^2. Also, if the amount of water is maintained to approximately 30 % to 40 % of the amount of soil, the soil to be sprayed will have a relatively stiff consistency, thereby preventing sprayed soil from flowing down the slope. Curing with an asphalt film provides high erosion resistance and this film may withstand heavy rains during typhoons or in the rainy seasons. A double solution of the cationic type is normally used at a rate of 1.0 litter/m^2 as the asphalt emulsion.

Different from the cement mortar spraying, seed spraying should be performed without holding the tip of spray normal to the surface of the slope, instead, the spraying distance and angle of nozzle should be adjusted in response to the hardness of ground so as not to roughen the surface of the slope. The thickness of the sprayed mixture should be as uniform as possible.

[Seed Base Material Mix Spraying]

Seed, fertilizer, Germinant base material, bonding material and water are mixed together to form a mud-state mixture and then splayed onto the surface of the slope up to the required thickness using the same type of spray gun as for motor spraying.

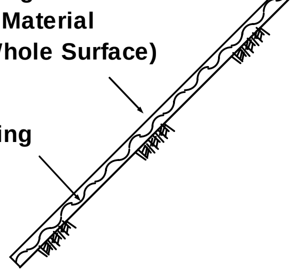


Figure 11.14 Seed Base Material Mix Spraying

A germinant base material should be used that contents highly improved organic soil material and that will hold the proper amount of moisture and fertilizer for the particular slope being dressed. The improved organic soil material usually has a ratio carbon/nitrogen of less than 35. Peat moss is frequently used for this purpose. High molecule resin, normal cement and fibers are used for the bonding material. Standard wire nets should meet the following requirements;

- Diamond-shape mesh with zinc coated iron wire
- Diameter of Wire Mesh : 2.0 ~ 4.0 mm
- Size of Mesh : 50 ~ 10 mm
- Size of Steel Pegs : φ = 9 ~ 16 mm, length = 20 ~ 40 mm

[Spreading Sodding Mats]

In spreading sodding mats, the surface of the slope is covered with mats containing seed and fertilizer. This method offers the protection effects of mats until completion of vegetation growth.

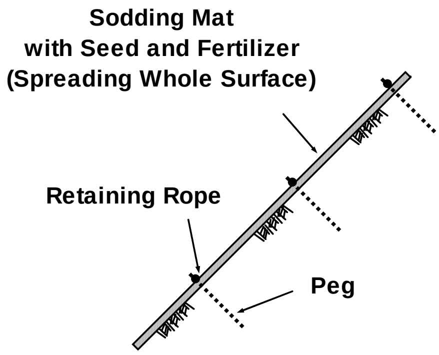


Figure 11.15 Sodding Mats Spreading

Mat materials used for the artificial sodding are non-woven cloth, rough cloth, paper, straw, straw mats and cut straw felt. Some mats are reinforced with nets. Products made of woven straw are used in the regions where extreme frost heaving occurs.

The slope should be smoothly finished without irregularities and the mats should be firmly fixed to the ground with pegs or rope to fit the mats with the ground without floating so as to prevent the mats flying away with the wind. Mats should be extended at least 20 cm from the edge of the top for coverage and the edge of mats should be embedded in the ground so as to prevent water from entering at the top of the slope. If mats float, germination may be delayed and water may flow underneath the mats to result in scour.

If long mats are to be used, they should be laid longitudinally where work on the face of the slope is finished and they should be laid transversely where they are to be installed while tamping the slope is ongoing. Mats should be overlapped by approximately 5 cm at each joint in all cases.

[Sodding]

This is a conventional method in which sod is directory laid on the surface and this method is suited to the easily erodable soils since the protection effects may be realized immediately after placement of the sod.

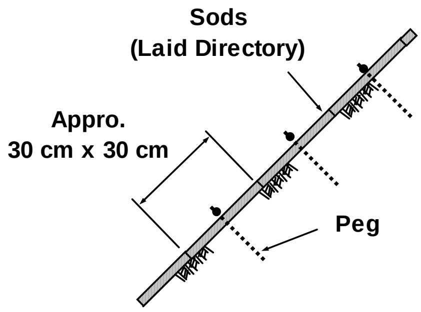


Figure 11.16 Sodding Placing

- Requirements for Delivering of Sod

The sod should consist of healthy, dense, well-rooted growth of permanent and desirable grasses indigenous to the general locality where it is to be used and should be free from weeds or undesirable grasses. At the time the sod is cut, the grass on the sod should have a length of approximately 5 cm and the sod should have been raked free of debris.

The sod should be cut into uniform squares approximately 30 cm x 30 cm, but not longer than is convenient for handling and transporting. The thickness of the sod should be as uniform as possible at approximately 4 cm or more depending on the nature of the sod, so that practically all of the dense root system of the grasses will be retained in the sod strip and that the sod may be handled without undue tearing or breaking.

- Preparation of Earth Bed

The area to be sodded should be constructed to the required cross section and contour, and the tops and bottoms of the slopes should be rounded, and also should be free from stones, roots or other undesirable foreign materials.

The soil on the area to be sodded should be loosened and brought to a reasonably fine texture to a depth of not less than 30 mm by means of equipment or hand methods adapted for the purpose.

- Placing Sod

The earth bed upon which the sod is to be placed should be moistened to the loosened depth, if not naturally sufficiently moist, and the sod should be placed thereon 24 hours after the sod was cut.

The sod on the slope should be laid in horizontal strips beginning at bottom of the slope and working upward, and the sod should be laid so that the joints caused by abutting ends of sod strip are not continuous. Each sod strip should be so laid as to abut snugly against the strip previously laid. As the sod is being laid, it should be lightly tamped with suitable wooden or metal tampers sufficiently to set or press the sod into the underlying soil.

At the points where it is anticipated that water may flow over a sodden area, the upper edges of the sod strips should be turned into the soil to be below the adjacent area and a layer of earth place over this juncture and thoroughly compacted. At the limits of the sodded area, the end strips should be turned in and treated similarly.

- Staking Sod

On all slopes steeper than one vertical to four horizontal, sod should be pegged with stakes 20 cm to 30 cm in length, spaced as required by the nature of the soil and steepness of slope. Stakes should be driven into the sod at right angles to the slope until flush with the bottom of the grass blades.

- Watering

After staking has been completed, the surface should be cleared of loose sod, excess soil or other foreign material, whereupon a thin layer of topsoil should be scattered over the sod as a top dressing and the area should then be thoroughly moistened by sprinkling with water. It should be required to regularly water and maintain sodded areas in satisfactory condition for the duration of construction.

[Simple Seed Mating]

Strip-shaped cloth or paper containing seed and fertilizer is horizontally inserted in the fill slope at the time of tamping. Artificial sods are basically strips of cloth, paper, cut-straw or synthetic net with seed and fertilizer attached to the strip.

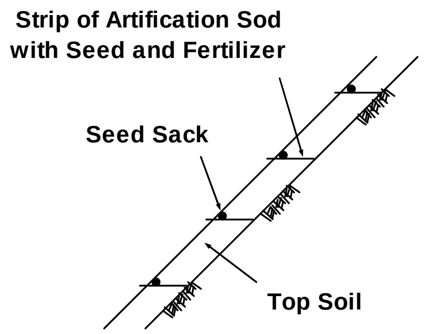


Figure 11.17 Simple Seed Matting

[Simple Sodding]

This is a conventional method in which narrow strips of sod are inserted in stepped horizontal planes into the fill slope when tamping the surface of the slope. Since the field sod grows slowly, many years are required until the whole surface is covered and considerable scouring may occur in the case of sandy soil during said time. Therefore, the growth of grasses should be accelerated by fertilization during the work and the soil should be fully compacted.

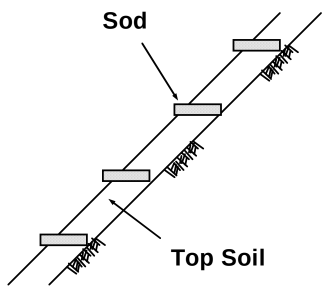


Figure 11.18 Simple Sodding

When using metric sod products (30 cm x 30 cm), each square of sod should be cut into half so as to have a width 15 cm, and then the pieces of sod should be laid horizontally in such manner that the long side of each piece of sod is flush with the surface of the slope. The spacing between the strips should normally be 30 cm along the surface of slope. A row of sod should be placed at the edge of the top of the slope to prevent edge collapse.

[Seed Boards]

Earth mixed with seed and fertilizer is molded into the form of boards, and the molded boards are laid in the form of strips in horizontal grooves made in the surface of the slope. These boards have a soil dressing effect because of the thickness of the board and seed boards may be molded either on the site or in a factory. The spacing of the grooves in which the boards are to be laid is normally 50 cm.

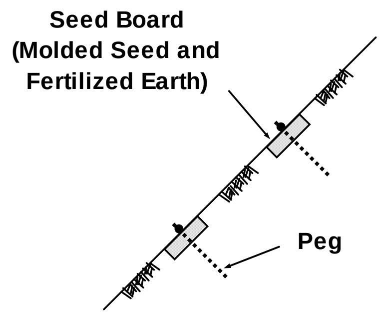


Figure 11.19 Seed Boards

[Seed Packets]

Seed and fertilized earth are filled in net packets and laid in the form of strips in horizontal grooves made in the surface of the slope. The seed and fertilized earth will not be washed off the slope since they are enclosed within the net packets, which are flexbible and may thus be firmly bonded to the ground.

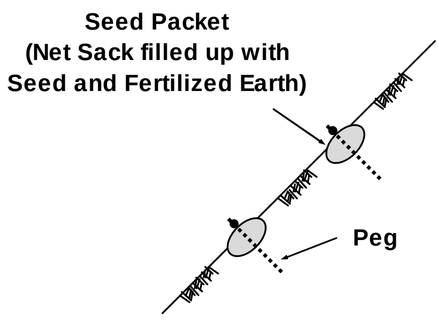


Figure 11.20 Seed Packet

Seed packets may be filled with seed and fertilized earth either on the site or in a factory. Synthetic resin should be determined in such a manner that the top of the packet should be flush with the surface of the slope or project out slightly from the surface of the slope. The packets tend to pack down too much and germination can be delayed if the packets are laid too deeply and covered with earth. The normal spacing of the grooves is 50 cm.

[Pick-hole Seeding]

Holes are made in the surface of the slope and the seed and fertilized earth is placed into the holes. This method may provide thick dressing soil, less runoff of fertilizer and a more lasting fertilizer effect. This is suited to cut slopes made of uniform soil such as hard clayey soils. The pick-hole seeding may be performed either

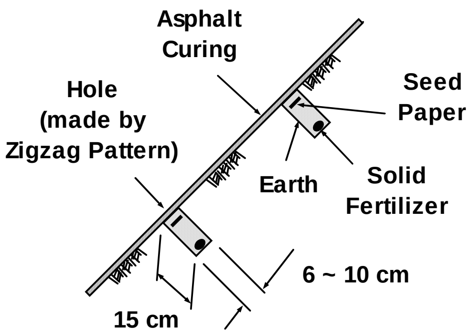


Figure 11.21 Pick-hole Seeding

by placing the seed and fertilized earth into holes made in the surface of the slope or by embedding peat pots in the holes, in which grass has been cultivated in advance. In the execution of the work, 15 to 20 holes are dug per square meter,each having a diameter of 6 to 10 cm and a depth of 15 cm, solid fertilizer is placed into the bottom of the hole, good quality soil is placed next, seed paper is placed on top of that and covered with earth, and then the seed paper is cured with asphalt emulsion.

[Sodding-bag Placing]

The sodding-bags should be carefully deliverd to the slope without any damage. When the framing is placed on the slope, the sodding surface should be finshed to be smooth without any settlement or swelling. If voids occur between the bags and the frames, the said voids should be filled with clayey soil.

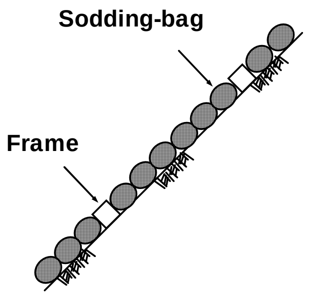


Figure 11.22 Sodding-bag Placing

Woven fiber material which will not disturb the germination should be used for the bag, and the earth to be filled into the holes should be less than 10 % gravel content and less than 10 mm miximum grain size.

(d) Construction Requirements for Top Soil

Top soil should be spread evenly on the areas and to the lines and levels as per the plans, and it is to be compacted with a light roller to a depth of not less than 10 cm. Spreading should not be done when the ground top soil is excessively wet, or in a condition determinal to such work. The roadway surfaces are to be kept clean during the hauling and spreading operations.

(e) Inspection of Germination

Whether the sodding work has been performed successfully or not should be determined by surveying the number of buds after the eslapse of a predetermined period of time. This is because re-execution of the work becomes necessary if the germination is extrmely poor, but vegetation cover may be restored by subsequent efforts, such as additional fertilization and/or partial seeding, if the gemination is not especially poor.

The timing of when inspection for germination should be conducted, should take into consideration the constrution area, season, weather after construction as so on. Table 11.4 presents the standard inspection criteria for germination after 3 months from completion of planting.

Table 11.4 Standard Criteria for Inspection of Vegetation

Evaluation		Germination Condition after 3 months
Wood Vegetation	Acceptable	The following conditions are observed; - Vegetation rate is 30 % to 50 % and number of wood vegetation is more than 10 piece / m^3, or - Vegetation rate is 50 % to 70 % and number of wood vegetation is more than 5 piece / m^3.
	Reservation	[Re-inspection Next Season] - Weed covers 70 % to 80 % and wood vegetation is more than 1 piece / m^3. [Continuing Observations for 1 to 2 month] - Germination is observed in place, but, entire slope is liked the bare ground.
	Unacceptable	[Considering Condition after Weeding] - Germination rate of botanical plants is more than 90 % and wood vegetation is underpressed. [Re-execution] - Germination materials have washed out and the vegetation is not expected to germinate.
Grass Vegetation	Acceptable	The following conditions are observed; - Entire slope looks green as viewed from 10 m away, and - Germination rate is more than 70 % to 80 %.
	Reservation	Germination rate is appoximately 50 % to 70 %, and if the following condition is observed, the observations are to be continued for 1 to 2 months; - Number vegetation is approximately 10 piece / m^3, but growth is slow.
	Unacceptable	Germination rate is less than 50 %, and if the following condition is observed, the vegetation work must be re-executed; - Germinant materials are washed out and the vegetation is not expected to germinate.

Source: Manual for Slope Protection, Japan Road Association (November 1999)

(2) Mortar Spraying

(a) Adjustments for the site Conditions

Mortar spraying is used on weatherable rock and rock likely to be weathered and stripped off even though there is no spring water in the slope and there is no danger for the time being as well as for mud-stone not suited to vegetation.

The standard thickness of spraying is 8 cm to 10 cm, if greater thickness is required, then concrete spraying, of which the standard range of thickness is 10 cm to 20 cm, should be applied. The thickness of spraying is determined by taking account of the slope condtions and weather conditions. Figure 11.23 and Figure 11.24 show the standard thickness of mortar or concrete spraying according to slope conditions.

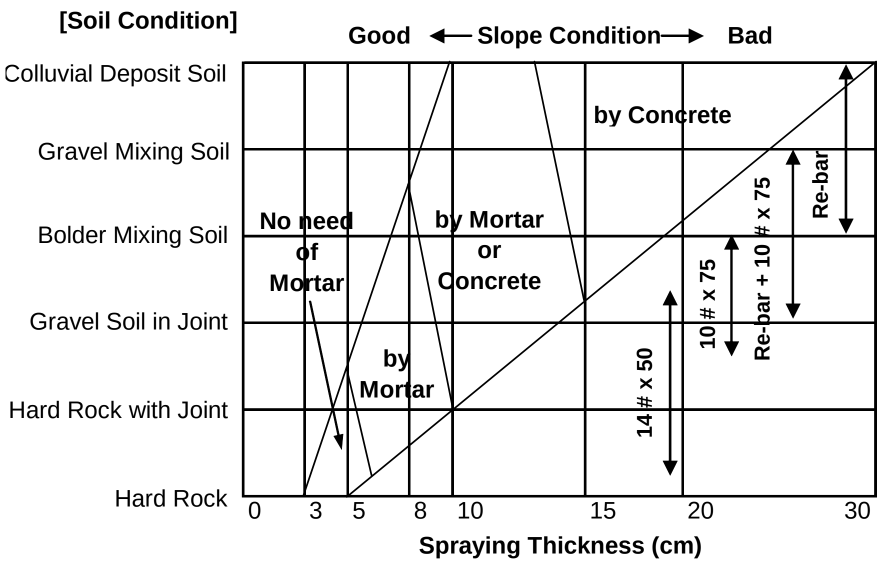


Figure 11.23 Standard Thickness of Spraying by Ground Conditions

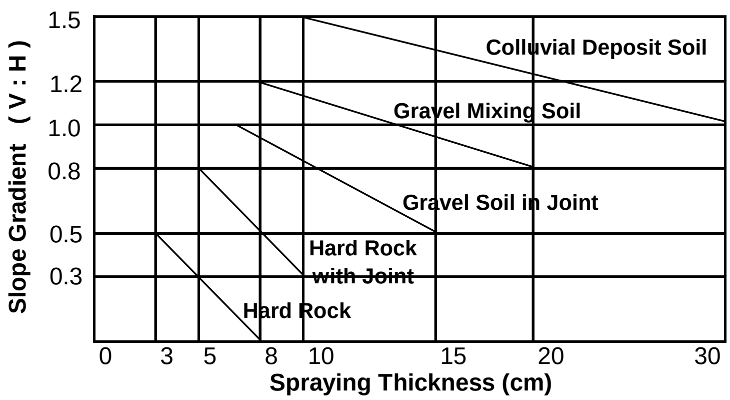


Figure 11.24 Standard Thickness of Spraying by Slope Gradient

(b) Mix Proportion and Material Requirements

[Mix Proportion]

Standard mix proportions by weight of cement and aggregates is 1 : 3 to 1 : 4 (C:S) and the water/cement ration is 45 % to 50 %. Mix proportions should keep rebound to a minimum and the minimum compressive strength should be 120 kg / cm^2 at 28 days.

[Cement]

Portland cement should be used for the mortar.

[Aggregate]

Aggregate for the mortar spray should be uniformly graded, dense, hard particles to avoid crumbling and forming of fine powder when passing through the nozzle. The fine aggregate should conform to the grading envelopes as shown in Figure 11.25.

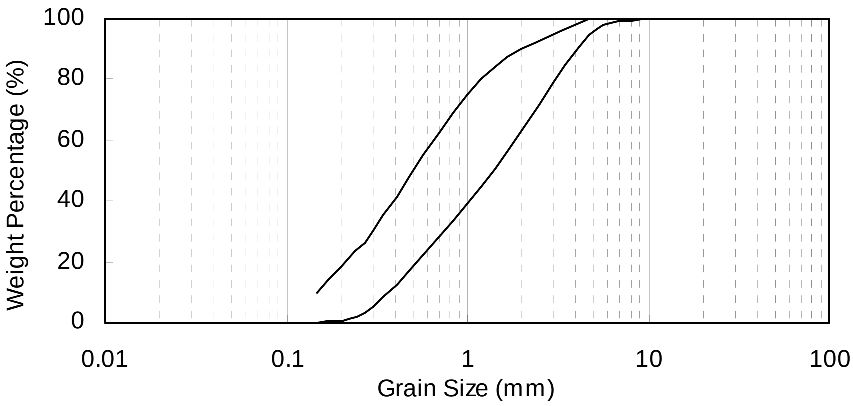


Figure 11.25 Required Range of Grain Size for Fine Aggregate

[Water]

The water used in the mortar should be fresh, clean and free from injurious amounts of sewage, oil, acid, alkali, salts or organic matter. Water will be tested in accordance with and shall meet the following requirements;

- SS : less than 2.0 g / litre
- Evaporation Residue : Less than 1.0 g / litre
- Concentration of Cl^- : less than 200 ppm
- pH : 5.8 to 8.6 pH

(c) Construction Requirements

[Preparation for Spraying]

Prior to spraying, it is required to lay wire mesh over the surface of the slope and to anchor it. Diamond-shape wire mesh is used when the surface of the slope is irregular, and welded wire mesh is used when the surface of the slope is only slightly irregular. If the wire mesh does not adhere to the slope sufficiently due to slope conditions, pegs should be installed as supplementary anchor bars. Standard materials to be used for the wire mesh and anchor bars are given as follows:

- Wire Mesh : Diameter = φ 2.0 ~ 4.0 mm (Standard : 2.0 mm)
  Size of Mesh = # 50 ~ 100 mm (Standard : 50 mm)

- Anchor Bars : Diameter = φ 16 ~ 20 mm (Standard : 16 mm)
  Length = 40 ~ 60 cm (Standard : 40 cm)
  Interval = 0.3 ~ 2.0 piece / m^2 (Standard : 0.3 piece / m^2)
- Pegs : Diameter = φ 9 ~ 20 mm (Standard : 9 mm)
  Length = 15 ~ 30 cm (Standard : 20 cm)
  Interval = 1.0 ~ 3.0 piece / m^2 (Standard : 1.5 piece / m^2)

The dewatering is important to succeed in slope protection by mortar spraying. For this purpose weep holes made of P.V.C. pipes of 40 mm diameter should be installed at 2.0 m intervals.

[Treatment at Edge]

In order to prevent infiltration of rain water, the mortar should be rolled to provide grooves on the edge and top of the slope. On the toe of the slope, the ground surface is to be grooved to prevent the motor from flaking off of the bottom. Figure 11.26 shows examples of edge treatment for mortar spraying.

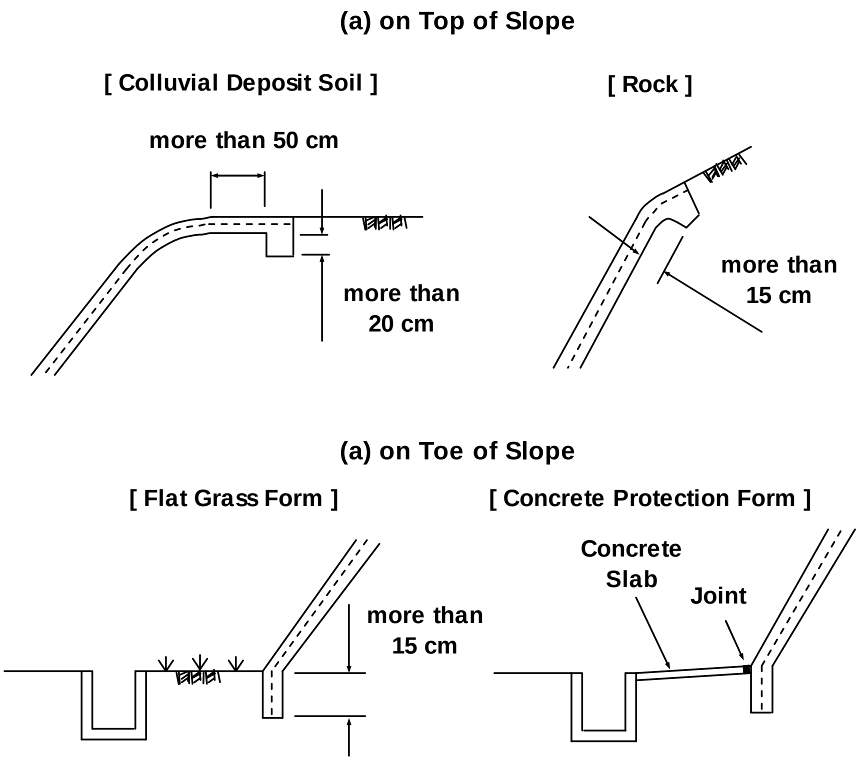


Figure 11.26 Edge Treatment for Mortar Spraying

[Spraying]

In dry spraying, water and the other materials are conveyed separately with compressed air through different hoses and then sprayed from the same nozzle. However, in the wet method, all materials, including water, are mixed together in a mixer, conveyed to a nozzle with compressed air, and then sprayed from the nozzle.

Spraying should normally be performed from top to bottom, but should be repeated where the sprayed thickness is large and where mortar is likely to drip down. The tip of the nozzle should be held normal to the surface of the slope to sprayed and moved slowly while spraying uniformly in a circular motion. Spraying should be stopped at places such as construction joints.

The distance from the tip of the nozzle to the surface to be sprayed should be approximately 1.0 m. The thickness of a single spraying should be determined from the cohesiveness of the mortar and the rate of setting. The rate of setting time may be reduced by adding an acceleration agent. These are available in the form or powder or liquid and an appropriate amount of agent is approximately 2.0 % to 4.0 % respectively of the weight of the cement for the powder and liquid.

[Rebound Ratio]

Losses due to the spray entering concave portions and rebounding should be taken into account. The rebound ratio (ratio between the amount of mixture ejected from the nozzle and the amount lost due to rebound) is governed by the mix proportion of material supplied to sprayer, properties of the aggregates, amount of accelerating agent added to the cement, gradient of the slope to be sprayed and the skill of the operator, but approximately 10 % to 15 % is a useful rebound ratio. Aggregate segregated during spraying should not be reused.

[Curing]

For a certain period depending on local conditions, the freshly placed mortar should be protected against sunshine, cold, running water, chemical attacks, and vibrations until it hardens and it should be kept moist for at least 7 days.

(c) Quality Control and Inspection

[Mortar Mixing]

The following quality control should be conducted for mortar mixing;

- Flow Test (120 m /m) and Slump Test,
- Compressive Strength Test by Test Piece (φ 10~ 20 cm) before Spraying,
- Spraying Test using a Test Panel as illustrated in Figure 11.27, Core Sampling and Compressive Strength Test.

[Thickness Control]

The thickness of the sprayed mortar should be controlled using spacer pins, as illustrated in Figure 11.28. These pins are to be embedded prior to spraying.

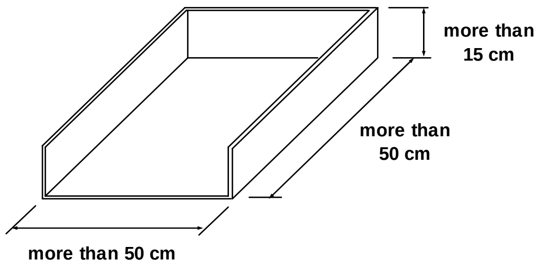


Figure 11.27 Panel Form for Spraying Test

The required thickness of mortar should be controlled so that it is always more than 75 % of design thickness, and the thickness pass rate should be more than 80 %.

Size of Measurement Pin Spacer

Type	Size (mm)		
	H	h	t
A	50	25	1.2
B	70	35	1.2
C	80	40	1.2
D	100	50	1.6
E	150	75	1.6

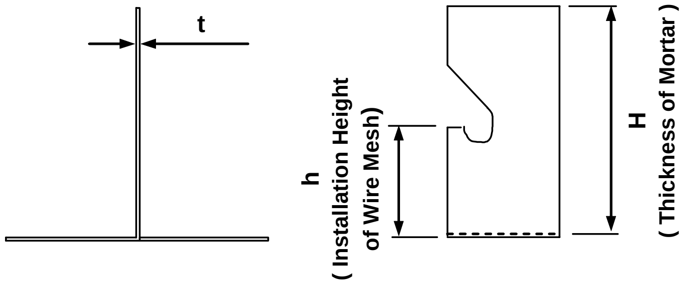


Figure 11.28 Spacer Pins for Measurement of Mortar Thickness

11.3.3 Retaining Structures

(1) Grouted Riprap Wall

(a) Materials

[Stones]

Table 11.5 Classification of Stones for Riprap

Class of Stones	Weight (kg)		
	Minimum	Maximum	More than 50 % of stones must weigh more than:
A	15	25	20
B	30	70	50
C	60	70	50
D	100	200	150

Stones for riprap should consist of rock as nearly rectangular in section as is practical, except that riprap of Class A may consist of round natural stones. The stones should be sound, tough, durable, dense, resistant to the action of air and water, and suitable in all respects for the purpose intended. Stones to be used for riprap should be one of the classes as shown in Table 11.5.

[Filter Materials]

The riprap should be placed on a filter layer to prevent fine embankment materials from washing out through the voids of the face stones, if required. The grading of the filter material requires that D_{50} of the filter is at least 4 times the size D_{85} for the embankment material, where D_{15} percent and 85 percent, respectively, pass by mass in a grain size analysis. Fine aggregate that satisfies the grading size as shown in Figure 11.25, described in Paragraph 11.3.2 (2) (b), may be used for the filter material.

[Mortar]

Mortar for the walls should consist of sand, cement and water conforming to the requirements given in Paragraph 11.3.2 (2) (b), mixed in the ratio between cement and aggregate of 1 : 3 by volume, and sufficent water to obtain the the required consistency.

(b) Construction Requirements

[Excavation]

The bed for the riprap should be excavated to the required depths and properly compacted, timed and shaped. The riprap should be founded in a toe trench dug below the depth of scour, and the toe trench should be filled with stone of the same class as that specified for the riprap.

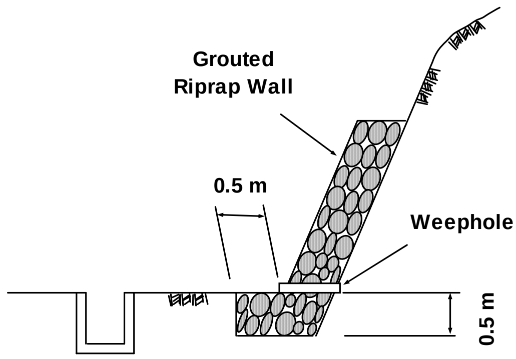


Figure 11.29 Example of Embedment for Riprap Retaining Wall

[Placing]

Stones above the water line shall be placed by hand or individually by machines. They should be laid with close, broken joints and should be firmly bedded into the slope and against the adjoining stones. Each stone should be laid with it is longest axis perpendicular to the slope in close contact with each adjacent stone. This riprap should be thoroughly rammed into place as construction progresses and the finished surface should present an even, tight surface. Interstices between stones should be filled with small broken fragments firmly rammed into place.

Riprap should have the following minimum thickness, measured perpendicular to the slope;

Class A : 30 cm, Class B : 50 cm, Class C : 60 cm, Class D : 80 cm

The surface of the riprap should not vary from the theoretical surface by more than 10 cm at any point.

[Grouting]

The horizontal and vertical contact surfaces between stones should be embeded with cement mortar having a minum thickness of 2.0 cm. The spaces between the stones should then be filled with motar throughout the thckness of the riprap. Sufficent mortar should be used to completely fill all voids, except that the face surface of the stones should be left exposed.

[Weep holes]

All walls should be provided with weep holes. The weep holes are to be placed horizontally at the lowest points where free outlets for water may be obtained and should be spaced at not more than 2.0 m center to center in a staggered manner. The length of the weep hole should not be less than the thickness of the walls and should be at least 50 mm diameter PVC, and must be provided with filter material covered with geotextile filter fabric.

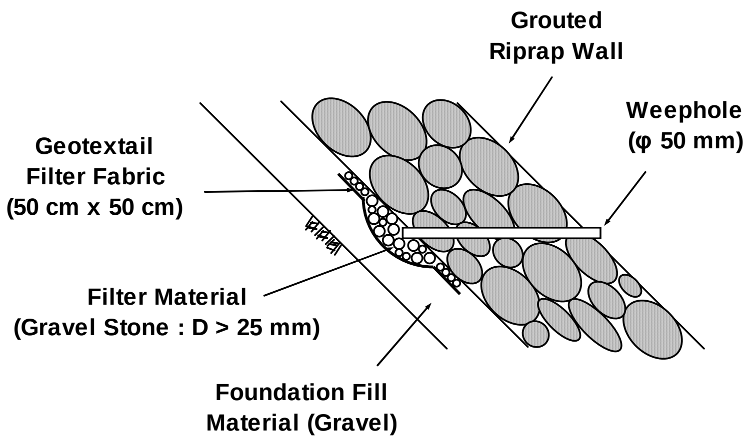


Figure 11.30 Example of Filter for Weep Holes Covered with Geotextile

The fabric of the geotextile filter is required to be non-woven, needle punched, and continuous filament type and manufactured from durable synthetic polymers. It shall have a permeability rate greater than the surrounding soils and have minimum physical properties as shown in Table 11.6.

Table 11.6 Standard Requirements for Geotextile Filter Fabric

Property	Required Values	Test Method
Min. Weight g/m^2	130	ASTM D3776
Min. Strip Tensile Strength kN/m	8	ASTM D4595
Max. Elongation at Failure %	50	ASTM D4595
Min. CBR Puncture Strength N	1,000	ASTM D4833

(2) Stone (or Concrete Block) Masonry Walls

In this paragraph, the type of stone or concrete block masonry to be described in clause 3.6.2 (2) 2) will be discussed. The type of masonry wall as shown in Figure 11.30 may be applied where the gradient of the slope is steeper than 1:1.0 (generally 1:0.3 to 1:0.6), and the acing earth pressure is relatively small such as on a cut slope of dense soil or on an embankment slope with well compacted back fill material.

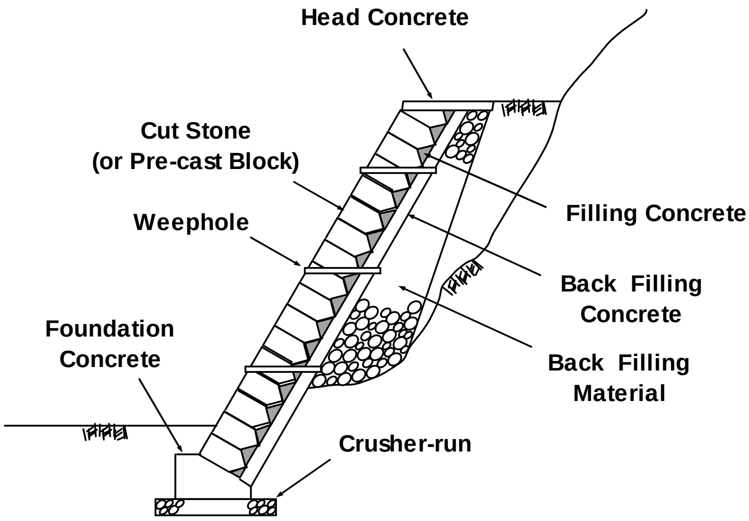


Figure 11.31 Standard Structure of Stone (or Concrete Block) Masonry Wall

(a) Stone of Concrete Block

[Stone]

A hard stone such as andesite or granite, or equivalent materials having sufficient specific gravity, strength and endurance, should be used for masonry walls. In order to facilitate placing in a regular pattern, the stone should be cut into the

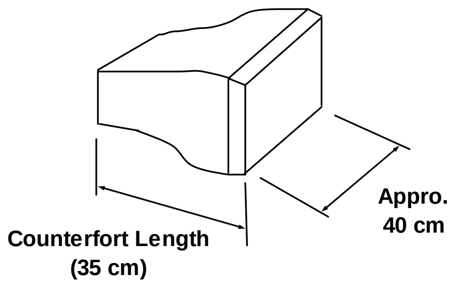


Figure 11.32 Standard Shape of Stone for Masonry Walls

shape shown in Figure 11.31.

[Concrete Block]

Pre-cast concrete blocks should be used for masonry walls. The standard shape and dimensions of the pre-cast concrete blocks are shown in Figure 11.32. The concrete blocks should satisfy the following requirements;

- Compressive Strength at 28 days : more than 180 kg/cm^2
- Specific Gravity of Concrete Block : more than 2.3
- Weight of Concrete Blocks in place: more than 350 kg/m^2

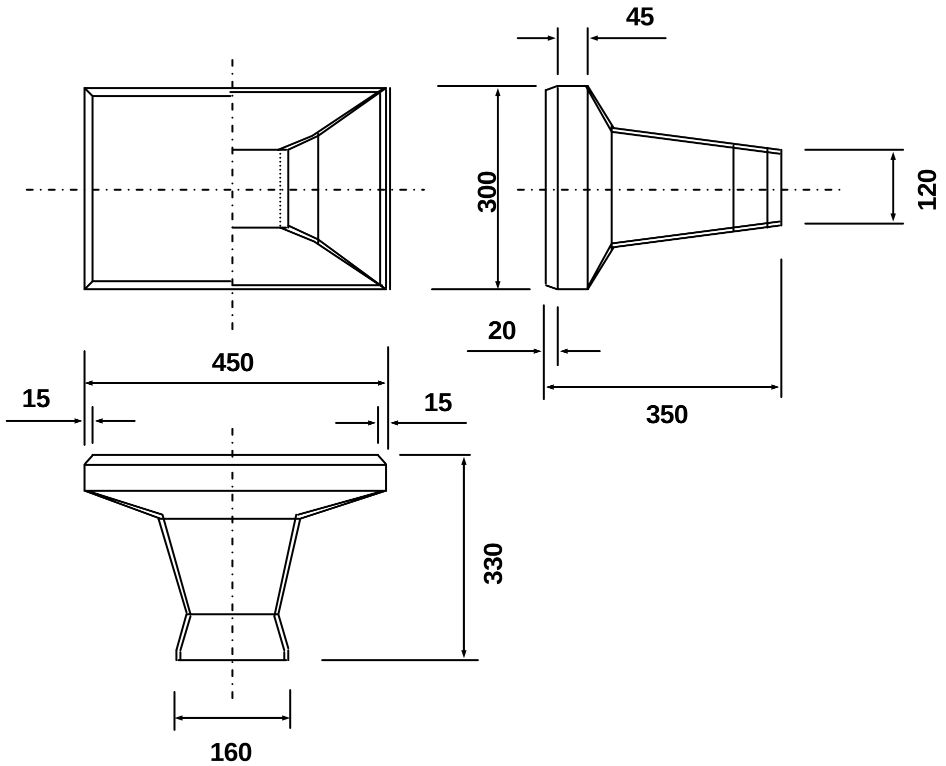


Figure 11.33 Dimensions of Standard Pre-cast Concrete Blocks for Masonry Walls

(b) Backfill Material

The backfill material to be installed aims to prevent the increase of pressure on the back of the wall by facilitating the drainage of water from behind the wall. Thus, well permeable material such as crushed stone should be used.

The backfilling material should be placed on the original ground surface, and impermeable material should be installed down to the bottom of the foundation, in order to prevent seepage water from affecting the foundation. In addition, weep holes of 50 mm diameter PVC should be provided at intervals of 2.0 to 3.0 m.

(c) Foundation Concrete, Concrete Fill, Concrete Backfill and Head Concrete

The compressive strength for foundation concrete, concrete fill, concrete backfill and head concrete should be more than 160 kg/cm^2, and construction expansion joints should be installed at intervals of less than 10 m. The joints to be used should satisfy the following requirements;

- Performed fillers for joints should conform to the requirements of AASHOTO M33 (ASTM D994), AASHOTO M153, AASHOTO M213, and AASHOTO M220, and have a nominal thickness of 20 mm, and should be punched to admit the dowels where called for on the plans.
- The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint. When the use of more than one piece is required for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means.

Under the concrete foundation, crushed stone or river gravel should be installed to a thickness of 10 to 20 cm.

(3) Gabion Walls

Gabion walls may be applied for slope protection, as a retaining structure at the toe of a slope or as treatment for spring water issuing from the slope. Since the gabion wall has flexible structure and characteristic, it can easily adopt the deformation of the slope.

(a) Types of Gabions

The following types of wire gabions are used for slope protection;

[Wire Cylinders]

Wire cylinders are used to prevent collapse of a slope or treatment of spring water where the slope is not very high and a gradient of the slope is gentler than 1:1.0. The cylinders have a diameter of 45 to 60 cm and length of 3 to 6 m as presented in Table 11.6.

The wire cylinder is placed to lie with its length parallel with the fall line of the surface of the slope, and if necessary, the wire cylinder is retained by wooden stakes where the slope is relatively steep.

Table 11.7 Standard Dimensions of Mesh Cylinders

Diameter (cm)	Length (m)	Rock Fill Volume (m^3)	Diameter (cm)	Length (m)	Rock Fill Volume (m^3)
45	3.0	0.43	55	3.0	0.64
	4.0	0.57		4.0	0.86
	5.0	0.72		5.0	1.07
	6.0	0.86		6.0	1.28
50	3.0	0.53	60	3.0	0.76
	4.0	0.71		4.0	1.02
	5.0	0.88		5.0	1.27
	6.0	1.06		6.0	1.52

[Wire Mats]

Wire mats are used as retaining structures on the lower portions of a slope, as a counter embankment against small scale landslides, or for prevention of erosion of the slope surface, where the slope is not very high and the slope gradient is gentler than 1:0.5. The shape of the wire mat is rectangular with a height of 0.4 m to 0.6 m, width of 1.2 m to 2.0 m and length of 2 m to 4 m as presented in Table 11.7.

Table 11.8 Standard Dimensions of Wire Mats

Reticulation (cm)	Height (cm)	Width (m)	Length (m)	Rock Fill Volume (m^3)
15 or 13	40	120	2.0	0.86
			3.0	1.30
			4.0	1.73
		180	2.0	1.30
			3.0	1.94
		200	2.0	1.44
			2.5	1.80
	50	120	2.0	1.08
			3.0	1.62
			4.0	2.16
	60	120	2.0	1.30
			3.0	1.94
			4.0	2.59

Reticulation (cm)	Height (cm)	Width (m)	Length (m)	Rock Fill Volume (m^3)
10	32	120	2.0	0.69
			3.0	1.04
			4.0	1.38
	40	120	2.0	0.86
			3.0	1.30
			4.0	1.73
	48	120	2.0	1.04
			3.0	1.56
			4.0	2.07
	64	120	2.0	1.38
			3.0	2.07
			4.0	2.76

The wire mats are placed in the form of a staircase, and if necessary, the mats are retained by wooden stakes.

(b) Materials

[Wire]

The wire mesh for gabion baskets should be galvanized steel having a zinc coating conforming to ATSMA 641 and satisfy the following requirements;

- Dimensions and Strength-

The minimum size of the galvanized wire used in the fabrication should be as shown in Table 11.8 and diameter tolerance should be ± 0.10 mm. The tensile strength requirements also should conform with the values shown in Table 11.8.

Table 11.9 Minimum Diameter and Tensile Strength of Galvanized Wire

Wire Member	Minimum Diameter (mm)		Tensile Strength (kg/cm^2)	
	Wire Mat	Wire Cylinder	Wire Mat	Wire Cylinder
Body Wire	3.05	2.20	4,950	5,250
Perimeter Selvedge Wire	3.80	2.70	4,950	4,950
Tying and Connecting Wire	2.20	2.70	5,250	5,250

- Weight of Coating -

The minimum weight of zinc per unit of uncoated wire surface should be as shown in Table 11.9.

Table 11.10 Minimum Weight of Zinc Coating

Wire Diameter (mm)	Class 3 Coating (g/m^2)
over 1.90 to 2.30	220
over 2.30 to 2.70	230
over 2.70 to 3.10	240
over 3.10 to 3.50	260
over 3.50 to 3.90	270

[Rock Fill]

Rock fill for gabions should consist of hard, durable rock pieces that will not deteriorate when submerged in water or exposed to severe weather conditions. Rock pieces should generally be uniformly graded in sizes ranging from 100 mm to 200 mm. Filled gabions should have a minimum density of 1,400 kg/m^3 and voids should be evenly distributed.

No rock size should exceed 2/3 the depth of the gabion and at least 85 % by weight of stone should have a size greater than 80 mm. No stone should be able to pass through the mesh.

(c) Construction Requirements

- For rock fill in gabion baskets, the bigger sized rocks should be placed one by one in the outer portions of the basket to minimize voids, and then the remaining space in the basket should be filled with the required amount of rock.
- The connections between wire cylinders should be knotted at 1.0 m intervals in the longitudinal direction.
- For wire mats, the upper mat should be piled up to move behind of the lower mat with ensuring the length of more than 1/2 of height of the lower mat, and then the gradient should be maintain more gently than 1:0.5.
- When the gabion is must be fixed on a slope with stakes, wooden stakes of approximately 10 cm diameter is to be used. The length of the stakes for wire cylinders should be equal to the diameter of the cylinder + 1.0 m. For wire mats, stopping stakes are to be placed through the bottom basket and fixing stakes to connect the upper and lower baskets are provided as shown in Figure 11.33.

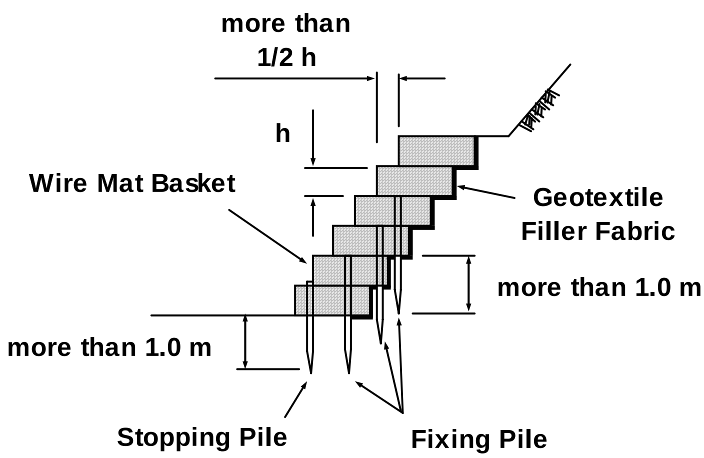


Figure 11.34 Example of Wire Mat Basket Installation

- Geotextile filter fabric should be placed between the earth surface and the gabion structure. Filter fabric should be rolled out onto a flat non-rutted surface free from sharp objects, and the edges weighted down. Construction equipment should not be allowed to drive over unprotected fabric. Jointing is normally done by overlapping not less than 30 cm, but it is preferable to joint by sewing or industrial stapling. Joint edges should face downwards to avoid protruding through the surface material.

11.3.4 Horizontal Drain Holes

The length of horizontal drain hole is generally 30 m to 50 m for shallow groundwater and 80 m to 90 m for deep groundwater. In case of the long lateral drilling, the borehole can become crooked. Therefore, proper boring equipment suited to the design length and geological conditions must be used, and proper temporary scaffold staging to support the boring equipment steadily must be employed.

(1) Construction Planning

Prior to boring, a construction plan containing the following items should be prepared;

- Temporary work and scaffold staging plan
- Work scheduling plan
- Equipment mobilization plan
- Safety measure plan

The most important matter is to mobilize suitable boring equipment as per design drilling diameter, borehole length, topography, geological conditions and groundwater condition. There are several types of drilling equipment including rotary drilling, rotary percussion drilling, down-hole drilling and so on. Since the geological condition of the landslide section is relatively soft, the rotary drilling equipment is also used for lateral boring work.

(2) Progress Control

Daily drilling progress reports should include the following items;

- Daily drilling length, and any collapse of borehole walls
- Spring water or flooding in the work area
- Color, size and hardness of the cores from slime, mud or samples from the borehole

In addition to the above items, a daily drainage water volume record sheet as presented in Table 11.10 is to be prepared for the purposed work in order to assess the effectiveness of the landslide prevention measure.

Table 11.11 Example of Drainage Water Volume Sheet for Horizontal Drain Hole

[Depth and Maximum Drainage Volume]

Boring No.	Drilling Length (m)					Direc-ti on	Incli-nation Angle (deg.)	Max. Drainage Volume (litter / min)	Note
	Clayey Soil	Sandy	Gravel Mix	Boulder Mix	Soft Rock				
1									
2									
3									
4									
5									

[Depth and Maximum Drainage Volume]

Date		/	/	/	/	/	/	/	/	/	/	/
Weather												
Drainage Volume (liters)	Boring No.1											
	Boring No.2											
	Boring No.3											
	Boring No.4											
	Boring No.5											
Groundwater Level (m)	Test hole 1											
	Test hole 2											
Amount of Rainfall (mm)												

(3) Borehole Protection Pipe

The diameter of the lateral boring is normally 66 to 100 mm and the borehole should be protected in order to install the perforated pipe after the completion of drilling as shown in Figure 11.34. Hard vinyl chloride pipe (PV pipe) or gas pipe should be used to protect the borehole.

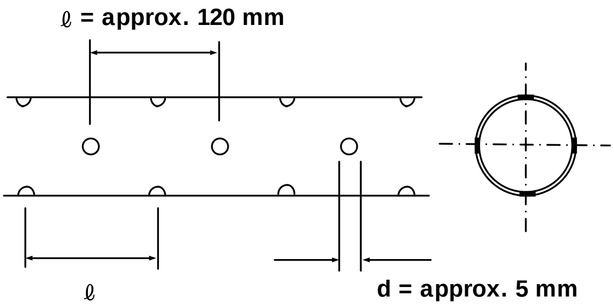


Figure 11.35 Example of Perforated Pipe for Horizontal1 Drain Holes

The diameter of round-hole perforations should be 2 to 5 mm, and slit type perforations should be 2 mm wide and 10 cm long. The shape and material of the pipe should conform with the fabricating factory certification.

Appendix-1

References

The main technical guidelines referred to and cited in the Guide III are as follows:

No.1 Highway Earthwork Series, MANUAL FOR SLOPE PROTECTION, Published by Japan Road Association, March 1999.

No.2 Highway Earthwork Series, MANUAL FOR DRAINAG WORKS, Published by Japan Road Association, June 1987.

No.3 Highway Earthwork Series, MANUAL FOR RETAINING WALLS, Published by Japan Road Association, March 1999.

No.4 MANUAL FOR COUNTERMEASURES AGAINST ROCK FALL, Published by Japan Road Association, June 2000.

No.5 DESIGN GUIDE －EARTHWORKS, Published by Japan Highway Public Corporation, May 1998.

No.6 MANUAL FOR RIVER WORKS IN JAPAN, Published by River Bureau, Ministry of Construction, November 1997.

No.7 DESIGN AND CONSTRUCTION MANUAL FOR MULTISTAGE ANCHOR TYPE REINFORCED EARTH WALL, Third Edition, Published by Public Works Research Institute, October 2002.

No.8 Technical Standards and Guidelines for Planning and Design, Volume IV, NATURAL SLOPE FAILURE COUNTERMEASURES, Project for the Enhancement of Capability in Flood Control and Sabo Engineering of DPWH, March 2002.

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No. 12 Costal Development Institute of Technology Japan 2004, Technical Criteria and Commentaries on Costal Protection Facilities

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No. 17 Japan Port & Harbor Association April 1989, under the editorship of Ministry of Construction, Japan, Guide to Design of Gentle Slope Dike

No. 18 U.S. Army Coast Engineering Research Canter 1984, Shore Protection Manual

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Appendix-2

Sources for Main Equations Used in This Guide III

The main equations used in the Guide III are cited from the following references:

No.	Equation No.	Reference No.
Chapter III		
1	3.1	2
2	3.2	2
3	3.3	2
4	3.4	1, 5, 6
5	3.5	10
6	3.6	10
7	3.7	10
8	3.8	10
9	3.9	10
10	3.10	10
11	3.11	10
12	3.12	10
13	3.13	10
14	3.14	10
15	3.15	10
16	3.16	10
17	3.17	10
18	3.18	10
19	3.19	10
20	3.20	10
21	3.21	10
22	3.22	10
23	3.23	10
Chapter IV		
1	4.1	4, 1
2	4.2	4
3	4.3	4
4	4.4	4
5	4.5	4
6	4.6	4
Chapter V		
1	5.1	2
2	5.2	1, 2
3	5.3	1, 2

No.	Equation No.	Reference No.
4	5.4	1, 2
5	5.5	2
6	5.6	2
7	5.7	1, 2
8	5.8	1, 2
9	5.9	2
10	5.10	2
11	5.11	1, 2
12	5.12	1, 2
13	5.13	1, 2
14	5.14	2, 11
15	5.15	2, 11
16	5.16	2, 11
17	5.17	2, 11
18	5.18	2, 11
19	5.19	2, 11
20	5.20	2, 11
Chapter VI		
1	6.1	1, 3
2	6.2	3
3	6.3	3
4	6.4	3

Note: Reference No. in the table above is the same as those listed in Appendix 1.