## 6.2 Selection of Damage Prevention Measures

This section discusses how to select a desirable damage prevention measures from the candidates listed in 6.1. A selection procedure is expressed as a flow chart in order to reach a final solution easily for each type of damage.

However, in the course of making a selection, attention shall be paid to cost effectiveness and social and environmental impacts.

### 6.2.1 Slope Erosion

A slope erosion is mainly caused by surface runoff water. If the slope is left as is for a long term without any prevention measures, the erosion may induce landslides and rockfalls.

In general, a slope surface can be protected from erosion applying the three measures listed below. A surface drainage is one of the measures to eliminate the cause of erosion. Surface vegetation and surface covering with structure are aiming the surface to be anti-erodible.

1. **SURFACE VEGETATION**
2. **SURFACE DRAINAGE + VEGETATION**
3. **SURFACE COVERING WITH STRUCTURE**

Among these three countermeasures, "surface vegetation" is the most inexpensive, with "surface drainage + vegetation" being next, The most costly measure is "surface covering with structure".

Prevention measures for slope erosion shall be selected in line with the flow chart shown in Fig.6.2.1.

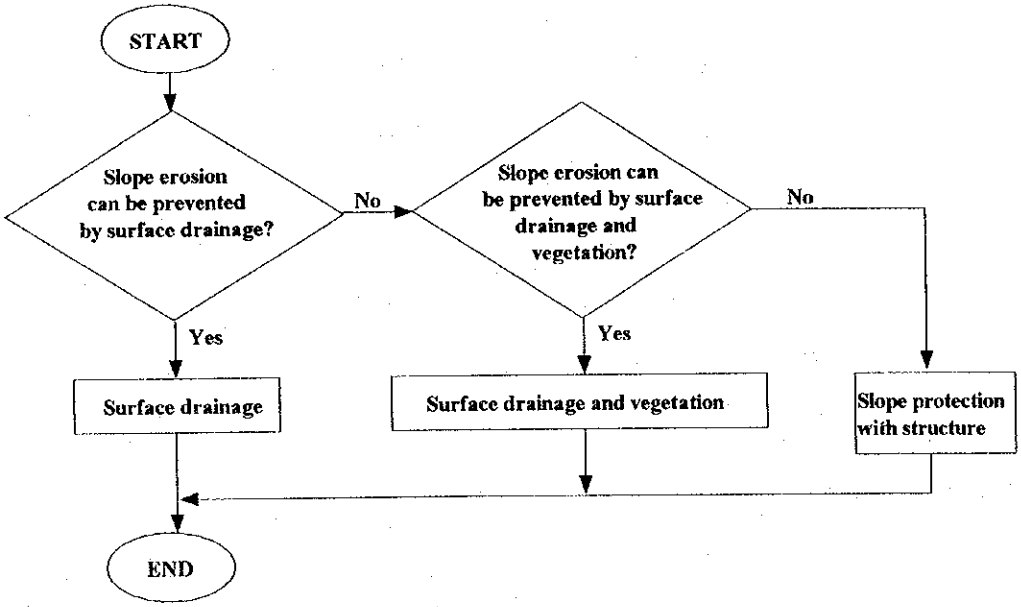



Fig. 6.2.1 Selection of Prevention Measures for Slope Erosion

1. Slope Protection Using Vegetation

The type of vegetation to be selected is based on its applicability to the slope conditions of a particular slope, as shown in Table 6.2.1.

Table 6.2.1 Application of Slope Vegetation

| Method | Geology | | | |
|---|---|---|---|---|
| | Cut Slope | | | Fill Slope |
| | Hard Rock | Soft Rock | Soil | Soil |
| Block sodding | D | D | A | A |
| Spot sodding | D | C | B | A |
| Seed packet work | D | A | A | D |
| Pick-hole seedling work | D | C | A | A |
| Seed spraying with a pump | D | B | A | A |

A: Highly recommendable
B: Recommendable
C: Difficult to recommend
D: Not Recommendable

2. Slope Protection with Surface Drainage and Vegetation

The type of drainage to be applied is selected from candidates described in Item 6.2 (refer to page ). The applicability of each type of drainage to the different conditions of slopes is shown in Table 6.2.2. Here, a combination of the

most suitable type of drainage and vegetation is chosen as a final solution for slope erosion.

Table 6.2.2 Application of Surface Drainage

| Method | Geology | | |
|---|---|---|---|
| | Hard Rock | Soft Rock | Soil |
| Crest ditch | B | A | A |
| Berm ditch | C | B | A |
| Toe ditch | A | A | A |

**A: Most suitable**
**B: Suitable**
**C: Not suitable**

3. Surface Covering with Structure

The type of structure for surface covering to be selected shall be based on the following Table 6.2.3.

Table 6.2.3 Application of Surface Covering with Structure

| Method | Geology | | | |
|---|---|---|---|---|
| | Cut Slope | | | Fill Slope |
| | Hard Rock | Soft Rock | Soil | Soil |
| Stone pitching | D | C | A | A |
| Concrete block pitching | D | C | A | A |
| Gabion work | D | D | C | B |
| Shotcrete | A | A | C | C |
| Cribwork | A | A | A | A |

**A: Highly recommendable**
**B: Recommendable**
**C: Diffcult to recommend**
**D: Not Recommendable**

Structural covering of the slope surface is an effective solution from mechanical point of view, but it is not aesthetic. Therefore, a combination of structure and vegetation, such as a cribwork and vegetation, is more desirable.

### 6.2.2 Rockfalls

A rockfall is mostly triggered by slope erosion and weathering. The cause of rockfalls is explained simply in Fig.6.2.2.

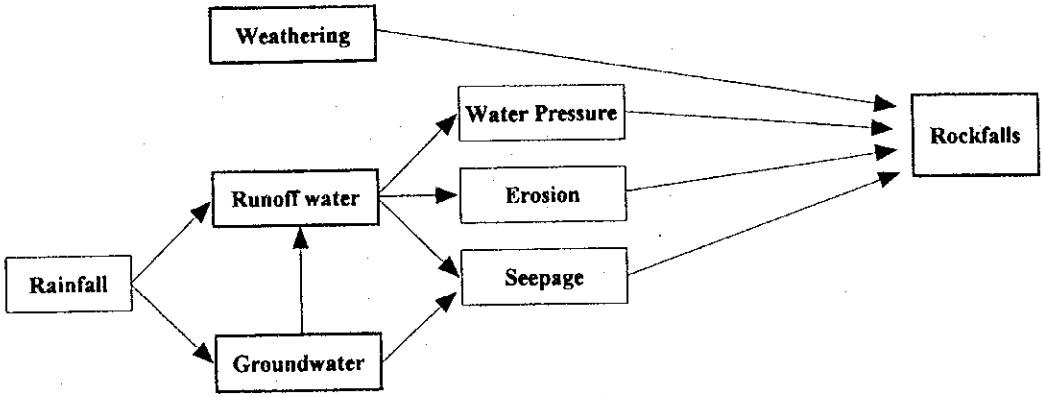



Fig.6.2.2 The Cause of Rockfalls

Preventive measures are mainly divided into the following four types, with the selection procedure shown in the flow chart of Fig.6.2.3.

1. **REMOVAL OF UNSTABLE MATERIALS**
2. **PROTECTION OF SLOPES FROM EROSION**
3. **STRUCTURAL SUPPORT**
4. **ROCKFALL PREVENTION DEVICES**

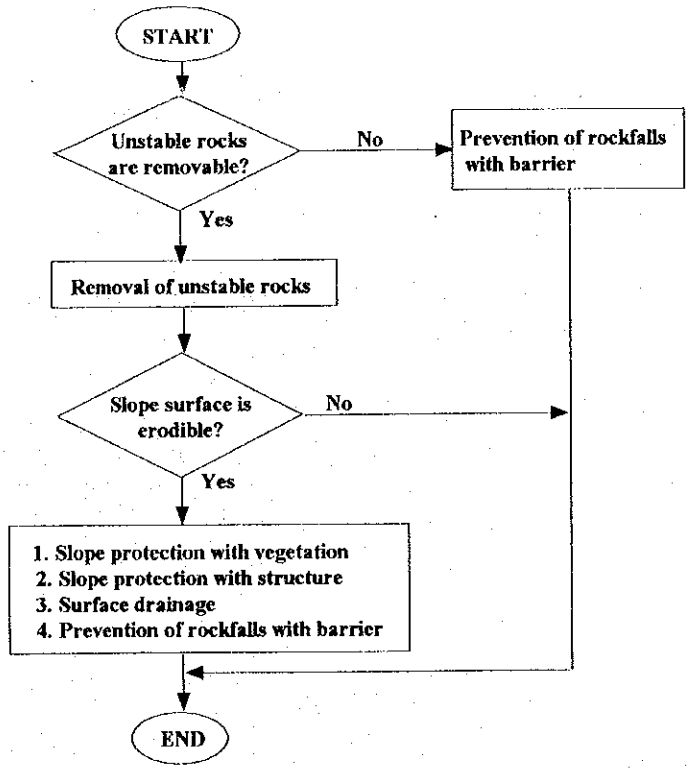



Fig. 6.2.3 Selection of Prevention Measures for Rockfalls

1. Removal of Unstable Materials

The removal of unstable material shall be executed mainly by applying the following measures. The type of removal method depends on the traffic conditions, slope conditions, etc.

- Mechanical/manual excavation
- Undercutting with hydraulic sluicing
- Blasting in place

This measure is the most reliable and recommendable.

2. Protection of Slopes from Erosion

In order to prevent unstable rock from undercutting, the following measures to protect slopes from erosion can be applied.

- Surface drainage
- Shotcrete
- Surface vegetation

3. Structural Support

Measures using structures for slope support are comprised of the following three types.

- Foot protection

Foot protection of unstable rock is carried out using either concrete or stone masonry.

- Structural surface protection

This usually consists of shotcrete, concrete revetments and cribwork.

- Rock bolt

## 4. Rockfall Prevention Devices

Fencing, retaining wall barrier for rockfalls and rockfall prevention net are categorized in this territory.

The relationship between the type of measure applied and the estimated size of falling rock is shown in Table 6.2.4.

In conclusion, 1.is the most reliable and recommendable measure. The construction cost of 2. is not so high, but the reliability of the measure is slightly lacking. Structural supporting is mainly applied when the size of falling rock is estimated to be rather huge, but the cost of this measure is generally high. Rockfall prevention device are generally applied for small- or medium-size rockfalls.

The most suitable measure(s) for a spot shall be decided after taking into consideration the function, durability, cost effectiveness and environmental impact of each measure.

**Table 6.2.4 Applicable Type of Measure**

| Estimated size of falling rocks | | Huge rock ( Ø 1.0 m) | | Medium size ( Ø 0.4 m) | | Small size | |
|---|---|---|---|---|---|---|---|
| Measure \ Type of rockfalls | | Toppling | Undercutting | Toppling | Undercutting | Toppling | Undercutting |
| Removal of unstable rock | | B | B | B | B | B | B |
| Slope protection from erosion | Surface drainage | B | A | B | A | B | A |
| | Shotcrete | C | D | B | D | A | D |
| | Vegetation | D | B | D | B | D | B |
| Structural support | Foot protection | B | B | D | D | D | D |
| | Concrete revetments | C | C | B | B | B | B |
| | Cribwork | C | C | B | B | B | B |
| | Rock bolts | B | C | D | D | D | D |
| Rockfall prevention device | Prevention net | D | D | D | D | A | A |
| | Prevention fence | D | D | D | D | A | A |
| | Retaining wall barrier | D | D | A | A | A | A |

A : Highly recommendable
B : Recommendable
C : Difficult to recommend
D : Not Recommendable

### 6.2.3 Landslide

Most landslides on roads occur mainly at cut-slope and fill-slope sections with steep slope gradients. The loss in slope stability is mostly brought about by increases in the groundwater level due to extensive rainfall and by a loss in slope balance due to human error.

In general, there are three types of prevention measures for landslides and they are listed below. The first measure, control of discharge water, tries to eliminate the origin of landslides. The second and third measure, weight shifting and structural support, try to prevent landslides by maintaining balance of the slope using external force.

1. **CONTROL OF DISCHARGE WATER**
2. **WEIGHT SHIFTING**
3. **STRUCTURAL SUPPORT**

A procedure to select suitable landslide prevention measure is shown in the flow chart of Fig.6.2.4.

1. Control of Discharge Water

In this category, the following two prevention measures are applicable. The first one is rather costly but effective for lowering the underground water level.

- Lowering of underground water by horizontal drain holes.
- Prevention of runoff water from permeating into the ground by surface drainage.

2. Weight Shifting

Weight shifting measures can be divided into the two types shown below.

- Removal of slide debris

  In some cases, all of slide debris is removed and, in other cases, a portion of slide debris is removed.

- Counterweight

  Earth fills, gabions and concrete walls are possible counterweight material.

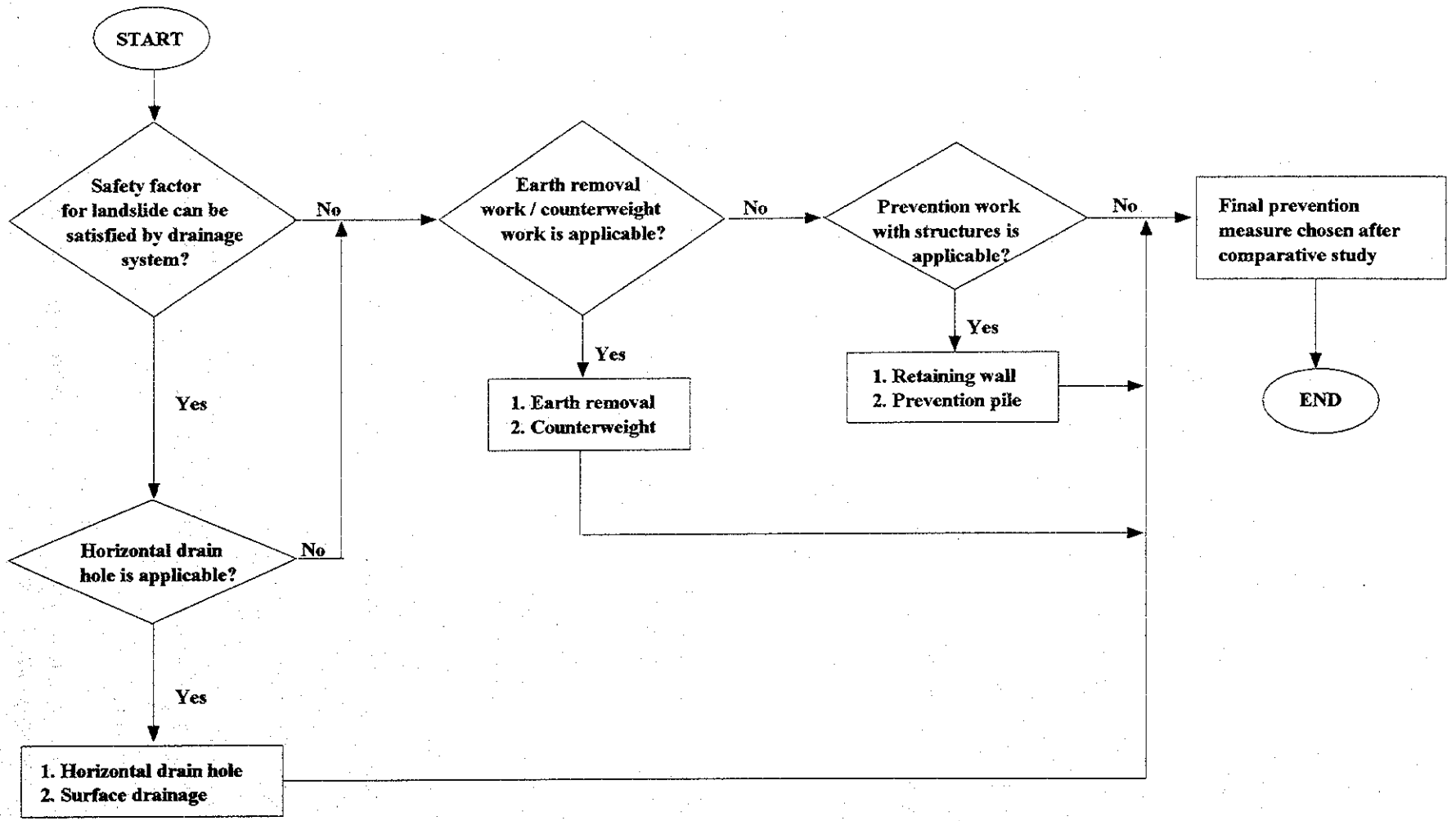



**Fig. 6.2.4 Selection of Prevention Measures for Landslides**

3. Structural Support

As for the types of structural support, it is possible to have a retaining wall at the foot of a sliding slope or a landslide prevention pile, which is driven into the ground deeper than the slip surface in the middle of slope.

Prevention measures for a spot can be selected referring to Table 6.2.5. However, final decisions shall be made after a comparative study on various possible measures.

Table 6.2.5 Relationship between Landslide Prevention Measures and Geology

| Type of slope | Geology | Surface drainage | Horizontal drain hole | Earth removal | Counter-weight | Retaining wall | Prevention pile |
|---|---|---|---|---|---|---|---|
| Cut slope | Rock | C | B | A | A | A | A |
| | Weathered rock | C | B | A | A | A | A |
| | Colluvium | B | B | A | A | A | A |
| | Clayey soil | A | B | C | A | A | B |
| Fill slope | Colluvium | C | A | C | A | A | A |
| | Clayey soil | C | C | C | A | A | B |

A: Most suitable
B: Suitable
C: Not suitable

### 6.2.4 Collapsing of Bridges

The collapsing of a bridge can usually be attributed to one of the following four causes, each of which has several countermeasures.

- **Insufficient discharge capacity**
- **Shifting of river channel**
- **Undesirable bridge crossing**
- **Meandering of river**

Countermeasures to eliminate the causes of damage and to protect a bridge from damage shall be selected in line with the flow chart shown in Fig.6.2.5.

A breakdown of the prevention measures is described below.

1. Insufficient discharge capacity

The only solution to this problem is to provide a sufficient waterway opening at the bridge crossing applying the following measures.

- Dredging of river channel
- Extension of bridge
- Construction of auxiliary bridge

2. Shifting of river channel

In the case where a river is in a flood plain, the river channel is prone to shift and result in the scouring of abutments and access road embankments. The measures shown below should be applied.

- Stabilization of river channel

  The stream's channel shall be protected from scouring using dumped rock and/or gabions.

- Abutment protection with gabions, stone riprap or concrete revetments.

- Protection of access road embankments with gabions, stone riprap or concrete revetments.

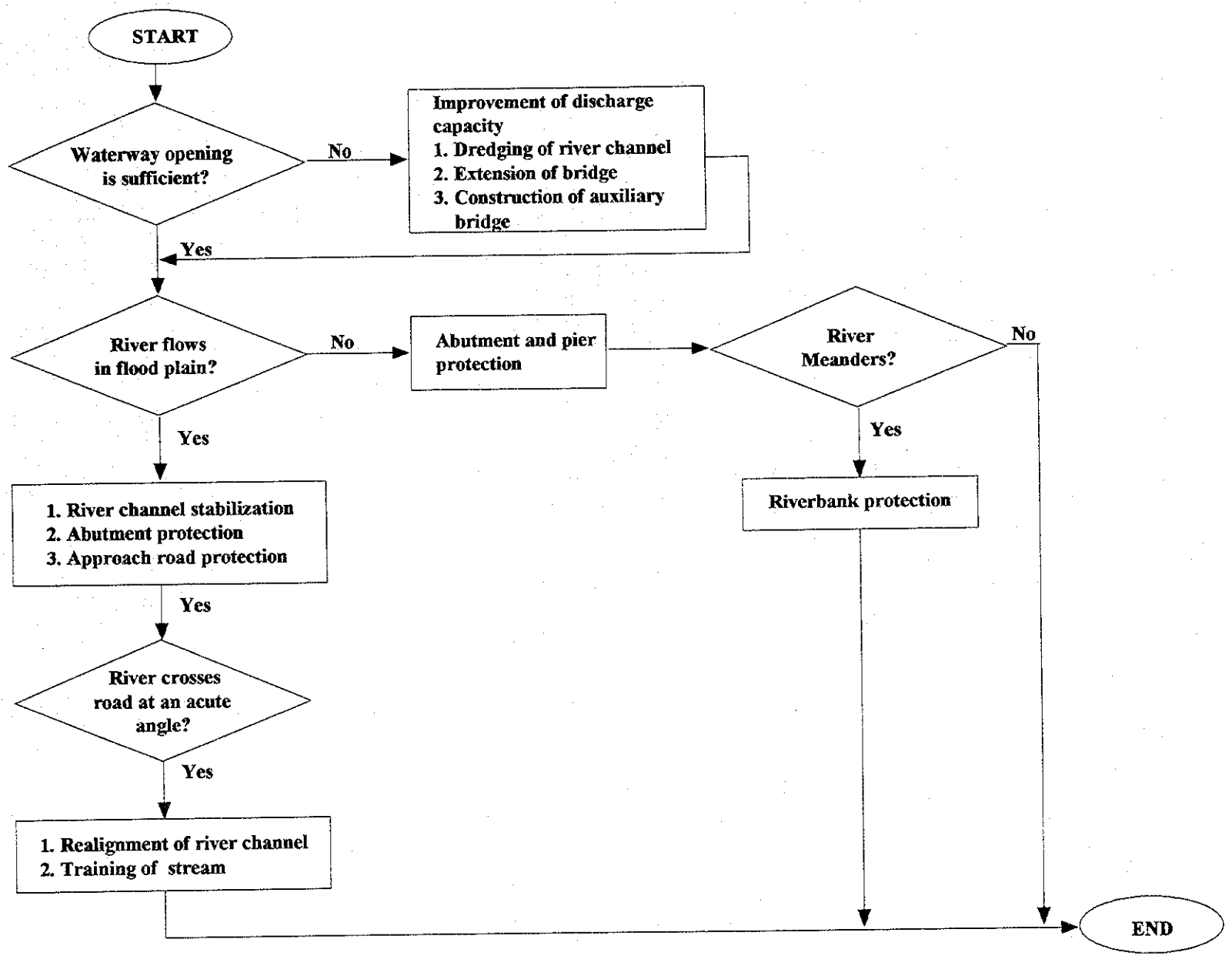



**Fig. 6.2.5 Selection of Prevention Measures for Collapsing of Bridges**

3. Undesirable bridge crossing

When the intersecting angle between a bridge and a road is extremely acute, the bridge and access roads to the bridge are prone to be damaged at the time of flooding by water turbulence. In this case, the measures shown below are applicable.

- Realignment of river channel

  The river channel is realigned to moderate the existing acute intersecting angle between the bridge and road.

- Training of the stream

  To eliminate water turbulence, the river flow shall be trained with a pair of guide dikes.

4. Meandering of river

When a river meanders, the river bank is prone to be scoured at bends in the river. If a bend is situated close to an abutment, the abutment protection can also be damaged by the influence of river bank scouring. Therefore, river banks shall be protected in the vicinity of the bridge with stone riprap or concrete revetments.

### 6.2.5 Collapsing of Embankment Roads

Most embankment damage occurs at the locations listed below.

1. **Embankment incident to a river**
2. **Embankment in a flood plain**
3. **Embankment on sloping ground**

The type of damage and its cause are peculiar to a location and are dominated by locational conditions described below. The procedure to select of damage prevention measures is shown in Fig.6.2.6.

1. Embankment incident to a river

This situation is illustrated in Fig.6.2.7. The type of damage and the cause of damage are also described below.

Damage: Scouring of embankment toe
Cause : High velocity river flow

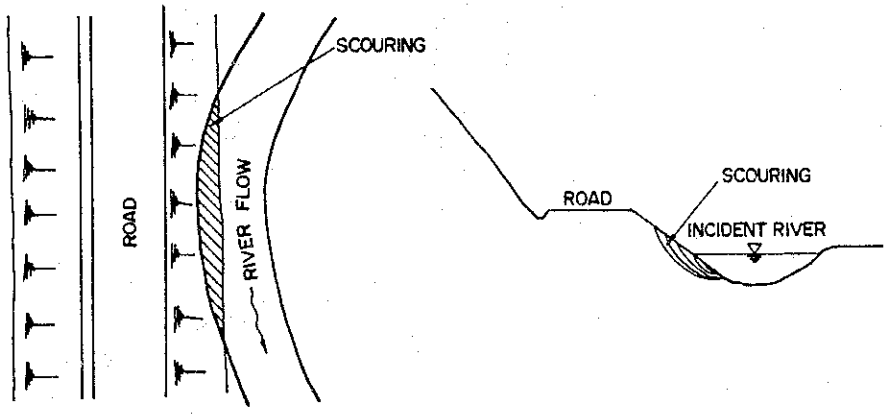



Fig.6.2.7 Embankment Scouring by Incident River Flow

In this case, an embankment shall be protected from scouring with either dumped rock, gabions, stone riprap, concrete revetments or retaining walls. In selecting a prevention measure, the volume and velocity of the river flow are fundamental factors.

In order to eliminate the cause of damage, the distancing of the river stream from the embankment by the realignment of the river can be an effective measure.

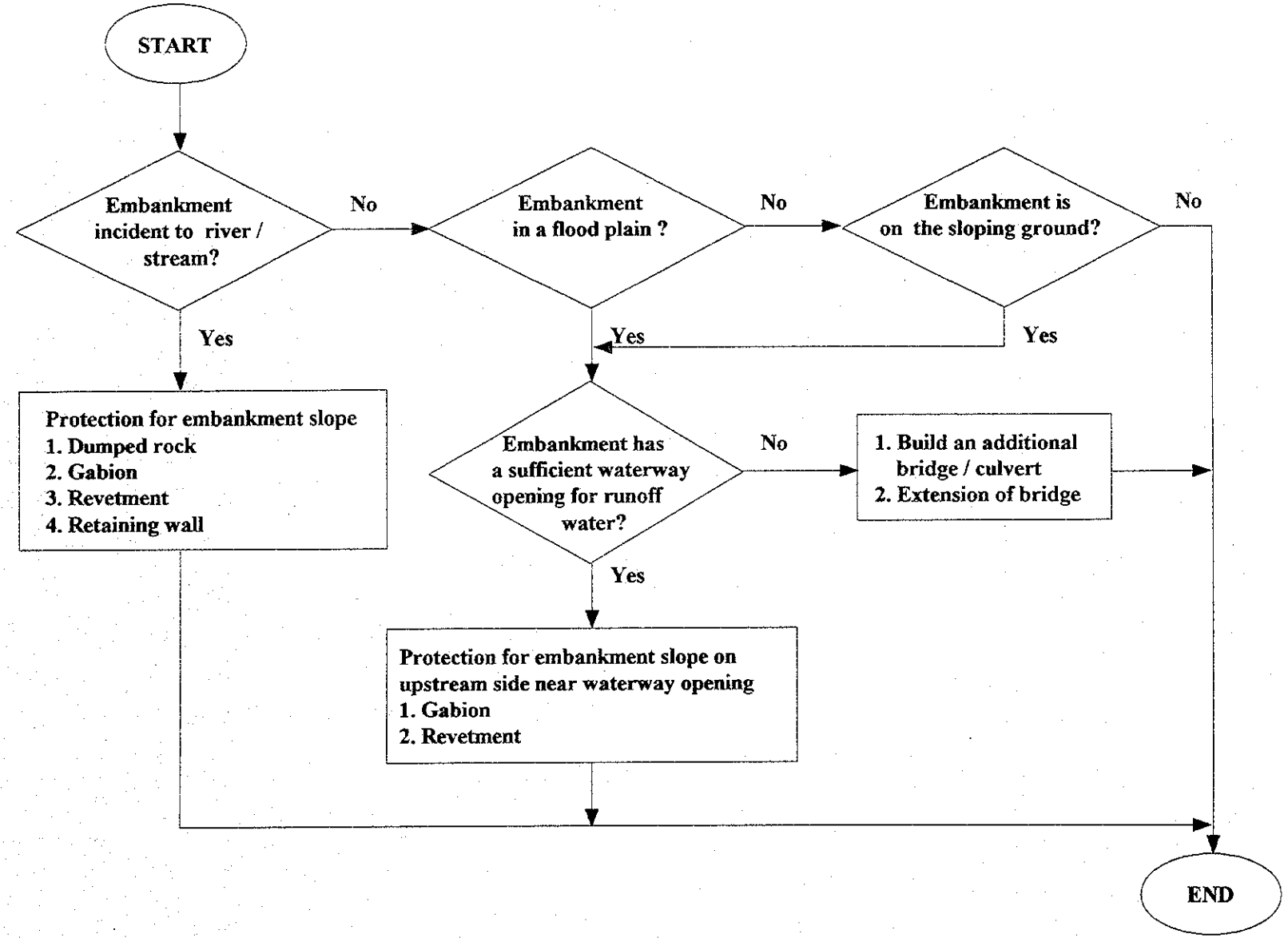
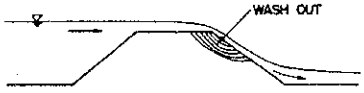
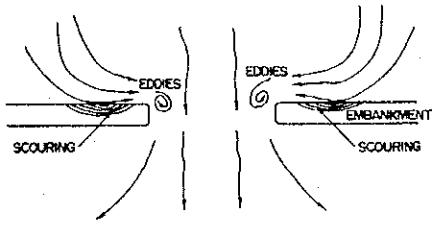



**Fig. 6.2.6 Selection of Prevention Measure for Collapsing of Embankment Roads**

2. Embankment roads in a flood plain

In this case, there are two types of damage-and-cause relationships as shown in Table 6.2.6.

Table 6.2.6 Damage-and-Cause Relationship for an Embankment Road in a Flood Plain

| | Case 1 | Case 2 |
|---|---|---|
| Cause | Overflow due to lack of discharge facilities | Flood flow along embankments at high velocity |
| Damage | Wash out of shoulder and embankment slope on downstream side | Scouring of an embankment on upstream side |
| Prevention Measure | •Extension of existing bridge<br>•Construction of auxiliary bridge or culvert | •Installation of guide dike<br>•Embankment protection with stone riprap, concrete revetments |
| Illustration |  |  |

3. Embankment on sloping ground

In this case, an embankment is prone to be washed out on downstream side when runoff water from upstream is blocked by the embankment due to a lack of discharge facilities, i.e. a culvert or bridge. If the embankment remains in this situation for a long time, the embankment might be totally swept away by water pressure or a landslide. The situation is illustrated in Fig.6.2.8.

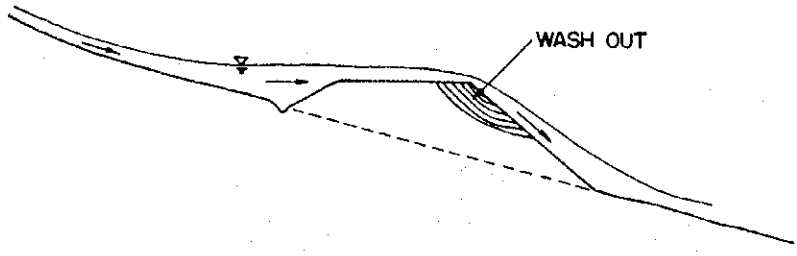



Fig.6.2.8 Washout of Embankment by Overflow

The only solution to this problem is to increase the discharge facilities that cross the embankment.

### 6.2.6 Road Flooding

Road flooding is not a problem restricted to a limited area, but occurs a wide area such as whole catch basin of a river. Therefore, measures for flood prevention can not only focus on roads. That is, river control, deforestation, etc,must also be considered.

In this context, the only solution to road flooding for the DOH is to raise roadway elevation where roads are prone to be submerged at times of flooding. The process for this is shown in the flow chart of Fig.6.2.9.

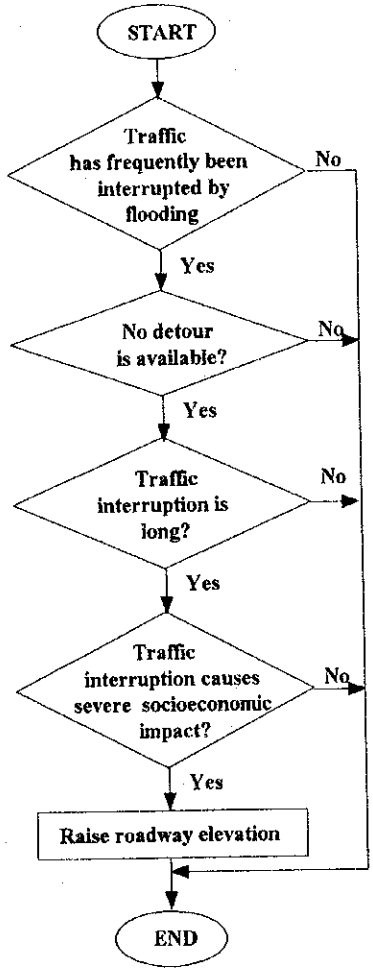



Fig.6.2.9 Selection of Prevention Measure for Road Flooding

When raising roadway elevation, an ADT (average daily traffic) of 2,000 or more vehicles is recommended as a criterion for raising a roadway elevation.

Chapter 7

# *Considering Road Damage Prevention at the Planning/Designing Stage*

# Chapter 7 Considering Road Damage Prevention at the Planning/Designing Stage

In Thailand, damage sustained by roads at the time of a natural disaster is due mostly to man-made conditions and not to natural conditions. That is to say, if a road is carefully designed for disasters, much damage to the road can be avoided. For instance, weathered rock is stable as long as it is under the cover of top soil. However, once weathered rock is exposed to the air by construction work, it becomes friable and erodible without any proper surface treatment.

Nowadays, the highway network in Thailand is well developed. In the next era, the quality of roads shall be emphasized more than their quantity. In this context, a future road should be designed to be less prone to damage.

## 7.1 Route Selection

In planning a new road, its route should be carefully determined in order to decrease road damage potential and adverse environmental impacts. The main considerations in deciding a route are as follows:

1. To avoid a disaster-prone area

The following areas shall be avoided:

- An area prone to landslide and having a fractured geography
- An area prone to damage by debris/mud flows
- An area prone to flooding

2. To decrease adverse environmental impacts caused by road construction

From the standpoint of conserving the socioeconomic environment, damage to private property, such as cultivated land and residences, shall be reduced as much as possible.

Regarding the natural environment, the following shall be avoided as much as possible:

- A reduction of vegetation
- Significant changes in river flow

- Unsightly landscapes

## 7.2 Road Alignment

In general, if the alignment of a road is in harmony with the topography of the roadside, the road is less prone to damage. In order to coordinate road alignment and topography, the following shall be taken into consideration.

### 7.2.1 Alignment in a mountainous area

1. Route alignment shall be decided so as to **avoid high cut and high fill slopes.** Cut and fill slopes with a steeper gradient than that of the natural ground surface tend to result in the occurrence of landslides due to slope instability.

Moreover, the higher a slope is the easier it will erode. Thus, work to prevent erosion becomes very costly. In some cases, structures to protect a slope result in an unsightly landscape.

2. To decrease the height of either a cut slope or fill slope, the cut slope or fill slope shall be changed to **a cut and fill slope** (see Fig. 7.2.1).

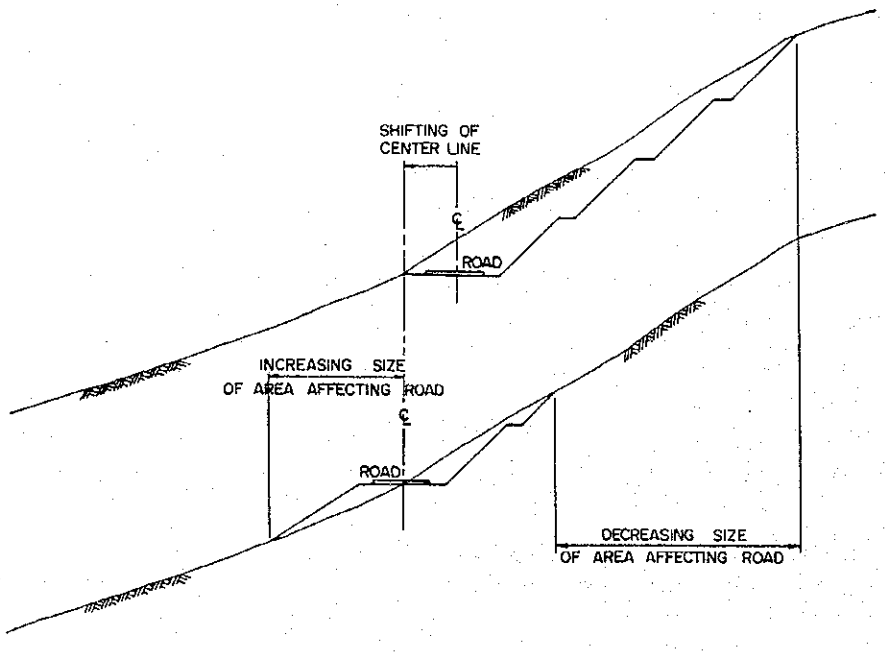



Fig. 7.2.1 From a Cut Slope to a Cut and Fill Slope

3. In order to avoid an alignment with high cut and high fill slopes, which result from the alignment crossing valleys and ravines, **trestles, viaducts and bridges shall be applied**(see Fig. 7.2.2(1)). These structures are also applicable for moderating road alignment in other parts of a mountainous area (see Fig. 7.2.2(2)).

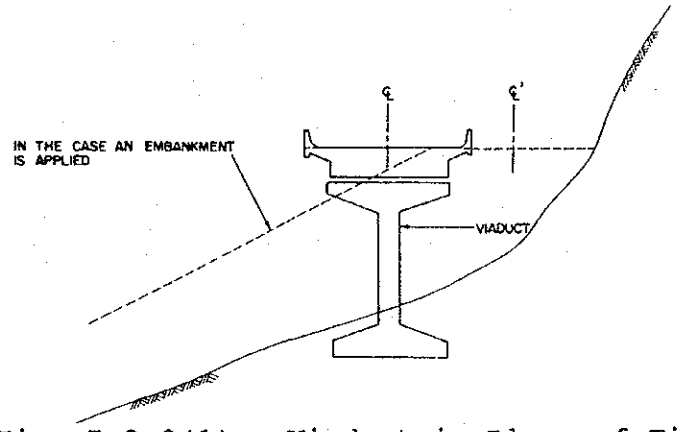



Fig. 7.2.2(1) Viaduct in Place of Fill Slope

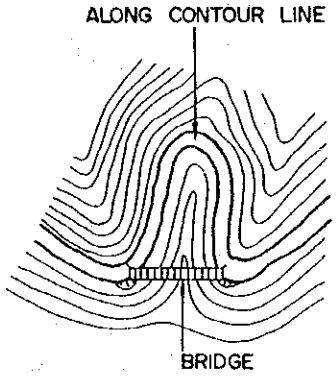



Fig. 7.2.2(2) Better Alignment by Bridge

4. **A tunnel** can also be one of choices to moderate road alignment in a mountainous area(see Fig. 7.2.3).

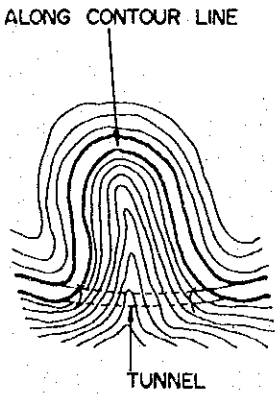



Fig. 7.2.3 Better Alignment by Tunnel

7.2.2 Alignment in a flood plain

1. The elevation of an embankment road in a flood plain shall be **higher than the past flood level by 50 cm.**

2. At a bridge crossing, **the clearance between the bottom of a girder and the high water level shall be more than 60 cm.**

3. At a point where a bridge crosses a river, **an intersecting angle larger than 60 degrees** is recommended.

In the case where the angle is more acute than 60 degrees, the length of the bridge shall be long enough to accommodate the total width of the river (see Fig. 7.2.4).

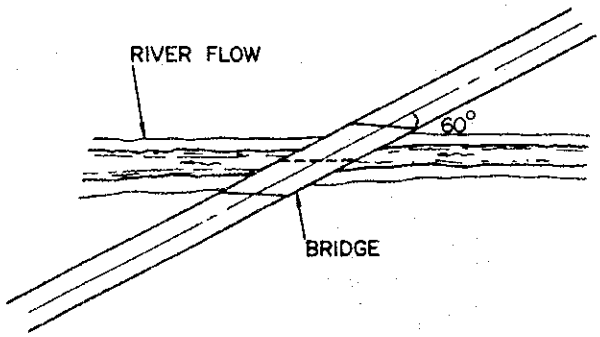



Fig. 7.2.4 Adequate River Crossing

A river shall not be realigned in the vicinity of the bridge in order to have a more moderate crossing angle (see Fig.7.2.5).

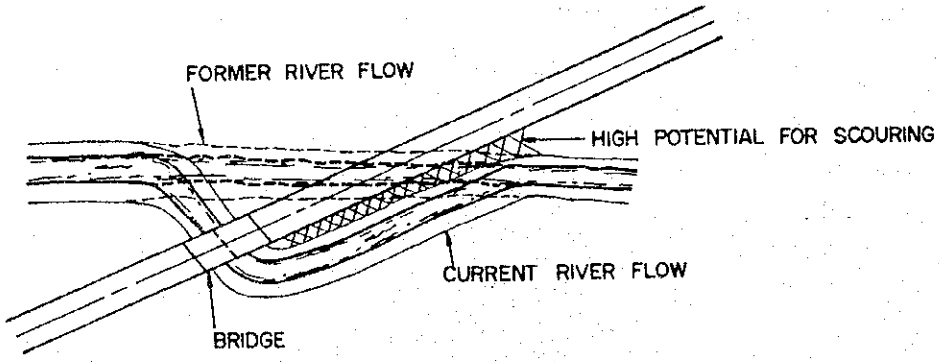



Fig. 7.2.5 Inadequate River Crossing

Road alignment can be modified in the vicinity of a bridge crossing to satisfy the above-mentioned conditions (see Fig. 7.2.6).

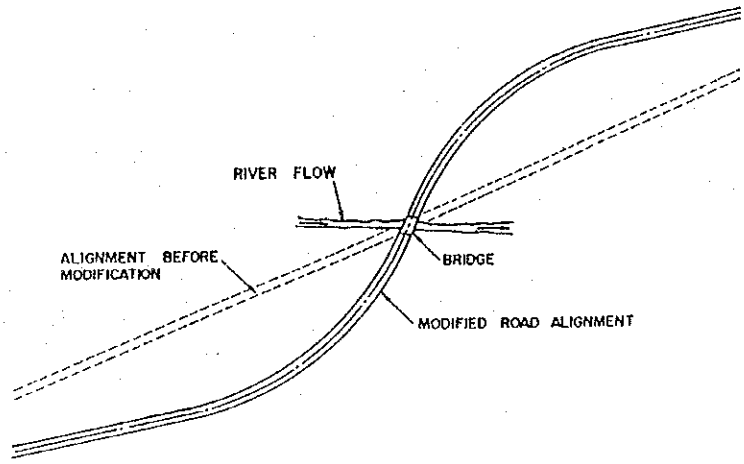



Fig. 7.2.6 Modification of Road Alignment

## 7.3 Design Considerations in Road Damage Prevention

1. Cut slopes and fill slopes

In order to decrease damage to slopes, the height of a cut slope and fill slope shall be limited. That is , **it is advised that the height of a cut slope with berms be less than 15 m.** On the other hand, it is advisable that **the height of a fill slope with berms be less than 20 m.**

To decrease the height of a slope, structural support at the slope toe is recommended as illustrated in Fig. 7.2.7.

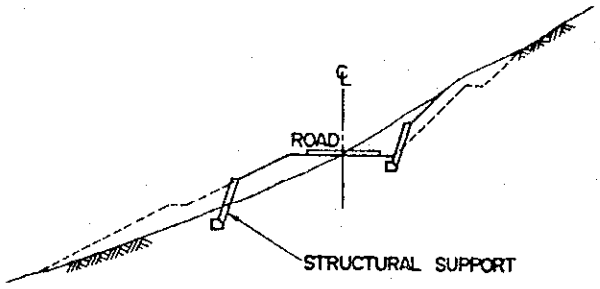



Fig. 7.2.7 Structural Support for Slope

Regarding slope protection, sufficient damage prevention measures have not been taken for existing road. That is, slope surfaces have been mostly exposed to runoff water without any countermeasures, due maybe to budgetary restraints.

For future roads, appropriate damage prevention measures shall be implemented in a timely manner to keep the roads in good condition. Cribwork with vegetation and seed spraying are the most recommendable measures.

2. Road embankments

In Thailand, a high embankment is commonly used even in a mountainous area and is prone to damage by natural disasters. Damage is mainly caused by a lack of proper drainage facilities and insufficient slope protection. Common types of damage are as follows:

- Localized landslide on a slope
- Slope erosion
- Wash out of a slope
- Complete failure of embankment by being washed out

Some types of damage have occurred repeatedly at the same place. For future roads, some of the high road embankments will be replaced by such structures as a trestle, viaduct or bridge.

3. Roads in a flood plain

Most damage to road embankments in a flood plain has been caused by poor road alignment, as described in 7.2. Some of the most common causes of damage are as listed below:

- Lack of embankment height
- Inadequate river crossing
- Inadequate waterway opening
- Lack of clearance at bridge section

Past experience has shown that floating debris blocked by piers and girders result in serious damage to a bridge. For this reason, the span length of a bridge shall be longer than the typical Thai length of 10 m. In addition, the clearance between the bottom of a girder and the high water level shall be sufficient to permit debris to flow freely by.

As for road embankments, they are generally lacking in drainage facilities, either in terms of capacity or spacing. These facilities shall be fully equipped based on discharge calculations. In addition, it is recognized that even if discharge capacity is sufficient, damage can still occur if the spacing of drainage facilities is not appropriate.

*PART 2*

# *DAMAGED ROAD RESTORATION MANUAL*

## PART 2 DAMAGED ROAD RESTORATION MANUAL

This manual describes restoration of damaged road from the detection of damage to the restoration of the damage. The main procedure, starting from the detection of damage and finishing with repair work, is shown with the name of the office or party responsible for the execution of each work step in Fig. P2.

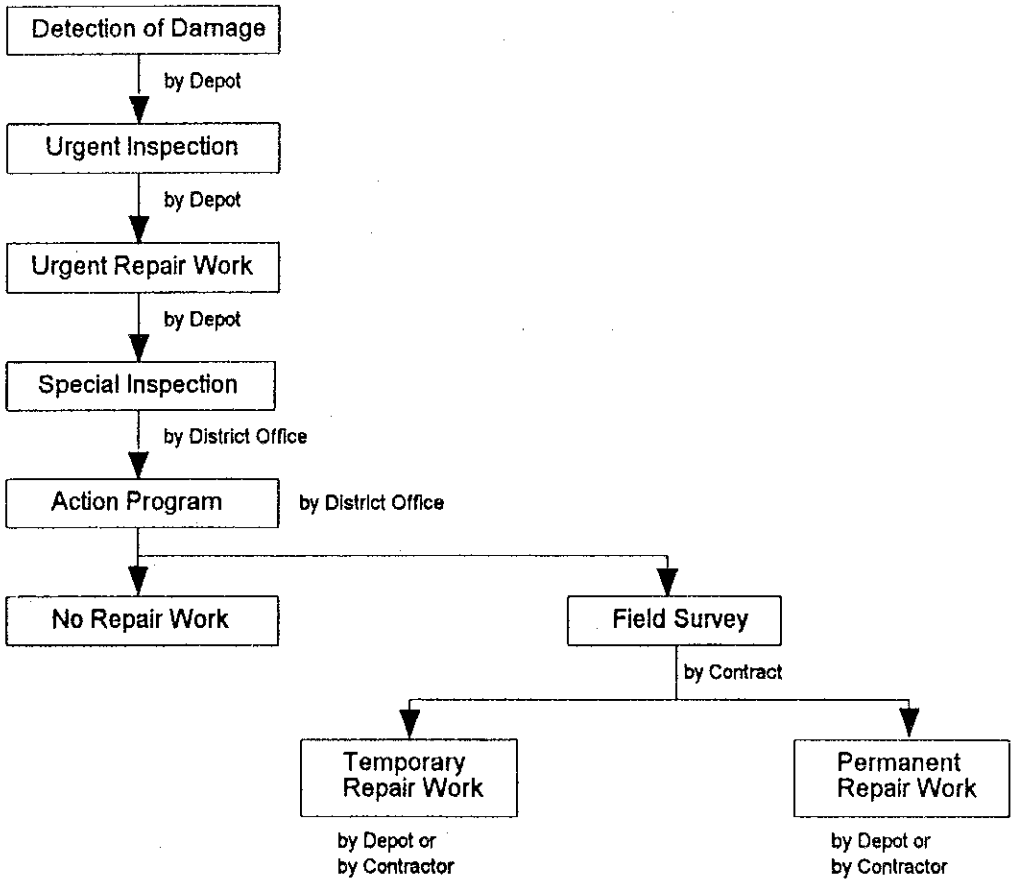



Fig.P2 General Flow of Damaged Road Restoration

At the time of repair work, especially for urgent repair work, material and equipment for the work shall be procured rapidly and smoothly. For this reason, a procurement and arrangement system for material/equipment is recommended in Chapter 10.

Chapter 8

# *Field Inspection and Survey for Damage Spots*

## Chapter 8 Field Inspection and Survey for Damaged Spots

### 8.1 Field Inspection

A field inspection for a damaged spot consists of two types of inspection, namely, an urgent inspection and a special inspection. The objectives and timing of each inspection are outlined in the flow chart of Fig.8.1.1.

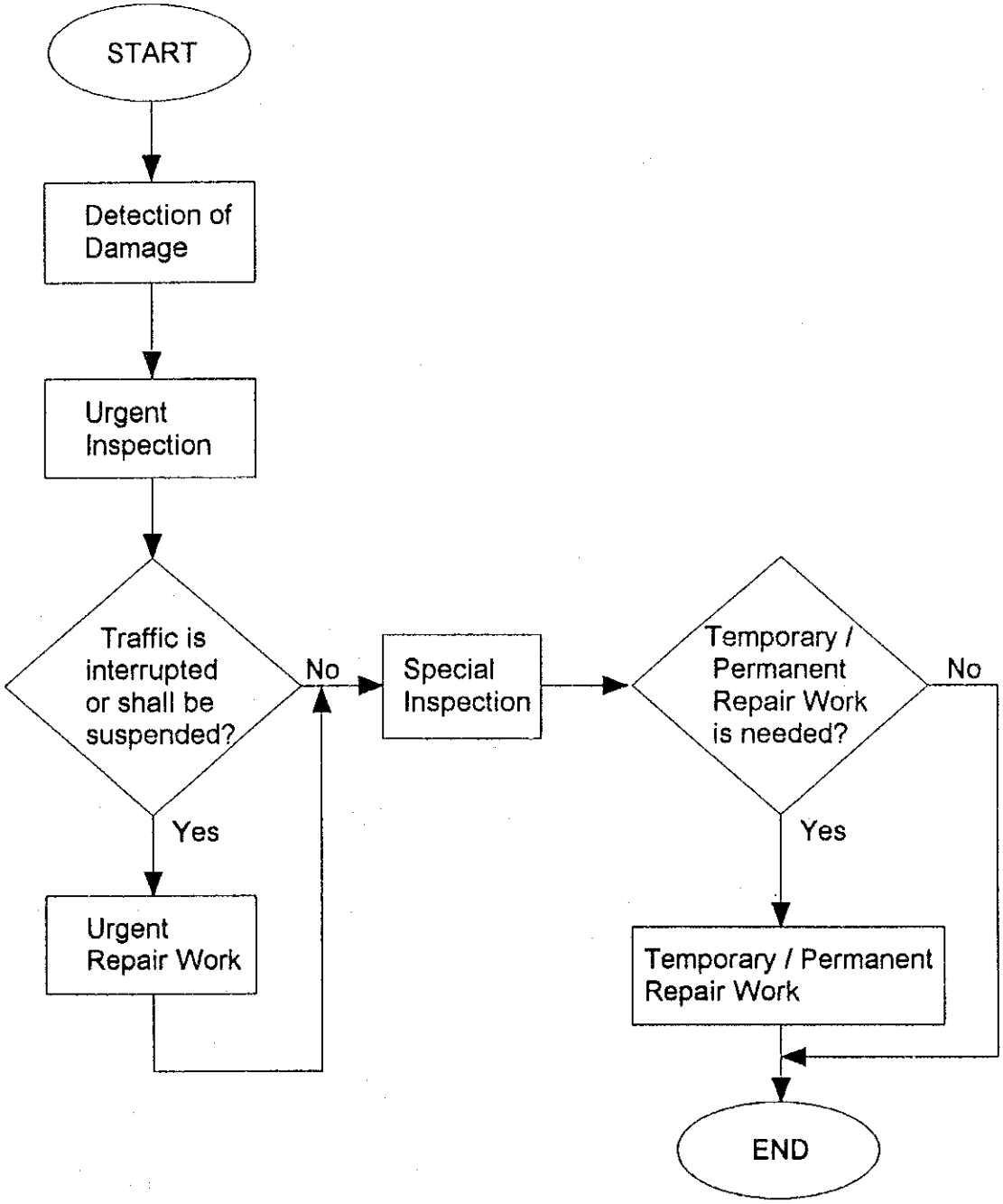



Fig.8.1.1 Relationship between Field Inspection and Repair Work

## 8.1.1 Urgent Inspection

### 1. Objective

When the flow of traffic is interrupted by road damage, the information regarding the situation of the damaged spot shall be collected to make an action program for urgent repair work.

When the occurrence of damage at a spot is anticipated, though the damage has yet to be sustained, information on the spot shall be collected to make an action program for the next step.

### 2. The time for inspection

A road prone to being damaged by rain, as judged from past records and experience in the relevant region, shall be continuously inspected during heavy rains.

When the flow of traffic is interrupted at a section of roadway, the damaged spot shall be urgently inspected in detail.

### 3. Staff in charge of inspection

The inspection shall be carried out by depot staff who are familiar with the road conditions in the relevant region.

### 4. Inspection method

Inspections shall be carried out using the urgent inspection sheet shown in Table 8.1.1. When a more detailed explanation of damage is required that can not be fully described by the inspection sheet, another sheet shall be used to make sketches to assist in the formulation of an action program.

Table 8.1.1 **Urgent Inspection Sheet**

Date of Damage: / /25 , Date of Inspection: / /25 , Name of Inspector:

| District Office | Depot | Route No. | Control Section | Chainage: | Name of Place |
|---|---|---|---|---|---|
| | | | | | |

| | |
|---|---|
| Continuous heavy rain: ..... days<br>Intermittent shower: ..... days | Lanes of traffic interrupted:<br>( ) 2 , ( ) 1 , ( ) none<br>Fear of traffic interruption:<br>( ) very high, ( ) high, ( ) some extent, ( ) low |

| Type of Damage | Status of damage |
|---|---|
| Cut Slope Erosion | Water flow on slope: ( ) channel flow<br>( ) sheet flow<br>( ) from slope to toe ditch<br>( ) from slope to carriageway<br>( ) .....<br>Erosion debris: ( ) in toe ditch<br>( ) on shoulder<br>( ) on carriageway<br>( ) .....<br>Affected road length: ..... m<br>Removal of erosion debris: ( ) manpower, ( ) machine, ( ) .....<br>Other: |
| Rockfall | Rockfall: ( ) in toe ditch, ( ) on shoulder, ( ) on carriageway, ( ) .....<br>Number of fallen rocks: ..... (approximately)<br>Size of rock: D = ..... m (max.)<br>Affected road length: ..... m<br>Other: |
| Landslide | Type of slide debris: ( ) soil, ( ) soil + boulders, ( ) rock, ( ) .....<br>Affected road length: ..... m<br>Removal of debris: ( ) manpower, ( ) machine, ( ) .....<br>Volume of debris to be removed: ..... cubic meter(s)<br>Other: |
| Bridge (abutment, pier and approach road) | Clearance: ..... m<br>Damage (occurred or occurring): ( ) scouring of abutment backfill<br>( ) scouring of approach road<br>( ) damming up of floating timber<br>( ) .....<br>Bridge length damaged: ..... m<br>Other: |
| Embankment | Washout of shoulder: L = ..... m<br>Scouring of embankment slope: A = ..... m²<br>Scouring of embankment toe: L = ..... m<br>Scouring of culvert inlet/outlet: A = ..... m²<br>Refilling work: ( ) earthfill ..... cubic meter(s)<br>( ) sandbag .....<br>( ) gabion .....<br>Other: |
| Road Flooding | Affected road length: ..... m<br>Water level above road surface: ..... cm (max.), ..... cm (average)<br>Sandbag: ( ) applicable, ( ) not applicable .....<br>Pumping out: ( ) applicable, ( ) not applicable<br>Other: |

* Use only one sheet for one spot.
* Make a check in the relevant parentheses and fill in the required information on the dotted lines.
* Damage shall be sketched on another sheet.

## 8.1.2 Special Inspection

### 1. Objective

The objective of a special inspection is to collect information on two types of damaged spots in order to make an action program for temporary/permanent repair work. One type of spot has received urgent repair work, while the other type of spot has received no urgent repair work but has sustained minor damage.

### 2. The time for inspection

Special inspections shall be carried out at least once a year at the beginning of the dry season.

### 3. Staff in charge of inspection

For damage that occurs regularly in a region, inspections shall be carried out by depot staff. However, for either uncommon or large damage, depot staff shall be accompanied by a district engineer or an engineer from the head office.

### 4. Inspection method

Inspections shall be carried out using the special inspection sheets shown in Table 8.1.2 - Table 8.1.6. There are five types of special inspection sheets as shown below:

| | |
|---|---|
| For slope erosion ..... | Table 8.1.2 |
| For rockfalls ..... | Table 8.1.3 |
| For landslide ..... | Table 8.1.4 |
| For the collapsing of bridges ..... | Table 8.1.5 |
| For the collapsing of roads and flooding .... | Table 8.1.6 |

Table 8.1.2

## Special Inspection Sheet

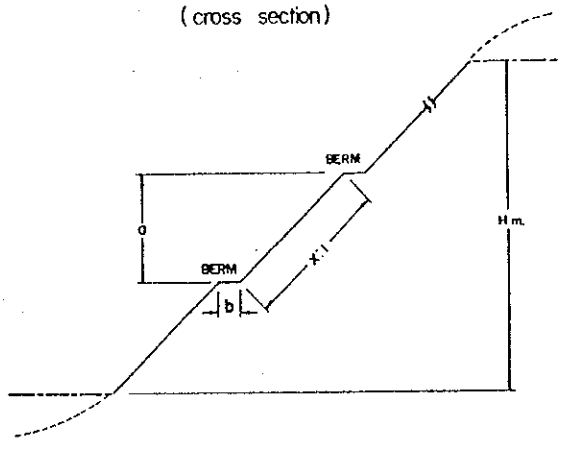
### (Slope Erosion)



Date of Damage: / /25

| | | | | |
|---|---|---|---|---|
| Road: | Chainage: | Date of Inspection: / /25 | Inspector: | |
| Road Type | (1) Class: | (2) Roadway Width: m | (3) Pavement Type: | (4) Pavement Width: m |
| Type of Slope | (1) Natural Slope | (2) Cut Slope | (3) Fill Slope | (4) Embankment |
| Height of Slope: H = ..... m<br>Slope Gradient: X : 1 Refer to Figure → | ..... : 1 | | | |
| Berm (1) None | (2) Present Height: a = m<br>Width: b = m<br>No. of Steps: | | | |
| Surface Protection | (1) None | (2) Type: | | |
| Slope Support | (1) None | (2) Type: | | |
| Surface Drainage | (1) None | (2) Type: | | |
| Affected Road Length: ..... m | | | | |
| Affected Area: ..... m x ..... m | | | | |
| Erosion Debris on Road Surface | (1) None (2) Present: .....<br>(1) None (2) Present: ..... | | | |
| Type of Erosion | (1) Sheet<br>(2) Rill<br>(3) Gully: ( ) Spacing ..... m<br>( ) Width ..... m<br>( ) Depth ..... m<br>(4) ..... | | | |
| Geomorphology | General Area | (1) Flat | (2) Undulating | (3) Hilly (4) Mountainous |
| | Road Site | (1) Crest | (2) Side of Slope | (3) Foot of Slope (4) Valley Floor |
| Weathering | (1) Much | (2) Little | (3) No | |
| Soil at Site | Dominant Grain Size | (1) Boulder | (2) Gravel (3) Sand (4) Silt (5) Clay | |
| | Moisture Content | (1) Wet | (2) Moist | (3) Dry |
| | Relative Density | (1) Dense | (2) Loose | |
| | Stratification | (1) Yes | (2) No | Thickness: m |
| Water Condition | Surface Water | (1) Sheet Flow | (2) Channel Flow | |
| | Groundwater Seepage | (1) None | (2) Present: | m above foot of slope |
| Meteorology | Annual Average Rainfall for Area | | | mm/year |

SLOPE / EMBANKMENT
(cross section)



# Special Inspection Sheet
## (Slope Erosion)



| | | |
|---|---|---|
| Engineering Appraisal | Scale of Erosion | (1) Small (2) Medium (3) Large (4) Very Large |
| | Cause(s) of Erosion | |
| | Period Traffic Interrupted | (1) < 1 day (2) 1 - 3 days (3) > 3 days ( )days |
| | Detour Road | (1) Available ( Rt. No.: ..... ) (2) None |
| | Consequences of Failure: (1) Minor (2) Moderate (3) Severe | |
| | Probability of Further Failure: (1) Low (2) Medium (3) High | |
| | Short Term Proposals: | |
| | Long Term Proposals: | |

| Photographs | Sketch |
|---|---|
| | |

Table 8.1.3

## Special Inspection Sheet

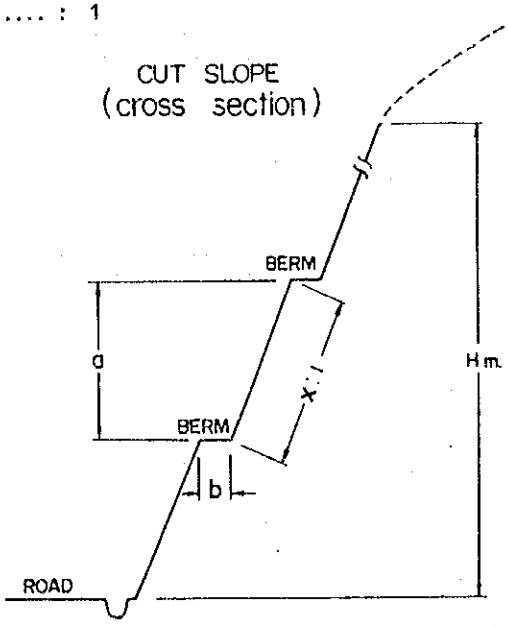
## (Rockfalls)



Date of Rockfall: / /25

| | | | |
|---|---|---|---|
| Road: | Chainage: | Date of Inspection: / /25 | Inspector: |
| Road Type | (1) Class: | (2) Roadway Width: m | (3) Pavement Type: (4) Pavement Width: m |
| Feature Type | (1) Natural Slope (2) Cut Slope (3) ..... | | |

| | | | |
|---|---|---|---|
| Height of Slope: H = ..... m<br>Slope Gradient: X : 1 Refer to Figure → | | | ..... : 1 |
| Berm | (1) None | (2) Present Height: a = m<br>Width: b = m<br>No. of Steps: | |
| Prevention Net | (1) None | (2) Area: | |
| Prevention Fence | (1) None | (2) Length: | |
| Prevention Barrier | (1) None | (2) Length:<br>Height: | |
| Surface Drainage | (1) None | (2) Type: | |
| Affected Road Length: m | | | |
| Height of Rockfall: m | | | |
| Rockfall | (1) in toe ditch (2) on shoulder<br>(3) on carriageway (4) ..... | | |
| | Volume of Fallen Rock: cubic m<br>Size of Rock (max.): m | | |




| | | | |
|---|---|---|---|
| Geomorphology | General Area | (1) Undulating (2) Hilly (3) Mountainous | |
| | Road Site | (1) Crest (2) Side of Slope (3) Foot of Slope (4) Valley Floor | |
| Geological Condition of Slope | Rock Type | (1) Hard Rock (2) Soft Rock | |
| | Weathering | (1) Much (2) Little (3) No | |
| | (1) Boulder in Soil Matrix (2) Debris or Talus (3) Rock with Cracks: ( ) Sparse ( ) Regular ( ) Developed | | |
| Soil at Site | Dominant Grain Size | (1) Boulder (2) Gravel (3) Sand (4) Silt (5) Clay | |
| | Moisture Content | (1) Wet (2) Moist (3) Dry | |
| | Relative Density | (1) Dense (2) Loose | |
| | Stratification | (1) Yes (2) No | Thickness: m |
| Water Condition | Surface Water | (1) Sheet Flow (2) Channel Flow | |
| | Groundwater Seepage | (1) None (2) Present: m above foot of slope | |
| Meteorology | Annual Average Rainfall for Area | mm/year | |

## Special Inspection Sheet
(Rockfalls)



| | | | |
|---|---|---|---|
| Engineering Appraisal | Scale of Rockfall | (1) Small (2) Medium (3) Large (4) Very Large | |
| | Cause(s) of Rockfall | | |
| | Period of Traffic Interrupted | (1) < 1 day (2) 1 - 3 days (3) > 3 days ( )days | |
| | Detour Road | (1) Available ( Rt. No.: ..... ) (2) None | |
| | Consequences of Rockfall: (1) Minor (2) Moderate (3) Severe | | |
| | Probability of Further Rockfalls: (1) Low (2) Medium (3) High | | |
| | Short Term Proposals: | | |
| | Long Term Proposals: | | |

| Photographs | Sketch |
|---|---|
| | |

Table 8.1.4

## Special Inspection Sheet

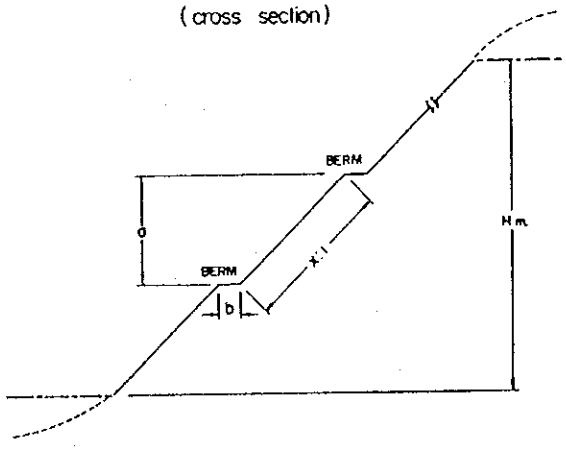
### (Landslide)



Time/ Date of Landslide: /25

| | | | | | |
|---|---|---|---|---|---|
| Road: | | Chainage: | Date of Inspection: / /25 | Inspector: | |
| Road Type | (1) Class: | (2) Roadway Width: m | (3) Pavement Type: | (4) Pavement Width: m | |
| Type of Slope | (1) Natural Slope | (2) Cut Slope | (3) Fill Slope | (4) Embankment | |
| Height of Slope: H = ..... m<br>Slope Gradient : X : 1 Refer to Figure → | ..... : 1 | | | | |
| Berm | (1) None | (2) Present Height: a = m<br>Width: b = m<br>No. of Steps: | | | |
| Surface Protection | (1) None | (2) Type: | | | |
| Slope Support | (1) None | (2) Type: | | | |
| Surface Drainage | (1) None | (2) Type: | | | |
| Sub-surface Drainage | (1) None | (2) Type: | | | |
| Affected Road Length: m | | | | | |
| Affected Area: ..... m X ..... m | | | | | |
| Landslide | Material of Slide Debris | (1) Soil<br>(2) Soil + Boulder<br>(3) Rock | | | |
| | Continuity of Slide Movement | (1) Unnoticed<br>(2) Existent | | | |

SLOPE / EMBANKMENT
(cross section)




| | | | |
|---|---|---|---|
| Geomorphology | General Area | (1) Undulating (2) Hilly (3) Mountainous | |
| | Road Site | (1) Crest (2) Side of Slope (3) Foot of Slope (4) Valley Floor | |
| Geological Conditions at Site | Rock Type | (1) Hard Rock (2) Soft Rock | |
| | Weathering | (1) Much (2) Little (3) No | |
| | Condition of Cracking | (1) Sparse (2) Regular (3) Developed | |
| Soil at Site | Dominant Grain Size | (1) Boulder (2) Gravel (3) Sand (4) Silt (5) Clay | |
| | Moisture Content | (1) Wet (2) Moist (3) Dry | |
| | Relative Density | (1) Dense (2) Loose | |
| | Stratification | (1) Yes (2) No | Thickness: m |
| Water Condition | Surface Water | (1) Sheet Flow (2) Channel Flow | |
| | Groundwater Seepage | (1) None (2) Present: | m above foot of slope |
| Meteorology | Annual Average Rainfall for Area | | mm/year |

# Special Inspection Sheet
## (Landslide)



| | | | |
|---|---|---|---|
| Engineering Appraisal | Landslide Scale | (1) Small (2) Medium (3) Large (4) Very Large | |
| | Cause(s) of Landslide | | |
| | Period Traffic Interrupted | (1) < 1 day (2) 1 - 3 days (3) > 3 Days ( )days | |
| | Detour Road | (1) Available ( Rt. No.: ..... ) (2) None | |
| | Consequences of Landslide: (1) Minor (2) Moderate (3) Severe | | |
| | Probability of Further Landslides: (1) Low (2) Medium (3) High | | |
| | Short Term Proposals: | | |
| | Long Term Proposals: | | |

| Photographs | Sketch |
|---|---|
| | |

Table 8.1.5

## Special Inspection Sheet

### (Bridge Collapsing)

Date of Damage: / /25

| | | | | |
|---|---|---|---|---|
| Road: | | Chainage: | Date of Inspection: / /25 | Inspector: |
| Name of Bridge: | | | Type of Bridge | (1) Permanent (2) Temporary |
| General Bridge Structure | | (1) Class: | (2) Total Width: m | (3) No. of Lanes: Lanes |
| Detailed Bridge Structure | Surface Type | | (1) Concrete (2) AC ( 3) PM (4) Gravel (4) Earth | |
| | Bridge Length (Span Length) | | m ( m) | Clearance of Bridge: ..... |
| | Type of Superstructure | | | |
| | Type of Abutment | | | |
| | Type of Pier | | | |
| | Type of Foundation | | | |
| Evidence of Damage | Superstructure | | | |
| | Substructure | Abutment | (1) Scouring (2) Tilting (3) Settlement (4) Sliding (5) ..... | |
| | | Pier | (1) Scouring (2) Tilting (3) Settlement (4) Sliding (5) ..... | |
| | | Others | | |
| | Damage to Approach Road | | (1) None (2) Present: ..... | |
| | Rainfall Intensity (basin) | | | |
| | Period Traffic Interrupted | | (1) < 1 day (2) 1 - 3 days (3) > 3 days ( )days | |
| Existing Conditions | General Area | | (1) Flat (2) Undulating (3) Hilly (4) Mountainous | |
| | Riverbed | (1) Boulder (2) Gravel (3) Sand (4) Mud | | Gradient of River: ..... |
| | Detour Road | | (1) Available (Rt. No.: ..... ) (2) None | |
| Engineering Appraisal | Impact on Traffic | | (1) Low (2) Medium (3) High | |
| | Cause(s) of Damage: | | | |
| | Countermeasure(s): | | | |

| Photographs | Sketch |
|---|---|
| | |

Table 8.1.6 **Special Inspection Sheet**

## (Road Collapsing & Flooding)

Date of Damage: / /25

| | | | | |
|---|---|---|---|---|
| Road: | | Chainage: | Date of Inspection: / /25 | Inspector: |
| Road Type | | (1) Class: | (2) Roadway Width: m | (3) Pavement Width: m |
| Road Structure | Surface Type | (1) Concrete (2) AC ( 3) PM (4) Gravel (4) Earth | | |
| | Terrain | (1) Flat (2) Rolling (3) Mountainous | | |
| | Cross section | (1) Embankment (2) Fill (2) Cut (3) Cut/Fill (4) Flat | | |
| Evidence of Damage | Type of Damage | (1) Culvert (Type: ..... Drainability: ..... )<br>(2) Washout/Scouring of Embankment<br>(3) Scouring of Shoulder<br>(4) Flooding (water level above road surface: .... cm <max.><br>: .... cm <average>)<br>(5) ..... | | |
| | Length of Damage | | | |
| | Period Traffic Interrupted | (1) < 1 day (2) 1 - 3 days (3) > 3 days ( )days | | |
| | Rainfall Intensity (mm/day) | (1) < 100 (2) 100-200 (3) 200-300 (4) > 300 | | |
| Existing Condition | Road Surface Condition | (1) Fair (2) Bad (3) Impassable | | |
| | Drainage Facilities | (1) Existing ( ) (2) None | | |
| | Surface Protection of Slope | (1) None (2) Present: ..... | | |
| | Detour Road | (1) Available (Rt. No.: ..... ) (2) None | | |
| Engineering Appraisal | Impact on Traffic | (1) Low (2) Medium (3) High | | |
| | Cause(s) of Damage | (1) Lack of Drainage Facilities (2) Flood<br>(3) Concentration of Surface Water (4) River Stream<br>(5) ..... | | |
| | Countermeasure(s): | | | |

| Photographs | Sketch |
|---|---|
| | |

## 8.2 Survey

A survey shall be carried out at damaged spot where temporary/permanent repair work is required. The findings of the survey shall be utilized in selecting a restoration measure and in designing the temporary/permanent repair work.

The survey basically consists of four types of survey: a soil and geotechnical survey, a topographic survey, a hydrological survey and an environmental survey.

In principle, the survey shall be executed by private companies on contract under the control of a district office.

### 8.2.1 Soil and Geotechnical Survey

Survey items vary with the types of damage. For the types of damage shown in Table 8.2.1, appropriate survey items are recommended. As a guide to the selection of a survey method, the relationship between survey items and survey methods are tabulated in Table 8.2.2.

Table 8.2.1 Soil Survey Items

| Type of Damage | Survey Method | Findings |
|---|---|---|
| Cut slope erosion | Boring | - Properties of surface soil<br>- Weathering of surface rock |
| | Soil test | - Strength of soil<br>- Strength of weathered rock<br>- Hardness of surface soil<br>- Fertility of surface soil |
| Rockfalls | Boring | - Properties of rock<br>- Stratification structure<br>- Cracks, joints of rock |
| | Rock test | - Properties of rock<br>- Cracks, joints of rock |
| | | - Strength of rock |
| Landslide | Boring | - Properties of soil<br>- Stratification structure<br>- Groundwater level<br>- Location of sliding plane<br>- Strength of soil |
| | Soil test | - Strength of soil |
| | Movement survey | - Location of sliding plane<br>- Direction of movement<br>- Amount of movement |
| Collapsing of bridge | Boring | - Properties of soil<br>- Depth of bearing layer<br>- Bearing capacity |
| | Soil test | - Strength of soil |
| Collapsing of embankment | Boring | - Properties of embankment material |
| | Soil test | - Strength of embankment material |

Table 8.2.2 Application of Geotechnical Survey

| Survey Item \ Survey Method | | Boring | Auger Boring | Test Pit | Sounding | Soil Test | Rock Test | Move-ment Survey |
|---|---|---|---|---|---|---|---|---|
| Soil/Rock Properties | | O | □ | □ | + | O | O | |
| Geological Structure | Stratification Structure, Fault, Fracture Zone, etc. | □ | | | | | | |
| | Crack, Joint | O | | □ | | | □ | |
| | Weathering | O | + | □ | | | + | |
| | Thickness of Top Soil | O | O | O | □ | | | |
| | Unconformity, Discontinuity | O | | □ | □ | | | |
| Strength of Ground | | □ | | □ | □ | O | O | |
| Strength of Embankment Material | | | | | | O | | |
| Properties of Embankment Material | | □ | □ | □ | | O | | |
| Condition of Groundwater Level | | □ | + | □ | | | | |
| Landslide | Location of Sliding Plane | □ | | □ | □ | | | O |
| | Direction and Amount of Movement | | | | | | | O |
| | Prediction of Movement | | | | | | | O |
| Vegetation | Soil Hardness | | | | | □ | | |
| | Soil Material | | | | | O | | |
| | Fertility of Soil | | | | | □ | | |
| | Composition of Soil Grading | | | | | O | | |

Note: O Most Applicable
□ Applicable
+ Supplemental

The outline of each soil and geotechnical survey method is as follows:

1) Boring: The purpose of boring is to collect information on the underground soil/rock of a site by boring a hole into the ground. Then, by the observing and laboratory testing of the soil/rock samples, the physical properties, strata information, etc. of the soil/rock are determined. Information on groundwater level and sliding surfaces in the case of landslides can also obtained by boring.

2) Auger Boring: The main purpose of auger boring is to examine only the properties and conditions of top soil using simple boring methods.

3) Test Pit: A test pit aims to observe soil directly by excavating a pit that can accommodate an investigator.

4) Sounding: The standard penetration test (STP) is usually carried out by sounding.

5) Soil Test: The purpose of a soil test is to obtain information on a soil's engineering properties via laboratory testing. Samples for the test are usually collected by

boring. Information on the applicability of vegetation work can also be determined by soil testing.

6) Rock Test: The engineering properties of rock are examined by laboratory tests using samples collected by boring.

7) Movement Survey: This survey aims to detect the movement of a slope, and provides information on the location of sliding planes, the direction of their movement, etc. A tiltmeter and extensometer are commonly used for these purposes.

### 8.2.2 Topographic Survey

Survey items in accordance with the type of damage are shown in Table 8.2.3.

Table 8.2.3 Topographic Survey Items

| Type of Damage | Survey Method | Survey Items |
|---|---|---|
| Cut slope erosion | Plane table survey | - Entire affected area |
| | Cross-section survey<br>Measurement of size | - Entire affected area<br>- Cavity |
| Rockfalls | Plane table survey | - Entire affected area |
| | Cross-section survey<br>Measurement of size | - Entire affected area<br>- Remaining boulders / rock |
| Landslide | Plane table survey | - Entire affected area |
| | Cross-section survey | - Entire affected area & the gap between scarp and slide debris |
| Collapsing of bridge | Plane table survey | - Bridge and river concerned |
| | Cross-section survey | - Bridge and river concerned |
| | Level survey | - Along river |
| | Measurement of size | - Damaged portion |
| Collapsing of embankment | Plane table survey | - Entire affected area |
| | Cross-section survey<br>Measurement of size | - Entire affected area<br>- Damaged portion |
| Road flooding | Cross-section survey | - Entire affected area |
| | Level survey | - Along road |

### 8.2.3 Hydrological Survey

Applicable survey methods to collect hydrological information on a damaged spot are shown by type of damage in Table 8.2.4.

Table 8.2.4 Hydrological Survey Items

| Type of Damage | Survey Method | Survey Items |
|---|---|---|
| Cut slope erosion | Precipitation survey | - Catch basin concerned |
| | Surface water survey | - Water runoff, seepage |
| Rockfalls | Precipitation survey | - Catch basin concerned |
| | Surface water survey | - Water runoff, seepage |
| Landslide | Precipitation survey | - Catch basin concerned |
| | Boring | - Pore water pressure<br>- Groundwater level<br>- Groundwater distribution |
| | Surface water survey | - Water runoff, spring / seepage water |
| Collapsing of bridge | Precipitation survey | - Catch basin concerned |
| | Riverflow survey | - River concerned |
| | Survey related to bridge clearance | - Around bridge |
| Collapsing of embankment | Precipitation survey | - Catch basin concerned |
| | Survey related to drainag capacity | - Affected area |
| | Riverflow survey | - River concerned |

The outline of each hydrological survey method is described below.

1) Precipitation Survey: Consists of a site survey and data collection. A site survey collects information on past rainfall and flooding from witnesses living nearby a damaged spot. Regarding data collection, statistical data on precipitation in the area shall be collected at the Meteorological Department or Hydrology Division of the Royal Irrigation Department.

2) Surface Water Survey: Collects information on surface water flow and the tracks of surface water flow on site.

3) River flow Survey: Collects data on river flows at the Hydrology Division of the Royal Irrigation Department and analyzes the data (see list below).

- High water level at the time of flooding.
- Velocity of river flow.
- River discharge.
- Condition of riverbed.

### 8.2.4 Environmental Survey

In the course of selecting restoration measures, the following shall be taken in consideration to eliminate adverse environmental impacts directly or indirectly brought about by repair work.

- Alleviation of adverse impacts on residents who earn a living from natural resources.

- Minimization of adverse impacts on human health.

- Minimization of adverse impacts on flora and fauna.

- Alleviation of adverse impacts on residents living adjacent to a spot being repaired.

The general procedure for an environmental survey is illustrated in Fig.8.2.1, and begins with the collection of information on the state of the environment and ends with a decision on a final restoration plan.

1. Collection of information on state of environment

First, the draft of damaged road restoration plan shall be checked to see if it compromises the environmental restraints peculiar to a repair work spot. To grasp these restraints, information on the state of the environment shall be collected considering the following three fields:

- Socioeconomic environment
- Natural environment
- Environmental pollution

Survey items for each field are shown in the survey sheet (see Table 8.2.5).

2. Evaluation of environmental impacts caused by repair work

In the case of a new road project, the execution of an initial evaluation to assess potential of negative environmental impacts is generally recommended. For example, a total of 23 evaluation items for this initial evaluation are recommended in the case of road development study by JICA as shown in Table 8.2.6.

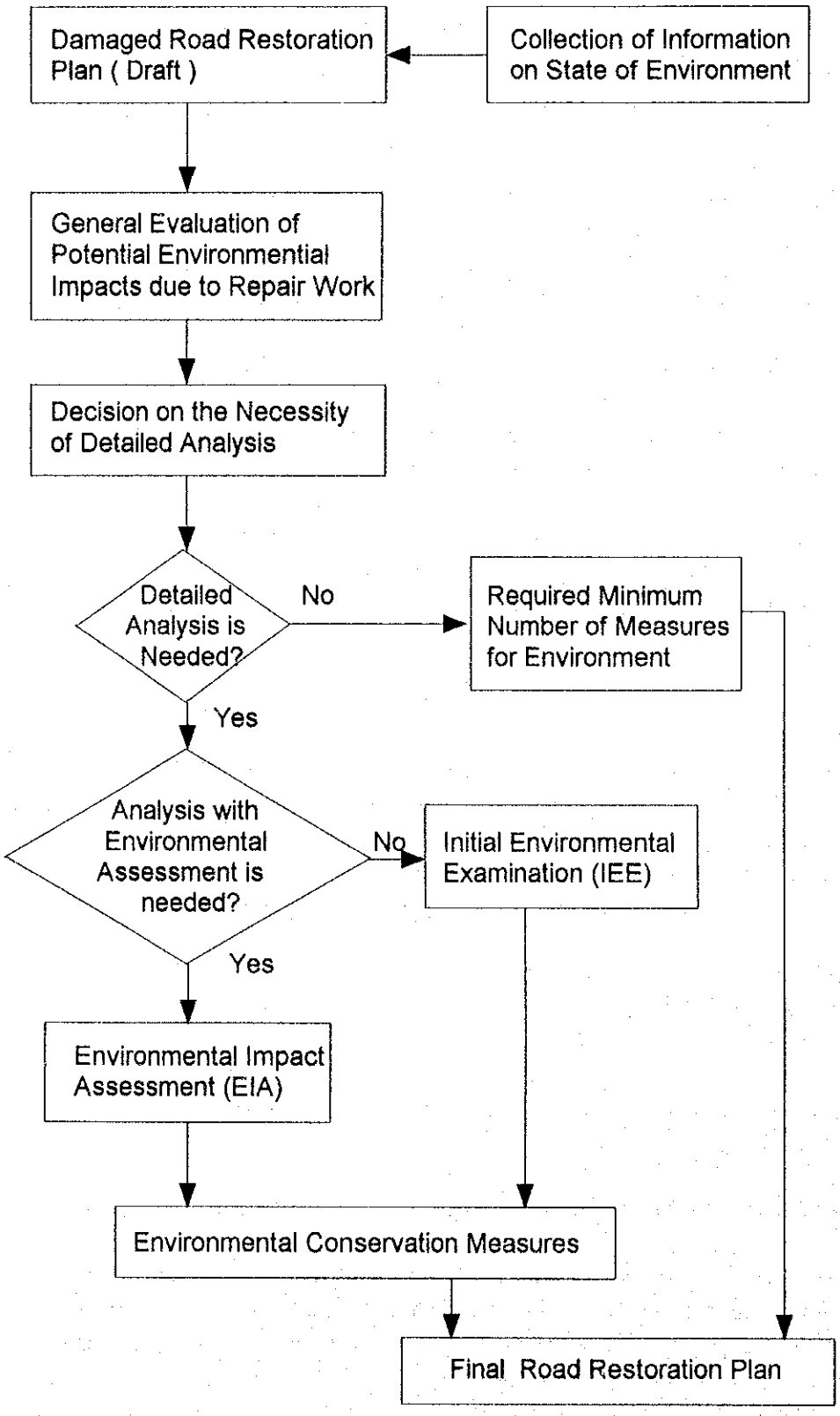



Fig. 8.2.1 Procedure for Environmental Survey

Table 8.2.5 Survey Sheet for Environmental Situation

Route No.:
Section Concerned: from ..... km to ..... km

| Item | | Present Situation |
|---|---|---|
| Socio-economic Environment | Area Residents (Inhabitants /Understanding of Project, etc.) | |
| | Land Use (City/Farm Village/Historic Site /Scenic Area/ Hospital, etc.) | |
| | Economic/Transportation Function (Commercial Area, Farm or Fishery Area/Bus Terminal, etc.) | |
| Natural Environment | Topography, Geology (Steep Slope, Soft Ground, Swamp/Fault, etc.) | |
| | Valuable Flora & Fauna, Territory (Sanctuary, Preservation of Species, etc.) | |
| Environ-mental Pollution | Frequency of Grievances (Highly-concentrated Pollution, etc.) | |
| | On-going Treatment (Institutional Measures, Compensation, etc.) | |
| Miscellane-ous | | |

Table 8.2.6 Initial Evaluation Sheet for Environmental Impacts from a New Road Project

| Evaluation Item | Evaluation during construction | | Evaluation after traffic is opened. | | | Total evaluation |
|---|---|---|---|---|---|---|
| | Changes in Topography, Land Use | Operation of Construction Machines and Vehicles | Changes in Land Use | Movement of Vehicles | Movement of People and Commodities | |
| <Socio-economic Environment> 1. Resettlement | | | | | | |
| 2. Economic Activities | | | | | | |
| 3. Traffic & Public Facilities | | | | | | |
| 4. Split of Communities | | | | | | |
| 5. Cultural Property | | | | | | |
| 6. Water Right, Right of Common | | | | | | |
| 7. Health, Sanitary | | | | | | |
| 8. Waste Materials | | | | | | |
| 9. Hazard (Risk) | | | | | | |
| <Natural Environment> 10. Topography, Geology | | | | | | |
| 11. Soil Erosion | | | | | | |
| 12. Ground Water | | | | | | |
| 13. Hydrological Situation | | | | | | |
| 14. Coastal Zone | | | | | | |
| 15. Flora & Fauna | | | | | | |
| 16. Weather | | | | | | |
| 17. Landscape | | | | | | |
| <Environmental Pollution> 18. Air Pollution | | | | | | |
| 19. Water Pollution | | | | | | |
| 20. Soil Contamination | | | | | | |
| 21. Noise & Vibration | | | | | | |
| 22. Ground Subsidence | | | | | | |
| 23. Offensive Odor | | | | | | |

In the case of repairing an existing road, the evaluation items are more limited than in the case of a new road project, since only the environmental changes caused by repair work are taken up. Therefore of the above-mentioned 23 items, only 8 items are recommended and are listed in Table 8.2.7.

Table 8.2.7 Evaluation Items in the Case of Repair Work

| | During Repair Work | After Completion of Repair Work |
|---|---|---|
| Socioeconomic Environment | - Waste material | - Water rights |
| Natural Environment | - Soil erosion<br>- Groundwater<br>- Hydrological situation | - Hydrological situation<br>- Landscape |
| Environmental Pollution | - Water pollution<br>- Noise & Vibration | |

3. Formulation of road restoration plan

It is necessary to decide whether detailed analysis of environmental impacts is required at the same time of an engineering study.

The necessity of a detailed analysis mainly depends on the scale of the repair work or the repair work method. However, most repair work will not be subjected to a detailed analysis. If the analysis is needed, an initial environmental examination(IEE) or an environmental impact assessment(EIA) shall be carried out. Then, environmental conservation measures based on the results of the detailed analysis shall be established.

In general, a final restoration plan for damaged road shall be formulated considering the evaluation items shown in Table 8.2.7.

Chapter 9

# *Restoration of Damaged Road*

## Chapter 9 Restoration of Damaged Road

In this manual, repair work for road damage is divided into the three categories of urgent repair work, temporary repair work, and permanent repair work, after taking into consideration the issues of time and quality. Below, each type of repair work is defined.

### Urgent Repair Work

Urgent repair work focuses on reopening as soon as possible a road section closed to traffic due to the occurrence of some unforeseen road damage or the occurring damage. In addition, urgent repair work also aims to prevent road crippling damage, which is inevitably occurring given present conditions, by taking appropriate preventive countermeasures. Consequently, emphasis is placed on how quickly the damaged spot is passable for traffic and not on the quality of the repair work itself.

### Temporary Repair Work

If permanent repair work is considered to be an over investment at present, temporary repair work with a lifetime of more than 5 years shall be carried out as a makeshift measure.

Temporary repair work shall be applied in the following cases:

- When a detour route, which does not result in a large increase in traveling time, is available:
- For road sections with a small amount of traffic volume that does not justify the higher repair costs of permanent repair work: and
- When further damage is not anticipated in the near future.

### Permanent Repair Work

Permanent repair work shall be applied in the following two cases:

- When the lifetime of a temporary repair job is about to expire; and
- When the damaged spot is located in an important part of

the road network that will produce adverse socioeconomic consequences if not permanently repaired.

The concept for damaged road restoration is summarized in Fig. P2 (see page P-2) in the form of a general flow chart.

## 9.1 Restoration Measures

Road restoration measures that can be effectively applied to damaged road are summarized by damage type in Table 9.1.1 - 9.1.4 and are accompanied with illustrations.

Table 9.1.1 (1) Type of Restoration Measure in the Case of Slope Damage

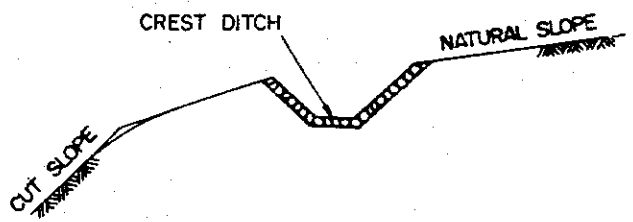
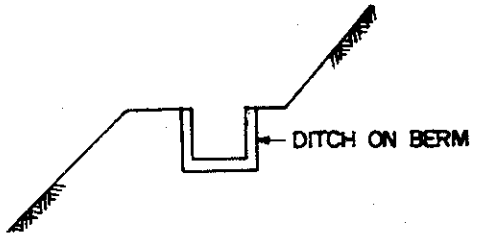
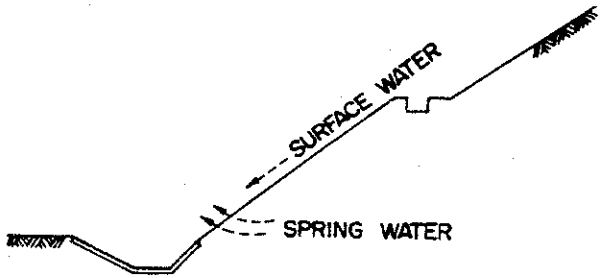
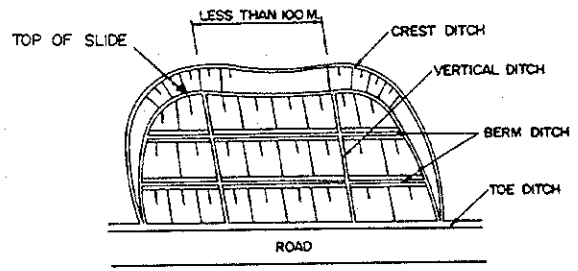
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Surface drainage | Crest ditch | - To prevent the erosion and scouring of a slope surface by collecting runoff water along the top of a cut slope. | - Cut slope.<br>- Weathered rock, soil. |  |
| | Berm ditch | - To prevent the erosion and scouring of a slope surface by collecting surface water in berm. | - Cut slope, fill slope.<br>- Weathered rocks, soil. |  |
| | Toe ditch | - To prevent runoff water from reaching a road's surface. | - Cut slope. |  |
| | Vertical ditch | - To collect and drain surface water on a slope with a vertical ditch to prevent the erosion and scouring of the slope's surface. | - Generally applied on a slope surface.<br>- Cut slope, fill slope. |  |

Table 9.1.1 (2) Type of Restoration Measure in the Case of Slope Damage

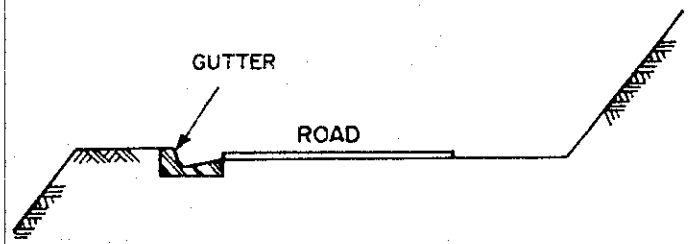
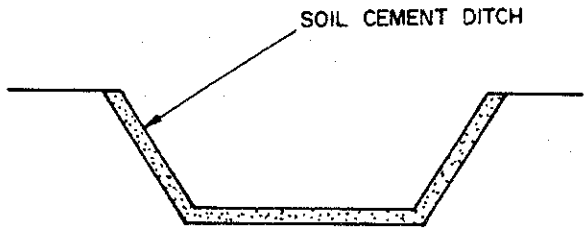
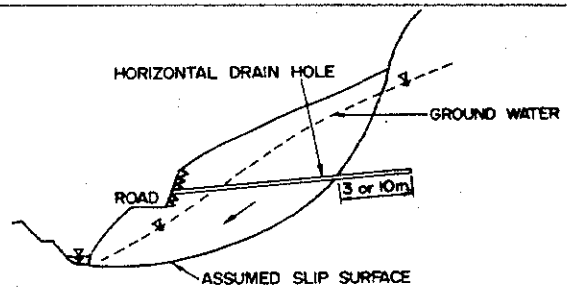
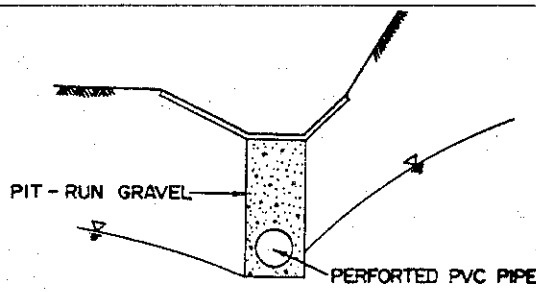
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Surface drainage | Gutters | - To prevent a fill slope or embankment slope from being scoured due to the flow of surface water.<br>- To collect road surface water at the shoulders using a gutter. | - Road shoulder of fill slope side.<br>- Fill section more than 6 m high. |  |
| | Soil cement ditch | - To prevent the erosion and scouring of a slope's surface by collecting runoff water.<br>- Surface of a ditch is reinforced by soil cement. | - Crest, berm, vertical and toe ditches. |  |
| (2) Subsurface drainage | Horizontal drain hole | - To stabilize a landslide-prone slope by draining groundwater. | - Generally applied to a cut or fill slope with high groundwater pressure. |  |
| | Underground drainage with pits and pipes | - To drain shallow groundwater and thus stabilize a slope. | - Usually used in combination with surface drainage.<br>- Generally applied to a slope with much seepage water. |  |

Table 9.1.1 (3) Type of Restoration Measure in the Case of Slope Damage

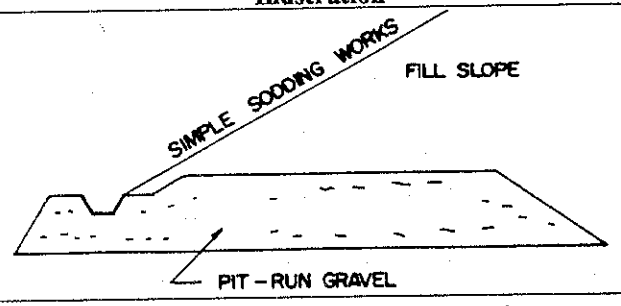
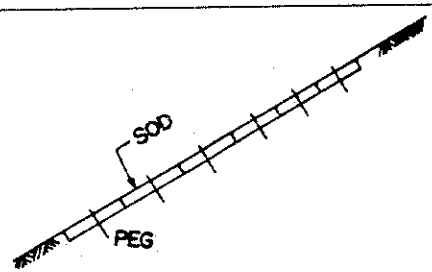
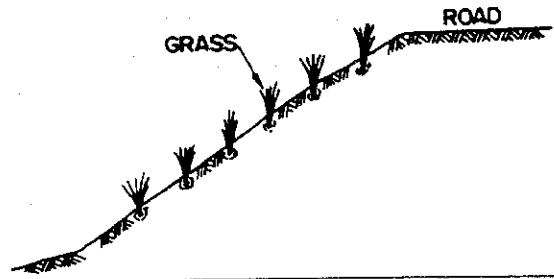
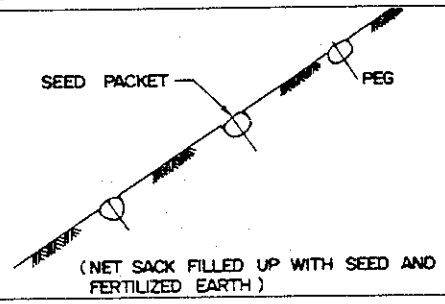
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (2) Subsurface drainage | Drainage with pit-run Gravel | - To drain seepage water and to stabilize a fill. | - Fill with much seepage water. |   |
| (3) Vegetation | Block sodding | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To place sod directly on a slope. | - Cut slope, fill slope.<br>- Soil. |   |
| | Spot sodding | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To plant sod directly on slope. | - Cut slope, fill slope.<br>- Weathered rock, soil. |   |
| | Seed packet work | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To place bags filled with seeds and fertilized soil on a slope. | - Applied to a slope relatively unsuitable to growing grass.<br>- Cut slope.<br>- Weathered rock, soil. |   |

Table 9.1.1 (4) Type of Restoration Measure in the Case of Slope Damage

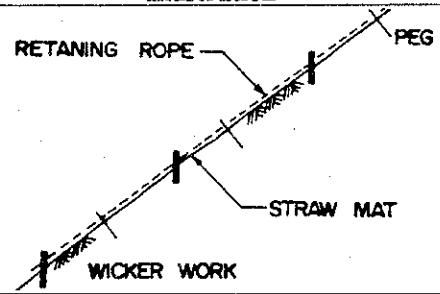
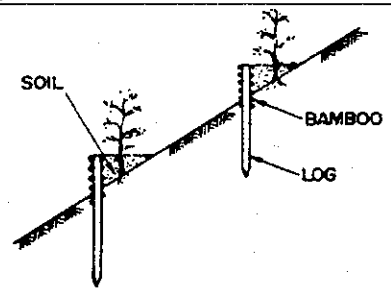
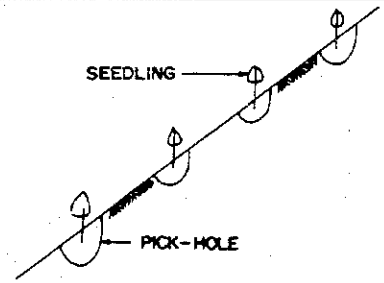
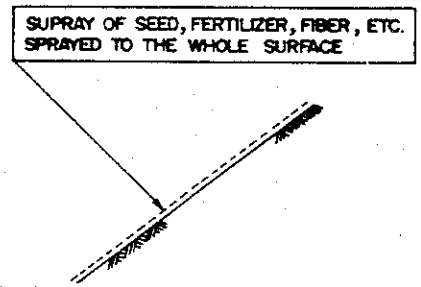
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (3) Vegetation | Erosion control with local material | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To cover seed with a straw mat. | - Cut slope, fill slope.<br>- Soil surface. |  |
| | Wicker work | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. | - Cut slope, fill slope.<br>- Weathered rock, soil. |  |
| | Pick-hole seedling work | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To fill holes on a slope with seeds and fertilized soil. | - Applied to a slope relatively unsuitable for growing grass.<br>- Generally applied to a cut slope.<br>- Weathered reck, soft rock. |  |
| | Seed spraying with pump (seed spraying) | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To spray seeds with a pump. | - Generally applied to the soil surface of a cut or fill slope. |  |

Table 9.1.1 (5) Type of Restoration Measure in the Case of Slope Damage

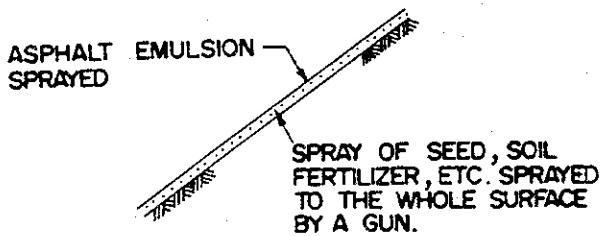
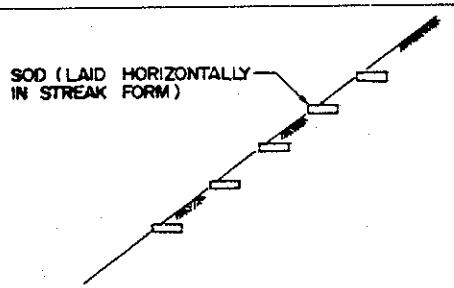
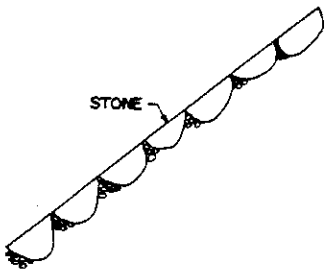
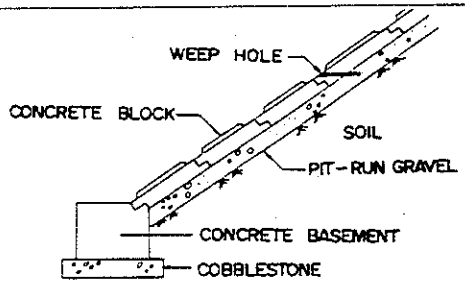
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (3) Vegetation | Seed-mix spraying with a gun (hydroseeding) | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To spray mixed slurry or mud composed of seed, water, fertilizer, soil etc., with a spray gun. | - Mainly applied to the weathered rock, soft rock and soil surface of a cut or fill slope. |  |
| | Stripe sodding | - To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.<br>- To place strip-shaped sod on a slope at regular intervals. | - Fill slope.<br>- Soil. |  |
| (4) Structure | Stone pitching | - To protect a slope by covering it with stone pitching. | - Usually applied to a slope surface gentler than 1.5 : 1. |  |
| | Concrete block pitching | - To protect a slope by covering it with cast-in-place concrete. | - Usually applied to a slope surface gentler than 1.5 : 1. |  |

Table 9.1.1 (6) Type of Restoration Measure in the Case of Slope Damage

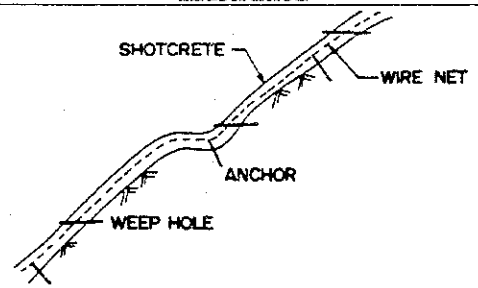
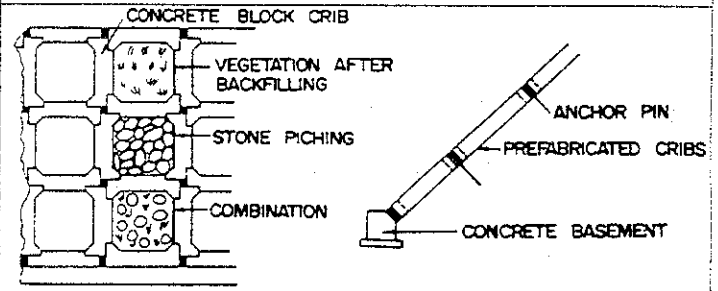
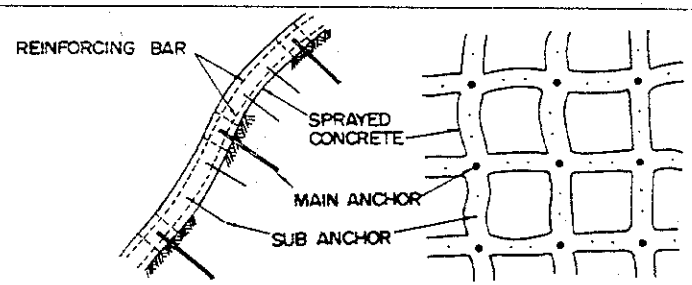
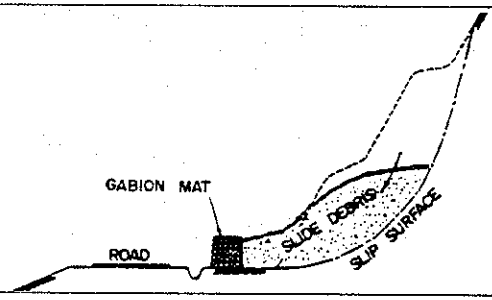
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (4) Structure | Shotcrete | - To protect a slope by covering it with sprayed concrete. | - Not applicable to a slope surface with much seepage water. |   |
| | Concrete block crib | - To protect a slope by covering it with a precast concrete block crib. | - Usually applied to a slope surface gentler than 1.0 : 1. |   |
| | Sprayed concrete crib | - To protect a slope by covering it with crib made by spraying concrete with a gun. | - Applicable to a slope surface steeper than 1.0 : 1.<br>- Applicable to an undulated surface. |   |
| | Erosion debris, rockfall barrier with gabion mat | - To prevent erosion debris and falling rock from reaching a road surface by providing gabion barriers along a slope toe. | - Applied where there is roadside space for rock and debris deposits.<br>- General applied to urgent work. |   |

Table 9.1.1 (7) Type of Restoration Measure in the Case of Slope Damage

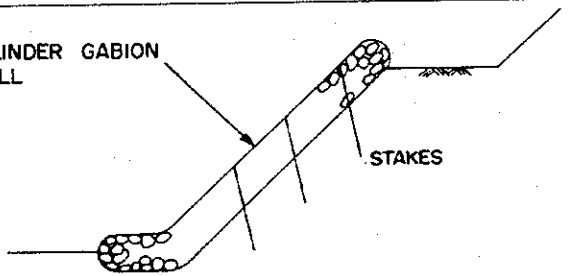
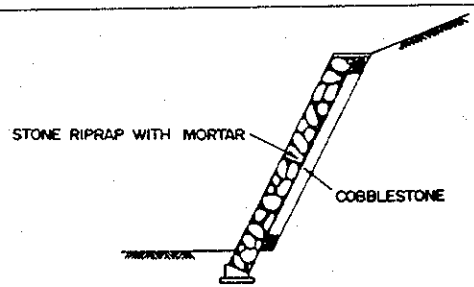
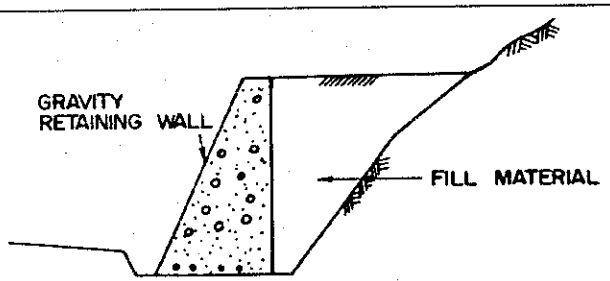
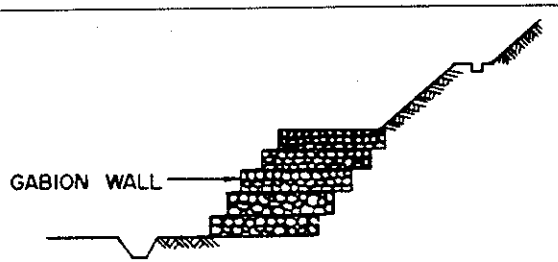
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (5) Structural support | Cylinder gabion wall | - To protect a slope by covering it with gabions. | - Usually applied to a slope surface gentler than 0.5 : 1 with seepage water. |  |
| | Stone riprap wall | - To protect a slope from landslide by resisting earth pressure. | - Applicable to a riprap wall less than 5 m high.<br>- Generally applied to a cut or fill slope. |  |
| | Gravity-type retaining wall | - To protect a slope from landslides by resisting earth pressure. | - Applicable to a wall less than 3 m high.<br>- Generally applied to a cut or fill slope. |  |
| | Gabion wall | - To protect a slope from landslides by resisting earth pressure. | - Mainly applied to the toe of a fill slope with seepage water. |  |

Table 9.1.1 (8) Type of Restoration Measure in the Case of Slope Damage

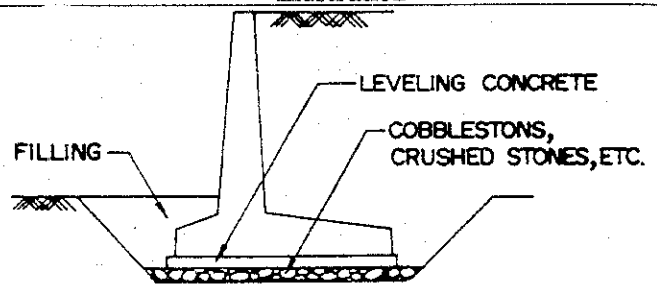
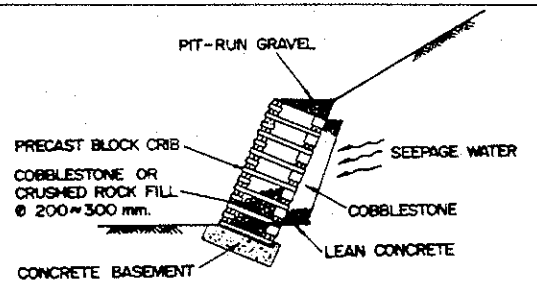
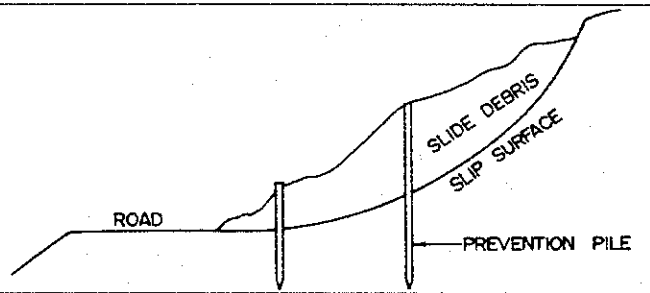
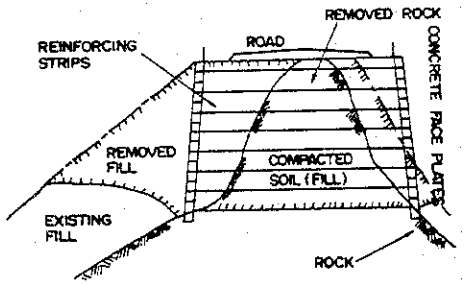
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (5) Structural support | T-shaped retaining wall | - To protect a slope from landslides by resisting earth pressure. | - Usually applied to a wall 3 to 10 m high.<br>- Generally applied to a cut or fill slope. |  |
| | Crib retaining wall | - To protect a slope from landslides by resisting earth pressure with a precast concrete block crib. | - Mainly applied to a cut slope with spring water. |  |
| | Prevention piles | - To prevent a slope from sliding by resisting earth pressure with piles. | - Generally applied to a cut and fill slope. |  |
| | Reinforced embankment | - To construct a stable earth structure by placing reinforcing materials therein. | - Fill slope requiring a perpendicular slope because of construction restraints. |  |

Table 9.1.1 (9) Type of Restoration Measure in the Case of Slope Damage

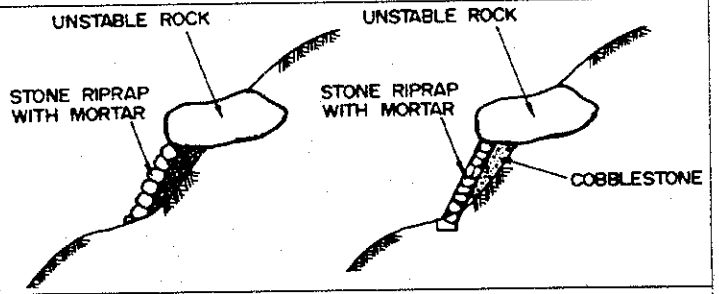
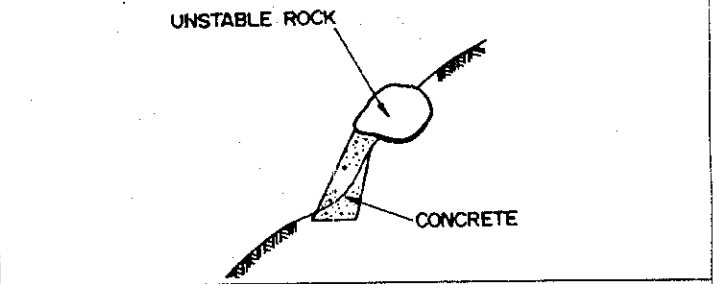
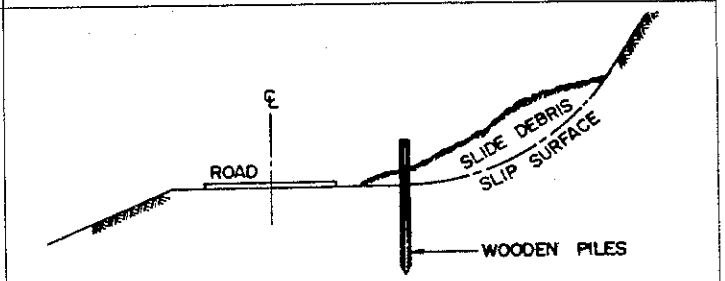
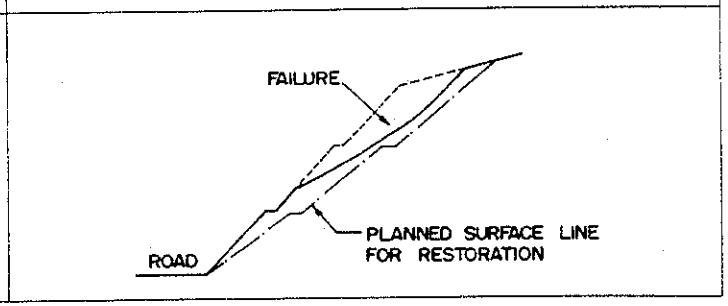
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (5) Structural support | Foot protection with stone riprap | - To prevent unstable rock from falling down by supporting it with stone riprap. | - Applied to huge rocks which are fall prone. |   |
| | Foot protection with concrete | - To prevent unstable rock from falling down by supporting it with a concrete structure. | - Applied to huge rocks that are accessable. |   |
| | Wooden prevention pile | - To prevent s slope from sliding by resisting earth pressure with wooden piles. | - Generally applied to a cut or fill slope.<br>- Generally applied to urgent work. |   |
| (6) Earth work | Recutting | - To stabilize a slope by cutting it to its optimum gradient. | - Usually drainage work and slope protection work. |   |

Table 9.1.1 (10) Type of Restoration Measure in the Case of Slope Damage

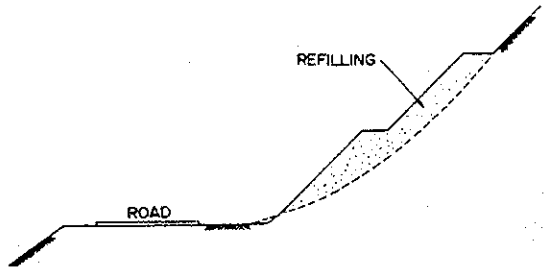
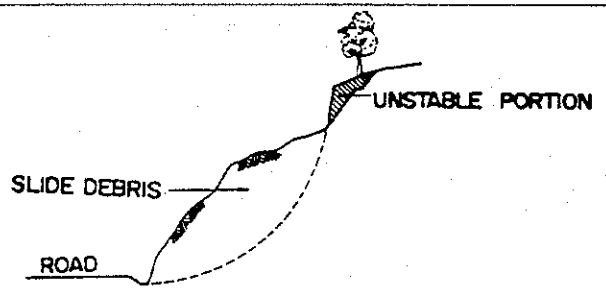
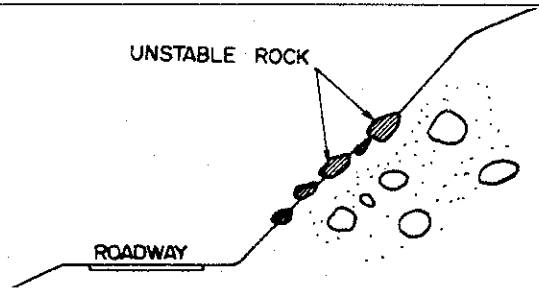
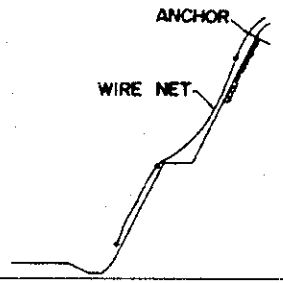
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (6) Earth work | Refilling | - To refill a cavity created by erosion, scouring, etc. | - Cut slope, fill slope. |   |
| | Removal of unstable portion | - To stabilize a slope by removing unstable portions. | - Usually applied to remove a scarp with some drainage work. |   |
| | Removal of unstable rock | - To remove unstable rocks before they falling down. | - Generally applied to huge and medium-size rocks. |   |
| (7) Rockfall prevention device | Prevention net | - To prevent falling rock from reaching a road by providing a catch wire net. | - Applied where there is no roadside space.<br>- Unsuitable for a slope with rock that easily weathers. |   |

Table 9.1.1 (11) Type of Restoration Measure in the Case of Slope Damage

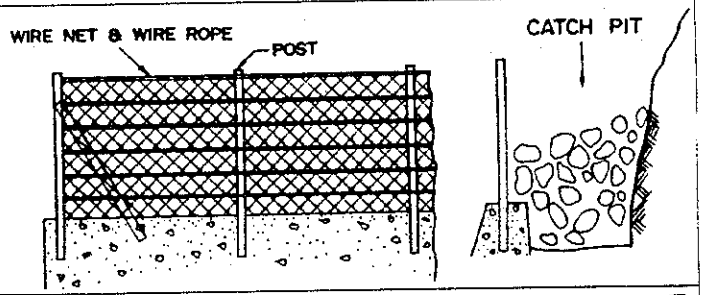
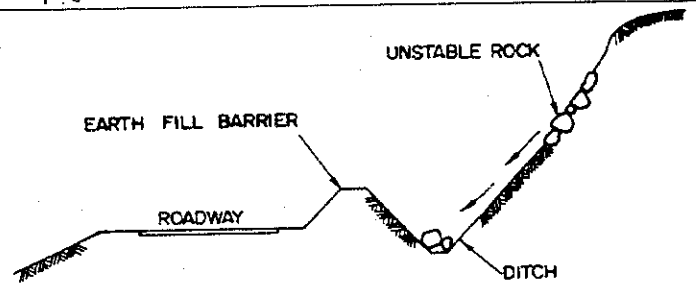
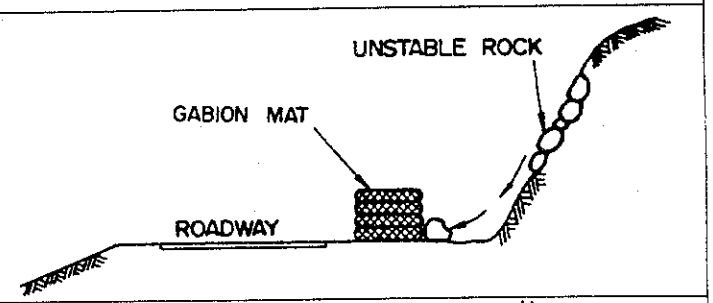
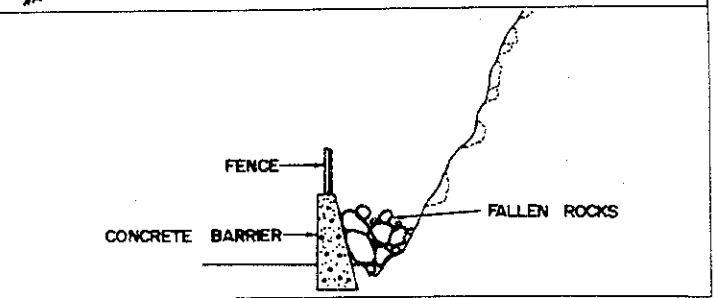
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (7) Rockfall prevention device | Prevention fence | - To prevent falling rock from reaching a road by providing a catch fence. | - Applied where there is sufficient roadside space to contain fallen rock. |  |
| | Barrier with earth fill | - To prevent falling rock from reaching a road by providing an earth fill and ditch. | - A wide space is required between a road edge and toe of slope to contain fallen rock.<br>- Cut slope. |  |
| | Barrier with gabion mat | - To prevent falling rock or debris from reaching a road by providing a gabion barrier. | - Applicable where there is sufficient roadside space to contain fallen rock. |  |
| | Barrier with concrete wall | - To prevent falling rock from reaching a road by providing a concrete wall. | - Applicable where there is sufficient roadside space to contain fallen rock. |  |

Table 9.1.1 (12) Type of Restoration Measure in the Case of Slope Damage

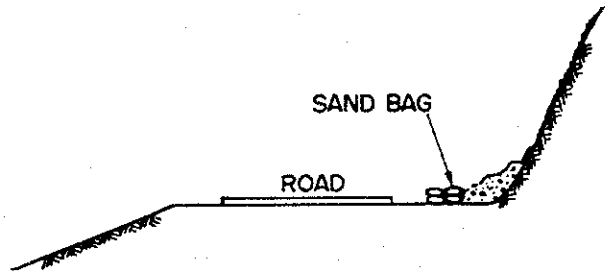
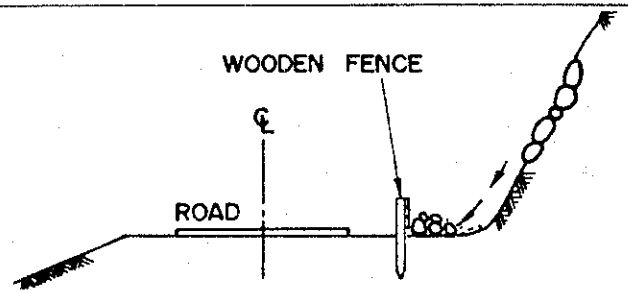
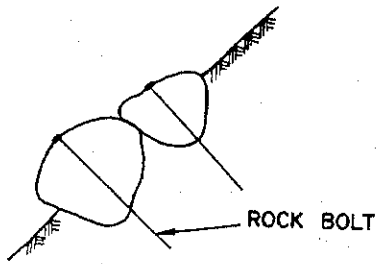
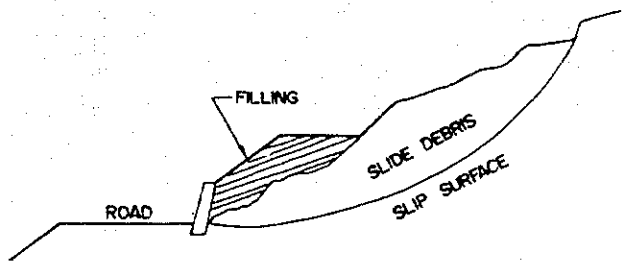
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (7) Rockfall prevention device | Debris barrier using sandbag | - To prevent erosion debris and falling rock from reaching a road by placing sandbags along the toe ditch or slope toe. | - Applied where there is sufficient roadside space for rock and erosion debris deposits.<br>- Cut slope. |  |
| | Wooden fence | - To prevent falling rock from reaching a road by erecting a wooden fence. | - Applicable where there is sufficient roadside space for rock deposits.<br>- Mainly for small rocks.<br>- Generally applied to urgent work. |  |
| (8) Anchoring | Rock bolt | - To prevent unstable rocks from falling down by anchoring them to bedrock with rock bolts. | - Applicable to huge rocks. |  |
| (9) Weight shifting | Counterweight fill | - To resist landslide's force with a counterweight fill at foot of a slope. | - Cut slope, fill slope. |  |

Table 9.1.1 (13) Type of Restoration Measure in the Case of Slope Damage

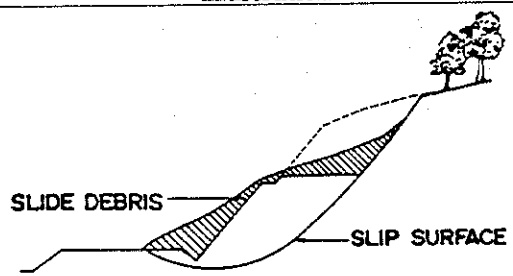
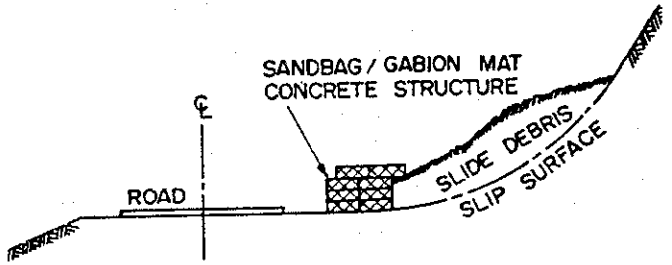
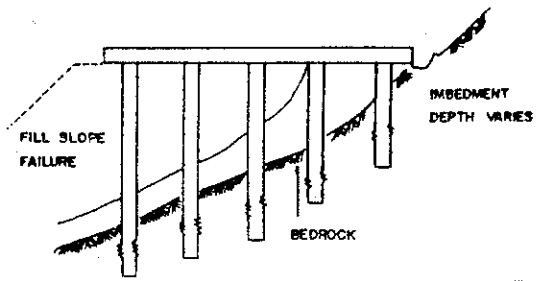
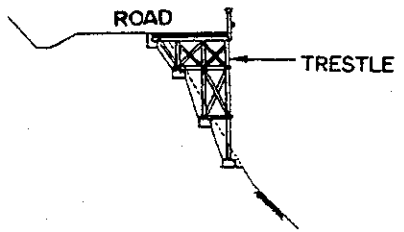
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (9) Weight shifting | Removal of head of slide debris | - To reduce the sliding force of slide debris by removing the head portion. | - Generally applied to a cut slope. |  |
| | Counterweighting with sandbags / gabion mat / concrete structures | - To resist the sliding force of a slope installing counterweights at the foot of a slope. | - Cut or fill slope.<br>- Generally applied to urgent landslide prevention. |  |
| (10) Bridge | Viaduct | - To replace a high embankment or fill slope with a viaduct. | - Fill section. |  |
| | Trestle | - To replace an earth structure with trestle. | - Fill section. |  |

Table 9.1.1 (14) Type of Restoration Measure in the Case of Slope Damage

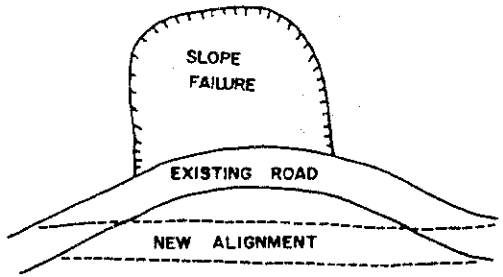
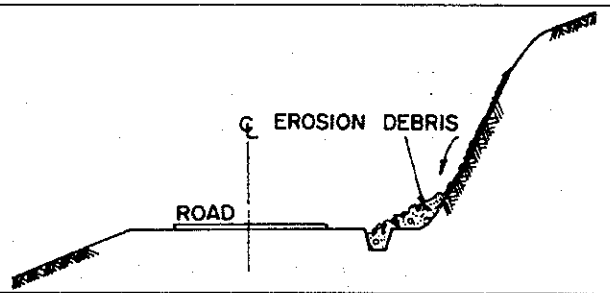
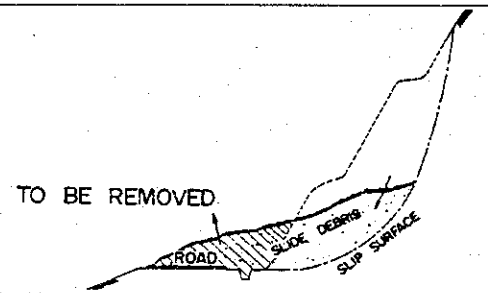
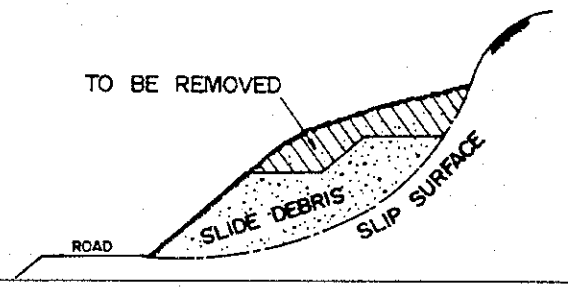
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (11) Realignment | Shifting of road alignment | - To avoid a damage-prone area. | - Applicable where there is sufficient space for new road. |  |
| (12) Removal work | Removal of erosion debris | - To remove erosion debris from a road's surface.<br>- To remove erosion debris from a toe ditch. | - Cut slope.<br>- Toe ditch.<br>- Generally applied to urgent work. |  |
| | Removal of landslide debris (1) | - To remove landslide debris from a road's surface. | - Cut slope.<br>- Generally applied to urgent work. |  |
| | Removal of landslide debris (2) | - To reduce the sliding force of landslide debris by removing the head portion of the debris. | - Cut slope.<br>- Generally applied to urgent work. |  |

Table 9.1.1 (15) Type of Restoration Measure in the Case of Slope Damage

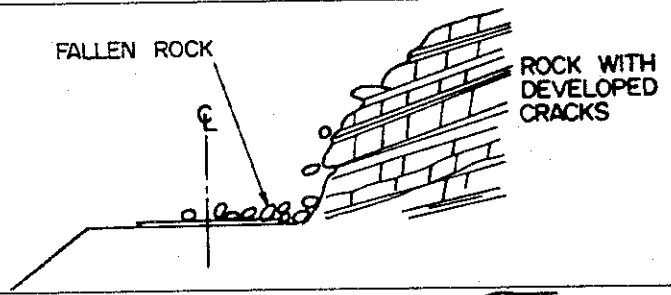
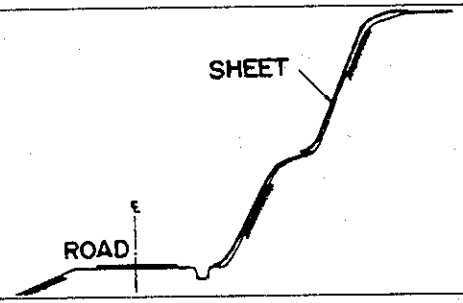
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (12) Removal work | Removal of fallen rock | - To remove fallen rock from a road's surface. | - Cut section.<br>- Generally applied to urgent work. |  |
| (13) Equipment | Sheet covering | - To prevent erosion by covering a slope's surface with a sheet.<br>- To prevent the surface of landslide debris from erosion or permeation by runoff water. | - Cut or fill slope.<br>- Applicable where runoff water flows over the surface of landslide debris.<br>- Generally applied to urgent work. |  |
| | | | | |
| | | | | |

Table 9.1.2 (1) Types of Restoration Measures in the Case of the Collapsing of Bridges

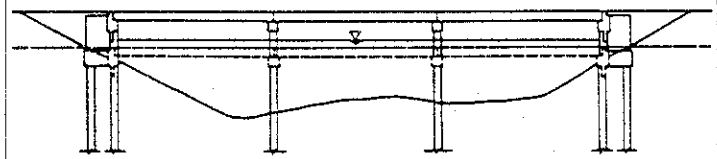
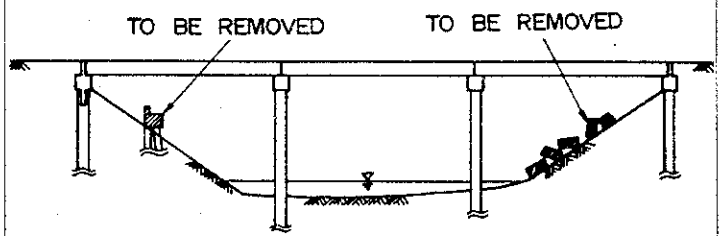
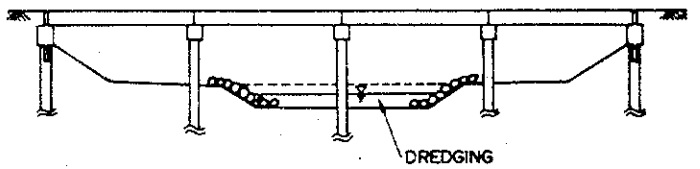
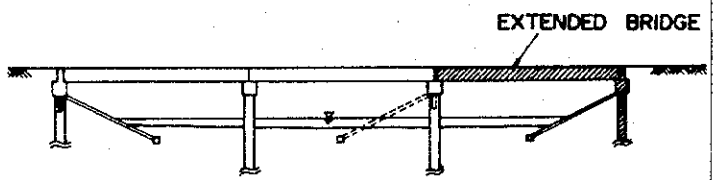
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Improvement of discharge capacity | Raising of bridge elevation | - To increase discharge capacity | - Applicable to a short bridge. |  |
| | Removal of obstacles in waterway | - To increase discharge capacity. | - Applicable to a short bridge. |  |
| | Channel dredging | - To increase discharge capacity.<br>- To stabilize a river channel. | - Applicable to long and short bridges. |  |
| | Extension of bridge length | - To increase discharge capacity. | - Generally applied to a short bridge. |  |

Table 9.1.2 (2) Types of Restoration Measures in the Case of the Collapsing of Bridges

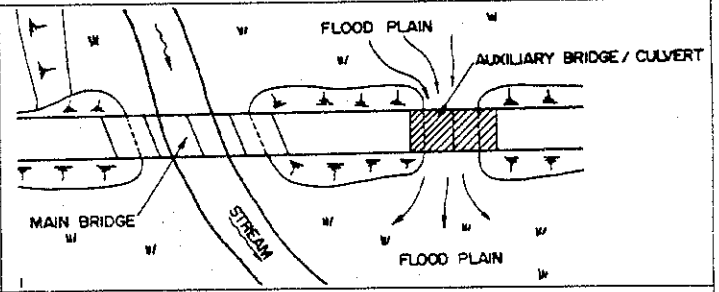
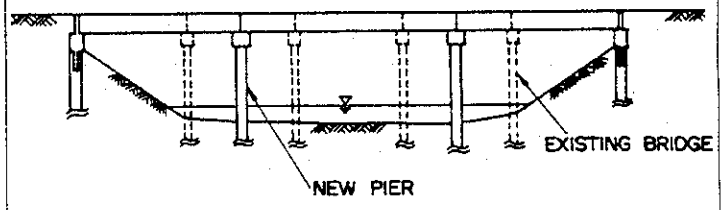
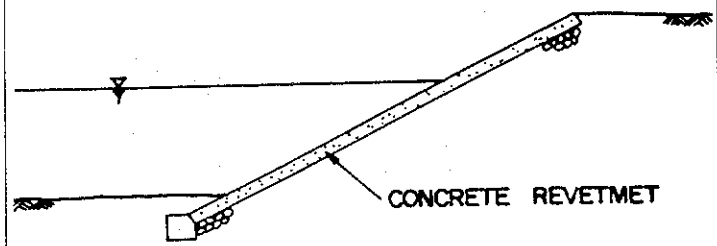
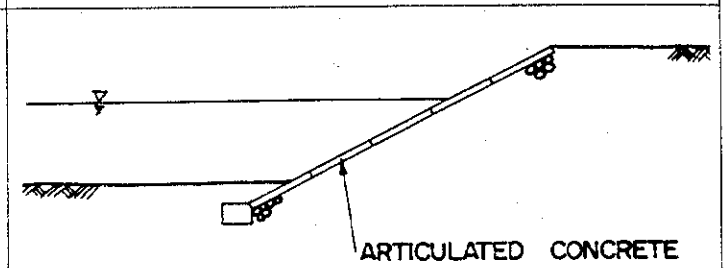
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Improvement of discharge capacity | Auxiliary bridges / culverts | - To increase discharge capacity by adding an auxiliary bridges / culvert. | - Generally applied to a bridge in a flood plain. |   |
| | Extension of span length | - To increase discharge capacity. | - Applicable to a short bridge. |   |
| (2) Abutment and pier protection | Concrete revetments | - To protect an abutment fill slope from scouring. | - Usually applied to a slope gentler than 1.0 : 1. |   |
| | Articulated concrete revetments | - To protect an abutment fill slope from scouring. | - Usually applied to a slope gentler than 1.0 : 1. |   |

Table 9.1.2 (3) Types of Restoration Measures in the Case of the Collapsing of Bridges

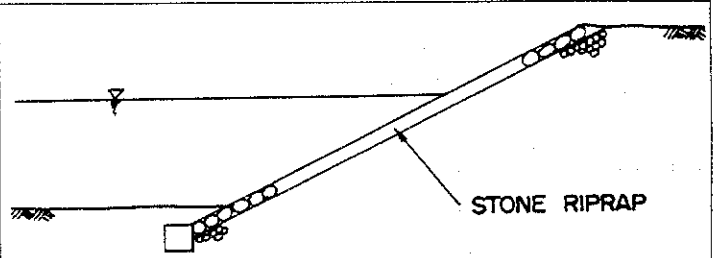
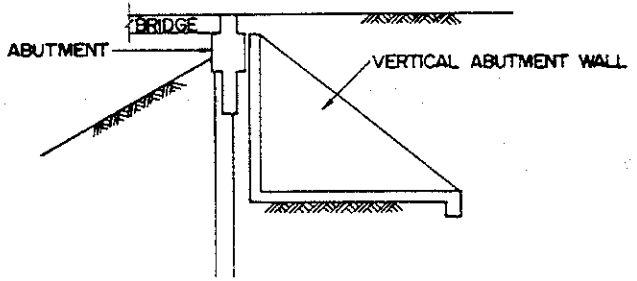
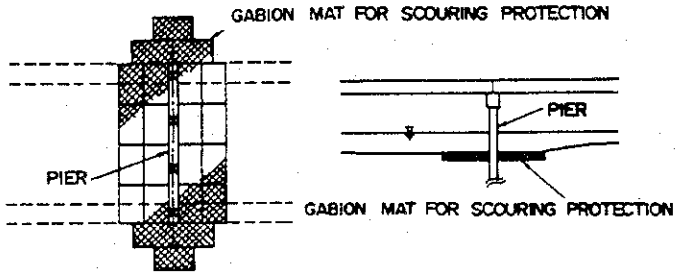
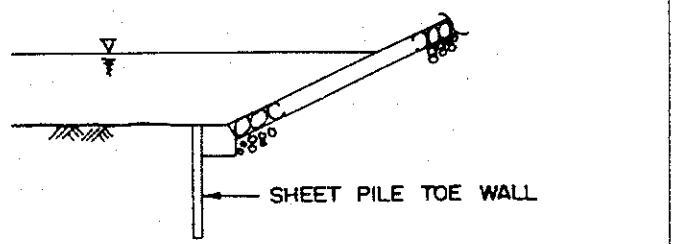
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (2) Abutment and pier protection | Stone riprap revetments (with mortar) | - To protect an abutment fill slope from scouring. | - Usually applied to a slope gentler than 1.0 : 1. |  |
| | Vertical abutment wall | - To protect an abutment back fill from scouring. | - Effective for a pile-bent abutment. |  |
| | Gabion foot protection | - To protect the foundation of an abutment and pier from being scoured by a river. | - All types of abutment protection / pier foundation. |  |
| | Sheet-pile toe wall | - To protect the foundation of an abutment revetment from deep scouring. | - Applicable to a place with high velocity river flows. |  |

Table 9.1.2 (4) Types of Restoration Measures in the Case of the Collapsing of Bridges

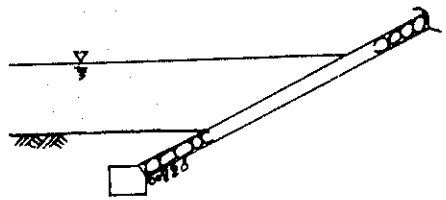
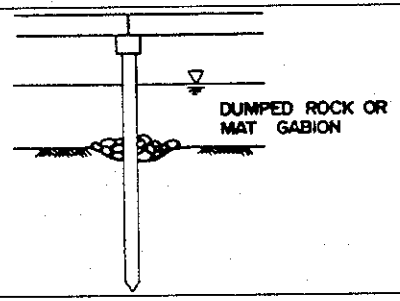
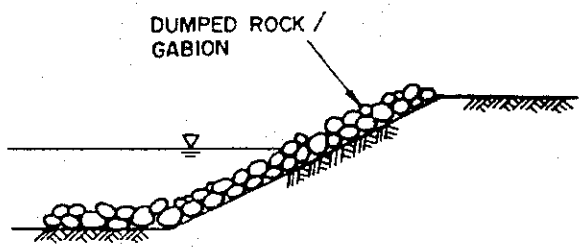
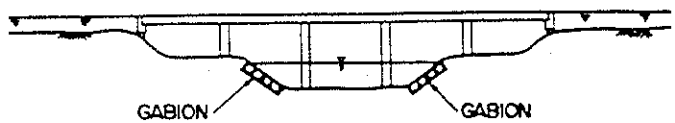
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (2) Abutment and pier protection | Deep embedment of bases | - To protect the foundation of an abutment revetment from deep scouring. | - Applicable to a place with high velocity river flows. |  |
| | Pier protection | - To prevent the foundation of a pier from being scoured by a river. | - Applicable to a long and short bridge.<br>- Generally applied to urgent work. |  |
| | Dumped rock / gabion mat | - To prevent an abutment from scouring by dumped rock or placing gabion mat. | - The abutment of a long or short bridge.<br>- Generally applied to urgent work. |  |
| (3) River channel stabilization | Stabilization with gabion | - To prevent the scouring of a river bank. | - Generally applied to a meandering river. |  |

Table 9.1.2 (5) Types of Restoration Measures in the Case of the Collapsing of Bridges

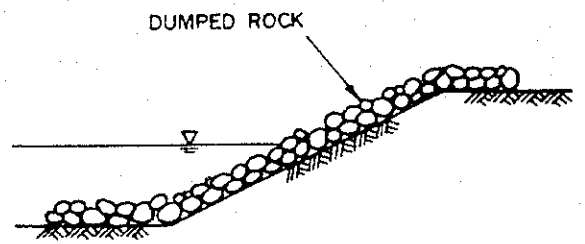
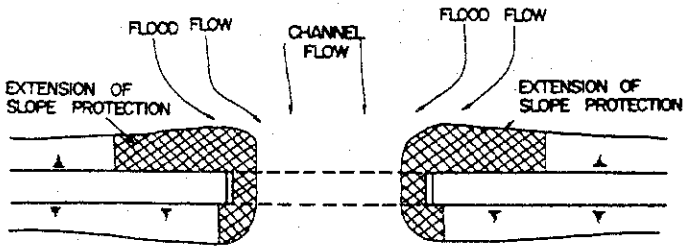
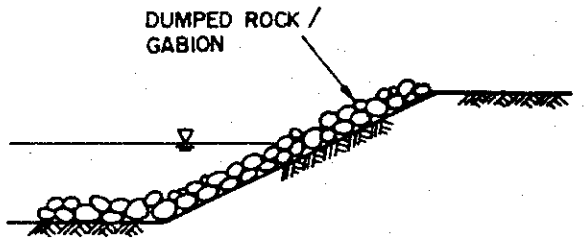
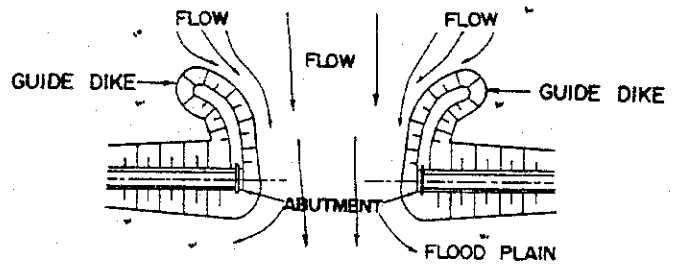
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (3) River channel stabilization | Stabilization with dumped rocks | - To prevent the scouring of a river bank. | - Generally applied to a river that has shifted. |  |
| (4) Approach road protection | Protection of approach road embankment | - To prevent the scouring on the upstream side of an approach road. | - Generally applied to bridge in a flood plain. |  |
| | Dumped rock / gabion mat | - To prevent an embankment from scouring by dumped rock or placing gabion mat. | - An embankment in a flood plain.<br>- Generally applied to urgent work. |  |
| (5) Training of stream | Guide dike | - To prevent an abutment and / or approach road from high velocity water flows. | - Applied to a bridge in a flood plain. |  |

Table 9.1.2 (6) Types of Restoration Measures in the Case of the Collapsing of Bridges

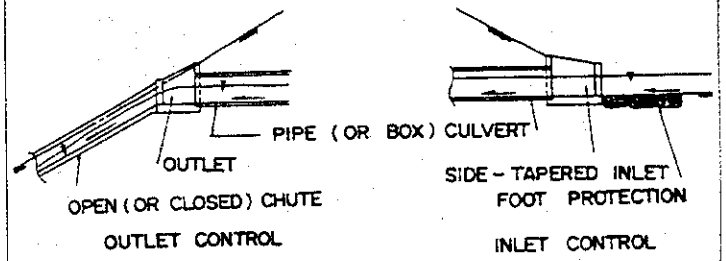
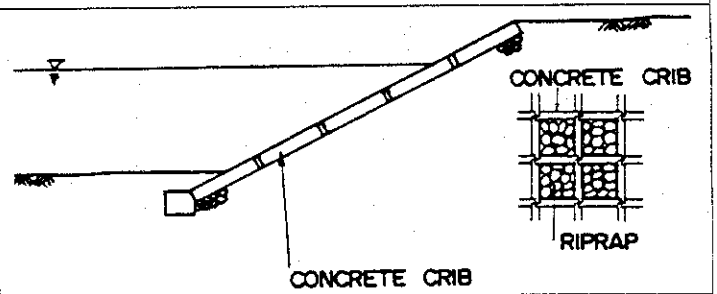
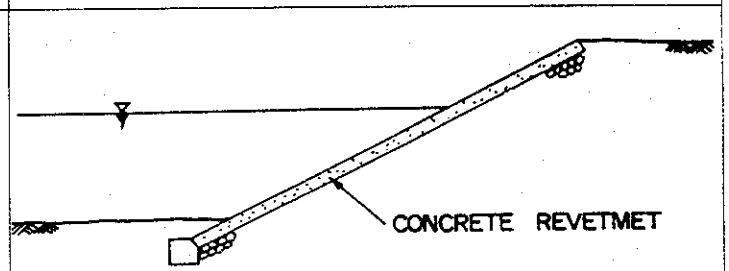
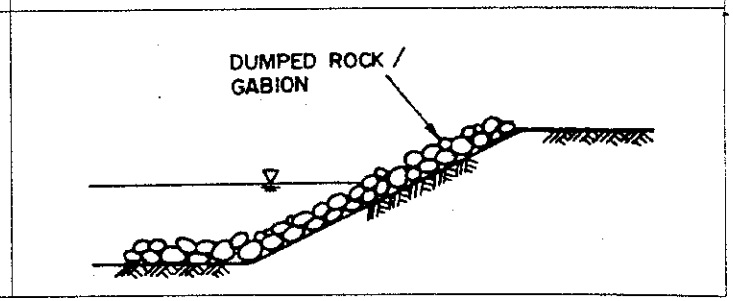
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (5) Training of stream | Improvement of culvert inlet / outlet | - To prevent an approach road from being scoured by the impact of excess water not capable of being handled by culvert. | - Applied to a culvert inlet / outlet. |  |
| (6) Riverbank protection | Cribwork with stone riprap | - To protect a riverbank from scouring. | - Usually applied to a riverbank gentler than 1.0 : 1.<br>- Applied to the outside bank at the bend of a river. |  |
| | Concrete revetments | - To protect a riverbank from scouring. | - Usually applied to a riverbank gentler than 1.0 : 1.<br>- Applied to the outside bank at the bend of a river. |  |
| | Dumped rock / gabion mat | - To protect a riverbank from scouring by dumped rock or placing gabion mat. | - Outside bend of river.<br>- Generally applied to urgent work. |  |

Table 9.1.2 (7) Types of Restoration Measures in the Case of the Collapsing of Bridges

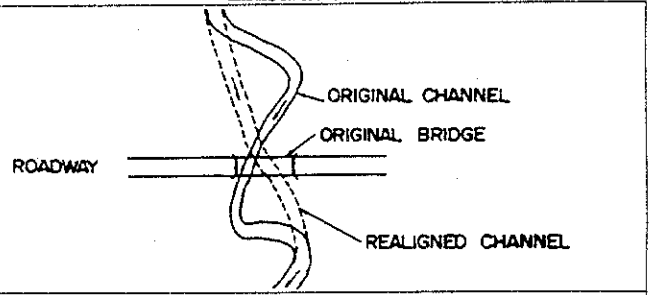
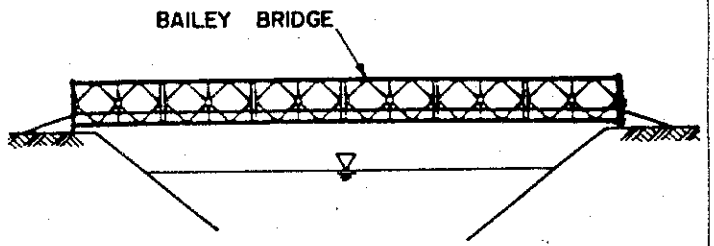
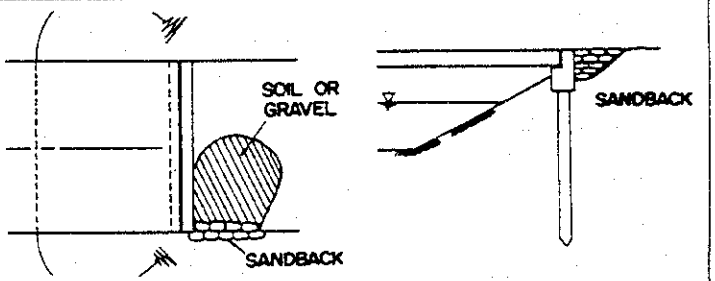
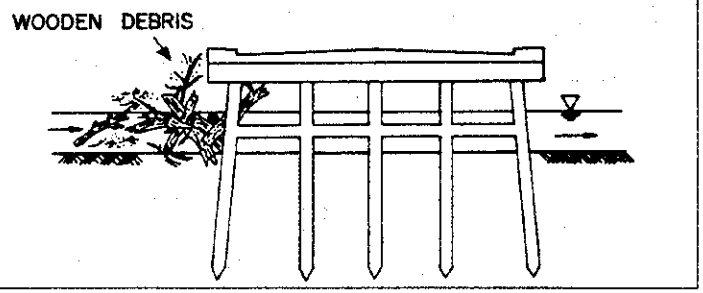
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (7) Realignment of river channel | Realignment | - To protect an abutment and / or approach road from the turbulence of a river flows. | - Applied to a meandering river. |   |
| (8) Structure | Bailey bridge | - To reopen traffic by the erection of a Bailey bridge. | - Applicable where a bridge or approach road has collapsed.<br>- Applicable to a short-span bridge.<br>- Generally applied to urgent work. |   |
| (9) Earth work | Refilling | - To prevent the continued scouring of an approach road by refilling with soil, sandbags or gravel.<br>- To refill the cavity of an abutment backfill. | - Applicable to the scouring of an abutment backfill.<br>- Generally applied to urgent work. |   |
| (10) Removal work | Removal of wooden debris | - To prevent a bridge from collapsing by decreasing the lateral pressure from wooden debris. | - Applicable to a long or short bridge.<br>- Generally applied to urgent work. |   |

Table 9.1.3 (1) Types of Restoration Measures in the Case of the Collapsing of Embankment Roads

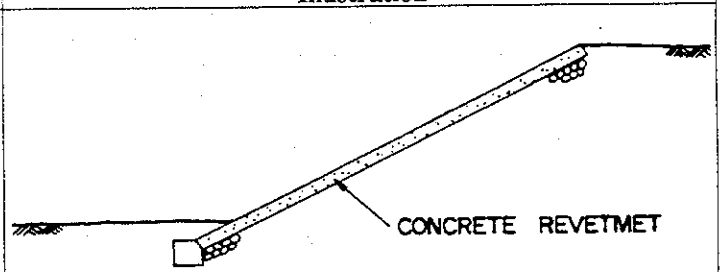
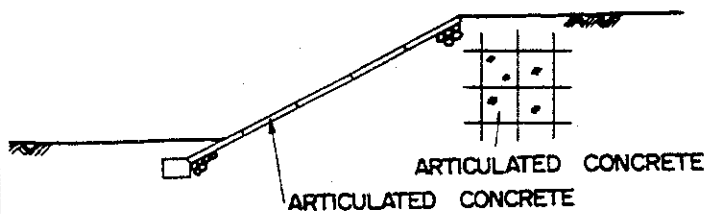
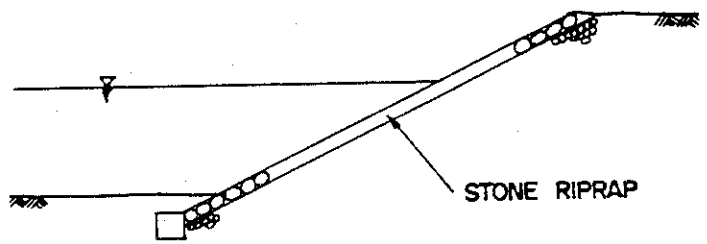
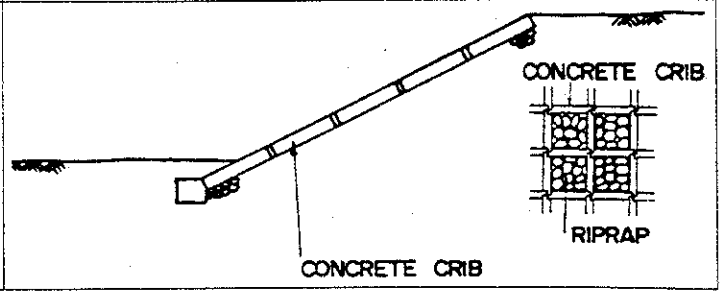
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Protection of embankment slope | Concrete revetments | - To protect an embankment from scouring by covering it with cast-in-place concrete revetments. | - Usually applied to a slope gentler than 1.0 : 1. |  |
| | Articulated concrete revetments | - To protect an embankment from scouring by covering it with precast concrete block. | - Usually applied to a slope gentler than 1.0 : 1. |  |
| | Stone riprap with mortar | - To protect an embankment from scouring by covering it with stone riprap. | - Usually applied to a slope gentler than 1.0 : 1. |  |
| | Cribwork with stone riprap | - To protect an embankment from scouring by covering it with a concrete crib with stone riprap. | - Usually applied to a slope gentler than 1.0 : 1. |  |

Table 9.1.3 (2) Types of Restoration Measures in the Case of the Collapsing of Embankment Roads

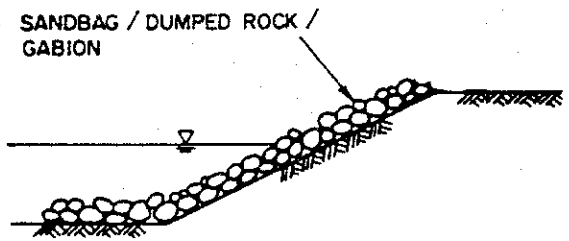
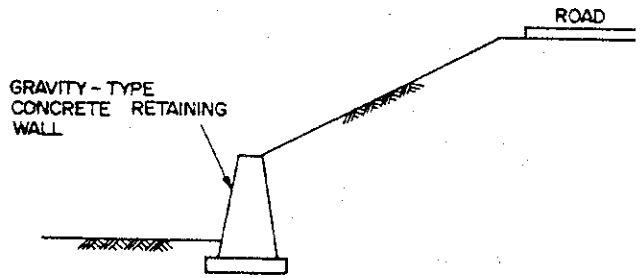
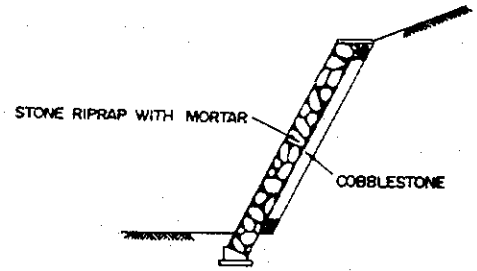
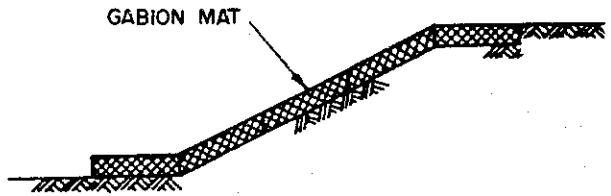
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Protection of embankment slope | Sandbags / dumped rock / gabions | - To protect an embankment slope from continued scouring by covering it with sandbags / dumped rock / gabions. | - Embankment section.<br>- Generally applied to urgent work. |  |
| (2) Protection for toe of embankment | Gravity-type concrete retaining wall | - To protect an embankment by resisting earth pressure. | - Applicable to a wall less than 3 m high. |  |
| | Stone riprap retaining wall | - To protect an embankment by resisting earth pressure. | - Applicable to a wall less than 5 m high. |  |
| | Gabion | - To protect an embankment by resisting earth pressure. | - Mainly applied to an embankment slope with seepage water. |  |

Table 9.1.3 (3) Types of Restoration Measures in the Case of the Collapsing of Embankment Roads

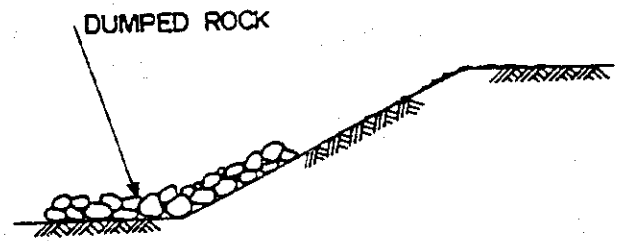
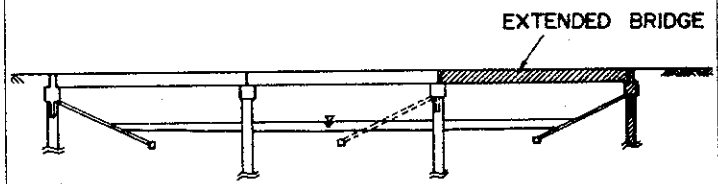
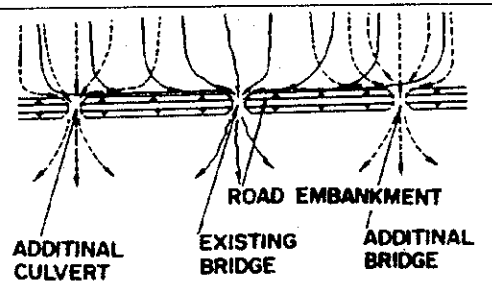
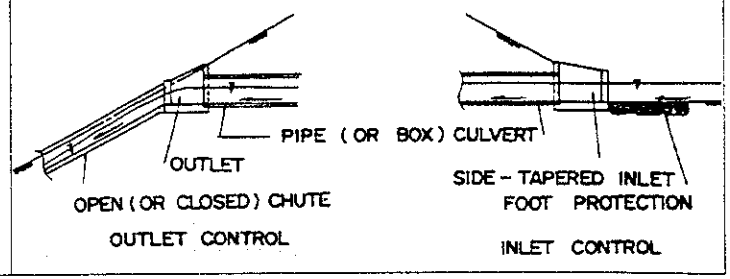
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (2) Protection for toe of embankment | Dumped rock | - To protect a slope from scouring by high velocity water flows. | - Usually applied to a slope gentler than 1.5 : 1.<br>- Applicable to a stream bank. |  |
| (3) Improvement of drainage capacity | Extension of bridge length / enlargement of cross-sectional area of culvert | - To drain water runoff that crosses an embankment. | - Applicable to a bridge or culvert whose discharge capacity is insufficient. |  |
| | Construction of additional bridges / culverts | - To drain water runoff that crosses an embankment. | - Applicable to an embankment with few drainage facilities. |  |
| | Improvement of culvert inlet / outlet | - To prevent an approach road from being scoured by the impact of excess water not capable of being handled by culvert. | - Applied to a culvert inlet / outlet. |  |

Table 9.1.3 (4) Types of Restoration Measures in the Case of the Collapsing of Embankment Roads

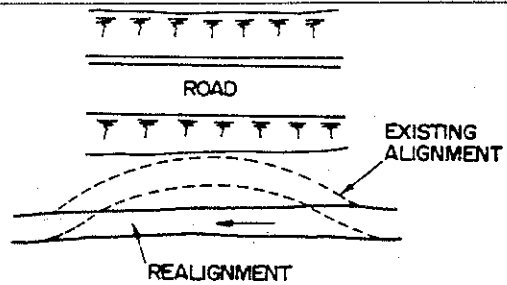
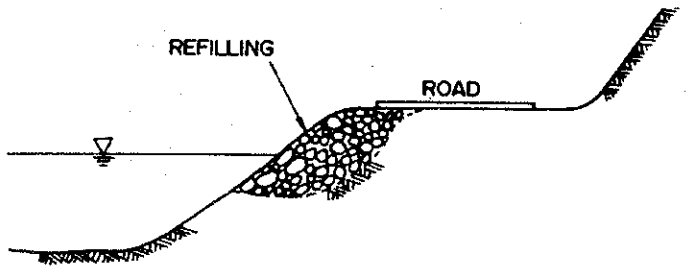
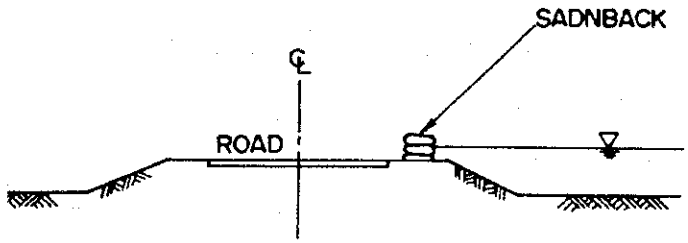
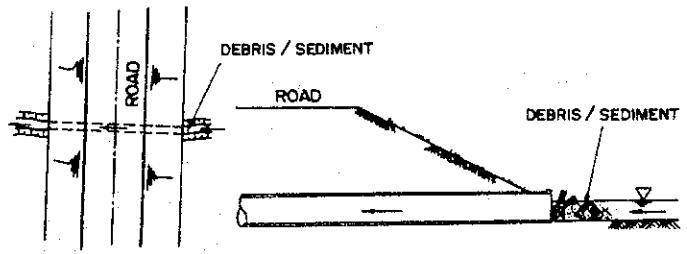
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (4) Realignment of river channel | Realignment | - To prevent the erosion and scouring of an embankment slope. | - Applied to a meandering river. |   |
| (5) Earth work | Refilling | - To reopen road by refilling traffic-stopping cavity with earth / sandbags / dumped rock / gabions. | - Embankment section. |   |
| (6) Protection from submerging | Placing of sandbags | - To prevent the submerging of an embankment road by placing sandbags at the road's shoulders. | - Embankment section.<br>- Flat section.<br>- Generally applied to urgent work. |   |
| (7) Removal work | Removal of debris / sediment | - To increase discharge capacity by the removal of debris and sediment from culvert inlet. | - Applicable to pipe or box culverts. |   |

**Table 9.1.3 (5) Types of Restoration Measures in the Case of the Collapsing of Embankment Roads**

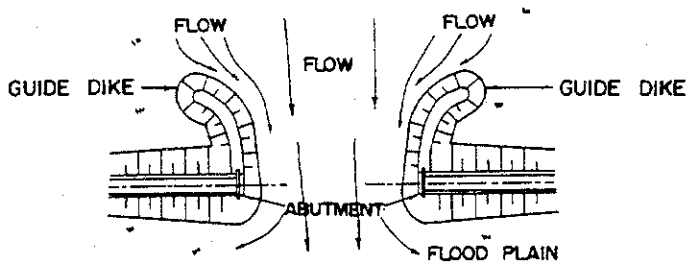
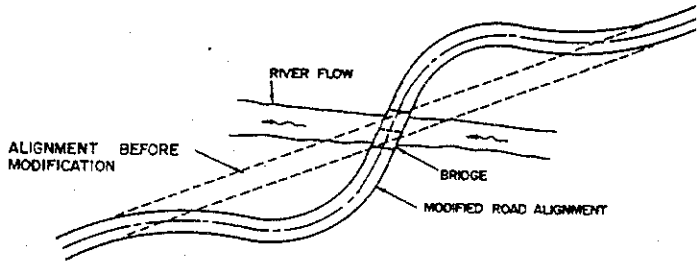
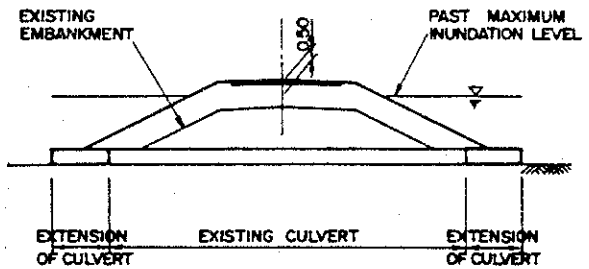
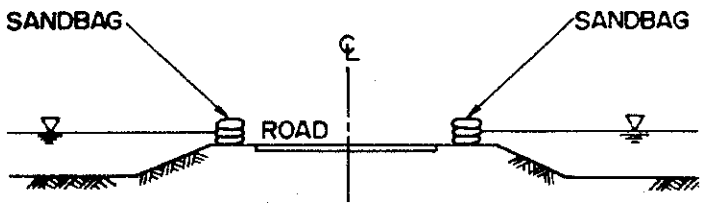
| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (8) Training of stream | Guide dike | - To prevent an abutment and / or approach road from high velocity water flows. | - Applied to a bridge in a flood plain. |  |
| (9) Realignment of road | Realignment | - To prevent the erosion and scouring of an embankment slope. | - Applied to a river crossing with an acute angle. |  |
| | | | | |
| | | | | |

Table 9.1.4 Types of Restoration Measures in the Case of Road Flooding

| Classification | Type of Work | Functional Characteristics | Application | Illustration |
|---|---|---|---|---|
| (1) Protection from submerging | Raising roadway elevation | - To prevent a road's surface from being submerged. | - Low embankment road in a flood plain. |  |
| | Placing of sandbags | - To prevent a road from being submerged by placing sandbags along the road's shoulders. | - Embankment in a flood plain.<br>- Generally applied to urgent work. |  |
| | | | | |
| | | | | |

## 9.2 Selection of Restoration Measures

This section discusses how to select a desirable restoration measure from the candidates listed in 9.1. The selection procedure is expressed as a flow chart in order to reach a final solution easily for each type of work and damage.

In the case of urgent restoration, the promptness of repair work shall be emphasized in selecting a restoration measure. On the other hand, priority shall be placed on cost effectiveness and social and environmental impacts in the case of temporary or permanent repair work.

### 9.2.1 Urgent Repair Work

The primary objective of urgent repair work is to reopen as soon as possible a road section closed to traffic after the detection of the damage. The second is to prevent the damage from expanding using makeshift measures.

In the selection of an urgent restoration measure, the above-mentioned factors shall be taken into consideration. In addition, it should be noted that most of the material and equipment for urgent repair work are supplied from the stockyards of designated depots that generally have a limited type and quantity of material and equipment.

1. Slope Erosion

When reopening a road section closed to traffic, most of the work consists of removing accumulated erosion debris from the road surface and preventing any further erosion debris from reaching the road surface again. To achieve these objectives, placing sandbags/gabions along road shoulders at the foot of slopes where erosion occurs is a useful measure.

To prevent surges of water from a slope surface from reaching a road surface and obstructing the smooth flow of traffic, the countermeasures that can be applied are:

- To install a crest ditch along the top of the slope.
- To remove deposits in the toe ditch.
- To place sandbags/gabions along the road's shoulder at the foot of the slope.

A selection procedure for urgent restoration measures in the case of slope erosion is shown in Fig.9.2.1.

2. Rockfalls

In order to reopen a road closed to traffic by fallen rock, the highest priority shall be given to prompt removal of this rock. If further rockfalls are anticipated, the following measures will be effective in preventing rocks from reaching the road's surface:

- To install a barrier along the road's shoulder to catch rocks.
- To remove unstable rocks/boulders from the slope's surface.
- To install a crest ditch along the top of the slope.

The barrier can be made of earth, sandbags, gabion mats, wooden fence, etc.

A selection procedure for urgent restoration measures in the case of rockfalls is shown in Fig.9.2.2.

3. Landslide

In order to quickly reopen a road closed to traffic by a landslide, slide debris on the road's surface shall be removed as soon as possible. However, if the total mass of slide debris is not physically stable, the remaining slide debris will move again onto the road's surface. Therefore, makeshift stabilization work for the total debris mass shall be executed after removing road surface debris.

To directly stabilize the slide debris mass, the measures that can be applied are:

- To remove some portion of the slide debris.
- To place counterweights made of earth, sandbags, or gabion mats.
- To drive piles.
- To install a retaining wall made of gabion mats.

As an indirect countermeasure, the groundwater level of slide debris can be lowered to increase the strength of the soil. To achieve this, the following can be applied.

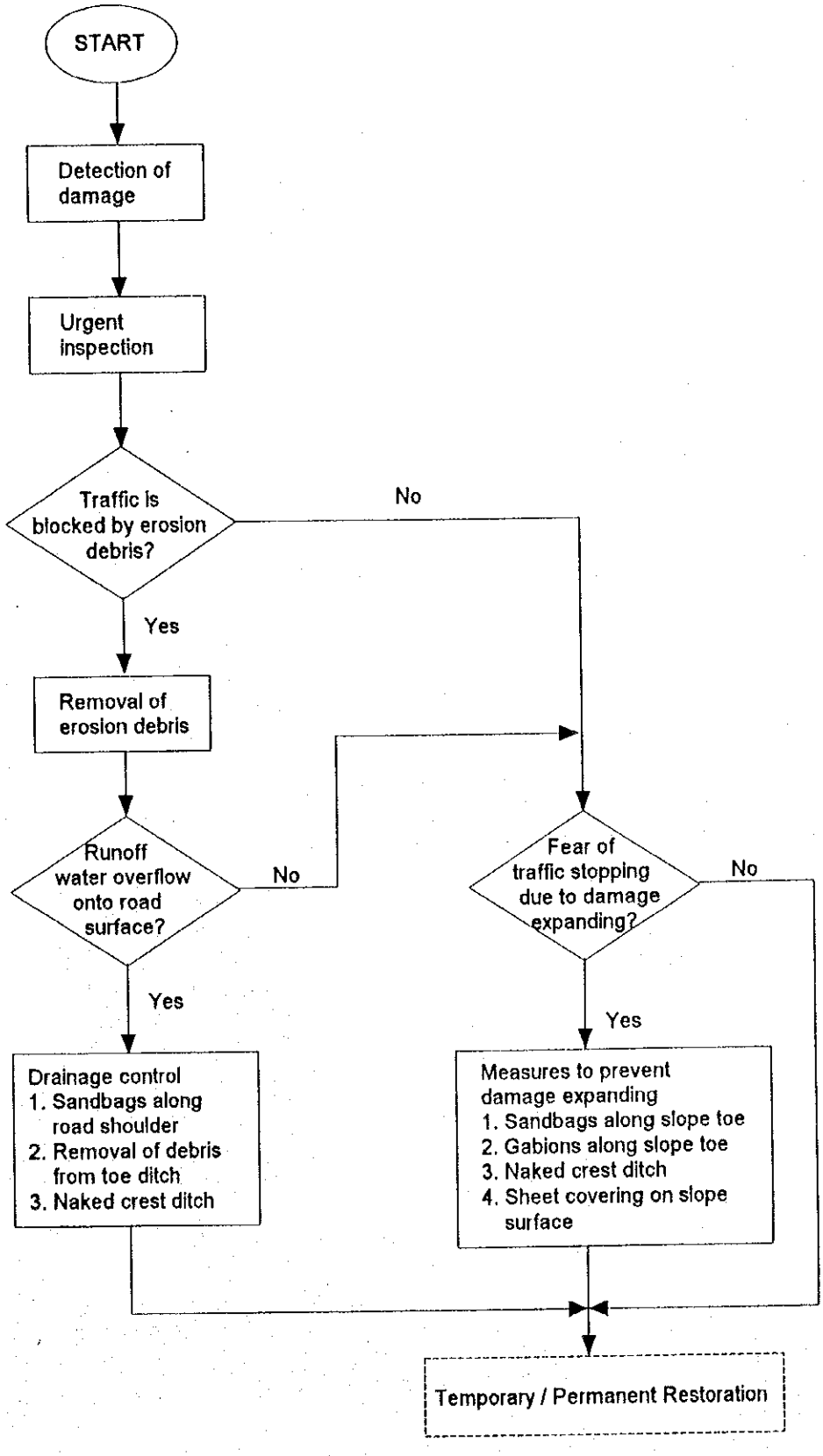



Fig.9.2.1 Selection of Urgent Restoration Measures in the Case of Slope Erosion

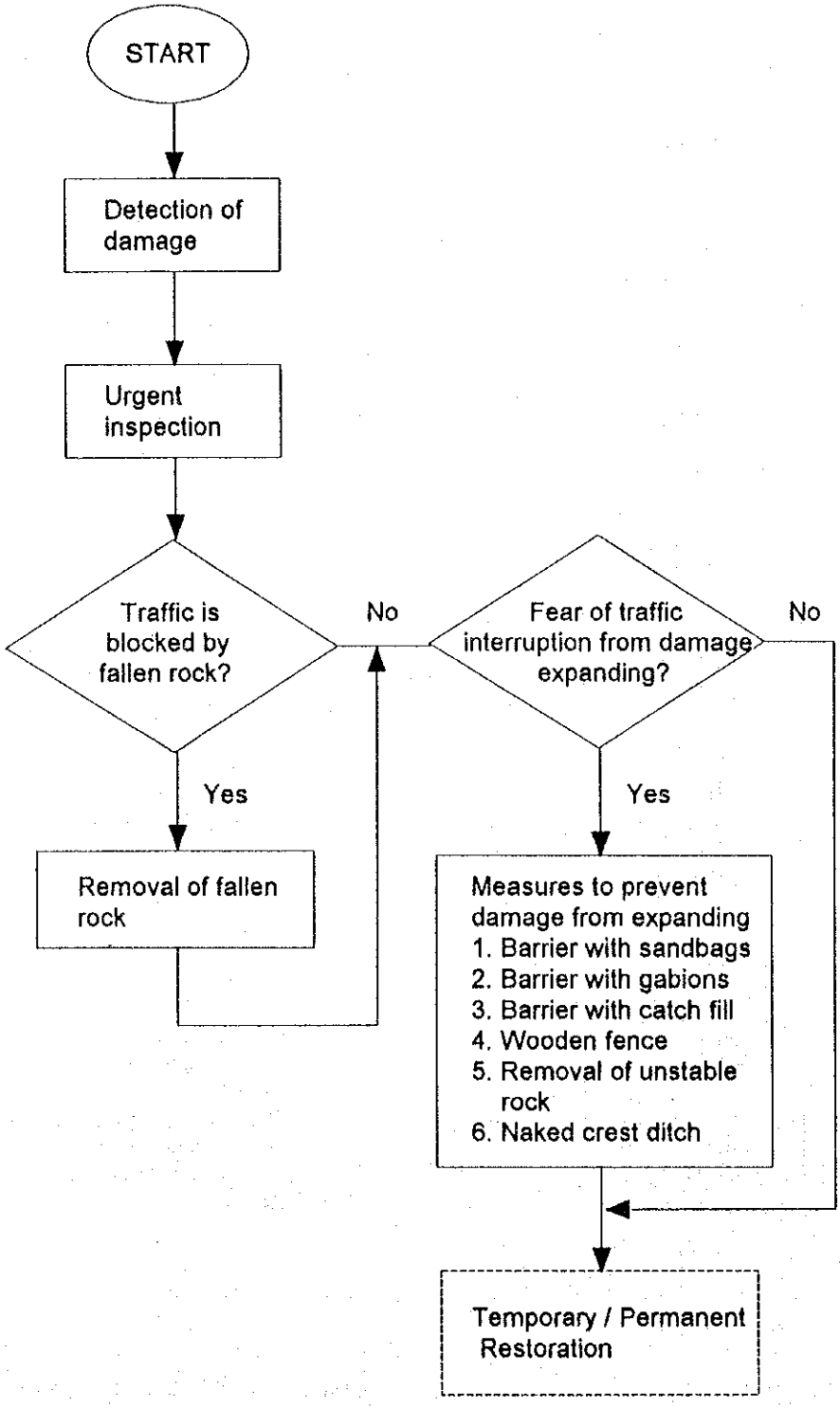



Fig.9.2.2 Selection of Urgent Restoration Measures in the Case of Rockfalls

- To install a surface ditch along the top of the slope and on the surface of slide debris to prevent runoff water from permeating into the slide debris ( a crest is particularly effective).
- To cover the surface of slide debris with a sheet for the same purpose.

A selection procedure for urgent restoration measures in the case of a landslide is shown in Fig.9.2.3.

4. Collapsing of a Bridge

When a road is closed to traffic due to the collapsing of a bridge or approach road, the following restoration measures shall be taken to reopen the road to traffic:

- To erect a Bailey bridge to replace the collapsed bridge or the collapsed embankment of approach road.
- To refill the damaged portion of the approach road embankment.

If any further damage is observed on site, the following urgent measures shall be applied for preventive purposes:

- To protect abutments, approach roads and/or river banks adjacent to abutments using dumped rock or gabion mats.
- To remove floating debris dammed up along a bridge in order to reduce lateral force.

A selection procedure for urgent restoration measures in the case of the collapsing of a bridge is shown in Fig.9.2.4.

5. Collapsing of an Embankment Road

Embankment damage is likely to occur at locations where an embankment is situated as follows:

- incident to a river flow;
- in a flood plain; and
- on sloping ground.

The types and causes of embankment damage are peculiar to the characteristics of each of these locations. Therefore, the selection procedure for urgent restoration measures is also divided into three parts as shown in Fig. 9.2.5(1)-(3).

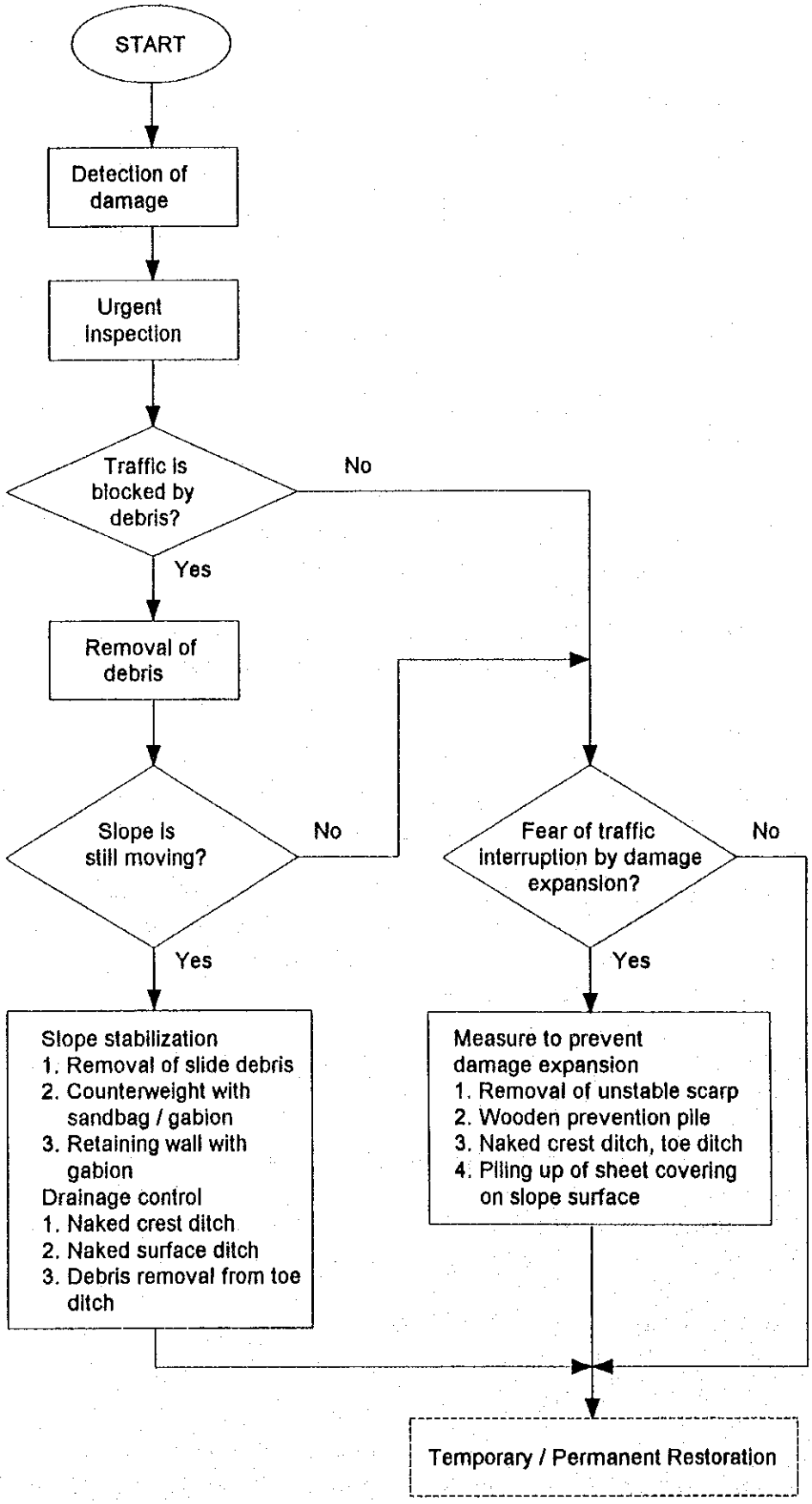



Fig.9.2.3 Selection of Urgent Restoration Measures in the Case of a Landslide

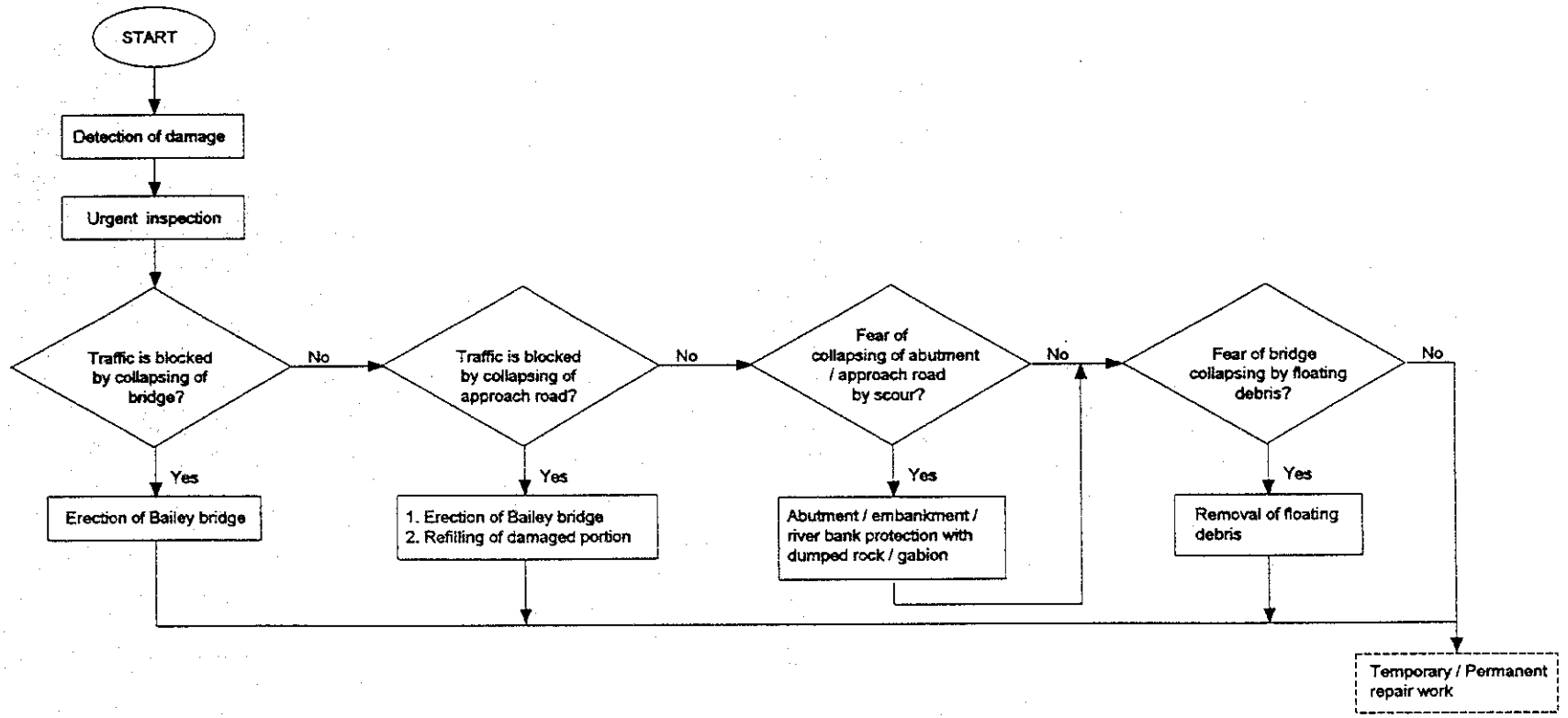



Fig.9.2.4 Selection of Urgent Restoration Measures in the Case of the Collapsing of a Bridge

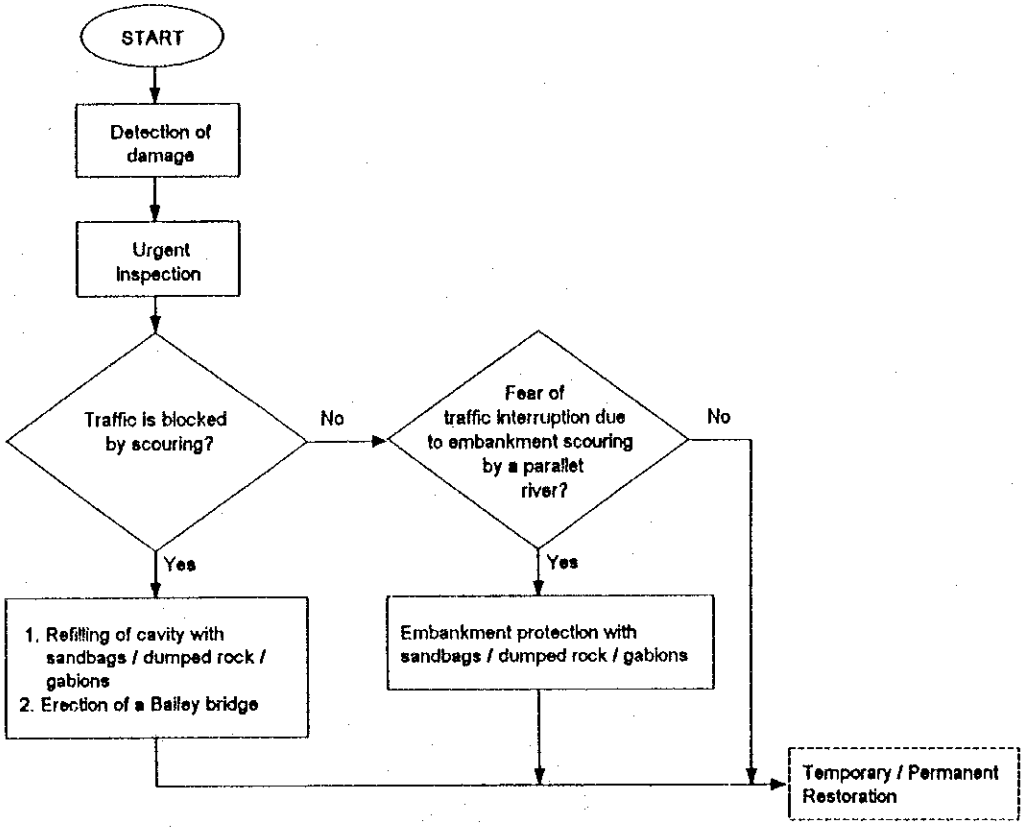



Fig. 9.2.5 (1) Selection of Urgent Restoration Measures in the Case of the Collapsing of Embankment Roads Incident to a River

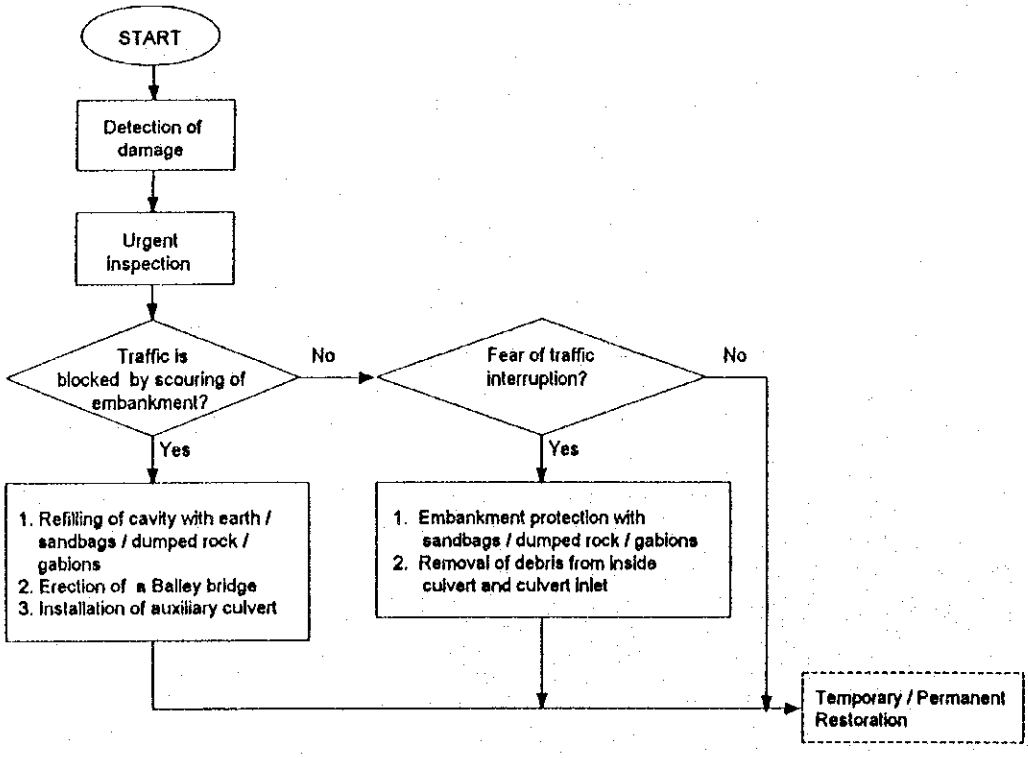



Fig. 9.2.5 (2) Selection of Urgent Restoration Measures in the Case of the Collapsing of Embankment Roads in a Flood Plain

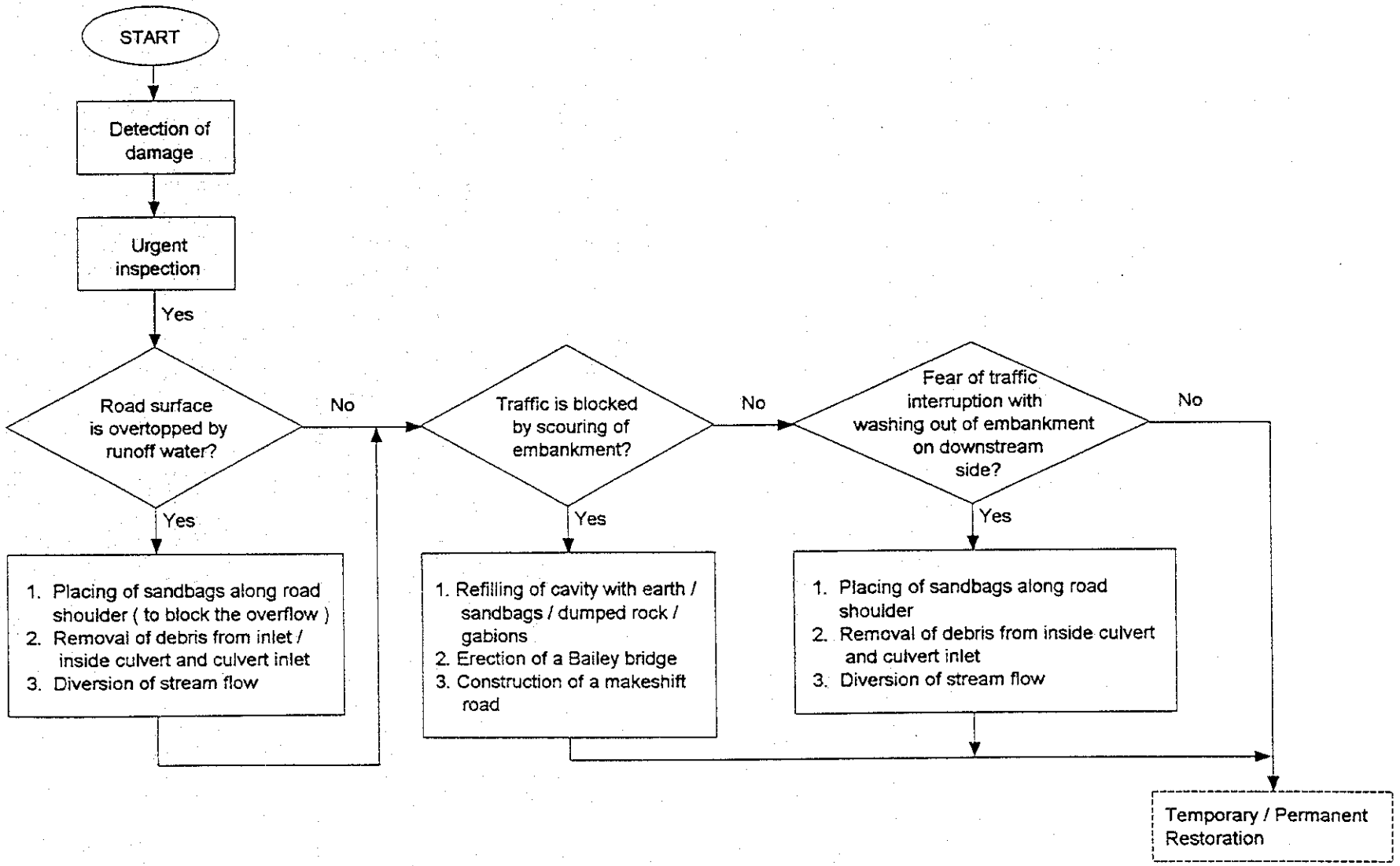



Fig. 9.2.5 (3) Selection of Urgent Restoration Measures in the Case of the Collapsing of Embankment Roads on Sloping Ground

1) In the case of an embankment being parallel to a river, emphasis shall be placed on how the foot of the embankment is scoured by the river flow when selecting a restoration measure.

If the whole embankment is scoured away, a Bailey bridge would be erected to substitute for the embankment. If scouring damage is minor, the damaged portion would be refilled and embankment protection from scouring would be installed using sand bags, dumped rocks or cylinder gabions.

2) In the case of an embankment road lying in a flood plain, emphasis shall be placed on how the embankment is damaged in the vicinity of the drainage facilities that cross the embankment when selecting an urgent restoration measure.

When an embankment totally collapsed, either a Bailey bridge will be erected or an auxiliary culvert will be installed as an urgent restoration measure. For partial damage to an embankment, the only solution is refilling the damaged portion.

3) In selecting an urgent restoration measure for an embankment on sloping ground, if the embankment has totally collapsed, a Bailey bridge is erected or a makeshift road constructed. If the embankment is partially damaged, the damaged portion shall be refilled.

In the case of runoff water or water from a mountain stream overflowing onto an embankment that has yet to be damaged, sandbags can be placed along the road's shoulder. In addition, to prevent runoff water from accumulating in places that can threaten the road, the diversion of the runoff water's flow is an effective solution.

6. Road Flooding

When road traffic is interrupted by flooding and the water depth on the road's surface is shallow, sandbags can be placed along the road's shoulders to alleviate the flooding problem.

### 9.2.2 Temporary/Permanent Repair Work

The objectives of temporary and permanent restoration measures are to restore the original functions of a damaged road and to maintain those functions. To achieve this, temporary and permanent repair work is carried out as a part of the restoration measures. Temporary repair work refers to the short service life of a job, while permanent repair work refers to a long service life.

Under present budgetary restraints, consideration of the following factors shall be taken into when selecting restoration measures.

a) Traffic volume

If the social impact of closing a road traffic is not large due to small traffic volume, the investment in repair work shall be executed step by step. Basically, temporary repair work shall be mainly applied when average daily traffic volume is less than 2,000 vehicles. In other cases, a permanent repair work would be suitable.

b) Availability of detour

If a detour is available, investment in repair work shall be executed stepwise. On the other hand, if a detour is not available and traffic volume is high, permanent repair work is recommended.

c) Quality or quantity

As a fundamental policy for road restoration on a district office basis, a choice between costly repair work with a long service life or many low-cost repair work with a short service life shall be made before selecting a restoration measure.

d) Introduction of new technologies

If no effective countermeasures for a type of damage has been found, new technologies for repair work shall be positively introduced.

e) Effective usage of local materials

In order to lower repair work costs, local materials shall be effectively applied.

f) Rerouting of a road

If there is an entire road section prone to damage and a large amount of money is required to repair it, the rerouting of the road should be considered as a viable choice.

g) Alleviation of environmental impacts

In general, application of a restoration measure having adverse environmental impacts shall be avoided.

1. Slope Damage

Slope damage can be broken down into three specific types of damage: (1) slope erosion, (2) rockfalls, and (3) landslide.

The flow chart in Fig.9.2.6 explains the selection procedure for a restoration measure for a damaged slope.

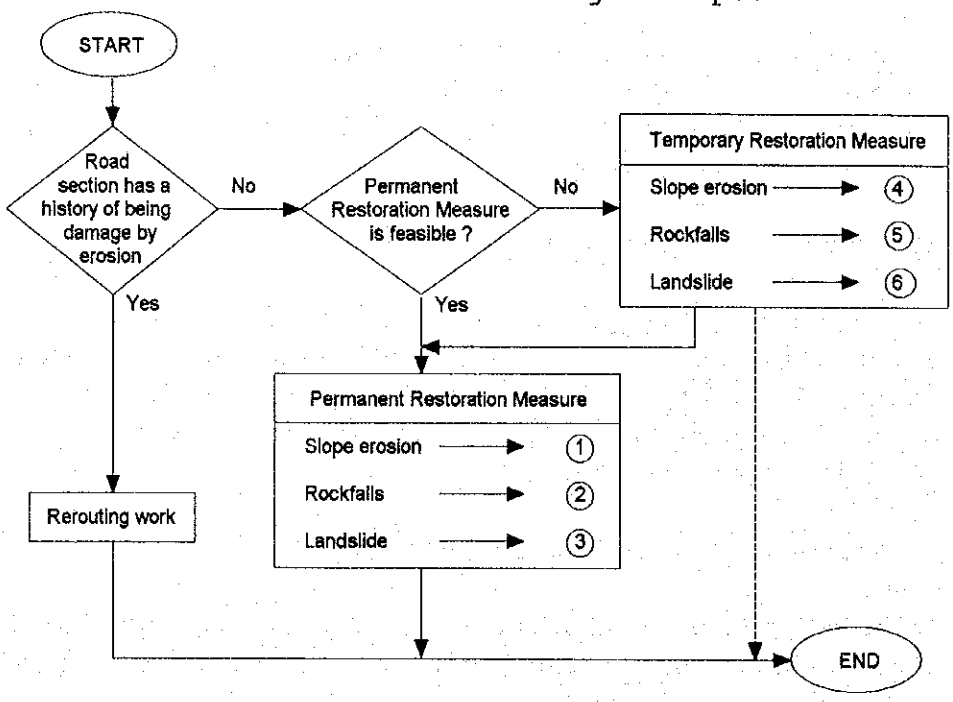



Fig.9.2.6 Selection of a Restoration Measure for Slope Damage

This flow chart shows just part of the selection procedure, and is followed by six flow charts which describes the selection of restoration measure for the different types of slope damage.

1) **Slope Erosion**

Here, the main purpose of selecting of a temporary restoration measure is to prevent a slope from further deteriorating. On the other hand, a permanent restoration measure aims to restore the damaged slope to its original status.

Selection procedures of the temporary and permanent restoration measures are explained using flow charts shown in Fig.9.2.7 and Fig.9.2.8, respectively.

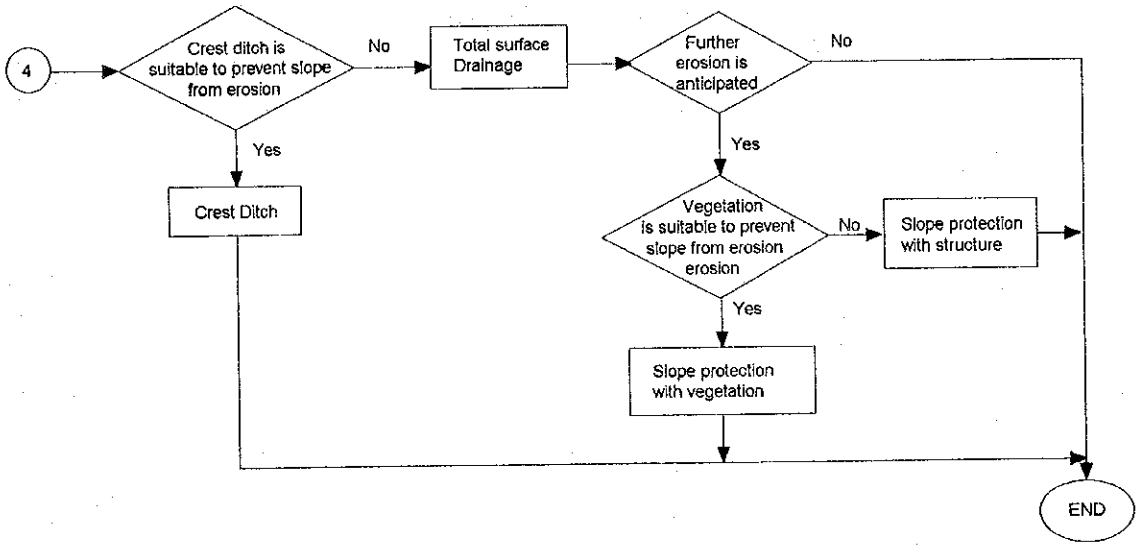



Fig.9.2.7 Selection of Temporary Restoration Measures in the Case of Slope Erosion

In general, restoration measures for slope erosion are classified into the following six types.

a) Rerouting

If a road section has a history of being damaged by erosion at many different sites and repair work is estimated to be very costly, the following two basic ideas shall be compared and the most preferable one chosen.

- Rerouting of road section to avoid area prone to erosion.
- Restoration of damaged spots original functions.

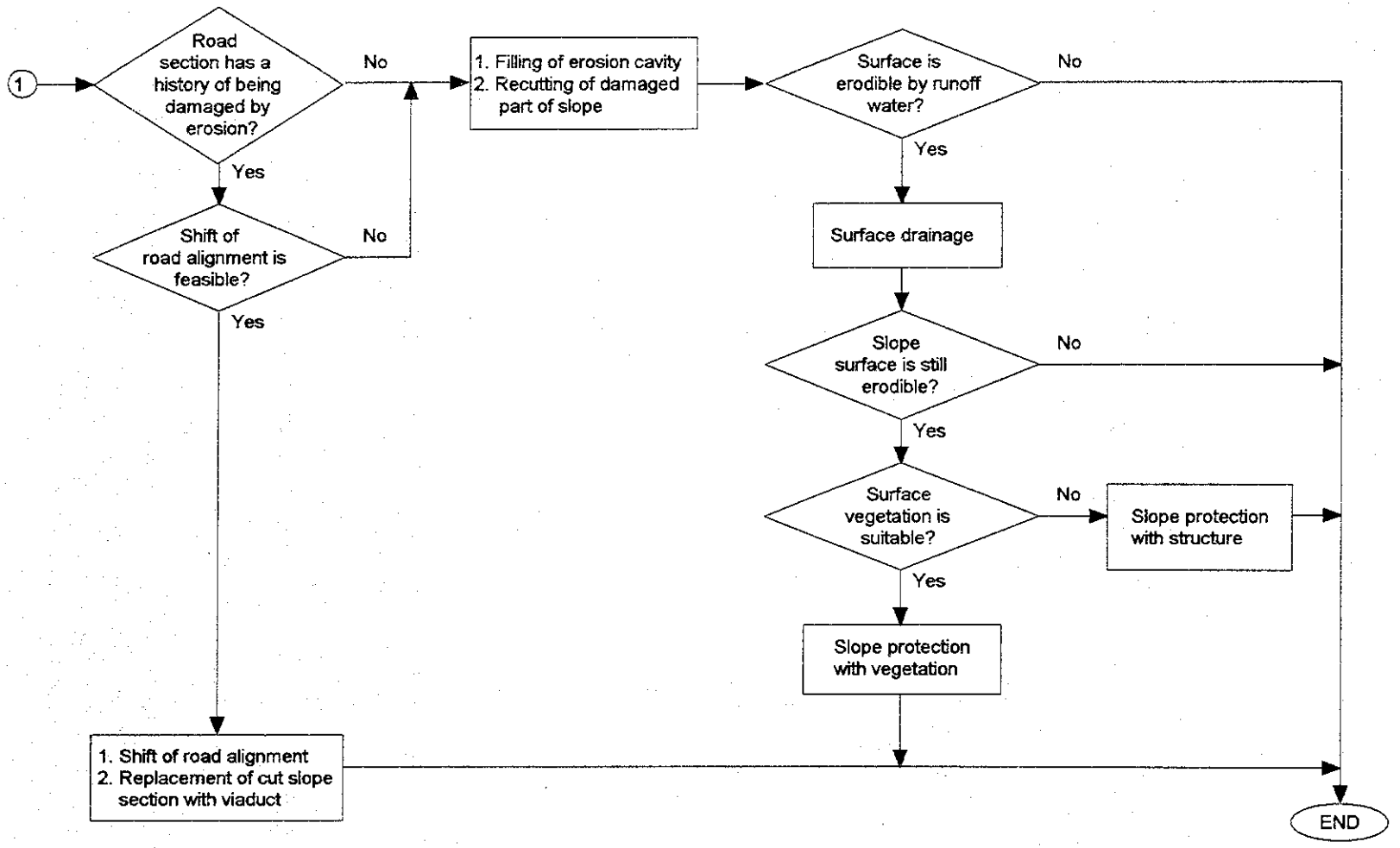



Fig.9.2.8 Selection of Permanent Restoration Measures in the Case of Slope Erosion

b) Shifting of road alignment

The lateral shifting of a road alignment shall be compared with other alternatives, and an examination will be made to see if there is sufficient apace for shifting and if the new alignment will be unaffected by erosion debris.

b) Restoration of original functions with earth work

This work can be executed using two types of measures. One fills the erosion cavities until the original surface is restored. The other recuts the damaged slope deeper than the original slope.

c) Elimination of the cause of erosion

The flow of runoff water on a slope's surface is a major cause of erosion. This problem can be eliminated greatly by surface drainage, in particular, by a crest ditch.

The applicability of different types of drainage for different slope conditions is shown in Table 9.2.1.

Table 9.2.1 Application of Surface Drainage

| Method | Geology | | |
|---|---|---|---|
| | Hard Rock | Soft Rock | Soil |
| Crest ditch | B | A | A |
| Berm ditch | C | B | A |
| Toe ditch | A | A | A |

A: Most suitable
B: Suitable
C: Not suitable

d) Protection of slope surface with vegetation

Vegetation on a slope's surface is effective in reducing the velocity of runoff water flow and therefore preventing erosion. For reference, the relationship between the geological conditions of a slope and the different types of vegetation work is shown in Table 9.2.2.

Table 9.2.2 Applicability of Vegetation Work by Type of Slope

| Method | Geology | | | |
|---|---|---|---|---|
| | Cut Slope | | | Fill Slope |
| | Hard Rock | Soft Rock | Soil | Soil |
| Block sodding | D | D | A | A |
| Spot sodding | D | C | B | A |
| Seed packet work | D | A | A | D |
| Pick-hole seedling work | D | C | A | A |
| Seed spraying with a pump | D | B | A | A |

**A: Highly recommendable**
**B: Recommendable**
**C: Difficult to recommend**
**D: Not Recommendable**

e) Protection of slope surface with a protective structure

Covering a slope surface with a protective structure is a reliable solution, but it is unsightly and costly. Therefore, combining structures and vegetation, such as cribwork and vegetation work, is more desirable for aesthetic reasons.

The type of protective structure to be used as a surface covering will be selected based on Table 9.2.3.

Table 9.2.3 Applicability of Protective Structures by Type of Slope

| Method | Geology | | | |
|---|---|---|---|---|
| | Cut Slope | | | Fill Slope |
| | Hard Rock | Soft Rock | Soil | Soil |
| Stone pitching | D | C | A | A |
| Concrete block pitching | D | C | A | A |
| Gabion work | D | D | C | B |
| Shotcrete | A | A | C | C |
| Cribwork | A | A | A | A |

**A: Highly recommendable**
**B: Recommendable**
**C: Diffcult to recommend**
**D: Not Recommendable**

2) **Rockfalls**

As shown in Fig.9.2.9, a rockfall is mostly triggered by rainfall or the weathering of a slope.

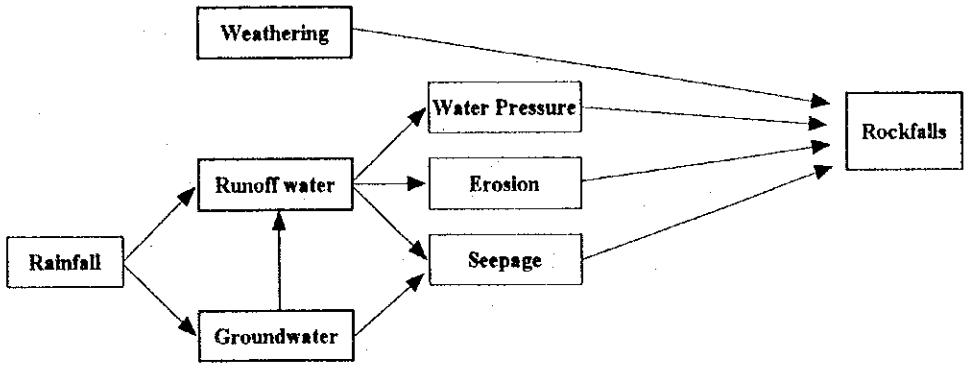



Fig.9.2.9 The Cause of Rockfalls

The selection procedures for the temporary and permanent restoration measures are explained using the flow charts shown in Fig.9.2.10 and Fig.9.2.11, respectively.

Applicable restoration measures in the case of rockfall damage are described below.

a) Rerouting

If a road section has a history of being damaged by rockfalls frequently and the cost for repair work is estimated very high, the two fundamental ideas below shall be compared and the most suitable one chosen.

- Rerouting of the road section to avoid the area prone to rockfalls.
- Restoration of damaged spots to their original state.

b) Shifting of road alignment

The lateral shifting of a road alignment shall be compared with other alternatives, and an examination will be made to see if there is sufficient space for the shifting and if the new alignment will be unaffected by rockfalls.

c) Removal of remaining unstable rocks

If there are still unstable rocks remaining on the slope surface, they shall be removed using the measures below. The

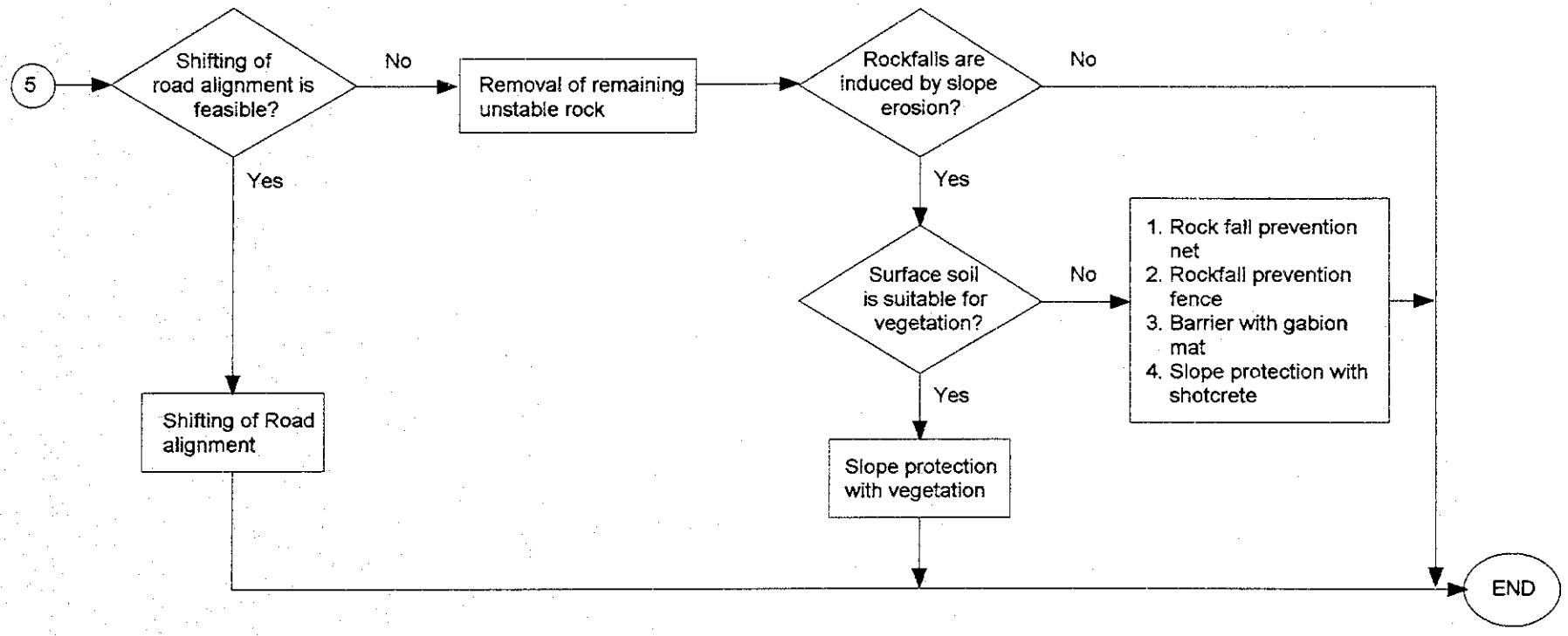



Fig. 9.2.10 Selection of Temporary Restoration Measures in the Case of Rockfalls

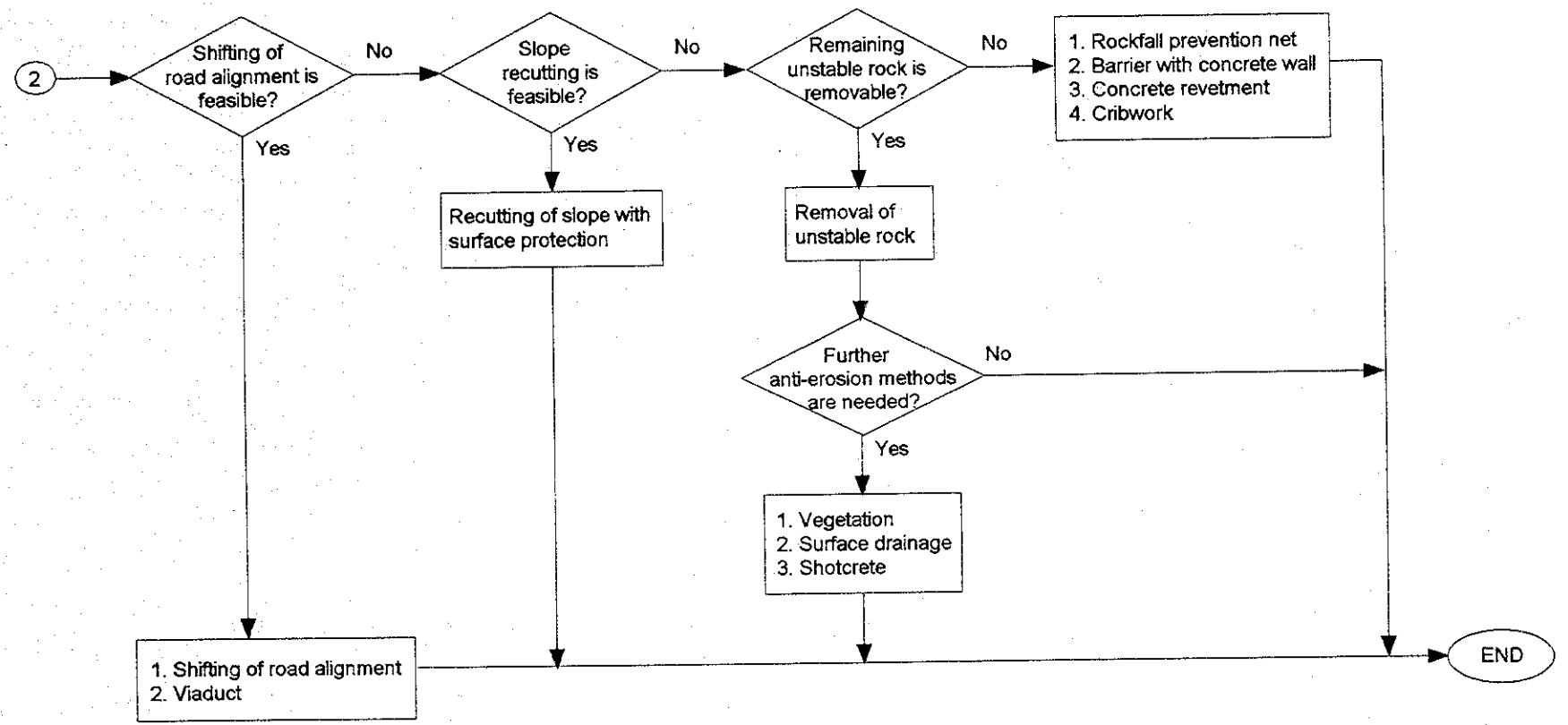



Fig. 9.2.11 Selection of Permanent Restoration Measures in the Case of Rockfalls

type of removal method depends on traffic conditions, slope conditions, etc.

- Mechanical/manual excavation
- Undercutting with hydraulic sluicing
- Blasting in place

This measure is the most reliable and recommendable.

d) Protection of slope from erosion

In order to prevent stable rocks from becoming unstable rocks due to erosion, the following measures can be applied.

- Surface drainage
- Shotcrete
- Surface vegetation

e) Rockfall prevention devices

The followings are applied as rockfall prevention devices.

- Slope covering with wire net.
- Rockfall prevention fence installed at the foot of a slope.
- Rockfall prevention barrier made of gabion mats or a concrete wall.
- Slope covering with structure (concrete revetments, cribwork, etc.).

The relationship between the type of measure applied and the estimated size of falling rock is shown in Table 9.2.4.

Table 9.2.4 Applicability of Rockfall Prevention Measures by Rock Size

| Estimated size of falling rock | | Huge ( Ø 1.0 m) | | Medium ( Ø 0.4 m) | | Small | |
|---|---|---|---|---|---|---|---|
| Measure \ Type of rockfall | | Toppling | Undercutting | Toppling | Undercutting | Toppling | Undercutting |
| Removal of unstable rock | | B | B | B | B | B | B |
| Slope protection from erosion | Surface drainage | B | A | B | A | B | A |
| | Shotcrete | C | D | B | D | A | D |
| | Vegetation | D | B | D | B | D | B |
| Structural support | Foot protection | B | B | D | D | D | D |
| | Concrete revetments | C | C | B | B | B | B |
| | Cribwork | C | C | B | B | B | B |
| | Rock bolts | B | C | D | D | D | D |
| Rockfall prevention device | Prevention net | D | D | D | D | A | A |
| | Prevention fence | D | D | D | D | A | A |
| | Retaining wall barrier | D | D | A | A | A | A |

A : Highly recommendable
B : Recommendable
C : Difficult to recommend
D : Not Recommendable

## 3 **Landslide**

Most landslides on roads occur mainly at cut-slope and fill-slope sections with steep slope gradients. The loss in slope stability is mostly brought about by an increase in the groundwater level due to extensive rainfall and by a loss in slope balance due to human error.

In general, restoration measures for landslides are categorized into three types (excluding rerouting) and they are describe below.

The procedure to select suitable temporary and permanent restoration measure in the case of a landslide are shown in the flow charts of Fig.9.2.12 and Fig.9.2.13, respectively.

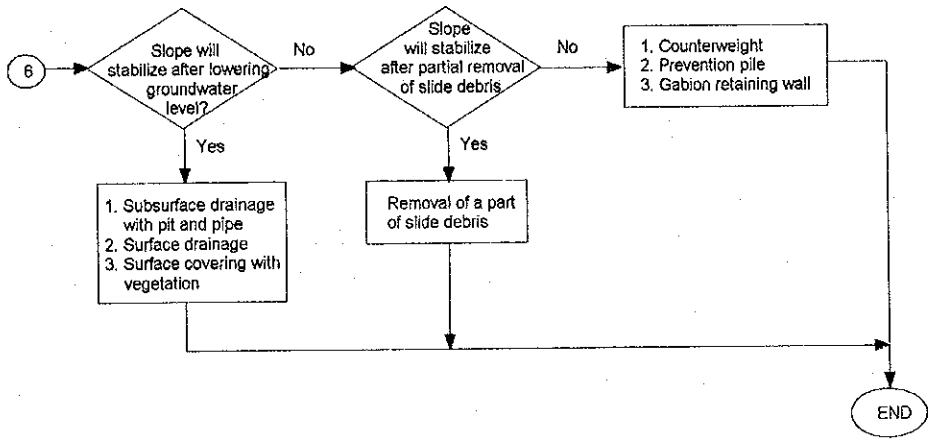



Fig 9.2.12 Selection of Temporary Restoration Measures in the Case of a Landslide

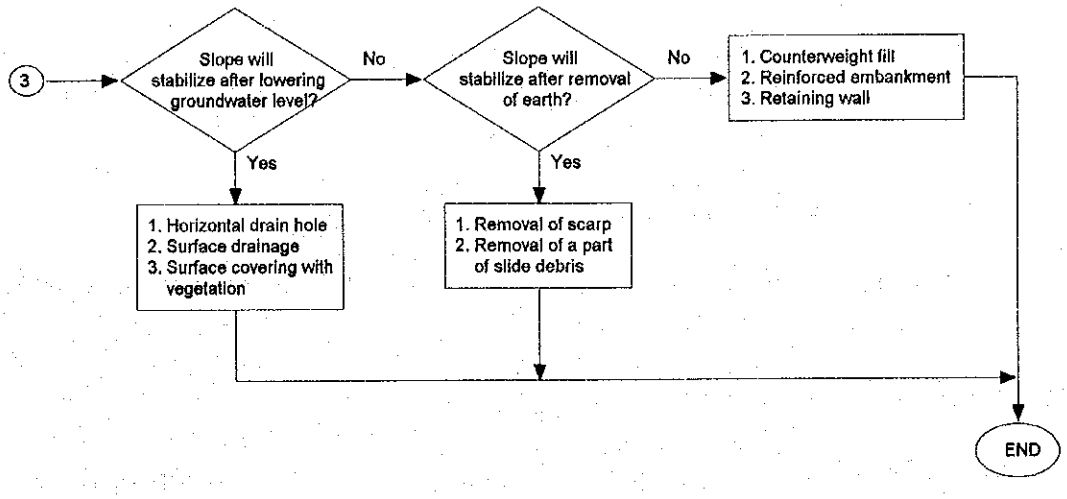



Fig.9.2.13 Selection of Permanent Restoration Measures in the Case of a Landslide

a) Rerouting

If an entire road section has a history of being damaged by landslides and repair work is very costly, the two basic ideas below shall be compared and the most suitable one chosen.

- Rerouting a road section to avoid the area being to landslide.
- Restoration damaged spots to their original state.

b) Control of discharge water

Here, the following two measures are applicable for controlling discharge water:

- Lowering of underground water: a temporary restoration measure would be the application of underground drainage using pit and pipe, while a permanent restoration measure would be the construction horizontal drain holes.

- Prevention of runoff water from permeating into the ground using surface drainage or surface covering with vegetation.

c) Weight shifting

Weight shifting aims to keep the mechanical balance of a slope by removing or filling in some portion of the slope. Specific measures are given below.

- Removal of slide debris: In some cases all of the slide debris is removed, while in other cases a only a portion of the slide debris is removed.

- Removal of scarp portion.

- Counterweight: Earth fills, gabions and concrete walls are possible counterweight material.

d) Structural support

As for the types of structural support, it is possible to have a retaining wall at the foot of a sliding slope or a landslide prevention pile, which is driven into the ground

deeper than the slip surface in the middle of the slope.

Restoration measures for a spot can be selected referring to Table 9.2.5. However, final decisions shall be made after a comparative study on various possible measures.

Table 9.2.5 Relationship between Slope Geology and Restoration Measures in the Case of Landslide

| Type of slope | Geology | Surface drainage | Horizontal drain hole | Earth removal | Counter-weight | Retaining wall | Prevention pile |
|---|---|---|---|---|---|---|---|
| Cut slope | Rock | C | B | A | A | A | A |
| | Weathered rock | C | B | A | A | A | A |
| | Colluvium | B | B | A | A | A | A |
| | Clayey soil | A | B | C | A | A | B |
| Fill slope | Colluvium | C | A | C | A | A | A |
| | Clayey soil | C | C | C | A | A | B |

A: Most suitable
B: Suitable
C: Not suitable

4) **Collapsing of Bridge**

The collapsing of a bridge can usually be attributed to one of the following four cases, each of which has several countermeasures.

- Insufficient discharge capacity
- Scouring by river flow
- Undesirable bridge crossing
- River bank scouring by meandering river flow

Restoration measures suitable for the cause of damage shall be selected in line with the flow chart in Fig.9.2.14.

a) Insufficient discharge capacity

In general,in the case of a bridge collapsing, the role of repair work is to restore the original functions of the bridge. However, this is not sufficient in the case of damage occurring due to insufficient discharge capacity. Accordingly, the improvement of discharge capacity would be required to prevent future damage, and specific measures are as follows:

- Dredging of river channel
- Extension of bridge
- Construction of auxiliary bridge

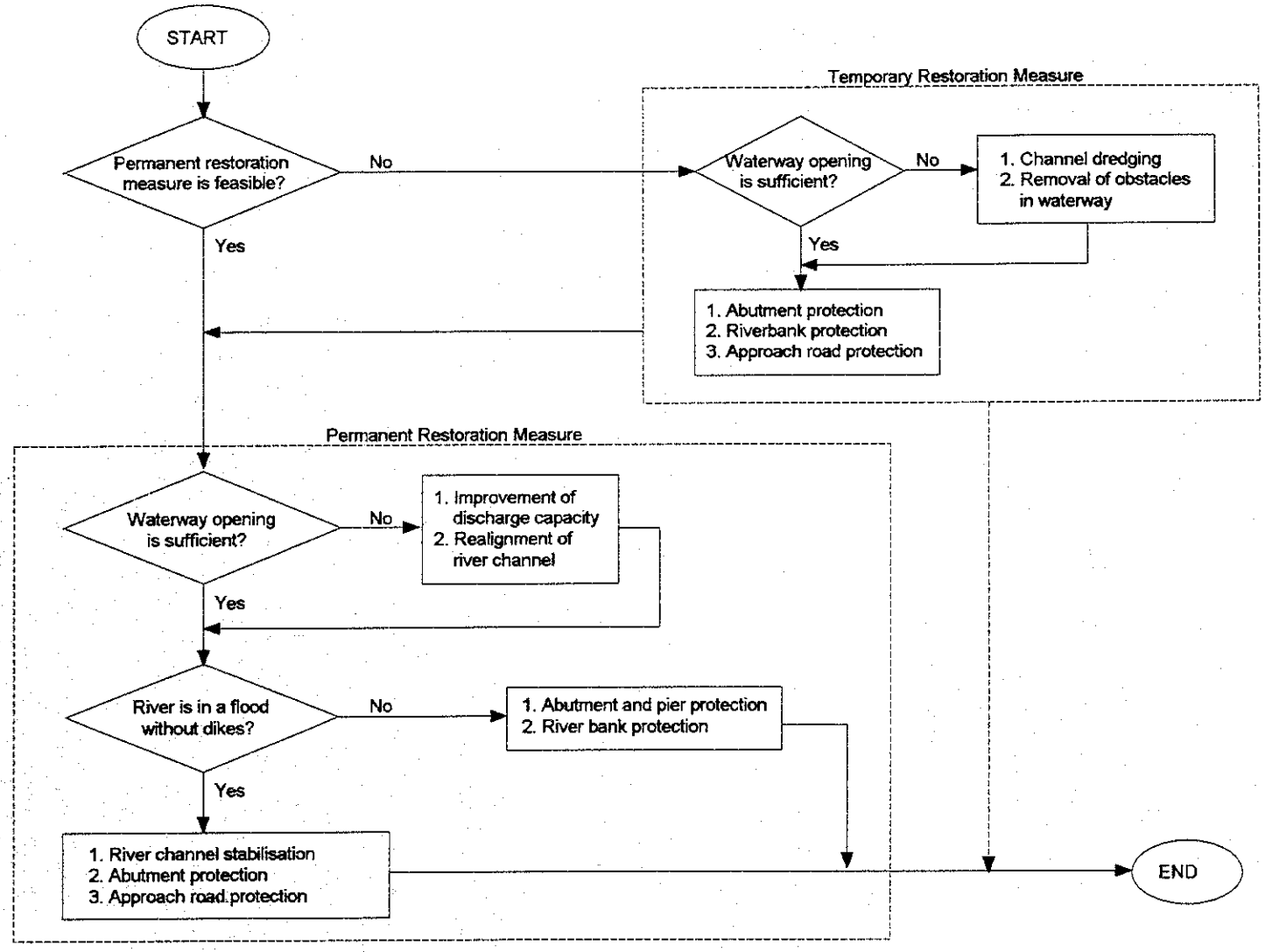



Fig.9.2.14 Selection of Restoration Measures in the Case of the Collapsing of a Bridge

b) Scouring by river flow

If a river is in a flood plain, the river channel is prone to shift and result in the scouring of abutments and access road embankments. Therefore, when the above-mentioned damage occurs, the damaged portion shall be restored applying the measures below.

- Restoration of abutment and pier scouring: For abutments, cylinder gabions, stone riprap or concrete revetments are applicable, while for pier scouring, mat gabions are used.

- Restoration of access road scouring: Earth fill and gravel fill is applicable to repair damage, while gabion mats,stone riprap or concrete revetments are used to maintain repaired portion in good condition.

In addition, the following measures shall be applied to eliminate the causes of damage:

- Stabilization of river channel: The stream's channel shall be protected from scouring using dumped rock and/or cylinder gabion.

- Training of the stream: In the vicinity of a bridge crossing, the river shall be trained to eliminate water turbulence with a pair of guide dikes.

c) Undesirable bridge crossing

When a road or a bridge is damaged due to the acute intersecting angle between the bridge and the road, the road alignment shall be modified to mitigate the influence of the acute angle in the vicinity of the bridge.

d) Damage of river bank

When a river bank is scoured by a meandering river flow, the river bank shall be restored using stone riprap or concrete revetments.

5) **Collapsing of Embankment Roads**

Most embankment damage occurs at the locations listed below.

- Embankment incident to a river
- Embankment in a flood plain
- Embankment on sloping ground

The type of damage and its causes are peculiar to a location and are dominated by locational conditions described below.

a) Embankment incident to a river

This situation is illustrated in Fig.9.2.15. The type of damage consists mainly of the scouring of an embankment toe caused by a high-velocity river flow.

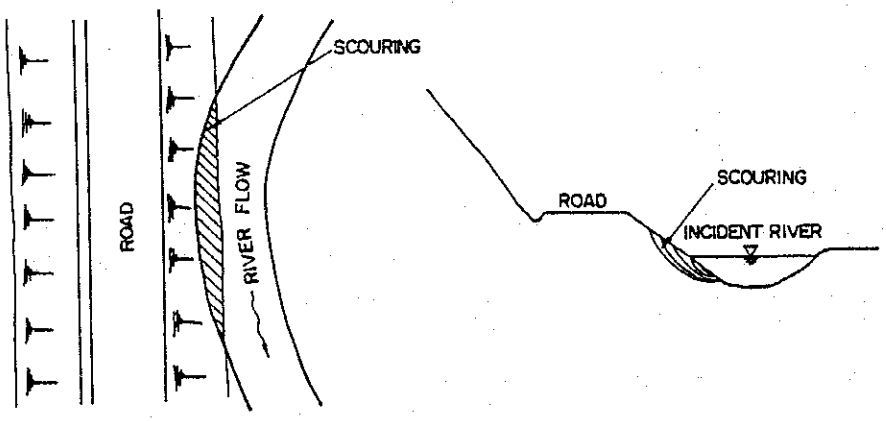



Fig.9.2.15 Embankment Scouring by Incident River Flow

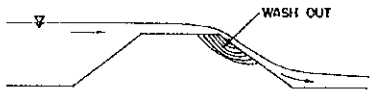
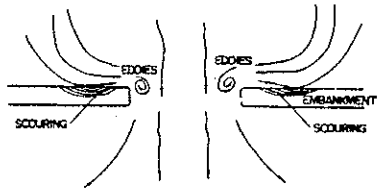
The damage caused by scouring shall be refilled either with earth or gravel fill. The surface of the refill shall be covered with either dumped rock, gabions, stone riprap, concrete revetments or retaining walls to protect it from future scouring.

In order to protect the embankment from future damage, the distancing of the river stream from the embankment is effective.

b) Embankment roads in a flood plain

In this case, there are two types of cause-and-damage relationships as shown in Table 9.2.6.

Table 9.2.6 Cause-and-Damage Relationship for an Embankment Road in a Flood Plain

| | Case 1 | Case 2 |
|---|---|---|
| Cause | Overflow due to lack of discharge facilities | Flood flow along embankments at high velocity |
| Damage | Wash out of shoulder and embankment slope on downstream side | Scouring of embankments on upstream side |
| Illustration |   |   |

In both cases, direct repair work would consist of restoring the damaged portions to original state by filling the cavities caused by scouring with either earth or gravel fill.

To prevent a repetition of such damages, preventive measures shall also be taken at the same time of repair work. For example, if discharge facilities that cross an embankment from the upstream side to the downstream side are not sufficient, the following measures are effective:

- Extension of bridge length
- Enlargement of cross-sectional area of culvert
- Construction of additional bridges and/or culvert

In the case an embankment is scoured by high velocity flood flows in parallel with the embankment, the installation of a pair of guide dikes can be applied.

c) Embankment on sloping ground

In this case, the downstream side of embankment is prone to be washed out when runoff water from upstream is blocked by the embankment due to a lack of discharge facilities, i.e. a culvert or bridge. The cavity caused by the washing out shall be filled using common embankment materials. The situation is illustrated in Fig.9.2.16.

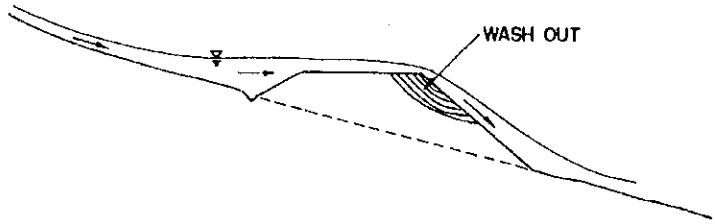



Fig.9.2.16 Washout of Embankment by Overflow

In order to prevent a repetition of this damage, discharge facilities that cross the embankment shall be increased.

Chapter 10

# *Procurement and Arrangement of Materials and Equipment for Urgent Repair Work*

# Chapter 10 Procurement and Arrangement of Materials and Equipment for Urgent Repair Work

When traffic is interrupted by road damage, the road shall be reopened as soon as possible by means of urgent repair work. In order to respond quickly to the demand of urgent repair work, materials and equipment shall be supplied immediately when they are needed.

For this reason, some materials and/or equipment for urgent repair work shall be stored at a stockyard or workshop under the responsibility of a division office. Regarding other materials and/or equipment, the procurement route shall be decided prior to the rainy season.

## 10.1 Materials for Urgent Repair Work

### 10.1.1 Materials to be Stored

In principle, raw materials and primary processed materials for urgent repair work shall be stored at a stockyard. Costly materials that can be procured quickly from nearby suppliers do not need to be stored.

1. List of Materials

A list of the minimum types of materials to be stored are shown in Table 10.1.1. Other additional materials can also be listed based on the type and frequency of past damage in an area.

2. Quantity of Materials

The quantity of each material to be stored shall be estimated based on the past experience of urgent repair work. In case some materials can not be stored sufficiently for some reason, a material procurement route shall be established.

3. Stockyard

Materials for urgent repair work shall be stored at the stockyard of a district office and/or depot as shown in Table 10.1.1.

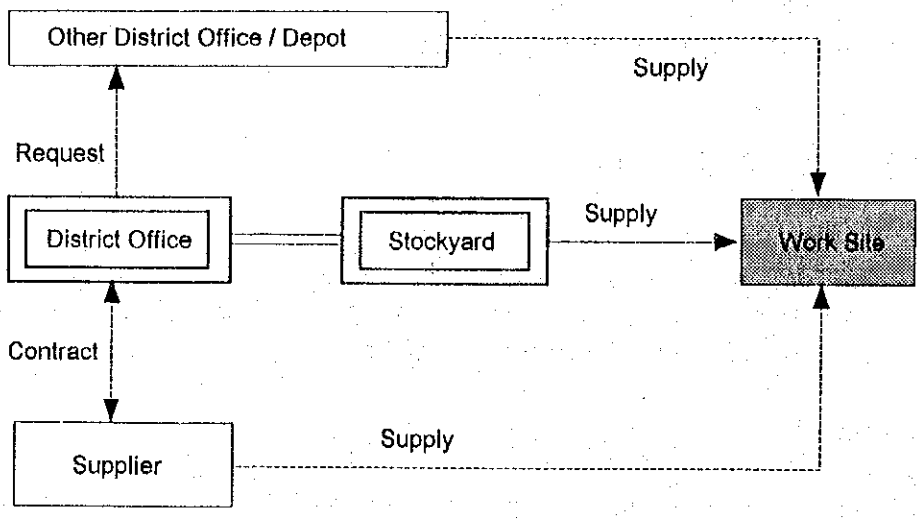
Table 10.1.1 List of minimum type of Materials to Be Stored and Place of Storage

| MATERIAL | TYPE / SIZE | STOCKYARD | |
|---|---|---|---|
| | | District Office | Depot |
| Sand | | ○ | △ |
| Crushed Stone | | ○ | |
| Gravel | | ○ | |
| Portland Cement | | ○ | △ |
| Cold Asphalt | | ○ | |
| Vinyl Sheeting | | | ○ |
| Wire | # 8 - 10 | | ○ |
| Rope | | | ○ |
| Sacks for Sandbags | | | ○ |
| Wire Mesh for Gabion | | ○ | △ |
| Pre-cast U - Type Ditch | 0.30 x 0.30 | ○ | |
| Pipes for Culverts | Ø 0.40 - 1.00m | ○ | |

○ : Main Stockyard
△ : Supplementary Stockyard

## 10.1.2 Procurement of Materials

Materials for urgent repair work shall be procured based on the procurement system shown in Fig. 10.1.1.




——— : Basic Supply Flow
- - - - - : Supplemental Supply Flow

Fig. 10.1.1 Material Procurement System

* Materials for urgent repair work shall basically be supplied from the stockyard of the district office concerned.

* In case the district office concerned can not supply the materials required due to a shortage, it can request assistance from another district office and/or depot.

* When materials are not stored at the stockyard of the district office concerned, they shall be procured from a supplier based on a contract.

Before the beginning of the rainy season, the following precautionary measures shall be taken.

(1) The quantity of materials shall be checked and supplemented if necessary.

(2) The quality of materials shall be inspected and replaced if necessary.

## 10.2 Equipment for Urgent Repair Work

### 10.2.1 Equipment to be on Standby

In principle, equipment for urgent repair work shall be on standby at the workshop of the division office and/or district office and/or depot concerned.

1. List of Standby Equipment

A list of the minimum type of equipment to be on standby is shown in Table 10.2.1. Other equipment needed to repair the damage peculiar to the area concerned can also be listed.

2. Quantity of Standby Equipment

The quantity of each piece of equipment shall be estimated by referring to the past experiences of urgent repair work. In the case a sufficient amount of equipment can not be arranged within a division's jurisdiction, a procurement route and system equipment shall be established prior to the rainy season.

3. Place of Standby

Equipment for urgent repair work shall be on standby at the workshop of a division office and/or district office and/or depot as shown in Table 10.2.1.

Table 10.2.1 List of Minimum Type of Equipment to Be on Standby and Place of Standby

| EQUIPMENT NAME | TYPE / SIZE | STOCKYARD | | |
|---|---|---|---|---|
| | | Division Office | District Office | Depot |
| Patrol Car | | | ○ | ○ |
| Light Truck | 4 - Wheel | | ○ | |
| Medium-size Truck | 6 - Wheel | | ○ | |
| Truck with Crane | 10 - Wheel | | ○ | |
| Bulldozer | 1 - 11 ton | | ○ | |
| Back-hoe | 0.1 - 0.6 cubic meter | | ○ | |
| Motorized Grader | | | ○ | |
| Jackhammer | | | ○ | |
| Tamper / Rammer | | | ○ | |
| Vibration Roller | | | ○ | |
| Compressor | | | ○ | |
| Generator | | | △ | ○ |
| Pump / Hose | | | △ | ○ |
| Barricade | | | △ | ○ |
| Rubber Cone | | | △ | ○ |
| Illumination | | | △ | ○ |
| Shovel | | | △ | ○ |
| Survey Equipment | | | △ | ○ |
| Transceiver | | ○ | ○ | ○ |
| Bailey Bridge | 1 or 2 lanes | ○ | | |

○ : Main StockYard
△ : Supplementary StockYard

### 10.2.2 Procurement of Equipment

Equipment for urgent repair work shall be procured in line with the procurement system shown in Fig.10.2.1.

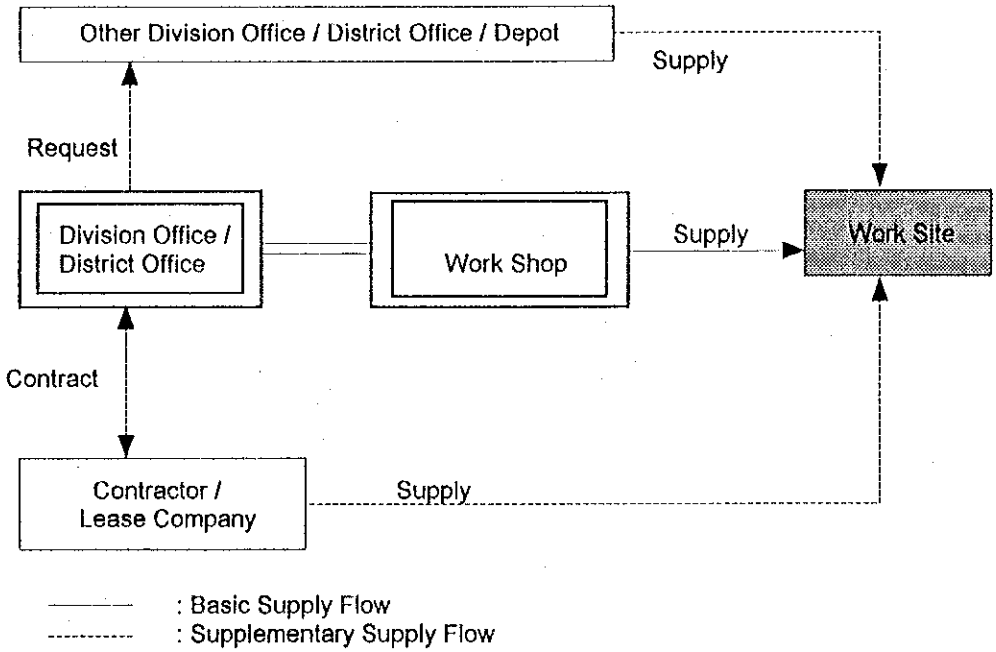



Fig.10.2.1 Procurement System for Equipment

* In general, equipment for urgent repair work shall be provided from the workshop of a division office and/or district office and/or depot concerned.

* In case some equipment is not available within the jurisdiction, the division office and/or district office can request equipment from another division office and/or district office and/or depot.

* In some cases, the division office and/or district office can procure the equipment from a contractor and/or lease company based on a contract.

Standby equipment shall be well maintained to handle emergencies.

Chapter 11

# *Management and Operation for Restoration of Damaged Roads*

# Chapter 11 Management and Operation for Restoration of Damaged Roads

## 11.1 Detection of Road Damage

At the time of a natural disaster, depot staff shall patrol roads on a frequent basis to detect either road damage or occurring damage as a part of a special inspection. The spots to be carefully inspected are as follows:

- Those spots having a history of being damaged.
- Spots adjacent to the spots mentioned above.
- Spots slightly damaged in the past but not yet repaired.

In addition, a road information monitoring system shall be formulated to collect information on damage more promptly. The monitoring system shall be organized by designating truck drivers with regular runs or roadside residents as monitors on a contractual basis. When a monitor witnesses damage or hears of damage, he would report this to the depot or district office concerned.

## 11.2 Transmission of Information

When a road has sustained damage and traffic is interrupted, the information related to the incident shall be transmitted to the authorities concerned, etc. In the transmission of information on road damage, the following two factors shall be focused on.

- The presentation of information to road users.
- The transmission of information to other agencies.

### 11.2.1 Presentation of Information to Road Users

When a traffic is interrupted at the section of a route, the fact of traffic interruption shall be presented to road users using the following measures (refer to Fig. 11.2.1).

- A detour sign
- A road closed sign
- Radio broadcasting

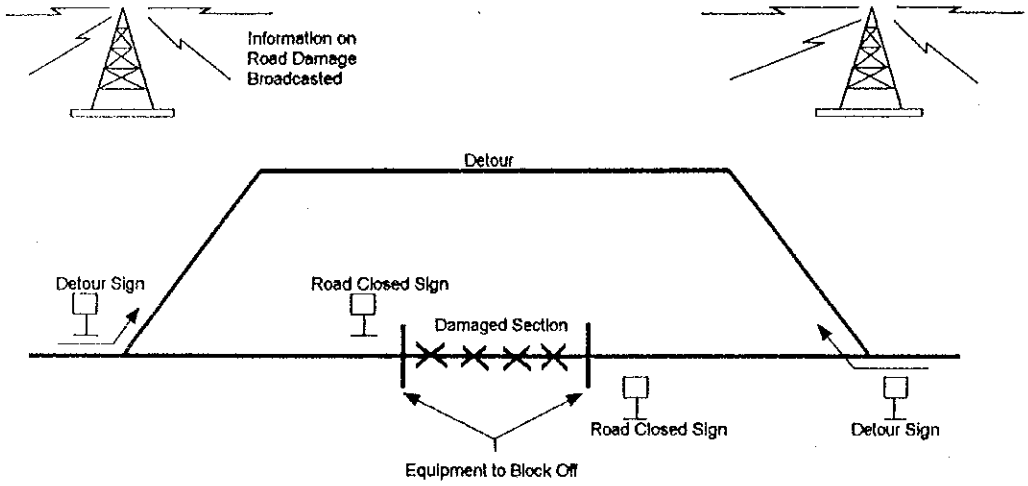



Fig. 11.2.1 Presentation of Road Damage Information to Road Users

## 11.2.2 Transmission of Information to Other Agencies

Information on traffic interruptions due to road damage shall be transmitted to the police department and the local radio station (see Fig. 11.2.2). When the damage is serious and extends over a wide area, the information shall be sent to and broadcast by radio stations throughout the nation.

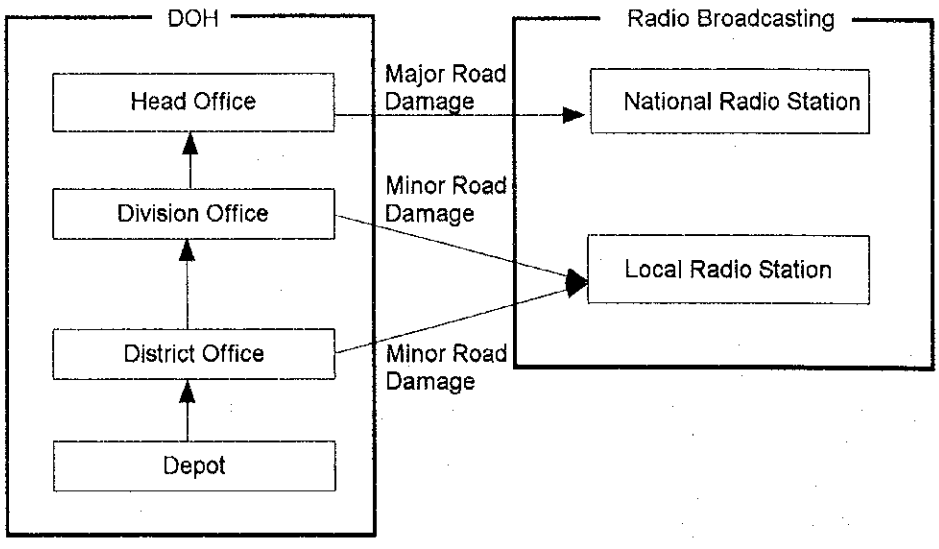



Fig.11.2.2 Transmission of Information to Radio Stations