Standard Operating Procedure for
Road Slope Data Collection induced by Slope Failures

Second Edition
November 2025

Department of Surface Transport
Ministry of Infrastructure and Transport
Royal Government of Bhutan

Preface

This document presents the **Standard Operating Procedure (SOP) for Road Slope Data Collection induced by Slope Failures**. The SOP provides a structured methodology for inspecting, evaluating, and documenting road slope failure conditions, ensuring consistent data collection and supporting informed decision-making for slope management.

This **second edition** supersedes the previous version and has been revised in line with the redeveloped **Road Slope Failure Database (RSFD)** to enhance usability, standardize procedures, and align with current slope monitoring and management practices.

The SOP is intended to support engineers in accurately assessing slope conditions, prioritizing high-risk slopes, planning appropriate countermeasures, and maintaining comprehensive and reliable records. It serves as a practical guide for all personnel involved in slope inspection, monitoring, and data management within the Department of Surface Transport.

The Department expresses its gratitude to the Green Climate Fund for funding this project, and to JICA for its foundational work on the Master Plan Study on Road Slope Management in Bhutan. Appreciation is also extended to Ms. Yeshey Choden, Deputy Executive Engineer, Design and Geotechnical Division, for leading the revision effort and enhancing the SOP to better support users during field data collection.

CONTENT

1. Introduction

Road network plays a crucial role in a country's economic development and growth thereby bringing significant social benefits. Many events perceptibly affect the smooth operation of road traffic especially causing road blocks due to natural disasters such as landslides, debris flow, floods and earthquakes. These events isolate communities, disrupt transport and impose high annual restoration costs on the department.

To strengthen resilience, the department has developed ***Road Slope Failure Database (RSFD)*** to support systematic record-keeping of the road slope failures, selection of countermeasures and improved budget planning. The initiative is built on the *Slope Disaster and Management Database (SDMD)*, first established under the *JICA Project for Master Plan Study on Road Slope Management in Bhutan, 2016* and is now being improved through the Green Climate Fund Project with support from UNDP for uniform adoption.

While the technical aspects of the SOP on road slope data collection remain consistent with the original JICA development, the improved RSFD now integrates both a mobile application (iOS & android) and a web platform. This allows direct field data collection using mobile application, replacing the earlier manual, paper-based process. The upgrade makes data entry more user-friendly and ensures improved effective management of road slope disasters. In line with this enhancement, the SOP is also revised accordingly.

2. Aims and Purposes

To ensure consistent collection of road damage data (induced by slope failures) and inclusion in the database.

3. Objectives

- To maintain proper slope failure inventories
- To select and assess the effectiveness of countermeasures proposed at the sites
- To provide a basis for budget planning and forecasting
- To minimize road operation and maintenance cost
- Guide the site engineers in collecting and maintaining the road slope data

4. User Role & Responsibilities

- **Site Engineers:** The respective site engineers shall be responsible for the collection, regular monitoring, and timely entry of road slope failure data within their jurisdiction. These responsibilities must be included in the Individual Work Plan (IWP) and will form a basis for performance evaluation.

- **Sub-Division Heads:** Shall ensure that all data submitted by site engineers is accurate, valid, and complete, and shall verify that all required monitoring and data entry tasks are fully carried out. The SD Heads shall also collaborate with site engineers during the preliminary site selection for inclusion of slope failure sites in the database.

- **Executive Engineer, Maintenance Section:** Shall strictly enforce and verify that these duties are carried out in full.

- **Chief Engineer, RO:** Shall ensure that the regular inspections are carried out and report to be submitted to the DGD.

The roles mentioned above will be registered as Regional Office users in the database and will have access rights limited to their respective RO, enabling them to add, view, and download data accordingly. The Geotechnical Investigation Section under the Design and Geotechnical Division shall function as the administrator, which will oversee system supervision and address any queries or issues brought to its notice.

5. Framework for Road Slope Disaster and Data Management

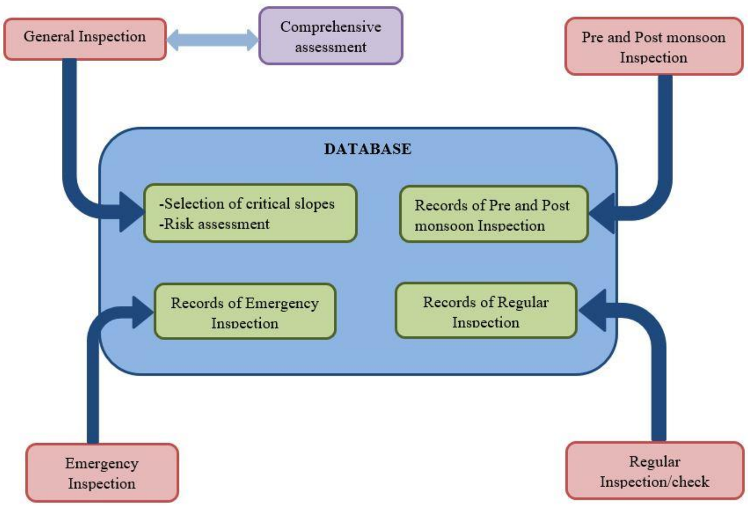


Figure 1: Concept of Road Slope Failure Database

6. General Slope Inspection

A manual for slope disaster inspection indicates a standard methodology of how road engineers should inspect for slope disasters on roads such as landslides, rock falls, slope failures and debris flows. The data can be collected using the mobile application on site and input into the system.

The manual outlines the methodology and procedures for:

1. Disaster inspection at site
2. Evaluation of slope disasters

3. Regular check
4. Management and database

The inspections are performed according to the inspection manual (described in detail here onwards). Data should be updated in real time as inspections are carried out.

Table 1: Contents of the Inspection Manual/ Inspection Tools

Sl. No	Title	Contents
1	Disaster inspection	• General information • Evaluation
2	Evaluation of slope disaster	• Risk assessment • Propose countermeasures
3	Regular check	• Regular check (applicable)
4	Management and database	• Inclusion in the database

7. Inspection Manual (A manual for slope disaster inspection on roads in Bhutan)

The inspection manual provides a standard methodology for engineers to inspect slope disasters such as landslides, rock falls, slope failures, and debris flows, and record the results systematically. Inspections shall evaluate the topographical and geological conditions, past disaster history, and the effectiveness of existing countermeasures. Based on the evaluation, slopes are classified and assigned a criticality rank, which guides prioritization for

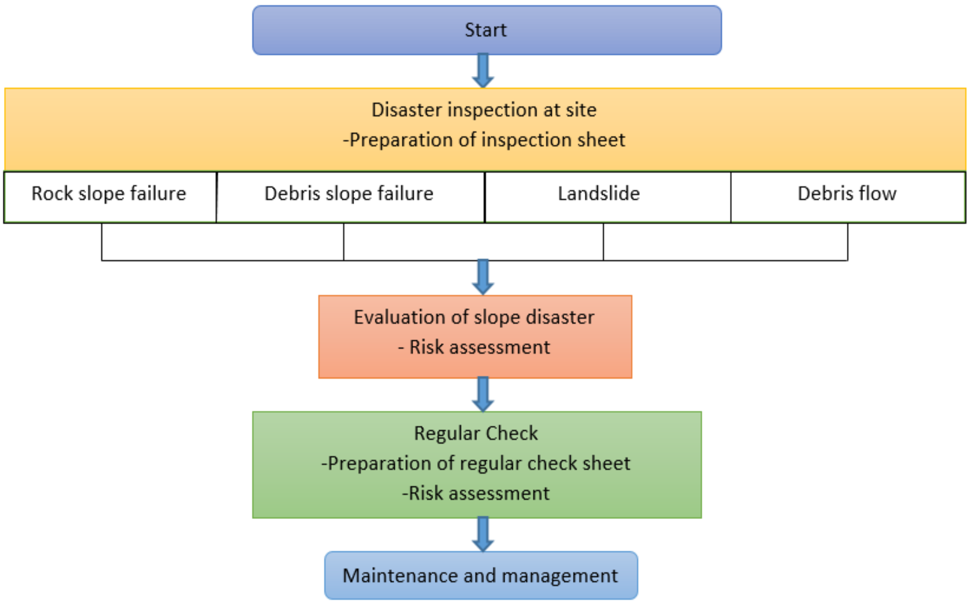


Figure 2: Flowchart of Inspections for Slope Disaster on Roads

management, identification of slopes requiring countermeasures, and monitoring of high-ranked slopes through systematic database entry. Further detailed investigations and analyses may still be required to support the design and construction of countermeasures.

7.1. Slope Disaster Types

The first step upon reaching the site is to categorize the slope according to its disaster type. The evaluation procedure varies depending on the identified type; therefore, correct classification is essential. Each road slope disaster must be categorized into one of the following four types:

1. Rock slope failure - It is a phenomenon in which foliated rocks and gravels start to fall down a slope due to enlarged cracks in the bedrock or outcropped rocks.

2. Debris slope failure - It is equivalent to falls of debris and earth materials and includes rockfalls in some cases. It consists of failures of rock mass detached to steep slopes along the surface and failures of a mass of debris covering weathered or fractured bedrock. This has a quick move in a small-scale in comparison with landslides and the inclination of debris slope failure is relatively higher than that of landslide.

3. Landslide - It is a phenomenon in which the soil mass slips on one or more slip surfaces and gradually shifts downward when triggered by heavy rain, earthquake, erosion, earthworks etc. The land mass moves forming specific topography in relatively large scale, the inclination of the landslide slope is relatively gentle in comparison with that of debris slope failure.

4. Debris flow - It is equivalent to flows of debris and earth materials. Debris flow occurs in the area where soils and boulders are liquefied by surface water or groundwater and tend to flow downward rapidly through a mountain torrent. It usually has huge energy and destructive force. It is generally caused by severe rains as well as rains of long duration.

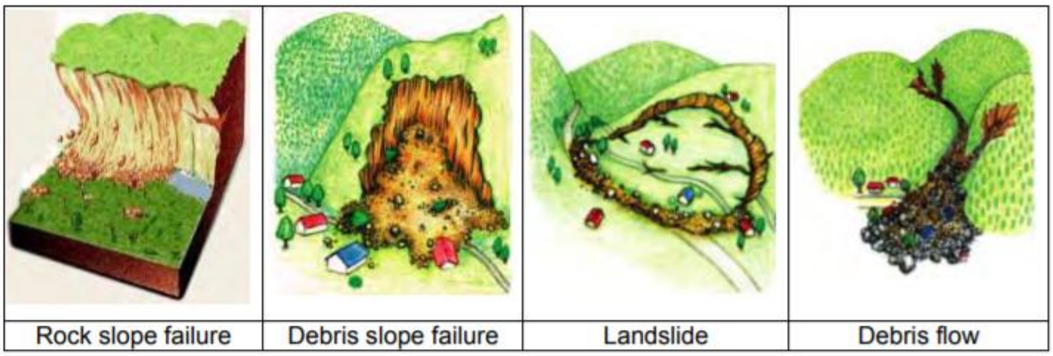


Figure 3: Schematic Images of the Slope Disasters

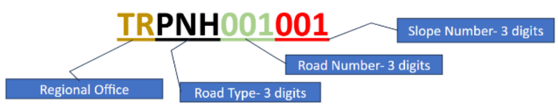
7.2. General Information

The first step is to collect the general information of the slope which gives brief information of the basic condition and situation of the slope. It includes details such as:

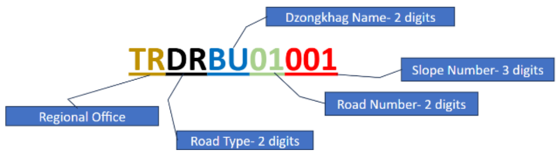
a. Slope disaster name and type
b. Regional Office, Sub-division and Section
c. Road name and type
d. Chainage
e. GPS coordinates and elevation
f. Inspector's name
g. Environmental and social considerations
h. Brief description of the site
i. Critical observations

Upon entry of the general information, a *unique slope ID* is automatically generated for each slope. This 11-digit alphanumeric code serves as the identifier for the target slope and is structured to represent the regional office, road type, road number, and slope number.

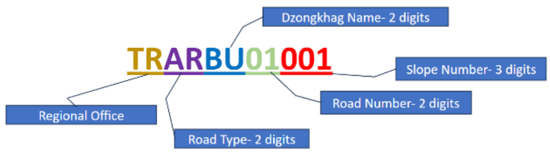
For National Highways



For Dzongkhag Roads



For Access Roads



For Farm Roads

- Regional Office (2 digits) - TR: Trongsa, TH: Thimphu, LO: Lobeysa, LI: Lingmethang, SA: Sarpang, PH: Phuentsholing, TG: Trashigang, SJ: Samdrup Jongkhar, TI: Tingtibi

- Road Type - PNH: Primary National Highway, SNH: Secondary National Highway, DR: Dzongkhag Road, AR: Access Road, FR: Farm Road

- Road Number (2 digits) - 01, 02, 03…

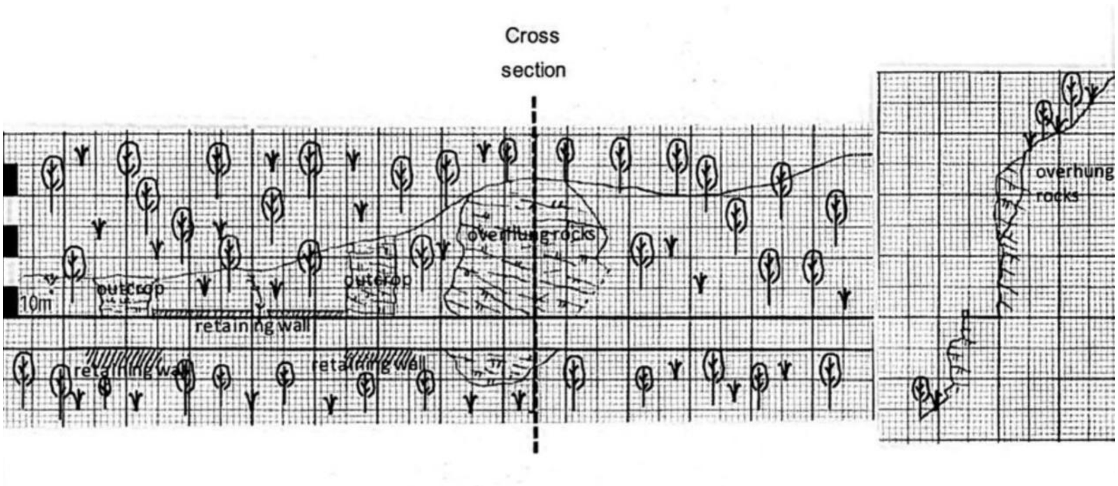
- Slope Number (3 digits) - 001, 002, 003... [Slope number assigned -------]

7.3. Landslide Sketch Mapping

Engineers shall prepare a sketch map of the target slope area along with the cross-section details to supplement the inspection data. The sketch should be drawn on paper at the site and must capture the overall geometry of the slope, the extent of the landslide, and any notable features along with proper legend. Important elements to be included are, but not limited to the following:

- Slope boundaries and orientation
- Location and extent of the landslide or failure area
- Tension cracks, scarp lines, and displaced materials
- Drainage lines, streams, or seepage points
- Existing slope protection or countermeasures, if any
- Adjacent road alignment, structures, and utilities
- Vegetation cover or bare soil patches

The landslide sketch provides a visual record of slope condition that supports the evaluation and helps in future comparison, monitoring, and documentation



. *Figure 4: Example of a slope failure sketch*

To ensure a uniform understanding of the legend, a list compiled from recognized international practices and standards is provided below.

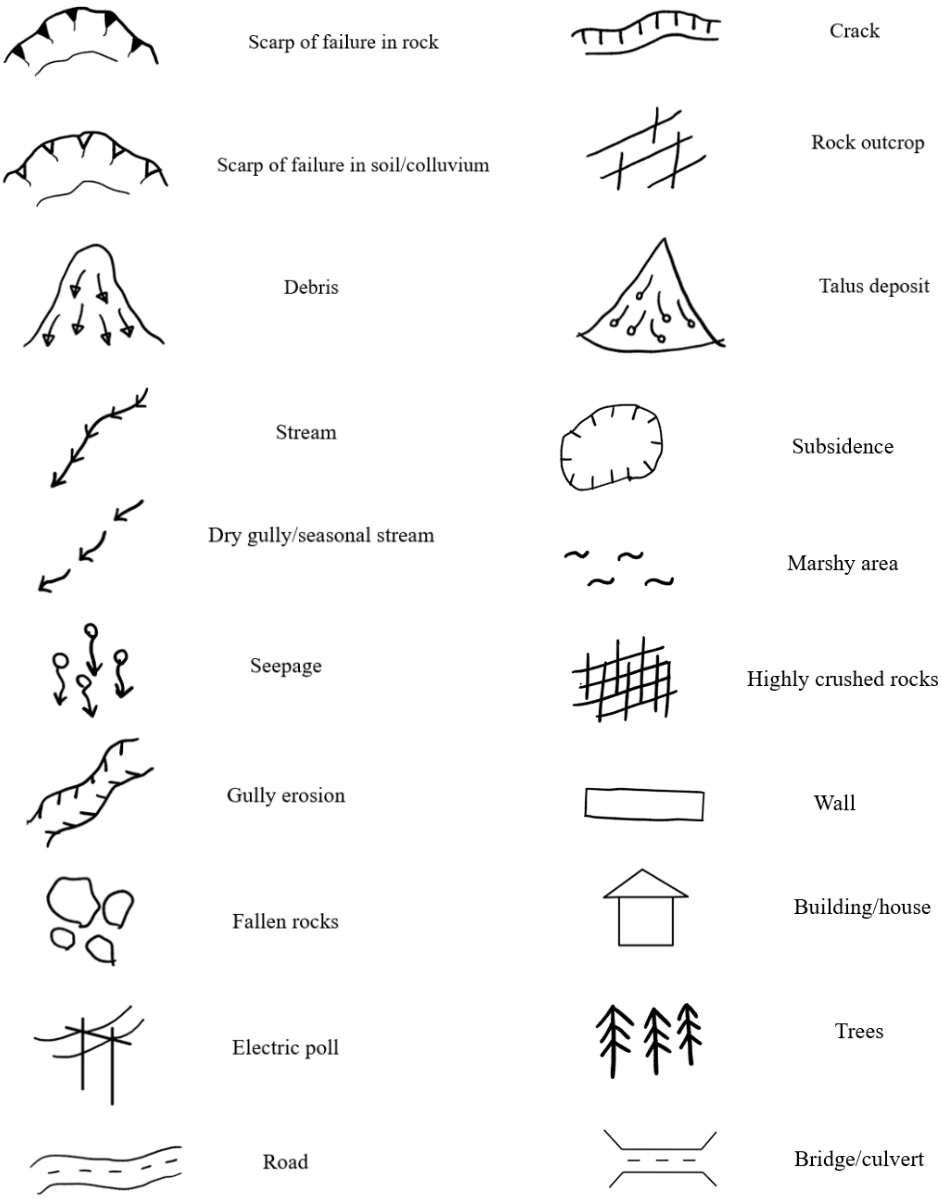


Figure 5: Legend of slope features

7.4. Evaluation of Slope Disaster

7.4.1 Evaluation for Rock/Debris slope failure

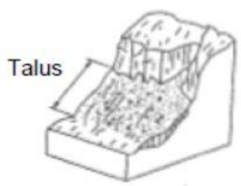
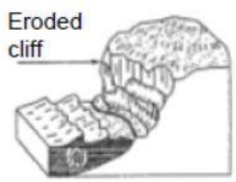
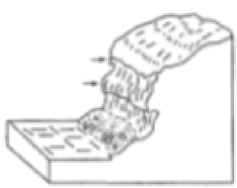
The next step in the process is the evaluation of the target slope. The evaluation process depends on the type of disaster and focuses on key aspects such as topography, geology, surface conditions, and slope anomalies. In addition, the history of slope disasters at the site must be reviewed, and any existing countermeasures should be assessed for their effectiveness.

To ensure uniformity in field inspections, the following section provides a guide to the terminology used in slope evaluation, enabling engineers to carry out inspections accurately and consistently at site. In particular, for debris flow and landslide evaluations, engineers shall use *Google Earth* to support accurate assessment.

a. Topography:

Generally, specific topographical features which are created as a result of the activity of slope failure can be found at the failure prone area. The topographical feature which has those factors of collapse is as follows:

Table 2: Topographical factors

Talus slope		It is a natural slope which shows a sudden gentle angle at the lower part of the slope. It is created by sedimentation of fallen debris from the upper part of the slope and is generally composed of gravelly soil.
Clear convex break of slope (Knick line)		It is a line connecting the point which changes suddenly from gentle angle to steep angle of slope, in view from top of the natural slope.
Eroded toe of slope		Generally the part of the slope which faces the curved river line is eroded by river flow and shows rock exposure or bare land.
Overhang		Overhang can be found on the undulated rock or soil slope surface. Overhang part shows more than 90 degrees of slope angle.

Water catchment slope		It shows a basin-shaped valley and the flow down area is narrow. It is notable that debris can flow down from small scale of water catchment slope and mountain stream

b. Geological conditions

Soil, rock and geological structures which are prone to collapse are evaluated based on their standards. When it is difficult to observe those factors on the target slope, it can be evaluated from neighbor slope condition or existing data, if available.

Soils
The inspector checks whether conditions of the most parts of the target slope conform to the following soil material, and evaluates as “marked”, “a little marked” and “none” according to the actual condition.

- The soil which is “susceptible to erosion” - volcanic ash, highly weathered rock, terrace gravel and sand, sandy soil, etc.
- The soil which has “less strength with water” - silty sand, sandy silt, silty cohesive soil, fine grained soil, etc.

Rocks
The inspector checks whether the condition of most parts of the target slope conforms to the following rock condition, and evaluates the same as above.

- The rock which has “high density of cracks and weak layers” - the rock has crack or weak layer (joint, fault, weak bedding plane, schistosity, intrusion plane, etc) developing within 20 cm to 30cm interval and shows its fragment in the form of plate, column, or cubic.
- The rock which is “susceptible to erosion” - the rock is soft and can be broken by a hammer easily. The rock slope is prone to small scale surface collapse frequently.
- The rock which is “fast weathering” - it is expansive rock and prone to slaking (mudstone, shale, tuffaceous sedimentary rock, weathered schist, etc). Even though these rocks look hard, they are prone to fragmentation.

Geological structure
The inspector checks whether conditions of most parts of the target slopes conform to the following geological conditions and evaluate the same as above.

- The structure which shows "dip slope of bedding plane"
  Check the target slope condition based on the following figures:

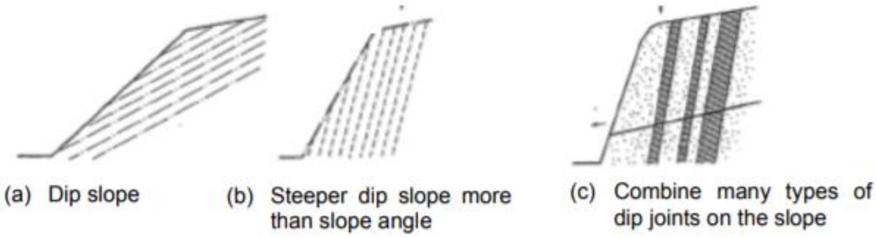


Figure 6: Example of dip slope

- Debris on impermeable bedrock
  Check the target slope condition based on the following figures:

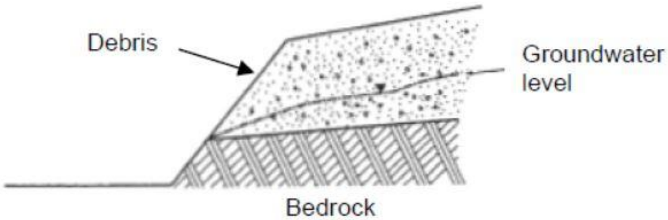


Figure 7: Example of debris on impermeable

- The upper part is hard/the toe of the slope is weak
  The following figure shows this condition. This geological structure is also known as the Cap Rock Structure. The inspector checks not only the structure but deformation of the soft layer at the lower part of the slope and vertical cracks of the hard rock layer at upper part of the slope also.

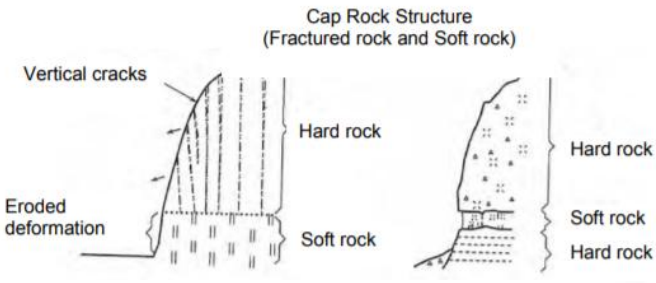


Figure 8: Example of cap rock structure

c. Surface condition

It is important to check the surface conditions on the target slope and it requires careful observation. The inspector checks the surface conditions as listed below and evaluates it according to its standard.

❖ Topsoil, detached rock and unsteady rock

The Stability of topsoil, detached rock and unsteady rock is evaluated in reference to table no. 3. In case of evaluation of instability, it is evaluated based on recent rock slope failure, unsteady rock, bedrock condition around detached rock, bearing condition of fallen rocks, soil, and vegetation condition as well.

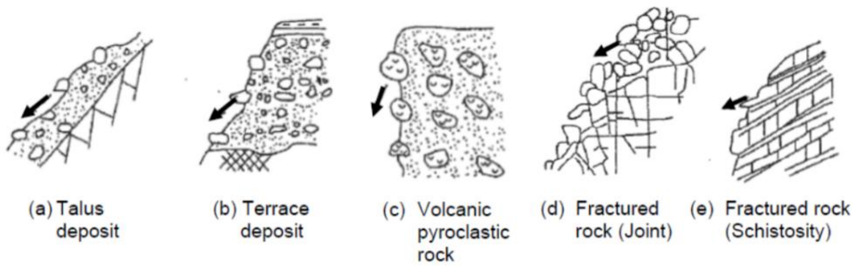


Figure 9: Insufficient bearing condition of detached/fallen rocks rock

Table 3: Criteria of stability of soil, detached rock and unsteady rock

Category	Topsoil	Detached rock and unsteady rock
Unstable	• Thick topsoil layer (more than 50 cm) • Erosion • Trace of movement	A number of rocks with the following conditions are found: • ⅔ part of the fallen/detached rock is exposed • Detached completely or estimated to be moved even by human
A little unstable	• No eroded and trace of movement even if topsoil layer is thick • Topsoil layer is thin but it is eroded or has trace of movement	• The above conditions apply but only in few places • Grade of exposure of rocks is less than ⅔ • Detached slightly and it is estimated to be hard to move by human
Stable	• There is no or thin layer of topsoil and has no trace of movement	• No detached and unsteady rock • Detached/fallen rocks are in stable condition

❖ Spring Water

Even though the number of spring water points and amount of water flow is subjected to change before and after rainfall, it is evaluated following the three stage approach.

- Notable spring water - more than one point of spring water can be found.
- Seepage - observation of wet condition on the cut/natural slope
- None

❖ Vegetation

It is collected from the following three conditions:

- Bare land with minor vegetation - The slope consists of rock and gravel or mainly soil with a grass plant which has weak binding force.
- Intermediate (bare, grass, tree) - Slope surface condition is non-uniform. The slope is covered with mixed conditions with bare land, plant and tree.
- Mainly structure/ mainly tree - It is the slope which is covered with artificial structures or trees

❖ Height and dip

The inspector measures the height (H) and a dip (i) of the target slope in reference with the following figures.

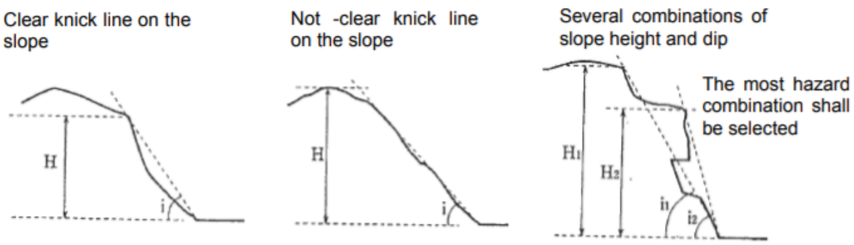


Figure 10: Methodology of measurement of slope height and dip

❖ Anomalies on the cut/natural slope are indications to evaluate the stability of the target slope. Anomalies which are related to slope stability are as follows:

Surface collapse, small fallen rock (more than a few cm diameter), gully, erosion, piping hole, subsidence (more than 10 cm width), heaving (more than 10 cm width), bending of tree root, fallen tree, crack, open cracks, anomaly on existing countermeasure.

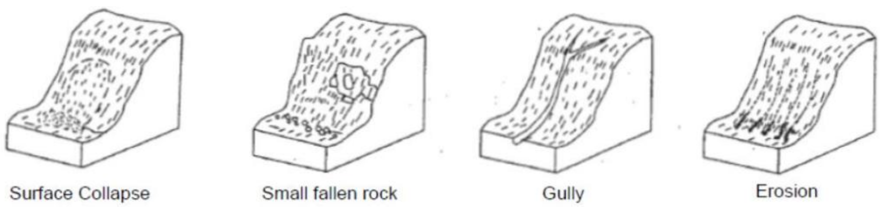


Figure 11: Anomalies on slope

7.4.2 Evaluation for Landslide

Landslides typically involve slow-moving mass movements over extensive areas, which can make field detection of progressive changes challenging. Therefore, a preliminary desktop study using high-resolution satellite imagery, such as Google Earth, is necessary to analyze temporal changes and landslide evolution over multiple years. An example of landslide progression over the years using Google Earth is sown in *Fig. 12*. At the field site, direct observations should focus on indicators of mass movement, including ground subsidence, differential settlement of road surfaces, and the formation of cracks in pavements or other infrastructure.

Figure 12: Example of landslide progression over the years studied on Google Earth

Assessing whether a landslide is located on or near a fault or fracture zone is critical, as field inspection alone cannot reliably establish this. In such cases, the Geological Map of Bhutan should be referred, enabling spatial correlation of the landslide with known structural features, including faults, folds, and fracture zones, while also providing information on local lithology, stratigraphy, and geomorphological context.

These desktop analyses, field observations, and geological assessments must be conducted to evaluate the factors that may contribute to landslide initiation and progression.

7.4.3 Evaluation for Debris Flow

Debris flows typically occur where large volumes of unstable sediment have accumulated along steep channels, or where intense rainfall within the catchment increases the likelihood of debris mobilization. Conducting full walk-through inspections of entire catchment areas is often impractical for many sites. To facilitate preliminary assessment, Google Earth can be used as an efficient alternative for identifying potential source zones and channel pathways. Although the ideal approach involves analyzing topographic data using specialized software, such detailed assessments will be incorporated as the work progresses. For the initial phase, Google Earth will serve as the primary tool for evaluation.

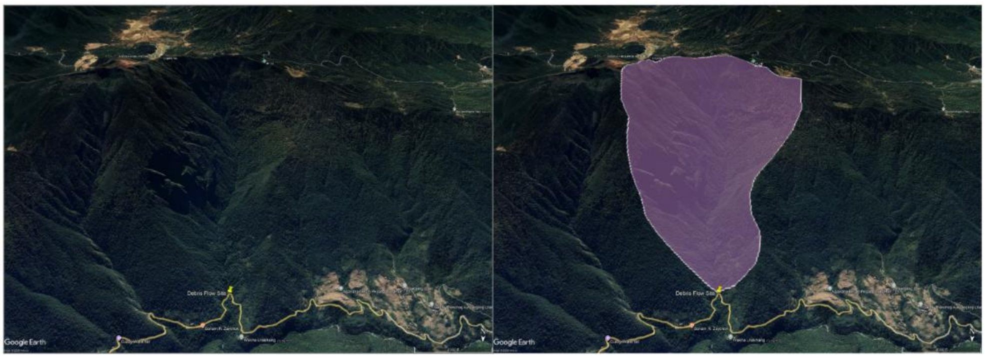


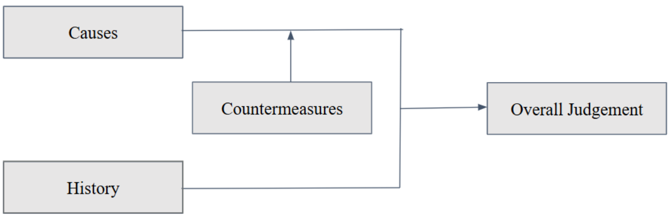
Figure 13: Example of landslide progression over the years studied on Google Earth

Using Google Earth, the catchment boundary should be mapped as shown in *Fig. 13*, and the corresponding debris flow pathway should be examined. In most debris-flow-prone locations, particularly in the local context, cross-drainage structures are typically installed. As part of the assessment, the adequacy of these drainage structures must be evaluated with respect to the contributing catchment area. This includes examining whether the provided clear height and width are sufficient to safely convey expected debris flow volumes.

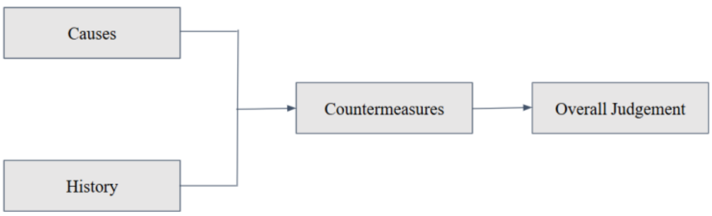
Figure 14: Consideration of structure/cross drainage opening

7.5. Hazard Evaluation

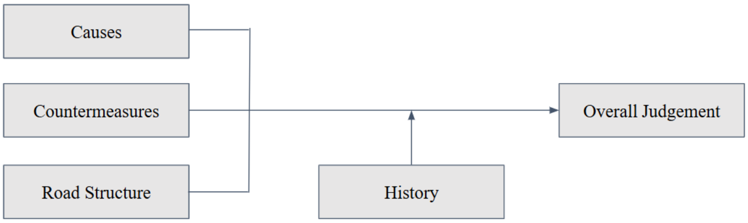
Slope hazards along roads are evaluated based on the road slope inventory, which considers factors such as topography, geological conditions, soil characteristics, effectiveness of countermeasures, and disaster history. For each feature selected as a probable cause of failure, points are assigned accordingly. These points are subject to change based on the effectiveness of existing countermeasures and the history of past disasters at the site depending upon the type of disaster. The final judgement on the slope condition is derived which forms the basis for prioritizing management actions.



Hazard evaluation and risk for Rock/debris slope failure



Hazard evaluation and risk for Landslide



Hazard evaluation and risk for Debris flow

The final judgement is classified into three criticality ranks as shown in table 4; if the total accumulated points from the evaluation, say x, is ≥ 90, then it falls under Rank 1, if x is in between 70 and 90, it falls under Rank 2 and if x ≤ 70, it falls under Rank 3.

Table 4: Rank of Hazard Evaluation

Rank	**Content/Actions**
1	Countermeasure works are necessary
2	Although urgent countermeasures are not necessary, regular checks are needed
3	Countermeasure work is not necessary

8. Road Slope Inspection

8.1. Regular Check/Regular Slope Inspection

Regular checks are conducted for slope sites where the rank of overall judgment by the inspection is either under criticality rank "**1**" or "**2**". These checks serve as a management measure to reduce road risks associated with slope disasters. To assess slope activity, engineers shall identify and mark notable points on the slope that require monitoring during regular inspections. These points shall be recorded in the "check points" section and also marked on the slope sketch. At each marked point, specific features or indicators to be observed shall be documented, providing a reference for all subsequent inspections to track changes or activity in the slope.

Inspections are to be carried out three times a year; typically, in **January**, pre-monsoon in **April**, and post-monsoon in **October**. Regular checks must be performed by all engineers within the stipulated month to ensure timely monitoring and consistent risk management.

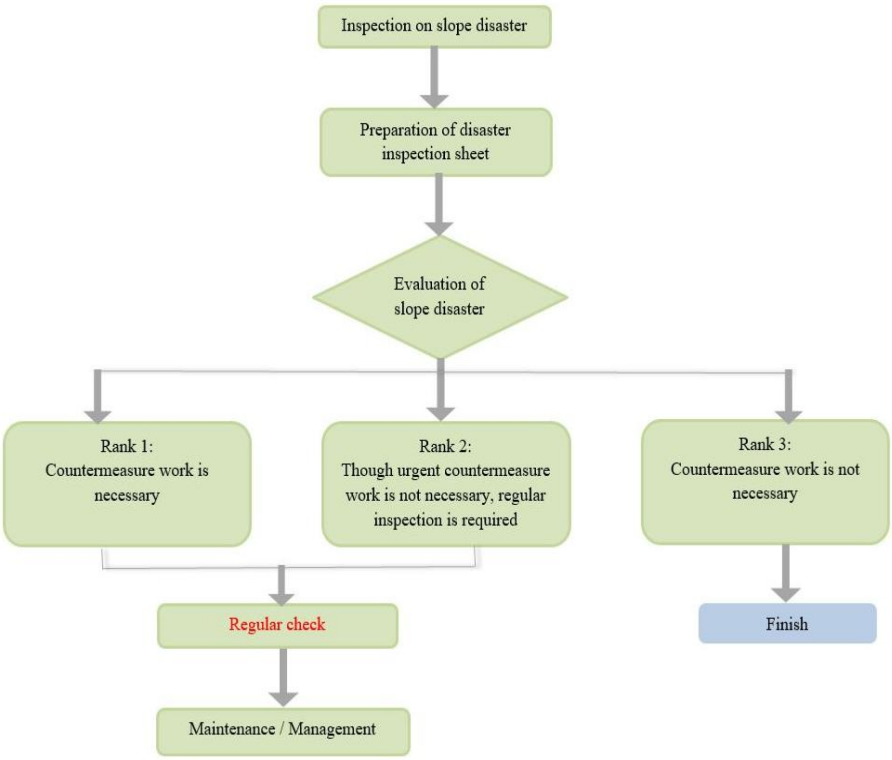


Figure 15. Positioning of Regular Check for Slope Disaster on Roads

8.1.1. Regular Check

The marked points shall be monitored during each regular inspection. Any observed changes must be documented against the respective point with a clear description. If significant updates are required, the slope sketch shall be revised to serve as an accurate basis for subsequent inspections.

Additionally, the overall condition and situation of potential disasters and roads are described in "Condition" as quantitatively as possible. Countermeasures and remedial actions to control/restrict the slope disasters are proposed in "Proposed countermeasure". The details of road blocks, including their duration (in hours) and frequency, up to the time of the regular check for that particular year should also be recorded.

Examples of describing the marked points during regular check/inspection is provided below for proper guidance:

- Rock slope failure - progress and anomalies of potential rock slope failure such as rock fall(s), enlarged crack(s) on rock slope and erosion of unstable rock(s) are checked.
- Debris slope failure/landslide - progress and anomalies of potential debris slope failure/landslides such as new failure(s), swelling, new/enlarged step(s)/cliff(s) and new/enlarged crack(s) on slope are checked.

- Debris flow - progress and anomalies of potential debris flow such as filling up of debris sediments, overflow of debris on road, clogged culvert and new failure(s) on river slope are checked.
- Spring water - anomalies of spring water such as depletion, decrease, increase, new spring and turbidity which are highly connected with slope disaster activities are checked.
- Road - anomalies with road surfaces such as new/enlarged step(s)/settlement(s) and new/enlarged crack(s) on roads which are related with slope disaster activities are checked.
- Countermeasures - anomalies of existing countermeasures such as damage, deformation, clogged drainage and overflow drainage are checked.
- Other problems/anomalies other than those described above are noted.

8.1.2. Expenditure

It is important to record the expenditure details incurred for each target slope. All costs related to slip clearance and the implementation of countermeasures shall be documented and updated annually, ensuring that yearly expenditures are properly reflected for each slope. Maintaining these financial records not only supports accurate budget planning and forecasting but also enables the department to evaluate cost–benefit aspects of slope management, prioritize investments, and justify resource allocation for future works.

8.1.3. Photo Attachments

Photographs must be taken both during the initial data collection and for every regular inspection sheet to ensure continuity of records. To enable meaningful comparison over time, photos should, as far as possible, be captured from the same positions during each inspection.

The photo attachments include at least the following photographs:

- Front view of the target slope,
- Side view (left and right side) of the target slope with the adjoining road,
- Notable findings or anomalies observed on site,
- Slope surface conditions, and
- Existing countermeasures.

**Note: Photographs of the front view, right-side view, and left-side view of the slope are mandatory. **

8.2. Emergency Slope Inspection

Emergency slope inspection shall be carried out after the event of an earthquake or very high intensity rainfall or rainfall for a longer duration in the vicinity. The inspection shall be made in sections which are prone to recurrent disaster and selected slopes evaluated as Rank 1&2.

Similar to the regular check inspection, the date of the emergency inspection shall be recorded along with detailed descriptions of site conditions and observations. Road block details, including duration and extent, must also be documented. Photographs and updated sketches of the slope shall be attached to provide visual evidence of the conditions observed. For slopes assessed during Emergency Slope Inspections that require urgent action, the information shall be reported to the Head Office (HQ) without delay, depending on the severity and extent of the slope failure or disaster.

9. Management and Database

The Road Slope Failure Database (RSFD) is developed to systematically record and update the road slope inventory and inspection data. Site Engineers shall bear the primary responsibility for collecting accurate slope data during inspections and ensuring timely entry and updates in the database without exception. The Sub-Division Heads must be involved with the respective Site Engineers in the preliminary site selection for inclusion of slope failure sites in the database, and then ensure that the data collected is valid and carried out in properly. The Executive Engineer, Maintenance Section under each Regional Office, shall strictly enforce and verify that these duties are carried out in full. The Chief Engineers shall ensure that the regular inspections are carried out and report to be submitted by the RO. Overall supervision and monitoring of the database will be carried out by the *Geotechnical Investigation Section* under the Design & Geotechnical Division, DoST.

The importance of Database are as follows:

- The information collected during slope inspection is useful in identifying potential slope failures in the near future whereby suitable actions could be taken at the earliest in order to prevent occurrence of slope disaster that may cause damage to the road traffic and facilities.
- The records and information on the condition of slopes and applied countermeasures will be useful for the engineers under DoST as well as other agencies.
- Historical records of disaster occurrences and countermeasure implementation provide useful information to prepare further effective and efficient slope management plans.

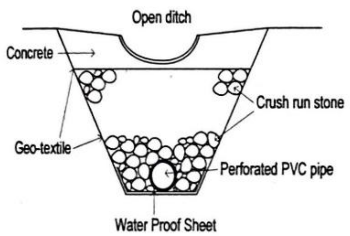
10. Calendar of Events

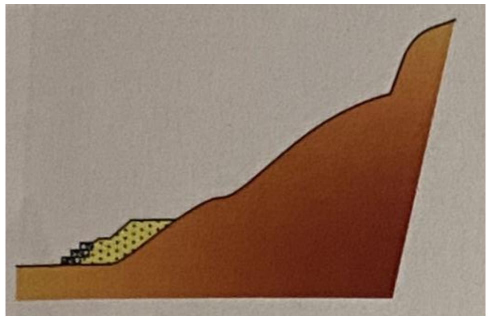
January ○ Regular check/ inspection	February	March
April ○ Pre-monsoon inspection	May	June *Monsoon* * Emergency inspection maybe required *
July *Monsoon*	August *Monsoon* * Emergency inspection maybe required *	September *Monsoon*
October ○ Post-monsoon inspection	November	December

Note: Emergencies can arise at any time and are inherently unpredictable. Events such as high-intensity rainfall, prolonged rainfall, earthquakes, or cloudbursts significantly increase the risk of slope instability. When such conditions occur, inspections must be carried out promptly in accordance with the Emergency Slope Inspection.

11. Catalog of countermeasure works for slope disasters

11.1 Landslide

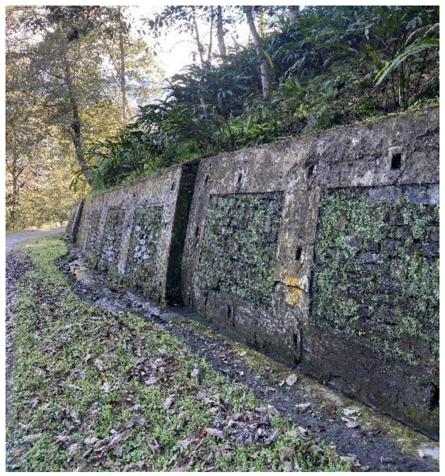
Item	Photo/Drawing	Purpose		Availability	Limitation
Surface Drainage (Open ditch)		To collect surface water and to properly drain it out from the landslide area		This is the one of the simplest countermeasure works for landslides. The work can be expected to avert infiltration of rainfall into the landslide block. Generally, maintenance of the work will not be difficult.	A flexible type of drainage maybe required so that it can adjust to movements in the ground surface due to landslide activity. Otherwise, the drainage will be damaged by the ground movements, and then the water will penetrate into landslide from the damaged points.
Open-Blind Ditch (French drain)		To properly collect and discharge the surface water and shallow groundwater in the landslide area.		In case the groundwater level is near to the surface in the landslide area, the structure will be effective in draining the groundwater and surface water	If the groundwater level is deeper than 2 m from the ground surface, the blind ditch (conduit) part will not function.
Horizontal Drainage		To collect groundwater to draw down the groundwater level in the landslide area.		This is one of the general countermeasure works for landslides. The ordinary drilling machine can be used for the work. Since the work does not require large scale operation, it can be applied as an emergency countermeasure.	If the target groundwater level is deep, the work shall not be applied, and maximum length of the drainage shall be less than 50m. The work will be difficult to apply if the landslide consists of material with a lot of boulders.
Earth Removal		To reduce the sliding force of landslides by removing the part of landslide block		This is one of the simplest countermeasure works for landsides. The work can be expected to have a direct effect for stability of landslides. The work can be used as an emergency countermeasure work.	Depending on the shape of slip surface, the work may not contribute to making stable conditions of the slope.

Counterweight Fill		To increase the resisting force against the sliding force of landslides		This is one of the simplest countermeasure works for landslides. The work can be expected to have a direct effect for stability of landslides. The work can be used as an emergency countermeasure work.	Depending on the location of fill (embankment) on the slope, the work may not contribute to making stable conditions on the slope.
Steel Pile Work		To increase the resisting force against the sliding force of landslides by shear strength of piles.		This work is designed to stop a landslide from moving through structural strength. Therefore, the work can be expected to have a direct effect on stability of landslides.	The pile work will not work properly under the following conditions: • Locations that show steep slip surface or; • Locations on an active landslide; and • Locations which consist of loose material.
Cast-in place concrete Shaft (Caisson)		To increase the resisting force against the sliding force of landslides by shear strength of piles.		This work is designed to stop landslide from moving through structural strength. Therefore, the work can be expected to have a direct effect for stability of landslide. If the restraint force of steel pile is insufficient for the required force to stop the landslide, the shaft work can be adopted. The shaft work can be carried out manually to dig the borehole for the caisson depending on the site condition.	The pile work will not work properly under the following conditions: • Locations that show steep slip surface and; • Locations on active landslide; • Locations which consist of loose material; and • The shaft work requires a firm ground foundation for the structure.

Ground Anchor		To fix a landslide body by transferring tension stress of structure to firm ground.		The work can be used in the following cases; • No ground reaction force expected at a steep slope; • Immediate effect is required for emergency; and • Stabilization measures will be required at the toe part of landslide against partial collapse.	The work requires specific machineries, equipment and materials. Such work may not attain its intended effect if the length of the anchor (free length of anchor) needs to be more than 20 m.

11.2 Debris slope failure

Item	Photo/Drawing	Purpose		Availability	Limitation
Ditch on slope		To collect surface water and to properly drain it out of the slope.		This is the one of the simplest countermeasure works. The work can be expected to avert infiltration of rainfall into the slope. Generally, maintenance of the work will not be difficult.	Nothing special
Re-Vegetation	 	To support stability of slope surface.		This can be recommended for application on all cut slopes if possible. Advantages of the work are as follows: • It is cheap • Easy to implement • Good for environment and landscape.	Good effects are not expected on loose conditions of slope surface. If the work is adopted on a loose surface slope, wicker fence or crib works shall be combined with the work to keep plants on the slope.

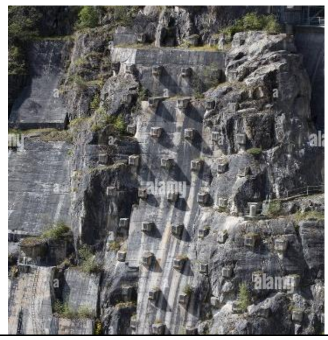
Wicker fence			To maintain stability of a slope surface until the plants planted in the re-vegetation work grow sufficiently.		The work can be adopted on a loose surface slope to keep the material of slope surface. The fence can be made by wood and wooden branches. No machinery is required to implement the work.	The work will be difficult to adopt on hard rock slopes.
Wooden Log Crib			To keep stability of a slope surface until the plants planted in the re-vegetation work grow sufficiently.		The work has almost the same function as a wicker fence. The main materials for the work will be wood and stone.	The work will be difficult to adopt on hard rock slopes.
RRM Retaining Wall	Mas onry Wall		To avoid erosion of slope surface and to keep stability of a slope surface		The work can have a good effect on slopes, especially sediment and weathered rock slopes. The work is designed to avoid erosion and weathering on the surface of slopes. Required materials for the work is boulder and concrete.	The masonry wall shall not be expected to support slope stability as the retaining wall does. The wall shall not be adopted on a slope which has many water seepages without any drainage work for the water.
	Ben ded Wall		To support stability of a slope surface and avoid erosion of slope surface		The work can be adopted if the slope cannot be secured at the appropriate/standard angle due to the limitation of site or topography. The work can be applied to various slope conditions such as a slope with earth pressure or failure-prone slope by water seepage.	The work shall not be installed at slope(s) where the excavation of the toe part of the slope(s) (for installation of the wall) will make conditions of the slope unstable.

RCC Crib retaining wall		To retain slope stability and to avoid erosion and weathering of slope.		It can be used in emergency cases. According to the structure of the wall, the wall does not receive water pressure from the back slope and can flexibly follow deformation of back slope.	The design for members of the wall shall be made properly. It will be difficult to obtain an expected retaining force on slope stability.
Barrier Wall (Concrete/Gabio n)		To avert failed debris or fallen rocks from reaching the road.		If the countermeasure work is difficult to apply on the slope directly, the work can be installed as a prevention measure.	Sufficient space to catch failed debris or rocks shall be required between the slope and the wall.
Re-shaping slope with benching		To make stable slope conditions with appropriate/standard angle		The work gives a direct effect on slopes stability. It is recommended to consider adoption of the work at the first step.	Since a space for machinery like an excavator is required, the work will be difficult to be adopted on steep slopes.
Shotcrete		To avoid erosion, weathering and infiltration of water into the slope.		The work can be adopted on various types of slopes.	Since the work does not have a retaining function, the work shall not be applied on slopes where many unstable rocks are found.

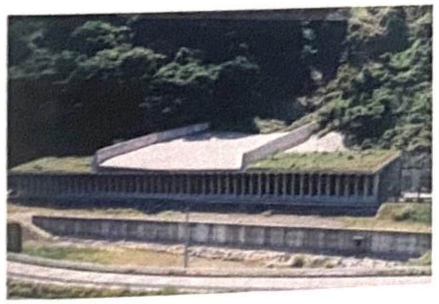
Surface Protection		To support the slope surface stability.		The work can be adopted on various types (forms) of slopes and is a way of avoiding cutting the tress on the slope.	The work may not be adopted on slope which is considered to have potential of large scale failure, and which consists of hard rocks.
Ground Anchor		To fix a slope surface by transferring tension stress of structure to firm ground		In the following cases, this work will be appropriate. • No ground reaction force can be expected at a steep slope • Immediate effect is required for emergency.	The work requires specific machineries, equipment, and materials. The effect of this work may not be obtained as planned; in case the anchor length required (free length of anchor) is more than 20 m.
RC Concrete Crib		To support slope surface stability and prevent erosion.		The work can be adopted to various types (forms) and materials of slope. Generally, this work can be applied with ground anchor work.	This work is not used for artificial slopes.

11.3 Rock slope failure

Item	Photo/Drawing	Purpose		Availability	Limitation
Rock Removal		To remove problematic parts or unstable rocks on slope		The work has a direct effect on hazards of rock slope failures or rockfalls. This work shall be the first option to consider for rock slope failure measures.	The following slope conditions may not be good for implementation of this work. • Hard and massive rocks. • Steep/overhanging slopes; • No access for the machinery for excavation.

Concrete Retaining Wall		To support stability of slopes and avoid erosion and weathering of slope surface.		The work can be adopted if the slope cannot be secured at the appropriate/standard angle due to limitations of site or topography. The work can be applied to various slope conditions such as failure-prone slopes from water seepage.	The work shall not be installed at the slope where excavation of the toe part of the slope for installation of the wall will make unstable condition of the slope.
Barrier Wall (Concrete/Gabion)		To avert fallen rocks from reaching the road		In case of the countermeasure work is difficult to apply on the slope directly as with rock removal or protection rock net; this work can be installed as a preventive measure.	Sufficient space to catch failed debris or rocks shall be required between the slope and the wall.
Protection Rock Net		To fix unstable rocks at original position		The work shall be adopted in case unstable rocks cannot be removed because of site conditions	Since the net shall be fixed by anchor bolt on the slope, such work is not recommended to be adopted on slopes with fractured or weathered rocks.
Rock Bolt (Nailing)/Anchor		To fix loose rock slope or unstable rocks at original position		The work shall be adopted for unstable rocks or unstable rock slopes.	This work is not recommended to be applied in fractured or weathered rock slopes.

11.4 Debris flow

Item	Photo/Drawing	Purpose		Availability	Limitation
Sabo Dam		To catch debris, big boulders or wood debris from trees flowing in the river, such as during the flood, and to discharge only water or with a minimal amount of debris.		The work can be adopted in the following cases. • Expected volume of debris is massive • The river is deep.	Firm ground is required for foundation of the dam
Check Dam (Gabion/RRM)		To break speed of debris or water flow, and to catch some debris, boulders or wood debris from trees flowing in the river, such as during a flood.		The work can be applied on small tributary valleys or gulley as well. The work can be adopted on various gradient of valleys	The dam may not work properly in valleys where there are a lot of debris deposits
Buffer Forests		To break energy of debris flow		The work can be adopted on gentle ground. Advantages of the work are as follows; • Low cost and easy to implement • Good for environment and landscape.	The work cannot be adopted in the following cases. • Steep slopes • Rocky slopes
Shed Work		To discharge debris flow or river water without affecting the road.		The work can be adopted in the following cases, • The estimated volume of debris flow is too massive to be stopped by a Sabo dam • The height of the river bed is higher than the road.	If the height of the river bed is lower than the road, the work cannot be applied.

Culvert/Bridge (RRM)		To make flowing debris pass under the road		The work can be adopted in various conditions of water streams.	It cannot be adopted if large size boulders or large amounts of debris surpassing the dimension of water stream are expected to flow down the stream

11.5 Rock fall

Item	Photo/Drawing	Purpose		Availability	Limitation
Rock Removal		To remove unstable rocks on slopes		The work has a direct effect on hazards of rock falls. The work shall be the first option to consider for rock fall measures.	The following slope conditions may not be good for implementation of the work; • The place is too high to conduct the work • The machinery for excavation is unable to access the site
Protection Wall (Concrete/Gabion)	 	To avert fallen rocks from reaching the road.		If the countermeasure work is difficult to apply on the slope directly as with rock removal or protection rock net, this work can be installed as a prevention measure	Sufficient space to catch failed debris or rocks shall be required between the slope and the wall

Rock Catch Net		To avert fallen rocks from reaching the road by catching fallen rocks from slopes		The work can be adopted on the slope where unstable rocks are extensively distributed.	The net shall not be expected to deal with large energy of fallen rocks. The target rocks shall not be big rocks or rocks at high slope.
Fixing Work by shotcrete		To fix unstable rocks at original position		The work shall be adopted if the unstable rocks cannot be removed because of the site conditions	Since the work does not have a retaining function, the work shall not be applied on slopes where many or massive unstable rocks are found
Shed Work		To protect roads from fallen rocks		This work can be adopted for the slope where many unstable rocks, which are difficult to deal with by other measures, are found.	The shed work has capacity limitations for bearing against falling rock energy. Estimated falling rock energy shall be examined in the design stage of the work.

11.6 OTHERS

Item	Photo/Drawing	Purpose		Availability	Limitation
Tunnel -Route Shift-		To avoid problematic Road sections by shifting routes		The work can be adopted for road sections that cannot be dealt with by other countermeasures because of site conditions or for economic reasons.	The availability shall be determined according to not only topographical and geological conditions, but also economic or political planning.
Bridge -Route Shift-		To avoid problematic road sections by shifting routes.		The work can be adopted for road sections that cannot be dealt with by other countermeasures because of site conditions or for economic reasons.	The availability shall be determined according to not only topographical and geological conditions, but also economic or political planning.

APPENDIX I

Form I (Evaluation Sheet for Debris Slope Failure)

Management Number										

Evaluation sheet (debris slope failure)

Mountain side

Inspector	
Organization	

[Causes] (A)

Item		factor	category of score	Point	score
topography	Collapsed factor	talus slope, clear convex break of slope, eroded toe of slope, overhang, water catchment slope	3 or more correspondences	6	
			2 correspondences	5	
			1 correspondences	3	
			no correspondence	2	
Geological conditions	Soil	susceptible to erosion less strength with water	marked	12	
			a little marked	1	
			None	0	
	Rock	high density of cracks and a weak layers, susceptible to erosion, fast weathering	marked	-	*
			a little marked	-	
			None	-	
	Structure	dip slope of bedding plane	It corresponds.	22	
			None	2	
		debris on impermeability bedrock, the upper part is a hard /the toe of slope is weak.	marked	-	*
			a little marked	-	
			None	-	
Surface codition		Topsoil, detached rock and unsteady rock	instability	8	
			a little unstable	3	
			stability	0	
		Spring water	notable spring waster	8	
			seepage	7	
			none	2	
		Surface condition	bare land with minor vagetation	3	
			intermediate (bare• grass• tree)	2	
			mainly structure, mainly tree	0	
Profile		Height (H), dip (i)	height: H≧ 50m	7	
			height: 30≦ H< 50m	3	
			height: 15≦ H< 30m	-1	
			height: H< 15m	-7	
			dip: i≧ 70˚	21	
			dip: 45˚≦ i< 70˚	4	
			dip: i< 45˚	1	
Anomaly		Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure	2 or more correspondences• clarity	12	
			certain• unclarity	2	
			none	0	
			sum total	(A)	

* : No score

[Disaster type]

Rock slope failure	
Debris slope failure	

[Main check object]

Cut slope	
Natural slope	

[Countermeasure] (B) = (A) +α or (A) ×0

Effectiveness of existing countermeasures	point (α)	check
Potential slope failure are prevented enough, or, it is defended enough when it is generated.	×0	
Potential slope failure are considerably prevented, or it is considerably defended when it is generated.	− 20	
Potential slope failure are partly prevented, or it is partly defended when it is generated. However, it is not enough for the remaining factors.	− 10	
There is no countermeasure, or there is not effective even if countermeasures are not performed.	±0	
sum total	(B)	

[History] (C)

Level of disaster history	point	check
There is a history about large fallen rocks and slope failures that were obstacles to the road traffic after construction of recent measures.	100	
There is a history about large fallen rocks and slope failures that gets to the road though there is no obstacle to traffic.	70	
There is a history about small fallen rocks and slope failures that did not get to the road.	40	
No disaster records	0	
	(C)	

(D) =MAX (B,C)

Score in evaluation from cause	(B)
Score in evaluation from history	(c)
Among (B)&(C), large one.	(D)=MAX(B,C)

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	

[Description]

Form II (Evaluation Sheet for Rock Slope Failure)

Management Number								

Evaluation sheet (rock slope failure)

Mountain side

Inspector	
Organization	

[Causes] (A)

Item		factor		category of score	Point	score
topography	Collapsed factor	talus slope, clear convex break of slope, eroded toe of slope, overhang, water catchment slope		3 or more correspondences	10	10
				2 correspondences	9	
				1 correspondences	6	
				no correspondence	-10	
Geological conditions	Soil	susceptible to erosion less strength with water		marked	16	16
				a little marked	4	
				None	3	
	Rock	high density of cracks and a weak layers, susceptible to erosion, fast weathering		marked	8	8
				a little marked	7	
				None	6	
	Structure	dip slope of bedding plane		It corresponds.		*
				None	-	
		debris on impermeability bedrock, the upper part is a hard /the toe of slope is weak.		marked	-	*
				a little marked		
				None	-	
Surface codition		Topsoil, detached rock and unsteady rock		instability	17	17
				a little unstable	0	
				stability	-1	
		Spring water		notable spring waster	12	12
				seepage	6	
				none	5	
		Surface condition		bare land with minor vagetation	7	6
				intermediate (bare · grass · tree)	6	
				mainly structure, mainly tree	6	
Profile		Height (H), dip (i)	height	H≧50m	12	12
				30≦H＜50m	10	
				15≦H＜30m	8	
				H＜15m	-4	
			dip	i≧70°	13	13
				45°≦i＜70°	-2	
				i＜45°	-7	
Anomaly		Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure		2 or more correspondences · clarit	6	6
				certain · unclarity	5	
				none	2	
				sum total	(A)	100

＊ : No score

[Disaster type]

Rock slope failure	
Debris slope failure	

[Main check object]

Cut slope	
Natural slope	

[Countermeasure] (B) = (A) +α or (A) ×0

Effectiveness of existing countermeasures	point (α)	check
Potential slope failure are prevented enough, or, it is defended enough when it is generated.	×0	
Potential slope failure are considerably prevented, or it is considerably defended when it is generated.	−20	-20
Potential slope failure are partly prevented, or it is partly defended when it is generated. However, it is not enough for the remaining factors.	−10	
There is no countermeasure, or there is not effective even if countermeasures are not performed.	±0	
sum total	(B)	80

[History] (C)

Level of disaster history	point	check
There is a history about large fallen rocks and slope failures that were obstacles to the road traffic after construction of recent measures.	100	
There is a history about large fallen rocks and slope failures that gets to the road though there is no obstacle to traffic.	70	70
There is a history about small fallen rocks and slope failures that did not get to the road.	40	
No disaster records	0	
	(C)	

(D) =MAX (B,C)

Score in evaluation from cause	(B)	80
Score in evaluation from history	(c)	70
Among (B)&(C), large one.	(D)=MAX(B,C)	80

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	O
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	

[Description]

Form III (Evaluation Sheet for Landslide)

Evaluation sheet (landslide)

Mangement number								Inspector	

[Main body of landslide]

Mountain side	
Valley side	
Both	

[Causes] (A)

category			Point	score
Topographical factor	Result of photo interpretation	exist clearly	10	10
		exist but partial and not clear	9	
		exist but not clear	6	
	Surface anomalies	large and new cracks, steps and subsidence	47	7
		small and old cracks, steps and subsidence	7	
		slight deformation	-2	
		no anomalies	-6	
Geological conditions	Geological structure	fault, fracture zone	3	11
		dip slope	4	
		undip slope/ no characteristic feature	11	
	Main rock formation of landslide body	metamorphic rock (schist, quartzite, phyllite etc.)	7	20
		sedimentary rock (sandstone, limestone etc.)	-5	
		igneous rock (granite etc.)	0	
		quaternary deposit (colluvial deposit etc.)	20	
	Hydrological feature	much springs / much seepage	12	11
		little springs /little seepage	11	
		trace of water	10	
		no water observed	2	
		sum total (maximum points:100)	(A)	59

[History] (B)

category			point	score
Records of Landslide	Existing record (documents or patrimony)	obvious	100	75
		slight	75	
		none	0	
	Damage on road facilities and houses	obvious	100	75
		slight	75	
		none	0	
		sum total (Among aboved scores, large one.)	(B)	75

(C) =MAX (A,B)

Score in evaluation from cause	(A) 59
Score in evaluation from history	(B) 75
Among (B)&(C), large one.	(C) =MAX (A,B) 75

[Countermeasure] (D) = (c) + α or (c) x 0

category		point (α)	check
There is no countermeasure		±0	
Effectiveness of countermeasure	No effect	±0	
	Some effect	-30	-30
	High effect	x0	
	sum total	(D)	45

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	o

[Description]

Form IV (Evaluation Sheet for Debris Flow)

Evaluation sheet (debris flow)

Management number								

Inspector	
Organization	

[Causes] (A)

itme	factor	category	point	score
Property of river	areas that river bed is 15°or more in watershed area	0.50km2 or more	10	10
		0.15km2 - 0.50km2	8	
		less than 0.15km2	4	
	steepest slope of river bed	40°or more	10	5
		30° - 40°	5	
		less than 30°	0	
Property of slope	area that slope gradient is 30° or more in watershed area	0.20km2 or more	8	8
		0.08km2 - 0.20km2	6	
		less than 0.08km2	2	
	area that meadow and shrub (less than 10m height) occupy in watershed area	0.20km2 or more	8	8
		0.02km2 - 20km2	4	
		less than 0.02km2	0	
	artificial works that cause negative effects	certain	5	5
		none	0	
	new crack and/or slope failure in stream	certain	5	5
		none	0	
	traces of large slope failure in stream	certain	10	10
		none	0	
		sum total	(A)	56

[Countermesure] (B)

Item・category		sum total of score (A) 20 -	15 - 20	10 - 15	- 10
Effect of existing countermesure	none・low	100	70	50	30
	moderate	70	50	30	10
	high	50	30	10	0
	enough	0			
		(B)	70		

[Road structure] (C) = (B) +α

structure	category of score	point (α)	score
River width	10m or more	-40	-20
	5m - 10m	-30	
	3m - 5m	-20	
	less than 3m	±0	
Beam height	less than 1m or		0
	No bridge / box culvert	±0	
	1m - 2m	-5	
	2m - 3m	-15	
	3m - 5m	-30	
	5m or more	-40	
	sum total	(C)	-20

[History] (D)

category of score	point	check
There is a history about debris flow that were obstacles to the road traffic after construction of recent measures.	90	
There is a history about debris flow though there is no obstacle to traffic.	40	
There is no history of debris flow	0	
	(D)	

(E) =MAX (C,D)

Score from cause	(C)	50
Score from history	(D)	90
Among (C)&(D), large one.	(E) =MAX (C,D)	90

[Potencial disaster mode]

Damage of bridge/culvert	
Outflow of embankment	
Debris flooding on the road	

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	○
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	

[Description]