Japan International
Cooperation Agency (JICA)

Basic Research on Preventive Countermeasures to Cope with Disasters on Roadside Slopes (QCBS)

Final Report

February 2023

Oriental Consultants Global Co., Ltd.
Japan Conservation Engineers Co., Ltd.
Eight-Japan Engineering Consultants Inc.

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List of Abbreviations and Acronyms

Abbreviation / Acronyms	Meaning
AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
ALOS	Advanced Land Observing Satellite
ASTM	American Society for Testing and Materials
AW3D	Advanced World 3D map
B/A	Bank arrangements
BOQ	Bill of Quantity
BOT	Build, Operate and Transfer
BS	British Standard
CBR	California Bearing Ratio
Ch.	Chainage
CHF	Swiss Franc
C/S	Construction Supervision
DB	Design Build
DCP	Dynamic Cone Penetration test
D/D	Detailed Design
DEM	Digital Elevation Model
DGPS	Differential GPS
DLP	Defect Liability Period
DNP	Defect Notification Period
DOD	Draft Outline Design
DoR	Department of Road
DPRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
E/N	Exchange of Note
EIA	Environmental Impact Assessment
EL	Elevation
EOT	Extension of Time
EPC	Engineering, Procurement and Construction
EPS	Expanded Poly-Styrene
FCB	Foamed Cement Banking
FIDIC	Fédération Internationale Des Ingénieurs-Conseils / International Federation of Consulting Engineers
F/S	Feasibility Study
Fs	Factor of Safety / Safety Factor
G/A	Grant Agreement
GCC	General Condition of Contract

Abbreviation / Acronyms	Meaning
GCP	Grand Control Point
GDP	Gross Domestic Product
GIS	Geographic Information System
GL	Ground Level
GNP	Gross National Product
GoJ	Government of Japan
GPS	Global Positioning System
GSI	Geological Strength Index
H.W.L.	High Water Level
ICB	International Competitive Bidding
IEE	Initial Environmental Examination
In-SAR	SAR Interferometry
JAXA	Japan Aerospace Exploration Agency
JGS	Japanese Geotechnical Society
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
JPY	Japanese Yen
L/A	Loan Agreement
L/A	Land Acquisition
LCB	Local Competitive Bidding
L/D	Liquidated Damage
LiDAR	Light Detection And Ranging
M/D	Minute of Discussion
MDB	Multilateral Development Bank
MLIT	Ministry of Land Infrastructure, and Transport
MoRTH	Ministry of Road Transport, and Highway
MoFA	Ministry of Foreign Affairs
MVS	Multi-View Stereo
Mw	Momentum Magnitude
NEXCO	Nippon EXpressway COmpany Limited
NOC	No Objection Certificate
OD	Origin Destination
ODA	Official Development Assistance
O&M	Operation and Maintenance
PC	Pre-stressed Concrete
PFI	Private Finance Initiative
PMU	Project Management Unit
PPP	Public Private Partnership

Abbreviation / Acronyms	Meaning
PQ	Pre-Qualification
PRISM	Pico-satellite for Remote-sensing and Innovative Space Missions
P/S	Preparatory Survey
R/D	Record of Discussion
RFP	Request for Proposal
RMR	Rock Mass Rating
ROW	Right of Way
RQD	Rock Quality Designation
SAR	Synthetic Aperture Radar
SfM	Structure from Motion
SMR	Slope Mass Rating
SOW	Scope of Work
SPT	Standard Penetration Test
T/C	Technical Cooperation
TOR	Terms of Reference
TS	Technical Specification
TTB	Telegraphic Transfer Buying
TTS	Telegraphic Transfer Selling
UAV	Unmanned Aerial Vehicle
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	US Dollar
USGS	United States Geological Survey
VAT	Value Added Tax
V/O	Variation Order
WB	World Bank

CHAPTER 1 Background and Purpose of Research

1.1 Background of Research

In the ODA projects for roads and facilities by JICA including bridges, in case road side slopes are located close to the planned facilities, slope stability of such slopes should be paid attention from viewpoints of disaster prevention of road. And thus, depending on the importance of the facilities, landslide countermeasures should be constructed in the project.

In recent years, many countries with mountainous areas request ODA or Technical Cooperation (T/C) projects for landslide countermeasures. Certain amounts of demand for landslide countermeasures are constantly recognized.

For hill and mountain road development, we have a variety of guidelines and standards already developed in Japan, such as “Technical Manual for Highway Earthwork Structures” recently publicized in 2017. In addition, Japanese engineers have substantial amounts of collective knowledge for hill and mountain road development starting from planning, study and investigation, design, construction, to O&M.

Besides technical knowledge, Japanese engineers share the common understanding against uncertainties in slope disasters on roadside slopes. In addition to constructing special countermeasures or facilities, we understand that continuous efforts should be paid throughout the life cycle of hill roads from planning, study and investigation, design, construction, to O&M to counteract such uncertainties.

In the developing countries where ODA projects are implemented, however, sufficiently developed guidelines and standards such as in Japan and other developed nations are not expected. The collective knowledge and common understanding among the engineers are different from those of Japan as well.

In Japan, in the course of hill road development, road alignment and bridge locations are deliberately considered during planning and design stages so that landslides as well as slope failures caused by road and bridge construction can be avoided. In a preliminary study, which is the earliest part of the project, relevant information is collected not only at bridge locations or along planned alignment but from wide areas surrounding a project route. Such information is used for selecting alignment and/or bridge locations in the aim of reducing not only project cost but life cycle cost against landslides and slope failures.

In ODA projects, similar requirements as in Japan should be fulfilled to limit roadside landslides as well as cost for landslide countermeasures. Thus preliminary information from wider areas surrounding project routes / sites should be utilized for selecting road alignment and/or bridge locations. In ODA Grants, the targeted section of an ODA Grant project is usually sort of short and limited to some important stretches or bridges. Thus comprehensive selection of entire stretch road is not so realistic. Although in a small ODA Grant project targeting a limited section in mountainous / hilly areas, however, in the aim of limiting damage by roadside landslides, road alignment should be well studied by considering available options, such as adopting tunnel / rock shed, shifting alignment slightly to keep pockets for hazards, and shifting alignment to the opposite side of a river with bridges.

For bridge projects in mountainous and hilly regions, in addition to the normal practice for design of bridges, roadside slopes of approach roads should be well studied. Among various factors of bridge design, bridge location significantly affects the efforts of limiting roadside slope failures and thus should be deliberately considered and selected.

Although optimal road alignment and/or bridge location is selected, for bridges in mountainous and hilly regions, certain amount of landslide countermeasures should be properly employed. As understood from an example of Abay Gorge in Ethiopia where an ODA Grant bridge project faced significant damage by the landslides along the approach roads to the bridge, proper planning and design of landslide countermeasures are extremely important.

In addition, landslide countermeasures heavily involve underground conditions, which are difficult to observe by visual inspection from the surface. Substantial of projects have faced unforeseeable landslides and slope failures during and after construction, which often result in variation orders.

In ODA Grants, the project cost stipulated in a Grant Agreement (G/A) is subject to approval by the Cabinet of Japan and thus rarely allowed to change. A preceding preparatory study by JICA provides a project cost estimation for a G/A. This means the ceiling of the project is decided and severely fixed far before the implementation. If the project faces a numbers of variation orders due to unforeseeable landslides, the project cost stipulated in G/A may be insufficient to complete the project and sometimes lead to cut a part of the scope of the project. To avoid such situation, a preparatory study for ODA Grants should be properly conducted to reduce the risks from unforeseeable underground conditions as much as possible.

Furthermore, operation and maintenance (O&M) of roadside slopes in recipient countries of ODA Grants should be properly accounted into consideration for design. Since similar manners of construction and O&M to those of Japan are hardly expected in such countries for roadside landslide countermeasures, in ODA Grants, easy and simple construction and O&M should be taken into consideration for design. In other words, simple and easy construction and O&M should be considered in selecting landslide countermeasures. Since the capabilities of construction as well as O&M are different by recipient countries, in preparatory studies, those capabilities of the recipient countries should be well studied.

On the other hand, when Japanese landslide countermeasures are introduced to developing countries, at the same time, similar technologies developed in other countries should also be understood. The developed countries with mountainous regions also developed landslide countermeasures with high performance. Some developing countries have potential to develop indigenous technologies suitable for soil and geology of their countries.

The 70% of our territory is composed of mountains. Thus landslide countermeasures in Japan are said to be more developed than any other developed countries. The reports or documents that clearly explain superiority of Japanese landslide countermeasures by comparing study methods and functionality of the works are scarcely found.

1.2 Purpose of Research

This research was conducted for the following purpose:

To collect lessons and experience obtained through landslide countermeasures under ODA, especially ODA Grants.

- To collect guidelines and manuals as well as know-hows and expertise from the developed countries of landslide countermeasures and compare them with those of Japan.
- To prepare handbooks (hereinafter referred to as HB) organizing knowledge and expertise effective for design and construction of landslide countermeasures under ODA Grants.
- To facilitate effective implementation and improvement of quality of landslide countermeasures in developing countries.

In the HB, as mentioned in Chapter1.1, to prevent roadside landslides and slope failures, importance of alignment study / route selection is explained. Assuming that alignment study / selection of bridge location is optimized to minimize risks of slope failures, the HB describes necessary technologies in designing essential and proper countermeasures against roadside slope failures. Especially, deliberate consideration on capabilities of construction and O&M of recipient countries is mentioned.

In addition, relative superiority of Japanese landslide countermeasures is explained, if any, in the aim of facilitating formulation of ODA projects. Issues to be faced when introducing Japanese technologies to developing countries are also discussed.

The report of this research is prepared in English as well, in the aim of disseminating the results of research as well as promoting Japanese technologies for landslide countermeasures.

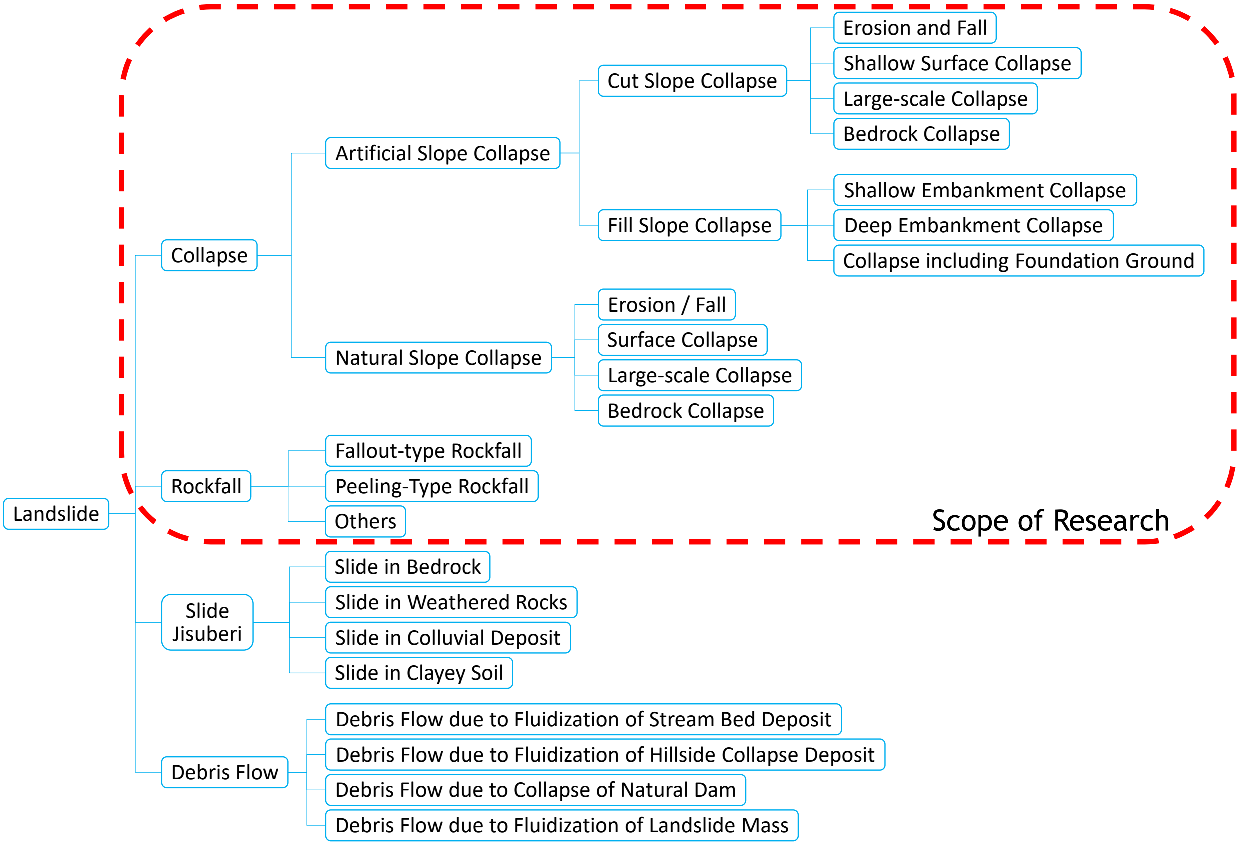
1.3 Scope of Research

1.3.1 Scope of Slope Disaster and Countermeasures to Study

This research assumes a project with landslide countermeasures for important arterial highway. This research also assumes a project to introduce landslide countermeasures to mitigate traffic disruption by roadside slope failures.

This research studied the methods of investigation, design, construction supervision, and quality control for landslide countermeasures, which can be applied to various conditions, such as soil / rock types, groundwater variation, and slope gradient and magnitude.

The type of landslides to be studied are rock fall and slope failure / collapse, as shown in Figure 1-1, surrounded by the red broken line. Rock fall and slope failure / collapse usually occur besides or close to the hill road under ODA Grants. In many cases, the source of rock fall or slope failure / collapse are located within ROW of the project or adjacent to it. Thus countermeasures at the source of disasters are possible under ODA Grants.



(From Manuals for Slope Works and Slope Stabilization, Japan Road Association)

Figure 1-1 Scope of Landslides to Be Studied

On the other hand, repeated landslides on gentle slope, which is referred to as slide / Jisuberi in Figure 1-1, often have a large block of more than several ten meters in length. Possible extent of countermeasures against slides / Jisuberi are likely to exceed ordinary extent of ROW of a project. Thus vast area of land should be acquired if countermeasures against Jisuberi is necessary. In addition, considerable cost is usually required for implementation of preventive measures against Jisuberi. For the implementation of particular countermeasures, special types of equipment is required to be transported to a partner country. Furthermore, design of countermeasures against Jisuberi requires landslide monitoring, which often exceeds usual contract period of preparatory studies for ODA Grants.

Since slides / Jisuberi involves particular types of topographic features, however, blocks of active or dormant Jisuberi can be detected through aerial photo / contour map interpretation as well as field survey.

For new road construction or road widening project, therefore, Jisuberi can be mitigated by shifting alignment in a manner to avoid blocks of Jisuberi or to select less risky areas of such blocks. In preparatory studies for ODA Grants, the aforementioned deliberation should be conducted.

For debris flow, if an ODA Grant project wants to implement countermeasures at sources, surveys and construction should be implemented at mountain / hill slopes and/or steams / torrents, which are usually located far away from ROW of road projects.

As an ODA Grant road project, therefore, passive countermeasures such as avoiding debris flow by bridges and culvers and/or shifting alignment in a manner to avoid middle band of alluvial fans should be adopted. In preparatory study for an ODA Grant, studies and investigation for the aforementioned measures should be conducted.

Although slide / Jisuberi is excluded from the scope of this research, the investigation technologies to identify blocks of slide /Jisuberi are included in this research. And slide / Jisuberi is not excluded for the selection of the existing ODA project to be reviewed in the research.

Landslide countermeasures include structural measures, such as concrete crib works, and non-structural ones, such as landslide monitoring and EWS. This research includes both measures.

One of the purpose of the research is to propose proper methods for study and design as well as construction supervision and quality control of landslide countermeasures that are to be done under ODA projects. The HBs are prepared for this purpose.

1.4 Deliverables of the Research

As the deliverables of the research, HBs and this report were prepared mainly focusing on the countermeasures against rock fall and slope failures. Table 1-1 explains the contents and targets of HBs and each section of this report. These HBs and the report are expected to support planning and implementation of ODA Grants in mountainous regions for highway development and/or improvement as well as bridge construction.

Table 1-1 Contents and Targets of HBs and Report

(JICA Study Team)

Deliverables		Targets	Contents
Handbook	Part 1 Survey and Design	Consultants	✓Shows guidance for study, design, construction plan and cost estimation for ODA Grants in mountainous regions to minimize landslide risks in the project, which may substantially affect G/A amounts. ✓Requests to allocate capable engineers with sufficient experiment to achieve the aforementioned purpose. ✓Requests to establish disaster scenarios for the basis of selection and design of countermeasures. ✓Explained study procedure in flow required to detect unforeseeable disaster risks, even in the project such landslides are not evident.
	Part 2 Construction Supervision and Quality Control	Consultants Contractors	✓Shows guidance for construction supervision and quality control in implementation stages of ODA Grants in mountainous regions, by listing items for construction supervision plan and construction plan / method statements. ✓Highlights the importance of information sharing among the employer, the consultant, the contractor, and JICA as well as monitoring to detect landslides on construction site. ✓Clarifies procedures against landslides on construction sites. ✓Requests handing over risk information to O&M.
	Part 3 Technical Edition	Consultants Contractors	✓Explains technical norms. ✓Explains differences among technologies in Japan and overseas. ✓Explains points to review in design. ✓Shows Q&A about landslide countermeasures.
Final Report		JICA Officials	✓Chapter 1: Purpose and background ✓Chapter 2: Review and analysis of existing ODA projects ✓Chapter 3: Japanese landslide countermeasures ✓Chapter 4: Landslide countermeasures in developed countries ✓Chapter 5: Landslide countermeasures in developing countries

CHAPTER 2 Review and Analysis of Existing ODA Projects with Landslide Countermeasures

2.1 Summary of Existing ODA Projects with Landslide Countermeasures

From the annual reports of JICA and its predecessors, the existing ODA projects with slope protection and landslide countermeasures were selected, including highway and bridge projects with slope / landslide problems. The annual reports listed in Table 2-1were studied.

Table 2-1 Annual Reports and Organization

(JICA Study Team)

Annual Reports	Organization	Fiscal Year Studied	Remark
Japan International Cooperation Agency	JICA (before FY 2004)	FY 1975 ～FY 2003	Details of the projects were not found between FY 1999 and 2003.
	JICA (before FY 2009)	FY 2004 ～FY 2008	After FY 2008, details of the projects were not found.
	JICA (Current)	FY 2009 ～FY2020	After merged with JBIC
Overseas Economic Cooperation Fund	OECF	FY 1987 ～FY 1999	
Japan Bank for International Cooperation	JBIC	FY 2000 ～ FY 2015	After FY 2010, details of the projects were not found.

Some projects were famous for troubles relating to landslides during its construction but not identified in the annual reports. Such projects were added to the selection by supplementing information from webpages of JICA and the ministry of foreign affairs of Japan (MOFA).

As a result, 71 projects were found from the annual reports and other information.

Some trends were understood from the study of the 71 projects and listed in Table 2-2.

Table 2-2 Time Series Trends of ODA Projects Relating to Landslides

(JICA Study Team)

Periods	Trends
1970's	• "Central and East Java Road Betterment Project" was implemented in Indonesia. The project sites included the areas of expansive soil.
Early 1980's	• In the Republic of Colombia, feasibility studies (hereinafter referred to as "F/S") were conducted for road improvement and development crossing the Andes. • An F/S was made for slope protection for a tunnel project crossing Dalton Pass. • A series of F/S were made from FY 1983 for 3 years for "Road Disaster Prevention Project" in the Philippines. This project seems to be the first project from viewpoint of roadside slope disaster prevention.
Late 1980's	• A series of F/S were made from 1985 to 1986 for "The Project for Construction of Sindhuli Road" in Nepal. The project proposed by the F/S was, however, considered to put heavy burden to Nepal. Then an aftercare study was requested by Nepal and "Aftercare study for the Project for Construction of Sindhuli Road" was conducted in FY1993. • From FY 19889 for 3 years, a series of F/S were made for "Bogor-Bandung Road Project ". Along the project route, expansive clay should appear on cut slopes. In the reports of F/S, possibilities of landslide were described.
Early 1990's	• ODA Loans for road development and improvement were implemented in the Philippines, including slope protection and landslide countermeasures. ODA Loans including slope protection and landslide countermeasures were implemented in Indonesia and Papua New Guinea as well. • F/S were implemented for roadside slope disaster prevention in the Philippines and the Kingdom of Thailand. "Aftercare study for the Project for Construction of Sindhuli Road" was conducted.
Late 1990's	• ODA Loans including slope protection and landslide countermeasures were implemented in the Philippines, Peru, and Kyrgyzstan. • A series of ODA Grants were implemented in Nepal for construction of Sindhuli Road.
Early 2000's	• Following late 1990's, ODA Loans including slope protection and landslide countermeasures were implemented in the Philippines and Peru. • Following late 1990's, ODA Grants continued in Nepal for construction of Sindhuli Road. • Another ODA Grant were implemented in Ethiopia for "The Project for Rehabilitation of Trunk Road, Phase 3", in which the New Abay Bridge and its approach roads were constructed. The project suffers multiple landslides slope failures during its construction phase.

Periods	Trends
Late 2000's	・ODA Loans were implemented for various hill road projects. An ODA Loan were implemented in Guatemala to make a highway to avoid a massive slope failure. ODA Loans for highways including hill sections were implemented. In Sri Lanka, "Southern Highway Construction Project (2)" was implemented and in Georgia, "East-West Highway Improvement Project (1)". Both projects faced massive slope failures during construction. ・Following early 2000's, ODA Grants continued in Nepal for construction of Sindhuli Road. ・In the Kingdom of Bhutan, the ODA Grant of "The Project for Reconstruction of Bridges（Phase 3）" was implemented. In the project, shotcrete, rock bolts, and ground anchor works were added during the construction to cope with instability of slopes behind the abutment.
Early 2010's	・An ODA Loan to support operation and maintenance (hereinafter referred to as "O&M") of hill road was implemented in Sri Lanka. The "Landslide Disaster Protection Project of The National Road" aimed at the countermeasures against rock fall, slope failures, and landslides. ・Technical Cooperation (hereinafter referred to as "T/C") projects were implemented in Ethiopia, Nepal, and Bhutan for O&M of roadside slopes. ・ODA Grants continued in Nepal for construction of Sindhuli Road.
Late 2010's ~ Present	・ODA Loans including roadside slope protection and landslide countermeasures were implemented in India, Kyrgyzstan, Vietnam, and Georgia. ・T/C projects for O&M of roadside slopes were implemented in India, Kyrgyzstan, Tajikistan, Nepal, and Bhutan. ・ODA Grants continued in Nepal for construction of Sindhuli Road. ODA Grants for countermeasures against roadside slope failure and landslides were implemented in India, Honduras, and Bolivia. ・ODA Grants for bridges in Bhutan and recovery from earthquake in Nepal added countermeasures against slope failure during its construction.

Reviewing of ODA projects from viewpoints of time-series basis provides the following perspective:

- ODA projects including roadside slope protection were implemented in the 20th Century but limited to certain countries, such as Indonesia, the Philippines, the Kingdom of Thailand, and countries in South America. Those countries were moderately developed and keeping close relationship with Japan. Among ODA Grants, projects for construction of Sindhuli Road are distinctive.
- In the 21st Century, ODA projects for hill road development / improvement including roadside slope protection are expanding to wider areas, including South, Central, and West Asia as well as Africa.

- In 2010's and onward, ODA Grants and Loans as well as T/C Projects aiming at roadside slope protection and landslide countermeasures have been implemented in South and Central Asia as well as Central and South America and Africa.
- Economic development of the said developing nations may lead the aforementioned changes. High demand of land transportation requires road development / improvement in mountainous / hilly regions, which often suffers from roadside slope failures / landslides.
- In general, developing countries have less knowledge and experience in hill road development / improvement including slope protection and landslide countermeasures. Lack of skill and knowledge may lead thoughtless road construction / widening in mountainous / hilly regions, which often triggers slope failures as well as landslides and causes difficult problems in O&M of hill roads.
- In short, economic growth of developing nations puts heavy burden on O&M of hill roads. As a result, requests to Japan from such developing nations regarding slope protection and landslide countermeasures should increase.

2.2 Analysis on Trends and Issues of Existing ODA Projects with Landslide countermeasures

The items in Table 2-3 were studied from the preparatory survey (hereinafter referred to as "P/S) report studied in Chapter 2.1 for analysis on trends and issues of the existing ODA projects.

Table 2-3 Items Analyzed from Preparatory Survey Report

(JICA Study Team)

Items	Method of Analysis and organization
Abstract of Project	Position of projects in road network in the country. Location of roads; topographic condition and surrounding land use Predicted traffic volume Year of design (P/S and D/D), construction period, and year of completion. Slope failures / landslides during and after construction. C/P organizations and their roles
Landslide countermeasures in P/S	Description and design of landslide countermeasures in P/S Abstract and magnitude of landslide countermeasures Natural condition survey for landslide countermeasures Geological investigation, survey for groundwater, hydrology, and hydrogeology, and study for material. Selection of protection / stabilization works and design methods. Design standard. Analysis methods. Cost estimation and its validity, including that for temporary works. Remaining issues in P/S and proposal for further studies. Proposal for technical transfer especially for O&M.

The trends and issues analyzed from preparatory study reports are described in the following chapters.

2.2.1 Outlines of Recipient Countries

Outlines of the recipient countries of ODA projects with landslide countermeasures are explained below:

(1) Indonesia

Table 2-4 Trends and Issues of ODA Projects (Indonesia)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans
	Location of Roads	Highways connecting major cities of Java Island.
	Predicted Traffic Volume	Less than 1,000 ~ 85,000 vehicles/day, depending on the sections
	Commencement of Projects	Late 1970's and Late 1980's
	Landslides during & after Construction	Unclear from the documents we studied. In the reports, however, importance of O&M against damage by rock fall and landslides is highlighted. Thus, in certain sections, roadside slope failure are considered to have occurred.
Preparatory Study	Needs for Landslide Countermeasures	Description of expansive clay and frequent landslides are confirmed.
	Outline and Magnitude of Works	Unclear from the documents.
	Natural Condition Survey	Unclear from the documents.
	Selection and Design of Works	Unclear from the documents.
	Remaining Issues	Unclear from the documents.
	Cost Estimation	Unclear from the documents.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

Damage of slope and pavement of express ways by expansive clay was reported.

(2) Kingdom of Thailand

Table 2-5 Trends and Issues of ODA Projects (Thailand)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	F/S
	Location of Roads	F/S was made for national roads with high traffic volume and priority.
	Predicted Traffic Volume	Less than 1,000 ～ 5,000 vehicles/day
	Commencement of Projects	1993
	Landslides during & after Construction	Unclear from the documents. Suspended?
Preparatory Study	Needs for Landslide Countermeasures	By classifying landslides, outline design for 38 sections of eight national roads were made.
	Outline and Magnitude of Works	Outline design for reshaping slopes, vegetation, concrete crib works, horizontal drainage borings, surface drainage, and rock fall net.
	Natural Condition Survey	Boring investigation. Laboratory tests for physical properties. Monitoring well.
	Selection and Design of Works	Selection of works and outline design with standard cross section were carried out for the supposed slope failures.
	Remaining Issues	Unclear from the documents. Suspended?
	Validity of Cost Estimation	No temporary works were planned.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents. Suspended?

In Thailand, landslide countermeasures were in demand as well.

(3) Philippines

Table 2-6 Trends and Issues of ODA Projects (Philippines)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans, F/S, T/C
	Location of Roads	Major highways
	Predicted Traffic Volume	Less than 1,000 ～ 18,000 vehicles/day
	Commencement of Projects	1980's ～ early 2000's
	Landslides during & after Construction	Damage by slope failures, erosion of road shoulders, and debris flow due to typhoons and earthquakes.
Preparatory Study	Needs for Landslide Countermeasures	Since the country is rich in disasters, hazards of landslides, rock fall, and debris flow were acknowledged before the projects commenced.
	Outline and Magnitude of Works	Rock shed. concrete pitching, concrete crib works, stone pitching, vegetation, soil removal, surface drainage, river bank protection, flow control works, horizontal drainage boring, and ground anchors.
	Natural Condition Survey	Unclear from the documents.
	Selection and Design of Works	Unclear from the documents.
	Remaining Issues	Unclear from the documents.
	Cost Estimation	Unclear from the documents.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

The ODA projects for the Philippines started from 1980's and the damage by landslides and debris flow emerged earlier due to its frequent strikes by typhoons. The damage to the existing ODA projects was treated by the following ODA Loans in some cases.

For the Philippines, an F/S in 2007 prepared guidelines for slope protection and landslide countermeasures.

(4) Vietnam

Table 2-7 Trends and Issues of ODA Projects (Vietnam)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans, F/S
	Location of Roads	The expressway running north and south along the coastal region of central Vietnam.
	Predicted Traffic Volume	15,000 vehicles /day (predicted in 2017)
	Commencement of Projects	2011
	Landslides during & after Construction	Rock slide on the cut slope with slope protection
Preparatory Study	Needs for Landslide Countermeasures	No description was confirmed.
	Outline and Magnitude of Works	No description was confirmed.
	Natural Condition Survey	Unclear from the documents.
	Selection and Design of Works	Unclear from the documents.
	Remaining Issues	Unclear from the documents.
	Cost Estimation	Unclear from the documents.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

In Vietnam, ODA Loans have been implemented for expressways and major bridges in Hanoi and Hoh Chi Ming City (HCMC) as well as north and south expressways connecting Hanoi and HCMC. The North-South Expressway Construction Project (DN-QN) (3) is one of such projects. The project included cut slopes of bedrock around Da Nang.

The corresponding cut slopes were not designed with slope protection works in the P/S by JICA. In the D/D by the World Bank (WB), however, optimal slope gradient and concrete crib works were introduced.

After cutting, it was proven that the corresponding cut slope had dip slope structure toward the expressway and the cast-in-situ concrete crib works designed for the section was not sufficient. In fact, massive rock slide occurred at the section. The supervision consultant for the section proposed a gentler gradient of slope to cope with the rock slide and the project management unit (hereinafter referred to as "PMU") agreed the proposal. The process of variation order (hereinafter referred to as "V/O") commenced but further approval by upper organization of PMU such as VEC (Vietnam Expressway Cooperation) and MOT (Ministry of Transport) were required. This process took a long period and even after the expressway opened for public, the proposed gentle gradient was not executed.

(5) India

Table 2-8 Trends and Issues of ODA Projects (India)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grants, ODA Loans, T/C
	Location of Roads	ODA Loans have been implemented for the highways in the North Eastern Region including mountainous / hilly areas. An ODA Grant was planned for a hill road of NH55 in the State of West Bengal. A T/C aimed at hill roads, especially in the Himalayas and the North Eastern Region
	Predicted Traffic Volume	3,000～15,000 PCU/day
	Commencement of Projects	Late 2010's ~ present.
	Landslides during & after Construction	Some slope failures were said to occur in ODA Loans but documents were not in public. The conditions of the North Eastern Regions is severe in terms of landslides. The ODA Grant for NH55 was for providing rehabilitation works against damage by slope failure but suspended.
Preparatory Study	Needs for Landslide Countermeasures	The reports of P/S for ODA Loans were not in public. Japanese countermeasures against landslides were, however, proposed in phase 1 of such projects. Introducing Japanese technologies are hampered due to some reasons, such as reluctance of Japanese contractors to work in India and strict requirements for transparency of procurement by the government of India, which limits use of particular patents for the works.
	Outline and Magnitude of Works	The reports of P/S for ODA Loans were not in public. Spray crib works, horizontal drainage borings, rock bolts / soil nailing, and ground anchors were, however, proposed in phase 1 of such projects. In the ODA Grant for NH55, light-weight embankment by air-mixed cement was proposed.
	Natural Condition Survey	In the ODA Grant for NH55, core boring, groundwater monitoring, rainfall observation with rain gauges, and simple measurement with laser range finders were conducted in the P/S.
	Selection and Design of Works	In the P/S for ODA Grant for NH55, rehabilitation works and landslide countermeasures were designed in accordance with Japanese design standards.
	Remaining Issues	Not specified in P/S reports.

Items		Trends and Issues
	Cost Estimation	In the P/S for ODA Grant for NH55, cost estimation was done by establishing temporary plan for the work including use of un-manned machinery.
	Proposal for Technical Transfer (Especially for O/M)	In the P/S for ODA Grant for NH55, O&M with load cells for anchors was proposed. Inspection items were also proposed.

In India, due to the policies that put importance on North East Region and the needs from national defense along the mountainous borders, the needs of hill road development have been very high in the states along the Himalaya and in North East Region. The requests to Japan reflect such demands from India.

Along with Bhutan and Nepal, India has the Himalayas, which is the most active orogenic range in the world. Thus, the hill roads in the northern states of India are developed / improved on very steep slopes composed of hard rock with loosened zones. Such slopes are often influenced by gravitational / creep deformation of bedrock slope, which is considered one of the major causes of road sinking. The road sinking of hill roads is one of the biggest headaches for the administrators of hill roads in India. In the T/C project of "Capacity Development Project on Highways in Mountainous Regions" prepared a guideline for slope protection, featuring the gravitational deformation and road sinking.

On the other hand, road sinking by gravitational deformation is not so focused in Japan because the hill roads in Japan make detours by tunnels and/or bridges when facing difficult sections including road sinking. Thus scarce experience is expected in Japan in terms of countermeasures against gravitational deformation. In India, so far, most of the road administrators cannot afford to make detours by tunnels and/or bridges. They manage to cope with the road sinking issues by continuous efforts in O&M. From this reason, development of mitigation measures against gravity deformation is long-awaited in India.

(6) Nepal

Table 2-9 Trends and Issues of ODA Projects (Nepal, Sindhuli Road)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grants, ODA Loans, T/C
	Location of Roads	Connecting the capital Kathmandu and India as well as the southern fertile terrain of Terai basin.
	Predicted Traffic Volume	Section 2 and 3: 7,000pcu／day (predicted in 2018) Section 4: 10,000 vehicles/day
	Commencement of Projects	Section 2: E/N signed in 2000 Section 3: E/N signed in 2009 Section 4: E/N signed in 1997
	Landslides during & after Construction	Slope failures in hill side slopes, collapse of road shoulder, erosion by rivers and streams, and debris flow frequently occurred. The Nepal Earthquake in 2015 struck severely. For the rehabilitation of such damage, the following three ODA Grants were implemented: ・The Project for Countermeasure Construction against the Landslides on Sindhuli Road Section 2 ・The Project for Emergency Rehabilitation of Shindhuli Road (Section 4) ・The Project for the Rehabilitation of Sindhuli Road affected by Earthquake
Preparatory Study	Needs for Landslide Countermeasures	Section 2: Special consideration was made for 8 landslide sections. Section 3: Landslide monitoring was conducted in one landslide section. As a result, gentler gradient of slope was proposed. Section 4: Recognized landslides with weathered rock or clay. Designed to avoid toe of landslides.
	Outline and Magnitude of Works	(Section 2) General: applying proper gradient of cut slope, gabion/concrete retaining wall, and reinforced embankment with geotextile. High embankment: French drain, drainage filter for toe of embankment, drainage ditches along berms, and vertical drain. High & long cut: shotcrete and rock bolts. Landslide: river bank protection + buttress fill at toe of landslide, designing alignment avoiding landslides, fixing dip

Items		Trends and Issues
		slopes with rock bolts, forming road bed by gabion retaining wall, surface drainage, and rock fall pockets with retaining wall along hill side slopes (Section 3) Applying proper gradient of cut slope and berms. Concrete crib works for the slopes steeper than proper gradient. Rock bolts for high and long cut sections. The measures including avoiding landslides, earth removal at head and buttress fill at toe of landslides, and securing pockets by keeping some space at hill side are employed for landslide sections. (Section 4) Applying proper gradient, gabion, groundwater drainage, and surface drainage.
	Natural Condition Survey	Section 2 and 4: Aerial photo interpretation and field survey. Section 3: Field survey and special study at Mulkot landslide including topographic survey, boring, and landslide monitoring.
	Selection and Design of Works	Section 2 and 4: Referring to the Highway Earth Work Manual in Japan, gradient of cut slope was proposed based on geological conditions. Section 3: Not specified in P/S reports.
	Remaining Issues	Not specified in P/S reports.
	Cost Estimation	Very simple estimation in P/S reports
	Proposal for Technical Transfer (Especially for O/M)	Not specified in P/S reports. But the Project for Operation and Maintenance of the Sindhuli Road (Phase 1 & 2) was implemented.

Nepal is famous for the ODA Grants for Sindhuli Road, where Sections 2, 3, and 4 are hill areas. Among them, Section 2 is mainly composed of hilly/mountainous routes.

The ODA Grants were implemented in an order of Section 1, Section 4, Section 2, and Section 3.

For Section 4, slope protection works were selected in the aim of minimizing the cost. Thus gabion, groundwater drainage, and surface drainage works were implemented.

Stable gradients of cut slopes were proposed in the P/S reports. Cutting at the toe of landslides was avoided in the design. In case required, retaining walls were planned.

Rock bolts and ground anchor works were proposed but not adopted in the design.

The ODA project for Sindhuli Road was originally planned in the F/S for "The Project for Construction of Sindhuli Road", which was implemented in FY 1986. Since the government of Nepal was unable to prepare the budget for the project, however, the project was suspended. In FY 1993, however, “Aftercare study for the Project for Construction of Sindhuli Road” was implemented to seek possibilities for ODA Grants. Due to the history of the project mentioned above, the cost reduction for Section 4 seemed to be highly demanded.

Section 2 inherits the trend of cost reduction from Section 4. Special cares were paid, however, for the 8 landslides along the road. Cost reduction were considered for selection of landslide countermeasures. With a few cases of rock bolts, earth removal at the head and buttress fill at the toe were the basic measures.

In Section3, special study including topographic survey, boring, and landslide monitoring was conducted in the landslide section, where rock bolts and concrete crib works were adopted.

Wirth project proceeds, more detailed studies and advanced countermeasures were introduced to cope with the newly founded phenomena.

In the earliest study for Sindhuli Road, the F/S for “The Project for Construction of Sindhuli Road” in FY 1986, a basic policy for design was set as “utilizing retaining walls to reduce the heights of fill and cut sections while securing stability of slopes. The following study inherited this policy.

In the same F/S, to avoid landslide prone areas, a policy for alignment was adopted to shift the road toward river side by constructing retaining walls along the rivers. For the design of hill roads, engineers should decide the way of securing necessary width for the planned road, by cutting hillside or by filling on valley side or combination of both. For Sindhuli Road, putting retaining wall on river bed and filling on valley side were adopted.

During the construction and after being put in service, however, Sindhuli Road faced severe landslides in the monsoon seasons. Slope failures of cut slopes, collapse of road shoulders, erosion by the rivers and streams, and debris flow damaged the road. Nepal Earthquake in 2015 struck the road severely.

For the rehabilitation of such damage, the following three ODA Grants were implemented:

- The Project for Countermeasure Construction against the Landslides on Sindhuli Road Section 2
- The Project for Emergency Rehabilitation of Shindhuli Road (Section 4)
- The Project for the Rehabilitation of Sindhuli Road affected by Earthquake

In The Project for Emergency Rehabilitation of Shindhuli Road (Section 4), erosion protection for the foundation of the bank protection works was introduced because the road was damaged in the sections where the road was shifted to riverside by constructing retaining walls on river bed. In the design of erosion protection and rehabilitation works, design criteria was revised through reviewing probable rainfall because the road was damaged by the rainfall exceeding the design amounts of rainfall for original project.

Table 2-10 Trends and Issues of ODA Projects (Nepal, excluding Sindhuli Road)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	A: Study on Disaster Risk Management for Narayangharh – Mugling Highway B: ODA Grant of "The Program for Rehabilitation and Recovery from Nepal Earthquake"
	Location of Roads	A: arterial highway B: bridges in Gurkha District struck by Nepal Earthquake in 2015
	Predicted Traffic Volume	A: arterial highway section: 3,041vehicles / day (in 2006) B: N/A
	Commencement of Projects	A: in 2007, B: in 2017
	Landslides during & after Construction	A: damage of retaining walls and embankment at more than 2,000 sites B: cut slope was replaced by retaining wall. Gabion and surface/subsurface drainage were placed where abundant groundwater spring was confirmed.
Preparatory Study	Needs for Landslide Countermeasures	A: for slope stabilization B: not specified in P/S reports.
	Outline and Magnitude of Works	A: horizontal drainage boring, gabion, spray crib works & rock bolts, rock fall protection net, and rock fall barrier. B: not specified in P/S reports.
	Natural Condition Survey	A: studies for topography, geology, weather, and groundwater, topographic survey, boring, and strain gauge monitoring B: topographic survey, boring, and laboratory tests
	Selection and Design of Works	A: not specified in P/S reports B: no design in P/S reports.
	Remaining Issues	A: difference of technical terms for landslides between Japan and Nepal. Importance of rainfall observation. Concerns on road widening. Detecting failure sites by comparing aerial photos and satellite images taken in different periods. B: not specified in P/S reports.
	Cost Estimation	Very simple estimation in P/S reports
	Proposal for Technical Transfer (Especially for O/M)	A: project for road disaster prevention B: not specified in P/S reports.

Other than “The Project for Construction of Sindhuli Road”, in Nepal, ODA projects relating to hill roads were implemented. The “Study on Disaster Risk Management for Narayangharh - Mugling Highway” was F/S for the arterial highway, including proposals for studies for risk of landslides as well as basic policy for landslide management with an implementation plan.

“The Program for Rehabilitation and Recovery from Nepal Earthquake” was an ODA Grant developed from an F/S study for the same. In the F/S study, along with establishing rehabilitation plans as well as introducing earthquake resistance design, formulating prioritized rehabilitation project was implemented. As a result, the ODA Grant of “The Program for Rehabilitation and Recovery from Nepal Earthquake” was initiated. The ODA Grant has three sub project. Among them, the “Project for Construction of Barahkilo – Barpak Road Bridge” was to construct three bridges.

During the construction of the bridges, concerns of instability arose and then retaining walls and surface/subsurface drainages were introduced.

(7) Kingdom of Bhutan

Table 2-11 Trends and Issues of ODA Projects (Bhutan)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grants, T/C
	Location of Roads	Arterial highway in mountainous region
	Predicted Traffic Volume	300 vehicles/day (predicted in 2024)
	Commencement of Projects	In and after 2009
	Landslides during & after Construction	One ODA Grant had two incidents. Slope failure occurred behind an abutment and stabilization works were added. Unstable massive rock were found during construction at another bridge site, which required additional measures. In another ODA Grant, concerns of slope failure arose and stabilization works were added.
Preparatory Study	Needs for Landslide Countermeasures	P/S for one ODA Grant did not care slope protection but that for another ODA Grant introduced ground anchors.
	Outline and Magnitude of Works	Shifting alignment to avoid hazardous areas, securing stable gradient, placing berms, shotcrete, and ground anchors.
	Natural Condition Survey	P/S included natural condition surveys for bridge foundation. In the P/S for the ODA Grant with ground anchor, stability analysis was done based on the results of field survey and boring for bridge foundation.
	Selection and Design of Works	Referring to the Highway Earth Work Manual in Japan
	Remaining Issues	Boring investigation was proposed for high and long cut section.
	Cost Estimation	Very simple estimation in P/S reports
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

The land of Bhutan is mostly composed of the mountainous regions formed by the orogenic activities of the Himalayas like in northern India and Nepal. Construction of hill roads and bridges is fairly challenging in such areas. In the Himalayas, steep hillside slopes are composed of hard rock. At the same time, fractured or sheared zones form fragile geological conditions. The risks of slope failure and rock fall are increased by steep slopes and fragile geological conditions.

In Bhutan, a series of ODA Grants were implemented for construction of road bridges. Slope failures occurred or concerns of failures arose behind a couple of abutments under ODA Grants, which leads variation order.

(8) Sri Lanka

Table 2-12 Trends and Issues of ODA Projects (Sri Lanka)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans
	Location of Roads	SHCP: expressway connecting Colombo and the southern part of Ceylon Island. LDPP: slope protection and landslide countermeasures along arterial highways in the Central Highland.
	Predicted Traffic Volume	Less than 1,000 ~15,000 vehicles / day (LDPP)
	Commencement of Projects	L/A： SHDP in 2000, LDPP in 2013
	Landslides during & after Construction	SHCP: after put in service, large slope failure occurred in November 2012. LDPP: slope failures occurred at 3 locations.
Preparatory Study	Needs for Landslide Countermeasures	SHCP: no consideration in F/S. In D/D, slope protection was considered. LDPP: project for slope protection and landslide countermeasures.
	Outline and Magnitude of Works	SHCP: gentle gradient and vegetation were planned in D/D. LDPP: Countermeasures against rock fall, spray crib works, rock bolts, ground anchors, horizontal drainage borings, drainage wells, surface drainage, and pile works.
	Natural Condition Survey	SHCP: unclear from the documents LDPP: In F/S, field survey, aerial photo reading, and topographic survey were conducted. Detailed surveys were done in D/D.
	Selection and Design of Works	SHCP: gentle gradient was adopted for cut slope in D/D. Vegetation was adopted as basic slope protection. LDPP: F/S identified hazardous slopes and planned countermeasures for such slopes. Japanese methods were used for design.
	Remaining Issues	SHCP: unclear from the documents LDPP: no boring was conducted in F/S. Detailed surveys and design was done in ODA Loan project.
	Cost Estimation	SHCP: unclear from the documents LDPP: since no boring was done in F/S, cost was roughly estimated.

Items		Trends and Issues
	Proposal for Technical Transfer (Especially for O/M)	SHCP: unclear from the documents LDPP: the F/S was done for data collection rather than P/S. Detailed planning for T/C for O&M was not required.

ODA Loans in Sri Lanka has stark contrast. In SHCP, massive cut slope failure occurred after the expressway was put in service. In LDPP, various slope protection and countermeasures were implemented including those against rock fall, slope failure and landslides.

The F/S for SHCP was done by ADB, which hired Wilbur Smith Associates as a consultant.

The F/S for LDPP was Data Collection Survey on Road Protection against Natural Disaster (Landslide-Disaster) done by JICA, which is basically a data collection survey. The survey has a short contract period of around half a year, in which an ODA Loan project was formulated and outline design and cost estimation were conducted including explanation to an appraisal mission dispatched by JICA. Thus no time for conducting topographic survey, core boring, and landslide monitoring was secured in the survey. Such detailed surveys and design were planned to be done in ODA Loan Project. For the phase 2 project for LDPP, however, a normal P/S was conducted.

(9) Tajikistan

Table 2-13 Trends and Issues of ODA Projects (Tajikistan)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	T/C
	Location of Roads	93% of its territory is categorized as mountain. Around half of the territory is covered by the mountains of over 3,000 m in elevation. Mountainous roads suffer snow avalanche in winter and flood, rock fall, and landslide in spring due to snow melt.
	Predicted Traffic Volume	N/A (Not Applicable)
	Commencement of Projects	April 2017
	Landslides during & after Construction	N/A
Preparatory Study	Needs for Landslide Countermeasures	Project for disaster management of roads. Seminar, training, and OJT for rehabilitation works.
	Outline and Magnitude of Works	N/A
	Natural Condition Survey	N/A
	Selection and Design of Works	N/A
	Remaining Issues	N/A
	Cost Estimation	N/A
	Proposal for Technical Transfer (Especially for O/M)	Preparation and utilization of manuals for disaster prevention. Development of database for roadside slope disasters.

In Tajikistan, a T/C project was conducted recently. The countries in Central Asia are mountainous. Thus needs for road side landslide countermeasures are considered high.

(10) Kyrgyzstan

Table 2-14 Trends and Issues of ODA Projects (Kyrgyzstan)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans, T/C
	Location of Roads	Kyrgyzstan is a mountainous country with 90% of its territory exceeding 1,000 m and 40% of the same exceeding 3,000m in elevation. The arterial highways in mountainous areas suffers landslides, snow hazards, and snow avalanche.
	Predicted Traffic Volume	1,800 vehicles / day in 2007(actual), 3,800 vehicles / day in 2024 (predicted)
	Commencement of Projects	L/A: in 1997 and 2015 (ODA Loans)
	Landslides during & after Construction	Bishkek-Osh Road Rehabilitation Project (BORRP): Rock fall and snow avalanches occurred during construction. F/S by ADB lacks safety precaution. Variation Orders (V/O) were necessary. Due to landslides and snow avalanches, the project delayed substantially.
Preparatory Study	Needs for Landslide Countermeasures	BORRP: a T/C was planned for countermeasures against rock fall and snow avalanche. International Main Roads Improvement Project (IMRIP): a T/C was conducted simultaneously with the ODA Loan for countermeasures against rock fall, landslide, and snow hazards.
	Outline and Magnitude of Works	Countermeasures against rock fall
	Natural Condition Survey	Field survey
	Selection and Design of Works	Unclear from the documents
	Remaining Issues	BORRP: detailed survey was proposed.
	Cost Estimation	Unclear from the documents
	Proposal for Technical Transfer (Especially for O/M)	BORRP: issues in data management for O&M was indicated.

Kyrgyzstan is one of the mountainous countries in Central Asia. The arterial highways run through its mountainous areas and slope problems are inevitable. Rock fall protection was adopted in the ODA Loans.

(11) Honduras

Table 2-15 Trends and Issues of ODA Projects (Honduras)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grant
	Location of Roads	Arterial highway
	Predicted Traffic Volume	8,240 vehicles / day（actual in 2016）
	Commencement of Projects	E/N in 2017
	Landslides during & after Construction	Unclear from the documents.
Preparatory Study	Needs for Landslide Countermeasures	The project aimed at landslide countermeasures.
	Outline and Magnitude of Works	Shotcrete, ground anchors, pile works, French drain, cutting, filling vegetation, and resin cell works.
	Natural Condition Survey	Topographic survey, boring, groundwater logging and quality, and landslide monitoring.
	Selection and Design of Works	Selection flow was prepared by referring to the Highway Earth Work Manual in Japan. Design of countermeasures to fulfil the design factor of safety (DFs) of 1.2.
	Remaining Issues	Not specified in P/S reports.
	Cost Estimation	Cost estimation was classified as of the time of research in January 2021.
	Proposal for Technical Transfer (Especially for O/M)	Technical transfer of design, construction, and O&M of landslide countermeasures was done in the ODA Grant. O&M structure for the works was proposed.

(12) Guatemala

Table 2-16 Trends and Issues of ODA Projects (Guatemala)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loan
	Location of Roads	Road development for post conflict area. Very steep slopes lie on the planned alignment.
	Predicted Traffic Volume	Less than 1,000 vehicles / day
	Commencement of Projects	L/A in December 2012
	Landslides during & after Construction	Unclear from the documents. In 2009, massive landslide occurred and the road was washed away. This section was outside of the scope of the ODA Loan but study for detour was carried out in P/S.
Preparatory Study	Needs for Landslide Countermeasures	Countermeasures against slope failures, rock fall, and debris flow was studied along with drainage works.
	Outline and Magnitude of Works	Slope drainage, shotcrete, rock fall net, and rock bolts.
	Natural Condition Survey	Boring with SPT
	Selection and Design of Works	Referring to the Highway Earth Work Manual in Japan.
	Remaining Issues	Proposal of technical component for management of environment
	Cost Estimation	Estimation of temporary works were not confirmed.
	Proposal for Technical Transfer (Especially for O/M)	Not specified in P/S reports. O&M of national and district roads are outsourced to private sector.

An ODA Loan project seems to have been implemented excluding massive landslide area.

In case massive landslides are recognized before project formulation, ODA projects should exclude such areas. In P/S of such ODA projects, however, governments of partner countries often request JICA to have studies for landslide countermeasures.

(13) Colombia

Table 2-17 Trends and Issues of ODA Projects (Colombia)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	F/S
	Location of Roads	A highway connecting major metropolitan areas, which suffers road blockade more than 180 times annually
	Predicted Traffic Volume	1,000~5,000 vehicles / day
	Commencement of Projects	F/S in 1979. The project was not realized.
	Landslides during & after Construction	Unclear from the documents.
Preparatory Study	Needs for Landslide Countermeasures	Slope protection and landslide countermeasures were mentioned in the report.
	Outline and Magnitude of Works	Japanese landslide countermeasures were mentioned, such as vegetation, earth removal, lattice works, horizontal drainage boring, drainage well, pile works, surface drainage, and subsurface drainage.
	Natural Condition Survey	Description of topographical and geological conditions. Classification of landslide and its causes. Risk evaluation of slope failure and landslides.
	Selection and Design of Works	Selection sequence are shown as flow chart, possibly based on Japanese flow.
	Remaining Issues	Unclear from the documents. The project was not realized.
	Cost Estimation	Estimation of temporary works were not found in the report.
	Proposal for Technical Transfer (Especially for O/M)	Establishing database for slope disaster record and construction record was proposed.

The ODA Loan was not realized in Colombia. According to the P/S report, the highway suffered serious damage by landslides.

(14) Peru

Table 2-18 Trends and Issues of ODA Projects (Peru)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loans
	Location of Roads	Arterial highways and district highways
	Predicted Traffic Volume	Several hundreds to thousands vehicles / day
	Commencement of Projects	In 1996 and 1999
	Landslides during & after Construction	Small slope failures.
Preparatory Study	Needs for Landslide Countermeasures	Not specified in P/S reports.
	Outline and Magnitude of Works	Not specified in P/S reports.
	Natural Condition Survey	Unclear from the documents.
	Selection and Design of Works	Unclear from the documents.
	Remaining Issues	Unclear from the documents.
	Cost Estimation	Unclear from the documents.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

In Peru, projects for development of highways with high risks of slope disaster were implemented under ODA Loans.

El Niño is considered one of the factors of landslides. High risks of slope disaster are inevitable for highway development in the mountainous regions close to the Andes. On the other hand, proper O&M seems to be carried out.

(15) Bolivia

Table 2-19 Trends and Issues of ODA Projects (Bolivia)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grant
	Location of Roads	Arterial highways and district highways
	Predicted Traffic Volume	Unclear from the documents.
	Commencement of Projects	E/N in 2015
	Landslides during & after Construction	Unclear from the documents.
Preparatory Study	Needs for Landslide Countermeasures	Disaster prevention works at 5 locations along the highways.
	Outline and Magnitude of Works	Shotcrete, rock bolts, rock fall net, rope net, and wire rope connected with rock bolts.
	Natural Condition Survey	Hydrological/ hydrogeological survey, field survey, resistivity survey, surface wave exploration, riverbed survey, topographic survey with LiDAR, boring, pipe strain gauge, and groundwater level monitoring.
	Selection and Design of Works	Selection was made based on O&M, cost, environmental and social consideration.
	Remaining Issues	Not specified in P/S reports.
	Cost Estimation	Cost estimation was classified as of the time of research in January 2021.
	Proposal for Technical Transfer (Especially for O/M)	A soft component was proposed with an objective of "Disaster prevention plan is prepared by Bolivian officials."

A project for roadside slope protection is now under construction in Bolivia.

(16) Papua New Guinea

Table 2-20 Trends and Issues of ODA Projects (Papua New Guinea)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Loan
	Location of Roads	Arterial highways connecting major cities
	Predicted Traffic Volume	360 vehicles / day at the appraisal mission
	Commencement of Projects	L/A in 1991
	Landslides during & after Construction	In November 2000, major debris flow damaged a bridge and pavement, which were rehabilitated by additional works.
Preparatory Study	Needs for Landslide Countermeasures	Unclear from the documents.
	Outline and Magnitude of Works	Unclear from the documents.
	Natural Condition Survey	Unclear from the documents.
	Selection and Design of Works	Unclear from the documents or not considered in P/S
	Remaining Issues	Unclear from the documents.
	Cost Estimation	Unclear from the documents.
	Proposal for Technical Transfer (Especially for O/M)	Unclear from the documents.

In the ODA Loan of “Arterial National Highway Improvement Project”, debris flow damaged the highway during construction and rehabilitation works were added.

(17) Ethiopia

Table 2-21 Trends and Issues of ODA Projects (Ethiopia)

(JICA Study Team)

Items		Trends and Issues
Abstract of Projects	Aid Scheme	ODA Grants, T/C
	Location of Roads	At the section crossing Abay Gorge on the national highway No. 3 connecting the capital Addis Ababa and the neighbouring Sudan through the State of Amhara.
	Predicted Traffic Volume	360 vehicles / day (actual in 2003)
	Commencement of Projects	In 2003.
	Landslides during & after Construction	During the construction of the 3rd phase, in 2006, cracks were observed on the pavement at Sta. 2. Afterwards a lot of slides (Jisuberi) and slope failures occurred in various places in Abay Gorge and damaged the national highway No.3. At some sections, road bed was slid away. Even after the project was put in service, slides and slope failures repeated. Provision of machinery by ODA Grant and two T/C projects were implemented to enhance capability of Ethiopian side. Even after such projects end, sinking of roads due to landslide have repeated at some sections.
Preparatory Study	Needs for Landslide Countermeasures	In P/S, descriptions about landslide and countermeasures were confirmed. No tangible proposals for landslide countermeasures, such as location and quantities, however, were recognized. In the Abay Gorge section, the national road No.3 passes through massive multiple slides and, after in service, the road was damaged at many locations. Before and during the project, however, it seems that such massive multiple slides were not recognized well.
	Outline and Magnitude of Works	No landslide countermeasures were made in the ODA Grant, excluding minor works such as putting gabion as a stopgap measure. In the pilot project in the T/C, horizontal drainage boring, surface drainage, subsurface drainage, and soil nailing were implemented.
	Natural Condition Survey	No surveys for countermeasures against slides and slope failures were conducted in the P/S for the ODA Grant.

Items		Trends and Issues
	Selection and Design of Works	In the P/S for the ODA Grant in 2004, simple slope protection was proposed. In the ODA Grant, however, no signs of studies and works for slope protection were confirmed.
	Remaining Issues	Additional survey for slides was proposed. As for slope protection, removal of boulders, horizontal drainage borings, check dam, and rock fall fence of a height of 2 meters were proposed. It seems insufficient considering the situation in Abay Gorge.
	Cost Estimation	No cost estimation for countermeasures against slides and slope failures.
	Proposal for Technical Transfer (Especially for O/M)	No records for landslide countermeasures or proposals for technical transfer / O&M were confirmed.

The ODA Grant of "Project for Rehabilitation of Trunk Road Phase 3" is an outstanding example where Japanese ODA Grants faced difficulties due to landslides.

Another problem lies in the T/Cs. Many officials trained in the two T/Cs left the authorities after the projects and the effects of the T/Cs were reduced.

(18) Projects Excluded from Annual Reports

The ODA Loan of "East-West Road Improvement Project (N70)" in Pakistan was not found in the annual report. But in the project, steel jetty works were implemented to avoid hazards of landslides in the section of steep bedrock slopes.

2.2.2 Disaster Types

The trends on disaster types dealt with in ODA projects are summarized in this section.

Table 2-22 Trend on Disaster Types (from 62 Cases)

(JICA Study Team)

Disaster Types	Cases
Rock fall	12
Collapse (slope failure)	36
Slide (Jisuberi)	20
Debris flow	14
Snow avalanche	4

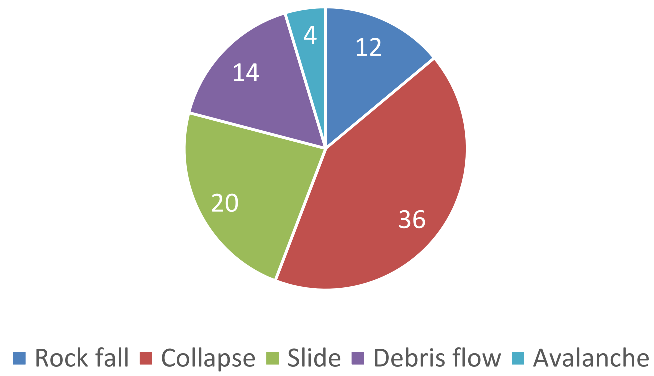


Figure 2-1 Trend on Disaster Types

(JICA Study Team)

The largest group is slope failure / collapse, followed by slide (Jisuberi), debris flow, and rock fall.

Difficulties in implementing countermeasures against slide (Jisuberi) seems to have pushed up the numbers of the cases because repeated requests were made by the partner countries, which lacks capabilities in implementation of countermeasures against slide (Jisuberi).

2.2.3 Countermeasures

The trends on countermeasures implemented in ODA projects are summarized in this section.

Table 2-23 Trend on Countermeasures

(JICA Study Team)

Countermeasures	Cases
Rock fall protection	15
Retaining wall	14
Slope protection	17
Concrete crib works (spray crib works)	12
Rock bolts/ ground anchors	20
Control works against slide	22
Pile works against slide	5
Surface/subsurface drainage	18
Rehabilitation of roads	6
Check dam / drop works	5
Erosion protection	5
Shifting alignment	8

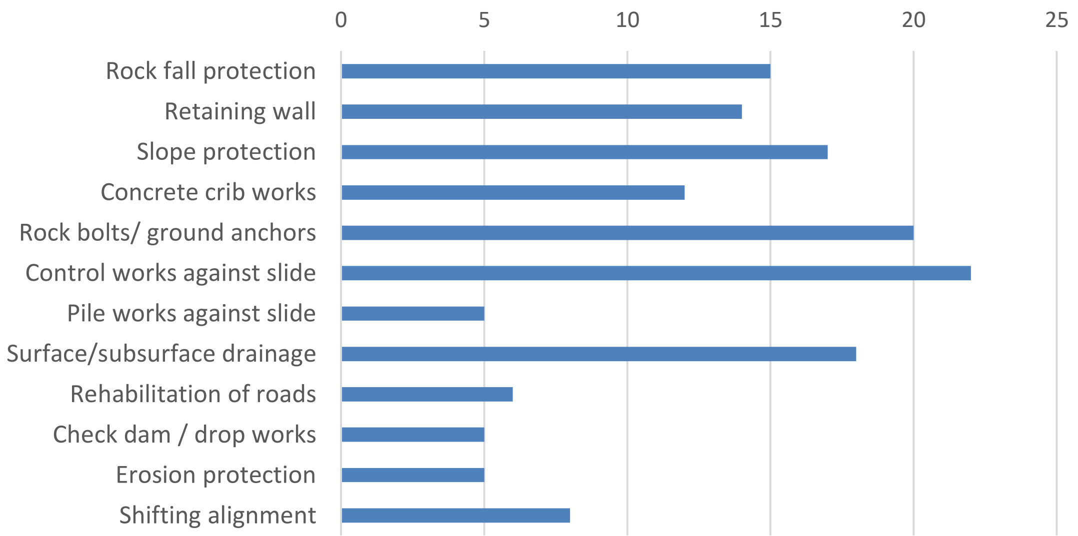


Figure 2-2 Trend on Countermeasures

(JICA Study Team)

Control works against slide (Jisuberi) is the largest group, which includes earth removal and buttress fill, followed by rock bolts / ground anchors, slope protection, and surface / subsurface drainage.

Concrete crib works can be included in the slope protection. On the other hand, concrete crib works are prominent works as Japanese technology and versatile with rock bolts and ground anchors. Thus concrete crib works including spray crib works are separately counted.

Shifting alignment is useful measures to avoid slide (Jisuberi) when budget ceiling is tight.

Table 2-24 shows the trend on rock fall countermeasures.

Table 2-24 Trend on Rock Fall Countermeasures

(JICA Study Team)

Rock Fall Countermeasures	Cases
Unspecified	3
Active measures at sources	3
Rock fall net (passive)	4
Rock fall fence (passive, roadside)	2
Rock fall merlon[1] (passive, roadside)	1
Removal	2

Table 2-25Table 2-24 shows the trend on retaining wall, slope protection, and crib works.

As a retaining wall, gabion is popular. The material for gabion is easily obtained on site. Local labors can be used for the construction of gabion. Thus gabion matches demands in developing countries.

As slope protection, shotcrete is popular along with vegetation.

Concrete crib works are popular in ODA projects including ODA Grants, where Japanese contractors are expected to come.

Table 2-25 Trend on Retaining Wall, Slope Protection, and Crib Works

(JICA Study Team)

Retaining Wall, Slope Protection, and Crib Works		Cases
Retaining Wall	Gabion	9
	Concrete Retaining Wall	3
	Unspecified	2
Slope Protection	Shotcrete	8
	Vegetation	7
	Unspecified	2
Crib Works	Crib works	12

[1] Rock fall merlon is a kind of embankments to trap rock fall behind them before reaching roads, as shown in Figure 4-4.
Debris flow merlon is to stop debris flow before reaching roads as shown in Figure 4-7 and Figure 4-8.

Table 2-26 shows the cases of rock bolts and ground anchors. Both rock bolts and nailing require insertion of steel bar to the borehole and fixing by grouting but do not apply tension force after grouting.

Table 2-26 Cases of Rock Bolts and Ground Anchors

(JICA Study Team)

Ground Anchors / Rock Bolts	Cases
Ground Anchors	7
Rock Bolts / Soil Nailing	13

Ground anchors are counted not only the use against slope failure but slide (Jisuberi).

Ground anchors are used in ODA projects where Japanese contractors are expected to come. On the other hand, rock bolts and soil nailing are used in the project where Japanese contractors are not expected.

Table 2-27 shows the trend on countermeasures against slide (Jisuberi).

The most popular works are earth removal / buttress fill, followed by horizontal drainage boring. Pile works Table 2-27 includes steel pipe and H steel.

Drainage well is not popular due to difficulties of construction in developing countries.

Table 2-27 Trends on Countermeasures against Slide (Jisuberi)

(JICA Study Team)

Countermeasures against Slide	Case
Horizontal Drainage Boring	9
Drainage Well	2
Earth Removal / Buttress Fill	11
Pile Works	5

Table 2-28 shows the trend on drainage works. Obviously surface drainage / channel works are popular. Surface drainage and channel works are well recognized as countermeasures against landslide in developing countries. Subsurface drainage and French drain are also popular as reasonable measures against slide (Jisuberi).

Table 2-28 Drainage Works

(JICA Study Team)

Drainage Works	Cases
Surface Drainage / Channel Works	14
Subsurface Drainage / French Drain	4

Table 2-29 summarizes the cases for rehabilitation of roadbed, which were washed away by landslides.

Reinforced Earth Embankment is well known in developing countries and easy to adopt.

On the other hand, light-weight embankment with air-mixed mortal is used in ODA projects but limited to the project where Japanese contractor joined.

Retaining wall with ground anchors were used for rehabilitation on steel hill slope.

Table 2-29 Rehabilitation of Road Bed

(JICA Study Team)

Rehabilitation of Road Bed	Cases
Light-weight embankment	2
Reinforced Earth Embankment	3
Retaining Wall with Ground Anchors	1

CHAPTER 3 Landslide Countermeasures in Japan

3.1 History of Landslide Countermeasures

3.1.1 History of Major Slope Protection Works

(1) History of Concrete Spray Works (Shotcrete)

Shotcrete machines are basically divided into those for spraying slopes and bedrock and those for supporting tunnels. Prior to 1965, dry type spraying machines such as American-made Nucleator and Super-Creator, and Swiss-made Ariba BS-12 and Ariba 300 were used (Japan Construction Machinery Constructors Association, 2019). Tazawa (1988) and Aikawa (2015) describe that mortar/concrete spray has been applied since late 1950s as surface protection for bedrock slopes and other slopes. In addition, it is said that this method was constructed as a surface protection for many slopes from 1965 to 1975. From this, these dry type spray machines were thought to be introduced to Japan around 1960. In the 1960s, the conventional dry construction method was changed to the wet construction method for slopes, and the S-4 spray machine was developed in Japan (Japan Construction Machinery Constructors Association, 2019).

Mortar/concrete spray was also introduced in the Highway Earthwork Guidelines revised in 1967.

On the other hand, in the field of architecture, cement spray machine was developed in Japan around 1931 for use on the outer walls of buildings. Mortar spray was already used before the WWII (Omata, 2015). It is presumed that the mortar spray described in the first edition of the Highway Earthwork Guidelines in 1956 applied this technology.

(2) History of Cast-in-Situ Concrete Crib Works

As explained in the previous section, the Highway Earthwork Guidelines issued in 1956 does not introduce slope construction. Concrete crib works were first introduced in the 1967 revision. The types of concrete crib works listed here are cast-in-situ concrete crib works and reinforced concrete products. According to the materials of the Hokkaido Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (2021), concrete crib works appeared in the latter half of the 1950s.

(3) History of Spray Crib Works

As introduced in the history of concrete spray works above, the wet type of concrete spray was developed in Japan in the 1960s. Utilizing this technology, in 1975, the Free Frame Construction Method was developed in Japan. It is a combination of the technology of Cast-in-Situ Concrete Crib Works, which has been used since late 1950s, and the wet concrete spray technology developed in the 1960s. In this construction method, wire mesh is used as formwork, main reinforcing bars and shear reinforcing bars are placed in combination with formwork, and concrete is sprayed inside and outside the wire mesh formwork to create concrete frames. It is a simple combination of wire mesh forms and reinforcing bars, and multiple products are currently used in addition to the Free Frame Construction Method.

(4) History of Soil Nailing /Rock Bolt

As explained in the previous section, soil nailing /rock bolt appeared as slope protection works in the Highway Earthwork Guidelines in the 1999 edition (1999) as reinforced earthworks. There is no description in the previous 1986 edition (1986). On the other hand, Public Works Research Institute (1988) classified soil nailing as a reinforced earthworks for landslide countermeasures and presented its design method, so this method is considered to become popular around this time. NEXCO (2007) published the design and construction guidelines for the reinforced earthwork method for cutting, and attempted to unify the design method of soil nailing/rock bolt for slope stabilization.

(5) History of Head Wire-Connected Soil Nailing / Rock Bolt

This construction method was developed in Nagasaki Prefecture as a construction method to stabilize slopes while preserving natural trees, and was first adopted in 1995 as an erosion control method. The first name of this method was Non-frame Construction Method because it does not use concrete frames on the ground surface (Figure 3-1). After the Non-frame Construction Method study group was established in 2000, the development of construction technology and materials progressed, and this method was established and developed as reinforced earthworks (or soil nailing / rock bolt) for natural slopes. (Uchida et al. 2015).

(a) Non-frame construction method

(b) Rope net and rock bolt combination method

Figure 3-1 Head Wire-Connected Soil Nailing / Rock Bolt

(Sagashiba HP, 2021, Murakami et al., 2002)

On the other hand, around 2004, Hyogo and Aichi Prefectures took the lead in developing a method of combining rope nets and rock bolts to prevent natural slope failures caused by earthquakes. In the same year, the "Rope Net and Rock Bolt Combined Construction Method Design and Construction Guidelines" (Hyogo Prefectural Forest Conservation and Forest Road Association, 2004) was prepared.

Around 2011, the ES Net Method was developed as a similar wire connection method, and around 2017, the DC Net Method was developed.

Although these construction methods have different structural details, the basic structure of connecting the heads of soil nailing / rock bolt with steel wires is the same.

(6) History of Ground Anchor Works

The basic anchor technology developed in 1928 by Eugene Freyssinet (1879-1962) in France. As the first use in Japan, it was adopted as a bedrock anchor in 1934 to fix embankment to bedrock foundation (Ministry of Land, Infrastructure, Transport and Tourism-2017, Uchida -2014). Ground anchors such as tie-back anchors became popular for temporary earth retaining structures, and are widely used for deep foundation of buildings, temporary walls for subway construction, etc. This construction method was widely introduced to Japan from Europe from 1957 to the 1960s. It was first adopted as a bedrock anchor, and expanded to include reinforcing the foundations of steel towers and bridges. It was initially used as a temporary earth retaining works and has been commonly using for such purpose since then. In late 1960s, it began to be applied to slope stability measures (Yamada, 2008). The first bedrock anchor (rock anchor) in Japan was adopted in 1957 to apply prestress to the auxiliary dam of the Fujiwara Dam in Gunma Prefecture. The first earth anchor was constructed in Tarumi, Kobe City in 1964 (Soil Engineering Society, 1976).

As an attachment, the “Design and Construction Standard of Earth Anchor Works - Soil Engineering Society Earth Anchor (Soil Engineering Society, 1976)" is published by the Soil Engineering Society (the predecessor of the Geotechnical Engineering Society). : Japanese translation of "Design and Construction of Pre-stressed Ground Anchorage First Edition (1973 edition)" published by Federation Internationale de la Precontrainte; and German standard DIN 4125 (1972) "Design, Construction and Testing of Earth Anchors for Temporary Construction”. In the design chapter of the book, there are many explanations about the use of temporary structures. It can be seen that the main anchorage ground targeted by earth anchor works at that time was soil. However, in the chapter of the practical example, there is an example of anchor works combined with slope protection carried out on the Tohoku Expressway as a slope stabilization anchor works. From this, it is clear that anchor works had been used practically as a countermeasure against landslides at that time.

In the 1970s, high-performance excavators were introduced from Europe, and then Japanese domestic construction machinery was improved. The reliability of anchor works was further enhanced by the establishment of the technical standards of the Soil Engineering Society (1976). In the 1980s, there was a growing debate about high durability anchors with multiple anti-corrosion functions. In 1988, the "Ground Anchor Design and Construction Standards (Soil Engineering Society, 1988)" (JSF Standard: D1-88) was enacted and clarified anti-corrosion standards such as double anti-corrosion for anchors. An anchor conforming to this requirement is called a new type anchor, and an anchor based on the previous standard is called an old type anchor. Since the beginning of the 1990s, the anti-corrosion structure of anchors has diversified. Improvements in material technology have made it possible to use epoxy-coated PC steel wires and continuous fiber reinforcements as anchor steel materials, which help simplify the anchor structure, and many products for anchor works were developed (Yamada, 2008).

(7) History of Rock Fall Barrier

In the Highway Earthwork Guidelines revised in 1967, Rock Fall Barrier were already introduced as "fence works." It is described as structures that are connected by wire ropes or wire meshes with anchored by steel struts. Stone guard works was developed in 1963. Figure 3-2 is a photograph of a rock fall barrier constructed in 1961. It is believed that such a rock fall barrier was firstly used in the 1950s.

Figure 3-2 Example of Rock Fall Barrier constructed in 1961

（Forestry Agency, 2018）

In 1996, Ring Net was introduced from Switzerland to Japan as a high-energy absorbing rock fall barrier. As a result, Rock Fall Barriers are divided into conventional types and high-energy absorption types. Around 2000, energy-absorbing Rock Fall Barriers such as ARC fences were also developed. At present, high-energy absorption Rock Fall Barriers are classified into post-strengthening fences and net-strengthening fences (Public Works Research Institute, 2017,Figure 3-3. Multiple products are being developed by various companies, such as Loop Fence, and High Joule Net.

(a) Support Reinforced Fence (b) Net Reinforced Fence

Figure 3-3 High-energy-absorbing Rock Fall Protection Barriers

（Public Works Research Institute, 2017）

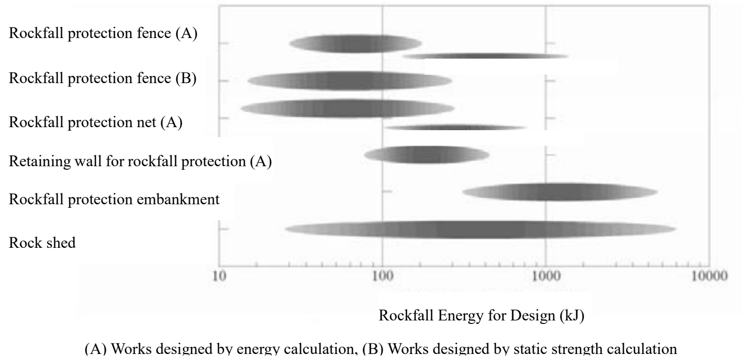


Figure 3-4 Approximate Scope of Application for Rock Fall Protection Works

（Japan Road Association、2000）

(8) History of Rock Fall Protection Net

The Highway Earthwork Guidelines revised in 1967 already included rock fall protection nets. Rock fall protection nets are classified into pocket type and covered type, and this classification is adopted in the 2000 revision of the Rock fall Countermeasure Handbook. In this 2000 version, the covered rock fall protection net is classified as rock fall protection works, but in the 2019 revision, it is classified as rock fall prevention works. In 1993, a curtain net was developed as a high-energy absorption rock fall protection net, and pocket-type rock fall protection nets came to be classified into conventional types and high-energy absorption types (Fig. 35). At present, multiple products such as Beads Ringer Net, Strong Protective Net, and Net One are being developed as high energy absorption types.

(a) Conventional Pocket-type Rock Fall Net

(b) High Energy Absorbing Rock Fall Net

Figure 3-5 Examples of Types of Rock Fall Protection Nets

（Public Works Research Institute, 2017）

Source:
Japan Construction Machinery Constructors Association (2019): Transition of Concrete Machinery, Construction Machinery Construction, Vol.71, No.11, pp.127-134.
Yujiro Tazawa (1988): Shotcrete works, Journal of the Society of Powder Technology, Vol.25, No.3, pp.168-174
Toshinori Aikawa (2015): Current status of Shotcrete works, Kensetsu Plaza, Feature Articles Museum
Kazuo Omata (2015): The path of Spray works, Bulletin of the Japan Building Finishing Materials Industry Association
National Specified Slope Protection Association (1987): Guidelines for Design and Construction of Glue Frame Works
Ministry of Land, Infrastructure, Transport and Tourism Hokkaido Development Bureau HP (2021): Section 2 Road Project Technology, Chapter 2 History of Technology Supporting Comprehensive Development of Hokkaido (https://www.hkd.mlit.go.jp/ky/ki/ kouhou/u23dsn0000001axq.html See 2021/5/11)
Public Works Research Institute, Ministry of Construction (1988): Slope Reinforcement Works with Reinforcing Bars, Public Works Research Institute Material No. 2568
NEXCO (2007): Design and construction guidelines for reinforcing cut embankment works
Yoji Uchida, Akihiro Nagata, Toshikazu Watanabe, Masahiko Ichimura, Takeho Ikeda (2015): Efforts to develop new works in the Fukuda area restoration project (Nagasaki City, Nagasaki Prefecture) -Non-frame works (Natural slope ground reinforcement earthwork)), Water Science, No.344, pp.106-123.
Hyogo Prefectural Forestry Road Association (2004): Rope net and rock bolt combined works Design and construction guidelines (draft)
Hyogo Prefectural Forestry Road Association (2011): Rope net and rock bolt combined works Design and construction guidelines (draft) (3rd edition)
Ground reinforcement network study group website (2021): https://www.jiyamahokyounet.jp/works/ (see 2021/5/12)
Rope net and rock bolt combined works research group website (2021): http://www.rr-kouhou.com/ (see 2021/5/12)
Non-frameworks Study Group HP (2021): http://www.non-frame.com/ (See 2021/5/12)
Japan Society of Soil Engineering (1976): Earth Anchor works-with Earth Anchor Design and Construction Standards, Japan Society of Soil Engineering, 236p.
Soil Engineering Society (1988): Ground Anchor Design and Construction Standards.
Soil Engineering Society (1990): Ground Anchor Design and Construction Standards, Commentary, 148.
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Geotechnical Society (2012): Ground Anchor Design and Construction Standards, Commentary, 211.
Yamada, Hiroshi (2008): Progress and History of Ground Anchor Technology (Part 1)-Structure and Construction Technology, Slope Disaster Prevention Technology, Vol.35, No.2, pp.42-53.
Ministry of Land, Infrastructure, Transport and Tourism (2017): Anchor inspection manual for dams, NILIM data No. 968

Uchida, Tsutomu (2014): The process and issues of anchor technology as a countermeasure against landslides, Journal of the Japan Landslide Society, Vol.51, No.5, pp.9-16.
Public Works Research Institute (2017): Research on performance verification methods for high-energy absorption type rock fall protection works, joint research report, No. 491
Forestry Agency (2018): Collection of Case Examples of Measures to Extend the Life of Erosion Conservation Facilities
Sagashiba HP (2021): https://sagashiba.jp/products/66
Harushige Murakami, Tetsuro Kaneko, Hiroyuki Kimura, Kiyoshi Kagamihara (2002): Proposal of design method based on deformation amount for joint works of rock bolts and rope nets for slope stability during earthquakes, 57th annual academic lecture of Japan Society of Civil Engineers meeting
Yuji Nakano (2006): Transition of slope greening [3], Agriculture and Science,

3.1.2 Roadmap of Landslide Countermeasures in Japan

Based on the contents up to the previous section, we created a roadmap for landslide countermeasures in Japan (Figure 3-6). Since the postwar 1940s, the types of landslide countermeasures have gradually increased, and individual countermeasures have been improved and new products have been developed. All major landslide countermeasures had been developed before the late 1990s.

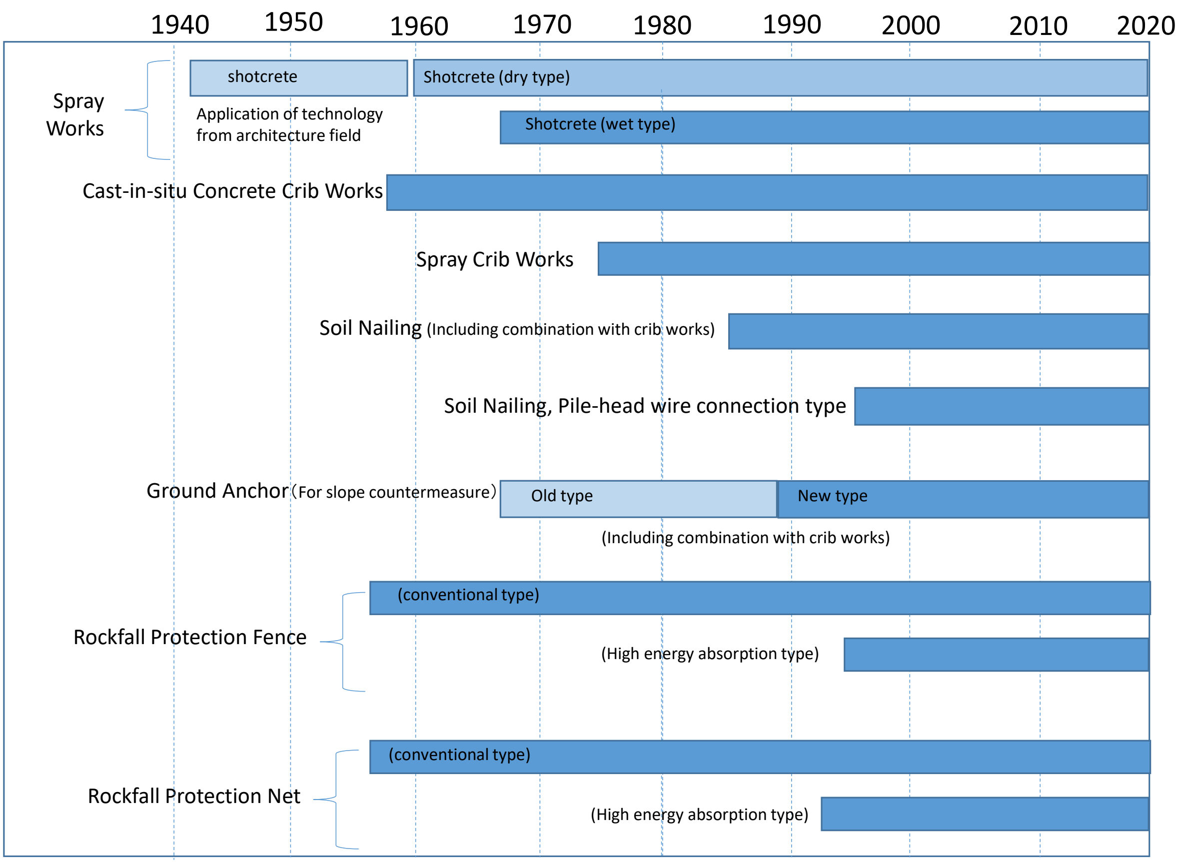


Figure 3-6 Roadmap of Major Landslide Countermeasures

(JICA Study Team)

3.2 Landslide Countermeasure in National Plans

The Basic Disaster Prevention Plan is the highest-level plan in the disaster management in Japan. It is the comprehensive and long-term disaster management plan. However, planning period in detail is not set, which is the reason why the contents have been repeatedly revised. Based on the legal system and the national plan, examples from the national and prefectural governments, individual laws with references to slope control measures and the slope control-related plans, projects, and budgets based on these laws are summarized.

3.2.1 Legal System and National Program

The landslide countermeasures covered in this study are referred to the individual laws that realize individual policies based on the policy set forth in Basic Act on Disaster Management (enacted in 1961), which is the highest law on disaster management in Japan.

In addition, the Road Act stipulates the road improvement. Road disaster prevention measures including disaster recovery in Japan, also involve the responsibility of road administrators. Therefore, risk management and disaster prevention management in the event of a disaster are not regarded as the special operations, but are included in the road management of ordinary times.

A list of the principal individual laws is shown below.

Table 3-1 List of Laws Related to Landslide Disasters and Slope Protection Measures

(JICA Study Team)

Items	Contents
Name of Law	Erosion Control Act
Date of Enactment	March 30, 1897
Summary	This act stipulates the required prevention measures against debris flow disasters along streams in mountainous areas. It also stipulates the permission to construct roads in erosion control areas.
Name of Law	Act on Protection of Cultural Properties
Date of Enactment	May 30, 1950
Summary	The purpose of this Act is to contribute to the cultural improvement of the people and contribute to the progress of the world culture by preserving and utilizing the cultural properties. According to this law, the prior notifications are obligatory when conducting development projects such as civil engineering works in the known cultural assets lying under ground based on Articles 93 and 94. Furthermore, when new archaeological ruins are discovered, they should be immediately notified to the Agency for Cultural Affairs without any change of the current situation.

Items	Contents
Name of Law	Forest Act
Date of Enactment	August 1, 1951
Summary	It is a basic law for forest administration that aims to contribute to the conservation of the national land and the development of the national economy by promoting the sustainable yield cultivation of forests and the forest productivity. Based on this act, the protection forests against erosion and hillside failure are designated to prevent landslide disasters such as debris flows and slope failures. Certain development activities are restricted within these protection forests, except for those executed by the national or local governments or those stipulated in Article 5 of the Forest Act Enforcement Regulations. The designation should be cancelled if their function as protection forests will be lost by construction of roads.
Name of Law	Road Act
Date of Enactment	June 10, 1952
Summary	This law is enacted with the purpose of contributing to the development of transportation. In order to improve the highway network, route designation and certification, administration, structures of roads, maintenance, burden sharing of cost, and so on, are stipulated. In addition, regulations on road management such as road definitions, occupation of road space, and agreements on road maintenance, and regulations on road cost sharing of roads are also stipulated.
Name of Law	Natural Parks Act
Date of Enactment	June 1, 1957
Summary	The purpose of this Act is to contribute to the health, recreation and increase awareness of citizens to the conservation of biological diversity by protecting excellent natural scenic areas and promoting the utilization of those areas. Natural parks include national parks, quasi-national parks, and prefectural natural parks. In the special protection areas and class I special areas, particularly strict preservation of the landscape are required, so that development activities are not permitted in principle. Development activities in class II and class III special areas are permitted only if they meet the standards and have little impact on the scenic beauty. On the other hand, notifications are required for the development activities in ordinary areas.

Items	Contents
Name of Law	Landslide Prevention Act
Date of Enactment	March 31, 1958
Summary	The purpose of this act is to conserve the land and maintain the people's livelihood against disasters caused by reactivated landslides. Structural measures are principally described, and permission and authorization for construction of roads in the landslide-threatened areas are stipulated in this act.
Name of Law	Act on Prevention of Disasters Caused by Steep Slope Failure
Date of Enactment	July 1, 1969
Summary	This act stipulates the prevention measures that prefectural governments should take in order to protect the lives of the civils from disasters caused by steep slope failures due to torrential rains or earthquakes. Based on this law, prefectural governments are obliged to designate the danger areas of steep slope failure and take preliminary measures to prevent disasters.
Name of Law	Nature Conservation Act
Date of Enactment	June 22, 1972
Summary	The purpose of this Act is to promote appropriate comprehensive conservation of the natural environment, including ensuring biodiversity, to secure a healthy and civilized lifestyle for current and future citizens. Under this act, the Wilderness Areas and the Nature Conservation Areas are designated. In addition, prohibitions and regulations against constructing, reconstructing, or extending buildings or other structures, and changes to the land are stipulated.
Name of Law	Basic Act on the Environment
Date of Enactment	November 12, 1993
Summary	The purpose of this Act is to promote policies for environmental conservation in a comprehensive and systematic manner to ensure wholesome and cultural life of the people at present and in the future, as well as to contribute to the welfare of humankind. The Government should take necessary measures to encourage project personnel engaged in changing the shape of land, construction of new structures and other similar projects to voluntarily examine, estimate and evaluate the impact on the environment in a proper manner in advance, and to give proper consideration to environmental conservation in relation to their projects based on the results thereof.

Items	Contents
Name of Law	Environmental Impact Assessment Act
Date of Enactment	June 13, 1997
Summary	This Act was enacted under the Article 20 of the Basic Act on the Environment. This Act stipulates that the project personnel should voluntarily examine, estimate, and evaluate serious impacts on the environment caused by the projects. It also stipulates that the methodology and results of EIP should be made public from an early stage, and the opinions of residents should be will be heard and reflected in the project plan. Furthermore, it sets forth procedures and other designed provisions to define clearly the responsibilities of the government, etc., regarding environmental impact assessments and to ensure that the environmental impact assessments are conducted properly and smoothly with respect to large-scale projects that could have a serious impact on the environment. This Act stipulates that the project personnel should voluntarily examine, estimate, and evaluate impacts on the environment caused by the projects. It also stipulates that the method and results of the environmental impact assessment should be made public from an early stage, and the opinions of residents should be reflected in the project plan. The classification of road projects is as follows. Class-1 Project (This Act is applied) National expressway Metropolitan expressway etc. National road with 4 or more lanes and length of 10 km or more Forest road with width of 6.5 m or more and length of 20 km or more Class-2 Project (This law is applied based on the investigation of a third party) National road with 4 or more lanes and length of 7.5 km or more and less than 10 km a forest road with width of 6.5 m or more and length of 15km or more, and less than 20 km
Name of Law	Act on Sediment Disaster Countermeasures for Sediment Disaster Prone Areas (Sediment Disasters Prevention Act)
Date of Enactment	May 8, 2000

Items	Contents
Summary	This act stipulates that information on the actual situation of past sediment disasters or the sediment disaster prone areas should be actively provided so that communities and persons can respond appropriately to sediment disasters. Within the sediment disaster hazard areas, prefectural governments have the authority to regulate the development of residential land, such as roads facing land. And if appropriate countermeasures are installed, the development will be permitted.
Name of Law	Landscape Act
Date of Enactment	June 18, 2004
Summary	The purpose of this Act is to build a beautiful and dignified national land by formulating landscape plans. Under this Act, it is aimed to form a beautiful and dignified national land and create an attractive and comfortable living environment as well as bring into being unique and vibrant communities through mutual cooperation between the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Ministry of the Environment (MOE). Landscape Administration Bodies mean Designated Cities, a core cities, prefectures, or other municipalities with the consent of the prefectural governor. The Landscape Administration Bodies stipulate the target areas of the landscape plans, the policy of formation of good landscapes, and the regulations of acts. Important public facilities such as roads and rivers and so on in the Landscape Planning Areas can be incorporated into the Landscape Plans with the consent of the managers. If the roads have been designated as the Public Facilities of Landscape Importance as referred to in Article 47, maintenance of the relevant roads should be carried out in accordance with the Landscape Plan. In addition, for the road occupancy, it is required to comply not only with the criteria for the permission under the Road Act, but also with the "criteria for the permission stipulated in the Landscape Plan" (Articles 49 to 54).

Source:

・ Ministry of Land, Infrastructure and Transport & Infrastructure Development Institute (2002): Guidebook for technology transfer (in Japanese)
・ Ministry of Land, Infrastructure and Transport, Ministry of Agriculture, Forestry and Fisheries, Ministry of the Environment (2004): Guideline of the Landscape Act (in Japanese)
・ Ministry of the Environment: Review of the Nature Conservation Act (in Japanese), Browsed the following URL on September 15, 2021, https://www.env.go.jp/nature/hozen/law.html
・ Agency for Cultural Affairs: Buried Cultural Property (in Japanese), Browsed the following URL on September 16, 2021, https://www.bunka.go.jp/seisaku/bunkazai/shokai/maizo.html
・ Natural Parks Act: Browsed the following URL on September 16, 2021,
・ https://elaws.e-gov.go.jp/document?lawid=332AC0000000161 (in Japanese), https://www.japaneselawtranslation.go.jp/ja/laws/view/3060/je (in English)

- Basic Act on the Environment: Browsed the following URL on September 16, 2021,
- https://elaws.e-gov.go.jp/document?lawid=405AC0000000091 (in Japanese)
- https://www.japaneselawtranslation.go.jp/en/laws/view/3850 (in English)
- Chiba prefecture (2017): Guidance on application for forest development permission (in Japanese)
- Japan Road Association (2009): Guideline on earthworks for road: Cutting and slope stabilization Works (in Japanese)
- Ministry of the Environment: Enforcement of the Environmental Impact Assessment Act (in Japanese), Browsed the following URL on September 16, 2021, https://www.env.go.jp/hourei/19/000016.html

The structure of the formulated Basic Disaster Prevention Plan pursuant to the Basic Act on Disaster Management is a response to be adapted to each actual disaster, with the Part 11, the Road Disaster. The countermeasures against slope disasters of roads are not mentioned in the Part 11 Road Disaster. However, in "Section 2 Improvement of Road Facilities, etc.", it is stated that "the National Government (Ministry of Land, Infrastructure, Transport and Tourism) and the Road Administrators should improve necessary facilities to prevent disasters on roads." And for that purpose, it is stated that "development of the road network with high safety and reliability should be systematically and comprehensively implemented through the Road Disaster Prevention Projects, etc."

As national program related to the landslide countermeasure project, there is the Technical Criteria for River works under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism. The landslide countermeasure planning is included in the erosion and sediment management planning (countermeasures for sediment disasters). The landslide disasters are defined as damages to lives, property, public facilities, etc.

In Chapter 3: Erosion and sediment management planning (Countermeasures for landslide disasters, etc.), the target phenomena of steep slope failure prevention measures shall be collapses caused by rainfall or earthquakes on steep slopes. The scale of the plan shall be determined by comprehensively considering the collapse expected on steep slopes, the importance of the object to be preserved, the urgency and effectiveness of the project, and other factors. The plan should be a comprehensive plan that combines structural measures such as the construction of steep slope failure prevention measures, and non-structural measures such as the establishment of warning and evacuation systems, land use control, etc.

The "Basic Act for National Resilience", enacted on December 11, 2014, stipulates that "Investing in disaster risk reduction for resilience", which is the priority action of the Sendai Framework for Disaster Risk Reduction, should be promoted in the field of road disaster prevention. Although it does not directly mention the landslide countermeasures, improvement of road disaster prevention measures is mentioned in "Transportation / Logistics" as one of the fields that should be strengthened.

3.2.2 Types of slope protection measure-related projects based on the national program

Landslide countermeasure projects are largely implemented as erosion and sediment-related projects, of which the national budget is allocated to the following categories: "Projects under ministerial jurisdiction," which are implemented directly by the national government; " Subsidy projects," which are implemented by subsidies issued by the national government to local governments; and "Grant projects," which are implemented by grants from the national government with greater flexibility in use by local governments.

And there are projects implemented by local governments as "non-subsidized projects" with their own budget.

Additionally, there are "projects related to disaster" urgently implemented after disasters occur.

Table 3-2 Table List of Landslide Countermeasure Projects

(JICA Study Team)

Project name	Related laws
Projects under ministerial jurisdiction	
Erosion and sediment control projects	
Specified emergency projects for erosion and sediment control	Erosion Control Act (Articles 6 and 14)
Landslide control projects	Landslide Prevention Act (Articles 10 and 28)
Projects on comprehensive disaster prevention measures for river basins	
Subsidized projects	
Subsidized projects for erosion and sediment control	
Specified emergency projects for erosion and sediment control	Erosion Control Act (Articles 5 and 13)
Subsidized projects for landslide control	
Special emergency project for prevention of recurrence of severe landslide	Landslide Prevention Act (Articles 7 and 29)
Specified emergency projects for landslide control	
Specified projects for promoting sediment disaster prevention measures	
Large-scale specified projects for erosion and sediment control	Erosion Control Act (Articles 5 and 13) Landslide Prevention Act (Articles 7, 29, 41 and 45) Act on Prevention of Disasters Caused by Steep Slope Failure (Articles12 and 21)
Erosion and sediment control projects through cooperation between different disaster prevention works	
Reintegrated large-scale projects for erosion and sediment control	
Projects by grant	
Erosion and sediment control projects	
Regular erosion and sediment control projects	Erosion Control Act (Articles 5 and 13)
Landslide control projects	

Project name		Related laws
	Landslide control projects	Landslide Prevention Act (Articles 7, 29, 41 and 45)
Steep slope failure prevention projects		
	Steep slope failure prevention projects	Act on Prevention of Disasters Caused by Steep Slope Failure (Articles12 and 21)
Projects on comprehensive disaster prevention measures for river basins		
	Erosion and sediment control projects	-
	Erosion Control Foundation Survey・Steep Slope Basic Survey	Act on Sediment Disaster Countermeasures for Sediment Disaster Prone Areas (Articles 4 and 33)
Projects related disaster		
	Disaster-related emergency projects for erosion and sediment control	Erosion Control Act (Articles 5 and 13)
	Disaster-related emergency projects for landslide control	Landslide Prevention Act (Articles 7, 29, 41 and 45)
	Disaster-related emergency projects for steep slope failure prevention	Act on Prevention of Disasters Caused by Steep Slope Failure (Articles12 and 21)
	Earth failure control projects for disaster-related areas	Local Government Finance Act (Articles16)
Project under ministerial jurisdiction		
	Disaster-related emergency projects for erosion and sediment control	Erosion Control Act (Articles 6 and 14)
	Disaster-related emergency projects for landslide control	Landslide Prevention Act (Articles 10, and 28)
Earth slope failure		
	Special disaster-related emergency projects for steep slope failure prevention (Earth fall)	Act on Prevention of Disasters Caused by Steep Slope Failure (Articles 12 and 21)

Aforementioned disaster prevention projects target damaged disaster prevention facilities for road slopes. In addition, preventive countermeasures for road slopes are implemented as the road disaster prevention projects by the budget for road administration. Road disaster prevention projects are classified into three categories, such as the projects under ministerial jurisdiction, the subsidized projects, and the toll road operation. And besides them, emergency projects for disaster prevention / mitigation and national resilience are implemented as temporary or special measures. Among them, slope protection projects are included in maintenance/repair activities implemented as the projects under ministerial jurisdiction. They are also implemented as large-scale repairs / renovation activities of the subsidy projects for local governments.

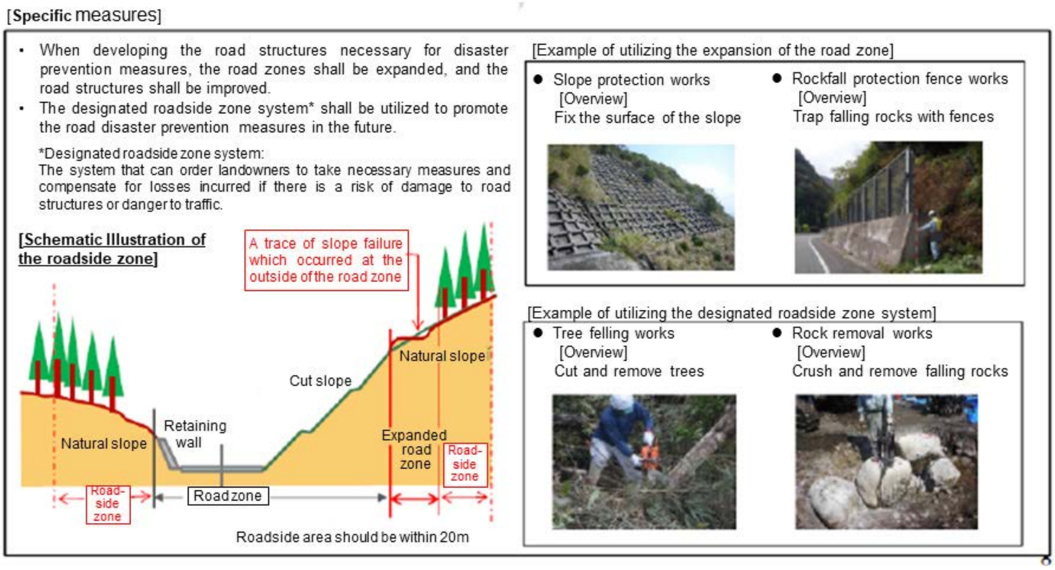


Figure 3-7 Countermeasures against Risks along Roads (Specific Measures)

(Ministry of Land, Infrastructure and Transport: Prevention and mitigation of road disasters, https://www.mlit.go.jp/common/001302646.pdf)

Based on the report of the Ministerial Meeting of "Results and Countermeasures of Emergency Inspection of Critical Infrastructure " held on November 27, 2018, as emergency measures in the Fundamental Plan for National Resilience, the functionality maintenance of the critical infrastructures for disaster prevention has been intensively implemented during three years by the MLIT. About 2,000 sites with high risk of sediment disasters or large social impacts had been extracted. At these sites, countermeasures against failure of roadside slopes or embankments were installed, road improvements and widening were implemented to prevent sediment disasters. In addition, based on the tendency of disasters in recent years, the necessity of risk assessment for roadsides including disasters caused outside of the road zone was reported. Through this, road disaster prevention measures are promoted by expanding the road zones or utilizing the designated roadside zones.

Source:

- Road Bureau, MLIT (2019): Recent situation of the road administration (in Japanese)
- Ministry of Land, Infrastructure, Transport and Tourism: Prevention and mitigation of road disasters, 2019 (in Japanese), Browsed the following URL on May 2022, https://www.mlit.go.jp/common/001302646.pdf
- Erosion and Sediment Control Department, MLIT (2020): Summary of the erosion and sediment control projects in 2020 (in Japanese)
- Ministry of Land, Infrastructure and Transport & Infrastructure Development Institute (2002): Guidebook for technology transfer (in Japanese)

3.2.3 Budgetary Provision and Improvement of Budget for Landslide Countermeasures

The budgets for slope protection projects in Japan are classified into the projects under direct control of the national government, the subsidized projects conducted by prefectural governments or designated city governments, and the projects by grant. The budget for each project is independent. In addition, the following Acts have been enacted to provide the national financial support for the implementation of disaster recovery projects. When a disaster is specified as the "disaster of extreme severity", the subsidy rate of the national subsidy projects for disaster recovery is raised by about 10 to 20%, so the burden on prefectural governments is reduced.

Due to the revision of the application procedure in 2020, when the projects under direct control of the national government and the subsidized projects after a disaster are planned promptly, the procedure which normally took about 3 months, are now able to start within 2 weeks to 1 month. This improvement is made to prevent secondary disasters in the affected areas at an early stage.

Table 3-3 Acts Stipulating National Financial Support for Disaster Recovery Projects

(JICA Study Team)

Items	Contents
Name of Law	Act on Special Financial Support to Deal with the Designated Disaster of Extreme Severity
Date of Enactment	September 6, 1958
Summary	This Act stipulates special financial support to local governments or disaster victims in the event of a significantly severe disaster stipulated in the Basic Act on Disaster Management.
Name of Law	Act on National Treasury's Sharing of Expenses for Project to Recover Public Civil Engineering Works Damaged by Disaster
Date of Enactment	March 31, 1951
Summary	This Act stipulates the burden of the national government for the expenses of projects to prompt recover of public facilities damaged by disasters to adapt to financial capacity of the municipal governments, and ensure public welfare.

As for road slope prevention projects, these are included in the road maintenance and repair portion of the road project cost, and the ratio of the national government's share and the subsidy are determined.

In Japan, when an unexpected large-scale disaster occurs, the national subsidy projects for disaster recovery will be launched. At the same time, financial measures by the local allocation tax will be taken. As a result, the actual burden on prefectural governments is about 1.7%, so the budget for disaster recovery of each prefecture becomes small. In addition, the subsidy system which the national government decided the purpose of use was abolished in 2011, and it became a lump sum grant that can be used freely at the discretion of prefectures. It is now unnecessary to limit it to the landslide countermeasure budget, therefore the annual fluctuations in prefectural budgets related to countermeasures are becoming smaller.

The following is a summary of changes in the national budget for the last five years. The budget for disaster-related projects and the budget for disaster recovery are adjusted as the budget because the amendment is large.

Table 3-4 Changes in National Budget for Slope Protection Measures from 2017 to 2021

(JICA Study Team)

Name of budget	2017	2018	2019	2020	2021
Budgets for erosion and sediment control projects					
Expenses for erosion and sediment control projects	84,302	83,254	112,347	111,737	87,122
Expenses for projects on comprehensive disaster prevention measures for river basins	6,357	6,565	8,013	8,059	7,505
Expenses for steep slope failure prevention projects	16	16	16	16	16
Expenses for riverine disaster prevention projects	24,737	50,580	56,053	87,209	14,957
Expenses for disaster recovery projects burdened by the National Treasury (Expenses for road disaster restoration)	38,320	13,101	44,864	30,922	2,934
Expenses for infrastructure development	1,954,700	2,000,300	2,188,600	1,801,500	1,485,100
Budgets for road disaster prevention projects					
Expenses for road disaster prevention projects under ministerial jurisdiction (Maintenance)	338,200	359,500	372,400	386,400	400,100
Expenses for subsidized projects for road disaster prevention	8,900	11,600	37,700	93,900	51,620

Unit: Million yen

- Details of the budget of the general account under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism from FY2017 to FY2021
- Details of the supplementary budget for the general account under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism from FY2017 to FY2020

Source:

- Erosion and Sediment Control Department, MLIT (2020): Summary of the erosion and sediment control projects in 2020 (in Japanese)
- Ministry of Land, Infrastructure and Transport & Infrastructure Development Institute (2002): Guidebook for technology transfer (in Japanese)
- Director General of the Cabinet Office for Disaster Management (2015): Disaster Management in Japan

3.2.4 Disaster Management Plans and Budgets for Landslide Countermeasure of Prefectural Governments

In Japan, disaster management plans for the prefectures are prepared by the Prefectural Disaster Management Councils to suit the local situation based on the Basic Disaster Management Plan established by the National Government. Therefore, the Prefectural Disaster Management Plans conform to the composition of the Basic Disaster Management Plan, and is revised according to the revision of the Basic Disaster Management Plan.

In Shizuoka prefecture, the citizens are highly aware of landslide disasters, because there are hazard zones where National Highway No. 1, Tomei Expressway, and JR tracks run almost parallel. In Nagano prefecture, most of the land is occupied by mountainous areas, so the technical level and awareness of road disaster management are high. Therefore, Shizuoka and Nagano prefectures are targeted in this study.

(1) Local Area Disaster Management Plan and Budgets for Landslide Countermeasure in Nagano Prefecture

Local Area Disaster Management Plan for Nagano Prefecture consists of the following five parts: "Storm and Flood Disasters", "Earthquake Disasters", "Volcano Disasters", "Nuclear Disasters", and "Other Disasters". In addition, information on hazardous areas such as "Road disaster prevention plan", “Landslide hazardous areas”, "Steep slope failure hazardous areas", and "Erosion control areas" is explained in the appendix.

The implementation plan in the “Storm and Flood Disasters” requires the following measures.

- Designation of disaster-prone areas and sediment disaster hazardous areas and preventive measures to be taken
- Development of public facilities that contribute to disaster prevention
- Ensuring safety of the disaster prevention facilities against sediment disasters
- Publication of sediment disaster hazardous area

- Erosion control facilities for debris flow hazardous torrents, landslide hazardous areas and steep slope failure hazardous areas, etc.
- Improvement of the prevention facilities against landslides and the steep slope failures

In addition, it is recommended to install rain gauges for the warning against sediment disasters and wire sensors to detect driftwood. Furthermore, it is proposed to promote comprehensive sediment-related disaster prevention measures.

The prevention program for secondary disasters is stipulated in the Section 31. It is mentioned that the preliminary measures against sediment disasters should be taken for the forest roads that may be diverted as emergency evacuation routes and transportation roads after a disaster.

In the Section 33 of the Chapter 3; "Activities to prevent the spread of disasters and the secondary disasters", the necessary measures (for example, emergency inspections, patrols, etc.) to prevent secondary disasters such as collapse of road structures and slopes are also mentioned.

Changes in the road disaster prevention projects and the budgets for landslide countermeasure in Nagano prefecture during the past three years are shown below. The landslide countermeasure project implemented with national subsidies or grants have a large budget. On the other hand, the budget for the non-subsidized project that are implemented by the prefectural government with its own budget is relatively small.

Table 3-5 Transition in Budgets for Landslide Countermeasure of Nagano Prefecture

(Edited by JICA Survey Team, obtained from Road Administration Division and Sabo Division of Nagano Prefecture)

Prefecture	Budgets	FY2019	FY2020	FY2021
Nagano	Road disaster prevention projects by grant or subsidy	1,897,861	8,769,967	1,320,290
	Non-subsidized road disaster prevention projects	812,275	749,175	711,716
	Landslide countermeasure projects by grant or subsidy	3,900,000	5,705,500	1,618,000
	Non-subsidized landslide countermeasure projects	127,000	122,000	140,000

Unit: Thousand yen

(2) Local Area Disaster Management Plan and Budgets for Landslide Countermeasure in Shizuoka Prefecture

The Local Area Disaster Management Plan for Shizuoka Prefecture consists of "General disaster prevention measures", "Earthquake Disasters", "Nuclear Disasters", "Storm and Flood Disasters", "Volcano Disasters", "Large-scale Fire Disasters", and "Large-scale Accidents". "Number of the sites for road disaster prevention projects", "The list of the landslide-threatened area", "List of the steep slope failure hazardous area", and "The list of the sediment disaster hazardous area, and the special sediment disaster hazard area" are published as the Appendix.

In Chapter 2: "Disaster Prevention Program", Section 4: "Road and Bridge Disaster Prevention Program" of the "Storm and Flood Disasters", it is mentioned that road managers should endeavor to conclude agreements with contractors, etc. regarding the removal of obstacles on roads, the securing of personnel, materials, and equipment necessary for emergency restoration, etc.

Table 3-6 Numbers of Hazardous Areas Listed in Local Area Disaster Management Plan for Shizuoka Prefecture

(Excerpted from p14 of "Storm and Flood Disasters" of "Local Area Disaster Management Plan for Shizuoka Prefecture")

Types of roads	Rock fall, slope failure, etc.	Others	Total
National highway	150	152	302
Main regional road	348	185	533
Prefectural road	204	106	310
Total	702	443	1,145

*: Numbers of the hazardous area for the road traffic caused by rock falls prepared and surveyed in 1996 by Road Maintenance Division

The project cost for the above measures is also described below for reference.

Table 3-7 Cost for Road Disaster Prevention Projects Described in Local Area Disaster Management Plan for Shizuoka Prefecture

(Excerpted from the Appendix of the "Storm and Flood Disasters" in the "Local Area Disaster Management Plan for Shizuoka Prefecture")

Table 4

Cost for the road disaster prevention projects

(Unit: Thousand Japanese Yen)

Type of the road	Actual project cost for in 2019	Actual project cost for in 2019	Remarks
Roads under jurisdiction of Shizuoka Prefecture	2,235,050	2,823,993	

(Road Maintenance Division)

The changes in the road disaster prevention projects and the budgets for landslide countermeasure during the past three years are shown below.

Table 3-8 Changes in Budgets for Landslide Countermeasure of Shizuoka Prefecture

(Budgets for road disaster prevention projects: Obtained on May 7, 2021 from Road Maintenance Division of Shizuoka Prefecture)

Prefecture	Budgets	FY2019	FY2020	FY2021
Shizuoka	Road disaster prevention projects by grant or subsidy	927	2,316	936
	Non-subsidized road disaster prevention projects	1,266	2,030	1,952
	Landslide countermeasure projects by grant or subsidy	8,537	6,629	5,422
	Non-subsidized landslide countermeasure projects	8,537	2,635	3,465

Unit: Million yen

Source:
- Erosion Control Division of Shizuoka Prefecture (2019): News of the Erosion Control Projects (in Japanese), No. 198, p5
- Erosion Control Division of Shizuoka Prefecture (2020): News of the Erosion Control Projects (in Japanese), No. 201, p5
- Erosion Control Division of Shizuoka Prefecture (2021): News of the Erosion Control Projects (in Japanese), No. 204, p5

3.2.5 Measures to Improve Life-time and Anti-aging of Road Facilities Including Slopes

The Road Maintenance Panel of the Government was launched in April 2014, and institutional support for the efforts of the local Governments to the deteriorating roads was established. As a result, measures to improve the life-span and anti-deterioration of road facilities including road slopes which have already been maintained are also being taken in prefectures.

Examples from Nagano and Shizuoka prefectures are described below.

(1) Programs for Extension of Life of Road Facilities in Nagano Prefecture

In Nagano Prefecture, the "Program for life span extension of spray crib works" (partially revised in December 2015) was formulated in June 2013, and the "Program for life span extension of the large-scale road facilities in Nagano Prefecture" was formulated in December 2015.

In addition, in the Program for life span extension of the large-scale road facilities in Nagano Prefecture formulated in 2015, the inspections have been conducted for the following structures.

Table 3-9 Road Structures to Inspect

(The Program for life extension of the large-scale road facilities in Nagano Prefecture, p1)

Type of works	Category	Details	Scale of structures
Retaining wall	Cast-in-situ concrete retaining wall	Gravity type retaining wall	Height > 8m
		Leaning-type retaining wall	Height > 8m
		Inverted T-beam counterfort retaining wall	Height > 8m
		L type retaining wall	Height > 8m
		U type retaining wall	Height > 8m
	Precast retaining wall	Counterfort wall	Height > 8m
		Concrete crib retaining walls	Height > 8m
		Stepped retaining wall	Height > 8m
	Block masonry retaining wall	Block masonry retaining wall	Height > 8m
		Big block masonry retaining wall	Height > 8m
		Composite retaining wall	No limitation
	Reinforced soil retaining wall	Concrete wall	Height > 8m
	lightweight retaining wall	Concrete wall	Height > 8m
Slope protection works	Cast-in-situ concrete crib work		Height > 8m
Box culvert			Box culverts under road surface are not applicable

(2) The Programs for Life Span Extension of Civil Engineering Facilities in Shizuoka Prefecture

"Guidelines for programs to extend the life span of civil engineering facilities for slope prevention (Draft)" was formulated in March 2007 by the Erosion and Sediment Control Office and Road Maintenance Office of the River Works General Office and the Road Maintenance Office of the Road General Office of the Civil Engineering Department, Shizuoka Prefecture. Based on these guidelines, the programs are implemented if the facilities are judged that their life-span should be extended based on the results of inspections by experts.

The slope prevention facilities covered by these guidelines are as follows.

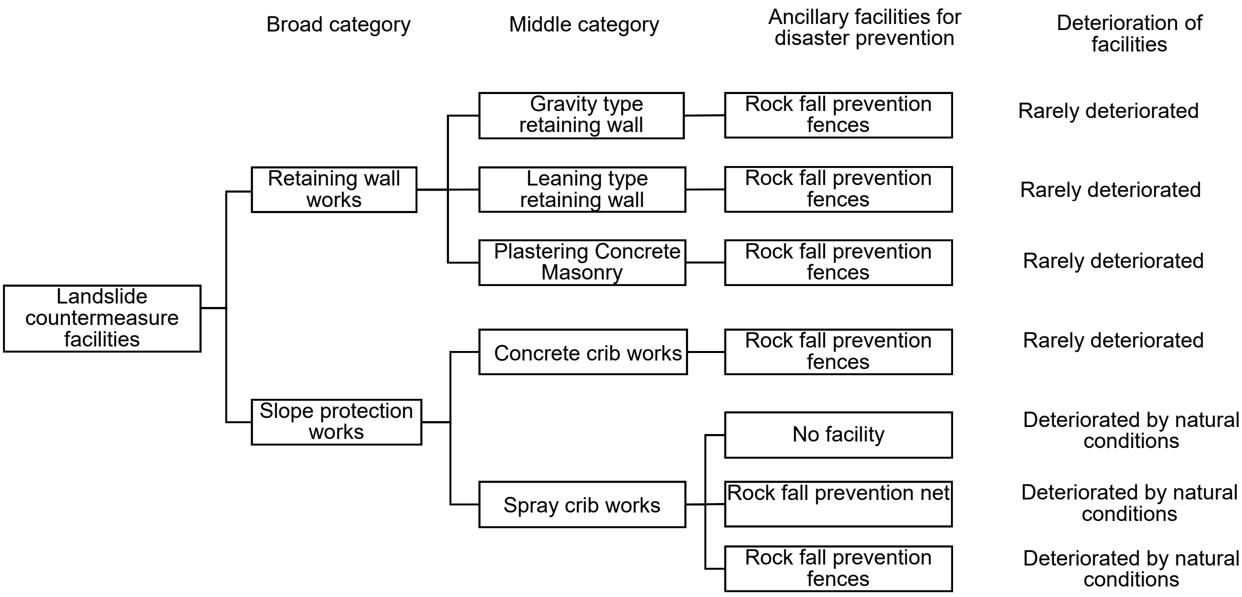


Figure 3-8 Types of Slope Protection Facilities

(Guidelines for programs to extend the life of civil engineering facilities for slope prevention, Shizuoka Prefecture, p3)

3.3 Topography and Climate Conditions (Prerequisites for Design)

Table 3-10 to Table 3-12 summarize the characteristics of the natural conditions in Japan in order to make comparisons with the climate, topography, and soil conditions from the other countries in ODA projects.

Table 3-10 Characteristics of Disaster Triggers (Natural Condition) in Japan

(JICA Study Team)

Weather, etc.	Characteristics	Description
Heavy rain	High precipitation per one time	The maximum daily precipitation is 922 mm/day under the management of the Japan Meteorological Agency (Hakone Town, 2019), and 1317 mm outside the management of the Japan Meteorological Agency (Shikoku Electric Power Observation, 2004). The maximum annual average rainfall is about 4,500 mm (Yakushima).
	There are periods when heavy rain occurs frequently	The heavy rain season is from May to July due to the seasonal rain front, late August to September due to the autumn rain front, and heavy rain due to typhoons from July to October. Heavy rains called torrential rains and localized heavy rains occur every year due to fronts and typhoons.
	There are regional deviations in annual mean precipitation.	The average annual precipitation in Japan is about 1,700 mm (Ministry of Land, Infrastructure, Transport and Tourism HP, 2021), with a maximum of about 4,500 mm (Yakushima) and a minimum of about 700 mm (Tokoro, Hokkaido).
Earthquake	Many times a year	In the 10 years from 2001 to 2010, an average of 160.2 earthquakes of M5.0 or higher occurred annually, but in 2011 there were 781 earthquakes of M5.0 or higher (Japan Meteorological Agency, 2021).
	Frequent large earthquakes	Since 2000, there have been 11 earthquakes that have caused large-scale landslides.
Heavy snowfall/melting snow	Heavy snowfall area	Heavy snowfall areas Hokuriku, Tohoku, Hokkaido. A decrease in snow load and temperature will trigger landslides and failures. Landslides occur frequently even in the early days of snow. In addition, earthwork cannot be done basically during the snowfall period.
	Due to melting snow	Hokuriku region, Tohoku region, Hokkaido.

Weather, etc.	Characteristics	Description
Temperature	Some regions have extremely cold winter temperatures	Tohoku region, Hokkaido A drop in temperature triggers landslides and collapses.
	Freezing and thawing is a problem in some areas.	Hokuriku region, central high altitude region, Tohoku region, Hokkaido. Depending on the degree of freezing and thawing, the suitability of the structure and construction of countermeasures (such as shotcrete) differs.
	There are 4 seasons with large temperature difference throughout the year.	The average temperatures range from 3 to 32 degrees Celsius in Fukuoka City, -6 to 30 degrees Celsius in Matsumoto City, and -12 to 26 degrees Celsius in Sapporo City.

Table 3-11 Features of Japan's Topographical Conditions

(JICA Study Team)

Topographical Conditions	Description
There are many mountainous areas and few plains.	Three-fourths of Japan's land area is mountainous.
Lots of steep terrain	As represented by the Central Alps, the general topography of Japan is steep, and there are many rivers with steep slopes, mainly on the Sea of Japan side.
Many landslide landforms exist nationwide	Many landslides are distributed from Hokkaido to Kyushu, and the National Research Institute for Earth Science and Disaster Resilience publishes the landslides distribution map.
There are many micro-topography in one big mountain body.	There are many areas where valley topography and ridge topography including small ones are distributed in a complicated manner.
There are many steep topography due to the river's erosion.	There are many steep valleys due to steep river gradients, heavy rainfall, and fragile geological features.

Table 3-12 Features of Geological Conditions in Japan

（JICA Study Team）

Geological Conditions	Description
Heavily folded strata	Many strata in mountainous areas are tilted due to folds caused by orogeny, and dip slopes and plunging are one of the predisposing factors for slope failures and toppling failures.
Numerous faults	Influenced by plate tectonics, numerous faults have been confirmed throughout Japan. In addition earthquakes also occur on unidentified faults, such as past earthquake disasters including the Great Hanshin Earthquake.
The geology is fragile due to the orogenic movement.	Schistosity, joints, developed geology, fold structure, fault gouge, and fractured zones are also widely distributed.
Widely distributed Neogene rocks that are easily weathered	Landslides are distributed innumerably throughout Japan. The distribution area of landslide-prone areas and the Neogene are almost the same.
There are areas where unconsolidated volcanic deposits are distributed.	From Hokkaido to Kyushu, volcanic areas are widely distributed, and strata deposited by past volcanic products are predisposing factors for landslide disasters in various places.

Source:
Ministry of Land, Infrastructure, Transport and Tourism HP (2021a): https://www.mlit.go.jp/river/pamphlet_jirei/kouhou/bousai/index.html (see 20215//18)
Japan Meteorological Agency HP (2021): https://www.jma.go.jp/jma/kishou/know/faq/faq7.html (See 2021/5/18)

3.4 Survey and Design Method

3.4.1 Investigation Method and Flow of Investigation on Landslide Countermeasures

Table 3-13 shows survey items and their contents for landslide countermeasures on road slopes, excerpted from "Japan Road Association (2009): Road Earthwork - Guideline for cutting and slope stabilization". The survey is divided into three categories: outline survey, preliminary survey, and detailed survey. It will be implemented step by step following the road construction stages. The contents of the survey in this table also include those related to landslide countermeasures. A geological measurement survey is introduced when landslide-related slope deformation is recognized. A groundwater survey will be conducted when landslide activity is confirmed.

Table 3-13 Survey Items Related to Roadside Landslide Countermeasures

(Japan Road Association (2009): Highway Earthwork - Light Embankment Works/Guidelines for Slope Stabilization)

Category	Survey type	Description
Outline survey	- Existing material collection - Wide-area field survey	Collection and analysis of topographical, geological and environmental data necessary for the outline design of the road. Furthermore, from a macroscopic point of view, a field reconnaissance survey will be carried out over a wide area.
Preliminary survey	- Collect existing materials - Aerial photo interpretation - Field reconnaissance - Boring survey of dangerous places, etc.	Collection of materials to identify areas prone to collapses and landslides: Topographic maps, geological maps, aerial photographs, geological and soil survey reports, construction records, disaster records, land condition maps, land use maps, landslide distribution maps
Detailed investigation	- Field reconnaissance - Geological and soil survey - Monitoring survey - Groundwater survey - Environmental /Landscape Survey	Geological and soil surveys include boring surveys, sounding, geophysical surveys, in-situ tests, and laboratory tests. A monitoring survey is a survey using instruments such as strain gauges and inclinometers. Groundwater survey includes observation of groundwater level and pore water pressure, groundwater logging, temperature logging, current direction and velocity measurement, and groundwater tracking survey. Note 1)

Category	Survey type	Description
Investigation of slope failure countermeasures	- Topographic map analysis - Aerial photo interpretation - Ground reconnaissance - Soil test - Geophysical exploration	It is divided into a preliminary survey to extract areas with a high possibility of slope failure and a detailed survey to obtain basic materials for detailed planning, design and construction of specific countermeasures. Preliminary survey and detailed survey are included in the above contents.

Note 1): The contents of this detailed survey include survey for landslide countermeasures. In the case of landslide countermeasures on steep slopes, groundwater surveys are usually not conducted during the dry season because the groundwater level does not often form in unstable soil masses. In addition, geological measurement surveys are not normally conducted, as it is assumed that prevention measures will be taken before slope changes are confirmed.

The contents of other technical standards related to highway earthwork are introduced.

The Technical Standards for Highway Earthwork Structures (2015) published in March 2015 is a technical standard based on the law, which stands above the road structure-related guidelines so far. Among the technical documents related to Highway Earthwork published by the Japan Road Association, the provisions of this technical standard shall take precedence over any content which were published before the enactment of this technical standard. This standard indicates basic matters related to survey, planning, design, construction and maintenance. As for the specific methods, until the subordinate guidelines are revised in accordance with the technical standards, the current guidelines will be utilized in accordance with the technical standards.

Japan Road Association (2017): Highway Earthwork Structure Technical Standards and Commentary is a technical guidebook for Highway Earthwork Structure Technical Standards (2015), which chapters of basic matters relating to survey, planning, design, construction and maintenance are indicated. In the Design Chapter, the required performance and design conditions of the road earthwork structure are described in addition to the basic items related to design. The survey is described as follows under the section of “Technical Standards and Explanations” in Chapter 3. “In surveying and planning road earthwork structures, the following shall be considered: topography, geology, environment, weather, hydraulics, landscape, past inspection status, maintenance and repair, and disaster history of the area and its surroundings, characteristics of road earthwork structures, materials used, target disasters, characteristics and maintenance of adjacent structures”. In addition, relating to topographical and geological conditions, there is the following description, “In the survey and planning of road earthwork structures, it is important to evaluate a wide range of topography and geology before conducting surveys, tests, and designs of the mechanical properties of the ground.” Regarding the target disasters, there is a description such as "It is important to clarify the form and scale of target disasters in the road earthwork structure plan". These are descriptions of research policies for roads in general, including flat roads, and do not refer to specific research contents. This technical standard has a chapter on "design" and a chapter on "construction" of road earthwork structures, but no chapter on "investigation". It emphasizes the explanation of the basic concept of the design and construction of civil engineering structures in general rather than surveys.

Japan Road Association (2009): Highway Earthwork Guidelines is the basic and common edition of the entire Highway Earthwork guidelines. Although this basic edition was abolished after the publication of Japan Road Association (2017): Technical Standards and Commentary for Highway Earthwork Structures, the consistent knowledge described in "Technical Standards and Commentary" of this Guideline can be used as a reference. Even though the common section is not abolished, the appropriate replacement is being carried out based on the description in the "Technical Standards and Commentary". In the basic edition, it explains the basic concepts of road earthwork, divided into survey, design, construction, construction management and inspection, and maintenance management. In these chapters, the survey is divided into outline survey, preliminary survey, detailed survey, construction stage survey, and maintenance stage survey, and the basic concept of each survey stage is explained. In the common edition, it is divided into survey methods and their utilization, drainage, countermeasures against frost heave, rainwater storage and infiltration facilities, construction planning, supervision and inspection, and items in common to each guideline of earthwork methods. Survey items and contents related to landslide countermeasures described in the Highway Earthwork guidelines are the same as the contents of Japan Road Association (2009): Road Earthwork - Guideline for cutting and slope stabilization listed in Table 3-13. Japan Road Association (2012): Highway Earthwork - Guidelines for Retaining Walls is a guideline that focuses on the design of retaining walls. The survey is outlined and qualitatively explained to determine the structure and foundation type of the retaining wall.

Japan Road Association (1987): The 1987 edition of the Highway Earthwork - Drainage Works Guidelines is the latest updated version, but the Japan Road Association (2009): Highway Earthwork Guideline excludes it from the system of Highway Earthwork guidelines. Its content is specialized on drainage measures for road surfaces, etc., but this content is taken over by the section on drainage in the common edition of the guidelines for Highway Earthwork. The contents of the chapter on slope drainage are taken over by the Japan Road Association (2009): Road Earthwork - Guideline for cutting and slope stabilization.

The specific contents of survey methods related to road-related landslide countermeasures are described in Japan Road Association (2009): Highway Earthwork - Light Embankment Works, Guideline for Slope Stabilization Works. In actual design, it is necessary to refer appropriately to Highway Earthwork standards, Highway Earthwork outlines, and other guidelines in order to apply the concept correctly as necessary.

Figure 3-9 shows the relationship between the flow of road construction and each survey category.

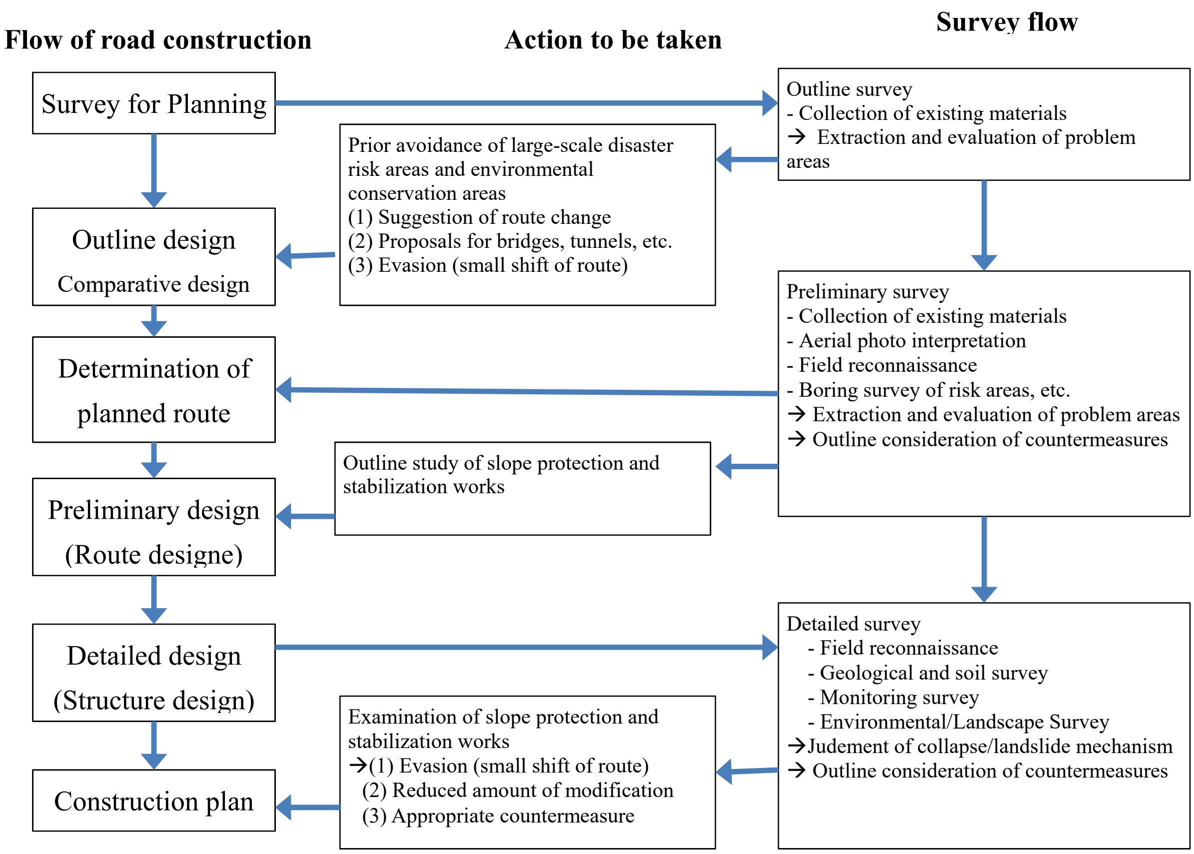


Figure 3-9 Relationship between Road Construction Flow and Survey Flow

(Excerpt from "Japan Road Association (2009): Highway Earthwork - Light Embankment Works/Slope Stabilization Works")

Table 3-14 shows the contents of standard detailed surveys according to the conditions of the target slopes. In this way, it is common to change the contents of the detailed survey according to the condition of the target slope.

Table 3-14 Level of Detailed Survey and Criteria for Survey Level Selection

(National Flood Control and Sabo Association (2019): Technical Guidelines for Slope Collapse Prevention Construction)

Survey Level	Overview of survey target slope	Standard survey content (addition to preliminary investigation)
I	1. Slope is small and gentle. 2. The geological structure is simple and can be clarified by surface geological survey. 3. The expected collapse scale is very small. 4. No history of collapse. 5. There is no slope destabilization in the construction process.	・Emphasis will be placed on detailed field surveys (surface geological surveys) with the main purpose of grasping strata structure, deformation of the ground surface, and estimating the form of collapse. Sounding is not necessarily required.
II	1. The slope height is a little high and the gradient is a little steep. The slope height is low, but the gradient is steep. 2. The stratum structure is rather complicated, and it is difficult to make it clear only by the surface geological survey. 3. The scale of the expected collapse is somewhat large. 4. Has a history of minor collapses. 5. There is a slight risk of destabilization of the slope during the construction process.	・Surface geological survey ・Simplified sounding (simple dynamic cone penetration test, portable cone penetration test, etc.): 2 to 3 survey/cross section (interval of about 5 to 20m) ・Boring survey・・・1 or more (Important if you need to check the foundation of the structure.)
III	1. The slope height is large and the gradient is also a little steep. 2. The geological structure is complicated and difficult to clarify with simple sounding alone. 3. The scale of the expected collapse is large. 4. There is a history of landslides of medium or larger size and abnormal deformation of slopes. 5. There is a risk of destabilization of the slope during the construction process.	・Surface geological survey ・Boring survey・・・2～3 or more ・Sounding (simple dynamic cone penetration test, portable cone penetration test, screw weight penetration test, standard penetration test) ・・・ several surveys/cross section lines (interval is about 5-20m) ・Seismic survey (interval is about 10 to 20m) ・Soil test

Table 3-15 shows the details of the detailed investigation to obtain the design parameters for landslide countermeasures. For example, if it is determined that the introduction of anchor works is necessary at the stage of preliminary survey or preliminary survey, anchor basic survey test and plate load test are included in detailed survey items.

Table 3-15 Detailed Survey to Obtain Design Parameters for Countermeasures

(JICA Study Team)

Survey type	Content	Corresponding countermeasure
Topographic survey	The geological structure will be understood by comparing the placement and quantity of countermeasure works, and the results of geological reconnaissance and boring surveys. Inaccurate topographic maps reduce their accuracy.	Necessary for almost all countermeasures. Also used for slope stability analysis. Necessary for calculating placement and quantity for concrete crib works that do not involve cutting. Even when cutting is involved, it is necessary to accurately reflect the results of boring surveys. Especially important for rock bolt / soil nailing and anchor works to grasp the anchorage position.
Survey boring	Confirmation of unstable soil masses and anchorage ground by visual inspection of geological conditions (weathering, cracks, etc.).	Rock bolt / soil nailing, anchor, and pile
Standard penetration test	Grasping of unstable soil mass depth by N value. Estimation of soil deformation modulus and soil strength constant.	Rock bolt / soil nailing, anchor, and pile
Sounding	Understanding the thickness of shallow unstable soil layers and estimating the deformation coefficient and soil strength constant of the ground	Rock bolt / soil nailing
Anchor basic survey test / flat plate loading test	Measurement of the peripheral friction resistance of anchor works. Understanding the maximum anchor force. The plate load test grasps the ground bearing capacity at the pressure plate position.	Anchor
Soil test Rock test	Understanding unit volume weight and soil strength constant. Necessary for countermeasure works involving earth pressure calculation and stability analysis	Retaining wall, rock bolt / soil nailing, anchor, and pile

Source:
Japan Road Association (2009): Highway Earthwork - Light Embankment Works, Guidelines for Slope Stabilization
Japan Flood Control and Sabo Association (2019): Design and Examples of New Slope Failure Prevention Work - Technical Guideline for Steep Slope Failure Prevention Work
Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures
Japan Road Association (2009): Highway Earthwork Guidelines
Japan Road Association (2012): Highway Earthwork - Guidelines for Retaining Wall
Japan Road Association (1987): Highway Earthwork - Drainage Works Guidelines

3.4.2 Performance Requirements for Landslide Countermeasures on Road

Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures describes the required performance of road earthwork structures from the perspectives of safety, usability, and easiness of repair as shown in Table 3-16. These required performances correspond to the performance regulations in the official technical guidelines: constant action (dead load, live load, etc.); rainfall action (rainfall on drainage facilities, spring water, groundwater); seismic motion action (level 1 and level 2 ground motion); other effects (wind, snow, rock fall, slope failure, rock failure, landslide, debris flow, drying shrinkage of concrete, ground displacement, scouring, temperature change, frost heave, salt damage, acid soil); corrosion deterioration, etc.); and others (Japan Road Association, 2017).

Table 3-16 Required Performance of Highway Earthwork Structures

(Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures)

Level	Required performance
1	The highway earthwork structure is sound, or the highway earthwork structure is damaged, but the performance does not affect the function of the road in the section where the highway earthwork structure exists.
2	Damage to highway earthwork structures will be limited. Performance that can be quickly restored even though some of the road functions are impaired in a certain section
3	Damage to the highway earthwork structure hinders the function of the road in the section covered by the highway earthwork structure, but the performance is such that the obstacle does not become fatal.

Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures describes the limit conditions for the required performance of cutting and slope stabilization facilities as shown in Table 3-17.

Table 3-17 Limit Conditions of Required Performance for Cutting/Slope Stabilization

(Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures)

Level	Limit Conditions of Required Performance
1	The cutting/slope stabilization is sound. Or when it is damaged, but it does not affect the function of the road on the section where it exists. It is not realistic to completely prevent deformation of the slope due to the effects of rainfall, seismic motion, collapse from natural slopes, etc. Therefore, from the viewpoint of satisfying road safety, usability, and easiness of repair, the following limit conditions are set. Even if the slope is slightly deformed, road still normally functions through regular inspections and repairs, as well as emergency inspections and emergency measures in the event of an earthquake.
2	Damage to the cutting/slope stabilization is limited to visual inspection, and will affect part of the road functions in the section where it is located. Therefore, from the viewpoint of satisfying road safety and easiness of repair, the limit conditions are set as follows. Even if structures are damaged and road closures are required, road functions can be restored through emergency restoration.
3	Damage to the cutting/slope stabilization will impede the functioning of the road in the section where it exists, but the concerned damages shall not cause fatal accidents. Therefore, from the viewpoint of satisfying safety even if the use and easiness of repair of the road are lost, the limit conditions are set as follows. It can be set as a limit state that the loss of the road itself or the serious impact on adjacent facilities due to a large-scale collapse such as a slope targeted by the facility can be prevented.

Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures defines the importance classifications of highway earthwork structures as shown in Table 3-18. Even if it is a municipal road, it is judged that especially important roads are as important as expressway national highways.

Table 3-18 Definition of Importance of Highway Earthwork Structures

(Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures)

Level	Description
1	(a) Of the highway earthwork structures on the road listed below, those that have a significant impact on the function of the road ・ National highways, urban highways, designated urban highways, Honshu-Shikoku Expressway and general national highways ・ Among prefectural roads and municipal roads, roads that are particularly important in light of their positioning in local disaster prevention plans and usage conditions, etc. (b) Highway earthwork structures that have a significant impact on adjacent facilities if damaged
2	Highway earthwork structures other than (a) and (b)

According to Japan Road Association (2017): Technical Standards and Commentaries for Highway Earthwork Structures, criteria for selecting the required performance for road structures are determined by road administrators. Although the selection criteria for such as surface drainage, embankments, retaining walls, culverts, and soft ground countermeasures are specified, the criteria according to the importance of roads are not indicated.

Japan Road Association (2009): 2-4 Design of Highway Earthwork Guidelines, the details are only written to refer to Japan Road Association (2009): Highway Earthwork - Light Embankment Works/Slope Stabilization Works Guideline.

In other words, there are no technical standards related to highway earthwork that specifically describe how to use "light embankment works/slope stability" depending on the importance of the road. In addition, Japan Road Association (2009): Highway Earthwork - Light Embankment Works/Slope Stabilization Works Guideline does not explain how to specifically give seismic motion in slope stability design.

3.4.3 Characteristics of Design Method for Landslide Countermeasure in Japan

Table 3-19 summarizes the characteristics of the design methods for landslide countermeasures in Japan in order to examine the differences in design methods from those in advanced countries such as Europe and the United States.

Table 3-19 Characteristics of Design Method for Landslide Countermeasure in Japan

(JICA Study Team)

Item	Description
Selection of slope stability analysis formula	Slope stability analysis using the limit equilibrium method is important for calculating the necessary prevention force for prevention works and evaluating the increase in slope stability due to countermeasures. In slope measures in Japanese road projects, it is common to use the most classical modified Fellenius formula for circular slip. Other stability analysis formulas such as the simple Bishop formula and the simple Janbu formula are rarely used.
Calculation method for soil strength parameters	The current factor of safety, Fs, for slopes without slope failures is Fs>1.0. For slopes and slopes judged to require landslide countermeasures, the factor of safety Fs for current slopes and cut slopes is assumed to be Fs=1.0. Then, the back analysis method is adopted to find either the cohesion c or internal friction angle ϕ of the soil strength parameters by back calculation.
Calculation of necessary prevention force for prevention works (anchor works)	A method is adopted in which the anchor force is divided into the normal force and the tangential force of the slip surface. Furthermore, the effect of increasing the shear resistance of the slip surface by the normal force is expressed as the tightening effect, and the effect of directly suppressing the landslide by the tangential force is expressed as the restraining effect.
Calculation of necessary prevention force for prevention works (soil nailing works)	The "strength" such as the tensile strength of the reinforcing material and the circumferential frictional resistance is expressed as "the tensile strength of the reinforcing material". A method of dividing the anchor force into the normal force and the tangential force of the slip surface is also adopted. As with the anchor, the method is divided into tightening effect and restraining effect, and both are added to the numerator in the stability analysis formula as the same manner with Anchor works.
Adoption of slope reduction factor for reinforced earthworks (soil nailing works)	In NEXCO (2007): Design and Construction Guidelines for Cutting Reinforcing Soil Works, a coefficient that reduces the tensile force of reinforcing materials is applied depending on the type of slope protection works. This is a design method developed in Japan, and this method has become the mainstream of design methods in Japan.

Source

NEXCO (2007): Design and construction guidelines for cutting reinforcement soil works, East Nippon Expressway Company, Central Nippon Expressway Company, and West Nippon Expressway Company, Ltd.

3.4.4 Selection Flow of Landslide Countermeasures

Road slope collapse is not a phenomenon that occurs only on cut slopes, but also occurs on natural slopes along roads. Figure 3-10 shows the selection flow for general landslide countermeasures. This flow does not presuppose the cutting works and is applicable to higher level roads than municipal roads. It should be noted that there is no complete selection flow due to the various natural conditions. Ultimately, about three works will be selected, and a final decision will be made after specific comparisons, including natural conditions and construction costs.

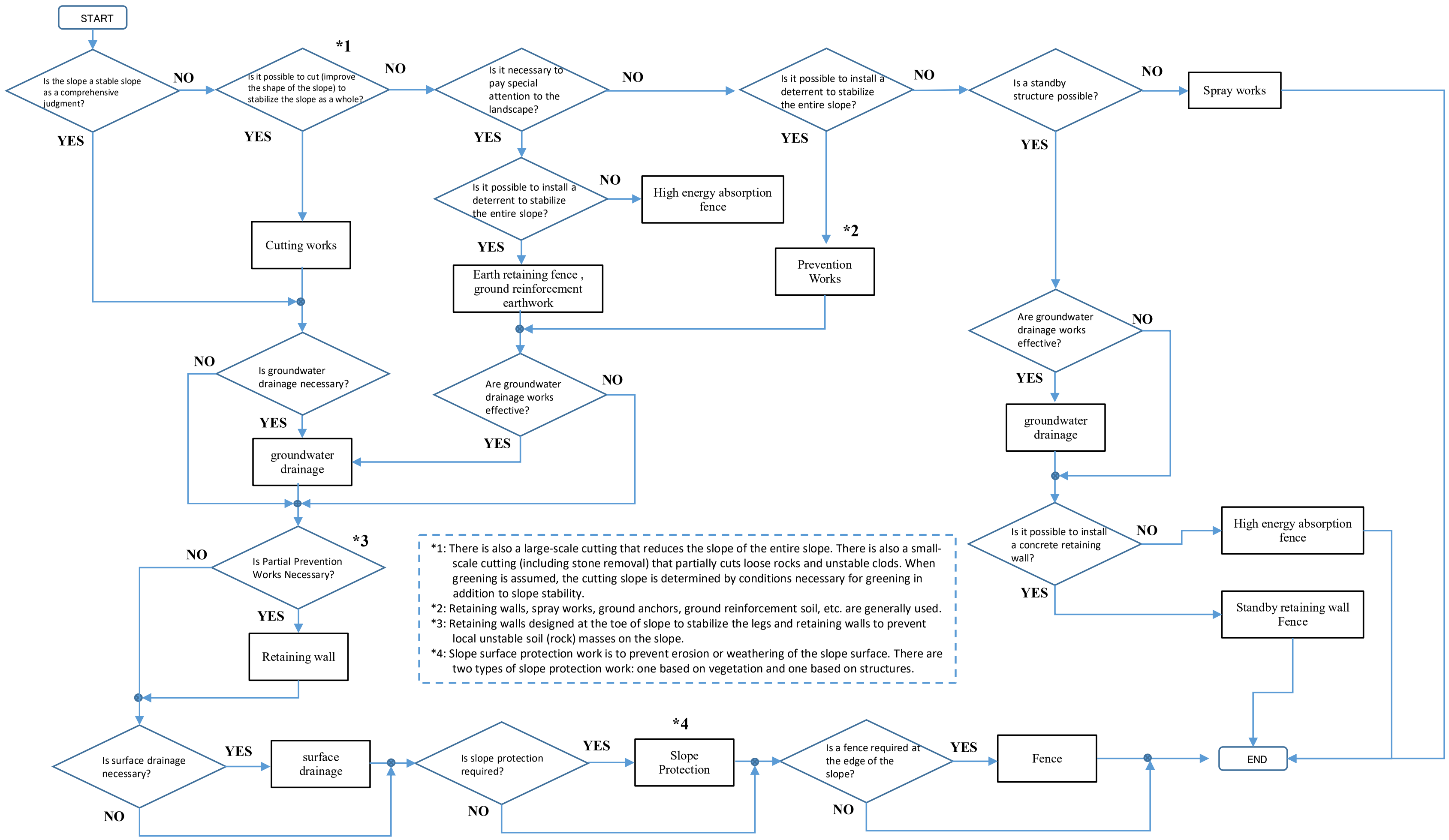
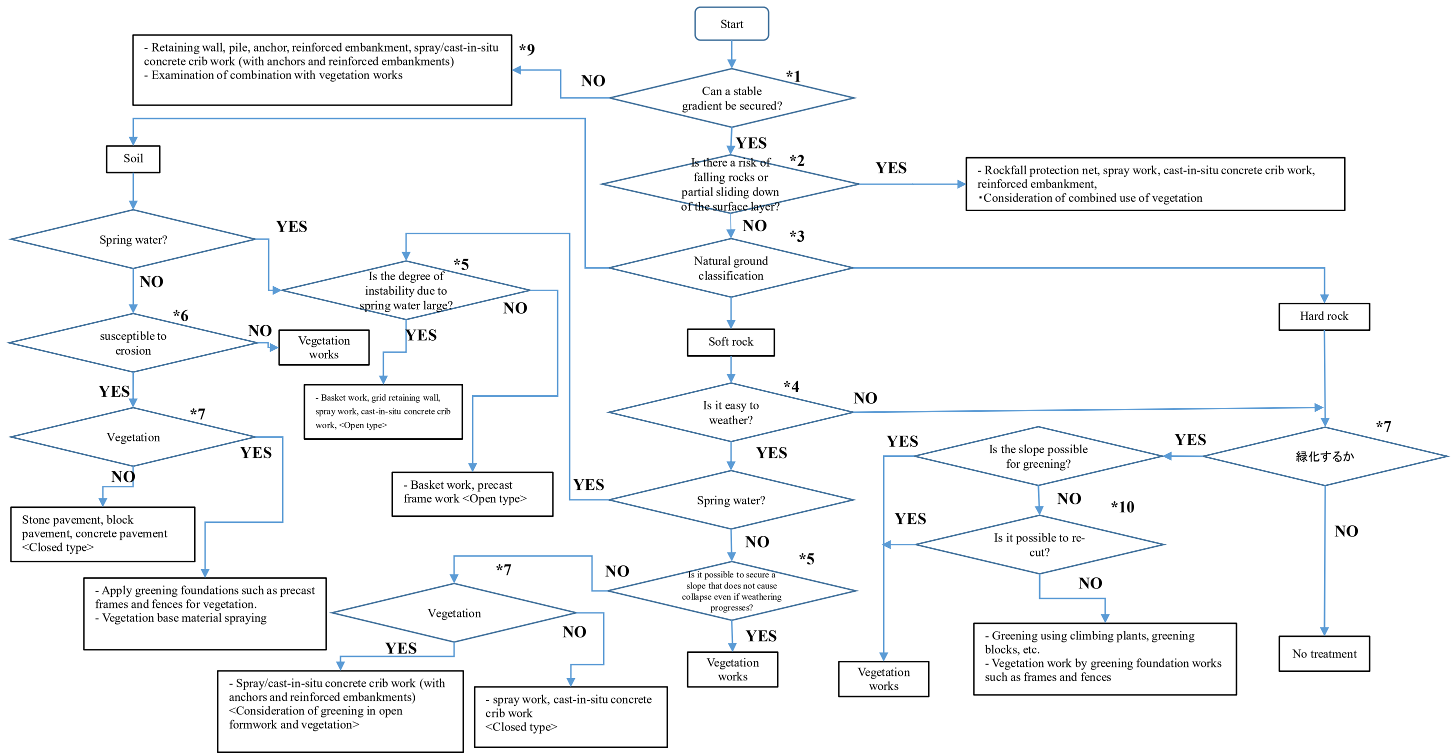


Figure 3-10 Selection Flow of Landslide Countermeasure

(National Flood Control and Sabo Association (2019): Technical Guideline for Slope Collapse Prevention Construction)

Figure 3-11 shows the selection flow of landslide countermeasure works associated with cutting works along roads. This selection flow is applicable to municipal roads and above. It should be noted that there is no comprehensive selection flow due to the various natural conditions. Ultimately, based on the basic concept of the Highway Earthwork standards, the final decision will be made after specific comparative examinations, including natural conditions and construction costs, for each location to be addressed.



*1: The average value of the standard slope gradient for the soil quality of the ground is used as a guideline for the stable gradient according to the soil quality of the ground. In addition, as a countermeasure when a stable gradient cannot be secured, reshuffle is performed if possible.
*2: Determine whether or not there is a risk of falling rocks by referring to the "Handbook for Countermeasures against Falling Rocks."
*3: Classification of ground shall be in accordance with 1-4 Geotechnical Survey 9) Classification of Rocks and Soil in Highway Earthwork Guidelines Common.
*4: Tertiary mudstone, shale, low-cohesion tuff, serpentinite, etc. are easily weathered by unloading/releasing stress by cut slope, repeated drying and wetting, and repeated freezing and thawing.
*5: As a gradient that does not cause collapse even if weathering progresses, use the average value of the standard slope gradient for loose soil as a guideline.
*6: Shirasu, decomposed granite soil, mountain sand, etc., which are mainly composed of sandy soil, are particularly susceptible to erosion by surface water.
*7: Determined by taking into consideration the mitigation of impacts on the natural environment, harmony with the surrounding landscape, and the permanence of the target vegetation.
*8: Judged mainly by the degree of stability, and when the stability is particularly low, use cage works, grid retaining wall, spray works, cast-in-situ concrete crib works.
*9: On slopes protected by structures, greening will be carried out if necessary for environmental landscape measures.
*10: Re-cut means cutting for greening.

Figure 3-11 Selection Flow of Slope Protection Works for Cut Slope

(Japan Road Association (2009): Highway Earthwork - Light Embankment Works, Guidelines for Slope Stabilization)

Source
Japan Road Association (2009): Highway Earthwork - Light Embankment Works, Guidelines for Slope Stabilization
Japan Flood Control and Sabo Association (2019): Design and Examples of New Slope Failure Prevention Construction - Technical Guideline for Steep Slope Failure Prevention Construction
Japan Road Association (2017): Handbook for Countermeasures against Fallen Rock

3.5 Method of Construction Control and Supervision

In landslide countermeasures, the method of construction management and supervision differs depending on the type of works. Therefore, we summarized the flows, standards, methods and frequencies, etc. for representative countermeasures used in Japan, such as anchor works, rock bolt / soil nailing, mortar spraying works, spray crib works, drainage boring works, rope hanging works/ rope covering works, rock fall barrier, and rock fall prevention net. In addition, responses to disasters regarding construction control and supervision during construction period are compiled with a comparison between projects in Japan and ODA projects.

3.5.1 Construction Management and Supervision for Landslide Countermeasures

(1) Anchor Works

- Flow of Construction Control/ Supervision

Flow of anchor works includes mainly drilling, drilling-hole cleaning, tendon insert, grout injection, curing, and checking test. Proper construction control and supervision are required in each procedure. The standard flow is shown below. In addition, since detailed procedures are defined for each product, it is necessary to follow the flow of the product for actual construction management and supervision.

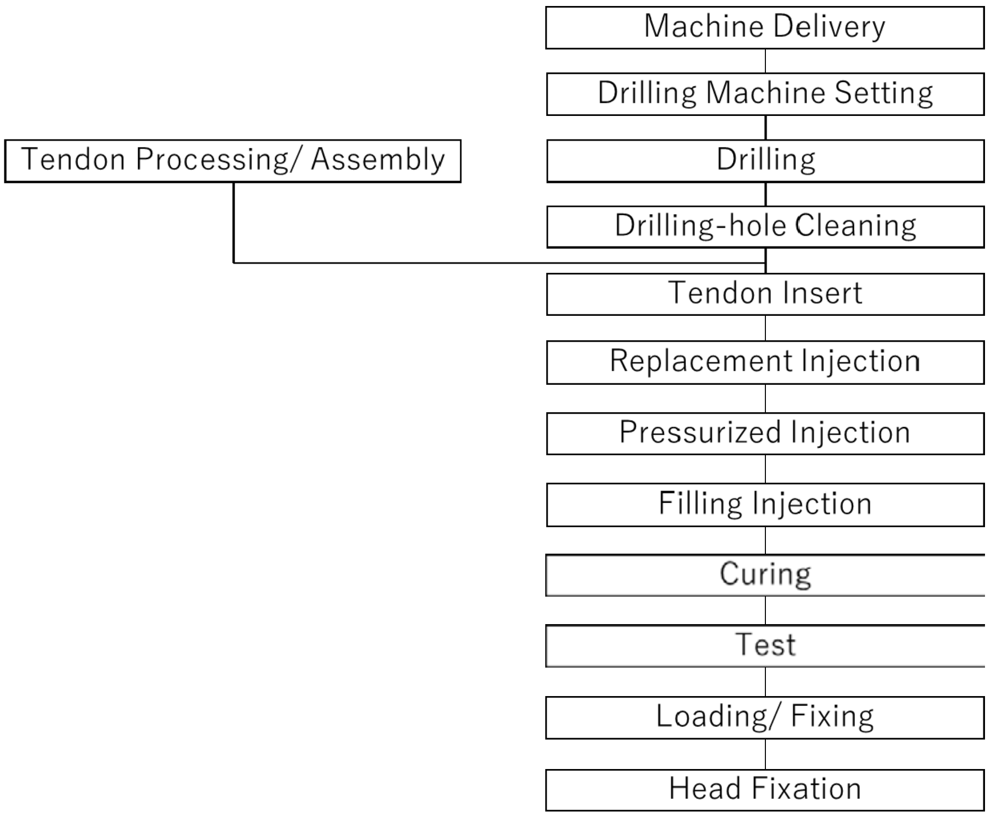


Figure 3-12 Standard Flow of Ground Anchor Works

(Japan Geotechnical Society (2012): Ground Anchor Design and Construction Standards, Commentary, P86)

- Standard for Construction Management and Supervision

The construction control standards are defined for each process, such as accuracy of drilling, material and assembly of tendon, quantity and pressure of grout, load of anchor, and anti-corrosion treatment of the anchor head. It is necessary to refer to the manual for each product for detail.

Table 3-20 Example of Construction Control Items for Ground Anchor Works

(Japan Geotechnical Society (2012): Ground Anchor Design and Construction Standards, Commentary, P88)

Work Item		Quality Control Item
Drilling	Machine Delivery	Machine Inspection
	Drilling Machine Setting	Accuracy of Setting
	Drilling	Hole Diameter (Bit Diameter)
		Hole Depth
		Anchorage Ground
	Drilling-hole Cleaning	Cleaning Water Concentration
Tendon Processing/ Assembly	Material Delivery	Material Quality
	Processing/ Assembly	Quantity of Tendon
		Specification of Tendon
		Length of Tendon
		Free Length of Tendon
		Binding Length of Tendon
Insert Tendon	Insert	Damage/ Dirt
		Tension Surplus Length
Injection	Material Delivery	Material Quality
	Mixing	Material Quantity
		Input Order
		Hours of Mixing
		Water Temperature
		Liquidity
	Replacement Injection	Injection Quantity
		Displacement Grout Concentration
	Pressurized Injection	Injection Pressure
	Casing Extraction	Tendon Pullout
	Filling Injection	Injection Shortage
Loading/ Fixing	Tension Device Delivery	Tension Device Inspection
	Fixing Parts Delivery	Fixing Parts Inspection
	Curing	Grout Strength
	Pedestal Installation	Loading Structure Strength
		State of Back Surface Processing
		Pedestal Installation State
	Fixing Parts Installation	Fixing Parts Installation State
	Loading	Tension Load
		Load-displacement Relationship
	Fixing	Tension Load of Fixing
Head Fixation	Back Surface Processing Work	Anti-corrosion Treatment State
	Head Fixation Work	Anti-corrosion Treatment State

- Method and Frequency of Construction Management/ Supervision

Tests required for anchor works include basic investigation tests to determine the various parameters required for design, suitability tests and acceptance tests to confirm the performance of the anchors actually used. The standard methods and frequencies are shown in "Ground Anchor Design and Construction Standards, Commentary", Japan Geotechnical Society, 2012, P103~. The tests of each product also follow the standards.

Table 3-21 Overview Comparison of Ground Anchor Tests

(Japan Geotechnical Society (2012): Ground Anchor Design and Construction Standards, Commentary, P104)

Test Category / Item		Basic Investigation Test		Suitability Test	Acceptance Test
		Pull-out Test	Long Term Test		
1) Purpose		Determine parameters for anchor design	Determine parameters to estimate residual tension force during service period	To conform that anchor design is adequate	To confirm that anchors are safe for designed anchor force
2) Schedule		Before Detail Design	Before Construction	First Stage of Construction	During Construction
3) Major Measurement Relationship		Load to Ultimate Friction Force ~ Displacement	Residual Tension Force during long term ~ Time Coefficient	Load during multi-cycles ~ Displacement	Load during 1 cycle ~ Displacement
4) Anchors for Test		Test Anchor	Test Anchor with the same specification as anchor to be used	Anchor to be used	Anchor to be used
5) Quantity of Test		Normally one	Normally one	5 % (minimum 3 Anchors)	All Anchors except for Suitability Test
6) Plan of Maximum Load (Tp)		Tp = Tug or Tp > Tu	Tp=1.1Td	Rank A: 1.25Td Rank B: 1.10Td	Rank A: 1.25Td Rank B: 1.10Td
7) Number of Cycle		5 ~ 10 cycle	1 cycle	5 cycle or more	1 cycle
8) Maximum Load in Each Cycle (example)		0.4Tp, 0.7Tp, 0.8Tp, 0.9Tp, 1.0Tp	1.1Td	0.4Tp, 0.55Tp, 0.7Tp, 0.85Tp, 1.0Tp	Rank A: 1.25Td Rank B: 1.10Td
9) Load Holding Hours	New Load	15 min. or more	7 ~ 10 days after 60 min.	1 ~ 180 min. (depend on ground condition)	1 ~ 15 min. (depend on ground condition)
	Experienced Load	1 ~ 2 min.		1 ~ 2 min.	1 ~ 2 min.
	Displacement Stability	< 1mm/ 3min.		Normal: Creep coefficient 0.5 mm or less Time extension: Creep coefficient 2.0mm or less	< 1mm/ 3min.
10) Hours of Measurement		1 min. for each new load	0, 1, 2, 5, 10, 15, 30 and 60min. Every 30 min. for 7 ~ 10 days, after that	1 min. for each new load	1 min. for each new load
11) Evaluation Item		Ultimate Friction Force	Coefficient of Tensile Force Reduction Estimated value of residual tensile force during service period	Design and Construction are suitable Elastic Displacement Amount Creep Coefficient Apparent Free Length	Designed Anchor Force satisfies the amount of safe elastic displacement

Tp: Plan of Maximum Load Td: Designed Anchor Force
Tu: Ultimate Anchor Force Tug: Ultimate Friction Anchor Force

Table 3-22 Characteristics of Construction Management for Ground Anchor in Japan

(JICA Study Team)

Item	Description
Drilling	Use casing pipes, basically
Drilling-hole Cleaning ~ Tendon Insert ~ Grout Injection	Clean with clear water or air Tendon insert and grout injection should be done immediate after the cleaning.
Spring Water Missing Water	It should be treated properly.
Confirmation of Fixing Part	Fixing part is confirmed by slime observation and drilling speed.
Tendon Insert	Handling that does not damage the anti-corrosion finish is required.
Grout Injection	Proper injection using replacement injection, pressurized injection, and filling injection is required. Replacement injection is started from the bottom of the anchor hole and is continued until it overflows from the hole with the same quality as the injected grout.
Loading	After the grout reaches the specified strength, the performance of the constructed anchor is confirmed by the suitability test and acceptance test. The anchor should be fixed with the specified initial load after the tests.
Head Fixation	Reliable waterproof is required based on anti-corrosion treatment and protection.
Method and Frequency of Control	Basic investigation tests for design, suitability tests and acceptance tests for confirming the performance of anchors actually used are specified in detail.
Work on Slope	Secure safe and enough working space with temporary scaffolding, basically

(2) Soil Nailing / Rock Bolts

- Flow of Construction Control/ Supervision

Construction of rock bolt / soil nailing is required to be carried out with appropriate procedures, taking into consideration stability and workability according to ground conditions and types of work (Japan Geotechnical Society, 2011). The standard construction flow is shown below. In addition, since detailed procedures are defined for each product, it is necessary to follow the flow according to the product for actual construction control and supervision.

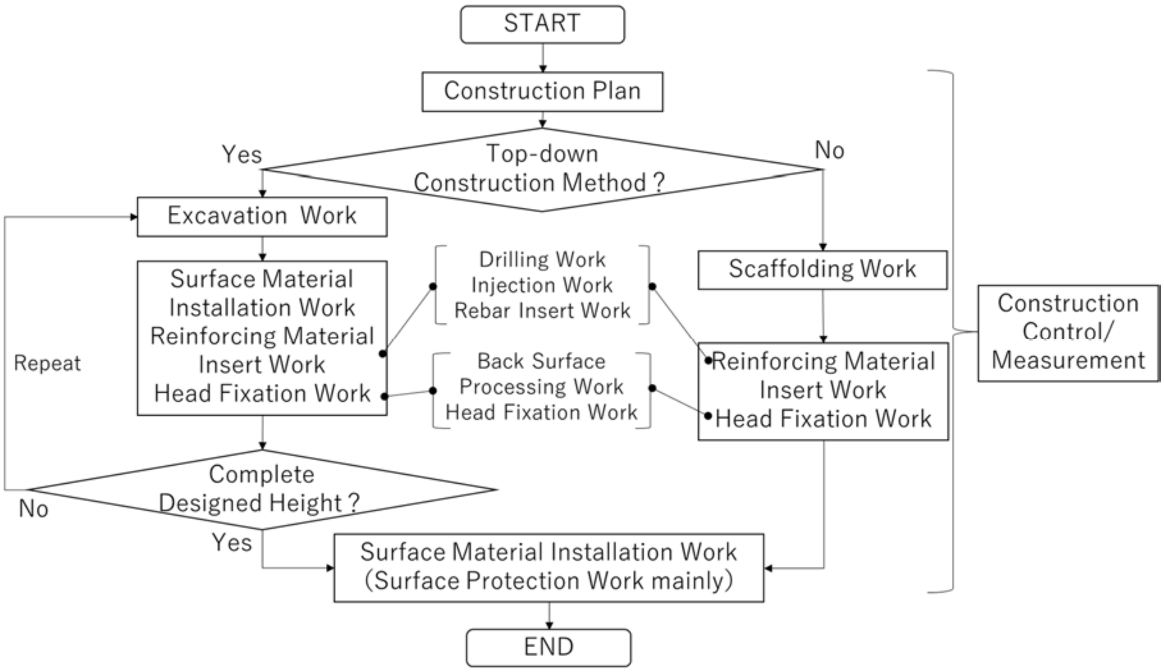


Figure 3-13 Standard Flow of Soil Nailing / Rock Bolts
(Japan Geotechnical Society (2011): Manual for Design and Construction of Ground Reinforcing Earthworks Method, P106)

- Standard for Construction Control/ Supervision

The Japan Geotechnical Society (2011) defines the focus points for each work item as criteria for construction control and supervision. In addition, it is necessary to carry out construction control and supervision while referring to manuals for each product and construction method.

Table 3-23 Points of Construction Control/ Supervison for Soil Nailing Works

(JICA Study Team)

Work Item	Note
Surface Material Installation Work	Surface material installation work can prevent erosion, weathering, and collapse of the surface layer on the slope of embankment, cut slope, and natural slope. It is necessary to carefully implement so that the reinforcing material is integrated with the ground in order to effectively work the earth retaining function, therefore (Japan Geotechnical Society, 2011). The Work may also include grid frames (crib works), spraying works, fibre reinforcement earthworks, independent pressure bearing plates, simple pressure bearing plates, and wire rope hanging works, therefore the noted points shall differ depending on the work, it is necessary to check the criteria for construction control and supervision by referring to the manual of each product.

Work Item	Note
Reinforcing Material Insert Work	Reinforcing material insert work consists mainly of drilling work, injection work and rebar insert work. Carefully construction is required to satisfy the specified reinforcement function (Japan Geotechnical Society, 2011). The main drilling methods are predrilling (auger drilling, rod drilling, casing drilling), self-drilling (injection after drilling, simultaneous injection drilling), and mechanical mixing. Depending on the drilling method, it is necessary to ensure the processes of drilling, cleaning, reinforcing material fixing and cement milk injection.
Head Fixation Work	It is necessary to carefully implement so that the reinforcing material is integrated with the ground in order to enhance the reinforcement effect (Japan Geotechnical Society, 2011). The work must be done so that there are no void gaps between the bearing plate and the ground. In general, mortar is used for drilling method, and soil cement is used for mechanical mixing method. The reinforcing material and surface material must be securely tightened with nuts. Torque values are sometimes used to control the tightening force. It is necessary to check the product manual, etc., for detail.

- Method and Frequency of Construction Control/ Supervision

Basically, construction control and supervision should be performed according to the manuals for each construction method. These manuals include the quality control standards for the materials used, the shape control standards, and the photo control standards as records.

Table 3-24 Characteristics of Construction Control for Soil Nailing Works in Japan

(JICA Study Team)

Item	Description
Surface Material	There are various options, such as crib works, spraying works, fibre reinforcement earthworks, independent pressure bearing plates, simple pressure bearing plates, wire rope hanging works etc.
Drilling	Self-drilling or casing drilling
Back Surface Processing	Work to fill the void gaps behind the head of reinforcing material is required before head fixation work.
Head Fixation	Detailed control items such as filling treatment and anti-corrosion treatment according to the slope surface, torque value for tightening the nut on the head of the reinforcing material, load of the head connecting material, etc. are specified.

(3) Mortar Spraying Works/ Spray Crib Works

- Flow of Construction Control/ Supervision

The construction management and supervision of mortar spraying (shotcrete) works should be focused on the anchor pin installation to fit lath wire mesh on slope surface, concrete or mortar mixing as per specification, and proper splaying work. Assembly of reinforcement and frame according to the specification is also required to spray crib works.

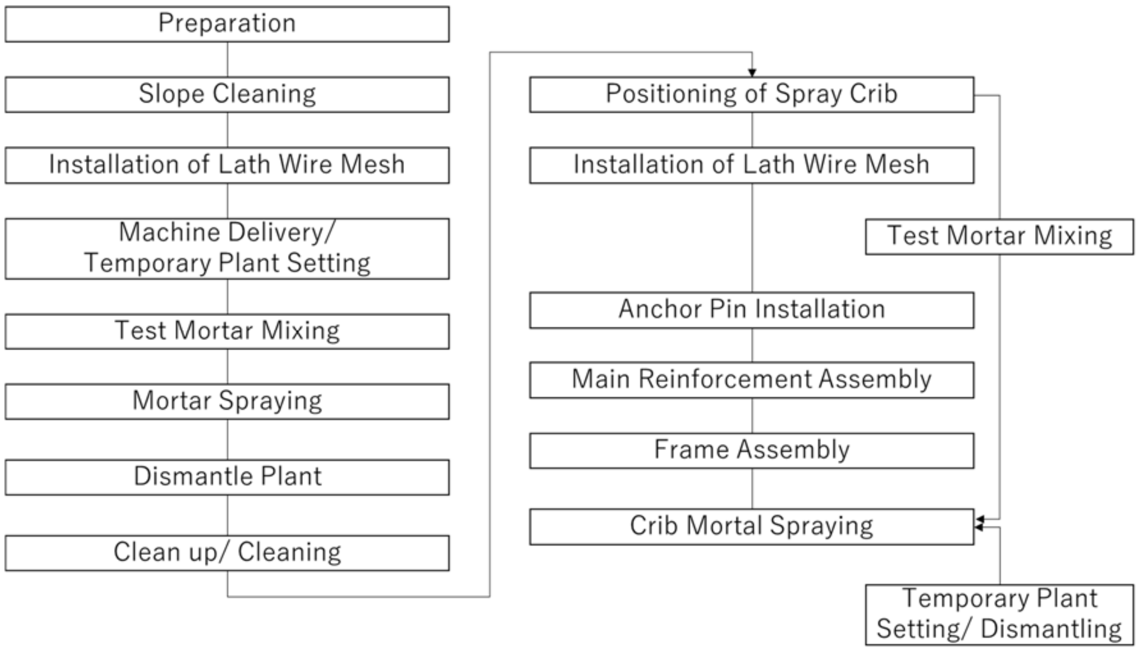


Figure 3-14 Flow of Mortar Spraying Works (left)/ Spray Crib Works (right), (example)

(Source: Construction Company in Japan)

- Standard for Construction Control/ Supervision

JIS (Japanese Industrial Standards) is used to stipulate compressive strength of mortar, chloride contents, surface moisture in fine aggregate, etc.

Table 3-25 Quality Control Standards/ Standard Value for Spray Crib Works (example)

(National Specified Slope Protection Association (2013): Guidelines for Design and Construction of Concrete Crib Works (Revised 3rd Edition), P71)

Category	Test Item		Test Method	Standard Value	Test Frequency
Material	Test for alkali-silica reactivity of aggregates		JIS A 1145, 1146	Use harmless Judgement Material	Before use and when changing material, according to test report
	Aggregates	Test for sieve analysis of aggregates	JIS A 1102		
		Test for density and water absorption of aggregates	JIS A 1109		
			JIS A 1110		
	Cement	Physical test for cement	JIS R 5201	Portland cement standard (JIS R 5210)	Before use, according to test report by supplier
		Chemical analysis of cements	JIS R 5202		
		Determination of the heat of hydration of cement	JIS R 5203		
Construction	Test for compressive strength of concrete		JSCE-F561-2005	>18N/mm^2	3 pieces/ test Material age 28 days or 7 days Every 50m^3 or 5 working day
			JIS A 1107		
			JIS A 1108		
	Test for surface moisture in fine aggregate		JIS A 1111		1 ~ 2 times/ day
	Total Chloride Control		Implementation Guidelines for Total Chloride Control in Concrete	0.3kg/m^3 in principle	3 samples/ test 1st day and every 5 working day

- Method and Frequency of Construction Management/ Supervision

Engineers shall plan methods and frequencies for shape control as follows,

i) Confirmation of wire mesh installation and overlapping width of wire mesh (check per certain area)
ii) Arrangement, diameter, quantity, and joint length of re-bars (check per certain beam length)
iii) Space between cribs, and width and height of formwork (check per certain beam length)
iv) Concrete thickness to cover re-bars (check per certain beam length)
v) Number of main and sub anchor bars (check per certain beam length)
vi) Width, height and space of crib works as final shape inspection (check per certain beam length)
vii) Length of slope as final shape inspection (check per certain construction length)
viii) Creation and accuracy of completion drawings

Table 3-26 Characteristics of Construction Management for Mortar Spraying Works/ Spray Crib Works in Japan

(JICA Study Team)

Item	Description
Lath Wire Mesh	There are detailed regulations regarding the installation of lath wire mesh to fit on the slope surface.
Assembly of Main Rebar and Frame	Regulated in detail (same as above) Spray Crib Works is originated in Japan. Mortar spraying is implemented to main re-bars in formwork on the slope.
Mortar Spraying to Crib Works	Regulated in detail (same as above) In order to secure the required strength, spray crib works must use a wet spraying machine which can spray mortar with an appropriate mix proportion from a nozzle. Wet spraying machines are improved in Japan from dry spraying machines. Wet spraying machines are used by Japanese construction companies only.
Safety Control	Install work ropes for safety work on slope

(4) Drainage Boring Works

- Flow of Construction Management/ Supervision

The construction management and supervision of drainage boring works should be focused on drilling machine setting on solid stage, drilling hole without bend, drilling length reached to target layer confirmed by slime, cleaning of drilling hole, proper installation of strainer pipes, etc.

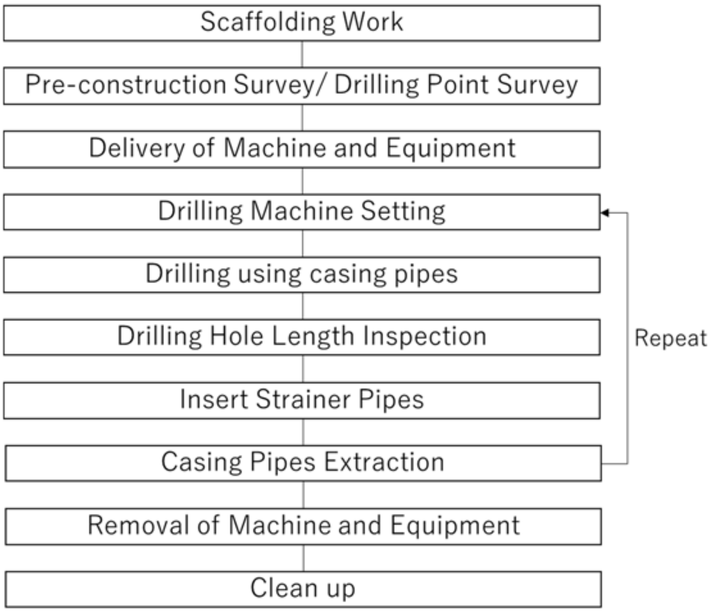


Figure 3-15 Flow of Drainage Boring Works (example)

(Source: Construction Company in Japan)

- Standard for Construction Management/ Supervision

Scaffold with required strength and space, specification and performance for the drilling machine must be met. However, the judgements are mainly based on the experience of the engineers. The material of the drainage pipes (un-plasticized poly pipes, VP) shall conform to JIS standards.

- Method and Frequency of Construction Management/ Supervision

In shape control, all holes of the drilling work shall be checked to meet the requirements of specifications including installation accuracy of the drilling machine, drilling diameter, drilling length, geology and spring water conditions, and the assembly and processing of the drainage pipes.

Table 3-27 Characteristics of Construction Control for Drainage Boring in Japan

(JICA Study Team)

Item	Description
Drilling Machine	Use rotary percussion drill
Drilling Work	Basically, double tube drilling using protective casing pipes
Drainage Pipes	Strainer pipes (VP40) Protective pipes for 2m of front side (VP75)
Safety Control	Strictly ensure the separation between workers and rotating parts in horizontal boring works.

(5) Rope Hanging Works/ Rope Covering Works

- Flow of Construction Management/ Supervision

In the construction management and supervision of the rope hanging works, it is required to carry out the prescribed management and supervision in the process of installation of the marking net, anchors and vertical and horizontal ropes. Procedures are documented in manuals for each product.

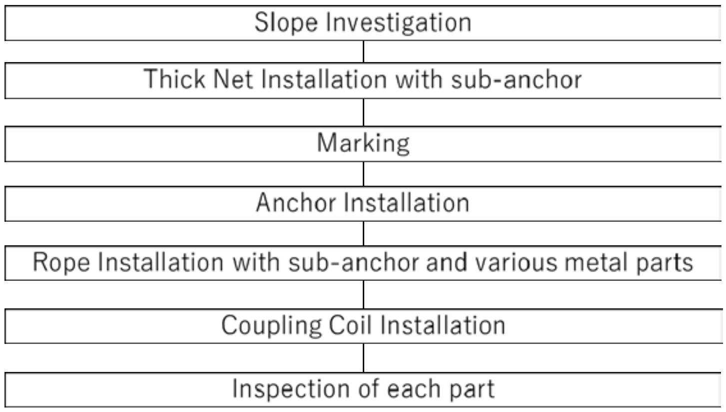


Figure 3-16 Flow of Rope Hanging Works (example)

(Source: Construction Company in Japan)

- Standard for Construction Management/ Supervision

It is necessary to conduct the tests specified for each product, such as anchor strength tests and grout specific gravity tests.

- Method and Frequency of Construction Management/ Supervision

Shape control values are specified for each product such as the spacing between vertical and horizontal ropes and the angle of anchor.

(6) Rock Fall Barrier

- Flow of Construction Control/ Supervision

The construction control and supervision flow differs slightly for each product. However, it basically consists of the installation of anchor foundations, pillars, horizontal ropes, and wire mesh.

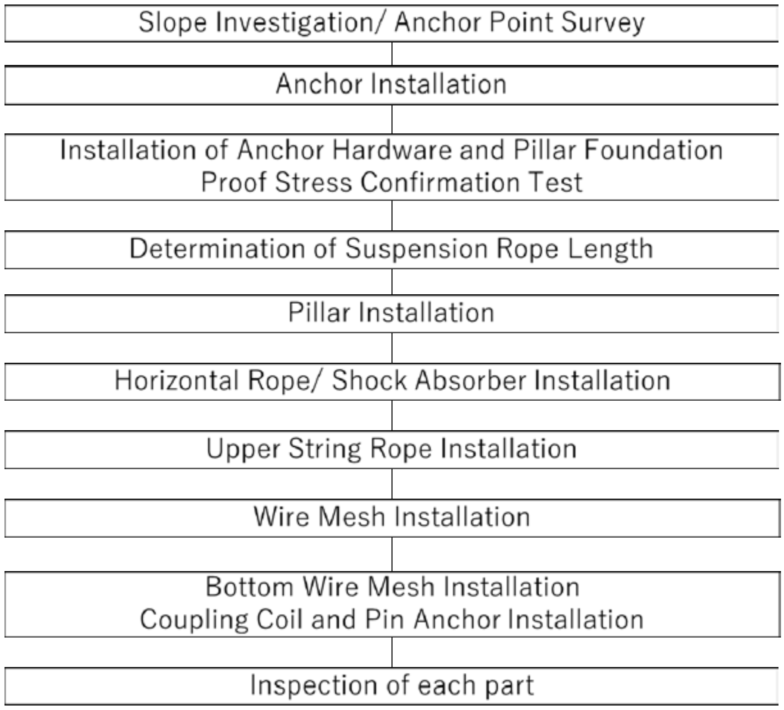


Figure 3-17 Flow of Rock Fall Barrier (example)

(Source: Construction Company in Japan)

- Standard for Construction Control/ Supervision

The Standards are determined for each product. Acceptance tests by axial pull-out tests must be carried out on the anchors used.

- Method and Frequency of Construction Management/ Supervision

Control values are determined for each product. Anchor lengths, anchor angles, angles of pillars, hanging ropes and horizontal ropes, spaces between pillars, pillar heights, and construction lengths are controlled by each control value.

Table 3-28 Characteristics of Construction Control for Rock Fall Barrier in Japan

(JICA Study Team)

Item	Description
Cement Capsule	In order to grout easily on steep slopes where it is difficult to secure an appropriate grout mix, cement capsules containing an appropriate amount of cement are used.
Man-power Work	The workflow is suitable for man-power work on steep slopes.

(7) Rock Fall Protection Net

- Flow of Construction Control/ Supervision

The construction control and supervision flow differs slightly for each product. However, it basically consists of the installation of anchor foundations, pillars, horizontal ropes, and wire mesh.

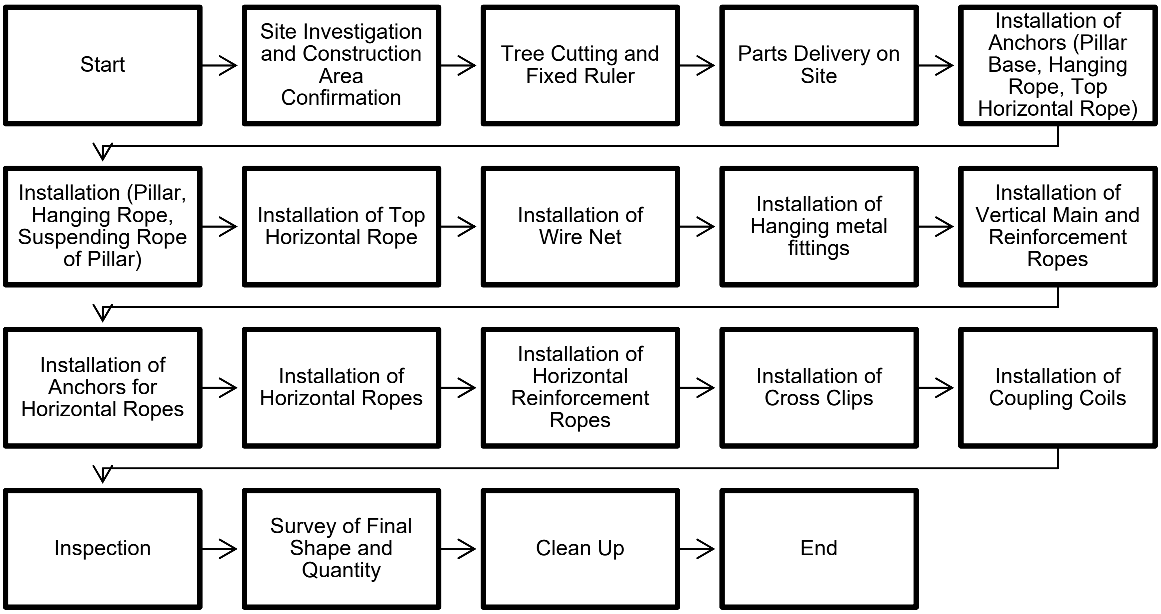


Figure 3-18 Flow of Rock Fall Protection Net (example)

(Source: Construction Company in Japan)

- Standard for Construction Management/ Supervision

The Standards are determined for each product. Since the construction method differs depending on the fixing layers (rock or soil) and on the type of anchor, the control criteria are also different. The fixing is confirmed by an axial pull-out test for rock anchors and by a lateral pull-out test for soil anchors. The test load varies depending on the standards of the anchor.

- Method and Frequency of Construction Control/ Supervision

Control values are determined for each product. The shape control standards and their allowable values are defined for each work process, such as anchor installation (drilling length/penetration length), anchor installation angle, vertical and horizontal rope installation, and wire mesh installation.

Source:

Japan Geotechnical Society (2011): Manual for Design and Construction of Ground Reinforcing Earthworks Method (in Japanese)

Japan Geotechnical Society (2012): Ground Anchor Design and Construction Standards, Commentary (in Japanese)

National Specified Slope Protection Association (2013): Guidelines for Design and Construction of Concrete Crib Works (Revised 3rd Edition) (in Japanese)

3.5.2 Differences from construction management/supervision of past slope protection ODA projects

(1) Differences in construction management

The comparison was made between Japan and ODA projects regarding the construction management of mountain roads and highways running through mountainous areas. The ODA projects are assumed to be civil engineering projects covering roads and roadside slopes.

Table 3-29 Differences between ODA Projects and Construction Management in Japan (by Types of Countermeasures)

(JICA Study Team)

Item	Japan	ODA projects
Ground Anchor	Double tube drilling with rotary percussion drills. Determination of fixed area by cuttings and excavation speed. Corrosion protection and protective treatment are required, and reliable water sealing is required. Meticulously regulated, including basic research tests, suitability tests and verification tests. Ensuring a safe and large enough working space by temporary scaffolding	If the Japanese contractor participates and there are no obstacles due to local circumstances, construction management is expected to be the same as in Japan. In construction by local contractors, differences are likely to occur in the following. Rotary percussion drills are possible to use but double tube drilling is not expected. There will be the case that the contractor chooses inappropriate decisions on the drilling method and the work area is not large enough. Pull-out tests can be expected to be carried out if required by technical specifications (TS). The same applies to anti-corrosion and protective treatment, but there is also a risk that cheaper materials which does not conform the requirement are used.
Rock Bolt/ Soil Nailing	There is a wide variety of surface materials, including slope construction, sprayed work and wire rope. Self-drilling or double-tube drilling Requires treatment to fill the cavity behind the reinforcement head.	If a Japanese contractor participates without any obstacles from local conditions, similar construction management as in Japan is expected. In construction by local contractors, differences are likely to occur in the following: Rotary percussion drills are possible to use but double tube drilling is not expected. Cavity filling at the back of the

Item	Japan	ODA projects
	Detailed control items such as rubbing and anti-corrosion treatments, torque values for tightening nuts on the head of reinforcement, tension on the head connecting material, etc.	reinforcement head, rubbing treatment, torque values for tightening the nut at the head of the reinforcement, tensioning force of the head connecting material, etc. can be expected to be implemented if required by technical specifications (TS), but there is a risk that cheaper materials which does not conform to the retirement for corrosion protection are used.
Mortar Spraying and sprayed formwork	Ensure lath net adherence to the ground. Detailed provisions for the installation of frames and main reinforcement bars. Use of wet spraying machines Working on the slope with a safety rope	If the Japanese contractor participates, construction management is expected to be the same as in Japan. The following differences are likely to occur in construction by local contractors. Local contractors are unlikely to own wet spraying machines, making it difficult to construct spraying works of the prescribed strength and performance. As for the adherence of lath net to the ground, it is unlikely that they can be expected to be as accurate as those of Japanese contractors. The construction of spray crib works is also subject to the use of wet spraying machines, so the construction of spray crib works by local contractors is limited to cast-in-place concrete crib works.
Horizontal Drainage Boring	Double tube drilling with rotary percussion drills. Strict separation between workers and rotating parts is ensured for horizontal boring works.	If the Japanese contractor participates, the same construction management as in Japan is expected. The following differences are likely to occur in construction by local contractors. Rotary percussion drills are possible to use but double tube drilling is not expected. As there are no more accident cases reported than in Japan, it will be necessary to take sufficient precautions to ensure separation between the operator and the rotating parts.

Item	Japan	ODA projects
Rock Fall Barrier/Net	Cement capsules in small portions to facilitate grouting on steep slopes where it is difficult to secure a suitable grout mix.	If the Japanese contractor participates, construction management is expected to be the same as in Japan. The construction method by local contractors is different from that of Japan in the appropriate mixing of materials on steep slopes and the safety measures/concept adopted by them as well.

Table 3-30 Differences between ODA Projects and Construction Management in Japan (by Type of Process of Work)

(JICA Study Team)

Item	Japan	ODA Project (ODA Grants)
Site location and constraints	When preparing construction plans, appropriate surveys are to be carried out on natural characteristics such as topography, geology, weather, and sea conditions, as well as on location conditions such as construction sites, obstructions, traffic, surrounding environment and facility management. (Technical Guidelines for the Safe Construction of Civil Engineering Works)	In grant aid projects, the site location and constraints are to be identified in the natural conditions survey at the preparatory survey stage. Since the site location is distant from Japan, the pre site visit by the contractor needs time and cost.
Construction organization	Specialist on slope protection is carried out by contractors registered with the respective construction method associations.	For slope protection works, specialist Japanese contractors are often directly involved in the construction, but even in such cases, the participation of Japanese engineers is limited to the minimum required, which is only a few, and decreases with the progress of technical instruction. Simple and skilled labour and foremen are procured locally but are supervised by Japanese foremen. If the participation of a Japanese specialist

Item	Japan	ODA Project (ODA Grants)
		contractor cannot be secured for ODA loan projects, the construction of slope protection works using Japanese technology may not be realised.
Selection of machines to be used and mobilization plans.	Machines specified in the construction manuals for each construction method are used.	Regarding the machinery used, there are cases where alternative equipment must be used due to the availability of local procurement or restrictions on means of transport and mobilization routes. However, in most cases, the machinery essential for carrying out construction is brought in from Japan. On the other hand, if the participation of Japanese specialists cannot be secured for ODA loan projects, the construction of slope protection measures using Japanese technology may not be realised, or the specifications may need to be changed.
Planning and deployment of temporary facilities	They are arranged according to a temporary works plan in accordance with the construction manuals for the respective construction method.	Temporary works plans should be devised to ensure safety and workability, paying attention to the possibility of local procurement and the restrictions on means of transport and mobilization routes. In most countries, temporary facilities like those in Japan cannot be procured, so it is important to conduct on-site surveys in advance. It is also possible to procure the necessary materials from third country or Japan even for the temporary works to secure the safety work.
Safety management	The industrial safety and health Law stipulates the establishment of safety and health management systems at workplaces and specific measures to prevent occupational accidents at workplaces, and safety	Basically, it is necessary to follow the relevant laws and regulations of the partner country, but in many cases the safety level of these laws and regulations is quite low to ensure the construction safety. Considering such situation, it is also required to follow the JICA's ODA Construction Safety Management Guidance.

Item	Japan	ODA Project (ODA Grants)
	management is implemented in compliance with the law.	However, awareness of safety management among local workers and local subcontractors is generally low, requiring safety training and safety patrols. In some cases, safety equipment such as safety helmet needs to be provided.
Public safety management	With a few exceptions, most security-related controls are crime prevention-related. Entry by persons other than those concerned is prohibited from the perspective of preventing accidents to third parties or workers (Technical Guidelines for the Safe Construction of Civil Engineering Works).	From the perspective of ensuring the safety of the personnel, it may be necessary to act, including armed guarding, depending on the security situation in the project country/area. In planning and implementation, close information gathering and consultations with local JICA offices, local embassies/consulates and local security authorities are necessary. Building good relationships with local authorities and locals is particularly important. Depending on the situation, deportation or suspension/interruption of the project may be envisaged, requiring unnecessary costs, care and attention in Japan.
Traffic Management	Traffic guides shall be posted as necessary at the entrances and exits to the site and at key points in the restricted section, and road signs, security lights, coloured cones or arrow boards shall be erected to ensure that the flow of traffic is not impeded at any time. Traffic guides shall lead the approaching vehicles in the security facility from a position where they can change direction and where they can be seen. When diverting general traffic, information signs etc. shall be	In developing countries, the quality of traffic guides is generally low, and in addition, the risk of traffic accidents due to poor traffic rules for passing vehicles (excessive speed and overtaking lanes), overloading and poor maintenance is high, and care must be taken to plan restricted sections and site entrances and exits in locations with good visibility. Preparatory studies should also include a survey and study of the turnaround route, to ensure that the construction does not impede traffic for the local population. During the construction phase, the establishment of turnarounds and the installation of safety equipment, including road signs, traffic guides, security lights and

Item	Japan	ODA Project (ODA Grants)
	installed in accordance with the instructions of the competent police chief. (Technical guidelines for the safe construction of civil engineering works)	arrow plates, are described in the contractor's construction plan and must be approved by the construction supervisor.
Environmental measure	Work that generates significant noise and vibration because of construction work is defined as 'specified construction work' under the Noise Regulation Act and the Vibration Regulation Act, and notification must be submitted to the competent local authority at least seven days prior to the start of the work if specified construction work is to be carried out. Standard values for noise and vibration are set and must be managed so that they are not exceeded. Specific measures are set out in the Technical Guidelines for Noise and Vibration Control in Construction Work (Ministry of Land, Infrastructure, Transport and Tourism).	Environmental and social consideration is the responsibility of the client/recipient. JICA requests the client/recipient to conduct an appropriate environmental and social consideration. In case that the client/recipient does not apply a sufficient environmental and social consideration, JICA request the client/recipient to comply the JICA Guideline for Environmental and Social Consideration in the preliminary survey stage.
Construction waste management plan	Sediment containing hazardous substances that exceed soil environmental standards is disposed of as construction sludge in accordance with the Construction Waste Disposal Guidelines (2010 edition).	The waste management plan shall be developed in compliance with the laws and regulations of the project country as well as the consistency with the environmental and social consideration.

(2) Differences in construction supervision

The construction supervision of mountain roads and roads running through mountainous areas is compared between Japan and ODA projects. ODA projects are assumed to be civil engineering projects covering roads and roadside slopes.

Table 3-31 Differences between ODA Projects and Construction Supervision in Japan

(JICA Study Team)

(Data) Item	Japan	ODA projects
Main body of construction supervision	Government offices/ Highway company	Based on the contract with the implementing agency (public authority), which is the road administrator and the client of the ODA project, the construction will be supervised by a Japanese consultant. ODA Grants: the company that conducted the preparatory study contracts with the partner government on the recommendation of JICA. ODA Loans: procurement by the recipient government. For ODA loans, a shortlist of Japanese consultants may be presented by JICA as eligible companies.
Standards for construction supervision (Project entity).	Quality and quantity/measurement management standards are established. The Common Specification for Civil Engineering Works is also referenced.	General Specifications, which are equivalent to common specifications for civil engineering works, have been developed in many countries. However, in most cases, it is necessary to prepare a new Technical Specification (TS) for Japanese slope protection works. As there are no defined quantity/measurement and quality control standards for slope protection works, they need to be described in the TS above; by requiring them in the TS, they become a quality control requirement for the contractor.

(Data) Item	Japan	ODA projects
Standards for construction supervision (External standard).	Referenced and readily available standards such as JIS standards and those of the Japanese Society of Civil Engineers	Commonly recognised standards are BS in the UK and ASTM and AASHTO in the USA. It should be noted that, although there may not be many opportunities for slope protection works, Russian standards may be required in the former Soviet bloc, and in French-speaking countries, compliance with French Standard NF may be quite strictly required. JIS standards are often referred to in TS for ODA Grants/ODA Loans, but there are also JIS standards without English versions. Situations can arise where components (e.g., reinforcing bars) specified in JIS standards are not specified in, for example, BS, and therefore the components required in the design cannot be procured locally. The issue of standards is that the TS allows equivalent standards as 'or equivalent', but consultants are also required to judge which standards are equivalent.
Contract Management	Contract management is carried out by the government officer/highway companies.	Except for key authorities, such as approval of design changes, consultants are delegated authority by the client to manage the contract.
Design Change	Design changes are subject to consultation between the public authorities/highway companies and the contractor. If the budget is insufficient, it will be secured by a budget request in the following year.	Design changes generally follow the following procedures. ODA Grants: Drafting of design changes > Approval by client > Consent of JICA before starting construction ODA Loan: Drafting of design changes > Approval of the client > (depending on the amount) JICA's consent In ODA Grants, the G/A amount is the ceiling and there is a limitation on the amount of design changes, and additional Grants is very hard option than ODA loans. In ODA loans, the L/A amount is also the ceiling, but in some circumstances, additional borrowing may be an option.

Source:

Japan International Cooperation Agency (2014): The Guidance for the Management of Safety for

Construction Works in Japanese ODA Projects, Sep. 2014
Japan International Cooperation Agency (2022): Guidelines for Environmental and Social Considerations, Jan. 2022
Ministry of Land, Infrastructure, Transport and Tourism (1987): Technical Guidelines for Noise and Vibration Control in Construction Work (in Japanese)
Ministry of Land, Infrastructure, Transport and Tourism (2022): Common Specifications for Civil Engineering Works (plan) (in Japanese)
Ministry of Land, Infrastructure, Transport and Tourism (2022): Technical Guidelines for the Safe Construction of Civil Engineering Works (in Japanese)
Ministry of the Environment (2011): The Construction Waste Disposal Guidelines (2010 edition) (in Japanese)

3.5.3 Response to disasters during construction (including comparison with response in ODA projects)

The response to disasters during construction in Japan starts from the perspective of preventing occupational accidents based on the highest priority of human life, and all stages from preliminary measures to the resumption of construction are being enhanced in detail, incorporating lessons learned from the past, and a system of cooperation between the public and private sectors is being developed.

In “The Outline of Construction Safety Measures in the Ordering of Public Works (1992)” , the role of the client is stated to make it known from the bidding stage that adequate attention should be paid to weather conditions, etc., and it can be read that disaster response is something that should be kept in mind even before construction work begins. In addition, disaster preparedness training is positioned as one of the items in the contractor's periodic safety training.

“Guideline of Preventing Occupational Accidents by Debris Flows (1998)” was formulated in response to the December 1996 landslide disaster in Kambarasawa, on the border between Nagano and Niigata Prefectures, which killed or injured 23 people, 14 of them fatal including 14 construction workers.

In response to the disaster, the Ministry of Labor (now the Ministry of Health, Labor and Welfare) enforced a ministerial ordinance partially amending the Industrial Safety and Health Regulation and formulated the guidelines for relevant businesses on this basis. Although the target is debris flows, the same approach should also be effective for slope hazards. In response to the above-mentioned notification and other guidelines, the common specifications prepared by the various prefectures also reflect provisions on efforts to ensure safety during construction.

Table 3-32 Differences between ODA Projects and Japan in Safety Management and Disaster Preparedness

(JICA survey mission).

Item	Japan	ODA projects
Safety management/ Disaster prevention measures	The Ministry of Land, Infrastructure and Transport (MLIT) has established "the Technical Guidelines for Safe Construction of Civil Engineering Works" as technical guidelines for safe construction, including general technical considerations and measures necessary for construction to ensure construction safety in civil engineering works. NEXCO also applies rainfall-based traffic restrictions to construction safety management. Municipalities require contractors to follow the national technical guidelines for safe construction as well as JISA 8972. In response to disasters, orders are placed in accordance with the construction safety guidelines and guidelines for the prevention of industrial accidents caused by Debris Flow are required to be applied.	The Guidance for the Management of Safety for Construction Works in Japanese ODA Projects has been published by JICA, as well as hazard prediction training materials for workers and safe construction management tools. For ODA Grants, the provision of safety costs is stipulated in "the Manual for the Design and Cost Estimation in the Preparatory Studies". Safety measures by the contractor are also required in the construction contract. JICA has published the JICA Safety Standard Specification (JSSS) for ODA Loans. (Application is individually specified). The Method Statement (abbreviated as MS) must describe safety measures, including diversion and traffic management during construction. And the consultant can only manage safety management with the approval of the MS (MS that does not ensure safety will not be approved and construction cannot start). The client, consultant and contractor shall periodically conduct joint safety patrols and report the results to JICA. However, if the client is unable to participate due to unavoidable circumstances, the consultant and contractor shall conduct joint patrols and report the results to the client for their opinion. In terms of disaster preparedness, consultants may instruct contractors to carry out routine and emergency inspections to foresee the occurrence of slope hazards, and if signs of disaster are recognised, the client may instruct to take emergency measures and inspections, and to install fixed-point observation and monitoring equipment.

Source:
Japan International Cooperation Agency (2014): The Guidance for the Management of Safety for Construction Works in Japanese ODA Projects, Sep. 2014
Japan International Cooperation Agency (2019): The Manual for the Design and Cost Estimation in the Preparatory Studies, Complementary Edition (Civil Engineering), Oct. 2019 (in Japanese)
Japan International Cooperation Agency (2021): JICA Standard Safety Specification (JSSS), Feb. 2021
Ministry of Health, Labor and Welfare (1998): Guideline of Preventing Occupational Accidents by Debris Flows (in Japanese)
Ministry of Land, Infrastructure, Transport and Tourism (1992): The Outline of Construction Safety Measures in the Ordering of Public Works (in Japanese)
Ministry of Land, Infrastructure, Transport and Tourism (2022): Technical Guidelines for the Safe Construction of Civil Engineering Works (in Japanese)

CHAPTER 4 Landslide Countermeasures in Developed Countries

In this research, surveys were done in the developed countries in Table 4-1.

Based on the information obtained through the interviews with the engineers in the developed countries in Table 4-1, technologies of landslide countermeasures are summarized in this chapter.

Table 4-1 Developed Countries Visited in Reserach

(JICA Study Team)

Countries	Survey Period
France	01 ~ 26 March, 01 ~ 12 May 2022
Switzerland	27 March ~ 09 April 2022
Italy	10 ~ 30 April 2022
States of California, United States (hereinafter referred to as “CA-US”)	02 ~ 17 September 2021

4.1 Standards and Guidelines of Landslide Countermeasures

The standards and guidelines collected in the survey are summarized.

4.1.1 France

Table 4-2 Guidelines Collected in France

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Surveillance des pentes instables /Guide technique	Oct. 1994	LCPC	A guideline for monitoring of unstable slope. Various types of monitoring methods for landslides are explained.
2	Stabilisation des glissements de terrain /Guide technique	1998/2	LCPC	Stabilization of landslides or `glissement de terrain` in French. Basic methods are explained with figures.
3	Parades contre les instabilites rocheuses /Guide technique	2001/5	LCPC	Stabilization of rock slope. A guideline for countermeasures against rockslide and rock fall from the size of small boulders to rock mass, with various types of measures including rock fall merlons and footing for unstable slope.

#	Title	Issued	Issuer	Contents
4	L'utilisation de la photo-interpretation das l'eablissement des plans de preventiontion des risques lies aux mouvements de terrain /Guide technique	1999/2	LCPC	Use of aerial photo interpretation for planning of landslide prevention. Useful guideline for aerial phot reading of landslides, showing abundant examples of stereoscopy of various types of landslides.
5	Caracterisation et cartographie de l'alea du aux mouvements de terrain	2000	LCPC	Risk evaluation and mapping of landslides. A guideline for risk evaluation of various types of landslides and methods of mapping with effective presentation.
6	Evaluation des aleas lies aux cavites souterraines /Guide technique	2002/6	LCPC	Risk evaluation on underground cavities. Explains process and mechanism of creation of cavities and methods for exploration of cavities with a lot of figures for explanation. Glossaries are attached.
7	Detection de cavites souterraines par methodes geophysiques /Guide technique	2004/10	LCPC	Detection of cavities with earth-scientific method. Various types of exploration methods for underground cavities are explained comprehensively but in detail. A lot of figures help understanding of the principle of the exploration.
8	Lutte contre l'erosion avant, pendant et apres les travaux / Les protections vegetales et structurelles des surfaces et des pentes	1993	LCPC	Erosion protection before, during and after construction, with vegetation and structure Explains use of vegetation for erosion protection and slope stabilization, considering regional conditions in France. Abundant figures and site photos help reader's understanding.
9	Les etudes specifiques d alea lie aux eboulements rocheux	2004/6	LCPC	Explains study for rock slide and collapse from viewpoints of structure, topography and hydrology, by showing methodology for data collection for vegetation and slope conditions as well as forms of collapse. Also explains potential instability, quantifying cracks, record of qualitative trajectory, and

#	Title	Issued	Issuer	Contents
				identification of rock fall hazard. In addition, 9 case studies are reported. Explains study, evaluation, and plan of countermeasures against rock fall from bedrock slope.
10	Surveillance des pentes et des falaises instables	2016/2	IFSTTAR	Monitoring of unstable slopes and cliffs. A technical manual for monitoring of unstable slopes and escarpments. Part 1 is for details of monitoring technique. Part 2 is for items of monitoring and proper instruments. Warning with monitoring is also explained. Part 3 is for 10 case studies.
11	Prévention et stabilisaion des glissements de terrain / Guide technique	2010/12	LCPC	Stabilization and prevention of landslides or \`glissement de terrain\` in French. A guideline for countermeasures against \`glissement de terrain\`, including buttress fill on the toe, earth removal from the head, slope protection with vegetation, and reinforcement works such as soil nailing, piles, ground anchors, and retaining walls. In addition, as a passive measures, reinforcement of structures to accommodate movement by \`glissement de terrain\` are explained.
12	Prise en compte du paysage dans les protections contre les chutes de matériaux rocheux / Guide technique	2016/5	IFSTTAR	Landscape friendly rock fall mitigation. Explains integration of rock fall mitigation and landscape preservation with explanation of relevant laws and regulations. Landscape preservation includes cultural heritage, natural environment, and biodiversity. Includes 10 case studies.
13	Caractérisation de l'aléa éboulement rocheux / Guide technique	2020	CEREMA	Features of rock slides. Explains the methods to numericalize the risks of rock fall and rock slides and to evaluate the risks quantitatively.

#	Title	Issued	Issuer	Contents
14	Maintenance des ouvrages de protection contre les instabilités rocheuses / Guide technique	2009/12	LCPC	Maintenance of rock fall countermeasures. Explains maintenance of rock fall mitigation including role of contracting parties, causes of deterioration of the works, and prevention of deterioration. Periodic and detailed inspections are also described. Replacement of anchor bolts and cables depending on corrosion condition are explained as well.
15	Les ouvrage deflecteurs / Guide technique	2020	CEREMA	Deflector works. A guideline for deflector works including rock fall net and fence. The rock fall is separately explained with pockets and without pockets as well as method to fixing. The requirements for deflector works are stipulated depending on the size and shape of fallen rock to trap. Some description about maintenance is included as well.
16	Protection contre les instabilités rocheuses / Guide méthodologique	2018	CEREMA	Countermeasures against unstable bedrock slope. Explains rock bolt and nailing works, including mechanism, design, selection of material, and construction of rock bolt /nailing. The construction methods include boring machine mounted on excavators and simple boring machine fixed by wires. Pull-out tests are explained as quality control.
Abbreviations of issuer： LCPC：Laboratoire Central des Ponts et Chaussees IFSTTAR：Institut francais des sciences et technologies des transports, de l'amenagement et des reseaux. University of Gustav Eiffel in present. CEREMA: ex Service d' tudes sur les Transports, les Routes et leurs Am nagements: SETRA				

The guidelines collected in France mainly focus on rock fall, rock slide, slide (Jisuberi in Japanese or" glissement de terrain" in French), and landslide monitoring.

Due to the geological and lithological conditions in the French Alps, many guidelines relating to rock fall and rock slide are issued in France. In the Alps, less weathered but partially fractured bedrock from steep slopes or escarpment. The main reasons of rock fall and rock slope collapse are erosion and loosening of bedrock along cracks and/or fractured zones. This is a fairly contrast to the conditions in the Himalayas, where both weathering and loosening affect the mechanism of landslides.

In the Alps, however, some rock types showing slaking properties, in which rock becomes fragmented due to unloading or exposing to the air or water, are confirmed, including marl.

Landslides occur not only in the Alps but the areas where problematic geological conditions are observed. The landslides in Europe includes not only circular and transitional slides but rock slide and spreads shown in Figure 4-1, the classification of landslides by Varnes

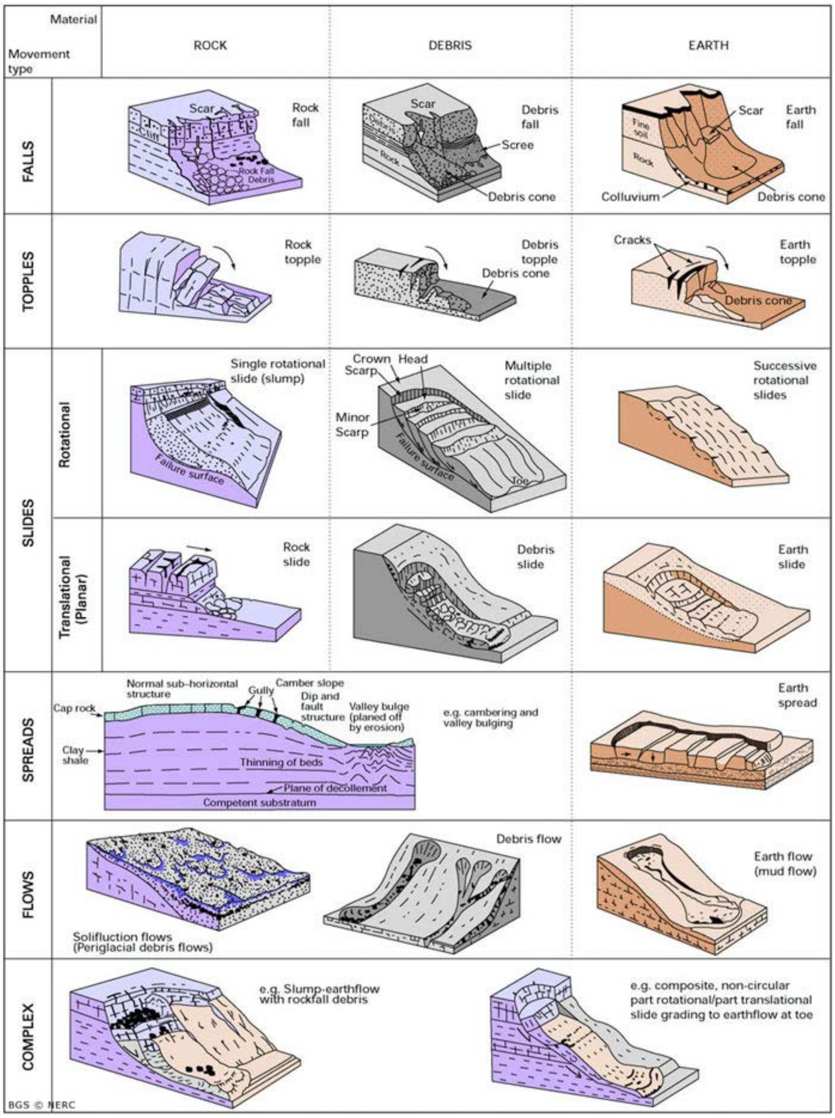


Figure 4-1 Landslide Classification by Varnes

(British Geological Survey)

In addition, the guidelines relating to underground cavities are also highlighted in France. This is partially due to land subsidence caused by abandoned mines. At the same time, form of karsts in the limestone strata dominating Europe and formation of caves due to dissolution of gypsum are major backgrounds. The problems of underground cavities are focused in Italy as well.

4.1.2 Switzerland

Table 4-3 Standards and Guidelines Collected in Switzerland

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Protection against Mass Movement Hazards	2016	FOEN	Protection against landslides. Starting from legal requirements, chapters and sections for situation analysis, countermeasures, hazard mapping, establishing disaster scenario and estimation of damage, reaction against uncertainties, and risk determination and reduction are described. The thought to accept some amount of risks is distinguished. In addition, periodic monitoring for and evaluation for the countermeasures are required so that necessary actions are taken, if any. Horizontal drainage boring and drainage tunnels are listed as countermeasures against slide (Jisuberi). On the other hand, early warning system (EWS) is regarded as measures to protect human lives and important assets.
2	European Guidelines for Soil and Water Bioengineering	2015/1	EFSWB	A European guideline for bioengineering. Explains basic principles and definition of bioengineering, role of plants, application of and requirements for bioengineering, calculation methods, recommendations for implementation and application, methods for bioengineering, and maintenance and efficiency.
3	Schweizer Norm 670 010	2011/8	SARTE	Standards for geotechnical exploration and surveys. Explains parameters for geotechnical engineering.
4	Schweizer Norm 670 004	2008/6	SARTE	Standards for geotechnical exploration and surveys. Explains soil classifications.

#	Title	Issued	Issuer	Contents
5	Schweizer Norm 640 621	2009/12	SARTE	Standards for bioengineering. Explains methods, techniques, and construction.

Abbreviations of issuer：
FOEN：Federal Office for Environment
EFSWB：European Federation for Soil and Water Bioengineering
SARTE：Swiss Association of Road and Transportation Experts

In Switzerland, to avoid excessive cost for disaster prevention, a threshold for the limitations of budgets is provided. This thought is relating to acceptance of risk.

In the process of planning for disaster prevention, establishing disaster scenarios and estimation of damage are important. The estimation of damage decides the ceilings for cost for disaster prevention. For human casualty, the upper limit for a death of one person is decided by administrative organizations. For example, Swiss Federal Railways (SBB)[2] has a limitation 10 million CHF and ASTRA[3] has a limitation of 5 million CHF.

Regarding landslides, shallow failure and collapse of steep slope are dominant.

As a prevention against shallow failure, bioengineering is focused. Application for bioengineering is studied in WSL[4], which provided the guideline and standards relating to bioengineering.

2 https://www.sbb.ch/en
3 Federal Roads Office: FEDRO in English
https://www.astra.admin.ch/astra/en/home.html
4 Swiss Federal Institute for Forest, Snow, and Landscape Research: WSL
https://www.wsl.ch/en/index.html

4.1.3 Italy

Table 4-4 Laws and Guidelines Collected in Italy

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Ingegneria Naturalistica	2022	RP	Natural engineering A guideline issued by Regione Piemonte. To mitigate severe natural disaster, the guideline focuses on growth of plants to prepare slope protection with self-recovery. Proposes combination of bioengineering and conventional measures along with geotextile, including drainage well and horizontal drainage boring. Focuses bioengineering to use wood and stone for structures of channel works and slope protections and live sapling and branch to facilitate recovery of plants.
2	Tecniche Naturalistiche nella Sistemazione del Territorio	N/A	PAT	Natural engineering for regional protection Issued by Provincia Autonoma di Trento. Focuses on mitigation measures by bioengineering.
3	Ingegneria Naturalistica nozioni e tecniche di base	N/A	RP	Natural engineering (basic concept and technique) A handbook for construction of bioengineering.
4	Interventi di sistemazione del territorio con tecniche di Ingegneria Naturalistica	2003	RP	Natural engineering for regional prevention Summarizes the item No.1. Ingegneria Natural istica". Comprehensively explains from design to construction including selection seeds for plants and machinery.
5	Aggiornamento delle «Norme tecniche per le costruzioni»	2018/1	MIT	Construction Law in Italy The Chapter 6 is for "PROGETTAZIONE GEOTECNICA (geotechnical design)" and the section 6.3 is for "STABILITÀ DEI PENDII NATURAL (stability of natural slope)". In Section 6.3.6, importance of landslide monitoring is highlighted, as essential parts of study and evaluation methods for mitigation works.

#	Title	Issued	Issuer	Contents
6	Linee Guida per il Monitoraggio delle Frane	2021/7	SNPA	Landslide monitoring guideline Comprehensively explains design of monitoring network, types of monitoring instruments, installation of instruments and observation, supply of electricity, data transmission and processing, and maintenance. In addition, describes the matters to be attended for public communication.
7	Atlante delle Opere di Sistemazione dei Versanti	2002/10	APAT	Slope protection and stabilization works manual and guideline A manual comprehensively explains slope protection and landslide countermeasures. Simply explains erosion protection and fixation of vegetation with bio-gradation materials, use of geotextile, mitigation measures against shallow failures with bioengineering, stone masonry, concrete retaining wall, lattice works, reinforced earthworks, gabion, piles, micro piles, ground anchors, shotcrete, rock fall barrier, rock fall net, rock fall and debris flow merlons, rock sheds, surface and subsurface drainage including French drains, horizontal drainage borings, drainage wells, drainage tunnels, injection works for underground cavities, deep-mixed cement works, heat treatments, chemical treatments, and electrical treatments.

Abbreviations of issuer：
RP: Regione Piemonte: Region of Piedmont
PAT：Provincia Autonoma di Trento: Autonomous Province of Trento
MIT : Ministero delle Infrastrutture e dei Trasporti: Ministry of Infrastructure and Transport
SNPA : Sistema Nazionale per la Protezione dell’Ambiente: National Organization for Env. Protection
APAT : Agenzia per la Protezione dell'Ambiente e per i servizi Tecnici : Technical Service for Env. Protection

In Italy, in Region of Piedmont in north Italy, the guidelines for bioengineering were collected. At ISPRA[5], the construction law in Italy and the landslide guideline issued from SNPA were collected.

[5] Istituto Superiore per la Protezione e la Ricerca Ambientale : Superior Institute for Environmental Protection and Research

In Italy, landslide monitoring is considered important in EWS and evaluating landslide countermeasures. The use of landslide monitoring is stipulated in the construction law in Italy for evaluation of the landslide countermeasures[6]. By landslide monitoring, the effect of the 1st batch of landslide countermeasures is evaluated and, based on the evaluation, the design of the 2nd or 3rd batches of the works is reviewed or additional works are implemented. This is called "observational methods" in Italy.

4.1.4 CA-US

Table 4-5 Standards and Guidelines Collected in CA-US

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Landslides Investigation and mitigation	1996	TRB	Describes landslide investigation and mitigation for road and railways, comprehensively from aerial photo reading in planning stages to implementation of mitigation methods. Comprehensively explains landslide investigation from aerial photo reading, geological mapping, geophysical exploration, and landslide monitoring to laboratory testing. Comprehensively explains methods for slope stability analyses as well. In addition, describes stability evaluation of rock slope. Lists mitigation works including groundwater drainage, ground anchors, retaining walls, reinforcement earthworks, and soil nailing as well as rock slope stabilization.
2	Highway Slope Maintenance and Slide Restoration Workshop - Participant Manual	1988	FHWA	Explains landslides along roadside slopes, including mechanism and countermeasures. Describes abstracts of countermeasures but lacks details of practical design methods. Describes landslide countermeasures including, vegetation, retaining wall, horizontal drainage boring, subsurface drainage, buttress fill, benching, vertical drain, retaining works, gabion, pile works, ground anchors, reinforced earthworks with geotextile, rock fall pockets, rock fall barrier,

6 In Italian, landslide countermeasures is called "interventi", same meaning with "intervention" in English.

#	Title	Issued	Issuer	Contents
				and rock fall net. Explains landslide monitoring after the event, but lacks preventive measures before the event. Lists landslide monitoring including embedded piezometer, borehole inclinometer, and crack measuring as well as fixed stake survey.
3	Highway Slope Maintenance and Slide Restoration Reference Manual	2008	FHWA	Different from the Item No.2 by the following items. Lists landslide countermeasures buttress fill, rock fall net, rock fall barrier and pockets, horizontal drainage boring, subsurface drainage and retaining wall. Describes landslide investigation including sieve analysis, Atterberg limits, direct shear tests, tri-axial compressive test, point load test, borehole inclinometer, Time-domain Reflectometry(TDR), embedded piezometer, and fixed stake survey
4	Federal lands highway Project development and design manual	2017	FHWA	Planning and design manual for the highways under the federal government. Comprehensively describe the process of road development with scarce exploration of technical issues. Explains basic principle for roadside landslide countermeasures but lacks practical methods for design. Lists landslide countermeasures including soil nailing, retaining walls, pile walls, ground anchor systems, embankments, reinforced soil slopes, surface drainage, subsurface drainage. Lacks O&M for highways.
5	SLOPE STABILITY EVALUATION AND ACCEPTANCE STANDARDS	2017	LADBS	Stipulates the minimum factor of safety at static condition is Fs=1.5 for cutting and filling as well as natural slopes. Stipulates abstract methods of slope stability as well but lacks formulae for that. Explains abstract idea of slope protection and analysis methods for each type of deformation of slopes. Explains stability in earthquake with conditions

#	Title	Issued	Issuer	Contents
				and seismic wave for analysis as well. Stipulates in-situ or laboratory tests for setting geotechnical parameters for forward analysis.
6	Caltrans Geotechnical Manual	2020	Caltrans	A technical manual for cutting slopes. Requires to identify potentially unstable slopes as the first step, through preliminary survey with aerial photos, topographic maps, and existing geotechnical studies. Lists survey items including core boring, cone penetration tests, geophysical exploration, groundwater level observation, and laboratory tests. Explains landslide countermeasures including vegetation, erosion protection mat, horizontal drainage boring, surface drainage, drainage channel, , rock bolts with wire mesh, shotcrete, and retaining wall with rock bolts or ground anchors. Stipulates the software for slope protection including SLOPE/W, SLIDE, XSTABLE, and ReSSA as well as formula for stability analysis such as Bishop, Janbu, Spenser, Sarma, Morgenstern-Price, and general limit-equilibrium.
7	Highway design manual	2020	Caltrans	Standard gradient for cut slope is explained in Topic 304 – “Side Slopes".
8	Slope stability in road construction, A guide to the construction of stable roads in Western Oregon and Northern California	1976	USBLM	Explains mechanism of landslides and destabilization of slopes as well as methods for slope stability analysis with Fellenius formula. In appendix, standard gradient for cut slope is attached.
9	LRFD Bridge Design	2020	AASHTO	Includes design standard for ground anchors.

#	Title	Issued	Issuer	Contents
10	Federal lands highway Construction Manual	2009	FHWA	Explains construction and construction supervision of highways. Details the work to be done by engineers at construction sites.

Abbreviations of issuer：
TRB：Transportation Research Board
FHWA : Federal Highway Administration(FHWA), U.S. Department of Transportation
LADBS : Department of building and safety, LA
Caltrans : California Department of Transportation (Caltrans)
USBLM : U.S. Department of the interior, Bureau of land management
AASHTO：American Association of State Highway and Transportation Officials

4.2 Risk Treatment against Landslide during Planning of Highways

Table 4-6 summarizes risk treatment against roadside landslides.

Table 4-6 Risk Treatment against Landslides in Developed Countries

(JICA Study Team)

Countries	Risk Treatment against Landslides
France	Currently, new mountainous roads are not planned or implemented. As a risk treatment of landslide, adopting tunnels and bridges for widening or improvements of existing roads are denied by the engineers due to the cost constraints. As a policy or planning theory, in mountainous regions, major road widening or improvement of alignment seem to be not so popular. Thus road widening or improvement with tunnels or bridges seems not to be practical. As for the identification of landslides, since guidelines for aerial photo reading in the aim of detecting landslides as well as risk evaluation of landslide and hazard mapping are issued, risk identification and evaluation as well as establishing disaster scenarios are conducted in France.
Switzerland	Implementation of express way project was ongoing as of the research. Discussions on the risk hedge by detour with tunnels and bridges were not sufficiently made. In Switzerland, however, debris flow and snow avalanche sheds as well as rock fall sheds are widely used to ward off the energy of such landslides disasters. In addition, when enough space are secured, rock fall merlons,, which can absorb high energy from rock fall, and combination of slit dam and merlons against debris flow and snow avalanche are adopted. The risk treatment in Switzerland starts from establishing disaster scenarios. Multiple disaster scenarios are evaluated and damage by each disaster scenario is estimated, including human casualty. When planning disaster prevention, budget for countermeasures should not exceed the estimated damage.
Italy	When a new road is planned, risk treatments are considered through evaluating disaster risks along the planned alignments and comparison of multiple alignments considering risk avoidance as well as lifecycle cost. Necessary countermeasures, including detour by alignment shift or by bridges or tunnels are selected through such deliberation. For the existing road, shifting alignment with tunnels and bridges is rarely considered. In Italy, observational methods with landslide monitoring are widely used. For road widening, before considering shifting alignment, observational methods seem to be adopted for considering necessary countermeasures.
CA-US	The necessity of aerial photo and map reading as well as geological survey and document study is understood. In the guidelines for landslide mitigation, such study methods are well explained. In the guidelines for highway development, however, detailed explanations are missing.

4.3 Surveys for Roadside Landslides

Table 4-7 summarizes the survey items in the developed countries.

Table 4-7 Items of Surveys for Roadside Landslides in Developed Countries

(JICA Study Team)

Countries	Topographic Survey	Boring	Laboratory Test	Geophysical Exploration	Landslide Monitoring
France	○	○	○	○	○
Switzerland	○	○	○	○	○
Italy	○	○	○	○	○
CA-US	○	○	○	○	○
○：To be conducted Information regarding requirements of quantity and frequency were not collected.					

Notable information is explained in the following sections.

4.3.1 France

The notable point in France in terms of survey is the use of borehole pressure meter tests, which are done in the similar frequency with SPT in Japan during borehole investigation. As geotechnical parameters are estimated with SPT-N Values in Japan, in France, geotechnical parameters are estimated with the test results of borehole pressure meter.

4.3.2 Italy

In Italy, landslide monitoring is highlighted. Even after the completion of countermeasures, landslide monitoring are continued in Italy to evaluate the effectiveness of the countermeasure. Based on the information obtained through landslide monitoring, additional countermeasures are planned and implemented, if necessary, or plan of the following countermeasures are revised.

4.4 Design of Countermeasures against Roadside Landslides

4.4.1 Standard Gradients of Cut Slope

Table 4-8 summarized the policy of gradients of cut slope in the developed countries.

Table 4-8 Policy of Gradients of Cut Slope in Developed Countries

(JICA Study Team)

Countries	Policy of Gradients of Cut Slope
France Switzerland Italy	A series of interviews were made in France, Switzerland, and Italy regarding standard gradients of cut slope. Some engineers or regional offices have empirical values. The standard gradients of cut slope stipulated in the documents were, however, not confirmed as a form of tables or something. According to the engineers we had interviews, gradients of cut slopes were decided case by case basis by the engineers after checking the geological conditions on site, especially direction and development of cracks. In Switzerland, gradients of cut slope may depend on the traffic volume for rural roads. For the rural road with less traffic, steeper gradients of cut slope is adopted while accepting risks to some extent.
CA-US	Standard gradients of cut slope is only stipulated in Highway design manual(Caltrans,2020) and the guideline for roadside slope stabilization for West Oregon and North California issued from U.S. Department of the interior, Bureau of land management, which are shown in Item No.8 of Table 4-5. On the other hand, according to Geoburgg US, which are implementing slope stabilization works in the State of California, stability of slope is examined for each slope to implement stabilization works. Thus standard gradients of cut slope seem not to be so common in CA-US.

As for the gradients of cut slope, in both Europe and CA-US, engineers in charge examine optimal gradients of cut slope based on the geological condition of each site.

4.4.2 Policy of Design and Flow Chart of Selection Sequence

Table 4-9 summarized the policy of design and flow chart of selection sequence in developed countries.

Table 4-9 Policy of Design and Flow Chart of Selection Sequence in Developed Countries

(JICA Study Team)

Countries	Policy of Design and Flow Chart of Selection Sequence
France Switzerland Italy	Flow charts for procedure of survey and design are stipulated in the guidelines. The flow chart of selection sequence was not confirmed in each country.
CA-US	The flow chart of selection sequence was not confirmed in each country. The countermeasures are selected by engineers.

In both Europe and CA-US, the guidelines stipulates procedures of study and design but lacks the selection sequence of countermeasures.

4.4.3 Slope Stability Analysis

Table 4-10 summarized slope stability analysis in the developed countries.

Table 4-10 Slope Stability Analysis in Developed Countries

(JICA Study Team)

Countries	Slope Stability Analysis
France Switzerland Italy	Forward analysis of limit equilibrium method is used. Only in the reply to our questionnaire from Ministry of Infrastructure and Transport in Italy, back analysis is mentioned. But it seems to be limited.
CA-US	Forward analysis of limit equilibrium method with software is used. Bishop, Jambu, Spencer, Sarma, and Morgenstern-Price are mentioned in the manuals issued from FHWA.

Each country uses forward analysis of limit equilibrium method with software.

FEM analysis are used for research purpose for the process of deformation but not used in the design of countermeasures to decide prevention force.

4.4.4 Slope Protection Works

Table 4-11 summarized types of slope protection works in the developed countries.

Table 4-11 Slope Protection Works in Developed Countries

(JICA Study Team)

Countries	Slope Protection Works
France Switzerland Italy	Vegetation is dominant. Geotextile is used to fix vegetation. At the sites of bioengineering, coir mat and jute mat are used. As for concrete structures, shotcrete were used in the past. Due to landscape consideration and features to block groundwater, shotcrete is not used anymore. Concrete crib works, which are common in Japan, were not confirmed. As for retaining walls, those of concrete, stone masonry, gabion, and lattice works were confirmed.
CA-US	Vegetation is stipulated in the manuals. Slope protection works were rarely confirmed on the slope, however, possibly due to small precipitation in the CA-US. As for retaining walls, concrete retaining walls were confirmed.

4.4.5 Slope Stabilization Works

Table 4-12 summarized slope stabilization works in the developed countries.

Table 4-12 Slope Protection Works in Developed Countries

(JICA Study Team)

Countries	Slope Protection Works
France Switzerland Italy	Steel nets with rock bolts / soil nailing are dominant in the Alps.（Figure 4-2)。 In the Apennine in Italy, stabilization works of gabion with nailing and piles with ground anchors were confirmed. As for bioengineering, lattice works with logs are used.
CA-US	Steel nets with rock bolts / soil nailing and concrete retaining wall with ground anchors were confirmed.（Figure 4-3)。

The examples of slope stabilization works are explained in the following sections.

(1) France and Italy

Cable net with rock bolts/nailing
(France)

Net and cables with rock bolts/ nailing
(Italy)

Gabion with nailing
(Italy)

Bioengineering
(Italy)

Figure 4-2 Slope Stabilization Works in Europe

(JICA Study Team)

(2) CA-US

Cable net with rock bolts/nailing

Retaining wall with ground anchors

Figure 4-3 Slope Stabilization Works in CA-US

(JICA Study Team)

4.4.6 Rock Fall Countermeasures

Table 4-13 summarizes rock fall countermeasures in the developed countries.

Table 4-13 Rock Fall Countermeasures in Developed Countries

(JICA Study Team)

Countries	Rock Fall Countermeasures
France Switzerland Italy	In the countries surrounding the Alps, active research and development for rock fall countermeasures are carried out. The rock fall countermeasures in France, Switzerland, and Italy can be categorized into active and passive measures. The active measures are the works at the source of the rock fall, such as removal of unstable parts of rock slope, fixing unstable rock by rock bolts or steel net with rock bolts, and footing support for unstable rock by concrete. The passive measures are usually placed along the road, such as rock fall barrier, rock fall net with pocket including attenuator, covering type rock fall net including drape net, rock fall merlon, retaining wall with rock fall pocket, and rock sheds. (Figure 4-4) The steel net and brake system used for rock fall nets and fence are developed by each country with ingenuity, such as specially woven steel net and very strong brake system. In France, particular research is done for rock fall barrier using live wood. In Switzerland, early warning system (EWS) against rock fall is used at the section where rock fall often occurs. The EWS utilizes Doppler radar[7] were confirmed. Once it detects rock fall, the EWS turns the signal on the road red and closes the traffic. (Figure 4-5)
CA-US	Rock fall pockets secured by concrete blocks were confirmed. (Figure 4-6)

The examples of rock fall countermeasures are explained in the following sections.

[7] Doppler radar uses Doppler effects to detect an object moving toward the radar. Doppler radar is used for detecting missiles aiming at aircrafts. The EWS using Doppler radar was provided by an Israel company and utilizes military technology.

(1) France, Switzerland, and Italy

Rock fall merlon which can endure fallen rocks of a weight of 1t hitting at 200km/h. (Switzerland)

Rock fall fence (Switzerland)

Rock fall fence (France)

Rock fall fence with retaining wall (France)

Rock shed (France)

Rock shed (Switzerland)

Figure 4-4 Rock Fall Countermeasures in Europe

(JICA Study Team)


Doppler radar to detect fallen rocks


Signal connected to Doppler radar

Figure 4-5 EWS against Rock Fall in Switzerland

(JICA Study Team)

(2) CA-US


Pockets secured by concrete blocks.


Pockets secured by concrete blocks with simple fence.

Figure 4-6 Rock Fall Countermeasures in CA-US

(JICA Study Team)

4.4.7 Debris Flow Countermeasures

Table 4-14 summarizes debris flow countermeasures.

Table 4-14 Debris Flow Countermeasures in Developed Countries

(JICA Study Team)

Countries	Debris Flow Countermeasures
France Switzerland Italy	Debris flow countermeasures combining merlon and slit dam to secure pockets for debris to trap behind merlon are found in each country. Especially in Italy, along national highways, debris flow merlons are placed just beside the highways to protect the road from the sudden attack by debris flow from adjacent mountain along the road (Figure 4-7). In Switzerland, combination of merlon and slit dam works against both debris flow and snow avalanche (Figure 4-8). In each country, the debris trapped behind the merlons should be periodically removed with heavy machinery. In each country, along stream and rivers, check dam and drop works were confirmed. In Switzerland, debris flow shed was confirmed (Figure 4-8). In Italy, similar structures were planned at the strategic point of traffic. EWS to close traffic by signals on the highways after detecting debris flow with sensors placed nearby source or pass of debris flow were confirmed in France and Italy (Figure 4-9).
CA-US	No debris flow countermeasures were found in the site trip.

The examples of debris flow countermeasures are explained in the following sections.

(1) France, Switzerland, and Italy

Debris flow merlon along the highway

Pockets to trap debris flow behind merlon

Figure 4-7 Debris Flow Merlon in Italy

(JICA Study Team)

Pocket behind debris flow and snow avalanche merlon with slit dam

Debris flow cum snow avalanche shed

Figure 4-8 Debris Flow Countermeasures in Switzerland

(JICA Study Team)

Signal connected with EWS (France)

Signal connected with EWS (Italy)

Figure 4-9 Debris Flow EWS in Europe

(JICA Study Team)

4.4.8 Slide (Jisuberi) Countermeasures

Table 4-15 summarized countermeasures against slide (Jisuberi).

Table 4-15 Countermeasures against Slide (Jisuberi) in Developed Countries

(JICA Study Team)

Countries	Countermeasures against Slide (Jisuberi)
France Switzerland Italy	In each country, horizontal drainage boring, drainage wells, and drainage tunnels are used (Figure 4-10 and Figure 4-11). Small diameter drainage wells, which connects each other and drains ground water by the action of the gravity, are used in Italy. The works can be constructed more reasonably than conventional drainage wells and thus may suit for ODA projects but there may be some difficulties in O&M due to the small diameter of the wells（Figure 4-10）. Pile works against slide were also confirmed in France and Italy.
CA-US	No countermeasures were found in the site trip. Special treatments not to facilitate slides were confirmed at the place where the highway passes through multiple landslides(Figure 4-16).

The examples of countermeasures against slide (Jisuberi) are explained in the following sections.

(1) Switzerland and Italy

Drainage tunnel at San Lorenzo Tunnel

Top concrete ceiling of small diameter drainage wells

Figure 4-10 Landslide Countermeasures in Italy

(JICA Study Team)

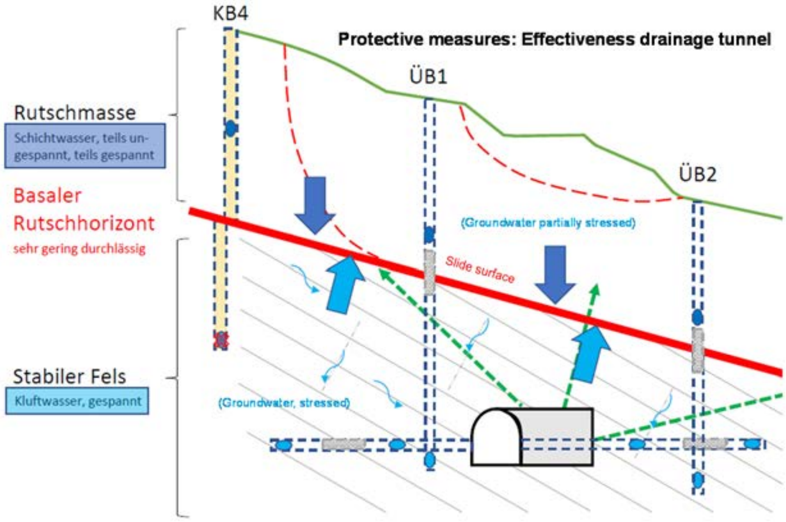


Figure 4-11 Landslide Countermeasures in Switzerland

(Civil Engineering Office of the Grisons, Graubünden Canton, Switzerland)

4.4.9 Road Widening and Rehabilitation Works

Table 4-16 summarizes road widening and rehabilitation works.

Table 4-16 Road Widening and Rehabilitation Works in Developed Countries

(JICA Study Team)

Countries	Road Widening and Rehabilitation Works
France Switzerland Italy	In each country, reinforced earthworks with geotextile are used for rock fall or debris flow merlons.
France	In France, reinforced earthworks are popular. With TerraLink method by Terre Armee, reinforced earthworks of more than 100 meters in height were used for rehabilitation of the highway in the mountainous regions where limited areas for narrow foundation was available (Figure 4-12). At Lyon Branch of University of Gustav Eiffel developed reinforced earthworks with precast concrete panels and soil nailing with backfilling by compacted gravel which can be injected from the holes of precast panels. The backfill of compacted gravel assures high permeability. Thus this works can be used for emergency rehabilitation of collapsed embankment even at the places where groundwater acts as triggers of collapse.
Switzerland	In Switzerland, to secure foundation of highway structures on steep slopes, caisson foundation constructed by manual is used. This methods does not require large scaffoldings and thus is notable for ODA projects.

Countries	Road Widening and Rehabilitation Works
CA-US	Although it was used behind abutment of bridges, no reinforced earthworks were confirmed as road widening or rehabilitation purpose.

The example of road widening and rehabilitation works is explained below.

(1) France

Figure 4-12 TerraLink Method by Terre Armee Constructed In India

(From Website of Terre Armee)

4.5 Construction of Countermeasures against Roadside Landslides

Table 4-17 summarizes the manner of construction of countermeasures against roadside landslides.

Table 4-17 Construction of Countermeasures against Roadside Landslides

(JICA Study Team)

Countries	Construction of Countermeasures against Roadside Landslides
France Switzerland Italy	For the construction of countermeasures against roadside landslides, the engineers in the three countries told that scaffolds to place heavy machinery were not used. Instead, fixing machinery on the slope with wires and fixing labors on the slope with safety harness are used. Thus, limited types of works can be executed, such as installing self-drilling rock bolts / nailing and applying rock fall nets on slope with anchor bolts as shown in Figure 4-13, or the works which can be executed by machinery placed on the toe of slopes. This limitation of construction methods definitely affects selection of countermeasures against roadside landslides in the process of design. The works which do not require scaffolds or heavy machinery on slope are only ones to be selected as countermeasures. The reason why the engineers do not want to use heavy machinery on slopes is to reduce cost for placing scaffolds on slope so that countermeasures can be implemented at more sites within limited budgets. According to the engineers in the three countries, sufficient budgets are not allocated to execute necessary countermeasures against landslides. Thus they are always forced to reduce the cost for the works as much as possible. In fact, in France, the JICA Study Team did not see very limited numbers of countermeasures along a mountainous rural road with very few traffic. In Italy, some landslide sites were left untreated only with emergency measures or EWS because necessary budgets for permanent measures were not allocated. In Switzerland, the ceiling of the budget is decided by damage estimation based on disaster scenarios. Even making temporary roads for material transport are not welcomed. Thus the material for construction of the works should be light weight or easy to transport. Thus micro piles, which is light weight and easy to transport, are often used in mountainous regions. In the region of Emilia-Romagna in Italy, a slit type check dam was constructed with micro piles. When we think about the superiority in ODA Loans in terms of selection of countermeasures by the borrower countries, the works with European technologies have clear advantages in cost due to the following features reducing the cost for construction: - The works do not require temporary roads or scaffolds , - The works use lightweight materials easy to transport and,

Countries	Construction of Countermeasures against Roadside Landslides
	- The works are implemented manually or with small machinery. On the other hand, such features limits the types of the works to adopt. In addition, concrete structures are not welcomed as landslide countermeasures on roadside slopes due to difficulties in quality control in casting, especially in cold weather during winter. The aesthetic viewpoint is another reason to avoid new construction of concrete structures on roadside slopes. In France, excluding special cases, new construction of concrete structures on roadside slopes is not accepted by the society. On the other hand, in Switzerland or Italy, concrete structures are constructed on roadside slopes if necessary, such as footing protection of rock slope.
Italy	In Italy, special types of machinery is used on steep slope without scaffolds. The work on steep slopes often uses spider type excavators (Figure 4-15) or small excavators (Figure 4-14) in the sites in Italy, especially in those of bioengineering.
CA-US	No information was available.

The examples of construction of landslide countermeasures on roadside slopes are shown below:

(1) France and Italy

Construction of horizontal drainage boring by an Italian contractor. Fully mechanized with a crawler mounted rotary percussion boring machine without casing insertion capability.

With a handheld jackhammer, installing anchor bolts for fixingthe lower end of rock fall nets.

Construction of rock fall nets by the labors fixing his / her body with safety harness on the steep slope.

Removing unstable rock from the shoulder of the cliff by the labor fixing his / her body with safety harness on the shoulder.

Figure 4-13 Construction of Landslide Countermeasures in France

(JICA Study Team)

Machinery for micropile installation.

Very simple rotary percussion boring machine, fixed by wires on the slope.

Small excavator.

Elevating work platform.

Figure 4-14 Machinery for Bioengineering in Italy

(From "Ingegneria Natural-istica" Issued from Region of Piedmont)

Work on steep slope.

Work on rock slope.

Figure 4-15 Spider Type Excavator

(From "Ingegneria Natural-istica" Issued from Region of Piedmont)

4.6 O&M of Roadside Slope and Countermeasures

4.6.1 Slope Inspection and Disaster Records

Table 4-18 summarizes slope inspection and disaster records in the developed countries.

Table 4-18 Slope Inspection and Disaster Records in Developed Countries

(JICA Study Team)

Countries	Slope Inspection and Disaster Records
France	Interviewed with the Organization of Natural Disaster of the Department of Savoie as an organization for O&M of mountainous highways. The Department of Savoie established a database for organizing more than 2,500 roadside slopes under danger of landslides, which includes rock fall, snow avalanche, debris flow and slide (Jisuberi). The Department of Savoie prioritize the roadside slopes by the urgency of countermeasures with the database, which includes supposed countermeasures for the slopes with cost estimation. The database also organize the records of disasters, which occur more than 100 cases per year. The database provides clear explanations for the priority and cost for the countermeasures for budget allocation.
Switzerland	Interviewed with ASTRA (Federal Roads Office) and the Civil Engineering Office of the Grisons of Graubünden Canton as organizations for O&M of mountainous highways. Due to limitation of time, however, sufficient information was not obtained regarding organization of slope inspection and disaster records.
Italy	Interviewed with ANAS (National Road Administration Agency) as an organization for O&M of mountainous highways. ANAS organizes a database for the structures relating to the national highways. Before 2018, the database was mainly used as archive. After the accident of Morandi Bridge in August 2018 in Genoa, the database includes design drawings as well as inspection results. The inspection is limited to the structures relating to the national highways, including slope protection works but excluding roadside slopes regardless of natural or artificial. In case unusual situation is found on roadside slopes during patrol, however, ANAS takes actions. As for database for landslides, ISPRA (Superior Institute for Environmental Protection and Research) establishes and operates the nationwide database.
CA-US	No information was available.

4.6.2 O&M for Countermeasures against Roadside Slopes

Table 4-19 summarizes O&M for countermeasures against roadside slopes in the developed countries.

Table 4-19 O&M for Countermeasures against Roadside Slopes in Developed Countries

(JICA Study Team)

Countries	O&M for Countermeasures against Roadside Slopes
France Switzerland Italy	As O&M activities for countermeasures, removal of debris and fallen rocks accumulated behind rock fall merlon / nets / fence as well as pockets behind retaining wall are inevitable. Replacement of nets and parts of the works damaged by rock fall or rusted by corrosion is also important. In addition, maintenance for avalanche fences is also highlighted. As for the maintenance of horizontal drainage boring, in the European Alps, clogging by lime often causes problems. Thus cleaning with acid is done to clean the clogging. In case cleaning with acid does not work, new horizontal drainage borings are carried out just beside the clogged ones. As for the maintenance of ground anchors, monitoring of tension force with instruments attached to the head of anchors was confirmed in France.
France	In France, manuals for maintenance of rock fall countermeasures are well developed. For the maintenance of rock fall nets / fence on the steep slopes difficult to access, helicopters are often used.
Italy	In Italy, landslide monitoring continues even after the completion of and in the service period of the works. Based on the information obtained from the monitoring in the service period, maintenance of the works and planning of additional works were confirmed to be carried out.
CA-US	No information was available.

4.6.3 Operation of EWS

Table 4-20 summarizes Early Warning System (EWS) in each developed country.

Table 4-20 Operation of EWS in Developed Countries

(JICA Study Team)

Countries	Operation of EWS
France Switzerland Italy	In each country, EWS with sensors and traffic signals is used for road closure of the dangerous sections as precaution against imminent disasters.
France	In France, EWS with traffic signal was confirmed at the section where the stream with debris flow hazards crossed the road (Figure 4-9).
Switzerland	In Switzerland, at the section where the road crosses the toe of the unstable rock slope with frequent rock fall and failures, EWS with Doppler radar and traffic signal was confirmed for preventive road closure against the imminent rock fall (Figure 4-5).
Italy	In Italy, at the section where the national highway crosses the toe of mountains with frequent and quick debris flow, as a temporary measures until the completion of permanent countermeasures, EWS with debris flow sensors and traffic signal was confirmed for preventive road closure (Figure 4-9). This EWS may close the road in the event of heavy rain fall.
CA-US	No information was available.

4.7 Others

4.7.1 Typical Landslides along Hill Roads

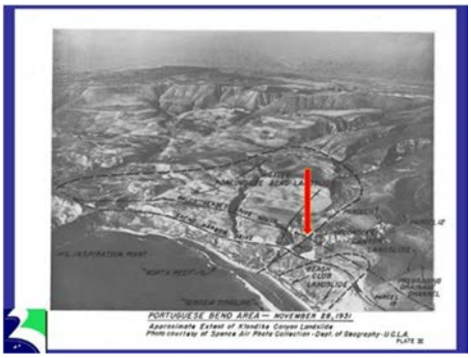
Table 4-21 summarized typical landslides along hill roads in the developed countries.

Table 4-21 Typical Landslides along Hill Roads in Developed Countries

(JICA Study Team)

Countries	Typical Landslides
France Switzerland Italy	In the Europe Alps, rock fall, debris flow and snow avalanche are frequent landslides. In the Europe Alps, relatively fresh bedrock slope with substantial cracks are dominant compared to the slopes with residual soil and weathered layers in Japan and Asia. Thus slope failures usually occurs in bedrock slope with cracks in the Europe Alps. On the other hand, damage by slow mass movement by gravitational deformation of bedrock slope (bedrock creep) and slides (Jisuberi) with slip surfaces in bed rock was confirmed at hill roads and mountain tunnels. Marl is highlighted as a problematic geological condition to cause massive mountain slope collapse and rock slides. Caving by karst and gypsum causes problems in the limestone areas. Such caves facilitates landslides by providing groundwater through it.
France	In France, landslides by clayey marl were reported in trench cut slope in gentle slope areas. In 1248, a massive mountain collapse occurred in Mt. Granier, where alternation of marl and limestone lies.
Italy	In the Apennines in Italy, slope failures due to slaking of mudstone in flysch (alternation of sandstone and mudstone) cause damage on the roads. The mudstone in flysch also causes landslides by formulating slip surfaces through getting plasticity helped with provision of groundwater. Slaking of rock was confirmed at the reddish rocks close to the Dolomites in the Italian Alps. In volcanic areas in the southern part of Italy, massive debris flow occurs due to slope failures in tephra deposits caused by formulation of weak planes by heavy rains.
CA-US	Substantial landslides occur in the states and affect the highways as shown in Figure 4-16.

At the middle of massive landslide, the municipal road follows the terrain formed by the landslide, without changing the terrain carelessly with cut and fill.



A landslide occurred in 1931. This landslide was reactivated in 1956 by filling for road construction and expalned gradually. The landslide is still active as of the research.

Figure 4-16 Landslides and Highway in CA-US

(Left: JICA Study Team, Right: City of Rancho Palos Verdes (2021))

4.7.2 Laws and Regulations regarding Countermeasures against Roadside Landslide

Table 4-22 summarizes laws and regulations regarding countermeasures.

Table 4-22 Laws and Regulations regarding Countermeasures in Developed Countries

(JICA Study Team)

Countries	Laws and Regulations
France	The regulations on the landslide countermeasures are given by the guidelines or manuals prepared by CREMA or other public organization. The guidelines are not considered completely binding unlike the laws, which should be followed without conditions. In law suits, however, incompliance to guidelines may affect adversely. In this sense, some binding force is working.
Switzerland	The upper ceiling of the budget for landslide countermeasure depends on the estimated damage based on disaster scenarios. This limitation is not stipulated in the laws but used by the organizations such as Swiss Federal Railways (SBB) and Federal Roads Office (ASTRA) based on value of Statistical Life (VSL). The Canton [8] in Switzerland has the authority to decide optimal countermeasures for the states.

[8] The member states composing Swiss Confederation.

Countries	Laws and Regulations
Italy	Construction Laws in Italy controls slope stability issues, which are totally binding. Besides the laws, guidelines are prepared for various purposes, including roadside slope protection as well as soil and bioengineering. The region in Italy has the authority to decide optimal countermeasures for the states. Thus wide variation are seen in the country.
CA-US	No information was available.

4.7.3 Natural Conditions

(1) Climate

(a) Climate

Table 4-23 summarizes the climate in the developed countries.

Table 4-23 Climate in Developed Countries

(JICA Study Team)

Countries	Climate
France	The territory of mainland France can be classified in to 4 climatic classifications; oceanic, maritime, alpine, and Mediterranean. The areas visited by this research fall in alpine or Mediterranean climates. Chambery in Savoie Department in the French Alps has annual precipitation of 800 mm with tow highlights in May and October. The difference by months is not so large. From December to February, snow falls. Even though the precipitation on statics is not so large, debris flow was triggered by the hourly rainfall of 150 mm. Flooding with debris flow occurred by the daily rainfall of 600 mm. Such records suggest heavy concentrated rain in sort time period cause landslides in the French Alps.
Switzerland	The Swiss Plateau falls in maritime climate whereas the Swiss Alps fall in alpine or tundra climate. Zurich has annual precipitation of around 900 mm with the large amount of rain in May to September. Even in other month, monthly precipitation is 60 mm or more. From November to March snow falls. Even though the precipitation on statics is not so large, rock fall and debris flow frequently occur.

Countries	Climate
Italy	The north of Italy and the Adriatic Sea side of the Italian Peninsula fall in humid subtropical or marine west coast climate. The Mediterranean side of the Italian Peninsula and the Island of Sicily and Sardinia fall in Mediterranean climate. The Apennines divides the climatic areas. Difference in precipitation among the climate is large.
CA-US	Precipitation is small. The largest precipitation of 1,351 mm /year was recorded in Grass Valley, 70 km northeast of the state capital Sacrament. Most of the cities, however, record annual precipitation of 600 mm or less. Many cities record annual precipitation of 400 mm.

(b) Earthquakes

Table 4-24 summarizes earthquakes.

Table 4-24 Earthquakes in Developed Countries

(JICA Study Team)

Countries	Earthquakes
France	Earthquakes are not so often. Small quakes occur in the south along the Pyrenees and in the east along the French Alps.
Switzerland	Earthquakes are not so often. In 1356, an earthquake of M7.1 occurred in Basel. The earthquakes of M6.0 or more occurred 5 times in 800 years in the past.
Italy	Relatively large earthquakes attack the country. In 21st Century, earthquakes with human casualties occurred, including L'Aquila Earthquake in 2009, 2012 Emilia Earthquakes, August 2016 Central Italy Earthquake, and 2017 Ischia Earthquake.
CA-US	CA-US are frequently attacked by earthquakes, most of which occur along the San Andreas Fault.

(c) Triggers of Landslides

Table 4-25 summarizes the triggers of landslides.

Table 4-25 Triggers of Landslides in Developed Countries

(JICA Study Team)

Countries	Triggers of Landslides
France Switzerland Italy	Heavy rain is blamed for the dominant triggers for landslides. It should be noted that the landslides are triggered by relatively small rainfall compared to those in Japan and Monsoon Asia.
France	Heavy rain, freezing and snow melt in winter, and snow avalanche are considered as triggers of landslides.
Switzerland	Similar to France, heavy rain, freezing and snow melt in winter, and snow avalanche are considered as triggers of landslides. In addition, bedrock creep causes massive landslides.
Italy	Similar to France, heavy rain, freezing and snow melt in winter, and snow avalanche are considered as triggers of landslides. In addition, earthquakes are major triggers. Provision of groundwater through the caves in karst was confirmed to facilitate debris flow.
CA-US	Heavy rain and earthquakes are considered as triggers.

(2) Topography

Table 4-26 summarizes topographic conditions.

Table 4-26 Topography in Developed Countries

(JICA Study Team)

Countries	Topography
France	Flat plane dominates the mainland of France. In the south and east, however, mountain ranges extend, such as the Pyrenees on the border with Spain, the Alps on the border with Italy, and the Jura Mountains on the border with Switzerland. In this research, the French Alps were visited.
Switzerland	Topography in Switzerland is divided into Swiss Plateau, the Alps, and Jura Mountains. The Swiss Plateau extends from Lake Geneva in the southwest to Lake Constance in the northeast at around 600 m in elevation. The Alps divides the North and South Europe along the border between Switzerland and Italy. The Alps occupies 2/3 of the territory of Switzerland and have 48 peaks of more than 4,000 m in elevation. The Jura Mountains are composed of lime stone and stretches from Lake Geneva to the Rhine River.
Italy	Italy is composed of the Italian Peninsula stretching from European Continent toward southeast and the islands including Sardinia and Sicily. Italy is mainly composed of mountains and less flat plain; 80 % of its territory is mountains. The Alps lie on the border with Switzerland and the Apennines is the backbone of the Italian Peninsula. In the south, Italy is covered by the volcanic belt including Mount Vesuvius, Mount Stromboli, and Mount Etna.
CA-US	Mountain ranges and valley extends parallel in north-south direction. In the middle of the state, the low land of Grate Valley stretches from northwest to southeast with the Klamath Mountains stretching on the north, the Pacific Coast Ranges stretching on the west, and the Sierra Nevada stretching on the east in north-south direction.

(3) Geology

Table 4-27 summarizes problematic geological conditions.

Table 4-27 Geology in Developed Countries

(JICA Study Team)

Countries	Problematic Geological Conditions
France	Jurassic limestone and dolomite. Granite and Gneiss in Brittany and Massif Central. Schist causes slides (Jisuberi) rather than rock fall whereas massive rock causes rock fall. Tertiary also causes slides around Paris and Bordeaux in the southwest. In Champagne Province, marl (marne in French) causes problems. Slides occur in the upper clippe. Lower Jurassic marl. Upper Triassic causes caving problems in the Alps, with erosion of clay with gypsum. Karst also causes problems. Rock fall is major issues in Triassic and the older. Lower Cretaceous marl causes problems. Flysch in Basque region causes erosion problems of the cast line. Marl and the alternation of marl and limestone causes massive collapse of mountains.
Switzerland	Rock fall, debris flow, snow avalanche, and shallow failure frequently occur. On the other hand, bedrock creep causes massive landslide including rock fall, failure, and slide at the same location. Bedrock creep is paid attention as factors of landslides in the Alps. Marl and alternation of marl and limestone forms fragile parts in the mountain and works as factors of landslides.
Italy	In addition to the problematic geological conditions, Italy has volcanic geology. In the Italian Alps, limestone, dolomite, marl, and issues relating to them including karst and sink holes caused by melting clay with gypsum. In the Dolomites, clay shale (Argilliti in Italy) causes problems. Clay shale in red color shows time-dependent deterioration by unloading or being exposed to the air and causes slaking, in which rock is decomposed to fragments. Flysch in the Apennines is composed of alternation of sandstone and mudstone. Similar to Argilliti in the Dolomites, the mudstone (Argilliete in Italy) in flysch causes slaking and forms fragile parts on the slope by decomposition to fragments. The mudstone also causes landslides by formulating slip surfaces

Countries	Problematic Geological Conditions
	through getting plasticity helped with provision of groundwater. In the south of Italy, many volcanos rise and tephra deposits, which is considered as a factor of debris flow, cover the land. Erupted lava may cause problems in the limited areas.
CA-US	Old and stable geology dominantly underlies the state and young geology such as sedimentary rock strata are limited. On the other hand, San Andreas Fault forms fractured zones where risks of landslides are usually high.

4.7.4 Organizations for Disaster Prevention

Table 4-28 summarizes organizations for disaster prevention.

Table 4-28 Organization for Disaster Prevention in Developed Countries

(JICA Study Team)

Countries	Fields	Organization for Disaster Prevention
France	O&M for roads	The ministry of transition to ecology is the central organization of the country. Interdepartmental road directorates (DIR) are regional organizations. Regional roads are maintained by département, the local government under région, helped by regional agencies of the central government. The Organization of Natural Disaster of the Department of Savoie is helped by RTM North Alps. The O&M of expressways and national highways are usually outsourced to the private sector and the concessionaires are responsible for O&M including landslide countermeasures on roadside slopes. According to an official of the government, concessionaires are responsible for unforeseeable landslides as of the time of the contract. The representative concessionaires are VINCI Autoroutes and AREA.
	Transport	University of Gustav Eiffel (ex. FFSTAR) and CREMA (ex. SETRA) are working for road sectors. University of Gustav Eiffel is mainly working for research and development and CREMA is working for preparing guideline and improvement of landslide countermeasures as well as support for design and construction of practical works.
	Agriculture and forestry	RTM under the National Forest Office implement landslide countermeasures and torrent control for the national land. INRAE is a research center for natural environment and doing research for countermeasures against torrent control, snow avalanche, rock fall, and flooding.
	Industry	French Geological Survey (BRGM) prepares geological maps of the nation along with hazard maps of landslides. BRGM also evaluates risks of landslides including risk evaluation of rock fall along a highway. INERIS works to limit environmental risks due to industrial activities, such as abandoned mines and factories. INERIS is not directly connected to roadside slopes but dealing with sink holes due to abandoned mines.

Countries	Fields	Organization for Disaster Prevention
Switzerland	O&M for roads	ASTRA (Federal Roads Office) is responsible for national highways including expressways. Regional roads are maintained by Canton (states) and rural roads are by municipalities.
	Laboratory	WSL (Institute for Snow and Avalanche Research SLF) is doing research and development for landslide countermeasures against rock fall, snow avalanche, and debris flow. WSL also involves countermeasures along hill roads.
Italy	O&M for roads	ANAS (National Road Administration Agency) maintain national highways and arterial highways close to national border. Province and commune maintains province and rural roads. Similar to France, expressway is maintained by the concessionaires, such as Autostrade per l'Italia.
	Related organization	IRPI is doing research for landslides including debris flow and design of countermeasures, not only on roadside slope but in entire country. ISPRA maintains landslide database and hazard maps for the nation. Civil Protection Agency of each region is responsible for landslide countermeasures and sometimes involves to landslide countermeasures along hill roads.
CA-US	O&M for roads	California Department of Transportation（Caltrans)
	Related organization	California Governor's Office of Emergency Services

4.7.5 Safeland Project

From 2010 to 2012, the Safeland Project[9] was conducted in Europe mainly led by EU for the research of landslide risks Europe wide. The Safeland Project was not aimed at hill road so this research did not get deep into the project. Substantial results came out of the project, however.

Safeland Project is composed of the 5 areas shown in Table 4-29.

The project prepared a landslide inventory[10] for entire Europe and, based on it, policies for landslide prevention were suggested to the governments.

Table 4-29 Areas of Safeland Project

(Edited from Safeland Project Web Page by JICA Study Team)

Areas	Objectives
Area 1	focuses on improving the knowledge on triggering mechanisms, processes and thresholds, including climate-related and anthropogenic triggers, and on run-out models in landslide hazard assessment;
Area 2	harmonises quantitative risk assessment methodologies for different spatial scales, looking into uncertainties, vulnerability, landslide susceptibility, landslide frequency, and identifying hotspots in Europe with higher landslide hazard and risk;
Area 3	focuses on future climate change scenarios and changes in demography and infrastructure, resulting in the evolution of hazard and risk in Europe at selected hotspots;
Area 4	addresses the technical and practical issues related to monitoring and early warning for landslides, and identifies the best technologies available both in the context of hazard assessment and in the context of design of early warning systems;
Area 5	provides a toolbox of risk mitigation strategies and guidelines for choosing the most appropriate risk management strategy.

9 https://esdac.jrc.ec.europa.eu/projects/safeland
10 https://esdac.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR25666EN.pdf

CHAPTER 5 Landslide Countermeasures in Developing Countries

5.1 History of Landslide Countermeasures

5.1.1 Sri Lanka

Table 5-1 shows the history of slope protection works in Sri Lanka.

Table 5-1 History of Slope Protection Works (Sri Lanka)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Landslide mitigation(countermeasures against slope disasters)	2006	Started in 2006 with NBRO and other institutions. Later, it expanded to the road sector through the World Bank project "Climate Resilience Improvement Project (CRIP), 2014". And, JICA project "Landslide Disaster Protection Project (LDPP), 2014" (Bandana et al, 2018).
Spay works	2005	Dissemination in Sri Lanka through the "SOUTHERN HIGHWAY CONSTRUCTION PROJECT" by Japanese ODA (coverage by RDA Headquarters Planning Division).
Soil nailing	2005	Same as above
Sri Lankan style embedded crib works	2001	Originally bamboo was also used instead of re-bar. Since around 2005, public works projects have used reinforcing bars as shown in Figure 5-1 (Interviewed by RDA-Kandy office and local contractor SOIL TECK).

Source:

Bandana. R.M.S・Jayasingha, P.(2018): Landslide Disaster Risk Reduction Strategies and Present Achievements in Sri Lanka, Geosciences Research, Vol. 3, No. 3,pp.21-27.

Kawamura, Y. (2015): Landslides along national roads in central highland in Sri Lanka: Review on current situation and suggestion for further development of landslide mitigation along highways in Sri Lanka.

Example of embedded crib works that has been implemented since 2000s

Example of combining embedded crib works and soil nailing

Figure 5-1 Sri Lankan Style Embedded Crib Works

(JICA Study Team)

5.1.2 Nepal

Table 5-2 shows the history of slope protection works in Nepal.

Table 5-2 History of Slope Protection Works (Nepal)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Drainage including check dam, sub-surface drainage	After 1988	Slope protection works on Dharan-Dhankuta Road supported by UK
Soil nailing	After 1988	Same as above
Anchor works, spray works, etc.	After 1996	Landslide countermeasures and pilot projects for road slopes by Japanese ODA (The Project for Construction of Sindhuli Road, etc.).
Bioengineering	After 1999	Created by the Department of Roads in conjunction with the British aid agency DFID. Manual of Bioengineering (DoR, 2002) first published in 1999

Source:

DoR (2002): Roadside Bio-engineering Reference manual, Department of Roads in Nepal

5.1.3 Ethiopia

Table 5-3 shows the history of slope protection works in Ethiopia.

Table 5-3 History of Slope Protection Works (Ethiopia)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Masonry retaining wall	Unknown	It has been used for a long time, but no records remain.
Masonry retaining wall with block pitching	Unknown	It has been used for a long time, but no records remain.
Drainage of masonry retaining wall	Unknown	It has been used for a long time, but no records remain.
Retaining wall using gabions	at least 50 years ago	Interview with a private Net Consultant
Precast frame works	About 2014	Used on the Addis Ababa-Adama Toll Expressway, which was constructed by China and completed in May 2014 as Ethiopia's first expressway.
Spray works	About 2012	Interview with ERA (Ethiopian Roads Authority)
Reinforcement embankment	Recent years	Interviews with private Net Consultants and Core Consultants

5.1.4 Philippines

Table 5-4 shows the history of slope protection works in Philippines Table 5-4.

Table 5-4 History of Slope Protection Works (Philippines)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Masonry retaining wall	Before 1990	Interview with AIP construction, a local construction company
Masonry retaining wall with cast-in-situ concrete crib works	1990s	Interview with AIP construction, a local construction company
Spray works	About 2007	Interviewed with the DPWH Planning Office. The impact of Japan's ODA (Rosario-Pugo-Baguio Road Rehabilitation Project), which began in 1993.
Anchor works (using PC steel bars)	About 2006	DPWH's 2006 Department order No.51 specifies technical specifications
Retaining wall using gabion	About 1975	Interviewed with Maccaferri Philippines
CoConet (coconut fibre erosion prevention sheet)	About 2008	DPWH's 2008 Department order No.29: officially approved technical specifications.
Wire mesh combined rock bolt	About 2014	DPWH's 2014 ministerial order (Department order No.63, Item 522A) specifies technical specifications
Reinforcement embankment	About 2018	In addition to Japanese products, products such as Maccaferri are also used.
Pocket-type rock fall protection net (curtain net)	About 2018	JICA pilot project

Source:

DPWH (2006): Department order No.51, DPWH Standard Specifications for Permanent Ground Anchors, Item 513

DPWH (2008): Department order No.29, DPWH Standard Specifications For Coconet Socio-Engineering Solutions, Item 518.

DPWH (2015): Highway design, Design guidelines, criteria & standards, Volime4.

DPWH (2019): Department order No.32, Item522-Active and passive protection systems for unstable slope (Amendments to Item 522-DPWH Generic specification for rock fall protection system and Item522A DPWH standard specification for protection system for unstable slope

DPWH (2013): Standard specifications for highways bridges and airports

This countermeasure began to be constructed in the 1990s.

Figure 5-2 Example of Masonry Retaining wall with Cast-in-situ Concrete Crib Works

(JICA Study Team)

5.1.5 Indonesia

Table 5-5 shows the history of slope protection works in Indonesia.

Table 5-5 History of Slope Protection Works (Indonesia)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Masonry retaining wall	1940s	Interview with local consultant Wiratman
Retaining wall using gabion	1970s/1980s	Interview with local consultant Wiratman
Spray works	About 1988	Interview with Bintek
Soil nailing	About 2015	Interview with local consultant Wiratman
Lattice works	About 2015	Interview with local consultant Wiratman
Anchor works	About 2008	Interview with Bintek

5.1.6 Honduras

Table 5-6 shows the history of slope protection works in Honduras.

The predecessor of the current Ministry of Infrastructure and Public Services (INSEP) was the Ministry of Public Works, Transport and Housing (SOPTRAVI). The Landslide Countermeasure Manual (SECOPT, 1988) developed by the Ministry of Communications, Public Works and Transport (SECOPT), the predecessor of SOPTRAVI, describes landslide countermeasures at that time. The Road Design Manual of the Central American Integration Organization (SIECA) (SIECA, 2011) also describes landslide countermeasures. The history of slope protection works in Honduras was summarized based on the results of interviews with local companies and the contents of those old manuals.

Table 5-6 History of Slope Protection Works (Honduras)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Surface water drainage (culvert)	Before 1988	It is described in the SECOPT (1988) manual.
Horizontal boring	Before 1988	It is described in the SECOPT (1988) manual.
Reinforced earth	Before 1988	It is described in the SECOPT (1988) manual.
Lattice works	Before 1988	It is described in the SECOPT (1988) manual.
Retaining wall	Before 1988	It is described in the SECOPT (1988) manual.
Spray works	Before 2011	Already listed in the SIECA (2011) Road Manual. Wet spraying works are currently used.
Spray crib works	Before 2011	Already listed in the SIECA (2011) Road Manual. Wet spraying works are currently used.
Soil nailing works	Before 2011	Information from an interview with Saybe & Asociados Inc.
Anchor works	Before 2011	Information from an interview with Saybe & Asociados Inc.
Measures against rock fall such as rock mesh and curtain net	About 2019	Information from an interview with Saybe & Asociados Inc.
Pile Screen: Cantilevered Retaining Wall	-	Information from interview by ACI Inc.
Gabion Wall: Gravity Retaining Wall	-	Information from interview by ACI Inc.
Berms: Profiling of slopes and construction of Berms	-	Information from interview by ACI Inc.

Source:

SECOPT (1988): Landslide in the Western Highway, Honduras, Secretaria de comunicaciones, obras publicas y transporte.

SIECA (2011): Manual Centroamericano de Normas para el Diseño Geométrico de Carreteras

5.1.7 Bhutan

Table 5-7 shows the history of slope protection works in Bhutan.

Table 5-7 History of Slope Protection Works (Bhutan)

(JICA Study Team)

Slope Protection Works	Period	Remarks
Retaining wall (concrete masonry or masonry)	Unknown	—
Drainage (open ditch, open/closed ditch, culvert)	Unknown	—
Earthworks and retaining wall with gabions	About 2000	Gabion was introduced from Italy's Maccaferri, and at the same time technical guidance was received on how to pack stones appropriately.
Bioengineering	About 2000	A manual was developed with the assistance of the World Bank (WB).
lattice works	Unknown	—

5.2 Countermeasures against Roadside Landslides in National DRRM Plan

The national DPRM (Disaster Risk Reduction and Management) plan in each country is explained below.

5.2.1 Sri Lanka

In this survey, no legal documents with specific descriptions regarding landslide countermeasures along roads has been found. Figure 5-3 shows an overview of the plans related to road slope disaster in Sri Lanka. (Based on interviews with DMC).

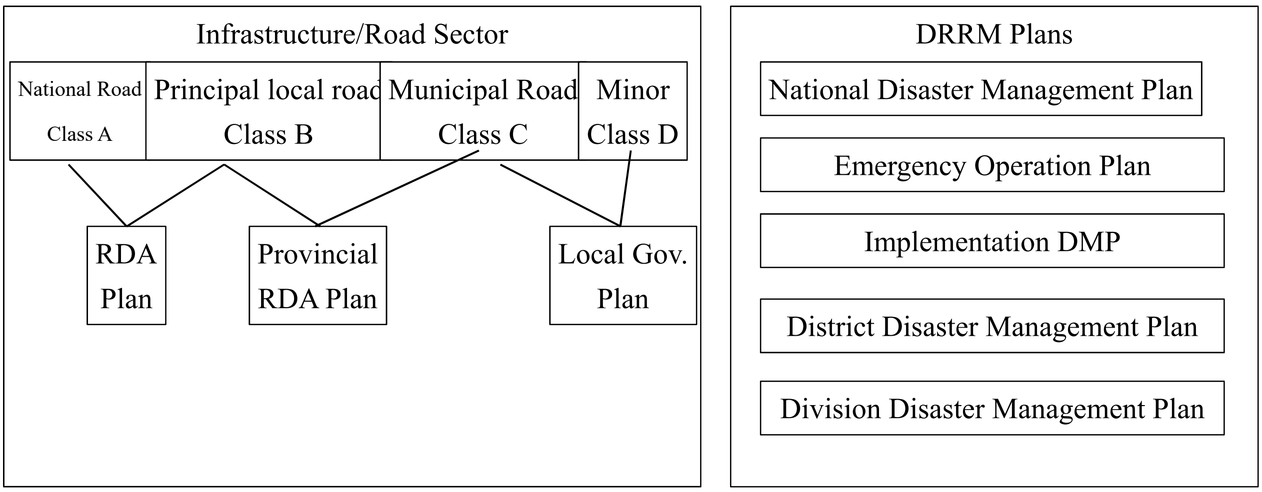


Figure 5-3 Plans Related to Landslide on Roadside Slopes in Sri Lanka

(JICA Study Team)

In the road sector, as shown on the left side of the figure above, there are plans by the RDA headquarters, plans by the Provincial RDA, and plans by local governments, from national roads to minor roads. At present, it is not confirmed whether or not there is a description of road slope disaster prevention in this document.

On the other hand, in the DRRM (Disaster Risk Reduction and Management) sector, as shown on the right side of the figure above, there are disaster prevention plans at the national level and disaster prevention plans at the municipality level. The content of Landslide was confirmed in the "National Disaster Management Plan" and "District Disaster Management Plan".

5.2.2 Nepal

In the interview survey, there were no responses regarding the law supporting the implementation of slope measures along the road.

There is no mention of landslide disaster on roadside slopes in both National Disaster Risk Reduction and Management (DRRM) plan and Local DRRM plans.

5.2.3 Ethiopia

ERA (Ethiopian Roads Authority) is drafting the Road Act. Unapproved as of June 2022. The draft includes the wording and content of safety assurance (safety assurance that can be interpreted to include perspectives such as Disaster Risk Reduction and Management in a broad sense).

5.2.4 Philippines

In this survey, there were no legal documents with specific descriptions of landslide disaster on roadside slopes.

According to the interview survey at the DPWH C.A.R office regarding the legal basis of responsibility for road slope disaster countermeasures, DPWH is legally responsible for ensuring the safety of national roads. For this reason, there was an answer that they are also in charge of landslide disaster on roadside slopes.

5.2.5 Indonesia

References to landslide disasters on roadside slopes in national plans, etc. have not been confirmed in this survey.

5.2.6 Honduras

There are four major laws, policies, and national plans related to Disaster Risk Reduction and Management in Honduras at the moment.

（1） Ley del Sistema Nacional de Gestión de Riesgos

（2） Reglamento de la ley del SINAGER

(3) Politica de Estado para la Gestión Integral del Riesgo en Honduras
(4) Plan Nacional de Gestión Integral de Riesgos (PNGIRH) 2014-2019

At present, Honduras does not have a legal system specific to landslide disasters on roadside slopes, and the above four frameworks are that for all disasters including landslide disasters on roadside slopes.

The Disaster Risk Reduction and Management Plan of Honduras is the National Integrated Risk Management Plan 2014-2019 (PNGIRH) (Table 5-8). This is a six-year plan formulated by COPECO in 2014 to operate PEGIRH effectively. The first two years (2014-2015) are the short-term plan, and the last four years (2016-2019) are the medium-term plan. The specific goals, strategic guidelines and measures of this plan are shown in the table below. Of these, the items related to landslide disasters on roadside slopes are underlined (implementation of risk analysis and assessment for identification of high-risk areas, promotion of scientific research for risk management). .

Table 5-8 Overview of the National Comprehensive Risk Management Plan (PNGIRH)

(JICA Study Team)

Objective	Strategic Guidance	Measure
Better understanding of disaster threats and risks	Strengthening early warning systems and information transmission systems, etc.	Establishment of procedures for information disclosure and communication
	Implementation of risk analysis/evaluation to identify high-risk locations, etc.	Identification of risk factors, magnitude, location, impact on residents, etc.
	Strengthening the knowledge and capacity of the government, private sector, and citizen regarding risks	Development of training programs to improve knowledge about risks
	Promoting scientific research for risk management	Strengthening research for risk management
		Promote collaboration with overseas organizations and universities to share knowledge
Incorporate the concept of comprehensive risk management into policies, regulations, strategies, etc.	Reflecting risk prevention and mitigation in national plans	Creation of guidelines for establishing and improving the functions of the DRRM Section
		Promoting risk management that incorporates a gender perspective
Strengthening budget management for DRRM	Establishment and strengthening of financial mechanisms	Establishment of FONAPRE

Objective	Strategic Guidance	Measure
Strengthening the capacity of organizations and citizen	Improving understanding of comprehensive risk management among citizens	Implementation of awareness-raising activities for citizens
		Examination of programs, campaigns, etc. to improve knowledge

5.2.7 Bhutan

Road act 2013 applies to general road construction laws. At the time of the interview, there were no responses regarding the laws supporting the measures against landslide disasters on roadside slopes.

5.3 Overview of DRRM Agencies/Organizations in Charge of Landslide Countermeasure

5.3.1 Sri Lanka

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

DMC (Disaster Management Center, Ministry of Disaster Management) coordinates and liaises with relevant organizations such as central ministries, agencies, and local governments regarding Disaster Risk Reduction and management (DRRM).

NBRO is the focal point for disaster management of Sri Lanka's central government agency. It is the responsible agency (including planning, survey, design, construction, maintenance and management) of all natural disasters for all conservation targets (not only roads, but also urban areas, housing, and social infrastructure).

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

RDA (Road Development Authority) is responsible for planning, designing, constructing and maintaining national roads in Sri Lanka. Surveys and construction of slope measures along roads are being carried out in cooperation with NBRO.

The inspection of national roads is carried out by the Provincial RDA.

Table 5-9 summarizes the types of roads and management systems in Sri Lanka.

Table 5-9 Road Type and Management System in Sri Lanka (modified from JICA, 2008)

(JICA Study Team)

Category	Class	Function	Owner	Management
National	A	Inter-provincial arterial roads connecting major cities and ports. Class A national highways are subdivided into three types: AA, AB, and AC.	Ministry of Transport and Highways	RDA
	B	Inter-provincial arterial roads connecting major urban areas		
Provincial	C	Main city roads and main roads connecting settlements and markets	Ministry of State and Local Government	PRDA
	D	Auxiliary roads and auxiliary roads connecting settlements and markets		
Municipal	-	Local roads to access specific locations	Ministry of State and Local Government	Road maintenance organizations in local governments
Others	-	Roads belonging to farms, forests and irrigation canals	Ministry of Local Development private company agricultural community	Village Development Associations (usually by contract) by the Ministry of Local Development
* Around 2008, E class was assigned to municipal roads. Since Sri Lanka's first expressway, the Southern Expressway (E01), opened around 2011, E class is currently assigned to the toll expressway (Expressway).				

Source:
JICA (2008): Sri Lanka Expressway Operation and Management Project Formation Survey Report

5.3.2 Nepal

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

Department of Road (DoR) under Ministry of Physical Infrastructure and Transport (MoPIT) is responsible for road planning, construction and maintenance. However, DoR's scope of responsibility is limited to the ROW. Slope measures outside the road site will be constructed by another organization. In the past, the Department of Water Induced Disaster Management (DWIDM) under the Ministry of Water Resources implemented countermeasures outside the ROW, such as erosion prevention measures along rivers and erosion control dams against debris flows. DWIDM is currently dismantled and absorbed into the Department of Irrigation, and there is no department in charge of landslide disaster outside the ROW in Nepal.

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

The need for landslide countermeasures arises mainly from maintenance.

In terms of maintenance, the DoR Divisional Office is in charge of minor slope failures, and the DoR Headquarters handles those that cannot be dealt with by the DoR Divisional Office. For projects of medium size or larger that DoR cannot handle, the design will be ordered to a consultant, and the contractor will carry out the construction. The contract in this case is BoQ (Item Rate).

On the other hand, DoR itself is also designing landslide countermeasures. Since the countermeasures designed by donors are expensive, the DoR head office is responsible for designing downgrades to countermeasures that can be done by the country itself.

(3) Organizational Structure for Survey and Construction of Landslide Disasters on Roadside Slopes

The DoR's Divisional Office is in charge of maintenance within the ROW. Road maintenance is managed by maintenance staff for 3km per day and managers for 18km. This team manages and maintains it like an inchworm. The maintenance team checks the condition of gutters, drainage and slopes. They also cut grass and clean clogged drains (Figure 5-4).

On the other hand, the DoR head office replied that they do not have maintenance manuals or maintenance equipment for ground anchor works, soil nailing, horizontal drainage boring, etc.

Regular inspections and emergency inspections are conducted by DoR's Divisional Office. The Divisional Office maintains a slope ledger, records inspections and damage, and submits them to the DoR headquarters before the rainy season. After the rainy season, additionally report the damage and costs caused by landslide will be submitted to the DoR headquarters.

During the rainy season, construction equipment is placed in potential locations where there is a danger of collapse, and a stand-by system is in place to remove debris. However, DoR does not observe rainfall, and the Department of Hydrology and Meteorology observes daily rainfall.

Figure 5-4 Maintenance Work by Divisional Office

(JICA Study Team)

5.3.3 Ethiopia

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

Although the need for a central government agency in charge of disaster management is recognized, in Ethiopia it is difficult to establish a central government agency in charge of disaster management due to frequent reorganizations of ministries and governments. International cooperation agencies and bilateral donors have pointed out the necessity, but so far there is no central government agency in charge of disaster management.
In Ethiopia, it is basically a post-disaster response and insufficient investment in prevention.

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

ERA (Ethiopian Roads Authority) is the main implementing body for the development of national highways, and orders construction consultants and contractors. Emergency countermeasures against slope disasters on existing road slopes are implemented by ERA's local offices themselves, but when permanent countermeasures are required, they are outsourced to construction consultants and contractors.

In Ethiopia, maintenance work is not carried out even if the slope protection works is partially damaged. If an existing road is closed due to a sediment disaster, ERA will implement emergency countermeasures. Basically, it is an emergency response that does not involve survey design such as soil removal. If permanent measures are required, survey and design works will be ordered from ERA.

5.3.4 Philippines

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

(i) OCD (Office of Civil Defense) [11]

OCD was positioned as a central organization of DRRM activities as the secretariat of NDRRMC by the “Disaster Risk Reduction and Management (hereinafter referred to as “DRRM”) Act” enacted in 2010. Its role is to implement and facilitate a wide range of activities in the country, from prevention and mitigation to emergency response. The organizational chart of OCD is shown in Figure 5-5.

[11] Disaster Risk Reduction and Management Capacity Enhancement Project Phase 2, Detailed planning survey, 2018, JICA

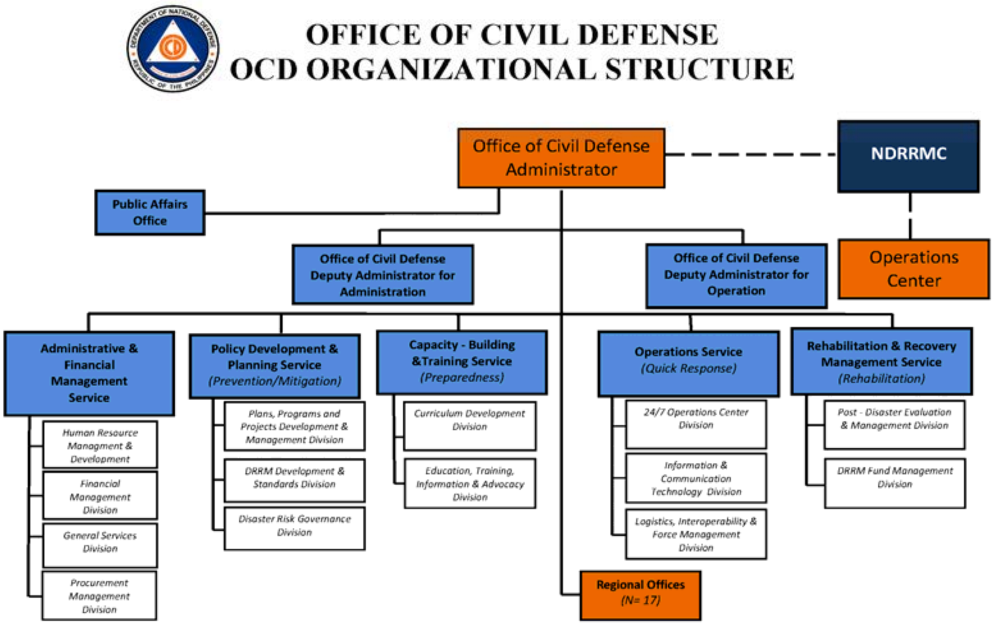


Figure 5-5 OCD Headquarters Organization Chart [12]

（OCD）

The action plan for implementation of the NDRRMP (National Disaster Risk Reduction and Management Plan) under the jurisdiction of OCD shows the basic policy on road slope disaster prevention including DPWH. In relation to landslide disasters, the NDRRMP Action Plan lists more than 20 activities by government agencies including DPWH, and OCD monitors these activities. DPWH is a member of the NDRRMP Development and Steering Committee. Through this committee, information on projects related to critical infrastructure disaster prevention, including road slope disaster prevention, and coordinate with relevant central government agencies are shared. In addition, DPWH is a member of the Technical Working Group of the NDRRMP Committee.

(ii) DPWH (Department of Public Works and Highways） [13]

The Department of Public Works and Highways (DPWH) is a government agency responsible for planning, designing, constructing, and maintaining infrastructure such as national highways, bridges, flood control, and water resource development. The main roles and responsibilities are as follows.

- Plans for roads, bridges, flood control, water resource projects and other infrastructure projects
- Design, construction and maintenance of national roads, bridges and major flood control systems

The DPWH Central Office (CO) has eight undersecretaries under the secretary. The Planning Service under the Undersecretary for Planning service, Public-Private Partnership and Information Management Service has jurisdiction over projects related to various plans including infrastructure planning. The Information Management Service manages and controls road information and various systems. In

[12] https://ocd.gov.ph/index.php/about-ocd/organizational-structure
[13] Road Disaster Prevention Project in Mountainous and Flood Area Basic Planning Survey Report, 2021, JICA

addition, DPWH has the Bureau of Construction, Bureau of Design, Bureau of Equipment, Bureau of Maintenance, Bureau of Quality and Safety, and Bureau of Research & Standards under the Undersecretary for Technical Services. There are 16 Regional Offices (RO), and 180 District Engineering Offices (DEO) are located below them (Figure 5-6).

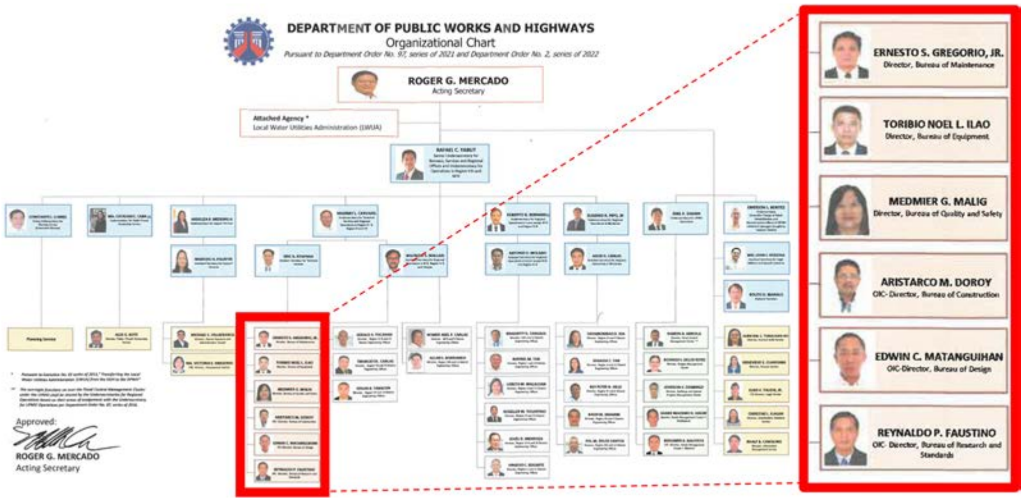


Figure 5-6 Organization Chart of DPWH Central Office[14]

（DPWH）

DPWH is responsible for public infrastructure development in the Philippines. According to the NDRRMP formulated in 2011, the DPWH is tasked with "(1) enhancing the resilience of infrastructure for disaster prevention and mitigation" and "rebuilding resilient infrastructure for disaster recovery and recovery." In the Philippines, based on the General Appropriations Act, the National Disaster Risk Reduction and Management Fund (NDRRMF), which aims to reduce, avoid, prevent, and prepare for disaster risks, is granted annually to DRRM agencies, including the DPWH. Since the NDRRMF is granted based on the implemented project, the grant amount varies from year to year for each institution. From 2009 to 2014, DPWH had the highest proportion (33%) of all institutions that received NDRRMF funding. In particular, when Typhoon Yolanda struck in 2012, the amount granted to the DPWH was exceptionally large, suggesting that the budget for reconstruction and restoration was extremely large.

(iii) PHIVOLCS (Philippine Institute of Volcanology and Seismology)[15]

Executive Order No. 984 of 1984 transferred authority over earthquake observation from PAGASA to PHIVOLCS. Executive Order 128 of 1987 established the current PHIVOLCS organization. PHIVOLCS, like PAGASA, is an external department under DOST. Volcano Observation and Eruption Prediction Department, Earthquake Observation and Prediction Department, Geological and

[14] https://www.dpwh.gov.ph/dpwh/about/org-chart/org-chart-main
[15] Disaster Risk Reduction and Management Capacity Enhancement Project Phase 2, Detailed planning survey, 2018, JICA

Geophysical Exploration Research Department, and Finance and General Affairs Department are placed under the general manager.

The main activities of PHIVOLCS are technical and information provision services (disaster prediction and warning services), training, and research and development for disasters related to crustal phenomena such as volcanic eruptions, earthquakes, and tsunamis. In relation to these activities, the following projects are being implemented. (From PHIVOLCS website)

- National volcano monitoring and volcanic eruption warning
- Nationwide earthquake monitoring and issuing earthquake information
- Nationwide tsunami monitoring and early warning
- Seismic hazard and risk assessment
- Analysis of seismic disaster potential of active faults and trenches
- Volcanic Hazard and Risk Assessment
- Records of volcanic eruptions and magma generation history
- Strategic talent management and development
- Strengthen leadership ability
- Analysis and development for superior strategic outcomes

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

DPWH/Planning Service (PS) has five divisions: Development Planning Division (DPD), Project Preparation Division, Programming Division, Statistics Division, Environmental and Social Safeguards Division (ESSD). In relation to road disaster prevention, DPD has constructed a road slope management database tool called "Road Slope Management (RSM)" and is implementing budget planning and project formulation for measures and programs related to road slope disaster prevention. In addition, DPD promotes capacity building programs for DPWH technicians through RSM and checks the survey reports and completion reports of RO and DEO slope disaster prevention measures projects that have been implemented, as well as provides technical advice. Prioritization, evaluation and formulation of implementation plans for practical slope protection projects are carried out by DPD.

The responsibilities of the DPWH/Bureau of Design (BOD) are: surveying, topographic and geological survey; roads and bridges; drainage and slope protection; pavement design; Management of related regulations and standards. BOD is in charge of all aspects of road construction, repair and maintenance. BOD is in charge of checks and reviews at the design stage in accordance with requests from ROs and DEOs. Specifically, whether the retaining wall design proposed/submitted by the RO conforms to the design guidelines, whether the geological conditions are understood, etc. will be checked. In general, BOD does not conduct on-site confirmation, but if there is any doubt, the BOD may conduct an on-site investigation.

DPWH/Bureau of Maintenance (BOM) consists of 4 divisions: Road Condition Monitoring & Evaluation Division (RCMED), Policies and Standards Division (PSD), Safety & Disaster Management Coordination Division (SDMCD), National Building Services Division (NBSD). The responsibilities of the BOM are as follows: monitoring, evaluation and report preparation of road conditions by regional/regional offices; management of maintenance regulations and standards; road maintenance system by regional/regional offices. Support for the construction of infrastructure; support for the implementation of maintenance work; monitoring and report preparation of maintenance work; RCMED inspects and evaluates the condition of roads and bridges on a regular basis; supervises road maintenance by local offices. The PSD checks the disaster status reports for each region periodically submitted by the ROs and considers the order of priority for countermeasures. SDMCD prepares a list of traffic regulations, etc., provides PS, etc., and organizes DPWH's Performance Governance System Scorecard (PGS). NBSD secures budgets for inspections and inspections of public buildings and construction, but does not carry out road disaster prevention responsibilities.

The DPWH/Bureau of Research & Standards (BRS) is the body responsible for the Standard Specification (called the Blue Book) used by DPWH. BRS issues a Specification after obtaining a Product Accreditation Scheme (PAS). BRS evaluation is required to obtain PAS. In DPWH, when new technology is introduced, BRS will verify and certify the technology based on Department Order (DO) No.189. After a theoretical evaluation based on documents, verification at the development stage, product testing, and two pilot trials, the product is finally approved for practical use. The same process applies when private companies introduce new technologies. BRS maintains a list of approved new technologies.

5.3.5 Indonesia

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

(i) Department of Public Works (PU)

The Ministry of Public Works (PU) has jurisdiction over road maintenance in Indonesia. The Ministry of Public Works consists of the General Directorate of Urban Housing, the Directorate of Roads, the Directorate of Water Resources and the Research and Development Agency. Among these, the Directorate General of Roads (Bina Marga) is mainly concerned with road slope disasters. The organizational structure of road management is detailed in the next section.

(ii) National Disaster Management Agency (BNPB)

Until the enactment of the Disaster Management Law in April 2007, the National Disaster Coordinating Agency (BAKORNAS PB) was responsible for inter-organizational coordination among the central government agencies in charge of disaster management. However, the current situation is that the emergency response authority in the event of a disaster is limited, and the lack of recognition as a coordinating agency and the lack of coordinating ability make it difficult to respond quickly when a disaster occurs. In order to improve this situation, the BNPB was established in May 2008, and was newly launched as an organization that comprehensively handles everything from preventive (damage suppression and mitigation) measures to emergency response, recovery and reconstruction, not limited to coordination functions.

BNPB's responsibilities are as follows:

1) Provision of guidelines and direction regarding fair and equitable preventive (damage prevention/mitigation) measures, emergency response, and disaster prevention measures that contribute to recovery/reconstruction
2) Standardization of disaster management organization and regulation of necessity based on the provisions of law
3) Disclosure of activities
4) Report the activity progress of the disaster prevention organization to the President every month or continuously when a disaster occurs.
5) Utilization and accounting of domestic and international donations/support
6) Accounting for funds supplied from the state budget
7) Implementation of other business based on the provisions of law
8) Preparation of guidelines for establishment of local disaster management bureaus

(iii) Center Volcanology and Geological Hazard Mitigation（CVGHM）

- An agency under the Geological Agency under the Ministry of Energy and Mineral Resources.
- Conducts survey research and provides advice on geology and geotechnical engineering in response to requests from the Ministry of Public Works.
- Has experience working with JasaMarga. Example: CVGHM utilized BNPB's landslide risk map during new expressway construction to assist in assessing geological vulnerability associated with road construction.
- After the large-scale landslide disaster in Pucha region in 2020, CVGHM conducted a field survey and submitted the survey results to relevant departments within central ministries and agencies such as the Ministry of Public Works.
- CVGHM also carried out 2010 landslide monitoring in Paneran region.

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

The main responsibility for landslide disaster on roadside slope is the Department of Roads (Bina Marga), Ministry of Public Works.

According to the Law of Republic of Indonesia No.13, 1980 on Road, roads are functionally classified into Arterial Roads, Collector Roads and Local Roads. Administratively, they are classified into national roads, state roads, prefectural roads, city roads, and toll roads.

The planning, construction, and improvement of national and state roads are carried out by the Directorate General of Roads and its local office, the Road Betterment Office (RBO). The maintenance and management of these national and provincial roads are carried out by the road departments (Dinas Bina Marga) of the public works departments of each province under the direction of the Directorate

General of Roads. Regarding prefectural roads and city roads, planning and technical standards are handled by the Directorate General of Roads, but construction and management are carried out by the public works departments of each prefecture and city under the guidance of the Directorate General of Roads. Table 5-10 shows jurisdiction by road classification and project type.

Table 5-10 Road Management System in Indonesia

(JICA Study Team)

Class	New Construction	Improvement	Maintenance
National	RBO	RBO	RBO
State	RBO	RBO	RBO
Prefectural	Prefectural Public Works Department	Prefectural Public Works Department	Prefectural Public Works Department
Municipal	Municipality Public Works Department	Municipality Public Works Department	Municipality Public Works Department

The organization of the Directorate General of Roads consists of the Planning Department, the Urban Road Department, the Western Regional Department, the Central Regional Department, the Eastern Regional Department, and the Equipment Department. The regional departments responsible for road construction in rural areas are the western regional department for Sumatra and Kalimantan, the central regional department for Java and Bali, and the eastern regional department for Nusa Tenggara, Sulawesi, Maluku and Irian Jaya.

RBO is the regional office of the Directorate General of Roads. As a branch office of the Ministry of Public Works, regional offices are located in each province to guide and supervise the state's public works.

The State Department of Public Works consists of the Urban Housing Department, the Water Resources Department, and the Road Department. The Road Department, which has jurisdiction over road projects, consists of the Planning and Design Section, the Maintenance Section, the Road Engineering Section, and the Bridge Engineering Section.

Toll roads are managed and operated by the Indonesian Roads Corporation (Jasa Marga). The Corporation is a state-owned joint-stock company (PT) established in March 1978 and wholly owned by the government. At the beginning of its establishment, it started with the management and operation of the Jagorawi Highway under the supervision of the Directorate General of Roads, and officially started in December 1980 with the official approval of the National Assembly (Law No.13). The scope of work is general toll road business, including planning, construction, maintenance, and operation. The business territory is all toll road projects such as inter-city, intra-city toll roads and toll road bridges throughout Indonesia.

5.3.6 Honduras

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

The disaster prevention agency in Honduras and the agency in charge of landslide countermeasures is the National Disaster Commission (COPECO: Comision Per-manente de Contncias) (Figure 5-7).

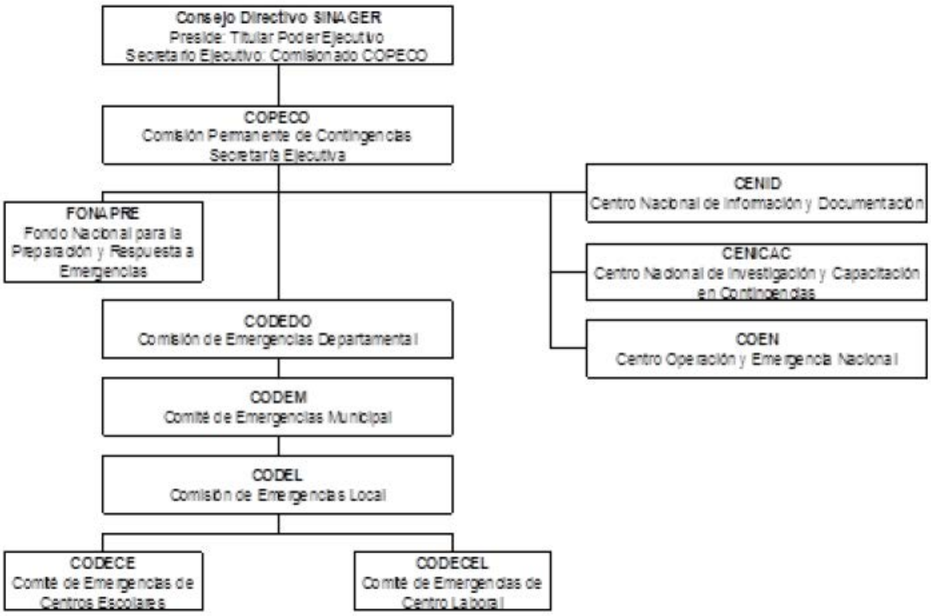


Figure 5-7 DRRM Organizational Structure in Honduras

(National Comprehensive Risk Management Plan 2014-2019 of Honduras)

(2) Organizational Structure for Survey and Construction of Landslide Disasters on Roadside Slopes

In Honduras, the Ministry of Infrastructure and Public Works (INSEP: Secretaria de Infraestructura y Servicios Publicos) is in charge of the survey and construction of slope measures along roads in Honduras. Roads below that level are handled by municipalities such as Tegucigalpa Capital City Council (AMDC: Alcaldía Municipal del Distrito Central).

(3) Organizational Structure for Maintenance of Landslide Disasters on Roadside Slopes

The Honduras Strategic Investment Fund (INVEST-H. Inversión Estratégica de Honduras) is in charge of the maintenance and management of slope measures along roads (there are some cases of new road construction by Invest-H). Primary/Secondary Roads are under the control of Invest-H maintenance. Roads below the tertiary are maintained and managed by local governments (in some cases, Invest-H provides support).

5.3.7 Bhutan

The following description excludes roads under Indian Army BRO/DANTAK control. The Indian Army BRO/DANTAK has declined to release information or provide interviews. The roads under Indian Army BRO/DANTAK management are as follows.

Paro - Thimphu, Thimphu - Phuntsholing, Chungsung - Ha, Ha - Paro, Trashigang - Sangjeopjongkha

(1) DRRM Agencies/Organizations in Charge of Landslide Countermeasure

The Department of Road (DoR) under the Ministry of Works and Human Settlement (MoWHS) is responsible for road planning, construction and maintenance.

The national disaster prevention plan is formulated by the DDM (Department of Disaster Management/Ministry of Home and Culture Affairs).

(2) Organizational Structure for Survey, Construction and Maintenance of Landslide Disasters on Roadside Slopes

DoR will be responsible for surveying, designing and constructing roadside slopes. However, only a few sections have landslide countermeasures.

DoR is assisted by the Department of Geology and Mines under the Ministry of Economic Affairs in surveying and designing sections where difficulties such as landslides are expected.

(3) Organizational Structure for Survey and Construction of Landslide Disasters on Roadside Slopes

DoR Regional Offices (ROs) are in charge of maintenance of landslide countermeasures. The main activity is to install retaining walls on collapsed slopes. Retaining walls are also inspected and maintained.

On the other hand, there is a ledger containing records of collapses and necessary countermeasures for places where slopes have collapsed. In addition, inspections are conducted before and after the monsoon for important sections.

During the rainy season, construction equipment is placed near areas at risk of collapse and stands by for removal of collapsed earth. Rainfall observations are conducted in-house at one or two locations. In many cases, data are obtained from the National Center of Hydrology and Meteorology.

For routine maintenance of roads, DoR/RO employs local residents. Maintenance personnel are provided with helmets and reflective vests, and each person is assigned 1.5km per month (Figure 5-8).

Figure 5-8 Maintenance Work by DoR

(JICA Study Team)

5.4 Standard/Guideline for Slope Protection Technology

This section describes the guidelines collected during the field survey. Some survey methods, including those developed by Japanese ODA Projects, are at a level close to Japan's Highway Earthwork guidelines. It was not confirmed that the content of descriptions on landslide countermeasures was close to the level of Japanese technical guidelines.

5.4.1 Sri Lanka

Sri Lanka's standard/guideline for slope protection technology is shown in Table 5-11.

Table 5-11 Standard/Guideline for Slope Protection Technology in Sri Lanka

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	GEOMETRIC DESIGN STANDARDS OF ROADS	1998	RDA	A manual for planning and designing roads according to traffic volume. The cut slope is explained in one line (e.g. cut slope gradient = 4V (vertical): 1 H (horizontal)), but there is no description of slope measures.
2	STANDARD SPECIFICATIONS FOR CONSTRUCTION AND MAINTENANCE OF ROADS AND BRIDGES	Jun 2009	MCES	It contains technical specifications for roads and bridges. There are almost no explanations with figures, and there are few designations with numerical values. Most of them are described as sentences, and technical specifications as a general theory are mainly described.

#	Title	Issued	Issuer	Contents
3	DESIGN OFFICE MANUAL FOR GEOTECHNICAL DESIGN, NBRO, 2019	Dec 2019	NBRO	Contents related to stability analysis such as selection method of stability analysis formula, setting of unit volume weight for each geological feature, setting of factor of safety of landslide in case of back calculation, etc. are described in detail. Regarding landslide countermeasures, we use text to explain the concept of countermeasures and the types of works for soil nailing, ground anchor works, retaining walls, surface drainage works, and slope protection works. There is no specific explanation of the design method.
4	GENERAL GUIDELINE FOR ASSESSMENT OF STABILITY OF CUT SLOPES IN EXPRESSWAYS	-	NBRO	Guidelines given by NBRO for expressway projects. The measures for cut slopes on expressways are mainly explained in text. It describes the setting of small steps on the cut slope and the standards for rock fall grooves to be installed on the side of the road as a safety belt against falling rocks from the cut slope.
Issuer abbreviation: RDA: Road Development Authority NBRO: National Building Research Organization MCES: Ministry of Construction and Engineering Services				

5.4.2 Nepal

Nepal's standard/guideline for slope protection technology is shown in Table 5-12.

Table 5-12 Standard/Guideline for Slope Protection Technology in Nepal

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Guide To Road Slope Protection Works	June 2003	DoR	These guidelines were created by JICA and are based on Japanese technical guidelines.
2	Road side Bio-Engineering Reference Manual	1999	DoR	A bioengineering manual produced by the DoR together with the British aid agency DFID. In addition to planning, design, and maintenance, the comprehensive content includes selection of seeds to be used, relevant laws and regulations, and technical specifications. It clearly stipulates that the collapse that bioengineering can handle is up to 50 cm from the surface layer. It explains the combination of 6 functions (Catch, Armor, Reinforce, Anchor, Support, and Drain) with single vegetation and simple civil engineering structures (gabions, concrete retaining walls, drainage, etc.).
3	Roadside Bio-Engineering Site Handbook (2076-01-12)			A bioengineering site handbook (maybe a nuance of "must-have"). It contains a lot of information about construction. Construction using simple civil engineering structures, vegetation, and locally available plant materials (branches) are described. There is also a chapter devoted to growing seedlings, and a list of vegetation available on Nepal's roadside slopes is attached. In addition, bioengineering and (simple) civil engineering structures are used to stabilize and maintain slopes.
4	Road Side Geo-Technical Problems_ A Practical Guide to their Solutions	June 2007	DoR	Guidance for roadside slope failure, intended to be used by DoR's Divisional Office. Along with the English version, the Nepalese version is also included. The DoR's Divisional Office is in charge of small slope failures, and the DoR Headquarters handles those that the Office cannot handle. For projects of medium size or larger that DoR cannot handle, the work to be carried out

#	Title	Issued	Issuer	Contents
				by the Divisional Office is indicated, in line with the flow of outsourcing the design to a consultant and the construction to a contractor.
Issuer abbreviation：DoR：Department of Road, Ministry of Physical Planning and Works				

5.4.3 Ethiopia

Ethiopia's standard/guideline for slope protection technology is shown in Table 5-13.

Table 5-13 Standard/Guideline for Slope Protection Technology in Ethiopia

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Route Selection Manual	2013	ERA	A manual on how to select road routes. It also includes detailed descriptions of past failures in road development, making it possible to understand what caused the failures. Notes on topography and geology are also detailed with photographs and explanatory maps.
2	Site Investigation Manual	2013	ERA	Survey manual for road development. Explanations of Ethiopia's weather, topography and geology are also relatively detailed. As for specific survey methods, the same survey types as in Japan, such as the use of topographic maps, remote sensing, various geophysical survey methods, boring surveys, sampling, and in-situ tests, are explained.
3	Geotechnical Design Manual	2013	ERA	Technical manual on road earthwork. Stabilization measures are described for fills and cuts. Regarding the standard cut slope gradient, there is an explanation of the standard value according to the detailed geological division, and there is also an explanation of the stability analysis method. However, it seems that the detailed cut slope gradient for each geology presented here is not adopted in practice. For embankments, there are also explanations on stabilization methods using gabions, embankment reinforcement soil works, and design of retaining walls. Regarding the stabilization of the cut slope surface, the list of works is shown.
4	Geometric Design Manual	2013	ERA	Design manual for road geometry. There is also a chapter on road cross-sections, showing standard cross-sections. Typical values for the back slope cut slope gradient are shown in tabular form for rough geological divisions. This cut slope gradient is used in practice.

#	Title	Issued	Issuer	Contents
5	Standard Detailed Drawings for Roadworks	2013	ERA	Standard design drawings for roads and road structures are shown. The standard shape of the road cross section is also shown in it, and the Standard cut slope gradient of Back Slope is also described in tabular form for rough geological divisions.
Issuer abbreviation: ERA：Ethiopian Roads Authority				

5.4.4 Philippines

Philippines standard/guideline for slope protection technology is shown in Table 5-14.

Table 5-14 Standard/Guideline for Slope Protection Technology in Philippines

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Design guidelines, criteria & standards（DGCS） Volume1 Introduction & overview	2015	DPWH	Explanation of outline of road design
2	Design guidelines, criteria & standards（DGCS） Volume2A Geohazard assessment	2015	DPWH	The main content is an outline explanation of damage caused by various geo-hazards such as direct damage from earthquakes, liquefaction, volcanic disasters, slope disasters, Karst topography, soft ground, floods, and tsunamis. A few general ideas about assessment are touched upon.
3	Design guidelines, criteria & standards（DGCS） Volume 2B Engineering surveys	2015	DPWH	Outlines of common surveys related to surveying and mapping, surveys for roads, bridges, flood control/water utilization/water supply, and architectural surveys are described. There is no description of slope surveys, and the term slope is rarely used.
4	Design guidelines, criteria & standards（DGCS） Volume 2C Geological & geotechnical investigations	2015	DPWH	Methods such as survey boring, core sampling, laboratory tests, groundwater observation, in-situ tests, and on-site measurement of facility deformation are explained. There is no description of slope surveys and the term slope is not used.
5	Design guidelines, criteria & standards（DGCS） Volume 3 Water engineering projects	2015	DPWH	Technical standards for flood control, water utilization, and water supply facilities
6	Design guidelines, criteria & standards（DGCS） Volume 4 Highway design	2015	DPWH	National highway design manual. Chapter 7 Earthworks has a description about slope measures, and the standard slope gradient for filling and cutting is described below. However, this table is essentially the

<table>
<tr><th>#</th><th>Title</th><th>Issued</th><th>Issuer</th><th>Contents</th></tr>
<tr><td></td><td></td><td></td><td></td><td>standard slope gradient for embankments. There is no information on the standard slope gradient of cutting.

Table 7-1 Stability of Cut and Fill Slopes for Different Material Types
<table>
<tr><th>Filling Material*</th><th>Nature of Material</th><th>Height of Cut/ Fill (m)</th><th>Slope Ratio (H:V)***</th><th>Remarks</th></tr>
<tr><td>Well graded sand (SW)
Gravel with Silt (GM)
Gravel with Clay (GC)</td><td rowspan="7">Soil</td><td>Less than 5</td><td>1.5:1 to 2.0:1</td><td rowspan="7">Applied to fills with sufficient bearing capacity at foundation ground, which are not affected by inundation (assumed drained and unsaturated).
Consistency assumed to be medium dense (non-cohesive) or stiff (cohesive) or better.</td></tr>
<tr><td>Well Graded Gravel (GW)
Poorly Graded Gravel (GP)</td><td>5 to 15</td><td>1.8:1 to 2.5:1</td></tr>
<tr><td>Poorly Graded Sand (SP)</td><td>Less than 10</td><td>1.8:1 to 2.5:1</td></tr>
<tr><td>Silty Sand (SM)</td><td rowspan="2">Less than 5</td><td rowspan="2">1.5:1 to 2.0:1</td></tr>
<tr><td>Clayey Sand (SC)</td></tr>
<tr><td>Hard clayey soils and clay of alluvium, loam (CL)</td><td>5 to 10</td><td>2.0:1 to 2.5:1</td></tr>
<tr><td>Soft Clay of high plasticity (CH), Silts (ML, MH)</td><td>0 to 5</td><td>2.5:1 to 3.0:1</td></tr>
<tr><td rowspan="2">Medium to High Strength Rock, Slightly Weathered to Fresh</td><td rowspan="6">Rock**</td><td>Less than 10</td><td>0.5:1 to 1:1</td><td rowspan="6">Assess all rock slopes in cut in accordance with Section 7.3.</td></tr>
<tr><td>10 to 15</td><td>0.75:1 to 1.2:1</td></tr>
<tr><td rowspan="2">Very Low to Medium Strength Rock, Extremely to Distinctly Weathered</td><td>Less than 5</td><td>0.75:1 to 1.2:1</td></tr>
<tr><td>5 to 10</td><td>1.0:1 to 1.5:1</td></tr>
<tr><td rowspan="2">Residual Soil to Extremely Low Strength Rock, Extremely Weathered</td><td>Less than 5</td><td>1.0:1 to 1.5:1</td></tr>
<tr><td>5 to 10</td><td>1.5:1 to 2:1</td></tr>
</table>
* Table 7-1 not applicable for soil and rock types not included
** Refer Section 7.3 for rock slopes for cuts
*** All slope ratios assume that berms are in place at regular intervals and slope protection such as nets, catch drains and other protective measures are in place, as required.

Regarding slope surface protection, almost all landslide countermeasures, including ground anchors, are listed as a list, but the purpose and characteristics of the works are only explained in sentences, and detailed design methods are not provided. No explanation. This list does not include rock fall countermeasures.</td></tr>
<tr><td>7</td><td>Department order No.68:(2017)
Minimum Design Standards for Industry Roads Under the DTIDPWH Convergence Program for Roads Leveraging Linkages for Industry and Trade (ROLLIT)</td><td>2017</td><td>DPWH</td><td>Minimum design standards for industrial roads set by DPWH. As Side slope ration (H: V), the following criteria corresponding to Cut Slope Material Type are described.
• Common Materials - 1:1 to 1.5:1
• Soft Rock - 0.5 :1 to 1: 1
• Hard/Solid Rock - 0.25: 1 to 0.5: 1
• Minimum fill slope of 1.5: 1</td></tr>
<tr><td>8</td><td>Department order No.15:(2020)
Amendment to D.O. No. 112, s. 2019 re: "Revised Design Standards for Tourism and Farm to Market Roads"(DPWH, 2020)</td><td>2020</td><td>DPWH</td><td>Revision of design standards for tourist roads and farm-to-market roads set by DPWH. This appendix contains a list of landslide countermeasure works. The list of landslide countermeasures published in Chapter 7 of DGCS Volume 4 (DPWH, 2015) is posted as is. For example, the lack of types of slope protection works listed and the descriptions of rock bolts, etc., do not reflect the contents</td></tr>
</table>

#	Title	Issued	Issuer	Contents
				of the Road slope protection manual (DPWH&JICA, 2019) developed by the JICA project.
9	Department order No.24:(2019) Technical Manuals and Guidelines on Road and Bridge Maintenance and Inspection	2019	DPWH	Ministerial Decree certifying 10 maintenance manuals for roads and bridges and 8 manuals for inspection of bridges as official manuals of DPWH. The officially certified manuals include the Road slope protection manual (DPWH, JICA, 2018) prepared by JICA project.
10	Standard specifications for highways bridges and airports	2013	DPWH	Technical specifications for construction. In Part-G, there are gabions, erosion prevention mats, ground anchors, spray works, reinforced earth walls, etc. for slope measures. There is a description about the cut slope gradient of soft rock (between 0.75:1 and 2:1). Since it is mainly a technical specification for materials, there is no explanation on how to design these landslide countermeasures (including the setting of the planning factor of safety).
11	Cocotech bio-engineering manual		Cocotech	Technical manual for anti-erosion mats using coconut fibre
12	Highway safety design standards manuals: Part 1-Road safety design manual	2012	DPWH	Technical manual for road design. There is almost no mention of landslide countermeasures.
13	Highway safety design standards manuals: Part 2-Road signs and pavement markings manual	2012	DPWH	Manual on Road Signs, etc.
14	BSDS Design standard guide manual	2019	DPWH	A seismic design manual for bridges. A manual prepared by JICA's ODA.
15	Department order No.32:(2019): Item522-Active and	2019	DPWH	Technical specifications for structural measures for road slopes. Structural measures are classified into two

#	Title	Issued	Issuer	Contents
	passive protection systems for unstable slope (Amendments to Item 522-DPWH Generic specification for rock fall protection system and Item522A DPWH standard specification for protection system for unstable slope			types: active and passive protection systems. Tokyo Rope International and European companies established the Item 522 study group, and at the time of revision in 2019, it became possible to adopt products from other companies in Japan and Europe. . It mainly describes material specifications, and does not explain the setting of the planning factor of safety or the design method.
16	Department order No.63:(2014): DPWH Standard Specification for Item 522A - Protection Systems for Unstable Slope	2014	DPWH	A technical specification that officially approves the specifications of GeoBrugg's wire mesh and rock bolting works. This made GeoBrugg's products publicly available for DPWH projects.
17	Department order No.51:(2006): DPWH Standard Specifications for Permanent Ground Anchors, Item 513	2006	DPWH	Technical specifications for ground anchors on road slopes. In effect, it assumes anchor works using PC steel bar, and although there is a description of pre-stressed steel, there is no description of PC steel wire. There is no description of the technical specifications of the PC steel wire and the corresponding anchor head nuts and head members.
18	Department order No.29:(2008): DPWH Standard Specifications For Coconet Socio-Engineering Solutions, Item 518	2008	DPWH	Technical specifications for CoConet (coconut fibre anti-erosion sheet)
Issuer abbreviation: DPWH：Department of Public Works and Highways				

5.4.5 Indonesia

Indonesia's standard/guideline for slope protection technology is shown in Table 5-15.

Table 5-15 Standard/Guideline for Slope Protection Technology in Indonesia

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Geotechnical design requirements	2017	NSA	Chapter 7 (Slope Stability for Excavation and Embankment) describes survey methods for slope stability evaluation and design methods for various countermeasures. Chapter 10 Earth Retaining Structures describes how to design multiple landslide countermeasures.
Issuer abbreviation: NSA：National Standardization Agency				

5.4.6 Honduras

The standard/guideline in Honduras for slope protection technology is shown in Table 5-16.

Table 5-16 Standard/Guideline for Slope Protection Technology in Honduras

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Geotechnics and Seismic Considerations Manual	2019	SIECA	A manual prepared by a JICA project from 2016. There is an English version and a Spanish version.
2	Road Manual volume 2: RECOGNITION AND LAYOUT OF ROADS	Dec 1996	SOPTRAVI	Developed by the Ministry of Public Works, Transport and Housing (SOPTRAVI), the predecessor of the Ministry of Infrastructure and Public Services (INSEP).
3	LRFD Bridge Design Specifications 9th Edition	2020	AASHTO	Ground anchor design criteria.
4	A Policy on Geometric Design of Highways and Streets	2018	AASHTO	Design policy of road alignment and road.
5	Highway Slope Maintenance and Slide Restoration Workshop-Participant Manual	1988	FHWA	Former manual of the US Federal Highway Administration. The latest version is FHWA (2008)

Issuer abbreviation:
SIECA: Secretaría de Integración Económica Centroamericana
SOPTRAVI: Secretaria de estado en los despachos de obras publicas, transporte y vivienda
AASHTO: American Association of State Highway and Transportation Officials

5.4.7 Bhutan

Bhutan's standard/guideline for slope protection technology is shown in Table 5-17.

Table 5-17 Standard/Guideline for Slope Protection Technology in Bhutan

(JICA Study Team)

#	Title	Issued	Issuer	Contents
1	Guidelines on Design, Construction, and Maintenance of Road Infrastructure incorporating Climate-resilient Features	Dec 2019	DoR	Comprehensive guidelines for road construction. There is a description about the type of landslide countermeasure works. However, except for drainage measures, there are few descriptions of specific survey methods and design methods.
2	Manual for Feasibility Study of Road Alignment	Apr 2022	DoR	Unstable slopes are taken up as a road problem. In addition to preliminary observations by aerial photograph interpretation and remote sensing, the understanding of the geological structure is also briefly described along with investigation methods and tools for crack systems.
3	Guidelines for Road Drainage System	Nov 2021	DoR	Guidelines for road drainage. Sub-surface drainage is mentioned as a countermeasure against seepage water, but it is a kind of French drain filled with underdrain or gravel, and there is no mention of drainage for slope stabilization or drainage horizontal boring for landslide countermeasures.
4	EFRC(Environmental Friendly Road Construction) Manual Bioengineering in Bhutan	Sep 2005	DoR	A bioengineering manual originally published with support from the World Bank (WB) and at the time of publication with support from the Netherlands Development Organization (SNV Bhutan –Netherlands Development Organization). A combination of structures and bioengineering is intended to stabilize slopes along roads. The Bioengineering Description is a detailed and comprehensive bioengineering manual.

#	Title	Issued	Issuer	Contents
5	EFRC(Environmental Friendly Road Construction) Field Handbook, Construction of Unpaved Road	Oct 2005	DoR	A handbook on the construction of feeder roads with the support of the Dutch Development Agency. In the landslide countermeasures section, gabions, masonry retaining walls, lattice works, etc., the structures and bioengineering measures described in the bioengineering manual mentioned above are taken up.
6	Standard Operation Procedure for Road Slope Data Collection Induced by Slope Failures	Dec 2021	DoR	This is the standard procedure for recording collapsed slopes. For slope failures that impede traffic, documenting them will be the protocol used in special budgets from the Ministry of Finance. It was prepared by the Bhutan government based on the deliverables of the JICA technical cooperation project mentioned in 7 below. , "Slope Chart", one of the road disaster prevention inspection methods in Japan, is applied to record at the time of disaster. Examples of assumed countermeasures include countermeasures that are assumed for road disaster prevention inspections in Japan, regardless of the performance and capabilities of Bhutan.
7	Manual of Slope Stability Inspection on Road	June 2016	JICA	One of the deliverables of JICA's technical cooperation project "Road slope management master plan survey project". It is a localized version of the Japanese road disaster prevention inspection manual, introducing the case of Bhutan. Together with the materials at the end of the book, it seems to have been the basis for the materials collected from DoR, (6) Standard Operation Procedure for Road Slope Data Collection Induced by Slope Failures".

Issuer abbreviation:
DoR：Department of Road, MoWHS

5.5 Response to Landslide Disaster in Road Planning Stage

Table 5-18 shows the results of the interview survey on responses to landslide disaster on roadside slope risk.

Table 5-18 Interview Result about Response to Landslide Risk in Planning Stage

(JICA Study Team)

Countries	Interview Result
Sri Lanka	NBRO has prepared a risk map for landslide disasters. With this as a reference, the RDA is prioritizing slope protection works according to budget. In the past, a team of geotechnical engineers at the RDA attempted to create an inventory of areas where countermeasures were needed, but there is none at present. The NBRO map risk rating is for a given area. From the aspect of road management, narrowing down to sections and locations, consideration of monitoring data, and clarification of evaluation items and criteria for risk rating are required.
Nepal	A consultant will be used to survey along the planned route of the new road, but no boring survey will be conducted. Because of the high cost of landslide countermeasures, landslides are basically avoided. In the case of existing routes, we do not shift routes unless the countermeasures against the risks are expensive. Bridge and tunnel projects are beginning to use this risk aversion measures.
Ethiopia	For the target section of the road project, cut out a geological map from the Geological Map (1/2.5 million) and confirm the geology. In addition, information such as topography, geology, and aquifers related to the landslide disaster on roadside slope is read from the Geomorphological Map and Hydrogeological Map, and hazard identification, risk assessment, and analysis are performed. In some cases, a geological profile of the target section is created.
Philippines	The DO (Department Order) of DPWH stipulates the minimum number of lanes on national highways. However, mountainous areas are an exception. For example, the landslide disaster on roadside slope risk is reduced by not requiring widening in areas of concern. DPWH requests PHIVOLCS (Philippine Institute of Volcanology and Seismology) for risk assessment of liquefaction and landslides for each new project. PHIVOLCS provides DPWH with the results of GIS and remote sensing risk assessments (without field surveys). The OCD (Office of Civil Defence) conducts risk assessments on national highways, taking into account multiple disasters such as landslides, earthquakes, and floods.

Countries	Interview Result
Indonesia	The alignment plan will be reviewed if there are geological conditions that cause considerable problems, such as landslides, on the road widening section. After that, if there are concerns about geological and ground risks, soil improvement, etc. will be carried out. If there are still concerns about risks, countermeasures will be considered. The Centre for Volcanology & Geological Hazard Mitigation may use the landslide risk map of the National Disaster Management Agency (BNPB: Badan Nasional Penanggulangan Bencana) to support studies on geological vulnerability related to road construction.
Honduras	Route and alignment options (alternative routes using bridges, tunnels, etc.) will also be considered for risk avoidance in areas where landslides are a concern. If there is a confirmed plan to pass through high-risk areas, the project is being implemented and countermeasures are being taken in line with that plan.
Bhutan	Risks on new routes, if identified by the Geotechnical Section of DoR, will be avoided by shifting the alignment. However, it will be a consultation with the cost. A geological engineer will be employed to investigate the risks, using photo interpretation and ground reconnaissance. Or ask the Department of Geology and Mines under the Ministry of Economic Affairs for help. Avoiding the risks of tunnels and bridges is not an option for budgetary reasons. Before starting a project, a social survey is obligatory. At that time, risk avoidance is attempted by obtaining information about landslides that only local people know. Risks found during design are addressed by changing alignment. The alignment study as a result of F/S is discussed and approved by the Technical Committee, which is composed of DCC (Department Coordination Committee) members.

5.6 Survey for Landsides on Roadside Slope

Table 5-19 compares the contents of surveys conducted at the time of new road construction by country.

Table 5-19 Survey for Landsides in New Road Construction

(JICA Study Team)

Countries	Use of Topographic/ geological Maps	Aerial photo Reading	Sounding / Core Boring/Test Pits	Soil Test/In-situ Test/Geophysical Exploration
Sri Lanka	▪ Create detailed topographic maps of target areas using drones, etc.	▪ Aerial photo interpretation is not carried out ▪ Complemented with detailed topographic maps from drones.	▪ For cut slope sections, every 200-300m in the longitudinal direction of the road. ▪ The transverse direction is the cut start and end points. ▪ Perform core sampling. ▪	▪ General soil test/rock test ▪ Standard penetration test ▪ Seismic and electrical prospecting
Nepal	▪ Topographic survey is carried out	▪ Not implemented	▪ Test pit (CBR every 500m) and dynamic cone penetration test. ▪ Survey boring is carried out.	▪ CBR test and physical test, etc.
Ethiopia	▪ Usually 1/2.5 million geological maps are used. ▪ 1/50,000 geological map development is 1.4% of the national land area. ▪ In value engineering, a consultant creates a detailed geological map of the target area.	▪ Interpretation of aerial photographs or satellite images using a stereoscope	▪ Investigation boring will be carried out only in cut sections where there are concerns about geological problems. Basically, near the road centre line or near the shoulder. ▪ If a boring machine cannot be brought into the planned cut slope section, it may be complemented by seismic survey. ▪ Core sampling by rotary boring machine. Utilize double core tubing as needed.	▪ Soil test: direct shear test, liquid plasticity limit test, consolidation test, etc. ▪ The N value of the standard penetration test is used for designing bridge foundations, etc., and is not used for slope stability evaluation. ▪ Elastic wave prospecting and electrical prospecting are also carried out as necessary.
Philippines	▪ In recent years, many roads have been expanded, but in the case of new road construction, topographic and geological maps are used as in Japan.	▪ In recent years, many roads have been widened, but in the case of new roads, the same aerial photo interpretation as in Japan is carried out.	▪ In recent years, road widening has become mainstream. Details of the construction of the new road have not been confirmed. Conducted survey boring and core sampling. ▪ Using a rotary percussion machine, a	▪ Shear strength parameters (c, ϕ) are obtained from soil tests.

Countries	Use of Topographic/ geological Maps	Aerial photo Reading	Sounding / Core Boring/Test Pits	Soil Test/In-situ Test/Geophysical Exploration
	▪ Surveys on landslide countermeasures have not been conducted at the time of road widening.	▪ Surveys on landslide countermeasures have not been conducted at the time of road widening.	rotary boring machine and a double core tube.	
Indonesia	▪ Micro-topographic topographic maps using LiDAR are used. ▪ The geological distribution is relatively simple, so geological maps are of little importance.	▪ Aerial photo interpretation is not effective in jungle-rich Indonesia. It uses the results of micro-topographic survey by LiDAR.	▪ Boring surveys and core sampling are basically carried out at all cut slope sections. ▪ Proper drilling arrangements are described in national standards.	▪ Soil tests required for stability evaluation of the cut slope are being conducted. ▪ Soil testing methods are described in national standards.
Honduras	▪ The road manual of the Central American Integration System (SIECA), which was developed in 2019 as a JICA project, describes the Japanese-style survey method. This is basically used. Therefore, the same survey as in Japan is being conducted for road slopes. ▪ Topographic/geological survey, laboratory test, remote sensing, survey boring, stability analysis (using Rocscience design software), etc. Road alignment change is being considered to avoid Landslide danger zone			
Bhutan	▪ Topographic survey is carried out	▪ Aerial photo interpretation, remote sensing	▪ Standard Penetration Test (SPT), Dynamic Cone Penetration Test, Test Pit (CBR)	▪ CBR test and physical test, etc.

Table 5-20 shows the survey for landside disaster in existing road by each country.

Table 5-20 Survey for Landsides on Existing Road

(JICA Study Team)

Countries	Description	Remarks
Sri Lanka	▪ After a disaster occurs, the RDA decides the order of priority, taking into account the opinions of the NBRO, including emergency measures. ▪ If landslide countermeasures are required, the necessary survey and design will be ordered from a consultant. If the bidding fails, the RDA itself will conduct research and design.	▪ It is based on post-disaster measures. ▪ Collapses of road slopes are dealt with by prioritizing them, so small collapses are left untouched.
Nepal	▪ Since survey boring is not carried out even when new roads are being constructed, it is inferred that sufficient surveys will not be carried out even after a slope disaster occurs.	▪ It is based on post-disaster measures.
Ethiopia	▪ After a disaster occurs, the Road Authority (ERA) will take emergency measures such as removing earth and sand. ▪ When constructing permanent measures such as retaining walls, a consultant will conduct surveys and designs.	▪ It is based on post-disaster measures.
Philippines	▪ Construction of landslide countermeasures as a preliminary measure against dangerous road slopes is the basis. Surveys and designs are also usually carried out as a preliminary measure. Instead of placing an order with a consultant, the landslide countermeasure manufacturer will conduct the survey and design free of charge. ▪ The same applies to post-disaster investigation and design.	▪ As in Japan, it is based on pre-disaster measures. ▪ The road authority only orders consultants to conduct surveys and designs for landslide countermeasures during large-scale projects such as new road development.
Indonesia	▪ The national standard specifies the survey method for ground deformation that occurs on roads. Survey will be ordered to the consultant accordingly.	▪ It is based on post-disaster measures. ▪ Collapses of road slopes are dealt with by prioritizing them, so small collapses are left untouched.

Countries	Description	Remarks
Honduras	▪ When a slope disaster occurs, an order for survey is sent to a consultant. In addition to survey boring, electric prospecting, laser extensometers, inclinometers, and crack measurements of structures are carried out. ▪ As for the survey method, the Japanese-style survey method is described in the road manual of the Central American Integration System (SIECA), which was developed in 2019 as a JICA project.	▪ It is based on post-disaster measures.
Bhutan	▪ The country's landslide countermeasures include gabions and masonry retaining walls. Surveys are basically not implemented. ▪ In the case of slope disasters on National Highway No. 4, surveys and designs have been outsourced to local consultants.	▪ National Highway No. 4 is being implemented by local consultants with assistance from overseas consultants.

5.7 Design of Landslide Countermeasures on Roadside Slope

5.7.1 Gradient of Cut Slope

Table 5-21 shows the standard cut slope gradient of each country. Four countries, Sri Lanka, Ethiopia, and Honduras, usually use the standard cut slope gradient. Philippines has a standard cut slope gradient for industrial roads (roads for linking industry and trade), but it is presumed that it is not adopted for normal national roads. Indonesia, which does not have a standard cut slope gradient, answered that it uses commercially available software compatible with the finite element method to evaluate the stability of all cut slopes.

Table 5-21 Standard Gradient of Cut Slope in Each Country

(JICA Study Team)

Countries	Standard Gradient of Cut Slope	Remarks
Sri Lanka	V:H=1:1/4	Standard cut slope gradient is described as a sentence in the text of Geometric design standards of roads (RDA, 1998).
Nepal	None	—
Ethiopia	The contents of description differ for each manual prepared by the road authority, and there are two types of cut slope gradient corresponding to detailed geological divisions and cut slope gradient corresponding to rough geological divisions. Although the values of the cut slope gradients of the two are different, the cut slope gradient corresponding to the rough geological divisions in the cross-section drawing of the standard drawing collection is actually used.	In many cases, contractors cut with a steeper gradient than designed in order to reduce construction costs.
Philippines	Highway design (DPWH, 2015) has a standard slope gradient table for cut and fill, but it has no information for cut. The contents of Department order No. 68: (2017) issued as the minimum design standards for industrial roads are effective values for the gradient of cutting.	Since the consultant explains that they evaluate the stability of the cut slope using design software, it is presumed that this Standard cut slope gradient is not widespread. In recent years, road widening is the mainstream, and since it is common to make the gradient steeper than the current gradient when widening, a steeper gradient is progressing.

Countries	Standard Gradient of Cut Slope	Remarks
Indonesia	None	Stability is evaluated in all cutting sections, but commercial software that supports the finite element method is used.
Honduras	The road manual (SIECA, 2019) of the Central American Integration System (SIECA), which was developed as a JICA project, lists Japanese standard values as they are without any explanation. The actual cut slope gradient refers to the old standard (SOPTRAVI, 1996).	The standard value (V:H) of the cut slope gradient is 1:1/4 to 1:1/2, but in reality there are many cases close to the cut slope gradient V:H=1:1/4.
Bhutan	Although there is a provision for standard slope gradient, it is not used because geological surveys are not conducted.	–

The following sections describe specific Standard cut slope gradient values for countries that have set Standard cut slope gradient.

(1) Standard Cut Slope Gradient of Sri Lanka

There is only one standard value for the cut slope gradient described in the standard document, and there is no description on geology.

Actual road slopes are often cut with the same gradient as this value, even in the case of earth and sand and strongly weathered rocks.

Standard cut slope gradient V:H=1:1/4

(2) Standard Cut Slope Gradient of Ethiopia

The values in the "Back/Cut slope" column of Table 5-22 indicate the Standard cut slope gradient.

Table 5-22 Standard Cut Slope Gradient actually used in Ethiopia

(Standard Detailed Drawings for Roadworks(ERA, 2013))

SLOPE RATIO TABLE				
MATERIAL TYPE	"Depth of Cut /Ht of Fill (H)" [m]	SIDE SLOPE		BACK / CUT SLOPE
		CUT	FILL	
EARTH / SOIL	0 – 1	2H : 1V	3H : 1V	3H : 1V
	1 – 2	2H : 1V	2H : 1V	2H : 1V
	2– 10	2H : 1V	3H : 2V	3H : 2V
	>10	2H : 1V*	3H : 2V	BENCHED SLOPE
DECOMPOSED ROCK	0 – 1	2H : 1V	3H : 1V	3H : 1V
	1 – 2	2H : 1V	2H : 1V	2H : 1V
	2– 10	2H : 1V	3H : 2V	3H : 2V
	>10	2H : 1V*	3H : 2V	BENCHED SLOPE
WEATHERED ROCK	0 – 2	2H : 1V	3H : 2V	1H : 2V
	> 2	2H : 1V	1H : 1V	1H : 3V
ROCK	0– 2	2H : 1V	5H : 4V	1H : 2V
	>2	2H : 1V*	1H : 1V	1H : 4V
BLACK COTTON SOIL	0– 2	2H : 1V	6H : 1V	3H : 1V
	>2	2H : 1V*	4H : 1V	2H : 1V
COLLUVIAL DEPOSIT	0 – 3	2H : 1V	3H : 1V	1H : 1V
	3 – 6	2H : 1V	2H : 1V	5H : 4V
	6– 10	2H : 1V	3H : 2V	5H : 3V
	>10	2H : 1V*	3H : 2V	BENCHED SLOPE

(3) Standard Cut Slope Gradient of Philippines

Table 5-23 shows valid descriptions in the standards issued by road authorities.

Table 5-23 Standard cut slope gradient of Philippines (for Industrial Roads)

(Department order No.68(DPWH, 2017)

Materials	Side Slope Ration(H:V)
Common Materials	1:1 to 1.5:1
Soft Rock	0.5 :1 to 1: 1
Hard/Solid Rock	0.25: 1 to 0.5: 1
Minimum fill slope	1.5: 1

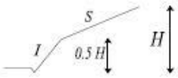
(4) Standard Cut Slope Gradient of Honduras

The standard cut slope gradient (H: V) is presented in two tables, Table 5-24 for earth/sand and Table 5-25 for rock. The features of the standard cut slope gradient for rocks classify igneous rocks (ÍGNEAS) into three categories: 1. Granito y Diorita (granite and diorite), 2. Andesita (andesite), and 3. Basalto (basalt). Sedimentary rocks (SEDIMENTARIAS) are divided into 4 groups: 1. Conglomerado y Brechas (conglomerate and gap), 2. Arenisca (sandstone), 3. Caliza y pizarra (limestone and slate), 4. Lutitas (shale). . Each rock condition subdivides the standard value of the cut slope gradient. There is no detailed classification for metamorphic rocks (METAMÓRFICAS).

Table 5-24 Standard Cut Slope Gradient of Honduras (for Earth / Sand)

（SOPTRAVI, 1996）

TABLA VII: **TALUDES DE CORTE EN ROCA**



	Talud (H:V) para V = altura indicada				Observaciones
	< 5 m	5 a 10 m	10 a 15 m	> 15 m	
ÍGNEAS					
1. Granito y Diorita					
a) Sano y masivo	1/4 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Tender talud en coronamiento 1/2 : 1
b) Sano fisurado en bloques	1/4 : 1	1/4 : 1	1/2 : 1	1/2 : 1	Sellar fisuras talud
c) Exfoliado. Grandes bloques empacados en arena	1/2 : 1	3/4 : 1	3/4 : 1	3/4 : 1	
d) Exfoliado. Grandes bloques empacados en arcilla arenosa	1/2 : 1	S 3/4 : 1 I 1/2 : 1	S 3/4 : 1 I 1/2 : 1	3/4 : 1	Disponer banco de 2 a 3 m de ancho altura pavimento para H > 5 m
e) Totalmente intemperizado	3/4 : 1	S 1 : 1 I 3/4 : 1	1 : 1	1 : 1	Si el producto intemperización es arena, proyectar bancos de 1 m con H < 15 m y de 3 m si H > 15 m
2. Andesita					
a) Fisurada, sin alteración	1/4 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Sellar fisuras talud
b) Fracturada, poco alterada	1/4 : 1	1/2 : 1	1/2 : 1	S 3/4 : 1 I 1/2 : 1	Banco 4 m en cambio talud si parte inferior corte no contiene arcilla en las fracturas
c) Fracturada y alterada	1/2 : 1	3/4 : 1	3/4 : 1	3/4 : 1	Tender talud en coronamiento 1 : 1
3. Basalto					
a) Fracturado sano	1/4 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Tender talud en coronamiento 1/2 : 1
b) Fracturado en bloques de todos tamaños	1/2 : 1	1/2 : 1	S 1 : 1 I 1/2 : 1	S 1 : 1 I 1/2 : 1	Si los fragmentos están empacados en arcilla firme y no hay flujo agua
c) Fracturado y muy intemperizado	1/2 : 1	1/2 : 1	3/4 : 1	3/4 : 1	En zona lluviosa colocar banco de 2 m con H < 15 m y de 3 m con H > 15 m en pie talud

Table 5-25 Standard Cut Slope Gradient of Honduras (for Rock)

(SOPTRAVI, 1996)

TABLA VII (Continuación)	< 5 m	5 a 10 m	10 a 15 m	> 15 m	Observaciones
SEDIMENTARIAS					
1. Conglomerado y Brechas					
a) Bien cementado con matriz silicosa o calcárea	1/8 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Sellar fisuras talud eliminando los fragmentos sueltos
b) Pobremente aglomerado con matriz arcillosa	1/2 : 1	3/4 : 1	S 1 : 1 I 3/4 : 1	S 1 : 1 I 3/4 : 1	Si matriz está saturada o sometida a cambios fuertes de humedad colocar banco de 4 m en cambio talud
2. Arenisca					
a) Sana. Fuerte cementación	1/4 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Tender talud en coronamiento 3/4 : 1
b) Poco cementada, muy alterada y con flujos de agua	1/4 : 1	1/4 : 1	1/2 : 1	S 3/4 : 1 I 1/2 : 1	Tender talud en coronamiento 1 : 1
3. Caliza y pizarra **					
a) Sana con estratificación gruesa o mal definida	1/8 : 1	1/4 : 1	1/4 : 1	1/4 : 1	Tender talud en coronamiento 1 : 1
b) Sana con estratificación fina o a favor del corte	1/4 : 1	1/2 : 1	1/2 : 1	S 3/4 : 1 I 1/2 : 1	
c) Intemperizada con flujo de agua	1/2 : 1	3/4 : 1	3/4 : 1	3/4 : 1	Proyectar subdrenaje y cunetas impermeabilizadas
d) Intemperizada y muy fracturada	3/4 : 1	3/4 : 1	S 1 : 1 I 3/4 : 1	S 1 : 1 I 3/4 : 1	Contrafoso impermeabilizado
4. Lutitas					
a) Dura y resistente, poco fracturada con estrato casi horizontal	1/4 : 1	1/4 : 1	1/4 : 1	S 1/2 : 1 I 1/4 : 1	Tender talud en coronamiento 3/4 : 1 y colocar contrafoso impermeable
b) Suave de resistencia media y muy fracturada	1/2 : 1	3/4 : 1	3/4 : 1	S 1 : 1 I 3/4 : 1	Tender talud en coronamiento 1 : 1 y contrafoso impermeable
METAMÓRFICAS					
Gneiss, Cuarcitas, Mármol	1/4 : 1	1/4 : 1	S 1/2 : 1 I 1/4 : 1	1/2 : 1	Tender talud en coronamiento 3/4 : 1

Abreviaturas (TABLA VII):
1) Tender talud en coronamiento cuando la roca está muy intemperizada en ésta parte.
2) S = Talud en 0.5 H superior
3) I = Talud en 0.5 H inferior
** Comportamiento de las pizarras que es roca metamórfica se asimila al de las calizas

5.7.1.2 Standard Cut Slope Gradient in Bhutan

The standard drawing collection of "Guideline on use of Standard Work Items for Common Road Works, MoWHS, 2015" has designation of cut slope gradient of Back Slope according to rough geology in the cross section drawing. It is summarized in Table 5-26.

Table 5-26 Standard cut slope gradient of Bhutan

(JICA Study Team)

Materials	Primary National Highway / Secondary National Highway / Farm Road / Dzongkhag Road
Ordinary Soil	1 : 1.0
Hard Soil	1 : 0.5
Soft Rock	1 : 0.25
Hard Rock	1 : 0.15

Source
RDA (1998): Geometric design standards of roads,
ERA (2013): Standard Detailed Drawings for Roadworks, Ethiopian Roads Authority
DPWH (2015): Highway design, Design guidelines, criteria & standards, Volume 4
DPWH (2017): Department order No. 68: 2017, Minimum Design Standards for Industry Roads under the DTIDPWH Convergence Program for Roads Leveraging Linkages for Industry and Trade (ROLLIT)
SOPTRAVI（1996）: Road Manual volume 2-RECOGNITION AND LAYOUT OF ROADS, Secretaria de estado en los despachos de obras publicas, transporte y vivienda
SIECA (2019): Geotechnics and Seismic Considerations Manual
MoWHS (2015): Guideline on use of Standard Work Items for Common Road Works, Ministry of Works and Human Settlement

5.7.2 Design Policy/Flow

Table 5-27 lists the design policies and design flow characteristics of landslide countermeasures in each country. In many countries, how to design retaining walls is described in the design manuals of the road authorities. For other landslide countermeasures, only the types and characteristics of countermeasures are often explained. Many countries leave the specific design method to the Western design software they use. As a special case, the Philippines does not outsource survey and design for roadside landslide countermeasures to consultants, and material manufacturers carry out surveys and designs free of charge.

Table 5-27 Overview of Design Policy/Flow for Countermeasures in each Country

(JICA Study Team)

Countries	Description	Remarks
Sri Lanka	▪ The road authority's design manual only explains the types and concepts of landslide countermeasures, but does not describe design methods. ▪ The design calculation targets are soil nailing and retaining walls. For the retaining wall, a normal retaining wall design calculation is carried out. ▪ There is no designation of the planning factor of safety in the technical guidelines. Some answered that the planning factor of safety for landslide countermeasures was about 1.3, while others answered that it was 1.6 to 2.0. ▪ European and American design software such as Canada's SLOPE/W (GeoSlope) is used for the actual design.	▪ Response after a disaster is the basis. ▪ After the disaster, the survey and design will be outsourced to a consultant, but if the bidding is unsuccessful, the road authorities will conduct the survey and design themselves.
Nepal	▪ The road authority's design manuals are prepared as part of JICA's project, and are basically based on Japanese technical guidelines. ▪ The planning factor of safety for slope measures is Fp=1.5, and the targeted prevention works are about soil nailing. ▪ Concrete retaining walls, masonry retaining walls, gabion retaining walls, and lattice works are the basics of landslide countermeasures, so retaining walls are the main design targets.	▪ Response after a disaster is the basis.
Ethiopia	▪ The road authority's design manual explains the types of landslide countermeasures, but does not describe the design method.	▪ Response after a disaster is the basis. ▪ The design of

Countries	Description	Remarks
	▪ There are no prevention works, and there is no planning factor of safety for slopes. ▪ The masonry retaining wall follows the design of the ordinary retaining wall. For gabion-based earthworks and retaining walls, the design manual only describes precautions regarding how to stack gabions and the angle of the foundation.	landslide countermeasures will be outsourced to a consultant.
Philippines	The road authority's design manual only explains the types and concepts of landslide countermeasures, but does not describe design methods. The road manual developed by JICA also explains the concept of landslide countermeasure planning, but does not describe the design method. There is no designation of the planning factor of safety in the technical guidelines. According to the interview, the static planning factor of safety is set to 1.5, the planning factor of safety during an earthquake is set to 1.2, and the seismic motion is considered as vertical seismic intensity 0.1 and horizontal seismic intensity 0.2. The design of landslide countermeasures is usually carried out free of charge by the material manufacturer. The material manufacturer will also conduct the site survey and soil test required for the design free of charge.	▪ Response after a disaster is the basis. ▪ Basically, we do not outsource the investigation and design of landslide countermeasures to consultants. ▪ If it is a large-scale road development project, we will outsource the survey and design to a consultant.
Indonesia	▪ It is basic to evaluate the stability by conducting stability analysis on all cut slopes without setting a cut slope gradient. ▪ There is a description of the design method of major landslide countermeasure works in the national standard, and for soil nailing, which is the main prevention works, it shows a unique method of determining the length of reinforcing bars by the ratio to the cutting height H. ▪ For specific designs, both road authorities and local consultants use Bentley's PLAXIS 2D/3D as standard. The basic design method is the finite element method instead of the limit equilibrium method.	▪ Post-disaster response is the basic response. In some cases, preventative measures have also been implemented. ▪ The policy is to conduct stability evaluations in all cutting sections. ▪ Note that the use of the finite element method is still controversial

Countries	Description	Remarks
Honduras	▪ The Central American Integration System (SIECA) road manual (SIECA, 2019), which was developed as part of a JICA project, explains the types and characteristics of landslide countermeasures. There is no explanation about a specific design method. It states that the planning factor of safety will be set at 1.1 to 1.2 in consideration of the importance of conservation objects, as in Japan. ▪ The old expressway landslide countermeasures manual (SECOPT, 1988) also describes the types of countermeasures and how to arrange them, but not about the design. ▪ SLIDE2 of Canada's Rocscience is often used for actual design.	▪ Most of the slopes are cut slopes that have not been protected at all. ▪ Response after a disaster is the basis
Bhutan	▪ Since landslide countermeasures are gabions and masonry retaining walls, etc., there is no need for a design policy or design flow for landslide countermeasures. ▪ There is no slope planning factor of safety as no stability analysis is performed.	▪ Response after a disaster is the basis

In Indonesia, the standard value of the planning factor of safety for slope measures is described as a sentence in the text of the national standard (SNI). The contents are shown in Table 5-28.

Table 5-28 Standards of Factor of Safety for Slope Protection Works in Indonesia

（SNI8460:2017 and JasaMarga）

No.	Conditions	Minimum Safety Factor for Landslide (Embankment)	Minimum Safety Factor for Landslide （Cut Area）
1	Short Term (Construction Period)	1.2	1.25～1.3
2	Long Term (Operation Period)	1.4～1.5	1.4～1.5
3	Earthquake Condition (Return Period of 500 Years)	1.1	1.1

Source:

SNI (2017): Persyaratan perancangan geoteknik (Geotechnical design requirements), Standar Nasional Indonesia, SNI 8460:2017

SIECA (2019): Geotechnics and Seismic Considerations Manual

SECOPT (1988): Landslide in the Western Highway， Honduras, Secretaria de comunicaciones, obras publicas y transporte.

5.7.3 Slope Stability Analysis

Table 5-29 shows an overview of slope stability analysis in each country. Western design software is used in countries other than Bhutan. Among them, Indonesia uses design software that supports finite element method stability analysis instead of limit equilibrium method stability analysis. Another characteristic of Indonesia is that it conducts stability evaluations on all cut slopes.

Table 5-29 Overview of Slope Stability Analysis in Each Country

(JICA Study Team)

Countries	Description	Remarks
Sri Lanka	The Design office manual for geotechnical design (NBRO, 2019) contains descriptions of how to select a stability analysis formula and how to set parameters. There is also an explanation about back analysis in it. In practice, we use design software such as Canada's SLOPE/W (Geo-Slope).	Since Japan's ODA has triggered the introduction of landslide countermeasures, Japanese techniques such as back analysis have been adopted.
Nepal	Slide (Rocscience) is used in practice. Adopt forward analysis in which soil parameters are given first. Find the most dangerous slip surface by circular slip trial calculation.	–
Ethiopia	The Geotechnical Design Manual (ERA, 2013) includes explanations about stability analysis, but in practice Western design software such as GeoStru (Italy) and Rocscience (Canada) is used.	–
Philippines	Volume 4; Highway design (DPWH, 2015) describes the use of design software such as SLOPE/W (Geo-Slope) to evaluate the stability of cut slopes.	–
Indonesia	Bentley's PLAXIS 2D/3D, which supports the finite element method, is used as standard for evaluating the stability of cut slopes. The limit equilibrium method is not commonly used.	In principle, all cut slopes are evaluated for stability. Note that the use of the finite element method is still controversial
Honduras	The road manual developed by JICA project (SIECA (2019): Geotechnics and Seismic Considerations Manual) explains Japanese-style stability analysis. In practice, SLIDE2 of Canada's Rocscience is used.	–
Bhutan	Slope stability analysis is not performed.	–

5.7.4 Types of Slope Protection Works

Table 5-30 shows the types of slope protection used in each country. Slope protection works using structures whose main purpose is slope failure countermeasures will be explained in the next section. Masonry retaining walls and gabions are used in all countries. Spray works is used in four out of seven countries. Sri Lanka and Honduras are two countries where concrete crib works are used.

Table 5-30 Types of Slope Protection Works in each Country

(JICA Study Team)

Countries	Description	Remarks
Sri Lanka	Spray works, cast-in-situ concrete crib works (Figure 5-9), spray crib works, retaining wall, gabion	There are spray crib works by Japanese ODA.
Nepal	Concrete retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	
Ethiopia	Stone pitching, gabion retaining walls, stone masonry retaining walls, and others.	There is a precast frame work by a Chinese company.
Philippines	spray works, masonry retaining wall, concrete leaning retaining wall, gravity concrete retaining wall, leaning-type retaining wall	–
Indonesia	Spray works, concrete retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	–
Honduras	Spray crib works, spray works, concrete retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	–
Bhutan	Gabions, masonry retaining walls, etc.	–

Figure 5-9 Cast-in-situ Concrete Crib Works (Excavated Type) in Sri Lanka

(JICA Study Team)

5.7.5 Types of Slope Failure Countermeasure

Table 5-31 shows the types of slope failure countermeasure used in each country. Among them, there are relatively many countries where soil nailing, which is classified as prevention works, is commonly used: Sri Lanka, Philippines, Indonesia, and Honduras. Ground anchor works are used for roadside landslide countermeasures in Sri Lanka and Honduras. All of them were constructed by Japanese ODA.

Table 5-31 Types of Slope Failure Countermeasures in Each Country

(JICA Study Team)

Countries	Types of slope failure countermeasures	Remarks
Sri Lanka	Soil nailing, combination of soil nailing and steel net, spray crib works, ground anchor works, stone masonry retaining wall, gabion retaining wall	Spray crib works and ground anchor works are mainly by Japanese ODA.
Nepal	Concrete retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	Soil nailing is constructed as an earth anchor.
Ethiopia	Gabion retaining wall, stone masonry retaining wall	–
Philippines	Soil nailing combined with wire mesh, stone masonry retaining wall, concrete leaning retaining wall, gravity concrete retaining wall, slope retaining wall	There are many products that imitate GeoBurgg's soil nailing with wire mesh.
Indonesia	Soil nailing, concrete retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	–
Honduras	Anchor works joint shaft pile retaining wall, reinforced soil retaining wall, ground anchor works, soil nailing, spray crib works, concrete	Ground anchor works are mainly by Japanese ODA.

Countries	Types of slope failure countermeasures	Remarks
	retaining wall, stone masonry retaining wall, gabion retaining wall, lattice works	
Bhutan	Gabion, stone masonry retaining wall, etc.	Micronet works was constructed by JICA project. Non-frame works were constructed on a trial basis.

5.7.6 Types of Rock Fall Countermeasure

Table 5-32 shows the rock fall countermeasures used in each country. Regarding rock fall countermeasure, there are many cases in which Japanese companies are involved in construction such as ODA in Japan.

Table 5-32 Types of Rock Fall Countermeasure in Each Country

(JICA Study Team)

Countries	Rock Fall Countermeasure	Remarks
Sri Lanka	There are rock fall countermeasures (roping works, covered rock fall protective net, pocket type rock fall protective net, rock fall barriers) constructed by Japanese companies in World Bank projects and yen loan projects.	Construction by a Japanese company (under a joint venture).
Nepal	Not implemented	A rock fall survey has been conducted, but countermeasures have not been implemented due to lack of funds.
Ethiopia	Not implemented	–
Philippines	Pocket type rock fall protection net (Japanese company)	Construction by a Japanese company.
Indonesia	It seems that rock fall countermeasures such as wire net are being constructed, but it is unconfirmed.	–
Honduras	Rock mesh, curtain net, etc.	–
Bhutan	There are rock fall countermeasures on a few slopes under Indian Army BRO/DANTAK control.	A rock fall protective embankment was implemented under JICA's SME support scheme.

5.7.7 Types of Debris Flow Countermeasure

Table 5-33 shows the types of debris flow countermeasures in each country. In Ethiopia, consolidation using gabions has been confirmed. While causeway overflow has been confirmed in Bhutan and Nepal.

Table 5-33 Types of Debris Flow Countermeasure in Each Country

(JICA Study Team)

Countries	Types of Debris Flow Countermeasure	Remarks
Sri Lanka	unconfirmed	–
Nepal	Let it overflow at the causeway.	–
Ethiopia	Floor consolidation with gabions	–
Philippines	unconfirmed	–
Indonesia	unconfirmed	–
Honduras	unconfirmed	–
Bhutan	Let it overflow at the causeway. Alternatively, bridges and culverts can be used.	Bridges and culverts are being tested by JICA technical cooperation.

5.7.8 Types of Slide (Jisuberi) Countermeasure

Table 5-34 shows the types of countermeasures against slide (Jisuberi) in each country. Achievements in each country are mainly due to Japan's ODA.

Honduras is the only developing country that has implemented its own countermeasures against slide. Figure 5-10 shows a continuous shaft pile retaining wall with ground anchor works that was constructed as a countermeasure against slide in Honduras.

Table 5-34 Types of Landslide Countermeasure in Each Country

(JICA Study Team)

Countries	Types of Slide (Jisuberi) Countermeasure	Remarks
Sri Lanka	There are drainage wells and ground anchor works implemented with Japanese ODA (paid).	Only achievement by Japan's ODA.
Nepal	Anchor works at Landslide countermeasure pilot site	–
Ethiopia	Not implemented outside of Japan's ODA.	Only achievement by Japan's ODA.
Philippines	unconfirmed	–
Indonesia	unconfirmed	–
Honduras	Continuous shaft pile retaining wall with ground anchor works (Figure 5-10). In addition, there are drainage wells, steel pipe pile works, and ground anchor works implemented by Japanese ODA.	Mainly by Japanese ODA.
Bhutan	Not implemented outside of Japan's ODA.	Only achievement by Japan's ODA.

Figure 5-10 Continuous Pile Retaining Wall Combined with Anchor in Honduras

(JICA Study Team)

5.8 Construction of Landslide Countermeasure on Roadside Slope

5.8.1 Construction Method (including Machinery and Temporary Construction, Safety Management)

Table 5-35 shows the construction method of landslide countermeasures in each country.

Table 5-35 Construction of Landslide Countermeasure on Roadside Slope

(JICA Study Team)

Countries	Machinery	Construction Method	Safety Management
Sri Lanka	▪ bulldozer, excavator ▪ Simple percussion boring machine, rotary percussion boring machine, self-propelled boring machine, wet spraying machine	▪ A small excavator is used to shape the slope. A temporary scaffolding is set up with a single pipe, and holes for soil nailing are drilled with a simple percussion boring machine (Figure 5-13). ▪ Drilling and inserting work using heavy machinery and suspended scaffolding (Figure 5-14).	▪ There are no supervisors on site, and work is carried out by workers only.
Nepal	▪ Bulldozer, excavator	▪ Slope shaping and cutting with heavy machinery ▪ There is no landslide countermeasure such as using temporary scaffolding.	–
Ethiopia	▪ Bulldozer, excavator	▪ Slope shaping and cutting with heavy machinery ▪ There is no landslide countermeasure such as using temporary scaffolding.	▪ Management by consultant

Countries	Machinery	Construction Method	Safety Management
Philippines	▪ Bulldozer, excavator ▪ Simple percussion boring machine, wet spraying machine	▪ Rope work is carried out without using temporary scaffolding. ▪ Supporting the boring machine with a rope and working at height. (Figure 5-11)	▪ Ropes and harnesses are used for removing boulders on slopes and placing wire mesh. ▪ In construction of soil nailing, ropes are used to support the machine. On the other hand, workers did not use safety equipment. ▪ There are no supervisors on site, and only workers work.
Indonesia	▪ Bulldozer, excavator ▪ Construction machine for soil nailing is unconfirmed ▪ spray works use wet spray machine	▪ Slope shaping and cutting with heavy machinery (light embankment works, spray works). ▪ Construction methods for spraying and soil nailing have not been confirmed, except for earthworks.	▪ Management by consultant
Honduras	▪ Bulldozers, excavators, wet spray machines	▪ Slope shaping and cutting with heavy machinery (Figure 5-12)	▪ Management by consultant
Bhutan	▪ Bulldozer, excavator	▪ Slope shaping and cutting with heavy machinery ▪ There is no landslide countermeasure such as using temporary scaffolding.	–

Figure 5-11 Drilling/Inserting Soil Nailing (left) and Removing Boulders before Placing Wire Mesh (right) in Philippines

(JICA Study Team)

Figure 5-12 Road Widening in Philippines (left) and Spraying Work in Honduras (right)

(JICA Study Team)

Figure 5-13 Drilling Work with Self-Propelled Boring Machine (left) and Drilling/Insertion of Soil Nailing with Single Pipe Scaffold (right) in Sri Lanka

(Left: Prepared by JICA Study Team, Right: Soiltech Brochure)

Figure 5-14 Two Types of Platform with Heavy Machinery in Sri Lanka

(Soiltech Brochure)

5.8.2 Types of Construction Contracts

Table 5-36 shows the types of construction contracts for landslide countermeasures in each country.

Table 5-36 Contract Type for Landslide Countermeasures in Each Country

(JICA Study Team)

Countries	Contract Type	Remarks
Sri Lanka	A unit price contract (BOQ or item rate) is generally used.	Design-build (DB) contracts and lump-sum contracts are also beginning to be tried.
Nepal	Mainly BOQ	DB is adopted for bridges, and Engineering, procurement, and construction contract (EPC) is adopted for Fast Track projects.
Ethiopia	Generally BOQ。	In recent years, DB has also been introduced.
Philippines	BOQ	–
Indonesia	BOQ	DB is also used on toll roads
Honduras	Unconfirmed	–
Bhutan	BOQ	DB is sometimes used in bridges

5.8.3 Prediction of Landside Disaster on Roadside Slope

Table 5-37 shows methods for predicting slope disasters in road development in each country.

Table 5-37 Prediction of Landside Disaster on Roadside Slope in Each Country

(JICA Study Team)

Country	Prediction method	Remarks
Sri Lanka	At the time of project implementation, a detailed topographic map of the target area is created using drones. In the cutting section, boring is carried out every 200 to 300m in the longitudinal direction of the road.	Geophysical exploration and laboratory tests are done to supplement information.
Nepal	Basically, follow-up measures after a slope disaster occurs	–
Ethiopia	Interpretation of aerial photographs or satellite images using a stereoscope The number of survey borings in the cutting section is small, and the data necessary for forecasting is scarce.	In order to reduce construction costs, slope disasters frequently occur due to cutting with a steeper gradient than the cut slope gradient at the time of design.
Philippines	In recent years, widening is the mainstream in mountainous areas. However, it is basic to implement some kind of measures such as stone masonry retaining wall for the cut slope surface when widening.	On existing roads, basic measures are taken before slope disasters occur.
Indonesia	Utilizing micro-topographic maps using LiDAR	
Honduras	The same preliminary survey as in Japan is described in the manual developed by JICA, but in reality, post-disaster response after the occurrence of a slope disaster is the mainstream.	Landslide distribution maps developed through Japanese technical cooperation are used by the Permanent Committee for Emergency Response (COPECO), but not by agencies involved in road development.
Bhutan	Almost not implemented	Frequent slope disasters due to road development.

5.9 Maintenance of Roadside Slope

5.9.1 Roadside Slope Inspection and Disaster History Management

Table 5-38 shows the contents of roadside slope inspection and disaster records in each country.

Table 5-38 Roadside Slope Inspection and Disaster Records in Each Country

(JICA Study Team)

Countries	Slope Inspection	Disaster Records
Sri Lanka	Slope conditions are managed in daily road management.	It is left to the local offices of the RDA. Currently, history management other than the damaged areas is almost not implemented. Damaged slopes will be dealt with after considering the order of priority
Nepal	Regular inspections and emergency inspections are carried out. Inspections and damage are recorded in the slope ledger	The damage situation of the road slope is recorded by the DoR regional office, together with the restoration cost and the amount of damage.
Ethiopia	A JICA project prepared a slope inspection manual, etc., but it has not been implemented since the end of the project. Since there is no concept of pre-disaster measures, there is no point in implementing slope inspection results.	Damage history management for road slopes has not been implemented.
Philippines	Conducted during regular road inspections.	Damage history management for road slopes has not been implemented.
Indonesia	Conducted during regular road inspections.	Damage history management for road slopes has not been implemented.
Honduras	Not implemented	Damage history management for road slopes has not been implemented.
Bhutan	As a result of the JICA project, the maintenance of the slope ledger is progressing, and the slope inspection is becoming established.	In order to obtain subsidies for repairs, DoR regional offices keep track of road slope damage.

5.9.2 Rainfall observation and maintenance of slope protection works

Table 5-39 shows the details of rainfall observation and maintenance of slope protection works in each country.

Table 5-39 Rainfall Observation and Maintenance for Slope Protection in Each Country

(JICA Study Team)

Countries	Rainfall observation	Maintenance for Slope Protection
Sri Lanka	Partial rainfall monitoring was carried out at the roadside landslide area developed by the World Bank project (Figure 5-15).	Weeding and removal of sediment from rock fall protection nets are carried out as part of normal road management.
Nepal	Using data from the Department of Hydrology and Meteorology	Grass cutting and drain cleaning are carried out as part of normal road management.
Ethiopia	Not implemented.	Respond to road damage such as collapses.
Philippines	Not implemented.	Damaged landslide countermeasures (pocket type rock fall protection netting) are in a state of being left unattended, and maintenance is almost non-existent.
Indonesia	Not implemented.	In the case of the degree of damage to spray works, it is prioritized and handled in the same way as other slope failures.
Honduras	Not implemented.	It is not done with the damage of the head of anchor works.
Bhutan	Conducted in 2-3 landslide-prone areas.	Grass cutting and drain cleaning are carried out as part of normal road management.

Figure 5-15 Rainfall Observation Instruments at Landslide Site in Sri Lanka

(JICA Study Team)