DATA COLLECTION SURVEY
ON
ROAD FRAGILITY
IN
TIMOR-LESTE

FINAL REPORT

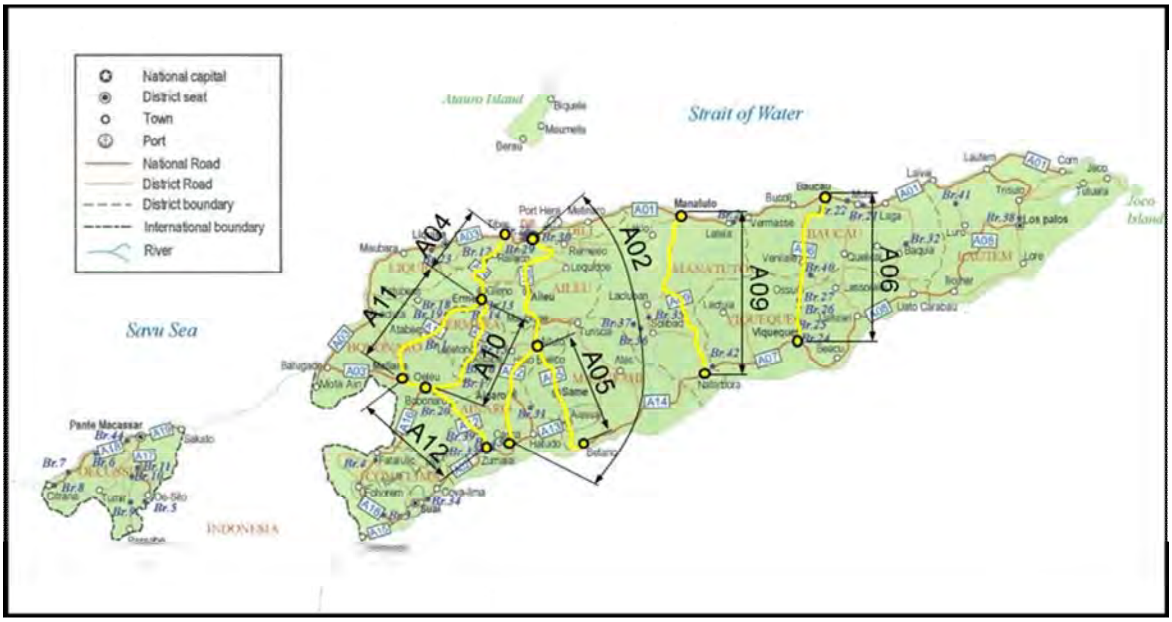
AUGUST 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

INGEROSEC CORPORATION

Map of Timor-Leste

（Source：JICA Preparatory Survey on Road Network Development Sector Project in the Democratic Republic of Timor-Leste）



Location Map of Survey

Data Collection Survey on Road Fragility in Timor-Leste
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Abbreviations

ADB	Asian Development Bank
AASHTO	American Association of State Highway and Transportation Officials
CBR	California Bearing Ratio
IRI	International Roughness Index
JICA	Japan International Cooperation Agency
ODA	Official Development Assistance
SDP	Strategic Development Plan
TP	Test Pit

Workshop Document

The workshop was held on 17th June 2013 and the Workshop Document, the summary of main report, is shown on the following page.

Workshop Document

DATA COLLECTION SURVEY
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IN
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DRAFT FINAL REPORT

June, 2013

JAPAN INTERNATIONAL COOPERATION AGENCY
INGÉROSEC CORPORATION

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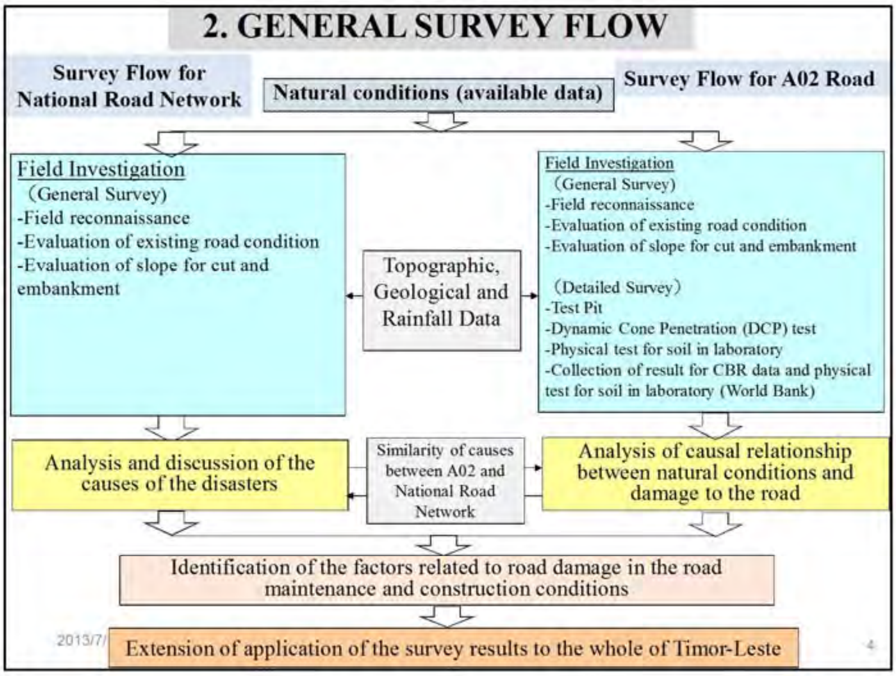
1. OBJECTIVES OF THE SURVEY

- Analyzing the technical aspects of ***road and pavement damages*** by natural disaster with an understanding of the ***geological, topographical and meteorological conditions*** in Timor-Leste

-To identify ***the neccessary items*** to be investigated;
for the selection of a ***maintenance method of existing roads***,
for the planning of ***future road development*** and for the ***construction and repair of roads***,

3



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3. RESULT OF SITE SURVEY

3.1 Road Section for Site Survey

	Road Section	Date of Survey
1	A02	22 March - 23 March 2013 26 March - 29 March 2013 4 April 2013
2	A05	5 April - 6 April 2013, 27 April 2013
3	A06	10 April 2013
4	A09	11 April - 12 April 2013
5	A04	17April 2013
6	A11	17April 2013
7	A12	18April 2013
8	A10	19April 2013

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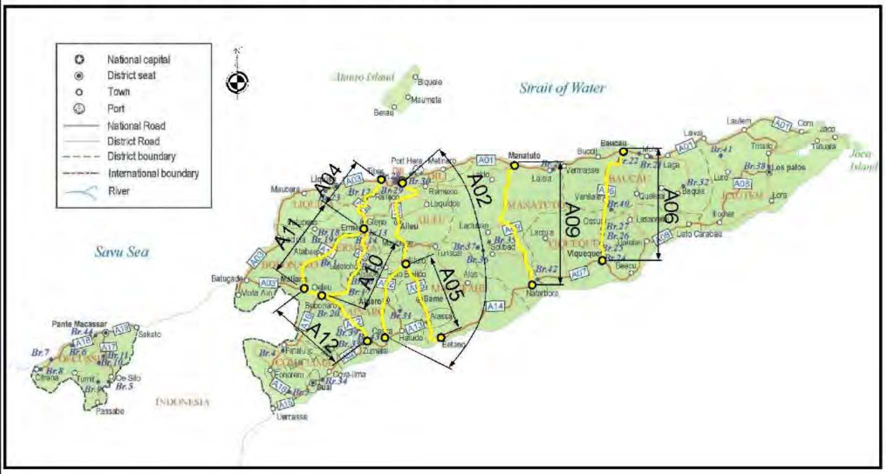
3.2 Location of Site Survey Section



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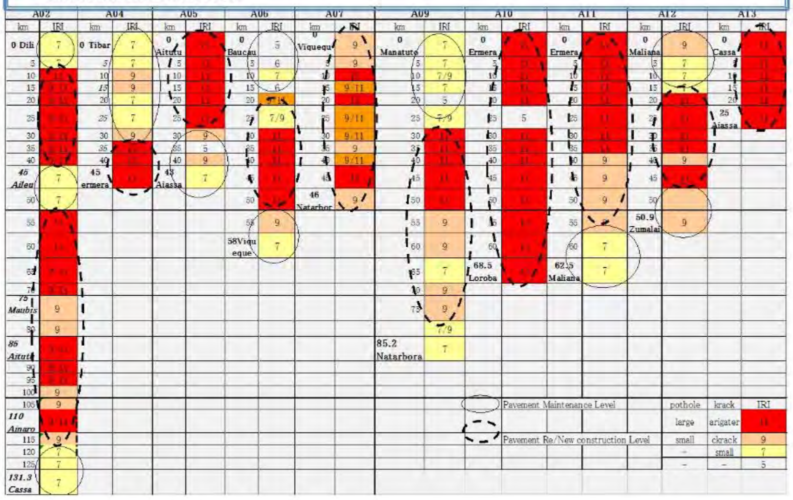
3.3 Road Pavement Condition

1. Only 3 sections at Dili, Ailue and Cassa are stable, others required reconstruction on A02.
2. Other North-South Roads are deteriorated to the level of reconstruction at Mountainous sections



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Road Pavement Condition

IRI (grade 7 to 11) with Pictures

IRI 7

IRI 9

IRI 11

IRI 11

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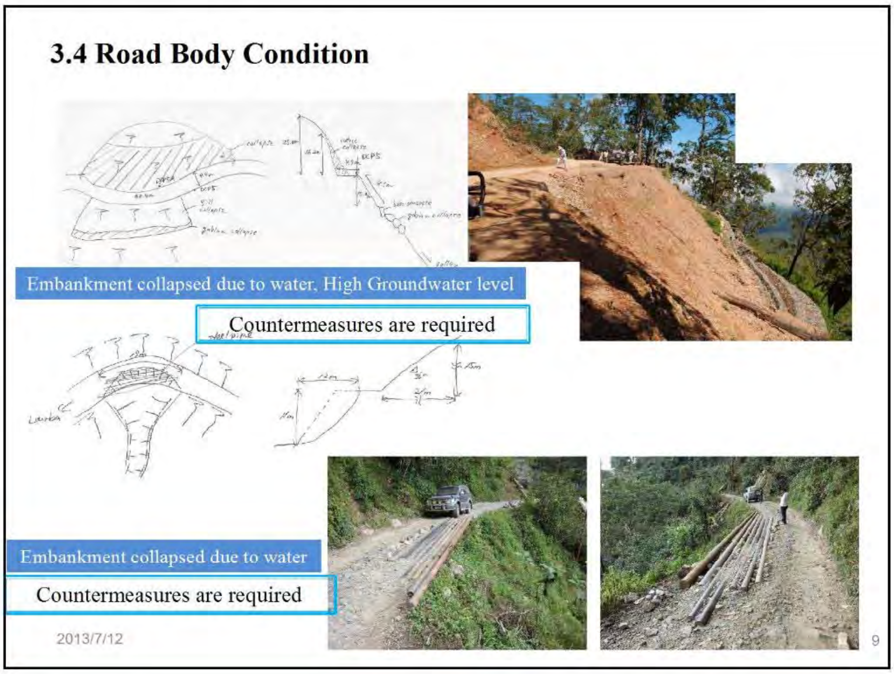
3.4 Road Body Condition
Embankment collapsed due to water, High Groundwater level
Countermeasures are required
Embankment collapsed due to water
Countermeasures are required
2013/7/12
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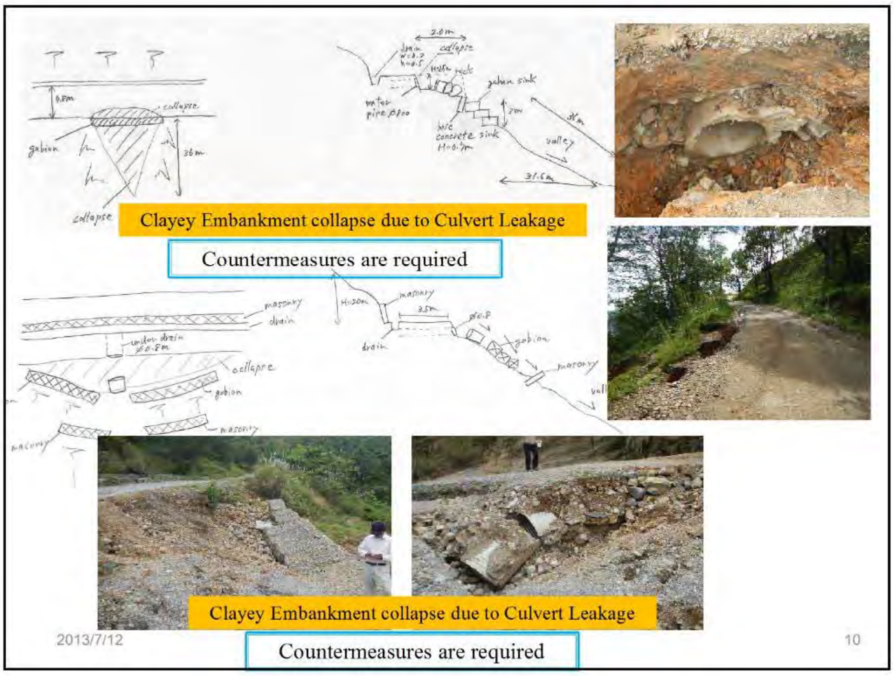
Clayey Embankment collapse due to Culvert Leakage
Countermeasures are required
Clayey Embankment collapse due to Culvert Leakage
Countermeasures are required
2013/7/12
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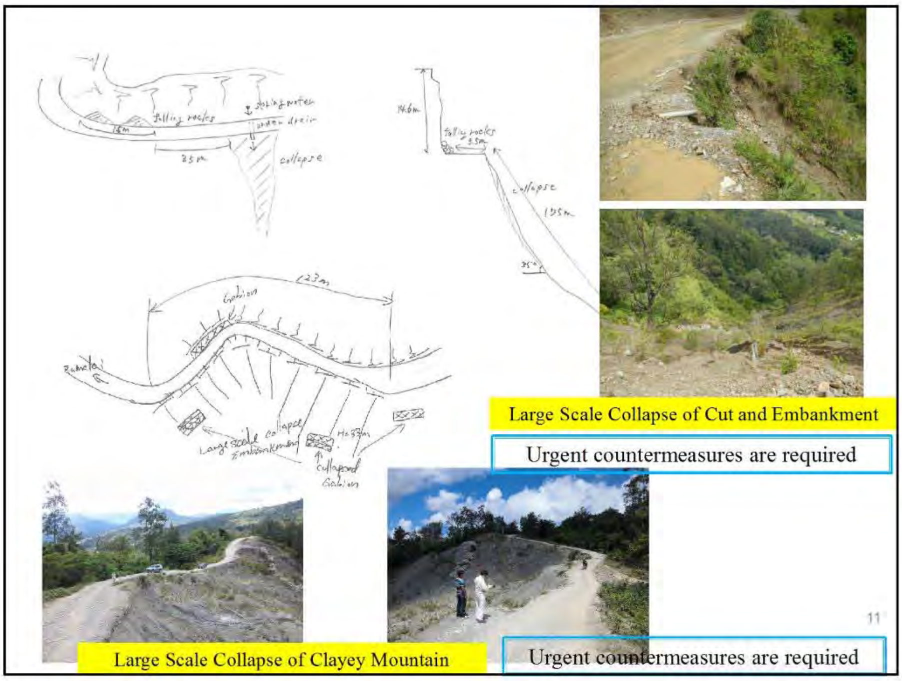

Road Body Condition

A2		A4		A5		A6		A9		A10		A11		A12	
Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point	Km	Stabiliy Point
Dili		Tibar		Aitutu	70	Baucau		Manatuto		Ermera		Ermera	70	Maliana	
5		5		5	70	5		5	80	5		5	81	5	75
10		10	73	10	[illegible]	10		10	72	10		10		10	75
15	46	15		15	[illegible]	15	63	15	70	15		15		15	[illegible]
20	48	20		20	70	20	72	20		20		20		20	[illegible]
25	70	25	[illegible]	25	70	25		25		25		25	70	25	[illegible]
30	70	30		30	70	30		30	75	30	70	30		30	70
35	75	35		35		35		35		35	[illegible]	35		35	[illegible]
40	67	40		40		40		40		40		40		40	
45		45		45		45		45		45	[illegible]	45		45	
50		Ermera		Aiassa		50		50		50	75	50		50	
55	47					Viqueque		55		55		55		55	
60	69							60		60	70	60		Zumarai	
65	38							65		65		65			
70	26							70	78	70		Maliana			
75								75		Loroba					
80	61							Natarbora							
85	62														
90	42														
95	45														
100	66														
105															
110	[illegible]														
115	89														
120															
125	79														
130															
Cassa															

Legend
- 100-90 : Emergency Mesures are required
- > 50 : Countermeasures are required
- < 50 : No countermeasures are required

1. Requiring over the whole mountainous section to take countermeasures for A02, A05, A12
2. Not requiring whole section comparatively to take countermeasures for A06, A11
3. Although countermeasures are not required for road body, but road pavement are deteriorated

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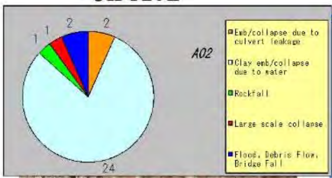
4. ANALYSIS OF SITE SURVEY

4.1 Heavy Pavement Deterioration due to Severe Road Damages on A02



1. Heavy Pavement Deterioration occurred due to Severe Road Damages by Natural Disaster.
2. Most Frequent Road Damages occurred by a collapse of Clay road-body penetrated water.
3. 2nd frequent Damages occurred by Leakage of water from joint of Cross Culvert which is installed near road surface without any concrete protection.
4. 3rd Damages by Flood and Debris Flow.

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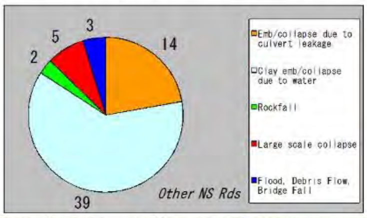
4.2 Heavy Pavement Deterioration due to Severe Damages by natural disaster on the Other North-South N.Rs



1. Sequence of Damages on other roads are almost same as on A02.
2. Proportion of Embankment Collapse by Culvert Leakage become ¼.
3. Large Scale Collapse becomes not negligible proportion.

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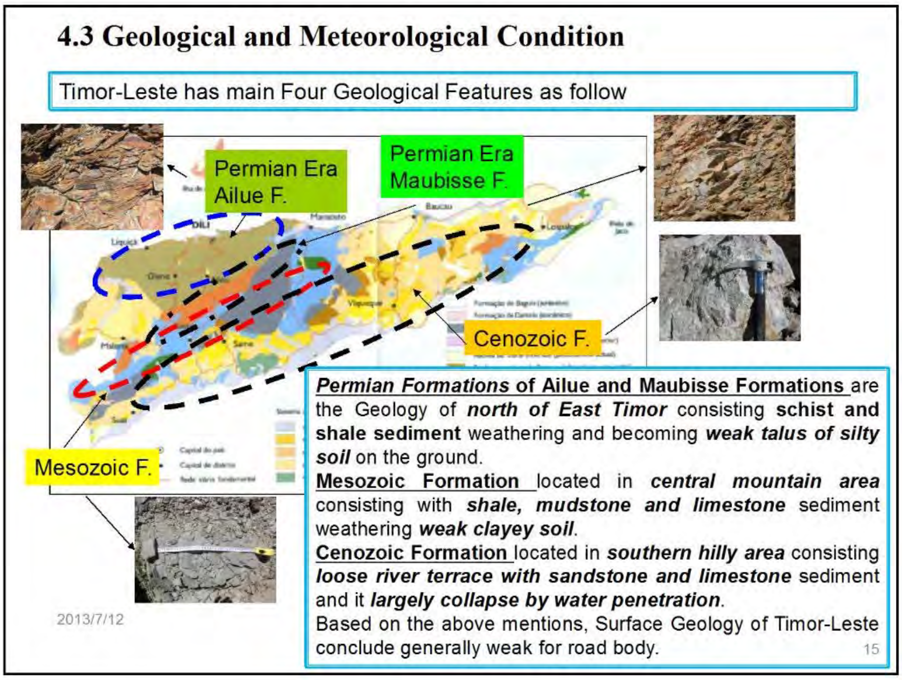
4.3 Geological and Meteorological Condition
Timor-Leste has main Four Geological Features as follow
Permian Era Ailue F.
Permian Era Maubisse F.
Cenozoic F.
Mesozoic F.
Permian Formations of Ailue and Maubisse Formations are the Geology of north of East Timor consisting schist and shale sediment weathering and becoming weak talus of silty soil on the ground.
Mesozoic Formation located in central mountain area consisting with shale, mudstone and limestone sediment weathering weak clayey soil.
Cenozoic Formation located in southern hilly area consisting loose river terrace with sandstone and limestone sediment and it largely collapse by water penetration.
Based on the above mentions, Surface Geology of Timor-Leste conclude generally weak for road body.
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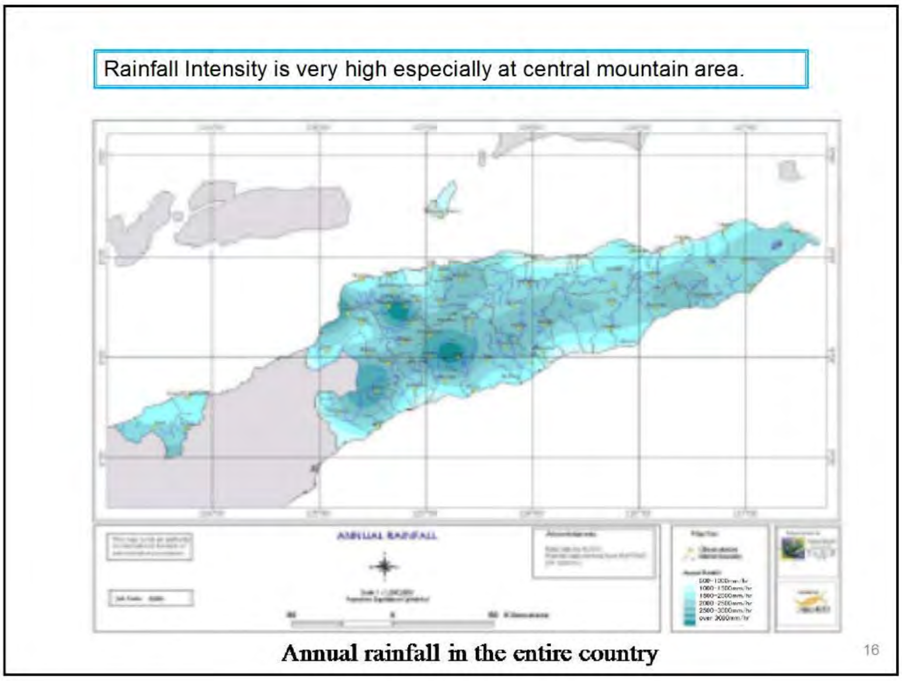
Rainfall Intensity is very high especially at central mountain area.
Annual rainfall in the entire country
16

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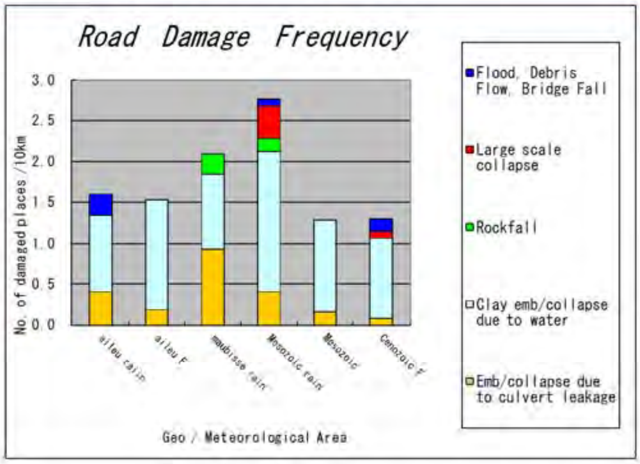
4.4 Road Damage Frequency by Type and Zone

1. Most Frequent Road Damages with variety types occurred at Mesozoic Foundation at Central Mountains with high rainfall.
2. On other geological sections, almost same frequency of road damages occurred if the embankment collapse by Culvert Leakage was settled.



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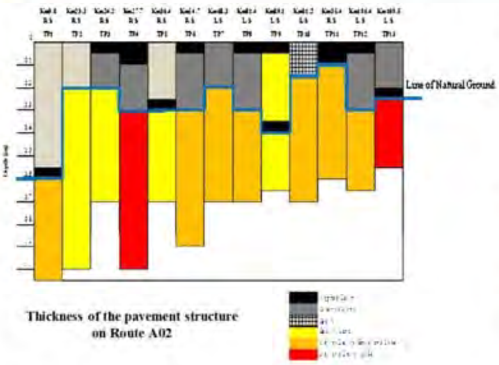
4.5 Pavement Damage due to Pavement Structure

1. Pavement deteriorated at <u>weak Silty and Clayey subgrade</u> sections.
2. Pavement deteriorated where <u>no Base Course constructed</u>.
3. Pavement deteriorated at high underground water even on Gravel and Sand Subgrade.



Thickness of the pavement structure on Route A02

Location	Rainfall (mm/year)	Spring water	Topography	Condition
16+200	<2000		Ridge	Stable
66+900	>2000		Sag	Stable
9+000	1000		Valley/Sag	Collapsed
23+300	>2000		Valley	Collapsed
23+500	>2000		Valley	Collapsed
24+200	>2000		Valley	Collapsed
27+700	>2000		Valley	Collapsed
27+800	>2000		Valley/Sag	Collapsed
54+700	<2000		Valley/Sag	Settlement
73+900	>2000	○	Valley/Sag	Collapsed
77+700	>2000	○	Valley	Collapsed
81+400	>2500		Valley/Sag	Settlement
83+100	>2500		Valley	Collapsed
85+800	>2500		Valley	Collapsed
89+100	>2500	○	Valley	Collapsed
91+200	>2500	○	Valley	Settlement
95+300	>2500	○	Valley	Washed away
103+600	>2500	○	Valley	Collapsed
106+400	<2000		Valley/Sag	Collapsed
114+500	<2000			Collapsed

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5. RELEVANT POINTS

5.1 Relevant Points for Re and New Construction

		Existing Damage	Re and New Construction
damage 1		***Clay embankment collapse due to water infiltration***	***New construction of embankment with adequate protection***
	main cause	High level of underground water	Installation of ***blind and horizontal drainage on slope*** **(Photo 3)**
	sub cause 1	Infiltration of surface water	Installation of ***vertical and berm drainage*** on slope **(Photo 4)**
	sub cause 2	Sagging and changing point of vertical gradient	Protection of culvert joints by concrete
	sub cause 3	Existence of clay embankment soil	Improvement of embankment material
	sub cause 4	No proper specifications for soil classification	Establishment of specifications for soil classification and testing method
damage 2		***Emb/collapse due to culvert leakage***	***Construction of new culvert with enough depth***
	main cause	Not enough depth of culvert cover	
	sub cause 1	No concrete fixing of culvert joints	Protection of culvert joints by concrete
	sub cause 2	No proper specifications for soil classification	Establishment of culvert specifications

Damage 1:
(a) Installation of Blind and Horizontal Drainage on slope for the main causes damage of High level of Underground Water (see photo 3),
(b) Installation of Vertical and Berm Drainage on slope for 1st sub cause of damage of Infiltration of surface water (see photo 4),
Damage 2:
(a) Construction new Culvert with enough depth for the main cause damage of not enough depth of culvert cover,
(b) Protection of Culvert Joint by Concrete for 1st sub cause of damage of No concrete fixing of culvert joint,
(c) Establishment of culvert specification for No existence of proper specification.

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		Existing Damage	Re and New Construction
damage 3		***Flood, debris flow, bridge fall***	***Construction of large capacity facilities***
	main cause	Low discharge capacity	Bridge recommendable rather than culvert
	sub cause 1	Blocking by rocks/ no maintenance	Removal of rocks
	sub cause 2	Weak filling material	Selection of better filling material
damage 4		***Large scale collapse***	***New construction of sifting or bypassing embankment with adequate protection***
	main cause	Weak slope material	
	sub cause 1	High underground water level	Installation of ***blind and horizontal drainage*** **(Photo 3)**
	sub cause 2	Existence of clay embankment material	Introduction of ***grating crib*** **(Photo 1)** ***and shotcrete*** **(Photo 2)**
	sub cause 3	Failure of proper drainage	***Vertical and berm drainage*** on slope **(Photo 4)**
damage 5		***Rockfall***	***Cutting of dangerous rock***
	main cause	Aging/weathering of rock	***Shotcrete, rock net and gabion wall***

Damage 3:
(a) Construction of large capacity Bridge for the main cause of damage of Low discharge capacity,
Damage 4:
generally new construction of sifting or bypassing road with adequate protection. But in case difficult of sifting and bypassing, following counter measures could be considered:
(a) Installation of Blind and Horizontal Drainage for high underground water level (see photo 3),
(b) Installation of Grating Crib for existence of clay embankment material (see photo 1),
(c) Installation of Vertical and Berm Drainage on slope for Failure of proper drainage on slope (see photo 4).
Damage 5:
(a) basically recommend the cutting of dangerous rock and consider the following measure as Schotcrete, Rock net and gabion wall (see photo 2).

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5.2 Relevant Points for Maintenance

Clay embankment collapse due to water infiltration is rather **steep Slope Cutting**
- Installation of ***Gabion Wall*** for protection and ***Drainage for both surface water on road and slope*** and cross culvert.

Embankment Collapse due to Culvert Leakage
- ***Emergency Repair*** of Existing Damaged Culvert by ***Concrete Protection of culvert and joint.***

Debris Flow
- Construction ***temporary detour road and temporary bridge.***

Large Scale Collapse
- Construction ***temporary detour road*** basically

Rockfall
- ***Cutting Dangerous Rocks*** and Installation of ***Gabion Wall for Rock Pocket.***

Deteriorated Pavement Maintenance on weak clay subgrade
- ***Adding of Base Course*** and Pavement or construction of ***Blind Drainage under Roadside Drainage*** with pavement depend on cost effectiveness.

Deteriorated Pavement Maintenance on No Base Course
- ***Adding of Base Course*** with Pavement.

Deteriorated Pavement maintenance where underground water level being high
- Installation of ***Blind Drainage under Roadside Drainage*** with pavement.

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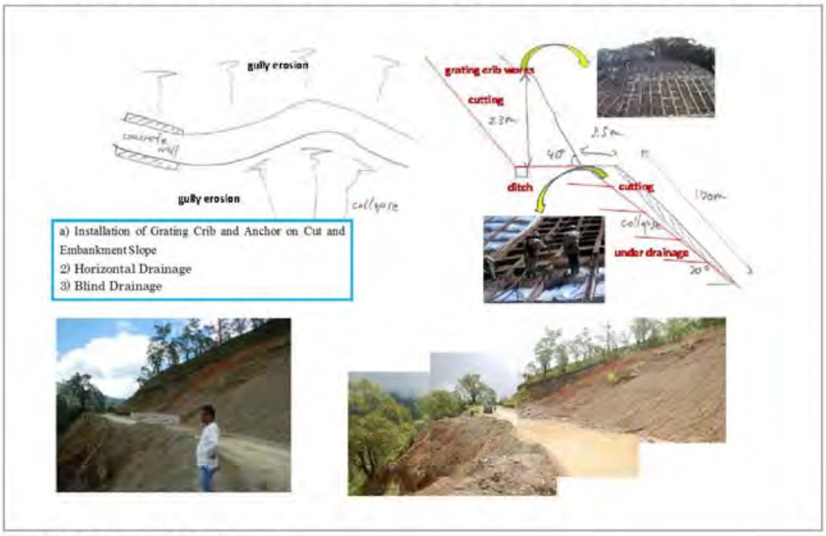
6. Proposed Technology for Large Scale Collapse for A05



A05 Road 5.1km

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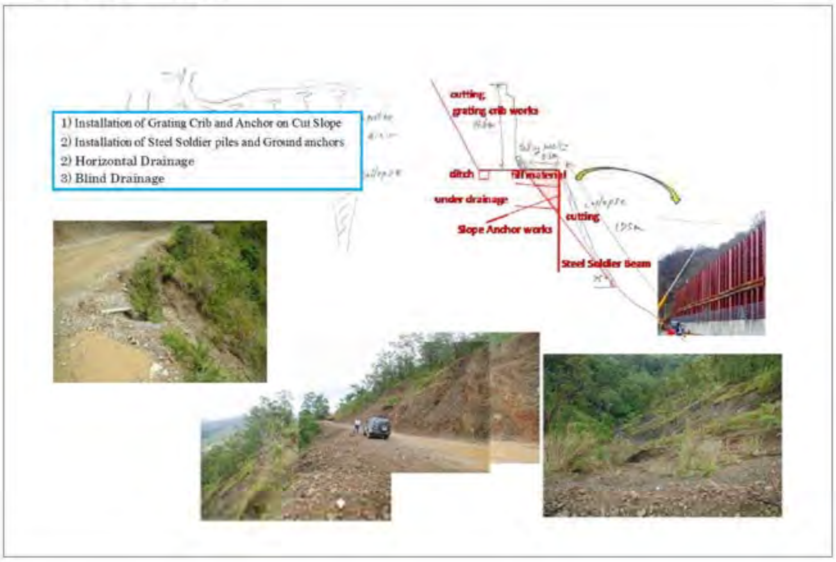
A05 Road 6.3km



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7. RECOMMENDATION

Feasibility Study of Road Fragility on National Road Network in Timor-Leste

- ***Identify road fragility on entire National Road*** (Network from A01 to A19 including Oecussi Region)
- ***Analize causes of slope collapse and pavement deterioration***.
- Identify and Formulate ***Priolity Project*** for ***Road Improvement and Maintenance***.
- ***Socio-economic Evaluation*** of the Project
- ***Implementation Program*** for the high priority Project for ***Road Improvement and Maintenance.***

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Chapter 1 Outline of the Survey

1. 1 Background of the survey

In July 2011, the Government of the Democratic Republic of Timor-Leste announced the "Strategic Development Plan (2011-2030)" (hereinafter referred to as the SDP). The government concentrated on promoting the development of the economic infrastructures as future priority sectors, and the part of the governmental budget allocated as "Infrastructure Funds" is to emphasize the special investment in the road and bridge sector.

Due to the urgency and necessity for development of the road sector, a master plan (10 year plan) was developed in 2009, ahead of the other sectors. Road development projects have been implemented by major donors such as JICA and the Asian Development Bank (ADB), including the "National Road No. 1 Upgrading Project," implemented in March 2012, which was the first loan financed for Timor-Leste. The ADB also financed a loan for a road sector project in May 2013, and the World Bank is working on preparations for a loan project in this sector. It is assumed that investment in the road sector by the Government of Timor-Leste and donors will be continuously provided in the future.

On the other hand, Timor-Leste is afflicted by floods that occur almost every year in the rainy season and cause substantial damage to the infrastructure. More specifically, the problems are; cracks and damage to the road surface, road shoulder damage and narrowing of the roads caused by the collapse of roadside slopes, affecting the safety of some road sections.

In past surveys and analyses, it was pointed out that locations under harsh natural, topographical and geographical conditions are liable to suffer the impact of flooding and it is necessary to design appropriate drainage as countermeasures for each section, and that the bearing capacity of the subgrade varies from one section to another. Under these circumstances, the maintenance method for the existing roads in Timor-Leste needs improvement and many other factors should be undertaken from the road construction planning stage to repair work in the future. It is necessary to evaluate and review future countermeasures for road network development by analyzing the technical aspects of construction and maintenance, with key consideration given to the natural and other conditions of Timor-Leste.

1.2 Objectives of the survey

The objectives of the survey are described below:

(1) To analyze the technical aspects of road and pavement damage due to natural disaster with an understanding of the geological, topographical and meteorological conditions in Timor-Leste, and,

(2) To identify the necessary items to be investigated

- for the selection of a maintenance method for existing roads, and
- for the planning of future road development and for road (re-) construction.

1.3 Basic policy of the survey

The survey will cover the national roads nationwide in Timor-Leste, including Routes A02, A04, A05, A06, A09, A10, A11 and A12, which run from north to south and are vulnerable from the perspective of road catastrophes. A general survey was conducted to grasp the situation of the affected areas in the country as shown in the figure below. Before expansion of the general survey of national roads nationwide, Route A02 was selected as the sample route for a general and detailed survey to grasp the characteristics especially concerning the durability of the road surface, and to analyze the causes of natural disasters for the roads, because Route A02, which crosses the island of Timor-Leste in the north-south direction, runs through areas with typical geological and topographic features, including 1) sections in the south with fragile, unstable ground, 2) sections with highly weathered ground, 3) sections susceptible to landslides, as well as plains, hills and high mountains, and 4) high precipitation of more than 2,000mm. Based on analysis of the general and detailed survey of Route A02, a general survey was carried out of other national roads. The points to be noted in designing the maintenance method for existing roads and planning construction and repair of the road network are identified as per the objectives of the survey. The following figure shows the examination flow.

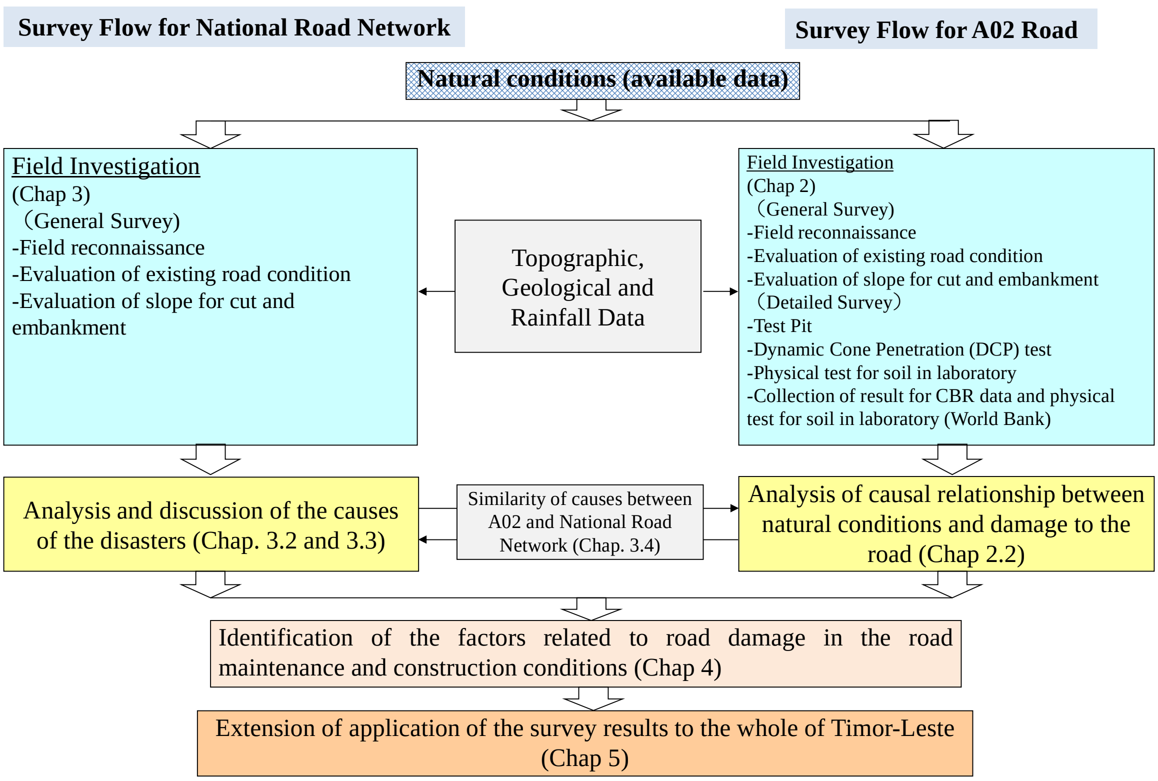


Figure 1.1 Survey Flow for Nationwide Roads and for A02 Road

(1) A02 Road Network Survey

Route A02 (between Dili and Cassa) which crosses the island of Timor-Leste in a north-south direction runs through areas with geological and topographic features typical of Timor-Leste, including a section in the south with fragile and unstable ground, sections with highly weathered ground and sections susceptible to landslides, as well as plains, hills and mountains. Natural conditions, such as rainfall, temperature, stratigraphic and geological characteristics, (which vary along the route that runs through areas with all the topographic and geological conditions existing in Timor-Leste), have a significant impact on the condition of Route A02.

In the work in Japan in March 2013, the Survey Team divided Route A02 into four sections in accordance with such characteristics as topography and rainfall (Section 1: hilly area with old stratum, Section 2: highly-weathered highland, Section 3: unstable mountains with fallen rocks and landslides, and Section 4: hilly area with fragile and very unstable ground) and identified the issues to be studied in each section. The survey team marked the characteristics, major structures, and locations prone to natural disasters on the available satellite images of the area concerned and developed a detailed schedule for the field survey.

The survey team carried out a test pit, Dynamic Cone Penetration (DCP) test, observation of the existing road conditions, and observation slopes for cut and embankment along Route A02 based on the preparation work in Japan. The Survey Team also carried out physical testing of the soil in the laboratory, collecting the existing results of California Bearing Ratio (CBR) and physical soil data. Then, the Survey Team carried out evaluation of the collected data to identify the causes of embankment and pavement damage.

(2) Nationwide Road Network Survey

The nationwide road network survey conducted before the sample route survey in the field work identified the causes of disasters along routes selected for the likelihood of occurrence of natural road disasters. The survey was conducted using the data available, including satellite imagery, topographic and geological data, temperature data and rainfall records of natural road disasters in the past. The results of the survey were utilized for confirmation of the existence of the risk of disasters during the field work. The survey team held discussions with the counterpart organization of the Government of Timor-Leste on the selection of sample routes and carried out the nationwide investigation survey of mainly, among others, national roads crossing the island in the north-south direction where an exceptionally large number of natural road disasters have occurred.

The survey team carried out observation of existing road conditions and slopes for cut and embankment through selected routes. The survey team conducted an evaluation to obtain data and identify the causes of damage to the embankment.

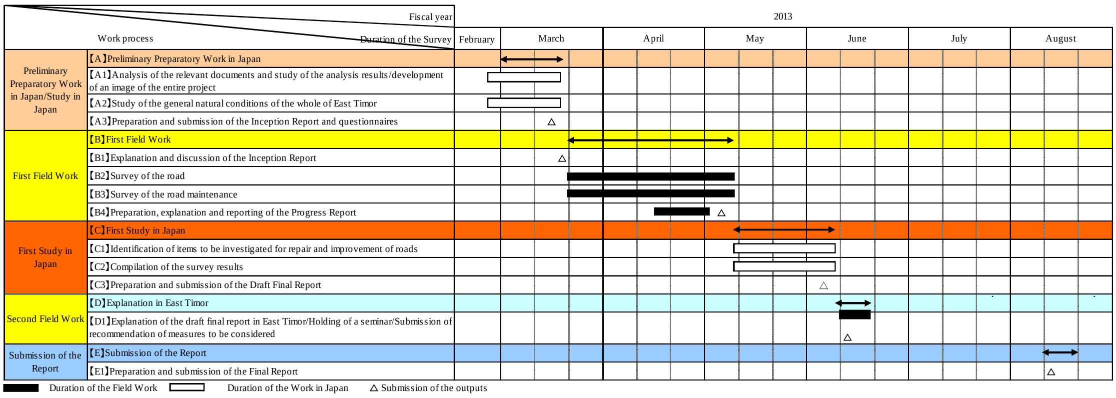
(3) Items and points to be considered

The survey team identified the items and points to be considered for road development planning, construction and maintenance from the results of the nationwide road network survey and the sample road survey, taking into consideration the geological, topographic and meteorological conditions of the entire region of Timor-Leste. The results of the surveys are shown in Chapters 2 and 3.

1.4 Work Flow

The work flow for the project period is shown in Table 1.1 below.

Table 1.1 Work Flow



1.5 Members of the Survey Team

The members of study team are shown in the table below.

Table 1.2 Members of the Survey Team

No.	Name	Job title	Occupation
1	Hisashi Muto	Team Leader/Surface Geology	INGÉROSEC Corporation
2	Hiroshi Kokubu	Soil/Slope, Ground	DAISHO Corporation
3	Nobuharu Shimizu	Road Pavement	INGÉROSEC Corporation
4	Shutaro Sakanaka	Soil/Slope, Ground II	INGÉROSEC Corporation

Chapter 2 Survey of National Road Route A02

2.1 Survey of Natural Conditions

National Road Route A02 is an important trunk road between the capital, Dili, and the center of agricultural development in the south of the country, Suai. Slope failure occurs frequently on the road especially in the central mountainous region because of the steep terrain, fragile ground and frequent heavy rainfall in the rainy season. This survey was conducted of the approx. 130 km-long section of the route between Dili and Cassa. The natural conditions along this section are described below.

2.1.1 Climate and Meteorological Conditions

Timor-Leste is located in the tropical region; there is little seasonal change of temperature and the average temperature in each place depends on the altitude. The average annual temperature in coastal areas is within the range of 25ºC to 27ºC, and in Aileu, which has an altitude of approximately 1,000 meters, the temperature is below 21ºC.

Timor-Leste has distinctive rainy and dry seasons. The capital Dili, has a five (5)-month long rainy season between December and April and the annual rainfall precipitation is between 1,000 mm and 1,500 mm. Meanwhile, Cassa in the south has a seven (7)-month long rainy season between December and June, with higher annual rainfall precipitation of between 1,500 mm and 2,000 mm.

The higher precipitation was observed in the mountains. There are some locations on Route A02, including Ainaro, where the average annual rainfall precipitation exceeds 2,500 mm.

Extraordinarily heavy rain occurred in the month of June 2010 in the central western region, causing serious damage to the roads in the mountains.

The figure below shows the average annual precipitation in Timor-Leste.

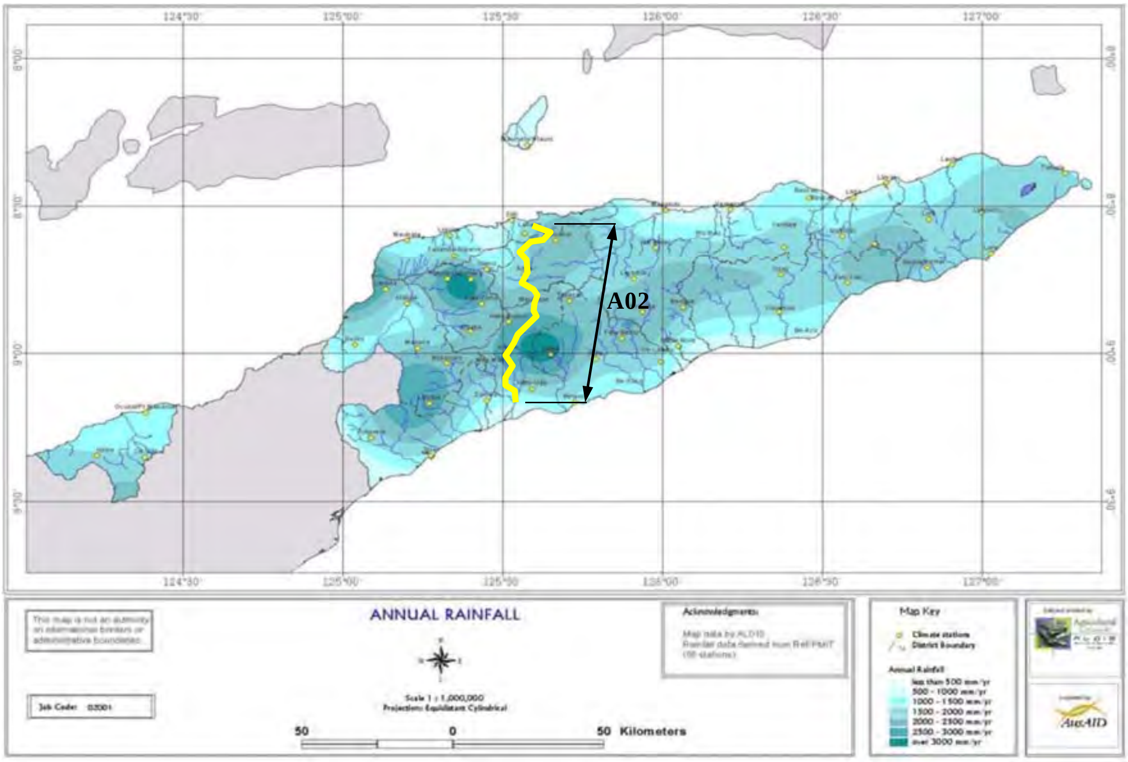


Figure 2.1 Annual precipitation in Timor-Leste (source: JICA report)

2.1.2 Topography

At first, an approximately 2-kilometer section of Route A02 runs from the capital Dili, where the urban area is situated, through the coastal lowlands. The following 20 km-section runs through mountainous steep terrain until the road enters a hilly area in the mountains with an altitude of approximately 1,250 meters. The road runs through the hilly area for approximately 15 km and goes down to the basin where Aileu is located. It runs through the basin for several kilometers then through gentle hilly terrain for approximately 10 kilometers. After reaching an altitude of approximately 1,600 meters, the road starts to go down and enters the town of Maubisse in the Central Basin with an altitude of approximately 1,450 meters.

The road goes down for a further 3 kilometers and then it starts again on an upward route. After going through a generally gentle upland area with some short steep uphill slopes, the road approaches the highest point on Route A02 (1,891 meters above sea level). From this point (approximately 81 km from Dili) where the mountains divide Timor Island into the northern and southern areas, the road enters the southern side of the island with steep mountainous terrain. The approximately 25 km-long section from this point on Route A02 suffers from the most disasters caused by frequent slope collapse.

The road runs through the upper terrace from a point103.6 km from Dili, approximately 5 km before entering Ainaro (108.5 km from Dili), and then through a lower terrace and finally coastal lowland before reaching Cassa.

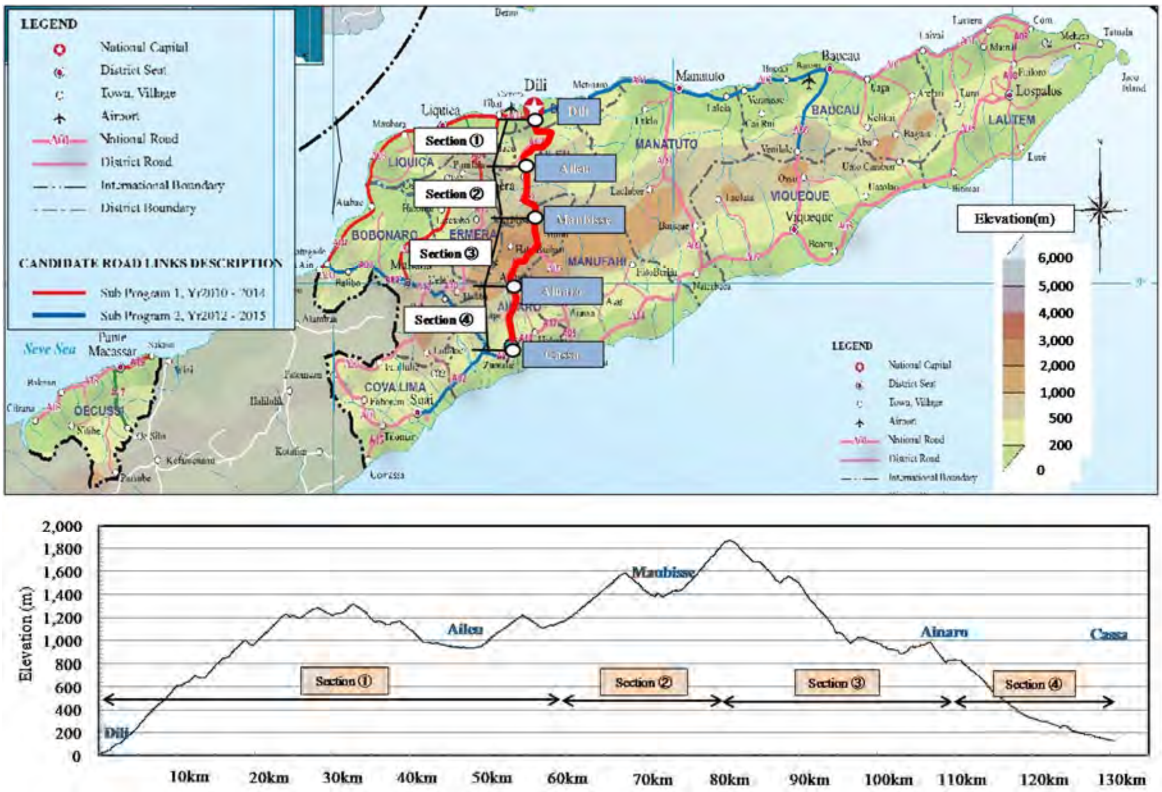


Figure 2.2 Route map and elevation profile of National Road Route A02

2. 1. 3 Geology

The coastal area, in which the capital Dili is located, is covered with alluvium consisting mainly of loose gravel. In the steep mountainous section between the 2km point and the 20km point, the ground surface is covered with lateritic shale, and schist that has been made fragile and susceptible to exfoliation by weathering and erosion. (See Photos 2.1 and 2.2.)

Evidence of recent collapse is observed in the terrain and screes at the base of the roadside slopes in the section between the 23km point and the 28km point. Outcrops of fresh bedrock and weathered rocks are also found in some locations in this section.

Photo 2.1 Lateritic shale (16.1 km)

Photo 2.2 Schist (24.2 km)

The basin terrain which is the section between the 40km point and the 55km point where ileu is located is covered with alluvium of loose gravel.

Schist is also predominant in the section between the 55km point and 60km point. The schist in this section has been made fragile and susceptible to exfoliation by weathering with erosion of the section between the 2km point and 20km point as mentioned above. Limestone ground and boulders are found at the 59.1km point and 66km point. However, schist and sandstone are also found. (See Photos 2.3 and 2.4.)

Photo 2.3 Limestone (59.1 km)

Photo 2.4 Schist (59.1 km)

While schist susceptible to weathering and exfoliation is predominant in the mountainous terrain along the section from Maubisse (70.7 km), in most of the sections mentioned above is found eroded clayey soil mixed with gravel in many places with schist rocks at the roadside cut slopes in the hilly terrain area.

Significant topographic changes were observed along the section between the highest point on Route A02 (81 km) and the 104 km point. Similar to geological changes from soil derived to weathered schist containing limestone of soil derived from weathered mudstone and shale containing limestone occurs in this area. Although the limestone is extremely hard, cracks have developed at 30 cm intervals.

Terrain as a result of landslides of limestone boulders is identified at the 91.2km point. An outcrop of fluvial terrace riser is found at the 103.6km point. The upper part of the riser contains boulders with a grain size of approximately 30 cm and the lower part contains a number of pieces of limestone with a diameter of approximately 1.5 meters. (See Photo 2.5.)

A trace of debris flow was identified at the 106.4km point. Pieces of sandstone and conglomerate, in addition to limestone, were found on the streambed. (See Photo 2.6.)

Photo 2.5 Limestone (103.6 km)

Photo 2.6 Conglomerate (106.4 km)

The area from Ainaro to Cassa (108.5 km) mostly consists of upper and lower fluvial terraces and is underlain by a bedrock of fluvial deposits of well-compacted gravel.

The area around Cassa (131.3 km) in coastal lowland terrain is covered with alluvium with loose gravel.

The figure below shows the geological map of the entire territory of Timor-Leste.

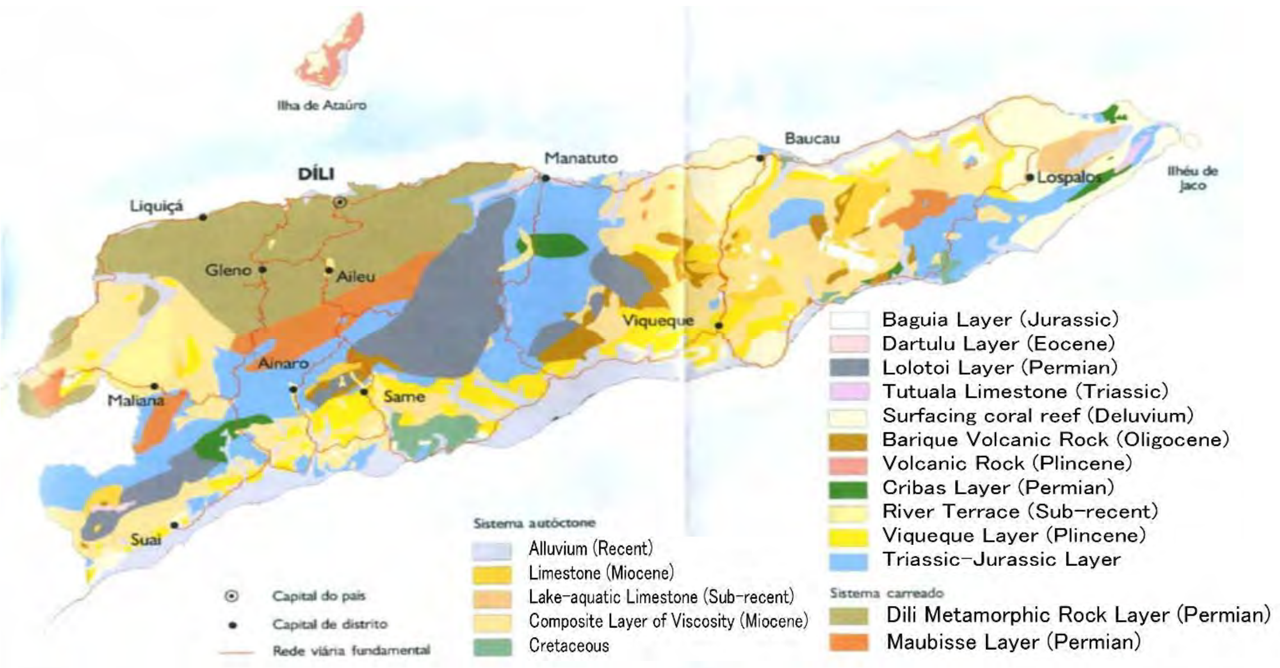


Figure 2.3 Geological map of Timor-Leste (source: Atlas de Timor Leste LIDEL, Edições Técnicas, 2002)

The table below shows the major geological features found along Route A02.

Table 2.1 Major geological formations found along Route A02

Section	Geological formation and era	Major rock components	Weathered soil
0 km – 60 km	Aileu Formation/Paleozoic Era	Schist, shale, etc.	Mostly laterite
60 km – 80 km	Maubisse Formation/ Paleozoic Era	Limestone, sandstone, etc.	Mostly clayey soil mixed with gravel
80 km – 110 km	Mesozoic Era (Triassic and Jurassic Periods)	Limestone, sandstone, schist, etc.	Clayey soil derived from weathered mudstone and shale
110 km – 131 km	Fluvial terraces/Cenozoic Era	Sandstone, mudstone, limestone, etc.	Sandstone and mudstone are often found as boulders

2.2 Survey of Road Facilities

National Road Route A02 was constructed and maintained in accordance with Indonesian standards while Timor-Leste was in the Indonesian era. The road which passes through areas of steep mountainous terrain has a pavement carriageway with a 4.5 meter width and road shoulder on either side with a 1.0 meter width. In this situation the volume of traffic is approx. 200 vehicles per day.

Since the sections in the steep mountains have narrow hairpin curves and steep longitudinal gradients, drivers of large vehicles use the road shoulder outside the pavement to pass other vehicles. In this case, the vehicles are forced to drive slowly at the narrow sharp curves in the road in view of the poor visibility. Small bridges and cross culverts have been installed where the road crosses the valleys. However, since they were not designed with sufficient flow area to allow pieces of driftwood and debris to pass under the road, the result is debris when the heavy rains come, devastation caused by water overflowing onto the road surface and cross culverts being washed away.

2.2.1 Survey of the Existing Pavement

2.2.1.1 Surface Condition of Pavement

Because of the relatively small traffic volume, the long section to the 79km point from the capital Dili was paved (asphalted) using the two-layer bituminous penetration macadam method which involves construction of a base course by compacting crusher-run stones or natural gravel, application of primer and gravel aggregate on top of the base course and manual roller compaction of bituminous materials. The general method for pavement work is applied to bituminous material with a penetration of between 60 (1/10mm) and 70 (1/10mm) at a proportion of 5%. As a result of using this method, the bituminous penetration macadam pavement has remained intact even after deformation or subsidence of the subgrade beneath the base course caused by water penetration or the volume of traffic load in some places. However, despite repair work to damage including potholes with rehabilitation in 2005, degradation of the road over several years since independence in 2002 is a serious matter with cracks and potholes in the pavement, deformity of the road surface and exemplary base course erosion by natural subgrade found in many locations. Consequently, large numbers of road repair works are urgently required. (See Photo 2.7.)

Photo 2.7 Examples of damage to the pavement in the section of Route A02 between 0 km and 79 km

More specifically, along the pavement sections between the starting point and the 3.0km point and between the 50km point and 60 km point around the city of Aileu, the road is maintained at level 7 (in a fair state) as per the International Roughness Index (IRI). However, a lot of potholes and alligator cracks can be found in various locations in the pavement sections at the 3km point, 50km point and 60km point as well as the 79km point. Since the natural ground along these sections, with clayey soil derived from weathered shale and mudstone as mentioned above, subsidence natural sub grade landslides have been brought by torrential rain, and road locations in this section have been destroyed by landslides and gradual sinking to a lower level. At all of these locations, the road has also been degraded to earth and road (above IRI level 10) with complete destruction of the pavement. Under these circumstances, the pavement section in the mountains has IRI level 9 or 11.

The pavement along the entire length of the section between the 79 km point and the 131km point was repaired with grant aid from the Government of Japan. The pavement in the flat section between the 120 km point and the 131 km point has been maintained in a good condition at IRI level 7. As the natural ground along this section is also clayey soil derived from weathered shale and mudstone, like the other sections mentioned above, in several places the pavement has been completely damaged, and the road has also been degraded to an earth and gravel road (IRI level 10 or above) where torrential rain has caused subsidence of the natural sub grade or landslides, and the subsidence and landslides have caused total road destruction. Under such circumstances, the pavement in the section between the 79km point and the 120km point in the upland area which is connected to the central mountains has IRI level 9 or 11. Pavement at this level requires immediate repair work.

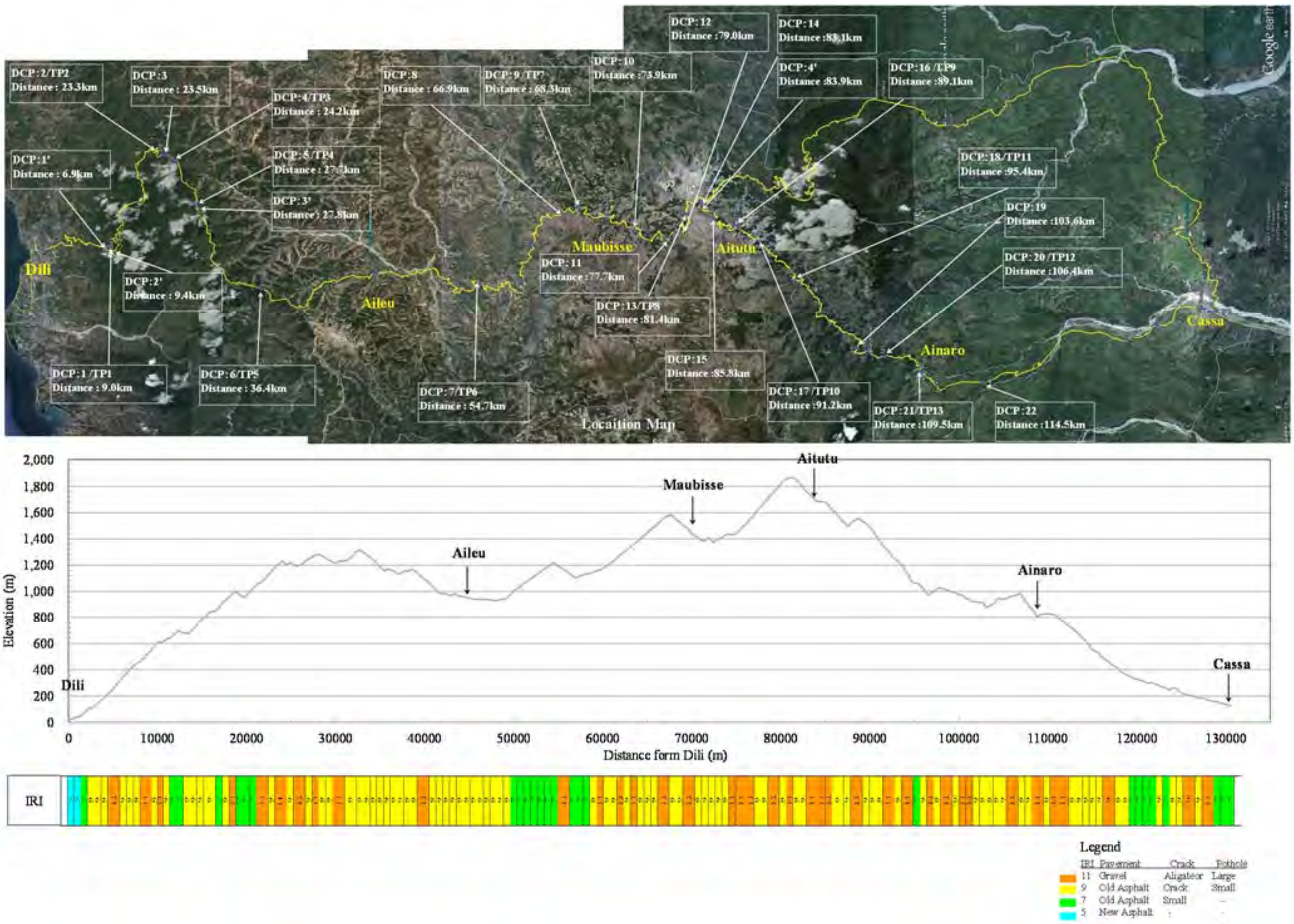


Figure 2.4 Condition of the pavement on Route A02 (between Dili and Cassa)

2.2.1.2 Condition of Pavement Composition

Figures 2.5 and 2.6 show the locations of the test pit sites and a schematic diagram of pavement composition.

Figures 2.5 Locations of the test pit sites

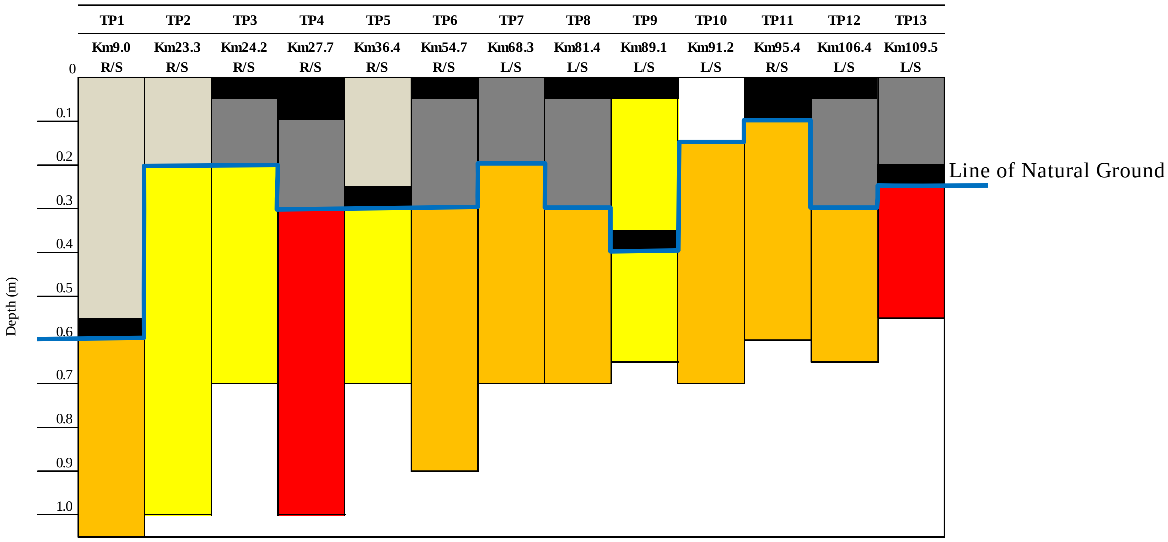


Figure 2.6 Thickness of the pavement structure on Route A02

Source: JICA survey team

- The test pitting was conducted in Talus terrain at all the sites except TP9, TP10, TP12 and TP13. The existing road was constructed on the embankment on the Talus.
- The pavement thickness on Route A02 is not uniform along its length.
- Natural ground, instead of compacted subgrade made of borrow material, is found below the base course (TP4, TP6, TP7, TP8, TP12).
- The natural ground mainly consists of clayey soil derived from weathered shale and schist (TP1, TP4, TP6, TP7, TP8, TP10, TP11, TP12, TP13).
- The pavement suffered serious damage and was totally disintegrated at five (5) sites where the surface course was constructed on natural ground of clayey soil (TP1, TP2, TP10, TP11, TP13).
- Groundwater was not found in test pitting at a depth of 1.0 meter in the roadside valley.
- In repair work conducted in the past, the embankment was constructed on top of the existing pavement using waste materials including base course material (gravel) and the surface course was constructed on the embankment (TP9).

The traffic volume on Route A02 is quite small. Either macadam was applied directly on a sand and earth subbase course, or a base course of crushed stone and asphalt pavement was constructed on fragile natural ground as the subgrade without implementation of large-scale countermeasures such as improvement of the subgrade.

Taking account of the above, it is assumed that the fragile natural ground or compacted subgrade which works as a natural subgrade of clayey soil derived from weathered shale and clay slate has been weakened by infiltration of rainwater and groundwater, and weakening of the natural ground or subgrade has led to subsidence of the base course with complete erosion of the natural subgrade. The deformation or loss of the base course has led to deformation of the asphalt surface course, the appearance of ripples, cracks and potholes in the pavement surface, and even the complete erosion of the pavement.

There are many places along the route where the ground is fragile as mentioned above. The natural subgrade is susceptible to the infiltration of rainwater and groundwater with a high water level. There is risk of disaster in steep mountainous areas as mentioned above, causing large-scale erosion of the highly natural subgrade. For these reasons, it is necessary to prepare a design for road width, pavement structure and stabilization of the natural subgrade along with countermeasures to stabilize the natural subgrade and prevent deformation of the pavement, taking into consideration the collapse and complete erosion of embankment slopes and repair of the route concerned.

2.2.2 Survey of Road Facilities other than the Pavement

The survey team conducted a portable dynamic cone penetration test, test pitting and physical tests of the soil in order to identify the road pavement composition and condition of the gabions installed in the roadside valley for the protection of the embankment along Route A02. The Team also conducted analysis using the CBR of the compacted subgrade and the physical constants obtained in the data available from previous surveys.

2.2.2.1 Portable Dynamic Cone Penetration (DCP) Test

The DCP test was conducted at a total of 35 points at 27 sites on Route A02. The purpose of the test was to obtain the CBR values of the compacted subgrade of the existing road. The CBR values obtained in the DCP test were converted to CBR values. The test was conducted at locations where the existing pavement had been degraded or the embankment had collapsed.

The results of the DCP carried out during the survey were not used in the survey analysis, because the correlation between the DCP and the CBR in the laboratory was quite poor due to over-evaluation by aggregate.

2.2.2.2 Physical Soil Tests

The samples collected from 13 sites on Route A02 in the test pitting were used for the physical soil tests in the indoor laboratory. The purpose of the tests was to classify the usage of soil as gabion backfill material. The following physical tests were conducted:

・Particle size distribution (sieving and sedimentation methods)
・Liquid limit and plastic limit
・Natural moisture content
・Classification and identification of soil types

Table 2.2 shows the results of physical tests of soil for usage as gabion backfilling material. Table 2.2 shows that most gabion material is derived from silt and sand.
The material from two places represents clayey soil where 75μm accounts for more than 35%.

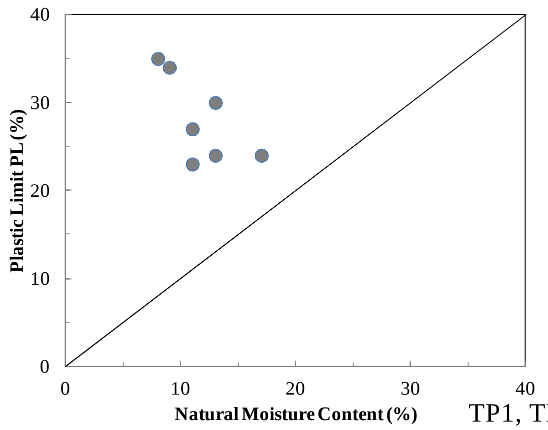
Table 2.2 Results of physical soil tests (gabion backfill material)

Test Pit ID	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10	TP11	TP12	TP13
Location	Km 9.0 R/S	Km 23.3 R/S	Km 24.2 R/S	Km 27.7 R/S	Km 36.4 R/S	Km 54.7 R/S	Km 68.3 L/S	Km 81.4 L/S	Km 89.1 L/S	Km 91.2 L/S	Km 95.4 R/S	Km 106.4 L/S	Km 109.5 L/S
MOISTURE CONT.,%	13	8	8	14	7	23	11	13	12	8	9	11	17
PART. SIZE DIST. (PSD)													
Sieve Size, mm	Percent Passing												
53.000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37.500	96.7	98.6	95.9	95.7	97.8	100.0	95.3	96.6	97.7	100.0	95.2	96.1	95.1
26.500	95.8	93.6	89.6	91.9	90.4	91.3	90.5	93.2	94.6	98.3	85.9	88.7	91.1
19.000	93.0	89.0	82.2	89.3	80.6	83.7	87.1	90.3	87.7	94.8	79.5	85.9	88.0
13.200	88.8	80.9	73.3	86.3	71.9	76.7	78.2	86.7	81.2	88.2	71.7	79.6	85.3
9.500	82.9	73.8	66.7	83.6	65.6	70.4	69.7	83.4	73.9	83.0	64.6	74.4	81.0
6.700	73.0	68.5	60.2	79.9	58.6	62.6	62.1	78.5	65.9	75.9	57.3	70.7	77.7
4.750	68.0	63.2	55.3	76.6	53.9	56.0	56.4	75.0	59.6	70.7	52.5	66.8	74.9
2.360	56.8	52.8	44.2	70.7	45.6	46.9	45.0	64.4	48.3	63.6	43.0	59.5	71.6
1.180	51.3	42.8	36.3	63.0	37.8	39.3	37.8	55.2	41.1	54.3	36.5	51.0	67.4
0.600	44.6	36.1	29.2	57.4	30.8	33.0	32.1	48.3	35.8	47.1	31.7	43.8	63.9
0.425	42.3	28.0	23.5	52.4	26.3	28.2	30.2	43.4	34.0	42.6	30.3	41.0	59.9
0.300	39.3	22.3	18.0	49.4	23.7	22.8	27.7	40.6	31.8	38.3	29.1	38.7	58.0
0.150	35.1	16.0	12.6	44.8	17.4	18.1	22.8	35.0	25.2	35.5	27.5	35.2	55.7
0.075	32.0	13.6	10.1	43.3	15.3	15.1	18.2	31.4	21.3	31.5	26.6	32.9	53.6
Silt 0.020	15.5	not req.	not req.	26.5	not req.	12.8	14.0	28.5	not req.	19.0	18.9	22.0	48.8
Clay 0.010	5.9	not req.	not req.	8.2	not req.	6.0	7.0	18.0	not req.	7.5	9.0	14.0	35.0
Colloids 0.001	0	not req.	not req.	0	not req.	0	0	0	not req.	0	0	0	0
CASS. PROPERTIES													
Liquid Limit (LL)	30	23	27	37	22	23	29	38	27	40	43	35	43
Plastic Limit (PL)	24	NL	NL	NL	NL	NL	23	30	NL	35	34	27	24
Plasticity Index (PI)	6	N/P	N/P	N/P	N/P	N/P	7	8	N/P	5	9	8	19
Consistency Index (Ic)	3.1						2.9	3.2		6.2	3.6	3.0	
SP. GARVITY	2.45	2.53	not det.	2.53	not det.	2.73	2.45	2.56	not det.	2.53	2.59	2.69	2.50
SOIL CLASS													
USCS (ASTM 2487)	SILTY SAND WITH GRAVEL (SM)	SILTY SAND WITH GRAVEL (SM)	SILTY SAND WITH GRAVEL (SM)	SANDY LEAN CLAY WITH GRAVEL(CL)	SILTY GRAVEL WITH SAND (GM)	LEAN CLAY WITH GRAVEL (CL)	CLAYEY GRAVEL WITH SAND (GC)	SILTY SAND WITH GRAVEL (SM)	SILTY GRAVEL WITH SAND (GM)	SILTY SAND WITH GRAVEL (SM)	SILTY GRAVEL WITH SAND (GM)	SILTY SAND WITH GRAVEL (SM)	LEAN CLAY W/ GRAVEL (CL)
Color	Reddish-Brown	Yellowish -brown	Brownish -gray	Reddish-brown	Brownish -gray	Reddish-Brown	Yellowish -brown	Yellowish -light/ brown	Grayish-brown	Dark-gray	Dark gray	Yellowish -gray	Yellowish -gray
AASHTO M145	A-2-4	A-1-a	A-1-a	A-4	A-1-b	A-2-4	A-2-4	A-2-4	A-1-b	A-2-4	A-2-5	A-2-4	A-7-6

Source: JICA survey team

(1) Condition of the Existing Gabions

Figure 2.7 shows the correlation between the natural moisture content and the liquid and plastic limits.



TP1, TP5, TP7 are not included

Figure 2.7 Correlation between natural moisture content and plastic limit
Source: JICA survey team

The correlation between the natural moisture content and the plastic limit reveals that the natural moisture content is lower than the liquid limit which is basically higher than the plastic limit. This finding indicates that the backfill materials are in a semi-solid state. However, it is assumed from observation of the backfill material in the field that the state of the backfill material changes to a plastic state with an increase of moisture content due to rainfall and becomes clayey.

Table 2.3 below shows the current state of the gabions, precipitation, geological features and soil classification. The AASHTO classification was used for the soil classification.
The gabions at seven (7) of the nine (9) sites surveyed were intact without deformation, while they had subsided and collapsed at the remaining two sites.

The following are assumed to be the causes of the damage to the gabions:

(i) The use of clayey material derived from weathered shale and schist as the backfill material (TP4, TP 6, TP 8, TP 10, TP 11, TP 12 in Table 2.3)

(ii) The rise in groundwater level and pore water pressure at places with high precipitation where surface water is likely to accumulate (TP10, TP11, TP12, TP9 in Table 2.3)

(iii) Gabions back-filled with gravel soil have been damaged in places with high precipitation and discharge of groundwater (TP4, TP9 in Table 2.3).

Table 2.3 Current state and condition of the gabions

TP	Location	Rainfall (mm/year)	Spring water	Geological Era	Geology	Soil Classification for Backfill Materilal	Situation	Remarks
TP2	23+300	>2000		Aileru/Palaezoic Era	Shale/Schist	A-1-a	Stable	Tobishima
TP3	24+200	>2000			Shale/Schist	A-1-a	Stable	Tobishima
TP4	27+700	>2000			Shale/Schist	A-4	Collapsed	Tobishima
TP6	54+700	<2000			Schist	A-2-4	Stable	
TP8	81+400	>2500		Mesozoic Era	Gravelly Clay	A-2-4	Stable	
TP9	89+100	>2500	○		Gravelly Clay	A-1-b	Settlement	Tobishima
TP10	91+200	>2500	○		Gravelly Clay	A-2-4	Stable	Tobishima
TP11	95+300	>2500	○		Gravelly Clay	A-2-5	Stable	Tobishima
TP12	106+400	<2000	○		Sandstone/Slate	A-2-4	Stable	Tobishima

Source: JICA survey team, Soil classification is derived from the survey team test pit

For the reasons mentioned above, waste soil generated on site, *i.e.* clayey soil derived from weathered shale and schist, should not be used as backfill material for the gabions. There is also a need for the use of highly permeable material and installation of drain pipes as additional countermeasures to counter the rising groundwater level and buildup of pore water pressure.

2.2.3 Survey of the Roadside Slopes

The roadside slope survey on Route A02 was conducted at 30 sites (refer to the appendix, Stability Investigation). Typical collapse of the embankment slope which affects the pavement and road surface was observed at 10 of the 30 sites. Therefore, embankment collapse has a significant effect on the pavement and road surface revealed in the survey of existing roadside slopes was described in the following. The appendix, “Results of survey and the evaluation of roadside slopes on Route A02”, shows the results of overall evaluation of the roadside slopes including those at the 10 sites mentioned above.

The representative 10 sites are described as follows.

(1) 27.7km point from Dili

The soil at the site, which mainly consists of weathered schist, is characterized by extreme fragility due to infiltration of water. Because the roadside slope at the site is long and steep, the deep-seated collapse that occurred in the slope on the mountain side spread to the slope on the valley side. As a result, a large-scale collapsed slope was created. The collapsed gabions remain on the valley side of the road (Photo 2.8).

Photo 2.8 Condition at 27.7 km

Photo 2.9 Condition at 27.8 km

(2) 27.8km point from Dili

Water leaked from the cross culvert under the road caused by the collapse of the embankment slope on the valley side (Photo 2.9). While the embankment is reinforced with gabions, the slope below the gabions is deep valley terrain. The surface characteristics of the soil are the same as at the 27.7 km point.

(3) 68.3km point from Dili

As the deep gully-shaped drain in the upper part of the cut slope on the mountain side is not adequate enough to control the water flow at the end, concentrated runoff of rainwater occurred at this slope. The concentrated runoff caused shallow collapse of the slope. In addition, because of the lack of drainage facilities, water flowed over the road surface. The overflow of water caused the collapse of the embankment slope on the valley side because it had weakened the road surface (Photo 2.10).

Photo 2.10 Condition at 68.3 km

(4) 81.4km point from Dili

The cut surface slope on the mountainside had become weathered and covered with clayey soil mixed with gravel. Shallow collapse likely occurred in the slope with the progress of gully erosion of the surface (Photo 2.11). The lack of facilities to control the flow of drain water on the valley side at the end of the drainage system, which consists of drains on the mountain side and cross culverts under the road, led to gully erosion of the embankment slope on the valley side (Photo 2.12).

Photo 2.11 Condition at 81.4 km point

Photo 2.12 Condition at 81.4 km point

(5) 83.1km point from Dili

Collapse of the slope was observed at the road edge on the valley side where rainwater from the slope on the mountain side and water on the road were drained. This concentrated flow of water is assumed to have caused the collapse of the slope on the valley side. Lack of water drainage control was the cause of the collapse (Photo 2.13).

Photo 2.13 Condition at 83.1 km point

Photo 2.14 Condition at 85.8 km point

(6) 85.8km point from Dili

The condition of this site is similar to the 83.1km point mentioned above. Improper drainage of water from the mountain side led to collapse of the embankment on the valley side (Photo 2.14).

(7) 91.2km point from Dili

The occurrence of a landslide was confirmed at the site. It occurred approximately 100 meters along the road and approximately 250 meters along the slope. No damage has occurred for the time being. There are cracks in the surface layer in several places on the upper part of the slope. A small stream has developed due to gully erosion in the central part of the slope and surface water has been observed in the stream. The slope is composed of generally clayey soil mixed with gravel. It is thought that groundwater and rainwater that infiltrated the ground created a slip surface. Discharge of groundwater is observed at the base of the road slope edge. Boulders are derived from the collapsed gabion (Photo 2.16). The slope on the valley side is reinforced with multiple layers of gabions (Photo 2.15). Planting of the slope on the mountain side has stopped the erosion.

Photo 2.15 Condition at 91.2 km point

Photo 2.16 Condition at 91.2 km point

(8) 103.6km point from Dili

The upper fluvial terrace was observed at the 103.6km point. The upper part of the terrace riser contains boulders with a grain size of 20cm to 30cm and the lower part also contains pieces of limestone with a diameter of 100cm or larger (Photo 2.17). A large volume of water flows from the top of the slope. If the water flow cannot be controlled, it will make the road surface unstable. There is fear of a weakened terrace riser and slope on the valley side (Photo 2.18).

Photo 2.17 Condition at 103.6 km point

Photo 2.18 Condition at 103.6 km point

(9) 114.5km point from Dili

An almost vertical collapsed surface has appeared at the road edge in the fluvial terrace riser (Photo 2.19). The collapse is quite deep and reaches the top of the lower fluvial terrace approximately 100m below (Photo 2.20). It is a naturally created collapse. Nevertheless, as the prevention of collapse will require no load or no vibration of the road surface in the upper terrace surface, re-routing of the road is a possible option.

Photo 2.19 Condition at 114.5 km point

Photo 2.20 Condition at 114.5 km point

(10) 125.4km point from Dili

Collapse of the river revetment is observed at this site (Photo 2.21). A rise in the water level in the hinterland caused by infiltration of water overflowing from the river on the upper side through potholes in the pavement is considered to be a more likely cause of the collapse of the revetment than a rise in the water level in the river on the lower side.

Photo 2.21 Condition at 125.4 km point

2.2.4 Division of the Route by Characteristics

The total length of the section of A02 is approximately 130 kilometers. The natural conditions, including the topographic and geological features and precipitation, vary along the route and accordingly, a wide variety of disasters occur in different locations on the route. In this section, the route is divided broadly on the basis of the natural conditions and the structure of the collapses mentioned above.

Table 2.4 Division of Route A02 by major characteristics

Name of division and section (km)	Terrain along the road	Characteristics of cut slopes and outcrops	Characteristics of disasters
Aileu Formation 9－60	Mountain slopes	・Gradient of lower part of cut slopes and naturally collapsed surface is 30º - 45º. There is a large amount of scree at the base. ・The upper part is characterized by gradients of 50º or more. ・The soil is mostly composed of reddish-brown (lateritic) clayey soil mixed with gravel. ・Predominant rock types are schist and shale which are susceptible to weathering and extremely weakened by infiltration of water.	・In the early stages, there are many disasters in which gully erosion by rainwater has developed into shallow collapse. ・It is thought that locally produced cut waste was used as material for the embankment (on the valley side). ・Even with reinforcement of the embankment with gabions, shallow collapse (and deep-seated collapse at certain places) occurs because of the characteristics of the ground.
Maubisse Formation 60－80	Mountain ridges	・The terrain along the road is gentler than the terrain along the preceding section. However, many cut slopes are steeper and unsupported. ・Clayey soil mixed with gravel is predominant. Limestone is found as the predominant rock type, in addition to schist and shale. ・The ground is susceptible to weathering and weakened by infiltrating water.	・Parts of the roadside slopes where outcrop of rock is found on the surface are more stable than the slopes on the sides of the preceding section. ・However, as there are also slopes similar to those in the preceding section, there is a risk that gully erosion will develop into shallow collapse. ・There is a possibility that worsening of gully erosion will cause loose rocks to fall.
Mesozoic Era 80－110	Fluvial terrace riser (upper)	・The terrace riser is stable without direct support regardless of whether it is artificial or natural. ・Many boulders with a grain size of approx. 30 cm are found in the upper part of the riser and large pieces of limestone are found in the lower part. ・The riser has a tendency to be susceptible to water infiltration from the top and back of the riser.	・Although the riser is relatively steep and stable, there is a risk that infiltration of rainwater and groundwater may cause it to collapse. ・Even if degradation of the riser has not resulted in collapse of the entire riser, there is a risk that boulders in the riser may fall.
Cenozoic Era 110－131	Fluvial terrace riser (lower)	・The lower terrace riser is stable without direct support, as is the case with the upper terrace riser. ・However, it has a tendency to collapse from the upper part due to weathering.	・A rise in the water level of the river at times of flooding causes collapse of the riser from the upper part at a location near the current riverbed.

Source: JICA survey team

2.2.5 Analysis of the Causes of Damage to the Pavement associated with Damage to the Road Embankment

(1) Causes of Damage to the Pavement associated with Damage to the Road Embankment

A summary of 2.2.3 identified the following five factors as the main causes of damage to the road embankment.

- Embankment Collapse due to Culvert Leakage
- Clayey Embankment Collapse due to Water
- Rockfall
- Large Scale Collapse
- Flood, Debris Flow, Bridge Fall

Figure 2.8 shows the large number of causes of damage to the pavement by type of cause. The results were obtained from the results of field reconnaissance and evaluation of the existing road conditions on Route A02.

Slope collapse was observed at a total of 30 sites.

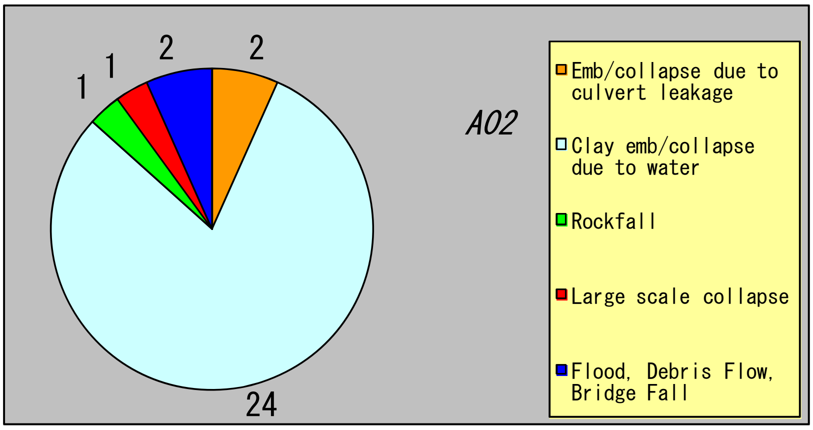


Figure 2.8 Classification of the causes of damage to the road embankment

Source: JICA survey team

A major characteristic is that “Clayey Embankment Collapse due to Water” caused 80% of all the damage to the pavement on Route A02. The main factors contributing to the occurrence of “Clayey Embankment Collapse due to Water” are the natural ground of weakened, weathered clayey soil and the concave terrain over which water flows down to the lowest point.

Embankment collapse caused by water leaking from cross culverts under the road (“Embankment Collapse due to Culvert Leakage”) has led to damage of the pavement. It is assumed that the earth covering of the cross culverts, which has a thickness of 40cm or less, was not enough to absorb the impact of the traffic load on the road, that the impact created stress and eventually damaged the joints of the culverts and water leakage started from the damaged joints. Lack of protection of the joints is also a factor contributing to the leakage. Therefore, “Embankment Collapse due to Culvert Leakage” is not considered to be a cause created by natural disasters, but a cause to which artificial factors significantly contributed.

Falling rocks from the slope occurs when surface water derived from rainfall has infiltrated the slope and loosened the earth supporting a block of rocks. After the rocks have fallen, groundwater discharged from the slope damages the pavement.

"Large Scale Collapse" is the gradual process of the collapse of a slope along the groundwater channel in the slope, caused by the flow of water infiltrating the slope from the surface of the channel. A "Large Scale Collapse" creates a precipice. Such precipices are found at the locations called Jakarta 1 and Jakarta 2 along Route A02.

At times of "Flood and Debris Flow," the water flow of small streams which usually have a small flow rate but which increases rapidly due to heavy rainfall carries deposit from the streambed downstream, water overflows the drainage structures because of the small flow area, and overflowing of water causes damage of the pavement.

The table below shows examples of pavement damage due to the causes mentioned above.

Table 2.5 Examples of damage to the pavement created by the main causes

Embankment Collapse due to Culvert Leakage		
Clayey Embankment Collapse due to Water		
Rockfall		
Large Scale Collapse		
Flood, Debris Flow, Bridge Fall		

(2) Relationship between Natural Ground Materials and Embankment Collapse

Table 2.6 below shows the precipitation, presence/absence of discharge of groundwater, topography, geology and AASHTO classification of the natural ground materials at 20 locations where the embankment has collapsed on Route A02 and which the survey team has studied.

The data on soil classification are drawn from the World Bank. The locations of the provided soil classifications are nearest to where the survey team studied.

Table 2.6 Locations of embankment collapse and conditions at the locations

Location	Rainfall (mm/year)	Spring water	Geological Era	Geology	Soil Classification (AASHTO) *1	Topography	Collapse	Remarks
9+000	1000		Aileu/Palaezoic Era	Shale	A-1-b	Valley/Sag	Collapsed	
16+200	<2000			Shale/Schist	A-2-4	Ridge	Stable	
23+300	>2000			Shale/Schist	A-2-5	Valley	Collapsed	
23+500	>2000			Shale	A-1-b	Valley	Collapsed	
24+200	>2000			Shale/Schist	A-2-4	Valley	Collapsed	
27+700	>2000			Shale/Schist	A-4	Valley	Collapsed	
27+800	>2000			Shale/Schist	A-4	Valley/Sag	Collapsed	
54+700	<2000			Schist	A-4	Valley/Sag	Settelement	
66+900	>2000		Maubisse/Palaezoic Era	Limestone	A-1-a	Sag	Stable	
73+900	>2000	○		Sandstone	A-6	Valley/Sag	Collapsed	
77+700	>2000	○		Sandstone	A-2-4	Valley	Collapsed	
81+400	>2500		Mesozoic Era	Gravelly Clay	A-7-5	Valley/Sag	Settelement	
83+100	>2500			Gravelly Clay	A-7-5	Valley	Collapsed	
85+800	>2500			Gravelly Clay	A-6	Valley	Collapsed	
89+100	>2500	○		Gravelly Clay	A-4	Valley	Collapsed	
91+200	>2500	○		Gravelly Clay	A-4	Valley	Settelement	
95+300	>2500	○		Gravelly Clay	A-2-4	Valley	Washed away	
103+600	>2500	○	Cenozoic Era	ndstone/Limesto	A-4	Valley	Collapsed	
106+400	<2000			Sandstone/Slate	A-4	Valley/Sag	Collapsed	
114+500	<2000			Sandstone	A-7-6		Collapsed	

Source: JICA survey team
*1: World Bank Data

The natural ground materials at the locations where the embankment had collapsed are A-4 and A-5, which are classified as silty soil, and A-6 and A-7, also classified as clayey soil. The embankment had also collapsed in the sections where the annual precipitation is 2,000 mm or above and discharge of groundwater is observed, even when the natural ground material is A-2, which is classified as gravel/sand mixed with silty soil.

Meanwhile, the embankments at sections with mountain ridges with an annual precipitation of 2,000 mm or less are stable, even when the natural ground materials in the section are A-1 or A-2, which are classified as gravel/sand.

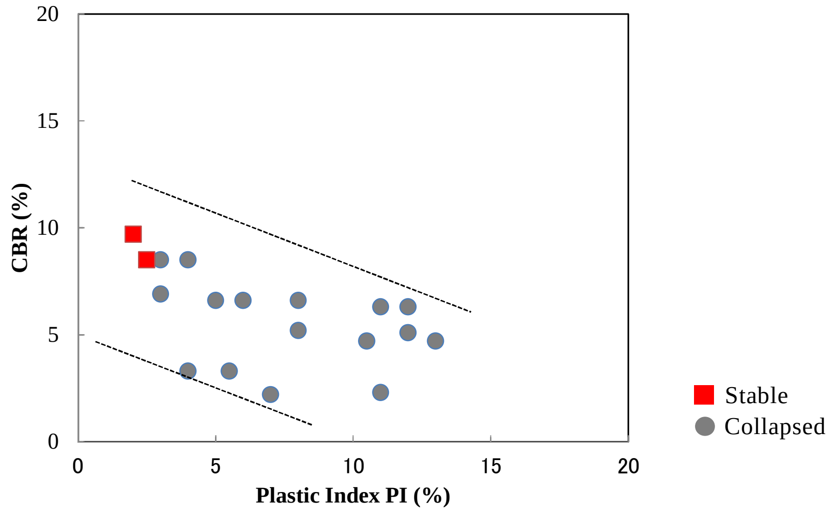


Figure 2.9 Correlation between plasticity index and CBR of the subgrade

Source: JICA survey team, CBR data is provided by the World Bank

Figure 2.9 shows the correlation between the plasticity index and the CBR of the subgrade, the natural ground material, with data taken at the locations of stable and collapsed slopes shown in different shapes and colors. The CBR value of the subgrade materials is seven (7) or lower and the plasticity indices of the subgrade materials are within the range of those for clayey soil at the locations where the roadside embankments have collapsed. These figures reveal the difficulty of maintaining the necessary bearing capacity of the subgrade with the materials used as subgrade materials at the locations where the embankments collapsed, and therefore, these materials are inappropriate subgrade materials.

The conclusions of the survey and the considerations when clayey natural ground materials are used as the materials for the subgrade are summarized as follows.

(i) Large drains and an underground drainage system should be installed on the mountain side of the road in order to minimize infiltration of rainwater into the subgrade.

(ii) Use of sandy soil and gravel with good drainage capacity should be considered as a means of improving the subgrade.

(iii) Expansion of cutting should be considered as an additional measure to prevent collapse of the embankment.

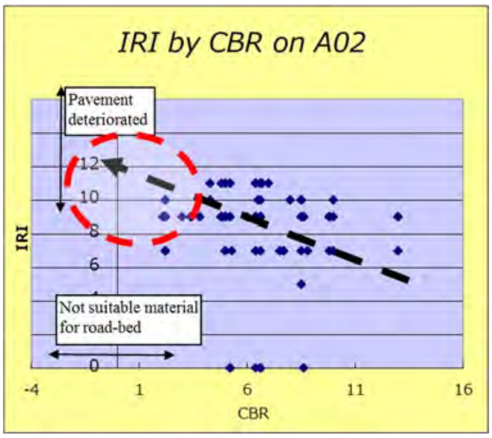


Figure 2.10 Relationship between damage to the pavement and fragility of the compacted/natural subgrade

Source: JICA survey team, CBR data is provided by the World Bank

The road embankment collapsed on Route A02 because of the reasons mentioned in 2.2.5 (2). Figure 2.4 shows that the pavement was also damaged in locations other than the above-mentioned. Refer to Figure 2.10 which shows that the IRI and CBR for the whole route of A02 are correlative. In addition, it appears that pavement damage has a tendency to deteriorate in locations where the subgrade is weak, as shown in Table 2.7. It can be inferred that the road embankment collapsed due to similar causes of deterioration of the bearing capacity of the subgrade. It can be stated that damage to the road embankment is most often caused by the fragility of the natural conditions in Timor-Leste.

2.2.6 Analysis of the Causes of other Types of Damage to the Pavement

The basic analysis for comparison of the pavement structure identified by visual observation by test pitting samples and the indices for the bearing capacity of the subgrade, *i.e.* CBR values and IRI values, was conducted in order to identify the causes of damage to the pavement not associated with damage to the road. Table 2.7 below shows the results of the analysis.

Table 2.7 Comparison of pavement structure and CBR and IRI values

TP	Location (km)	Subgrade Material*3	CBR*2	Base Course Material	Surface	Cause of Pavement Deteriorate*1
1	9+000	Clayey Sand	10.0	Nothing	Earth and Sand	(3)
2	23+300	Gravel Sand	8.5	Crushed Stone	Asphalt	Rock Fall
3	24+200	Gravel Sand	8.5	Crushed Stone	Asphalt	Subsidence of Base Course
4	27+700	Clay	3.4	Crushed Stone	Asphalt	(2)
5	36+400	Gravel Sand	2.2	Nothing	Earth and Sand	(1)
6	54+700	Clayey Sand	5.0	Nothing	Asphalt	(2)
7	68+300	Clayey Sand	6.5	Crushed Stone	Crushed Stone	(2)
8	81+400	Clayey Sand	6.4	Crushed Stone	Asphalt	(2)
9	89+100	Gravel Sand	6.6	Nothing	Asphalt	(1)
10	91+200	Clayey Sand	6.4	Nothing	Crushed Stone	(1)
11	95+400	Clayey Sand	6.6	Nothing	Asphalt	(1)
12	106+400	Clayey Sand	6.6	Crushed Stone	Asphalt	(2)
13	109+500	Clay	5.2	Nothing	Crushed Stone	(1)

Note *1 1 : In case no existence of base course and bearing capacity of Subgrade (CBR) less than 6.6 are remarkable
2 : In case bearing capacity of Subgrade (CBR) less than 6.6 are found deteriorated pavement
3 : In case base course material is clayey , even if bearing capacity of Subgrade (CBR) more than 8 are remarkable for deteriorated pavement
*2 CBR value are provided from World Bank .CBR test are located in the nearest of Test pit (TP)
*3 Subgrade Material are confirmed by eye observation in Test Pit
Source: JICA survey team

The following are the characteristics of the causes of damage to the pavement.

The basic descriptions in the table above of the causes of damage to the pavement are summarized as follows: (refer to Table 2.7 Cause of Pavement Deterioration and Figure 2.6).

Cause (1) Surface damage is conspicuous where there is no base course and the bearing capacity of the subgrade (CBR) is 6.6 or lower.

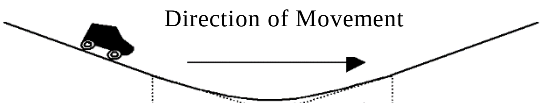
- The surface course was constructed of natural ground; the traffic load falls directly onto natural ground without being dispersed by the base course and damages the natural ground. The damage to the natural ground leads to damage in the surface course.
- The pavement structure is not uniform along the route. In other words, the road was constructed with a poorly prepared pavement design.

Cause (2) Surface damage is found where the bearing capacity of the subgrade (CBR) is 6.6 or lower.

- The material used in the existing base course does not have the necessary bearing capacity for base course material. In addition, the base course does not have sufficient thickness (refer to figure 2.6).

Cause (3) Pavement deterioration is conspicuous where the base course material is clayey, even when the bearing capacity of the subgrade (CBR) is 8 or higher.

- Weakening of the base course and subgrade by water in the concave parts of the road over which the water flows down as a result of lack of an adequate drainage system contributed to the occurrence of damage to the surface course (see the photo below). Despite fair surface conditions between the 110km point and the 130km point, the pavement collapsed due to water in the concave parts of the road.



Water in the concave parts of the road

The issues to be considered with regard to repair work for damage to the pavement are as follows:

- The base course materials should be installed before installing the surface course in sections where there is no base course material.
- Pavement design including the required thickness and materials of each course should be prepared taking into consideration the bearing capacity of the subgrade and the traffic load.

Chapter 3 Nationwide Road Survey

A nationwide road survey was carried out for National Road Routes A04, A05, A06, A09, A10, A11 and A12 which may be particularly prone to road disaster. The details of the survey are described below. Since old Indonesian rural road standards are applied to these roads, the pavement width is less than 4.5 meters. In mountainous areas where the road shoulder is narrow, it is not easy for even ordinary vehicles to pass in opposite directions and they are obliged to detour to where the section has more width available and it is enough for two vehicles to pass in opposite directions. Furthermore, mountain roads have poor vertical and horizontal alignment.

3.1 Natural Conditions and Slope Conditions

This section explains the natural conditions of National Road Routes A04, A05, A06, A09, A10, A11 and A12. The description is simplified as it mostly overlaps with the content of “2.1 Survey of Natural Conditions”.

3.1.1 Climate and Meteorological Conditions

The climate of Timor-Leste belongs to the tropical monsoon climate with distinct rainy and dry seasons. The northwest monsoon prevails from December to March, bringing humidity to the regions of the country. The southeast trade wind, which creates the windy season from May to October, causes the dry season. Along the southern coast and the southern slopes, however, the rainy season continues until July.

The annual average precipitation varies greatly, ranging between 573mm in Manatuto and 3,000mm in the mountainous area in the central and western region.

The annual average atmospheric temperature in the coastal region ranges between 25 and 27ºC, while in Aileu where the elevation is over 1,000 meters the temperature is 21ºC or lower. See Figure 2-1 for the national annual precipitation.

3.1.2 Topography

Timor-Leste covers almost all the eastern half of Timor Island, which is the easternmost of the Lesser Sunda Islands. It is a small island nation with a mountainous topography, it measures about 250 kilometers from east to west and has a total land area of 14,609 square kilometers.

Located in the inland area of western Timor-Leste is Mt. Tatamailau, which is the highest mountain in Timor Island with a total height of 2,963 meters and which bisects the island into east and west. Areas with an elevation of 100 meters to 500 meters account for 44% of the country and highlands of 1,000 meters or higher account for 35%.

Figure 2-2 shows a planimetric map of the country.

3.1.3 Geology

In the west of Timor-Leste, the Paleozoic Aileu formation spreads widely from Dili to Aileu in the north, and Maubisse formation, which is also Paleozoic, is distributed in areas around the central crest mountain range, which lies to the south. Moreover, a Mesozoic formation extends to the south and a Cenozoic formation extends along the coastal area centered on Same on the south side.

The main geological features of each national road are described below.

(1) Route A04

Replacing the Paleozoic formation, a Mesozoic formation covers the ground surface around Manatuto in the central region. A Cenozoic formation covers the top layer of the eastern region instead of a Mesozoic formation and raised coral reefs are observed along the northern coast of the eastern region. The geology at the 45.0km point of Route A04 from Tibar on the northern coast of Ermera belongs to the Paleozoic Aileu formation and it is very similar to the section of Route A02 from Dili to Aileu. The top layer is covered with schist and it is very fragile and susceptible to exfoliation due to weathering and erosion. (See Photo 3.1.)

(2) Route A05

Looking at the 53.6km point of Route A02 from Aituto to Betano on the southern coast, the geology from Same to the mountain region is noteworthy for its disaster-prone geology. It belongs to the Mesozoic formation from the Triassic to the Jurassic period and mainly consists of schist, shale and mudstone. (See Photo 3.1, 3.2.)

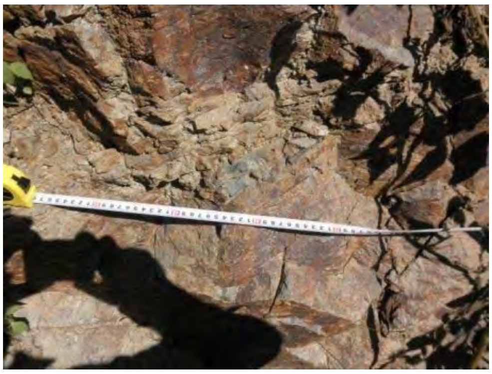


Photo 3.1 Schist (6.9km point on A04)

Photo 3.2 Shale (9.4km point on A05)

(3) Route A06

This 63.1km point section starts from Baucau to Viqueque. Most of the area around this section is covered with Cenozoic Baucau formation, which is typically comprised of coral limestone. While ordinary limestone is hard, coral limestone has high porosity and as such, it is slightly more fragile than ordinary limestone. (See Photo 3.3.)

(4) Route A09

This 85.2km point section starts from Manatuto to Natarbora. It mostly consists of Mesozoic formation from the Triassic to the Jurassic period which is typically comprised of schist, shale and mudstone. They form alternate layers of dip slopes that are liable to rockfall. (See Photo 3.4.)

Photo 3.3 Coral limestone (29.1km point on A06)

Photo 3.4 Shale (31.1km point on A09)

(5) Route A10

This 68.5km point section of Route A12 starts from Ermera to Hauba. It is geologically similar to the section of Route A02 from Dili to Aileu and mostly consists of a Paleozoic Aileu formation with lateritic schist covering the top layer. It is very fragile and susceptible to exfoliation due to weathering and erosion. (See Photo 3.5.)

(6) Route A11

This 62.5km point section starts from Ermera to Maliana. Geologically, it is classified into a mountain part and river part. The mountain part consists of a Paleozoic Aileu formation, which is mainly comprised of lateritic schist, like the above mentioned Route A10. (See Photo 3.6.)

Photo 3.5 Schist (50.5km point on A10)

Photo 3.6 Schist (8.0km point on A11)

(7) Route A12

This 50.9km point section links Maliana and Zumalai. Its geographical features are shown in the table below. While this section is Paleozoic and Cenozoic formations, it mostly consists of Mesozoic formations from the Triassic to the Jurassic period and is mainly comprised of schist, shale and mudstone. (See Photos 3.7 and 3.8.)

Photo 3.7 Schist (22.5km point on A12) **Photo 3.8 Shale (25.9km point on A12)**

See Figure 2.3 for the top layer geology across the country.

The geology of Timor-Leste can be summarized as follows:

a) Permian Formations of Ailue and Maubisse Formations from the north to East Timor, consisting of schist and shale sediment weathered to become weak talus of silty soil on the ground.

b) Nesozoic Formation located in the central mountain area, consisting of shale, mudstone and limestone sediment weathered to become weak clayey soil.

c) Cenozoic Formation located in the southern hilly area, consisting of loose river terrace with sandstone and limestone sediment and largely collapsed by water penetration.

Based on the above, the surface geology of Timor-Leste is concluded to be generally weak for roads on natural ground.

3.2 Survey of Road Facilities

3.2.1 Survey of the Existing Pavement

Regarding the north-south national roads, a survey was carried out of the pavement condition of National Road Routes A04, A05, A06, A09, A10, A11 and A12 which may be particularly susceptible to road disaster. As for the southern coastal roads which were not the subject of the survey, when any of the route turned out to be part of the route surveyed, the current pavement condition of the road was also surveyed for A07 and A13.

Figure 3.1 shows the survey results of each route in comparison with Route A02, which was the subject of the sample survey.

A02		A04		A05		A06		A07		A 09		A10		A11		A12		A13	
km	IRI	km	IRI	km	IRI	km	IRI	km	IRI	km	IRI	km	IRI	km	IRI	km	IRI	km	IRI
0 Dili	7	**0 Tibar**	7	**0 Aitutu**	11	**0 Baucau**	5	**0 Viequqe**	9	**0 Manatuto**	7	**0 Ermera**	11	**0 Ermera**	11	**0 Maliana**	9	**0 Cassa**	11
5	7	*5*	7	5	11	5	6	5	9	5	7	5	11	5	11	5	7	5	11
10	11	10	9	10	11	10	7	10	11	10	7/9	10	11	10	11	10	7	10	11
15	9/11	*15*	9	15	11	15	6	15	9/11	15	7	15	11	15	11	15	7	15	11
20	9/11	20	7	20	11	20	9/11	20	11	20	5	20	11	20	11	20	11	20	11
25	9/11	*25*	7	25	11	25	7/9	25	9/11	25	7/9	25	5	25	11	25	11	**25 Aiassa**	11
30	9/11	30	9	30	9	30	11	30	9/11	30	11	30	11	30	11	30	11		
35	9/11	*35*	11	35	5	35	11	35	9	35	11	35	11	35	11	35	11		
40	9/11	40	11	40	9	40	11	40	9/11	40	11	40	11	40	9	40	9		
45 Aileu	7	**45 Ermera**	11	**43 Aiassa**	7	45	11	45	11	45	11	45	11	45	9	45	11		
50	7					50	11	**46 Natarbo**	9	50	11	50	11	50	9	50			
55	11					55	9			55	9	55	13	55	9	**50.9 Zumalai**	9		
60	11					**58 Viqueque**	7			60	9	60	13	60	7				
65	9/11									65	7	**68.5 Loroba**	13	**62.5 Maliana**	7				
70	9/11									70	9								
75 Maubisse	9									75	9								
80	9										7/9								
85 Aitutu	9/11									**85.2 Natarbora**	7								
90	9/11																		
95	9/11																		
100	9																		
105	9																		
110 Ainaro	9/11																		
115	9																		
120	7																		
125	7																		
131.3 Cassa	7																		

(Solid circle) Pavement Maintenance Level
(Dashed circle) Pavement Re/New construction Level

pothole	crack	I R I
large	alligator	11
small	crack	9
-	small	7
-	-	5

Figure 3.1 Pavement condition of north-south national roads

Source: JICA survey team

(1) Route A04

The pavement condition of Route A04 that branches off from Route A03, the northern coastal road, at Tibar and runs through the south of the rural city in west Ermera is as follows: The International Roughness Index (IRI) of the section from Tibar to the 30km point is level 7 to 9, meaning fair. However, the IRI of the subsequent section up to Ermera is poor at level 11 and requires urgent repair of the pavement. For instance, a road repair project including road widening and pavement repair is scheduled and will start this year with the support of the ADB.

(2) Route A05

Route A05 branches off from Route A02 in Aituto which is located in the central mountains, and leads to Aiassa which is located at the intersection with Route A13, via Same, a major city in the southern part of the country. The IRI at the 25km point in the mountain section of Aituto to Same is 11; in the long term it will completely turn into road sand. The subsequent section from Same to Aiassa is a section where the asphalt pavement was recently repaired and the IRI is good at level 5 to 9. However, with regards to the 25km point in the mountain section from Aituto to Same, the road has been washed away because of the collapsed embankment and cut into three (3) locations, and it is difficult to bypass the affected area in spite of excavation at the existing cutting that is underway to secure the adequate road width. Nevertheless, since the collapsed embankment is advanced, drastic measures are required to avoid a worse scenario.

The pavement of these sections has been completely damaged and the road has turned into road sand. (See Photo 3.9.)

Photo 3.9 Large-scale collapse and pavement condition of Route A05

(3) Route A06

Route A06 branches off from Route A01, a northern coastal road, at Baucau and leads to Viqueque, a rural city in the south. While the IRI of the section in the central mountains is 9 or 11, the pavement condition of the preceding and subsequent sections is relatively good with an IRI of 5 to 9.

(4) Route A07

The pavement of Route A07, the southern coastal road linking Viqueque and Natarbora, has been significantly damaged and the IRI from beginning to end is 9 or higher. Furthermore, this route crosses the river and is no less than 50 meters wide at the 36.7km point from Viqueque, but it is difficult for any vehicles to cross the river because of the lack of a bridge and approach roads on both banks of the river. However, in order to transport commodities along the southern coast and exports to Viqueque Port, vehicles are required to detour by way of Routes A09, A01 and A06 and the building of a bridge in particular is immediately required.

(5) Route A09

Route A09 branches off from Route A01, the northern coastal road, at Manatuto and leads to Natarbora, a rural city in the south. Road repairs are urgently required along this route as the IRI of the section from the central mountains of Natarbora is 9 or 11 and a major landslide occurred in the central mountains. On the other hand, the pavement condition of the section from Manatuto to the 25km point is relatively good with an IRI of 5 to 9. Currently, detailed design is in progress with the support of the ADB for the repair of Route A09. The mountain part of Route A09 has sections with pavement consisting of an earthen subbase course, crusher-run stone base course and asphalt surface course. The surface course of these sections has been significantly deformed because of the outflow of fine granules at the subbase course caused by penetration of precipitation and groundwater into the subgrade. With regards to the improvement of the pavement in these sections, it may be necessary to consider countermeasures to prevent the penetration of water into the subgrade, such as the use of crusher-run stones or natural stones to construct the subbase course.

(6) Route A10

The pavement of Route A10, which passes through the mountains in the west and links Ermera on Route A04 with Lorba on Route A12, is significantly damaged and the IRI for almost the entire route except some sections is 11 or higher. As this route runs through steep mountains, it is difficult to develop a detour, so in this case, it is essential to develop or maintain the existing road. In addition, a chain of private houses exists along the route and the residents are actively engaged in farming, so it is essential to ensure the transport of daily commodities by land using the road. Repair of the damaged sections is particularly necessary for the reasons described above. Regarding the sections affected by damaged embankment caused by culvert failure as described below (the natural subgrade was swept away due to water leaking from the joints caused by inadequate coverage of backfilling soil materials and lack of concrete protection of the culvert joints), the natural subgrade and pavement should be repaired as soon as possible not only on Route A10 but also on other routes and countermeasures taken. (See Photo 3.10)

Photo 3.10 Road swept away due to culvert failure and pavement condition of Route A10

(7) Route A11

Route A11 links Ermera, the endpoint of Route A04, to Maliana, the starting point of Route A12. The IRI for the mountain section of this route from Ermera to the 35km point is level 9 or 11 and the bridge about seven (7) kilometers from the starting point has failed because the abutment was washed away. Vehicles crossing the river use the path of a submersible bridge located upstream, but since the bridge cannot be utilized when the water level is high, corrective measures are urgently required. Vehicles passing each other is not obstructed in the subsequent sections where the IRI is 7 to 9. With regards to the section around Milimao Bridge where the road has collapsed, construction work had been carried out for improvement purposes.

(8) Route A12

Route A12 links Maliana, the main city in the west, and Zumalai on Route A02, which runs southward. While the pavement of the section near the starting point and endpoint have only small problems, the pavement in the central section which passes through the upland area consisting of Mesozoic formation is significantly damaged and has an IRI of 11. Particularly the section that passes over a ridge consisting of a thick layer of sediment, large-scale natural ground collapse was observed at multiple locations. As a result, the road is also on the verge of collapse. (See Photo 3.11)

Because of the scale of the collapse, extensive natural measures are required to protect the improved section. However, since the traffic volume on this route is small, it is difficult to justify the cost of extensive repairs. In addition, it may be appropriate to consider countermeasures to detour or bypass the section for improvement

Photo 3.11 Large-scale collapse and pavement condition of Route A12

(9) Route A13

Route A13 is the southern coastal road that runs from Cassa on Route A02 to Aiassa on Route A05. All sections of this route pass through fluvial terrace plateaus, but the simple asphalt pavement was totally damaged and has an IRI of less than 11, equivalent to that of road sand.

Therefore, it was determined, when looking at the southern coastal roads that link the cities in the south, that damage to the pavement on Route A13 and the bridge which is used very often to cross the river on Route A07 form a bottleneck, and it is urgently required to develop improvement countermeasures.

3. 2. 2 Division of the Route by Characteristics

The following table summarizes the characteristics of slope disaster for each representative area classification.

Table 3.1 Representative area classifications

Geological Era	Cutting Surface/Outcrop	Features of Disaster	A04	A05	A09	A10	A11	A12
Aileu Formation	・The soil is mostly clayey soil mixed with gravel and reddish-brown (lateritic) soil. ・The rocks are mostly schist and susceptible to weathering. They become very fragile when they contain moisture.	・The embankment has collapsed because of the inflow of a large amount of rainwater from the mountain side and the road surface, which gathers and seeps into the embankment.	○			○	○	
Mesozoic (Steep slopes in the mountains)	・The road has been built on an extremely steep and long hilly slope. ・A substantial amount of spring water is observed in parts of the road. The topography is susceptible to landslide disaster. ・Clayey soil mixed with gravel covers the top layer. ・The rocks consist of shale and schist that are susceptible to weathering and become fragile with moisture.	・Because the slope is steep, long and unstable, collapse may lead to a deep-seated collapse. ・A large amount of spring water is observed at some locations, which may cause the road to collapse without rainfall. ・Collapsed earth and sand have fallen onto the side of the very deep valley below the road and formed an unstable slope.	○					
Mesozoic (Foothills)	・The gradient of the cutting slope and the mountain slope behind the road is gentle, but the groundwater level behind the road is high. ・The soil is mostly clayey soil mixed with gravel, clay, mudstone, shale and schist, which are prone to weathering and extremely susceptible to water.	・Since the groundwater level is high, a large amount of spring water always flows from the cutting slope. ・The spring water also makes a great impact on the embankment on the valley side, causing the embankment surface to collapse or subside. ・Slope collapse does not occur instantly except during rainfall but progresses slowly and extensively.			○			
Mesozoic (Mountains)	・Rockfall often occurs from the cutting surface of the bedrock on the mountain side (dip slope). ・The rocks are mostly mudstone, shale and schist.	・Because the slope is a dip slope, block-shaped rocks separated from the joint surface during rainfall are liable to fall, causing the slope to collapse.			○			

Mesozoic (Mountain ridges)	・Slopes formed after collapse are liable to collect rainwater. ・The soil mostly consists of clayey soil mixed with gravel and clay. ・The rocks are mostly mudstone, which easily weathers. ・Mudstone becomes very fragile when it contains moisture.	・The roads mostly pass along the ridges. Gully erosion observed on one of the slopes has progressed and caused deep-seated collapse. ・The slope on the valley side is very steep. The other slope is not steep but is liable to collapse because of geological similarities. ・The road surface is in poor condition. Major subsidence is observed in parts.						○

3. 2. 3 Analysis of the Causes of Damage to the Pavement associated with Damage to the Road

With regards to the north-south national road network, the survey was carried out of damage on Routes A04, A05, A06, A09, A10, A11 and A12. Figure 3.2 shows the classification of the causes of damage.

The causes of damage were classified into five (5) types in accordance with the classification survey of Route A02.

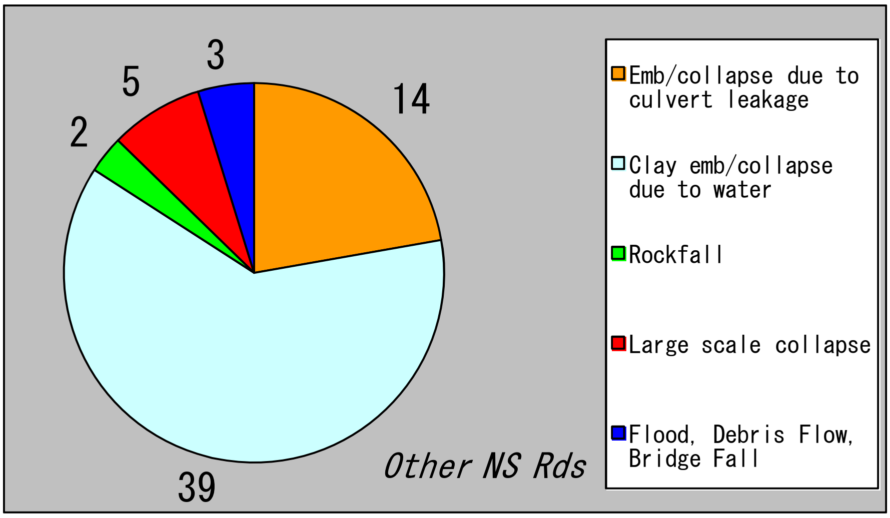


Figure 3.2 Classification of the cases of damage to the road pavement by cause

Source: JICA survey team

As in the case of Route A02, the main cause of the damaged roads covered by the survey is "Clayey Embankment Collapse due to Water". In comparison to the causes of damage to Route A02, one of the characteristics is that a quarter of all road damage was caused by "Embankment Collapse due to Culvert Leakage". This means that it is possible to reduce the costs of road repair works and improvement merely by eliminating the cause of road damage relating to inadequate technical standards.

3. 3 Analysis of Road Damage Frequency and Mechanism by Area Classification

Figure 3.3 shows the frequency of damage per 10km as classified by geological age and precipitation.

Formations of different geological debilitated deception from north to south in Timor-Leste in order of debilitation with a Paleozoic formation (Aileu Formation) located in the north, followed by a Paleozoic formation (Maubisse Formation) and Mesozoic and Cenozoic formations.

The Paleozoic formation (Aileu Formation) and Mesozoic formation are divided into an area with precipitation over 2,000mm and an area with 2,000 mm or less precipitation.

The Paleozoic formation (Aileu Formation) and Mesozoic formation are divided into an area with a precipitation of over 2,000mm and an area with a precipitation of 2,000mm or less.

The frequency of pavement damage is highest in the area where the geological debilitation is Mesozoic and the annual precipitation exceeds 2,000mm. “Clayey Embankment Collapse because of Water” is far by the most common cause of pavement damage. This is also the most common cause of pavement damage in the other areas. Damage caused by “Large Scale Collapse” frequently occurs in the Mesozoic formation area with an annual precipitation exceeding 2,000mm. This suggests that ground comprised of Mesozoic formation with high precipitation is fragile. Damage caused by “Embankment Collapse due to Culvert Leakage” has occurred in all the areas covered by the survey, but the frequency is marked in areas with an annual precipitation of over 2,000mm.

“Flood, Debris Flow and Bridge Fall” is the second major cause in the Cenozoic formation area. In view of this, it might be ground comprised of Cenozoic formation that has not yet consolidated.

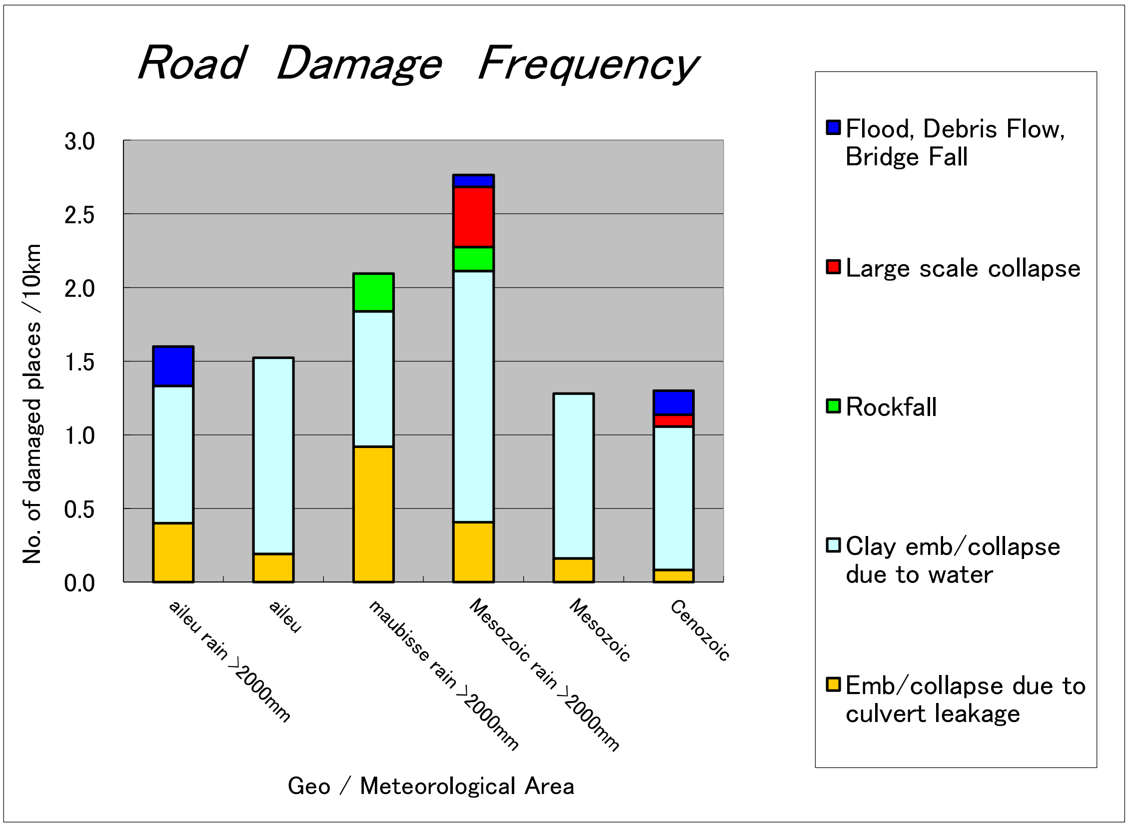


Figure 3.3 Road damage frequency by area classification

Source: JICA survey team

As is surmised based on the causes of road damage by area classification, road damage is particularly frequent in areas with high annual precipitation where the geological age is Mesozoic. Therefore, it is important to consider the precipitation and geological age when looking at points to be noted regarding road construction and maintenance in Timor-Leste.

3. 4 Similar Causes between A02 and National Road Network

It was confirmed by A02 that embankments which are classified as clayey soil are prone to collapse due to infiltration of water under conditions of annual precipitation of 2,000mm or above and groundwater discharge. Embankment collapse due to water is a major cause of road damage.

Meanwhile, for nationwide roads as well as A02, a major cause of road damage is identified as clayey embankment due to water. Damage to embankments due to water in the Mesozoic formation area with high annual precipitation over 2,000mm is especially conspicuous. The other four (4) main causes of collapse of the road on other national roads are also the same as for A02.

From the above, it may be inferred that similar natural conditions such as topography, geology and high annual precipitation as those of Route A02 might be a cause of similar road damage.

Chapter 4 Summary of findings from nationwide survey and sample survey

4.1 Natural Conditions

Timor-Leste was thrust up by tectonic plates, and is formed of geological formations in the Paleozoic era, Mesozoic and Cenozoic era from the north. Aileu and Maubisse formation in the Paleozoic era, fragile schist and shale outcrops that are weathered with many joints and collapsed clay deposits are found. In the Central Mountains with an altitude of approximately 3,000 meters, the annual rainfall is more than 2,500mm, and there are outcrops of mudstone, shale and limestone. The coastal area or river terrace in the south is covered with alluvium, and there are outcrops of sandstone and limestone.

Route A02 (between Dili and Cassa), which crosses the island of Timor-Leste in the north-south direction, runs through areas with geological and topographic features typical of Timor-Leste, including the section in the south with fragile and unstable ground, the sections with highly weathered ground and sections susceptible to landslides, as well as the plains, hills and mountains. Natural conditions, such as rainfall, temperature, stratigraphic and geological characteristics, which vary along the route as it runs through the areas with all the topographic and geological conditions that exist in Timor-Leste, have a significant impact on the condition of Route A02. The above-mentioned findings and damage on Route A02 are also found on other national roads nationwide. It was confirmed that significant damage impact to the roads is caused by the topographic and geological conditions in Timor-Leste.

4.2 Pavement Condition

The existing pavement condition in the mountain area is significantly damaged. Existing pavement at this level requires urgent repair work.

4.3 Cause of Damage to the Pavement Structure

- Surface damage is conspicuous where there is no base course and the bearing capacity of the subgrade (CBR) is 6.6 or lower.
- Surface damage is found where the bearing capacity of the subgrade (CBR) is 6.6 or lower.
- Pavement deterioration is conspicuous where the base course materials are clayey, even when the bearing capacity of the subgrade (CBR) is 8 or higher.

4.4 Cause of Damage to the Pavement due to collapse of Road

- The main cause damage of roads covered by the survey is “Clayey Embankment Collapse due to Water”.
- One characteristic is that a quarter of the road damage was caused by “Embankment Collapse due to Culvert Leakage”.

- Large scale collapse has also a measurably high percentage especially in the Mesozoic and Cenozoic formations.
- Falling rocks from slopes when water derived from rainfall had infiltrated the slope and loosened the earth supporting a block of rocks. After the rocks have fallen, groundwater discharged from the slope damages the pavement.
- Debris flow due to heavy rainfall carries deposit from the streambed downstream, water overflows the drainage structures because there is small flow area, and the overflowing water causes damage to the pavement.

4.5 Considerations

It is extraordinarily difficult to construct roads that can endure the severe natural conditions of Timor-Leste, where various factors synthesize and contribute to road weakness. In this survey, the road damage frequency and main factors of road damage have been specified, as described in Chapters 2 and 3. Countermeasures for the road damage could be summarized as follows;

(1) Road Damage Frequency and Mechanism by Area of Classification

The frequency of road damage is particularly high in areas with high annual precipitation where the geological age is Mesozoic.

It is possible to reduce the costs of road repair and improvement merely by eliminating the cause of road damage relating to inadequate technical standards.

(2) Pavement condition and clayey material subgrade with high groundwater level

- Large drains and an underground drainage system should be installed on the mountain side of the road in order to minimize the infiltration of rainwater into the subgrade.
- Use of sandy soil and gravel with good drainage capacity should be considered as a means of improving the subgrade.
- Expansion of cutting should be considered as an additional measure to prevent collapse of the embankment.

(3) Backfill Material at Gabion

- No use of clayey material derived from weathered shale and schist as the backfill material.
- Lowering the rise in groundwater level and pore water pressure at places with high precipitation where surface water is likely to accumulate.

Details of the countermeasures (1), (2) and (3) mentioned above are described in Chapter 5.

Chapter 5 Points to be noted in Road Design and Maintenance

5.1 Points to be noted in Road Design

As mentioned in the previous chapter, the causes of damage to the road pavement are classified into five types. Regarding the locations where damage occurs, road damage frequently occurs in those areas with high annual precipitation and also road damage frequently occurs in areas where Mesozoic Era formations are found particularly at the ground surface. Therefore, data on precipitation and the geological eras of the surface formations should be taken into consideration in the preparation of road design in Timor-Leste.

Countermeasures to be undertaken at the time of road design and maintenance against the main and subsidiary causes of each of the five types of road damage are described in the following details.

5.1.1 Measures against each type of disaster

Table 5.1 shows the basic countermeasures to be taken at the time of road design against each of the causes of damage.

Table 5.1 (a) Causes of damage to the roads and measures to be taken at the time of road design

Existing Damage			Re and New Construction
damage 1	**Clay embankment collapse due to water infiltration**		New construction of embankment with adequate protection
	main cause	High level of underground water	Installation of blind and horizontal drainage on slope (Photo 5.1)
	sub cause 1	Infiltration of surface water	Installation of vertical and berm drainage on slope (Photo 5.2)
	sub cause 2	Sagging and changing point of vertical gradient	Protection of culvert joints by concrete
	sub cause 3	Existence of clay embankment soil	Improvement of embankment material
	sub cause 4	No proper specifications for soil classification	Establishment of specifications for soil classification and testing method
damage 2	**Emb/collapse due to culvert leakage**		Construction of new culvert with enough depth
	main cause	Not enough depth of culvert cover	
	sub cause 1	No concrete fixing of culvert joints	Protection of culvert joints by concrete
	sub cause 2	No proper specifications for soil classification	Establishment of culvert specifications

Source: JICA survey team

Table 5.1 (b) Causes of damage to the roads and measures to be taken at the time of road design

Existing Damage			Re and New Construction
damage 3	**Flood, debris flow, bridge fall**		Construction of large capacity facilities
	main cause	Low discharge capacity	Bridge recommendable rather than culvert
	sub cause 1	Blocking by rocks/ no maintenance	Removal of rocks
	sub cause 2	Weak filling material	Selection of better filling material
damage 4	**Large scale collapse**		New construction of sifting or bypassing embankment with adequate protection
	main cause	Weak slope material	
	sub cause 1	High underground water level	Installation of blind and horizontal drainage (Photo 5.1)
	sub cause 2	Existence of clay embankment material	Introduction of grating crib (Photo 5.3) and shotcrete (Photo 5.4)
	sub cause 3	Failure of proper drainage	Vertical and berm drainage on slope (Photo 5.2)
damage 5	**Rockfall**		Cutting of dangerous rock
	main cause	Aging/weathering of rock	Shotcrete, rock net and gabion wall

Source: JICA Survey Team

Photo 5.1

Photo 5.2

Photo 5.3

Photo 5.4

Drainage work and reuse of soil generated at the site are additional countermeasures applicable to all types of causes. Details of these countermeasures are described in the following.

(1) Drainage Work

In many cases, water including rainwater that has infiltrated the ground and surface water, causes pavement damage associated with road damage. In many cases, rainwater that has infiltrated weathered clayey soil, the main component of natural ground material, causes gully erosion of the slope surface, leading to the occurrence of shallow and deep-seated collapse. In this case, appropriate drainage planning and design are essential.

The drainage work consists of drainage of discharged groundwater, drainage by road structures and drainage from the slope.

・ Drainage of discharged groundwater

The stability of the slope is established by the installation of horizontal drainage holes and slope protection work with drainage taken into consideration, *e.g.* crib work, where there is a risk of discharge of groundwater from a cut slope or in the event of rain. In this case, the water discharged from the horizontal drainage holes is discharged direct to the terrace drains so that it does not infiltrate the slope.

・ Drainage by road structures

Important measures that can be taken regarding road structures against damage of the road include (1) installation of ditches with sufficient flow area on the mountain side of the road, (2) installation of underground drains below the ditches to lower the groundwater level on the mountain side, (3) application of sufficient earth covering on cross culverts and concrete pipes,

(4) installation of cross culverts with sufficient flow area, and (5) joint protection in the cross culverts.

・ Drainage of slope surface

Intercepting ditches, berm drains and vertical drainage can be used for drainage of the slope surface. An intercepting ditch is constructed along the top edge slope to prevent the flow of surface water from the adjacent land slope. Berm drains are constructed in slopes with a length of 5 meters or more. Longitudinal ditches are constructed along the slope. This allows the water to drain into an intercepting ditch or berm drain and be discharged into the channel at the slope toe to control the discharge.

(2) Reuse of Soil Generated on Site for Embankments

Reuse of soil produced at the site created by collapse of roadside cut slopes as material for embankments was observed and studied at many locations of the national road network. The ground material at sites where the cut slopes have collapsed mainly consists of weathered material. It is characterized as weakened by water infiltration.

Points to consider when soil materials generated at the site will be used again are as follows:

Characteristics of good embankment material

The characteristics which are generally considered recommendable for good embankment material are as follows:

- High density and shear strength;
- Easy to compact;
- Absence of expansion or contraction which may affect the stability of the embankment;
- Absence of organic matter which may change the physical characteristics of the material;
- Little pore water pressure generated during the work; and
- Easy to transport

From the viewpoint of cost-efficiency, it is better to use material produced at the site or material that it is easy to obtain near the site for embankment work. However, there are many cases where good-quality material is not available on local markets. From the results of analysis of the causes of collapse and the material characteristics produced at the site, *i.e.* weathered clayey soil, it is deemed that the influx of water contributes significantly to collapsed embankments. Therefore, it should be noted that use of material produced at the site needs adequate measures against water infiltration.

5.1.2 Recommended Measures against Large-scale Collapse on Route A05

At the 25km point, the mountainous section at Aituto and the origin of Route A05 and Same, there are three locations where the need for urgent countermeasures is being addressed with the budget of the Government of Timor-Leste after the occurrence of large-scale collapse.

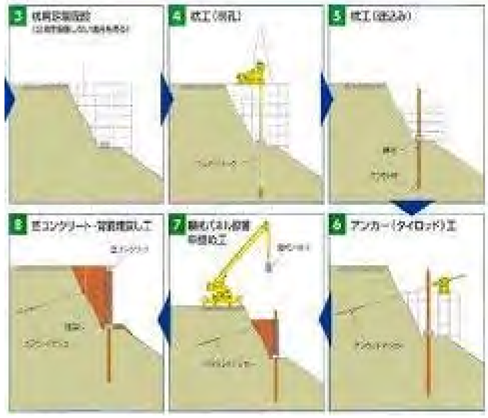
The table below shows the permanent recommended measures for cut slopes and embankment slopes at the site of a large-scale collapse.

Recommended measures for cut slopes

Option 1	Option 2	Option 3
Mortar-spray cribs	Mortar-spray cribs	Re-cutting & planting
		
Anchor work on the slope	Underground drainage work	Re-cutting & sodding
		

Recommended measures for embankment slopes

Option 1	Option 2
Mortar-spray cribs, anchor work	H-beam soldier piles and lagging, ground anchors
	

Re cutting & Underground drainage work	Method for Construction
	

5.2 Points to be Noted in Road Maintenance

5.2.1 Emergency Response at Times of Disaster

Emergency response in times of disaster aims for countermeasures to be taken immediately after the occurrence of the disaster for prompt resumption of road traffic and preparation for temporary countermeasures while maintaining the safety of road traffic. The major components of emergency response are (1) removal of earth and (2) water disposal.

(1) Removal of Earth

Removal of earth must be implemented without aggravating the damage or risk when working. The following are the points to be noted.

(i) Collapsed earth soil from the upper slope should be removed first, as starting removal from the lower part will disturb the equilibrium of the earth soil. Because of the high risk of the occurrence of another collapse, the condition of the upper slope should be monitor during the removal.

(ii) The upper part of the collapse surface usually has a steep gradient and in many cases is in an unstable condition. In some cases, work below the collapsed slope should be implemented after the main scarp had been stabilized.

(2) Drainage

Drainage is very important for keeping the damage to a minimum. As contact with water generally weakens the earth soil, the water needs to be drained immediately and appropriately. The following points should be noted regarding drainage.

(i) The collapsed surface slope should be covered with sheets. Attention should be given to not allowing the water to infiltrate the ground surface from where two adjacent sheets overlap each other.

(ii) If there is a risk of runoff of the collapsed earth soil, a berm should be constructed with sandbags near the base slope to prevent disturbing the traffic. However, if the berm is constructed without any gaps, water will accumulate along the berm and the accumulated water may adversely affect the road. In such cases, one or two temporary drain holes should be made in the berm.

(iii) In order to prevent infiltration of rainwater from the top of the collapsed slope, a temporary drain should be constructed with sandbags or other appropriate material above the main scarp.

(iv) In order to prevent infiltration of rainwater from the top of the collapsed slope, a temporary drain should be constructed with sandbags or other appropriate material above the main scarp.

Table 5.2 Types and purposes of temporary countermeasures

General purpose	Temporary countermeasure	Purpose of use	Notes
Measures against water	Construction of sandbag berm Temporary drainage work Installation of gabions Sheet covering	Shutoff and drainage of influent water Shutoff and drainage of influent water Disposal of discharged groundwater Prevention of rainwater infiltration	Also used for prevention of runoff of collapsed earth and local slope stabilization
Measures for stabilization of artificial and natural slopes	Earth removal work Installation of gabions Construction of sandbag berm Cutting of collapsed earth	Stabilization of artificial and natural slopes Reinforcement of surface and toe of slope Reinforcement of surface and toe of slope Prevention of shallow collapse	Where the scale of the collapse is large Where discharge of groundwater is observed Where discharge of groundwater is observed Where there is no risk of further damage
Measures to eliminate risk to road traffic	Temporary protection work	Prevention of rockfall and screening	
Measures for the maintenance of traffic routes	Detour	In case it takes a long time to repair the road	

5.2.2 Maintenance

Road maintenance should be implemented with attention paid to the following.

(1) Clay embankment collapse due to water infiltration

<u>Monitoring of cut slope surface for discharge of groundwater</u>

Cut slopes are relatively steep and stable without any supports. However, they are highly susceptible to water infiltration from the rear side; there is a risk that water infiltration may cause their sudden collapse. Therefore, the slope should be inspected for discharge of groundwater on a regular basis. If any discharge is confirmed, a survey should be conducted to locate the source of the groundwater, and appropriate countermeasures such as installing roadside ditches and installing blind drainage under the roadside ditches should be taken against the discharge. Also, it is better to install gabion walls for the protection of the slope.

Pavement and Subgrade

It is essential to repair the existing damaged pavement and subgrade. In the event that a clay embankment has collapsed because of water infiltration, the damaged pavement and subgrade material should be removed. As well as replacement by suitable material, cross culverts and blind drainage should be installed to allow water flow. During the construction work, it is better to block public traffic; however, in case blocking of public traffic is difficult to do, it will be better to make a detour around the construction site.

Vegetation on natural and artificial slopes

Poor vegetation on the slope allows weakening of the slope due to rainwater infiltrating the slope. Plants on the slope may fall to the bottom of the slope and clog the drainage system if the roots have not taken properly. This means that vegetation on the slopes should be inspected on a regular basis and kept in good condition.

Progress of gully erosion on the valley side

Gully erosion on the valley side may develop into shallow collapse, affecting the road surface; regular maintenance work should be conducted on the slopes on the valley side. It is essential to conduct a detailed survey to identify the causes of erosion and implement urgent countermeasures when gully erosion is observed on a slope.

Displacement and settlement of gabions

The condition of the gabions should be monitored for displacement and settlement in places where they are installed. As mentioned above, it is essential to conduct a detailed survey to identify the causes of erosion and to implement urgent countermeasures when displacement or settlement is observed.

Monitoring of potholes in road surface and settlement of road surface

When the appearance of potholes in the road surface or settlement of the road is observed, the potholes and subsided parts should be filled in so that normal road-surface drainage is maintained.

(2) Embankment collapse due to culvert leakage

Inspection of roadside drain ditches and cross culverts for accumulation of earth, wood debris and stagnant water and inspection of drains and cross culverts for damage

Drains and cross culverts play an important role in water discharge in places where it can be disposed of. Earth soil deposits in the drains may cause overflow or leakage of water onto the slope surface on the valley side, causing gully erosion and shallow collapse. For this reason, earth and wood debris in the drains should be removed immediately. It may damage the joints in the drain or cause the cross culvert to collapse, thus causing collapse of the slope in a similar way. A collapsed drain or collapsed cross culvert should be replaced and culvert joints should be protected by concrete foundations as soon as they are detected.

<u>Monitoring of clogging of drain pipes and footing depth</u>

Culverts should be inspected for clogging of the drain pipes and insufficient toe depth. If any of these problems is observed, the cause should be identified and urgent repair work should be undertaken.

(3) Flood, debris flow, bridge fall

<u>Monitoring of earth deposits in streams</u>

The cause of most debris flows in streams is earth on the streambed. Therefore, it is possible to predict the occurrence of debris flow by monitoring the earth deposits in the streams.

<u>Monitoring of collapse in river catchment areas</u>

At present, the vegetation in the catchment areas along the roads is rich and sound. However, there is no guarantee that it will remain in a rich and sound condition in future. Therefore, it is necessary to monitor the condition of the vegetation once a year after the end of the rainy season.

<u>Monitoring of collapse of surface and embankment</u>

Damaged roads should be replaced with suitable material from the subgrade to the surface. Subgrade material is required to have a modified the CBR value of over 7 at least. Base and subbase course material are required to be crushed rock. Every layer should be well compacted and then a field density test carried out to confirm the degree of compaction. During repair work, public traffic should take a detour around the road on a temporary basis.

(4) Large scale collapse

<u>Monitoring of surface course and terrain around the roads for cracks and settlement</u>

The roads located in the mountain area or in the fluvial terrace surface adjacent to the slope may collapse. Therefore, the roads in such locations should be monitored constantly in order to detect signs of the occurrence of collapse. When cracks or settlement is observed, a slope survey or terrace survey should be conducted and a detour road temporarily established to avoid congested public traffic.

(5) Rockfall

<u>Quantity of loose and trapped rocks on the slope</u>

Loose rocks and trapped rocks in the slope protection should be removed as soon as possible to avoid congestion of public traffic. A gabion wall for rock pocket should also be installed along the road side.

(6) Others

In case of Deteriorated Pavement on weak clay subgrade,

- First of all, weak clay subgrade should be replaced with suitable material if the CBR value of the existing subgrade material is less than 3. It is better to lay the subgrade layer with a minimum thickness of 45cm. Then, the appropriate crushed stone base course and surface pavement should be constructed.
- Blind drainage under the roadside drainage should be installed in order to lower the groundwater level. The blind drainage must be connected to the drainage to allow the flow of water. But the execution of drainage work depends on the cost effectiveness.

In case of Deteriorated Pavement on No Base Course

- After confirming the CBR value of the existing layer, unless the CBR value of the existing layer is less than 3, an appropriate crushed stone base course and surface pavement should be constructed.

In case of Deteriorated Pavement where underground water level is high

- Blind drainage under the roadside drainage should be installed in order to lower the groundwater level. The blind drainage must be connected to the drainage to allow the flow of water.
- Blind drainage should be installed in the cross section direction at intervals of around 25 to 30 m. But the execution of drainage work depends on the cost effectiveness.

5.3 Other Points to be noted

The following items are points to be noted with the exception of road design and road maintenance.

・Timor-Leste has high annual precipitation which was assumed to be one of the causes of damage in the classification of the causes of road damage. Areas where Mesozoic Era formations are found in the surface are particularly characterized by the frequent occurrence of pavement damage associated with road damage. Road network development planning in particular areas requires an understanding of the characteristics of every route and preparation of appropriate countermeasures; it requires the implementation of a feasibility study for road network development nationwide and establishment of a road construction priority order. Disaster countermeasures should also be considered.

・Elimination of the causes of damage deriving from human error, such as road damage due to water leakage from defective joints in the cross culverts, is also required to create a standardized design environment by countermeasures including design guidelines revision. Meanwhile, the elimination of disparities in pavement design will require the establishment of a pavement design manual and standardization of pavement specifications.

・Implementation of appropriate temporary countermeasures for emergencies, regular maintenance work that requires strengthening of the operation & maintenance mechanism, establishment of the scope of maintenance and repair work, improvement of the organizational structure and capacity development of the staff members concerned.

Appendix

Appendix-1 Survey Schedule

No.	Date				Team Leader/Surface Geology	Soil/Slope, Ground	Road Pavement	Soil/Slope, Ground II
					MUTO Hisashi	KOKUBU Hiroshi	SHIMIZU Nobuharu	SAKANAKA Shutaro
1	3	19	Tue		Narita－Denpasar			
2	3	20	Wed		Denpasar－Deli			
3	3	21	Thrs		Courtesy call on MOPW/DRBFC, Explanation of Inception Report, Meeting with JICA			
4	3	22	Fri		Joint Site Study (A02)			
5	3	23	Sat					
6	3	24	Sun		Internal Meeting			
7	3	25	Mon		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
8	3	26	Tue		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
9	3	27	Wed		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
10	3	28	Thrs		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
11	3	29	Fri	Good Friday	Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
12	3	30	Sat		Arrangement data	Arrangement data	Arrangement data	Arrangement data
13	3	31	Sun		Internal Meeting			
14	4	1	Mon		Arrangement data	Arrangement data	Arrangement data	Arrangement data
15	4	2	Tue		Seminar in MPW			
16	4	3	Wed		Arrangement data/Preparation fo Site survey			
17	4	4	Thrs		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
18	4	5	Fri		Site Study (A02)	Site Study (A02)	Site Study (A02)	Site Study (A02)
19	4	6	Sat		Site Study (A05)	Site Study (A05)	Site Study (A05)	Site Study (A05)
20	4	7	Sun		Internal Meeting			
21	4	8	Mon		Meeting with MPW/Arrangement of Data			
22	4	9	Tue		Interview with Local Contractor	Preparation of Site survey	Interview with Local Contractor	Preparation of Site survey
23	4	10	Wed		Site Study (A06)	Site Study (A06)	Site Study (A06)	Site Study (A06)
24	4	11	Thrs		Site Study (A09)	Site Study (A09)	Site Study (A09)	Site Study (A09)
25	4	12	Fri		Site Study (A09)	Site Study (A09)	Site Study (A09)	Site Study (A09)
26	4	13	Sat		Arrangement data	Arrangement data	Arrangement data	Arrangement data
27	4	14	Sun		Internal Meeting			
28	4	15	Mon		Meeting with MPW/Arrangement of Data			
29	4	16	Tue		Meeting with MPW/Arrangement of Data			Deli－Denpasar
30	4	17	Wed		Site Study (A04, A11)	Site Study (A04, A11)	Site Study (A04, A11)	Denpasar－Narita
31	4	18	Thrs		Site Study (A12)	Site Study (A12)	Site Study (A12)	
32	4	19	Fri		Site Study (A10)	Site Study (A10)	Site Study (A10)	
33	4	20	Sat		Arrangement data	Arrangement data	Arrangement data	
34	4	21	Sun		Internal Meeting			
35	4	22	Mon		Meeting with MPW/ Preparation of document			
36	4	23	Tue		Meeting with JICA/ Preparation of document			
37	4	24	Wed		Preparation of document/Arrangement data			
38	4	25	Thrs		Seminar in MPW			
39	4	26	Fri		Preparation of Progress Report			
40	4	27	Sat		Site Study (A02)	Site Study (A02)	Site Study (A02)	
41	4	28	Sun		Internal Meeting			
42	4	29	Mon		Meeting with MPW/Preparation of Progress Report			
43	4	30	Tue		Preparation of Progress Report			
44	5	1	Wed	Labor Day	Preparation of Progress Report			
45	5	2	Thrs		Preparation of Progress Report			
46	5	3	Fri		Meeting with DRBFC, Submission and Explanation of Progress Report			
47	5	4	Sat		Report to JICA/ Preparation of document			
48	5	5	Sun		Internal Meeting			
49	5	6	Mon		Meeting with MPW, Report to Embassy of Japan			
50	5	7	Tue		Deli－Denpasar			
51	5	8	Wed		Denpasar - Jakarta - Narita			
52	5	9	Thrs					
53	5	10	Fri					
54	5	11	Sat					
55	5	12	Sun					
56	5	13	Mon					
57	5	14	Tue					
58	5	15	Wed					
59	5	16	Thrs					
60	5	17	Fri					
61	5	18	Sat					
62	5	19	Sun					
63	5	20	Mon	Independent Restoration				
64	5	21	Tue					
65	5	22	Wed					
66	5	23	Thrs					
67	5	24	Fri					
68	5	25	Sat					
69	5	26	Sun					
70	5	27	Mon					
71	5	28	Tue					

No.	Date				Team Leader/Surface Geology	Soil/Slope, Ground	Road Pavement	Soil/Slope, Ground II
					MUTO Hisashi	KOKUBU Hiroshi	SHIMIZU Nobuharu	SAKANAKA Shutaro
1	5	1	Thrs					
2	5	2	Fri					
3	6	1	Sat					
4	6	2	Sun					
5	6	3	Mon					
6	6	4	Tue					
7	6	5	Wed					
8	6	6	Thrs					
9	6	7	Fri					
10	6	8	Sat		Haneda－Singapore－Deli			
11	6	9	Sun		Preparation of Document		Haneda－Denpasar－Deli	
12	6	10	Mon		Courtesy call on MOPW, Meeting with JICA		Courtesy call on MOPW, Meeting with JICA	
13	6	11	Tue		Explanation of Draft Final Report		Explanation of Draft Final Report	
14	6	12	Wed		Preparation of Document		Preparation of Document	
15	6	13	Thrs		Preparation of Document		Preparation of Document	
16	6	14	Fri		Report to Embassy of Japan		Report to Embassy of Japan	
17	6	15	Sat		Preparation of Document		Preparation of Document	
18	6	16	Sun		Internal Meeting		Internal Meeting	
19	6	17	Mon		Workshop		Workshop	
20	6	18	Tue		Repot to MPW, JICA		Repot to MPW, JICA	
21	6	19	Wed				Preparation of Document	
22	6	20	Thrs				Deli－Denpasar	
23	6	21	Fri				Denpasar - Narita	
24	6	22	Sat					
25	6	23	Sun					
26	6	24	Mon					
27	6	25	Tue					
28	6	26	Wed					
29	6	27	Thrs					
30	6	28	Fri					
31	6	29	Sat					

Appendix-2 List of Parties Concerned

Ministry of Public Works

Mr. Gastao Francisco de Sousa	Minister
Mr. JOSE G.R.C. PIEDADE	Director General
Mr. Rui GUTERRES	Director of Road and Bridge
Mr. Nene LOBATO	EPCC for Same district Regional
Mr. Antonio Naikoh	Assistant
Mr. Milton Monteiro	EPCC for Center Regional
Mr. Joao GAMA	EPCC for Center Regional
Mr. Rogerio FREITAS	EPCC for Center Regional
Mrs. Isabel M. L.G.	EPCC for Center Regional
Mr. Joao Pedro Amaral	EPCC for Dili District Regional
Mr. Aniceto A.T. Andrade	EPCC for Bobonaro District Regional
Mr. Pedro Alexandre	EPCC for Bobonaro District Regional
Mr. Aniceto A.T. Andrade	EPCC for Bobonaro District Regional
Mr. Candido AMARAL	EPCC for Oecusse District Regional
Mr. Leonarda Brites	EPCC
Mr. Julito PEREIRA	EPCC
Mr. Letigia corbavo	EPCC

Project Management Unit

Mrs. ODETE GENOVEVA V. DA COSTA	Project manager
Mr. FREDERICK G. SANTOS	Chief Technical Advisor

JONIZE Company

Mr. I JIN FILIPE	Director

CARYA TIMOR LESTE PTY. LTD

Mr. FRANS HO

RMS Engineering & Construction Pty Ltd.

Mr. Craig Burgemeister	Chief Representative

Mr. Lope Evangelisata	Material s and Quality Control Supervisor

Embassy of Japan in Timor-Leste

Mr. Yoshitaka Hanada	Ambassador
Mr. Toshihide Kawasaki	Councellor
Mr. Tomotaka Yoshimura	First Secretary

JICA in Timor-Leste

Mr. Hiroshiko TAKADA	Chief Representative
Mr. Atsushi SOMA	Representative