DEPARTMENT OF PUBLIC WORKS AND TRANSPORTATION
STATE OF YAP
FEDERATED STATES OF MICRONESIA

NO.

BASIC DESIGN STUDY REPORT
ON
THE ROAD IMPROVEMENT PROJECT FOR THE STATE OF YAP
IN
THE FEDERATED STATES OF MICRONESIA

OCTOBER 2000

JAPAN INTERNATIONAL COOPERATION AGENCY
KATAHIRA & ENGINEERS INTERNATIONAL

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PREFACE

In response to a request from the Government of the Federated States of Micronesia, the Government of Japan decided to conduct a basic design study on the Road Improvement Project for the State of Yap and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Micronesia a study team from March 22 to April 23, 2000.

The team held discussions with the officials concerned of the Government of Micronesia, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Micronesia in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Federated States of Micronesia for their close cooperation extended to the teams.

October, 2000

Kunihiko Saito
President
Japan International Cooperation Agency

October, 2000

Letter of Transmittal

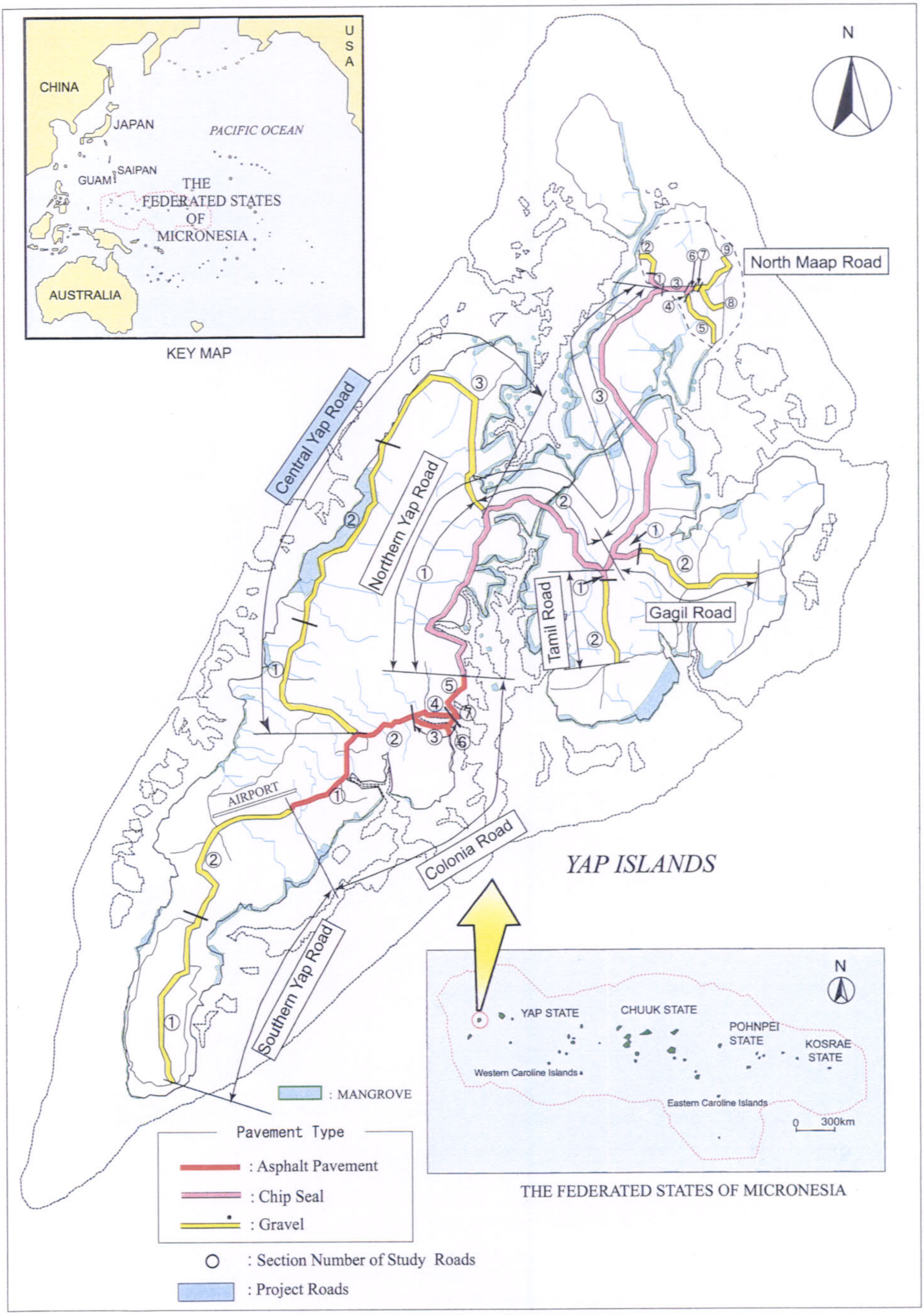
We are pleased to submit to you the basic design study report on the Road Improvement Project for the State of Yap in the Federated States of Micronesia.

This study was conducted by Katahira & Engineers International, under a contract to JICA, during the period from March 9, 2000 to October 10, 2000. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Micronesia and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Kunihiko Sawano
Project Manager,
Basic design study team on the
Road Improvement Project for the State of Yap
Katahira & Engineers International



Location Map of Study Roads

PERSPECTIVE

Abbreviations

AASHTO	:	American Association of State Highway and Transportation Officials
AC	:	Asphalt Concrete
ADB	:	Asian Development Bank
BHN	:	Basic Human Needs
CBR	:	California Bearing Ratio
ESAL	:	Equivalent Single Axle Load
FEMA	:	US Federated Emergency Management Agency
FSM	:	Federated States of Micronesia
GDP	:	Gross Domestic Product
GOJ	:	Government of Japan
PSIP	:	Public Sector Investment Program
PW&T	:	Department of Public Works and Transportation, Yap State Government
RC	:	Reinforced Concrete
SN	:	Structural Number

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CHAPTER 1 BACKGROUND OF THE PROJECT

The economy of the Federated States of Micronesia (FSM) relies considerably on the Compact assistance from the US. In fiscal year 1987, the US Compact funding accounted for 58% of consolidated government revenues in the FSM and although it fell to 47% in fiscal year 1998 as a result of step-downs thereafter, it still represents a high reliance on external assistance. The period of the assistance under the Compact of Free Association between the FSM and the US is up to 2001. Future funding after 2001 is uncertain although negotiations have been commenced for renewal of US economic assistance. Under such circumstances, the FSM is under the necessity of turning from assistance-dependent economy into self-reliant economy and major challenges therefor are considered to be downsizing of government organization, private sector development, acquisition of foreign currency by promotion of tourism industry and fishery, agricultural development, establishment of land ownership, etc.

To face the situation, the FSM since 1995 has shifted the national planning orientation from the Five Year Development Plan to the Public Sector Investment Program (PSIP). The PSIP is an implementation program of the major projects and the purposes of formulating the PSIP are: ① to identify major priorities for investment by all five governments to promote economic growth, ② to match the projects of the state governments to the investment funds likely to be available, ③ to indicate the continuing needs for funds over the next few years to complete implementation of the chosen priorities, ④ to be the major funding mechanism and basis for the FSM Economic Strategy, and ⑤ to indicate to foreign donors the FSM's needs for funds additional to its own resources for implementation of its major investment priorities.

In line with the development policy of the national government, the State of Yap aims at development of tourism industry and fishery, improvement of quality of life in rural areas and expansion of domestic market and therefore puts importance on the improvement of transport facilities as the basic infrastructure for industrial development, especially improvement of road network composed of primary and secondary roads.

The primary roads are located in Yap Island, Tamil Gagil Island and Maap Island. These primary roads have such problems as many cracks and potholes in paved roads, and uneven surface and road structure easy of deterioration in unpaved roads, causing the obstacle to the movement of people and transportation of living supplies.

In view of the above, the Government of the FSM made a request to the Government of Japan for grant aid for improvement of the primary roads in Yap, Tamil Gagil and Maap Islands and procurement of equipment for road maintenance and repair.

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 Objectives of the Project

The Project aims to promote the socio-economic development of the State of Yap by improving the road necessary to secure a safe, reliable and smooth means of transport. The necessity of road improvement in the State are as follows:

(1) Improvement of Basic Human Needs

Some coastal sections in Central Yap Road, Sections 2 and 3, are flooded during heavy rain. There are steep sections with a gradient of about 12% in Central Yap Road, section 1 and 3, where vehicles can hardly climb when becoming wet and muddy. The school bus stops the operation about 90 days in a year due to flood and about 20 days due to steep slope in wet condition.

The impassability of road causes the following problems:

- Schoolchildren have to walk to school for several kilometers.
- The school bus is the only public transportation and utilized not only by schoolchildren but also by public. When the bus stops, daily life (commuting, shopping, etc) is much affected.
- There is only one hospital of the state, located in Colonia, while dispensaries are distributed in rural areas. A doctor and nurse visit the dispensary once a month and are sent urgently for an emergency patient. However, when the road is interrupted, there is no means of arriving because of absence of detour road.

To solve the above problems, the improvement of the road is needed.

(2) Encouragement of Road Function

Central Yap Road is the only road serving the area in the west and north of Marabaao hills. It is an important component of the road network in the state and, so to speak, a life line for the inhabitants. The road is however insufficient in serviceability, reliability and steadiness, due to bad surface condition and blockade in some sections during heavy rain, causing the constraint for sound socio-economic activities. Thus, improvement of the road, which is the basic infrastructure for socio-economic activities, is of vital need.

(3) Environmental Improvement

The following environmental problems are caused by the road being unpaved:

- Water pollution of lagoon due to muddy water drained from the road.
- Dusty environment for pedestrians and inhabitants

To mitigate the problems, the improvement of the road is needed.

(4) Contribution to Economic Reform

The FSM is under the necessity of turning from assistance-dependent economy into self-reliant economy and major challenges therefor are considered to be downsizing of government organization, private sector development, acquisition of foreign currency by promotion of tourism industry and fishery, agricultural development, establishment of land ownership, etc.

To face the situation, the FSM since 1995 has shifted the national planning orientation from Five Year Development Plan to the Public Sector Investment Program (PSIP). The Yap State PSIP is composed of 15 projects, including the road construction and maintenance project. The road improvement is needed to support the economic reform. The said project is however pending due to lack of fund.

As mentioned above, the road improvement is needed from various points of view, especially for Central Yap Road which is impassable due to flood during heavy rain. This Project aims to improve Central Yap Road and thus contribute to the improvement of the basic human needs for the roadside inhabitants; securing the means of attending school, removing the obstacle to daily life, enabling emergency patients to be treated quickly, etc.

2.2 Basic Concept of the Project

The Scope of this Project is to improve Central Yap Road in whole length. Selection procedures of the Project road and the basic concept of the Project are described hereunder.

2.2.1 Selection of the Project Road

(1) Study Roads

Study roads are listed in Table 2.2.1-1 (see Location Map of Study Roads in the opening page).

TABLE 2.2.1-1 STUDY ROADS

	Paved Section		Unpaved Section		Total
	Section	Length (km)	Section	Length (km)	Length (km)
Central Yap Road	-	-	1, 2, 3	14.4	14.4
Southern Yap Road	-	-	1, 2	7.9	7.9
Colonia Road	1, 2, 3, 4, 5, 6, 7	9.5	-	-	9.5
Northern Yap Road	1, 2, 3	16.0	-	-	16.0
Tamil Road	1	0.1	2	2.2	2.3
Gagil Road	1	0.6	2	3.3	3.9
North Maap Road	1, 3, 4, 6	1.3	2, 5, 7, 8, 9	4.4	5.7
Total		27.5		32.2	59.7

(2) Evaluation of Priority

Presently, paved roads provide relatively good serviceability and have little problem in road alignment, width and drainage although some distress of the pavement such as cracking, potholes and weathering (loss of asphalt binder) is found now passing about 16 years and 6 to 8 years in case of asphalt concrete pavement and chip seal respectively after construction. Thus, improvement of paved roads are considered to be less urgent comparing to unpaved roads. Therefore, priority of improvement is evaluated only among unpaved roads.

Each item of the objectives/needs of road improvement described in 2.1 is used as factors for evaluation of priority. The rating criteria for each item are as follows:

- Encouragement of Road Function

  Regarding this factor, evaluation is made according to importance of road. Each road is rated A (trans-island artery), B (regional artery), C (access road to municipality), or D (access road to villages).

- Satisfaction of Basic Human Needs

  Evaluation is made based on number of days the school bus stops the operation, i.e. rating A (about 90 days per year), B (about 20 days), C (not applicable), or D (none).

- Environmental Improvement

  This factor is common to all dirt roads and therefore not used for evaluation of priority.

- Contribution to Economic Reform

  This factor is divided into two: savings in road maintenance cost and savings in transport cost / support to industrial development. Savings in road improvement cost is not used for evaluation because this effect is considered to be proportional to the cost for improvement.

  In view of the fact that more maintenance works are required as the road condition is deteriorated more easily, the rating in terms of the effect on savings in road maintenance cost is made as follows: A (gravel is easily lost due to steep gradient or road condition is easily deteriorated due to flooding), B (steep sections exist only partly), C (neither steep section nor flood section), or D (not applicable).

  The effect on savings in transport cost and support to industrial development is largely correlative to traffic volume. Rating is made as follows based on traffic volume : A (600 vehicles/day or more), B (400-600 vehicles per day), C (200-400 vehicles per day), or D (200 vehicles per day or less).

The results of the evaluation for each factor and priority based thereon are shown in Table 2.2.1-2.

TABLE 2.2.1-2 RESULTS OF EVALUATION OF PRIORITY

Road	Section	Encourage-ment of Road Function	Satisfaction of Basic Human Needs	Contribution to Economic Reform		Priority by Section	Priority by Road
				Savings in Road Maintenance Cost	Savings in Transport Cost/Support to Industrial Development		
Central Yap Road	1	B	B	A	A	1	1
	2	B	A	A	D	2	
	3	B	B	A	D	3	
Southern Yap Road	1	A	D	C	C	5	2
	2	A	D	C	B	4	
Tamil Road	2	C	D	B	B	6	3
Gagil Road	2	C	D	B	C	7	5
North Maap Road	2	D	B	B	D	7	4
	5	D	B	B	D	7	
	7 + 8	D	B	B	D	7	
	7 + 9	D	B	B	C	6	

(3) Selection of the Project Road

Based on the evaluation results shown in Table 2.2.1-2, whole sections of Central Yap Road given the first priority are selected as the Project Road.

2.2.2 Necessity of Procurement of Equipment

To assess the necessity of procuring equipment for the road maintenance purpose, a list of equipment for maintenance and repair of both paved and unpaved roads is set up and then corresponding equipment owned by PW & T is examined on operational condition and specification. Table 2.2.2-1 shows the equipment necessary for maintenance and repair of roads, specification and operational condition of existing equipment and assessment of necessity of procurement.

The Table shows that road maintenance and repair works can be performed by the existing equipment fleet adding a vibration plate which is inexpensive and easily procurable, although somewhat inefficient in some cases. In view of the above, procurement of equipment is not included in this Project.

TABLE 2.2.2-1 ASSESSMENT OF NECESSITY OF PROCUREMENT OF EQUIPMENT

(1/2)

Equipment Necessary for Maintenance and Repair of Roads				Existing Equipment				Necessity of Procurement**
Equipment	Specification	Number	Purpose	Equipment	Specification	Number	Operational Condition*	
Wheel Loader	Bucket capacity $1.2m^3$	1	Loading of earth	Wheel Loader	980G	1	○	× Existing equipment is available.
					950F	1	×	
					WA200	1	△	
					IT12	1	△	
Wheel Loader with Shovel	Bucket capacity $1.2m^3$	1	Excavation and loading of earth	Excavator	320L	1	△	
					PC200	1	△	
					416B	1	△	
					UH05	1	×	
					YB301	1	××	
Dump Truck	4 ~ 5t	1	Hauling of aggregate and excavated earth	Dump Truck	DM690S 10t	2	○	△ Small dump truck is more mobile and efficient but existing large dump truck can substitute.
					DM690S 10t	4	△	
					FK415 5t	2	×	
					2t	1	×	
Truck with Crane	4t, Crane Cap. 3t	1	Loading and hauling of equipment	Truck Crane	NK200	1	××	△ Truck with small crane is more efficient but existing fork lift and simple slope plate can substitute.
				Crawler Crane	KH150	1	○	
				Crawler Crane	KH150	1	×	
				Fork Lift	FD80	1	○	
Motor Grader	Blade width 3.7m	1	Grading of road surface	Motor Grader	140H	1	○	× Existing equipment is available.
					120G	1	×	
					770B	1	×	
Motor Grader with Ripper	Blade width 3.7m	1	Grading and ripping	Bulldozer	D6D	2	○	
Tire Roller	11 ~ 12t	1	Rolling compaction	Macadam Roller	SV90D	1	×	△ Tire roller is more mobile and efficient but existing macadam roller can substitute.
					SD100	2	△	

Equipment Necessary for Maintenance and Repair of Roads				Existing Equipment				Necessity of Procurement**
Equipment	Specification	Number	Purpose	Equipment	Specification	Number	Operational Condition*	
Vibration Roller	Hand guide type 0.5t	1	Compaction of narrow place					△ Hand guide type vibration roller is more effective but existing macadam roller or vibration plate depending on situation can substitute.
Vibration Plate	50 ~ 60 kg	1	Compaction of pot hole filling					○ Necessary (inexpensive and easily procurable).
Water Tank Truck	4,000L	1	Adjustment of moisture content					△ Dump truck and water tank can substitute.
Pickup Truck	Double cabin 4 x 2	1	Transportation of workers and small equipment	Truck	4t	1	△	× Dump truck can substitute.
				Trailer	30t	1	△	
				Concrete Mixer	10 m^3	1	×	
Pavement Cutter		1	Cutting of pothole					△ Flat chisel and hammer can substitute.
Asphalt Distributor		1	Distribution of asphalt for patching					△ Manual distribution can work.

* Operational Condition (as of April 2000) : ○ Good, △ Working although needing repair, × Unoperational, ×× Abandoned

** Necessity of procurement : ○ Necessary, △ Desirable to be procured but not indispensable, × Not necessary

2.2.3 Basic Concept of the Project

(1) Problems of the Project Road

Problems of the Project Road (Central Yap Road) are as follows:

- Road Alignment

  Vertical alignment of section 2 is good, while Sections 1 and 3 have steep portions with a gradient of some 12% where vehicles can hardly climb when being wet and muddy. Horizontal alignment is relatively good although there are curves with a radius of some 50m.

- Road Width

  About 66% of the whole length of the road is 8.0m or more in width, sufficient for two-lane road, while about 22% is about 7.0m, somewhat narrow and about 12% is only about 5.0m.

- Surface Condition

  Surface condition is bad due to dirt road and easily deteriorated in rainy season.

- Bridges

  There are three bridges, of which Qatliw Bridge is seriously deteriorated and insufficient in bridge length and width.

- Flooding

  There are flood sections in Sections 2 and 3 hindering the traffic. Causes of the flooding are as follows: inflow of seawater in the sections where road elevation is lower than high tide level, increase of flood water depth due to storm-water runoff, and accession of sea wave during depression in some sections.

(2) Basic Concept of the Project

The Project Road is the only road serving the area in the west and north of Marabaao hills. The objective of the Project is to improve the Project Road so as to assure safe and smooth traffic movement and thus to secure the traffic function of the road as an arterial road. Taking into consideration the problems mentioned above, the basic concept of the Project is as follows:

Design Traffic Volume and Design Speed

Projected traffic volume 10 years after completion of the Project (year 2013) is used as design traffic volume. Design speed is decided applying the one for collector roads is AASHTO standard. Design traffic volume and design speed are as follows:

	Design traffic volume	Design speed
• Section 1	810 vehicles per day	60 km/hr
• Section 2	240 vehicles per day	60 km/hr
• Section 3	120 vehicles per day	50 km/hr

Major Improvement

Major improvement works are as follows:

- Road alignment : Improvement of vertical alignment to reduce the gradient to 10% or less.
- Widening : Widening of the sections with insufficient width to secure carriageway (5.5m) and shoulder (1.2m on both sides), and where necessary, sidewalk (1.2m on one side) and side ditch.
- Pavement : Pavement with asphalt concrete.
- Bridge reconstruction : Reconstruction of Qatliw Bridge.

Basic concept for measures against flooding is that flooding is not completely prevented but flood water depth shall be reduced to the extent enabling vehicles to pass, say about 15 cm. Since the drainage capacity is increased by reconstruction of Qatliw Bridge and laying of culverts in the FEMA Project, this target is achieved by raising the road slightly.

2.3 Basic Design

2.3.1 Design Concept

2.3.1.1 Principle Design Concept

(1) Road Function and Applicable Standards

Basically, AASHTO is being applied to the road design in the FSM. AASHTO classifies the roads according to the functional system characteristics into arterial highways (linkage of cities), collector roads (linkage of village with city or other village) and local roads (access to individual farm). Since the project road is considered to have a function corresponding to the collector road in AASHTO, the following road standards are referred to for the design of road structure:

- (main reference) : collector road in AASHTO
- (sub-reference) : local road in AASHTO
- (sub-reference) : class 3 of type 3 road in Road Structure Ordinance in Japan

(2) Sectioning of the Road

The Project Road is divided into the following three sections according to terrain and traffic volume:

- Section 1 : from starting point to 4.6 km point (terrain: rolling)
- Section 2 : from 4.6 km point to 9.0 km point (terrain: flat)
- Section 3 : from 9.0 km point to end point (terrain: rolling)

(3) Design Traffic Volume

Projected traffic volume 10 years after completion of the Project (year 2013) is used as the design traffic volume. The traffic volume in year 2013 is projected based on the results of the 12-hour traffic counts and assuming the expansion factor (12-hour to 24-hour) of 1.25 and annual traffic growth rate of 1.6 per cent, as shown in Table 2.3.1-1. The bases of assuming the traffic growth rate are as follows:

- Average annual population growth rate from year 2000 to 2014 is estimated to be 1.62 per cent according to Statistical Yearbook 1999.
- The nominal GDPs from 1995 to 1999 are flat or rather reducing slightly according to Consolidating Reforms and Enhancing Self-Reliance.
- At present, car ownership rate is high, at a rate of one car per about four persons. The rate is not considered to increase sharply in the future.

TABLE 2.3.1-1 DESIGN TRAFFIC VOLUME

	Year 2000 12-hour traffic volume (vehicle)	Year 2000 daily traffic volume (vehicle)	Year 2013 Design Traffic Volume (vehicle)
Section 1	525	657	810
Section 2	156	195	240
Section 3	78	98	120

(4) Number of Lanes

Number of lanes shall be two because the Project Road has been operated as two-lane road and two lanes are good enough for the design traffic volume.

(5) Design Speed

Table 2.3.1-2 shows the design speed determined based on AASHTO.

TABLE 2.3.1-2 DESIGN SPEED (km/h)

	Design traffic volume (vehicle/day)	Terrain	AASHTO (minimum)		Road Structure Ordinance in Japan	This Project
			Collector road	Local road	Class 3 of Type 3	
Section 1	810	Rolling	60	60	60,50 or 40(30)	60
Section 2	240	Flat	60	50	ditto	60
Section 3	120	Rolling	50	50	ditto	50

Note: ( ) : value in special case

(6) Pavement Structure Design

The asphalt concrete (AC) pavement and chip seal are generally used in the FSM. AC is applied for the Project for the following reasons:

- Chip seal requires the frequent maintenance to keep a good surface condition as local damages are easy to occure. If the maintenance is insufficient, the local damages may easily expand and cause the serious damage. Furthermore, the rehabilitation such as overlay will be needed in early stage due to its short performance period. The maintenance and rehabilitation will impose a big financial burden on Yap State.

- AC will require little maintenance cost for at least first ten years. This meets the intention of contributing to the economic reform as mentioned in 2.1.

- Comparing the total costs including the initial construction cost, maintenance cost and rehabilitation cost, required for a long period of time, namely life cycle cost, AC is more economical than chip seal. An example of the life cycle cost analysis is shown in Figure 2.3.1-1.

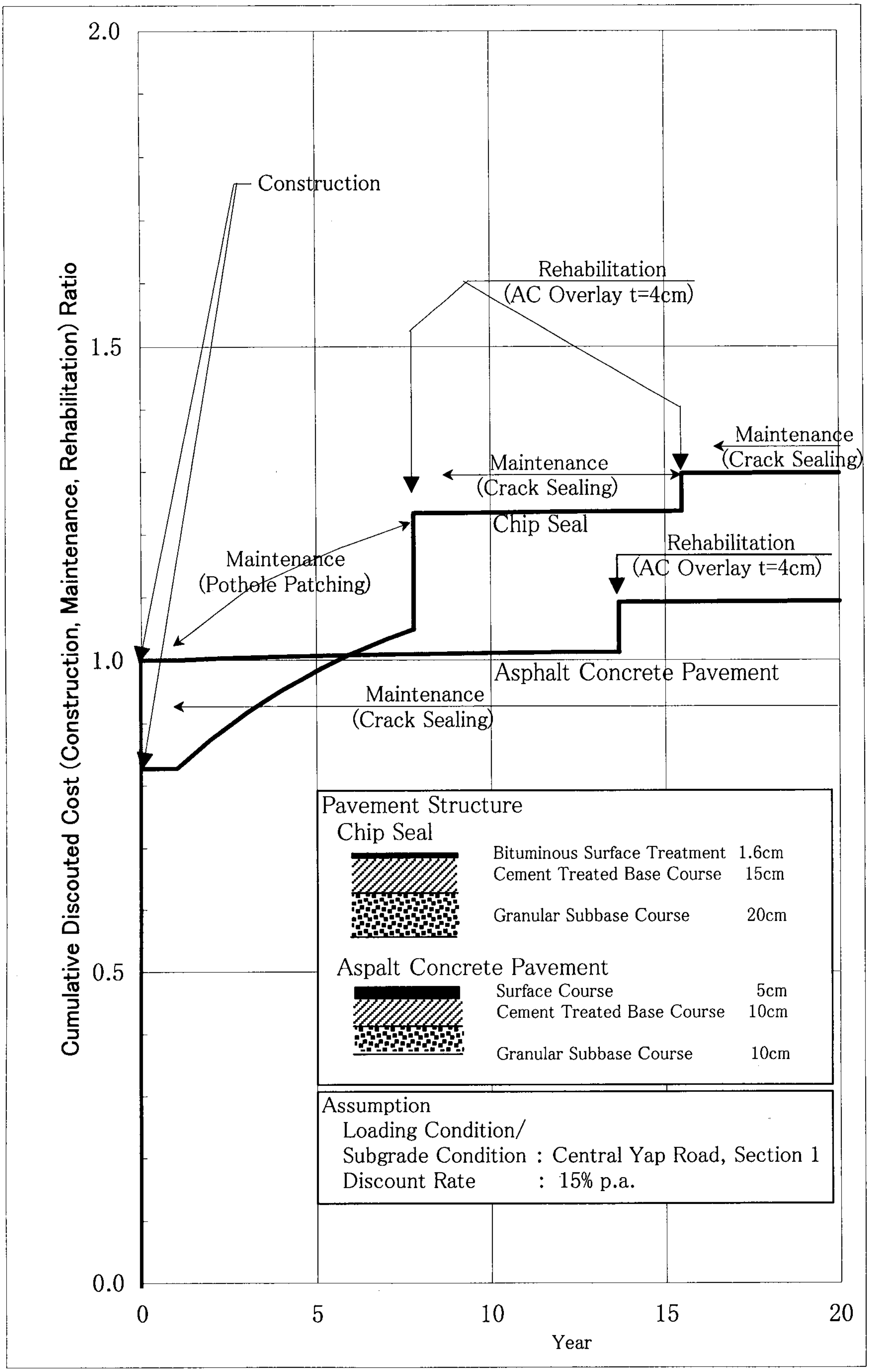
Initial performance period (defined as the period of time that an initial pavement structure will last before it needs rehabilitation) is set at 10 years, based on Japanese standard.

(7) Reconstruction of Bridge

The necessity of reconstruction of bridge is discussed considering the following factors:

Structural Aspect:	Reconstruction or structural reinforcement is needed in case that load-carrying capacity or stability of bridge is insufficient due to deterioration. In order to exactly assess the present load-carrying capacity and estimate the future durability, detailed information such as dimensions of members, material properties, reinforcing bar arrangement, foundation type including pile details, soil condition, hydraulic condition, degree of deterioration and prediction of its progress in the future etc. is required. Because of lack of such detailed information, rough assessment is made based on degree of deterioration at present.
Hydraulic Aspect :	Reconstruction or extension of bridge length is required in case that the bridge is blocking the flow due to its insufficient length.
Functional Aspect :	If the width is insufficient, reconstruction or widening of the bridge might be necessary to secure a smooth flow of traffic and insure safety. However, in case that bridge length is short and traffic volume is low, one-lane bridge has little problem from traffic management aspect.

The assessment results on three existing bridges along Central Yap Road are shown in Table 2.3.1-3. Quatliw Bridge shall be reconstructed.



FIFURE 2.3.1-1 LIFE CYCLE COST ANALYSIS

TABLE 2.3.1-3 ASSESSMENT ON NECESSITY OF BRIDGE RECONSTRUCTION

	Structural Aspect (defect of members)	Hydraulic Aspect (narrow opening, scouring)	Functional Aspect (width)	Necessity of Reconstruction
Qokaaw Br. (Length:10.7m, Width: 9.1m, PC Girder Br.)	○ No serious defect	○ No problem	○ No problem	Not necessary
Quatliw Br. (Length: 6.0m, Width: 6.0m, Steel H Girder Br.)	X Serious defects such as corrosion of steel girder, exposure and corrosion of reinforcing bars in the slab	X Riverbed seriously scoured due to insufficient bride length	△ A little narrow.	Necessary because of serious structural and hydraulic problems
Raeng Br. (Length:3.75m, Width: 4.3m, Concrete Slab Br.)	○ No serious defect on structural members	△ Riverbed scoured due to insufficient bride length	△ Narrow width	Although there are hydraulic and functional problems, neither is absolute reason of reconstruction.

(8) Measures Against Flooding

There are flood sections in Central Yap Road, Sections 2 and 3. Regarding situations and causes of flood, there are three cases as follows:

- Flood section affected by high tide
  The sections where the road elevation is lower than the high tide level is flooded during high tide. Furthermore, the flood water depth increases due to storm-water runoff when it rains at the time of high tide. In this case, the maximum water depth is about 30cm according to the information from PW & T and local residents. In these sections, there is little sea wave because the large mangrove belt on the sea side acts as a kind of breakwater.

- Storm-water overflow section not affected by high tide
  Storm-water overflows the road due to insufficient cross drainage facilities, although no sea water inflows because road elevation is high enough. In this case, the maximum water depth on the road is about 15cm.

- Flood section affected by sea wave
  Sea wave reaches up to the road surface during depression, although the elevation of the road surface is higher than the high tide level. There are two cases: the wave height goes up locally along water way in the life, and the sea wave runs up along the slope up to the road surface. In either case, the maximum water depth is about 10 cm.

Basic concept for measures against the flood is as follows:

- To prevent the inflow of seawater by raising the road higher than the high tide level.

- Not to prevent the flood/overflow perfectly but to reduce the water depth to the extent enabling vehicles to pass. This is to avoid the problems caused by big change is hydraulic condition such as significant rise of water level at the mountain side of the road, extreme concentration of water on culverts, big raise of construction cost, etc.

- To provide additional culverts if still required after evaluating the effect of increasing the drainage capacity by reconstruction of Quatliw Bridge and construction of culverts in the FEMA project.

(9) Others

- The Project shall be planned paying full attention to the environmental preservation, i.e., avoiding resettlement of resident, not affecting remains, minimizing construction waste, avoiding water pollution especially in excavation of coral materials, etc.

- To make it easy for the local construction companies/engineers to participate in the Project, the construction methods shall be as simple and easy in quality control as possible.

- Considerations shall be taken for enabling PW & T to maintain the road easily and economically.

- Some works are difficult to be executed during rainy season from June to October. This condition shall be reflected in the construction plan.

- Traffic shall be maintained during construction.

2.3.1.2 Geometric Design Standard

Table 2.3.1-4 shows the geometric design standards for this Project.

TABLE 2.3.1-4 GEOMETRIC DESIGN STANDARD

			AASHTO Collector Road	AASHTO Local Road	Road Structure Ordinance in Japan Class 3 of Type 3	Standards for This Project
Design Speed (km/h)		Section 1	60	60	60, 50 or 40 (30)	60
Design Speed (km/h)		Section 2	60	50	60, 50 or 40 (30)	60
Design Speed (km/h)		Section 3	50	50	60, 50 or 40 (30)	50
(1) Cross Section Elements	Carriageway width (m)	Section 1	6.6	6.0	6.0	5.5
(1) Cross Section Elements	Carriageway width (m)	Section 2	5.4	5.4	6.0	5.5
(1) Cross Section Elements	Carriageway width (m)	Section 3	5.4	5.4	6.0	5.5
(1) Cross Section Elements	Shoulder Width (m)	Section 1	1.5	1.5	0.75 (0.5)	1.2
(1) Cross Section Elements	Shoulder Width (m)	Section 2	0.6	0.6	0.75 (0.5)	1.2
(1) Cross Section Elements	Shoulder Width (m)	Section 3	0.6	0.6	0.75 (0.5)	1.2
(1) Cross Section Elements	Sidewalk Width (m)	All Sections	1.2～2.4	1.2～2.4	1.5 (1.0)	1.2 (specified section only, one side)
(2) Horizontal Alignment	Minimum Radius (m)	Section 1	115	115	280 (230)	115 (45)
(2) Horizontal Alignment	Minimum Radius (m)	Section 2	115	75	280 (230)	115 (45)
(2) Horizontal Alignment	Minimum Radius (m)	Section 3	75	75	280 (230)	75 (25)
(3) Vertical Alignment	Maximum Grade (%)	Section 1	8	10	5 (exceptional value in mountainous terrain: 9)	10
(3) Vertical Alignment	Maximum Grade (%)	Section 2	7	7	5	7
(3) Vertical Alignment	Maximum Grade (%)	Section 3	9	10	5 (exceptional value in mountainous terrain: 9)	10
Remarks		(1) Carriageway, shoulder and sidewalk widths were decided following those of the existing paved road. Sidewalk is provided only in the sections where many schoolchildren walk.				
Remarks		(2) Special values in the parenthesis are the values for the design speed reduced by 20 km/h, to be used in rolling sections. This is to avoid a significant increase of construction cost where big change in the existing alignment is required if designed following the standard value.				
Remarks		(3) Maximum grade was decided based on the local road standard of AASHTO, to avoid the increase of construction cost.				

Note: ( ) : value in special case

2.3.1.3 Pavement Design Concept

(1) Pavement Type

Asphalt concrete pavement is adopted (see 2.3.1.1 (6)).

(2) Materials

Aggregates produced in Yap State are schist and coral. Schist can be used for subbase course but cannot be used for base course because of its brittleness. Coral is stiffer than schist although abrasion loss is big, and if treated with cement, it can be used for base course as well as for subbase course without treatment. Accordingly there are two cases; using schist for subbase course and coral for base course, and coral for both subbase course and base course. The former case is uneconomical because crushing plants have to be prepared individually for two different materials.

There is no aggregate usable for asphalt concrete.

Considering the above, the following materials are used for aggregates for pavement:

- Subbase Course : Coral
- Base Course : Coral (treated with cement)
- Aggregate for Asphalt Concrete : Imported materials

(3) Construction Method of Pavement

New pavement is constructed on the existing gravel surface except where the vertical alignment is decided differently for some reason, e.g. constraint due to drainage. The use of the existing gravel as a part of subbase course is not considered suitable because of lack of reliability on material property of the existing gravel layer and uniformity of its thickness.

(4) Performance Period

Performance period is 10 years (see 2.3.1.1 (6)).

(5) Design Conditions

Standards to be applied	:	AASHTO Guide for Design of Pavement Structures, 1993.
Performance period	:	For 10 years from year 2003 to 2012.
Traffic growth rate	:	1.6 percent per annun

Reliability	:	Probability that traffic loadings are more than and pavement performance is less than predicted is assumed to be 50 per cent.
Serviceability criteria	:	Initial serviceability index P_o = 4.2 (AASHO Road test results) Terminal serviceability index P_t = 2.5 (standard in AASHTO Guide)

Materials property of pavement layer

: Asphalt concrete surface course	:	Elastic modulus = 350,000 psi
: Cement treated base course	:	Unconfined compressive strength = 356 psi
: Subbase course	:	CBR = 30
Drainage condition	:	Water removed within one week.
	:	Duration pavement structure is exposed to moisture level approaching saturation = 60%

2.3.1.4 Bridge Reconstruction Design Concept

(1) Bridge to be Reconstructed

Quatliw Bridge is to be reconstructed (refer to 2.3.1.1 (7)).

(2) Basic Plan

- Bridge Length
  The bridge length is decided so as to maintain the flowing capacity of the river (see Figure 2.3.1-2).

- Structure Type
  A box culvert type is adopted for the following reasons:
  - Two-cell box culvert is applicable for a length of 6.8m.
  - Driving pile method for foundation is difficult to be applied to the soil layer which contains the cobble stones of coral in the six to ten meter layer. Therefore, the box culvert type, not requiring the pile foundation, is advantageous.
  - The river channel should be temporarily shifted during construction in case of box culvert. However, this work is easy because there is enough space for shifting and unsupported excavation can work.

- Location of Structure
  The new structure is constructed in the same location as the existing bridge.

- Minimum Free Board

  The minimum free board is set at 60 cm based on the Japan's river management criteria.

- Reduction Rate of Cross-sectional Area of River

  A reduction rate of cross-sectional area of a river shall not exceed 5 percent, based on Japan's river management criteria.

(3) Design Criteria

Specifications applied	:	AASHTO Standard Specifications for Highway Bridges, 1996.
Live Load	:	HS 20-44
Main Materials	:	Concrete $\sigma ck = 240$ kgf/cm^2
	:	Reinforcing bar SD 295A or ASHTO Grade 40 (yield strength 3,000 kgf/cm^2)

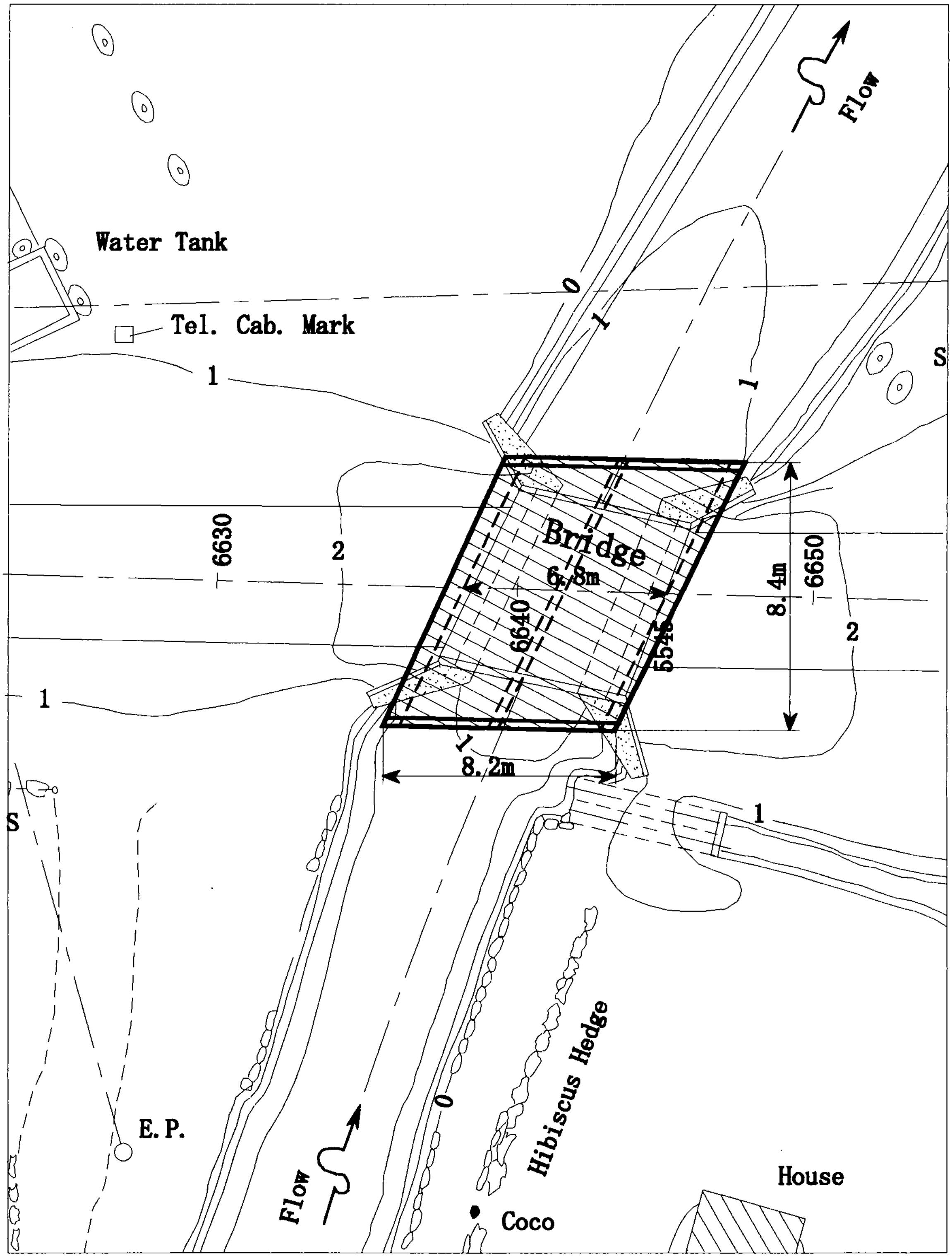


FIGURE 2.3.1-2 BRIDGE LENGTH OF QUATLIW BRIDGE

2.3.1.5 Drainage Design Concept

(1) Cross Drainage Facilities

Rainfall discharge at the return period of five years is used as design discharge, in accordance with the Road Drainage Guideline of the Japan Road Association.

① Flood Section Affected by High Tide

Design concept is as follows:

- High tide level is estimated to be 0.93m. The sections where the road elevation is below 1.0m is raised up to 1.0m, to prevent seawater from inflowing.
- The storm-water is allowed to overflow the road, but the flood water depth is held within about 15 cm so that vehicles may pass.
- The water level at the mountain side of the road shall not be raised more than 10cm from the condition before completion of the culverts construction in the FEMA project.

② Storm-water Overflow Section not Affected by High Tide

The drainage condition was improved by the recent FEMA project for installation of culverts and this effect is to be examined by a hydraulic analysis. Irrespective of the results of the examination, however, no additional installation of culvert shall be included in this Project, considering that even before the completion of the FEMA project, maximum flood water depth is 15 cm and passable for vehicles after paving and thereby eliminating local uneven portions.

③ Flood Section Affected by Sea Wave

It is not considered to raise the road elevation intentionally, considering that: maximum water depth is only 10 cm at present, traffic volume may be very low during storm, and access to surrounding houses might be difficult if the road would be raised.

Slope protection works with grouted riprap shall be provided for the sections affected by sea wave to prevent the scouring.

(2) Road Surface Drainage

Natural drainage shall be adopted for embankment sections, while side ditch shall be provided for cut sections. Rainfall discharge at the return period of three years is used as design discharge for the side ditch design.

2.3.1.6 Other Road Facilities Design Concept

(1) Slope Protection Works

Slope protection is provided in the flood sections affected by sea wave. Grouted riprap is used for this purpose. No slope protection is provided in the sections where storm-water overflows the road, as these sections abut on mangrove and marsh and overflowing water velocity is estimated to be low enough (at present no protection is provided and no slope damage is observed).

(2) Traffic Signs and Road Markings

The following facilities are provided from the viewpoint of traffic safety:

- Traffic Signs : Regulatory sign of speed limit, and warning sign of "reduction of road width ahead".
- Road Markings : Road center line.

2.3.2 Basic Design

2.3.2.1 Road Design

(1) Cross-Sectional Element

Cross-sectional elements are as follows:

- The width of carriageway is 5.5 m, and the width of shoulder is 1.2 m.
- Sidewalk of 1.2 m in width is provided on the east side of the road between intersections at 130 m north and 310 m south from Dalipeebinaew Elementary School because many schoolchildren walk in this section. A cement treated base course is placed on the side walk.
- Side ditches are provided in the sections which are at the same level as or lower than the abutting ground level (refer to 2.3.2.4)
- Unsuitable soil in the marsh area shall be replaced one meter in depth with suitable materials before filling work for widening.

Figure 2.3.2-1 shows the standard cross sections. Table 2.3.2-1 shows the cross-sectional elements of each section.

TABLE 2.3.2-1 CROSS-SECTIONAL ELEMENTS (1/3)

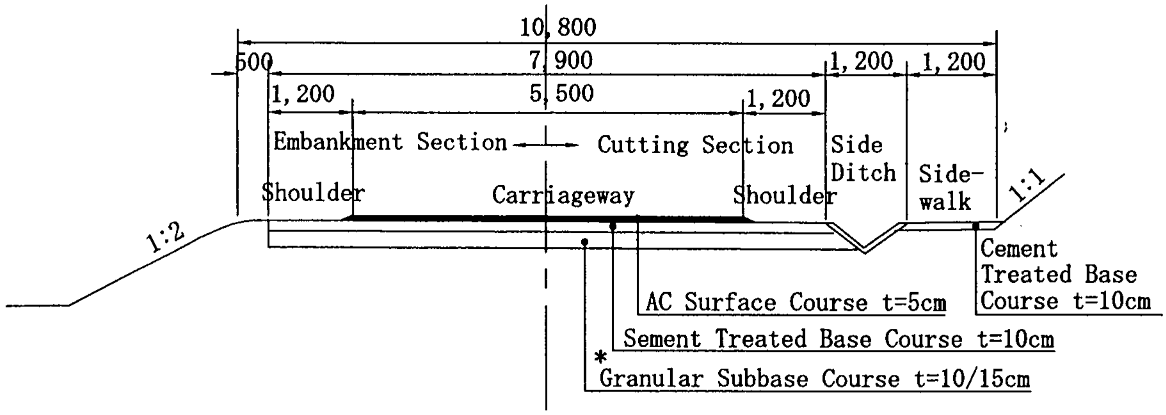
Section	Standard Cross Section Type	Side Ditch
Sta. 0+000 ~ Sta. 0+215	Type B	None
Sta. 0+215 ~ Sta. 0+430	Type B	East side
Sta. 0+430 ~ Sta. 0+555	Type B	None
Sta. 0+555 ~ Sta. 0+600	Type B	East side
Sta. 0+600 ~ Sta. 0+748	Type B	None
Sta. 0+748 ~ Sta. 0+770	Type B	West side
Sta. 0+770 ~ Sta. 0+886	Type B	Both sides
Sta. 0+886 ~ Sta. 0+915	Type B	East side
Sta. 0+915 ~ Sta. 1+078	Type B	None
Sta. 1+078 ~ Sta. 1+170	Type B	East side
Sta. 1+170 ~ Sta. 1+204	Type B	None
Sta. 1+204 ~ Sta. 1+235	Type B	Both sides
Sta. 1+235 ~ Sta. 1+287	Type B	West side
Sta. 1+287 ~ Sta. 1+343	Type B	None
Sta. 1+343 ~ Sta. 1+384	Type B	West side
Sta. 1+384 ~ Sta. 1+482	Type B	Both sides
Sta. 1+482 ~ Sta. 1+520	Type B	None
Sta. 1+520 ~ Sta. 1+685	Type B	Both sides
Sta. 1+685 ~ Sta. 1+790	Type B	None
Sta. 1+790 ~ Sta. 1+846	Type B	East side
Sta. 1+846 ~ Sta. 1+859	Type A	Both sides
Sta. 1+859 ~ Sta. 1+895	Type A	East side
Sta. 1+895 ~ Sta. 1+907	Type A	Both sides
Sta. 1+907 ~ Sta. 1+942	Type A	East side
Sta. 1+942 ~ Sta. 2+158	Type A	None

(2/3)

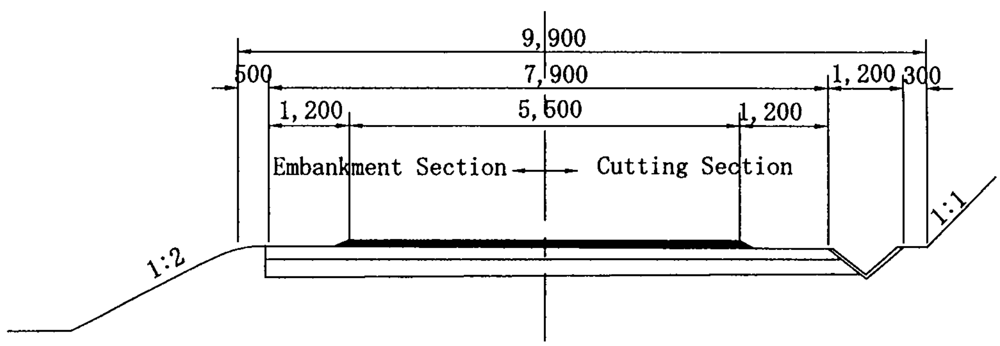
Section					Standard Cross Section Type	Side Ditch
Sta.	2+158	~	Sta.	2+286	Type A	East side
Sta.	2+286	~	Sta.	2+312	Type B	Both sides
Sta.	2+312	~	Sta.	2+362	Type B	East side
Sta.	2+362	~	Sta.	2+540	Type B	None
Sta.	2+540	~	Sta.	2+585	Type B	East side
Sta.	2+585	~	Sta.	2+720	Type B	None
Sta.	2+720	~	Sta.	2+860	Type B	Both sides
Sta.	2+860	~	Sta.	2+915	Type B	None
Sta.	2+915	~	Sta.	3+078	Type B	East side
Sta.	3+078	~	Sta.	3+167	Type B	None
Sta.	3+167	~	Sta.	3+210	Type B	East side
Sta.	3+210	~	Sta.	3+313	Type B	None
Sta.	3+313	~	Sta.	3+370	Type B	West side
Sta.	3+370	~	Sta.	3+411	Type B	Both sides
Sta.	3+411	~	Sta.	3+545	Type B	None
Sta.	3+545	~	Sta.	3+605	Type B	Both sides
Sta.	3+605	~	Sta.	3+840	Type B	None
Sta.	3+840	~	Sta.	4+090	Type B	Both sides
Sta.	4+090	~	Sta.	4+115	Type B	East side
Sta.	4+115	~	Sta.	4+248	Type B	Both sides
Sta.	4+248	~	Sta.	4+255	Type B	East side
Sta.	4+255	~	Sta.	4+400	Type B	None
Sta.	4+400	~	Sta.	6+111	Type C	None
Sta.	6+111	~	Sta.	6+371	Type C	East side
Sta.	6+371	~	Sta.	7+083	Type C	None
Sta.	7+083	~	Sta.	7+220	Type C	None
Sta.	7+220	~	Sta.	7+620	Type B	None
Sta.	7+620	~	Sta.	7+680	Type C	None
Sta.	7+680	~	Sta.	7+689	Type B	None
Sta.	7+689	~	Sta.	7+759	Type B	East side
Sta.	7+759	~	Sta.	7+890	Type B	None
Sta.	7+890	~	Sta.	8+170	Type C	None
Sta.	8+170	~	Sta.	8+383	Type B	None
Sta.	8+383	~	Sta.	8+468	Type B	East side
Sta.	8+468	~	Sta.	8+475	Type B	None
Sta.	8+475	~	Sta.	8+530	Type C	None
Sta.	8+530	~	Sta.	9+297	Type B	None
Sta.	9+297	~	Sta.	9+328	Type B	East side
Sta.	9+328	~	Sta.	9+721	Type B	None
Sta.	9+721	~	Sta.	9+865	Type B	East side
Sta.	9+865	~	Sta.	9+885	Type B	Both sides
Sta.	9+885	~	Sta.	10+086	Type B	East side
Sta.	10+086	~	Sta.	10+830	Type B	None
Sta.	10+830	~	Sta.	10+876	Type B	East side
Sta.	10+876	~	Sta.	10+995	Type B	None
Sta.	10+995	~	Sta.	11+072	Type B	Both sides
Sta.	11+072	~	Sta.	11+114	Type B	East side
Sta.	11+114	~	Sta.	11+215	Type C	None
Sta.	11+215	~	Sta.	11+318	Type B	None
Sta.	11+318	~	Sta.	11+341	Type B	East side

(3/3)

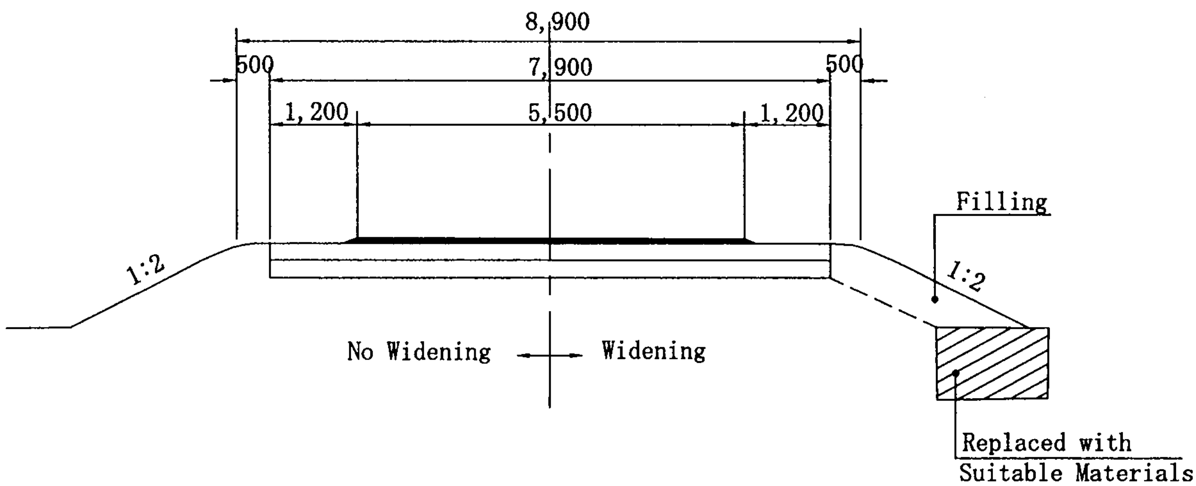
Section					Standard Cross Section Type	Side Ditch
Sta.	11+341	～	Sta.	11+554	Type B	Both sides
Sta.	11+554	～	Sta.	11+619	Type B	East side
Sta.	11+619	～	Sta.	11+683	Type B	Both sides
Sta.	11+683	～	Sta.	11+937	Type B	None
Sta.	11+937	～	Sta.	11+970	Type B	West side
Sta.	11+970	～	Sta.	12+059	Type B	Both sides
Sta.	12+059	～	Sta.	12+080	Type B	West side
Sta.	12+080	～	Sta.	12+224	Type B	None
Sta.	12+224	～	Sta.	12+287	Type B	Both sides
Sta.	12+287	～	Sta.	12+315	Type B	East side
Sta.	12+315	～	Sta.	12+358	Type B	None
Sta.	12+358	～	Sta.	12+404	Type B	East side
Sta.	12+404	～	Sta.	12+557	Type B	Both sides
Sta.	12+557	～	Sta.	12+809	Type B	None
Sta.	12+809	～	Sta.	12+827	Type B	East side
Sta.	12+827	～	Sta.	12+940	Type B	Both sides
Sta.	12+940	～	Sta.	13+128	Type B	East side
Sta.	13+128	～	Sta.	13+164	Type B	Both sides
Sta.	13+164	～	Sta.	13+264	Type B	None
Sta.	13+264	～	Sta.	13+365	Type B	West side
Sta.	13+365	～	Sta.	13+790	Type B	None
Sta.	13+790	～	Sta.	13+803	Type B	East side
Sta.	13+803	～	Sta.	13+885	Type B	Both sides
Sta.	13+885	～	Sta.	13+954	Type B	East side
Sta.	13+954	～	Sta.	14+037	Type B	Both sides
Sta.	14+037	～	Sta.	14+088	Type B	West side
Sta.	14+088	～	Sta.	14+105	Type B	None
Sta.	14+105	～	Sta.	14+163	Type B	East side
Sta.	14+163	～	Sta.	14+364	Type B	None



(1) General Section with Sidewalk (Type A)



(2) General Section without Sidewalk (Type B)



(3) Soft Ground Section (Type C)

* Thickness of Granular Subbase Course
Section 1,3 t=10cm
Section 2 t=15cm

FIGURE 2.3.2-1 STANDARD CROSS SECTION

Raeng Bridge has one lane. The transition section before and after the bridge is shown in Figure 2.3.2-2.

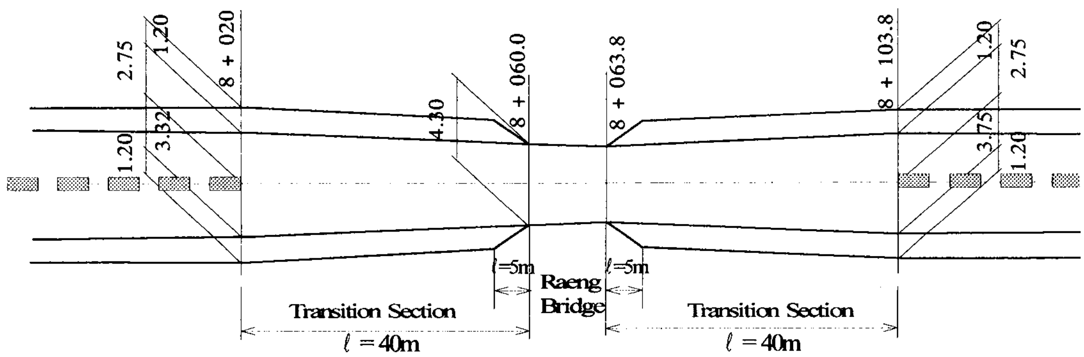


FIGURE 2.3.2-2 TRANSITION SECTION BEFORE AND AFTER RAENG BRIDGE

(2) Horizontal Alignment

Horizontal alignment is designed following the existing alignment since it meets the geometric design standard shown in 2.3.1.2, including the special values.

Table 2.3.2-2 shows the sections where the special values of radius are used and the corresponding design speeds to be applied as the result of the use of special values.

TABLE 2.3.2-2 SECTIONS WITH SPECIAL VALUES OF RADIUS

Section	Radius, R (m)	Design Speed (km/h)
Sta. 0 + 006.723 ~ Sta. 0 + 046.854	85	50
Sta. 1 + 834.393 ~ Sta. 1 + 919.494	85	50
Sta. 3 + 321.603 ~ Sta. 3 + 422.920	85	50
Sta. 4 + 109.080 ~ Sta. 4 + 179.641	100	50
Sta. 4 + 209.270 ~ Sta. 4 + 300.777	100	50
Sta. 4 + 758.683 ~ Sta. 4 + 806.092	90	50
Sta. 5 + 105.301 ~ Sta. 5 + 186.566	90	50
Sta. 5 + 961.320 ~ Sta. 6 + 051.535	100	50
Sta. 6 + 501.471 ~ Sta. 6 + 548.409	85	50
Sta. 7 + 522.537 ~ Sta. 7 + 610.480	100	50
Sta. 7 + 679.254 ~ Sta. 7 + 763.212	100	50
Sta. 7 + 872.415 ~ Sta. 7 + 910.696	55	40
Sta. 10 + 807.720 ~ Sta. 10 + 865.392	60	40
Sta. 13 + 576.072 ~ Sta. 13 + 658.980	45	40

(3) Vertical Alignment

The vertical alignment is designed taking into consideration the following:

- The vertical alignment in the steep sections is improved as necessary based on the geometric design standard set forth in 2.3.1.2. The sections where vertical alignments are improved are shown in Table 2.3.2-3.
- The sections of which the elevation is less than 1.0m in the flood sections are raised to an elevation of 1.0m. The corresponding sections are shown in Table 2.3.2-4.
- In other sections, the basic concept is to raise the existing elevation by the pavement thickness so as to construct a new pavement directly on the existing road.

TABLE 2.3.2-3 SECTIONS WHERE VERTICAL ALIGNMENT IS IMPROVED

Section	Present Grade (%)	Improved Grade (%)
Sta. 2 + 300 ~ Sta. 2 + 475	11.531	10.000
Sta. 3 + 975 ~ Sta. 4 + 350	11.779	10.000
Sta. 11 + 200 ~ Sta. 11 + 425	12.462	9.858
Sta. 12 + 150 ~ Sta. 12 + 250	12.740	9.936
Sta. 12 + 425 ~ Sta. 12 + 700	13.633	10.000
Sta. 12 + 775 ~ Sta. 12 + 925	11.787	10.000

TABLE 2.3.2-4 SECTIONS OF 1.0M IN ELEVATION

Section	Present Elevation (m)
Sta. 4 + 950 ~ Sta. 5 + 100	0.81 ~ 1.00
Sta. 5 + 325 ~ Sta. 5 + 525	0.94 ~ 1.00
Sta. 5 + 730 ~ Sta. 5 + 770	0.91 ~ 1.00
Sta. 6 + 725 ~ Sta. 6 + 875	0.93 ~ 1.00
Sta. 7 + 155 ~ Sta. 7 + 195	0.97 ~ 1.00

2.3.2.2 Pavement Design

(1) Basic Design Equation

AASHTO Guide for Design of Pavement Structures 1993 is adopted.

The basic design equation for flexible pavement is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_O + 9.36 \times \log_{10}(SN + 1)$$

$$-0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN + 1)^{5.19}}}$$

$$+ 2.32 \times \log_{10}(M_R) - 8.07$$

where:

W_{18} = predicted number of 18-kip equivalent single axle load applications,
Z_R = standard normal deviate,
So = combined standard error of the traffic prediction and performance prediction,
$\triangle$PSI= difference between the initial design serviceability index, Po, and the design terminal serviceability index, Pt, and
M_R = resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where:

a_i = i^{th} layer coefficient,
D_i = i^{th} layer thickness (inches), and
m_i = i^{th} layer drainage coefficient.

(2) Traffic Load (W_{18})

Load factor (an average of 18-kip equivalent single axle loads (ESAL's) per vehicle) is assumed as follows:

Type of Vehicle	Axle Load (ton)			18 kip ESAL Factor *			Load Factor
	Front Wheel	Rear Wheel	Trailer	Front Wheel	Rear Wheel	Trailer Wheel	
Small Bus	1.00	4.00	-	0.001	0.062	-	0.063
Large Bus	1.60	6.40	-	0.003	0.363	-	0.366
Pick Up	1.00	3.00	-	0.001	0.022	-	0.023
Truck	3.00	9.00	-	0.022	1.525	-	1.547
Trailer	2.00	8.00	8.00	0.005	0.918	0.918	1.841

Note: * Base on AASHTO Guide

A 12-hour traffic volume in year 2000 and number of 18 kip ESAL's (Σ (Vehicle x Load Factor)) are as follows:

		Section 1		Section 2		Section 3	
		South Bound	North Bound	South Bound	North Bound	South Bound	North Bound
Traffic Volume	Small Bus	4	4	6	4	0	0
	Large Bus	4	11	4	4	3	4
	Pick Up	90	90	28	28	17	13
	Truck	12	14	7	7	4	5
	Trailer	3	0	0	0	0	0
18 Kip ESAL's		27.87	28.01	13.32	13.19	7.68	9.50

Annual total number of 18 kip ESAL's in year 2003 (opening year) is obtained from the following equation:

$$W = W' \times m \times (1 + r/100)^3 \times 365$$

where, W = number of annual 18 kip ESAL's in year 2003
W'= number of 12-hour 18 kip ESAL's in year 2000
m = 12-hour traffic volume to daily traffic volume ratio (1.25)
r = traffic growth rate (1.6% p.a.)

Number of 18 kip ESAL's for 10 years from year 2003 to 2012 is obtained from the following equation:

$$W_{18} = W \times \frac{(1 + r/100)^{10} - 1}{r/100}$$

W_{18} = Number of 18 kip ESAL's for 10 years from year 2003 to 2012.

The results are as follows:

	Section 1	Section 2	Section 3
Number of 12-hour 18 kip ESAL's in year 2000 (W')	28.01	13.32	9.50
Number of Annual 18 kip ESAL's in year 2003 (W)	13,400	6,370	4,550
Number of 18 kip ESAL's from year 2003 to 2012	144,100	68,500	48,900

(3) Pavement Structure

<u>Design Condition</u>

Reliability $Z_R = 0$, $So = 0.45$ (Probability that traffic loadings and pavement performance are within the predicted range is 50%)

Performance Criteria $\Delta PSI = Po - Pt$
Po = 4.2 (AASHO Road Test results)
Pt = 2.5 (standard in AASHTO Guide)

Roadbed Property $M_R = 1{,}500 \times CBR$ (based on AASHTO Guide)

CBR used in the design is determined as follows:

- 80% of the CBR test result is applied, in consideration of dispersion.
- The maximum design CBR is 10.

Required Pavement Structure Number

Required pavement structural number (SN) is obtained from the formula shown in (1) for each section.

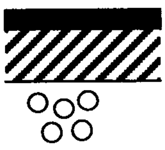
The results of calculation are as follows:

	Section 1	Section 2	Section 3
W_{18}	144,100	68,500	48,900
CBR (Test Result)	14.0	6.5	11.0
CBR (Assumed value for design)	10.0	5.2	8.8
Required SN	1.523	1.748	1.316

Pavement Structure

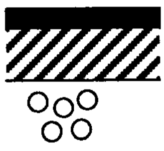
Pavement thickness is designed as follows:

Sections 1 and 3



AC Surface course 5cm
Cement Treated Base Course 10 cm
Granular Subbase Course 10 cm

Section 2



AC Surface course 5cm
Cement Treated Base Course 10 cm
Granular Subbase Course 15 cm

Material properties of each pavement layer are assumed as follows:

Layer Coefficient

AC Surface Course	: 0.39 (E_{AC} = 350,000 psi)
Cement Treated Base Course	: 0.145 (qu = 356 psi)
Granular Subbase Course	: 0.108 (CBR = 30)

Drainage Coefficient

Cement Treated Base Course	: 0.9
Granular Subbase Course	: 0.8 (Water removed within 1 week, duration pavement is exposed to moisture level approaching staturation is 60%)

SN is obtained as follows:

Sections 1 and 3

	Layer Coefficient (a)	Thickness in inch (D)	Drainage Coefficient (m)	SN = a・D・m
Surface Course	0.39	1.969	-	0.77
Base Course	0.145	3.937	0.9	0.51
Subbase Course	0.108	3.937	0.8	0.34
Total				1.62

Section 2

	Layer Coefficient (a)	Thickness in inch (D)	Drainage Coefficient (m)	SN = a・D・m
Surface Course	0.39	1.969	-	0.77
Base Course	0.145	3.937	0.9	0.51
Subbase Course	0.108	5.906	0.8	0.51
Total				1.79

SN of each section is higher than required.

2.3.2.3 Bridge Reconstruction Design

(1) Basic Plan

The Quatliw Bridge is reconstructed with a box culvert type at the same location as the existing bridge, providing the minimum free board of 60 cm.

A revetment made of grouted riprap is provided in five meters section downstream and 10 meters section upstream. Rubbles are laid on the riverbed to prevent the riverbed from being scoured and mud from going into the box culvert in the section where the revetment is provided.

Provision of a detour and temporary shifting of the river are required for the construction of the box culvert, as mentioned in 3.1.2.

(2) Dimension

The width and general view of the box culvert are shown in Figure 2.3.2-3 and Figure 2.3.2-4 respectively.

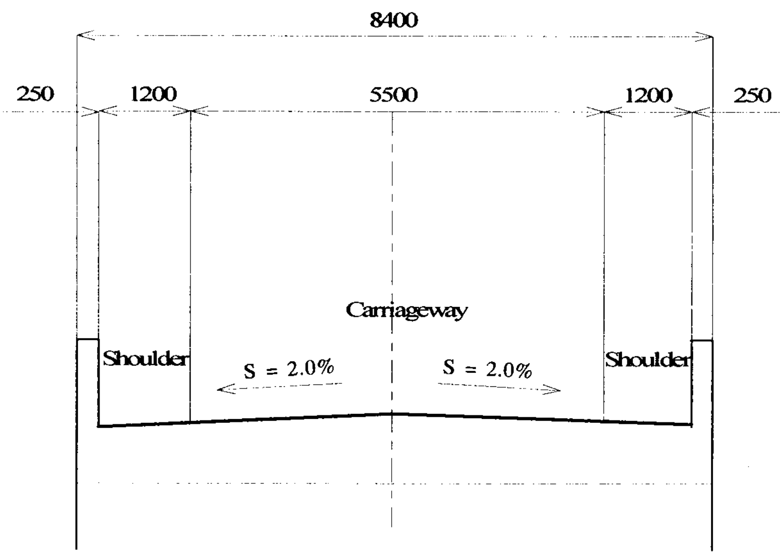


FIGURE 2.3.2-3 WIDTH OF QUATLIW BRIDGE

2.3.2.4 Drainage Design

(1) Cross Drainage Facilities

The basic concept for measures against flooding is to reduce the flood water depth to the extent enabling vehicles to pass, say about 15 cm, for the rainfall discharge at the return period of five years. Since this target is achieved by the slight raise of the road elevation in the related sections and reconstruction of Quatliw Bridge in addition to the existing culverts and the culverts constructed under the FEMA project, no additional culvert is installed in this Project. Table 2.3.2-5 shows the flood sections and the maximum flood water depth estimated through the hydraulic analysis (the hydraulic analysis is presented in Appendix 9).

The existing culverts which is shortage in length shall be extended. Table 2.3.2-6 lists the existing culverts.

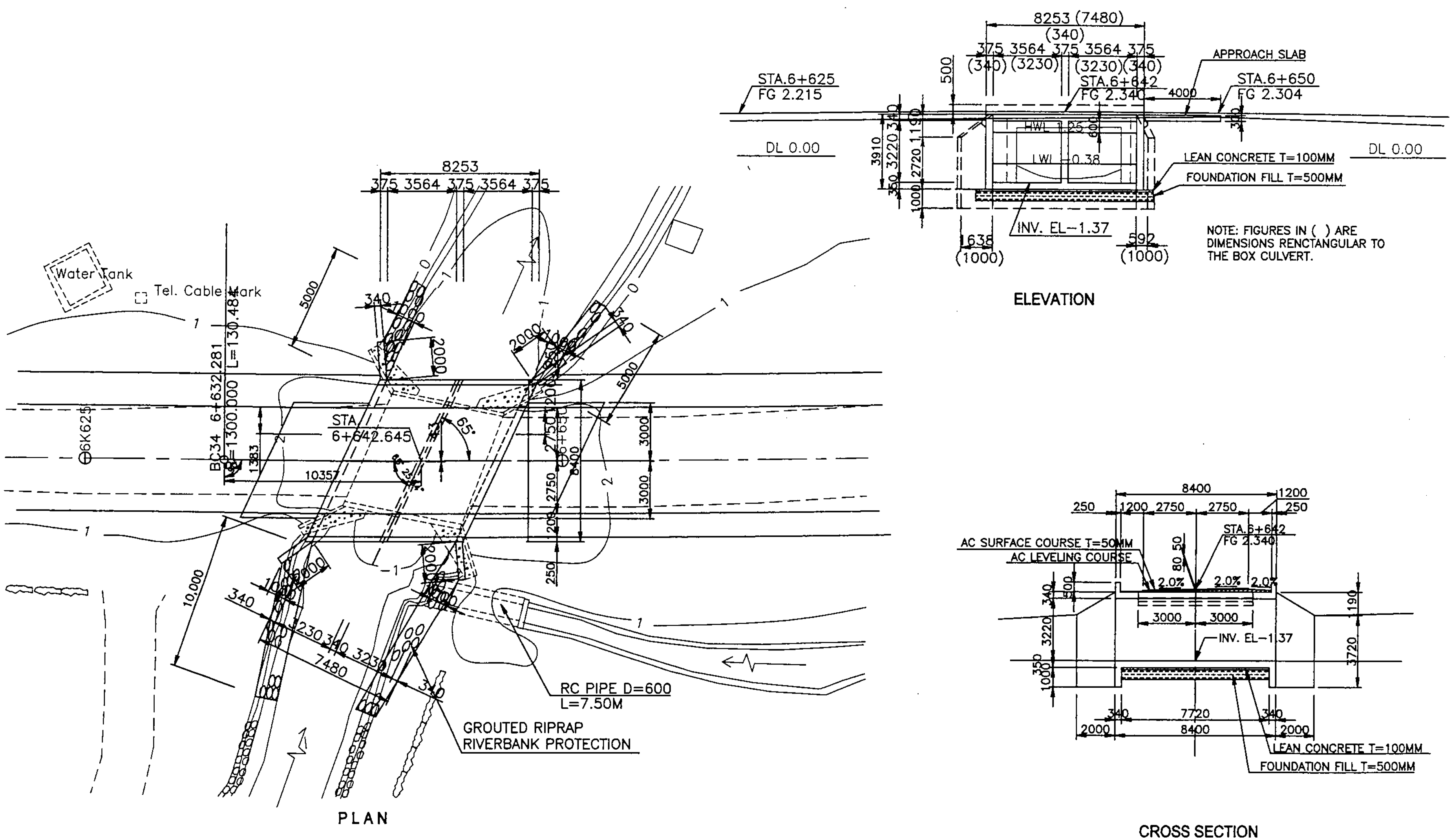


FIGURE 2.3.2-4 GENERAL VIEW OF QUATLIW BRIDGE

TABLE 2.3.2-5 FLOOD SECTIONS

Section	Section Length (m)	Maximum Waster Depth (cm)
Sta. 4.937 ～ Sta. 5.110	173	9.2
Sta. 5.319 ～ Sta. 5.528	209	9.2
Sta. 5.718 ～ Sta. 5.773	56	14.9
Sta. 6.713 ～ Sta. 6.898	185	14.9
Sta. 7.152 ～ Sta. 7.198	46	14.9

TABLE 2.3.2-6 EXISTING CULVERT

Number	Location	Type	Size (m)	Remarks
①	Sta. 59	2-cell Pipe	ϕ0.46 x 2	
②	Sta. 931	Pipe	ϕ0.46	
③	Sta. 2.093	2-cell Pipe	ϕ1.2 x 2	
④	Sta. 2.460	Box	H2.4 x B2.6	
⑤	Sta. 2.615	Pipe	ϕ0.76	FEMA
⑥	Sta. 3.127	Box	H2.4 x B2.6	
⑦	Sta. 3.455	Pipe	ϕ1.07	
⑧	Sta. 3.786	Pipe	ϕ0.91	
⑨	Sta. 4.390	3-cell Box	H1.22 x B2.14 x 3	
⑩	Sta. 4.483	Pipe	ϕ0.61	FEMA, extension by 4.7m
⑪	Sta. 5.201	2-cell Pipe	ϕ0.76 x 2	
⑫	Sta. 5.574	2-cell Pipe	ϕ0.76 x 2	
⑬	Sta. 5.810	Pipe	ϕ0.91	
⑭	Sta. 5.886	Pipe	ϕ0.91	
⑮	Sta. 5.949	3-cell Pipe	ϕ0.91 x 3	
⑯	Sta. 6.060	Pipe	ϕ0.91	FEMA
⑰	Sta. 6.338	Pipe	ϕ0.76	FEMA, extension by 1.5m
⑱	Sta. 6.514	Pipe	ϕ0.91	FEMA
⑲	Sta. 6.973	2-cell Pipe	ϕ0.91 x 2	
⑳	Sta. 7.227	Pipe	ϕ0.75	
㉑	Sta. 7.408	Pipe	ϕ0.6	FEMA
㉒	Sta. 7.582	2-cell Box	H1.25 x B2.3 x 2	
㉓	Sta. 7.792	Pipe	ϕ0.61	extension by 4.5m
㉔	Sta. 7.848	Pipe	ϕ0.61	FEMA
㉕	Sta. 8.018	Pipe	ϕ0.61	extension by 4.5m
㉖	Sta. 8.285	Box	H0.95 x B1.5	
㉗	Sta. 8.728	2-cell Box	H1.3 x B2.35 x 2	
㉘	Sta. 8.760	Box	H1.3x B1.35	
㉙	Sta. 8.841	2-cell Box	H1.2 x B2.3 x 2	
㉚	Sta. 9.001	2-cell Box	H1.7 x B2.25 x 2	
㉛	Sta. 9.056	Box	H0.4 x B0.9	
㉜	Sta. 9.113	Box	H0.4 x B0.9	
㉝	Sta. 9.194	Box	H1.22 x B3.2	

Number	Location	Type	Size (m)	Remarks
㉞	Sta. 9.332	Box	H1.22 x B3.2	
㉟	Sta. 9.404	2-cellBox	H1.4 x B2.2 x 2	
㊱	Sta. 9.583	Pipe	ϕ0.61	FEMA
㊲	Sta. 9.970	Pipe	ϕ0.61	FEMA
㊳	Sta. 10.159	2-cell Pipe	ϕ1.22 x 2	
㊴	Sta. 10.192	Box	H1.4 x B2.3	
㊵	Sta. 10.446	Pipe	ϕ0.76	FEMA
㊶	Sta. 10.710	Box	H1.22 x B2.3	
㊷	Sta. 10.955	Pipe	ϕ0.76	FEMA
㊸	Sta. 11.142	Pipe	ϕ0.76	FEMA
㊹	Sta. 11.193	2-cell Box	H1.22 x B2.3 x 2	
㊺	Sta. 11.702	Pipe	ϕ0.61	
㊻	Sta. 12.133	Pipe	ϕ0.61	FEMA
㊼	Sta. 12.756	Box	H1.23 x B2.44	
㊽	Sta. 13.590	Box	H2.4 x B4.0	
㊾	Sta. 13.690	Pipe	ϕ1.2	
㊿	Sta. 13.750	Pipe	ϕ1.2	FEMA
51	Sta. 13.892	Pipe	ϕ0.6	
52	Sta. 13.928	Pipe	ϕ0.6	
53	Sta. 14.151	2-cell Pipe	ϕ1.2 x 2	
54	Sta. 14.200	Pipe	ϕ1.2	

Note: Including culverts constructed under the FEMA project

(2) Road Surface Drainage Facilities

Natural drainage is adopted for embankment sections. V-type side ditch made of grouted riprap is provided in the sections where the elevation is the same as or lower than the abutting ground level.

Storm water run-off is calculated by the rational formula.

$$Q = \frac{1}{3.6 \times 10^6} \times C \times I \times a$$

Where:

Q : Run-off (m^3/sec)
C : Run-off coefficient
I : Intensity of rainfall for a duration of the time of concentration (mm/hour)
a : Catchment area (m^2)

Discharge area and mean velocity are computed by the following formula:

$$Q = A \bullet V$$

$$V = \frac{1}{n} \bullet R^{2/3} \bullet i^{1/2}$$

Where:

A	:	Cross-sectional area of flowing water (m^2)
V	:	Mean velocity (m/sec)
n	:	Roughness coefficient
R	:	Hydraulic radius (m) R = A/P (P = wetted perimeter length)
I	:	Hydraulic gradient

Design variables are assumed as follows:

- Run-off Coefficient C : 0.8 (Pavement surface or cement treated base course surface)
  : 0.5 (Other ground surfaces)
- Rainfall Intensity I : 135 mm/h (return period = 3 years, time of concentration = 10 minutes)
- Roughness Coefficient n : 0.025 (grouted riprap)

Hydraulic analysis results are shown in Appendix 10.

2.3.2.5 Other Road Facilities Design

(1) Slope Protection Works

The slope protection works with grouted riprap are provided in the sections affected by sea wave. The sections to be protected are shown in Table 2.3.2-7.

TABLE 2.3.2-7 SLOPE PROTECTION WORKS

Section	Section Length (m)
Sta. 7.132 ～ Sta. 7.224	92
Sta. 8.230 ～ Sta. 8.260	30
Sta. 8.504 ～ Sta. 8.595	91
Sta. 8.839 ～ Sta. 8.946	107
Sta. 10.333 ～ Sta. 10.363	30
Total	350

(2) Road Marking

Centerline is drawn with broken line.

(3) Traffic Signs

The following traffic signs are installed:

Speed Limit : Speed limit signs are installed at the starting and end points of the Project Road as well as at the changing points of the design speed. The design speed is changed at the boundary of Sections 2 and 3 and in the sections where the special values of radius are used.

Reduction of Road Width Ahead : These signs are installed before the transition section from 2-lane to 1-lane at Raeng Bridge.