No.

Road Development Authority
The Domecratic Socialist Republic
of Sri Lanka

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR
CONSTRUCTION OF NEW MANNAR BRIDGE
AND IMPROVEMENT OF CAUSEWAY
IN
THE DEMOCRATIC SOCIALIST
REPUBLIC OF SRI LANKA

December 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
AND
ORIENTAL CONSULTANTS CO., LTD.

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PREFACE

In response to a request from the Government of Sri Lanka, the Government of Japan decided to conduct a basic design study on the Project for Construction of New Mannar Bridge and Improvement of Causeway in the Democratic Socialist Republic of Sri Lanka and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Sri Lanka a study team from June 14, 2006 to June 20, 2006 and from July 27, 2006 to August 18, 2006, respectively.

The team held discussions with the officials concerned of the Government of Sri Lanka, 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 Sri Lanka 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 Sri Lanka for their close cooperation extended to the teams.

December 2006

Masafumi Kuroki

Vice-President

Japan International Cooperation Agency

December 2006

Letter of Transmittal

We are pleased to submit to you the basic design study report on the project for Construction of New Mannar Bridge and Improvement of Causeway in the Democratic Socialist Republic of Sri Lanka.

This study was conducted by the Joint Venture of Nippon Koei Co., Ltd. and Oriental Consultants Co., Ltd, under a contract to JICA, during the period from June, 2006 to January, 2007. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Sri Lanka 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,

Hiroshi Fujisawa
Chief Consultant
Basic design study team on
the project for Construction of New Mannar Bridge
and Improvement of Causeway
in the Democratic Socialist Republic of Sri Lanka
Nippon Koei Co., Ltd.
and
Oriental Consultants Co., Ltd.

Summary

Summary

1. Outline of the Country

The Democratic Socialist Republic of Sri Lanka (hereinafter referred to as "Sri Lanka") is an island country located in the southeast of the Indian Continent, having a land area of 65,550 sq.km and a population of 19.7 million. The country's road network has a total length of 91,862km consisting of 11,771km of national roads of Class-A and Class-B, 15,532km of provincial roads, and 64,569km of rural roads. Most roads were constructed more than 50 years ago. Road maintenance, rehabilitation and new construction have not kept abreast with the rapid growth of transport demand, resulting in negative consequences on road user costs, road safety and economic development in Sri Lanka. The Government of Sri Lanka (GOS) formulated a Road Sector Master Plan (RSMP) in 2005. The road development programme is based on the future traffic projections and on development activities decentralizing from Colombo to the economic growth centers in Sri Lanka.

2. Background and Outline of the Project

The Bridge and Causeway connecting the Mannar Island and the mainland were constructed in the 1930s with an overall length of 121.2m and an overall width of 4.26m. The 38.0m long steel truss center span of the bridge was blasted and the wreckage of the steel truss members still remains in the canal. It was re-built temporarily with a steel Bailey bridge. Both end sections, consisting of 4-lane 10.4m long concrete bridges, were also damaged severely due to the blasting. The use of the existing bridges is limited to 10-ton vehicles and at present there are risks of accident and damage caused by heavy vehicles, thus hindering smooth transportation and causing high transportation cost. Traffic safety is also not ensured for pedestrians passing the bridges. The existing causeway of approximately 3.5km long in total and 6.3m wide on average is retained by masonry walls. Its single-lane carriageway with a width of about 3.5m is paved by DBST and the sidewalks on both sides are paved by laterite soil. Heavy vehicles passing on the causeway must reduce speed and wait on the sidewalk for coming vehicles from the opposite side. The retaining walls are inclined or collapsed due to the wheel load of heavy vehicles. However, the bridge and causeway reconstruction programme was not implemented because of financial constraints and the prevailing security situation in the project area.

Following the result of the peace process, GOS requested the Government of Japan to extend Japan's Grant Aid for the construction of the new Manner Bridge and improvement of the causeway. In response to the request, the Japan International Cooperation Agency (JICA) dispatched a Preliminary Study Team to Sri Lanka in March 2006. The team held discussions with officials of GOS to confirm the requests from GOS and conducted a field survey. Through the preliminary study, the team basically confirmed the necessity of urgent construction of the bridge and improvement of the causeway. Based on the preliminary study result, JICA decided to conduct a Basic Design Study (the Study) on the Project for the construction of the new Mannar Bridge and improvement of the causeway, and dispatched a basic study team (the Study Team) to Sri Lanka in July 2006 to discuss the scope of the project and conduct the site survey and collect necessary data for basic design.

3. Design Policy and Facility Plans of the Project Construction Period and Estimated Project Cost

GOS has announced a concept to decentralize development activities to the areas outside Colombo and selected the Mannar area as an economic growth center in the Road Sector Master Plan (RSMP), 2005. The project aims at providing the national road class causeway and bridge with two carriageways to rehabilitate the infrastructure for administrative and economic activities in the Mannar area. The design of the facilities emphasizes the measures against damage by salty water and settlement of soft soil, environmental impact and traffic safety. As the existing bridge was severely damaged by the blast, it will be used only for the general traffic during the construction and a temporary bridge will be provided for the construction vehicles and equipment. Although the existing causeway is narrow and damaged by the increasing heavy traffic and also inundated at the highest tide, its eastern retaining wall is relatively strong enough to be used as a temporary road for construction vehicles and equipment during the construction. The causeway will be improved by widening it on the western side and maintaining the eastern retaining wall which will be incorporated in the new causeway. As for treatment of the soft soil of the sea bed in the widening area, the displacement method will be applied to minimize the settlement and to ensure smooth running.

The facilities designed according to the basic policy are as shown below:

Facilities of New Bridge, Causeway and Approach Roads

Items		Facilities
Bridge	Type	6 Spans Connection PC I-Girder
	Total Length	157.1m
	Width	Total Width: 10.40m
		Carriageway: 2 lanes (3.70m + 3.70m)
		Foot way: 1.50m each side (included Handrail)
	Abutment	Pile Bent Type (Cast-in-place concrete pile) 2 places
		Slope Protection: Stone Masonry
	Pier	Pile Bent Type (Cast-in-place concrete pile) 5 places
	Pavement	Cold Mixed Asphalt Pavement: 50mm (Carriageway)
Causeway and Approach Roads	Total Length	Approach Road in Beginning side: 140m
		Causeway: 3,140m
		Approach Road to Bridge: Mainland side: 155m
		Mannar Island side: 158m
	Width	Total Width: 11.00m
		Carriageway: 2 lanes (3.70m + 3.70m)
		Shoulder: 1.80m each side (including top of wall of 60cm)
		Causeway: Widening toward Western side
	Type of Slope Protection	West Side: New RC Concrete Reverse-T Wall and Gravity Retaining Wall Type including Soft Ground Measurement (Displacement Method)
		East Side: Repair of Masonry Wall and Reinforced with Concrete Cover
		Approach Road: Sod/Grass
	Pavement	DBST (Double Bituminous Surface Treatment): 20mm

4. Construction Period and Estimated Project Cost

The detailed design including tender process will take about 7 months. The construction period will be about 29 months. The total cost of the Project to be borne by the Japan's Grant Aid is estimated at Japanese Yen 1.878 billion and that by GOS at Japanese Yen 19 million (Sri Lanka Rupee 17 million).

5. Project Evaluation and Recommendation

The areas directly benefited by the Project cover Mannar and Vavuniya districts, where about 200,000 people accounting for about 1% of the total population of Sri Lanka.

The direct impacts and effects of the Project implementation are solving of traffic bottlenecks, reduction of transportation cost, activation of regional development and improvement of stability of the people's livelihood. Furthermore, the Government Agent of Mannar expects to improve the access to the road network of the mainland of Sri Lanka in line with the Road Sector Master Plan (RSMP) in 2005. The road development programme is based on the future traffic projections and on development activities decentralizing from Colombo to the economic growth centers in Sri Lanka.

In addition to such many direct impacts and effects, the regional industries such as agriculture and fisheries will be activated by the reconstruction of the Mannar Bridge and Causeway which constitute a bottleneck for the transport of products to/from agriculture and fishery facilities. The Project will improve the transportation system of Mannar Province, enhancing the agriculture and fisheries sectors and creating opportunities for resettlement of displaced persons into their original industries.

Upon completion of the Project the new Mannar Bridge and Causeway will play the role of a life-line corridor for the people living in Mannar and, as a result, a number of benefits discussed above will be realized and the livelihood of those people will be improved. In this regard, it is worth implementing the Project by the Japan's Grant Aid at an earliest date.

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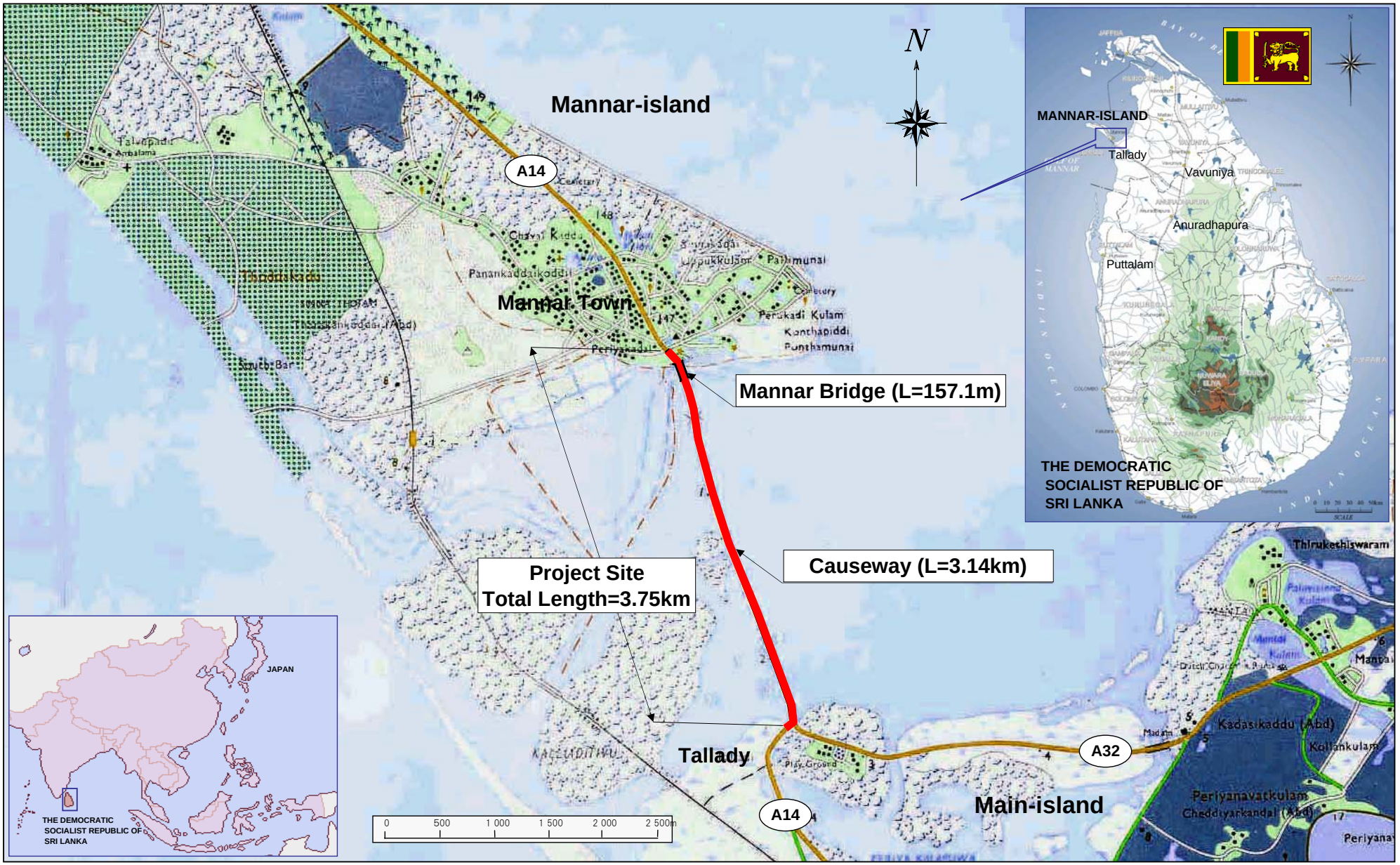
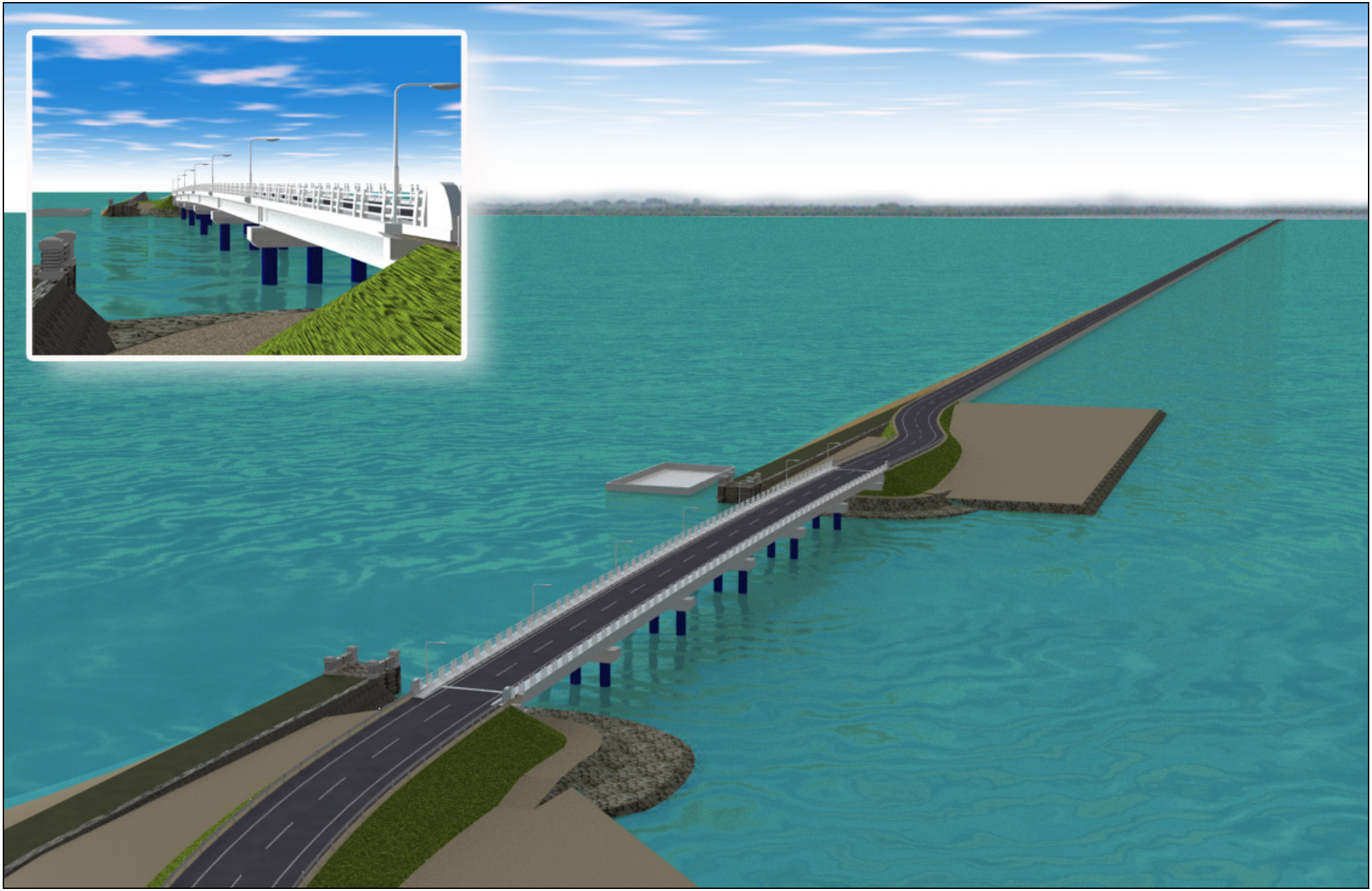


The Project for Construction of New Mannar Bridge and Improvement of Causeway Location Map



PERSPECTIVE VIEW OF NEW MANNAR BRIDGE AND CAUSEWAY

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Abbreviation

A/P	:	Authorization to Pay
A14	:	Route 14
AASHTO	:	American Association of State Highway and Transport Officials
B/A	:	Bank Arrangement
BS	:	British Standard
CBR	:	California Bearing Ratio
CCD	:	Coast Conservation Department, Ministry of Fishery and Aquatic Resources
DBST	:	Dabble Bituminous Surface Treatment
E/N	:	Exchange of Note
ESA	:	Equivalent Standard Axle
GA	:	Government Agents
GOJ	:	Government of Japan
GOS	:	Government of Sri Lanka
H.W.L.	:	High Water Level
HAT	:	Highest Astronomical Tide
IEE	:	Initial Environment Examination
JICA	:	Japan International Corporation Agency
LAT	:	Lowest Astronomical Tide
LTTE	:	The Liberation Tigers of Tamil Eelam
MHWS	:	Mean High Water Springs
MLWS	:	Mean Low Water Springs
MSL	:	Mean Sea Level
N/P	:	Notice to Proceed
PC	:	Prestressed Concrete
PMU	:	Project Management Unit
RC	:	Reinforced Concrete
RC&DC	:	Road Construction & Development Corporation
RDA	:	Road Development Authority
Rs	:	Sri Lankan Rupee
RSMP	:	Road Sector Master Plan
US$	:	United State Dollar
W/C	:	Water and Cement Ratio

CHAPTER 1

BACKGROUND OF THE PROJECT

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The Democratic Socialist Republic of Sri Lanka (hereinafter referred to as "Sri Lanka") is an island country located in the southeast of the Indian Continent, having a land area of 65,550 sq.km and a population of 19.7 million. The country's road network has a total length of 91,862km consisting of 11,771km of national roads of Class-A and Class-B, 15,532km of provincial roads, and 64,569km of rural roads. Most roads were constructed more than 50 years ago. Road maintenance, rehabilitation and new construction have not kept abreast with the rapid growth of transport demand, resulting in negative consequences on road user costs, road safety and economic development in Sri Lanka.

The Government of Sri Lanka (GOS) has put forward the concept of "Country to the Front" to promote comprehensive development of the country for the benefit of the entire population. In its national development policy, the GOS has given priority to the road network with a view of contributing to the well-being of the population and promoting the economic development. GOS formulated a Road Sector Master Plan (RSMP) in 2005. The road development programme is based on the future traffic projections and on development activities decentralizing from Colombo to the economic growth centers in Sri Lanka. The final target is to improve more than 19,000km of the existing road network and by investing 227 billion rupees during the programme implementation period.

Adequate transport infrastructure is an essential component for social and economic development of Sri Lanka. GOS has undertaken several projects for rehabilitation and improvement of the road network with foreign fund for enhancing the level of service and improving the traffic capacity. GOS has given a very high priority to the rehabilitation of the war-affected areas in the Northern Province following the start of the peace process. As rehabilitation of the infrastructure is a major component of the government programme, and as the Mannar Bridge is located within the northern area, the Project is in line with the government programme and policy.

The Mannar Bridge and Causeway connecting the Mannar Island and the mainland were constructed in the 1930s with an overall length of 121.2m and an overall width of 4.26m. The 38.0m long steel truss center span of the bridge was blasted and the wreckage of the steel truss members still remains in the canal. It was re-built temporarily with a steel Bailey bridge. Both end sections, consisting of 4-lane 10.4m long concrete bridges, were also damaged severely due to the blasting. The use of the existing bridges is limited to 10-ton vehicles and at present there are risks of accident and damage caused by heavy vehicles, thus hindering smooth transportation and causing high transportation cost. Traffic safety is also not ensured for pedestrians passing the bridges. The existing causeway of approximately 3.5km long in total and 6.3m wide on average is retained by masonry walls. Its single-lane carriageway with a width of about 3.5m is paved by DBST and the sidewalks on both sides are paved by laterite soil. Heavy vehicles passing on the causeway must reduce speed and wait on the sidewalk for coming vehicles from the opposite side. The retaining walls are inclined or collapsed due to the wheel load of heavy vehicles. However, the bridge and causeway reconstruction programme was not implemented because of financial constraints and the prevailing security situation in the project area.

Following the result of the peace process, GOS requested the Government of Japan to extend Japan's Grant Aid for the reconstruction of Mannar Bridge and Causeway.

In response to the request, the Japan International Cooperation Agency (JICA) dispatched a Preliminary Study Team to Sri Lanka in March 2006. The team held discussions with officials of GOS to confirm the requests from GOS and conducted a field survey. Through the preliminary study, the team basically confirmed the necessity of urgent construction of the bridge and improvement of the causeway and the fact that preliminary environmental approval for the Project has been issued by the Coastal Conservation Department (CCD).

Based on the preliminary study result, JICA decided to conduct a Basic Design Study (the Study) on the Project for the Construction of New Mannar Bridge and Improvement Causeway and dispatched a basic study team (the Study Team) to Sri Lanka in July 2006 to discuss the scope of the project and conduct the site survey and collect necessary data for basic design. After the Study Team

returned to Japan, further study and basic design were conducted and the draft final report was prepared. Then JICA sent the Basic Design Explanation Team to Sri Lanka from November 12 to November 18, 2006 and the Minutes of Discussion, which mainly covered the results of the basic design and the recipient country's obligations, was agreed by both sides.

CHAPTER 2

CONTENTS OF THE PROJECT

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2-1 BASIC CONCEPT OF THE PROJECT

2-1-1 OVERALL GOAL AND PROJECT PURPOSE

Sri Lanka is an island country located in the southeast of the India Continent. The Government has put forward the concept of "Country to the Front" to promote comprehensive development of the country for the benefit of the entire population. In its national development policy, GOS has given priority to the road network with a view of contributing to the well-being of the population and promoting the economic development.

GOS formulated a Road Sector Master Plan (RSMP) in 2005. The road development programme is based on the future traffic projections and on development activities decentralizing from Colombo to the economic growth centers in Sri Lanka. The final target is to improve more than 19,000km of the existing road network by investing 227 billion rupees during the programme implementation period.

The Mannar Bridge and Causeway connecting the Mannar Island and the mainland were constructed in the 1930s with a narrow width and a single lane. The existing bridge, which was reconstructed by a temporary Bailey bridge after being blasted in 1990, has a narrow width and its use is limited to 10ton vehicles. The causeway also has a narrow width and a single traffic lane, and has been damaged by the increasing heavy traffics. The causeway is frequently inundated and traffic is often interrupted for a long time, hindering smooth transportation and causing high transportation cost. Traffic safety is also not ensured for pedestrians passing the bridges.

GOS expects to resolve the traffic bottlenecks, improve mobility on the national road network, reduce overall vehicle operating cost, activate the regional development and enhance the stability of people's livelihood through the implementation of the Project.

2-1-2 OUTLINE OF THE PROJECT

Adequate transport infrastructure is an essential component for social and economic development of Sri Lanka. GOS has undertaken several projects for rehabilitation and improvement of the road network with foreign fund for enhancing the level of service and improving the traffic capacity. GOS has given a very high priority to the rehabilitation of the war-affected areas in the Northern Province following the start of the peace process. As rehabilitation of the infrastructure is a major component of the government programme, and as the Mannar Bridge is located within the northern area, the Project is in line with the government programme and policy.

The existing Mannar bridge built across the canal in the Mannar bay have an overall length of 121.2m and an overall width of 4.26m. The center span, consisting of a 38.0m long steel truss, was blasted and the wreckage of the steel truss members still remains in the canal. It was re-built temporarily with a steel Bailey bridge. Both end sections, consisting of 4-span 10.4m long concrete bridges, were also damaged severely due to the blasting. The use of the existing bridges is limited to 10-ton vehicles and at present there are risks of accident and damage caused by heavy vehicles, thus hindering smooth transportation and causing high transportation cost. Traffic safety is also not ensured for pedestrians passing the bridges. The existing causeway of approximately 3.5km long in total and 6.3m wide on average is retained by masonry walls. Its single-lane carriageway with a width of about 3.5m is paved by DBST and the sidewalks on both sides are paved by laterite soil. Heavy vehicles passing on the causeway must reduce speed and wait on the sidewalk for coming vehicles from the opposite side. The retaining walls are inclined or collapsed due to the wheel load of heavy vehicles. However, the bridge and causeway reconstruction programme was not implemented because of financial constraints and the prevailing security situation in the project area.

GOS requested the Government of Japan to extend Japan's Grant Aid for the construction of the New Mannar Bridge and improvement of the Causeway which are finally outlined in the basic design as follows:

- Construction of a new 157.1m long, 10.4m width bridge, with 6 PC I-Girder spans, 2 carriageways and foot walks on both sides.
- Improvement of the 3.14km long, 11.0m wide causeway, with 2 carriageways and foot walks on both sides.
- Construction and improvement of 0.45m long, 11.0m wide approach roads, with 2 carriageways and foot walks on both sides.

The New Mannar Bridge has been planned to be constructed on the western side of the existing bridge where existing important buildings and facilities that may be subject to environmental impact of the Project are very few on the bridge alignment, and the concrete bridge type has been selected to ensure durability against damage by salty water.

2-2 BASIC DESIGN UNDER THE REQUIRED JAPANESE ASSISTANCE

2-2-1 DESIGN POLICY

2-2-1-1 Basic Policy

(1) Cause of Damage and Reconstruction Method

The Mannar Bridge was blasted and damaged severely in both superstructure and substructure. The causeway was also damaged by the blast and has further deteriorated due to the increasing heavy traffics. It was also inundated at the highest tide and traffic was often interrupted in the raining season.

Since the existing bridge is in a risk of collapse due to heavy vehicles, it is necessary to construct a new bridge at 20m on the western side of and in parallel with the existing bridge. Besides, the causeway will be widened by 11.0m on the western side while the eastern retaining wall will be retained to minimize the construction cost.

(2) Measures against Damage by Salty Water

To protect concrete structures from damage by salty water, the following measures have been taken into consideration in designing the project bridges and concrete structures:

- PC (Prestressed Concrete) girders are selected for superstructure;
- One rank high strength concrete is applied as design concrete strength considering the conditions affected by salty water in accordance with the Bridge Design Manual, RDA, 1997;
- Bridge accessories such as expansion joints, shoes, railing are corrosion-resistant;
- Any steel material in contact with salty water is protected against corrosion; and
- The area of concrete surface in contact with salty water is minimized to avoid deterioration.

(3) Bridge Design and Construction Planning in Consideration of Dry and Rainy Seasons

According to the results of site survey conducted from June and August 2006, the construction works in the sea can be carried out in the dry condition. To minimize the

construction cost, the construction works below the high water level shall be completed during the dry season.

(4) Measure against Settlement

As the sea bed is a soft ground, settlement will occur under the embankment. The existing causeway and the widening section are in different conditions of soil consolidation, resulting in a gap between them due to settlement. Taking this condition into consideration, the displacement method (soft ground is excavated and replaced with good embankment material) has been applied as a counter-measure against settlement considering the reliability of this method, and the construction period and cost.

(5) Adopted Standards

The Geometric Design Standard of Road 1998 has been applied for geometric design of roads and bridges. The Bridge Design Manual, RDA, 1997 which refers to BS 5400 Part 2, has been applied for bridge design. The Japanese Industrial Standard (JIS) has been applied for expansion joints and rubber bearing shoes.

(6) Planning of Bridge and Causeway in Consideration of Future Maintenance

The bridge has been designed in consideration of minimum and easy maintenance. Bridge drains, expansion joints and shoes have been designed considering easy cleaning and durability. Concrete design strength, which should be durable against salty water, has been determined and designed for quality of cement, aggregate and sand and their design mix proportion.

2-2-1-2 Policy on Natural Condition

(1) Climatic Condition

The designs, construction plans and quality plans of the bridge and causeway have been prepared in consideration of the following climatic conditions:

- The average monthly temperature is the highest at 35.4degrees Celsius in April, and the lowest at 22.9degrees Celsius in February.
- The average annual rainfall at the Mannar observatory is about 986mm, concentrating in the period from October to January. The rainfall is relatively small but the maximum monthly rainfall is 472mm and the maximum daily rainfall is 202mm in December.
- The prevailing wind during the northeast monsoon (November to February) is from the southwest and that during the southwest monsoon is from the northeast. The design speed of 60miles/hr has been applied for bridge design. The lowest low pressure is 1,000hpa.
- There is no record of earthquake around the project site and few earthquakes in Sri Lanka because Sri Lanka is located on the center of the Indian Plate.
- A total of 14 cyclones have struck the east coast of Sri Lanka before moving to the west coast, but almost no damage by them was recorded in the project area.

(2) Tidal Condition

The standard tidal levels of the ocean are measured based on the Mean Low Water Springs (MLWS), and the standard levels of the land are measured by topographic survey based on the Mean Sea Level. The difference between both standard levels is 0.40m. The bridge and causeway structures have been designed using the survey levels measured from the official bench marks as shown in Table 2-1.

Table 2-1 Record of Tidal Levels

Description	Mark	Level of Ocean	Level of Survey
Highest Astronomical Tide	HAT	+1.0	+0.6
Mean High Water Springs (High Water Level)	MHWS (HWL)	+0.8	+0.4
Mean Sea Level	MSL	+0.4	+0.0
Mean Low Water Springs (Low Water Level)	MLWS	+0.0	-0.4
Lowest Astronomical Tide	LAT	-0.2	-0.6

(3) Geological Features

The soil at the bridge sites is mainly divided into four (4) layers based on the result of geo-technical survey. The first layer is very soft ground depositing at 2m~3m from the ground surface; it is fluid and has a low N-value along the causeway. The second layer (3m to 10m) is coarse sand with thin silty layer; it is consolidated and has a relatively high N-value (20~50). The third layer (10m to 20m) is hard clay containing sand; it is very hard with a N-value of over 50 and is considered to be completely consolidated. The fourth layer (below 20m) is called sand stone (very hard sand layer); it is considered to be the bearing layer for foundation piles. Based on the above survey results, the following design policies have been considered in the basic design:

- Embankment on the soft ground is subject to settlement due to embankment load, so that a method of the settlement measures should be adopted in designing the causeway;
- Hard clay and sand stone layers are generally considered as the bearing layer for the bridge. However, the sand stone layer is selected as the bearing layer for pile bents of pier foundation and cast-in-place concrete bored piles for abutment foundation to support the large load of the bridge without settlement.

(4) Drift Sand

The sand around the project area has tendency to drift from the northwest to southeast in view of geographical features of the Mannar Island. From hearing survey and site reconnaissance, there is no record of moving sand due to topographical change. A comparison between the bathymetric survey map prepared in the study and the sea bed map prepared in the 1970s shows that there is no sign of moving sand near the project area, therefore sand drifting has not been considered in the design of the bridge and causeway.

(5) Ocean Waves

There is no observation record of ocean waves around the Mannar Island. Thus the ocean waves have been inferred from wind direction and forces, low pressure, topographical features and tidal data. The abutment to be constructed on the Mannar Island side may be subject to damage due to ocean waves caused by the wind from the southwest at high tide during the raining season (northeast monsoon season). On the other hand, the northeast wind during the dry season (southwest monsoon season) does not cause any damage because the ocean water level is low.

2-2-1-3 Policy on Socio-Economic Condition

(1) Peace and Reconstruction Process

The project site is located in the government control area near the borderline between the government control area and LTTE control area. Approximately 65% of the population in the area is Tamils. The capital of Mannar prefecture is in the Mannar Island and the new Mannar Bridge and causeway play a major role not only for passenger transportation but also freight transportation. GOS expects to activate the regional development and improve the stability of people's livelihood near the borderline by implementing the construction of the new Mannar Bridge and causeway. This project is expected to accelerate the peace and reconstruction processes.

(2) Harmony with Local Society

For smooth implementation of the Project, the following factors are taken into consideration:

- As the project site is located at the entrance of the capital of Mannar prefecture, the design and implementation plan of the new Mannar Bridge and causeway will be conducted considering the surrounding environment;
- The construction methods shall provide job opportunities to local people because there are not sufficient jobs for people staying around the project site;
- Materials such as stone and sand that can be procured around the project site shall be used to the maximum extent;
- The construction facilities such as construction yards and temporary roads shall be planned with a view of re-using those facilities for residents' relaxation after completion of the Project.

(3) Land Acquisition and Displacement of Houses

At a stakeholders meeting, the General Manager of the Mannar district and stakeholders in the Mannar Island agreed to relocate the gasoline station and two abandoned houses, which are located in the right-of-way of the Project. The gasoline station will be relocated in the vacant lot after the Meteorological Office is moved to the outskirts by January 2007. The facilities of the gasoline station including fuel tank will be demolished by August 2007. Land for camp yards and construction facilities will be provided by GOS before the commencement of construction works.

(4) Policy on Environment

In the basic design, the Initial Environmental Examination (IEE) conducted in the Preparatory Study was reviewed in detail and the Category B (less adverse impact) was reconfirmed based on the JICA Environment Guideline, April 2004. However, most of the adverse impacts, such as movement of the existing gasoline station and deserted houses and preservation of mangrove, have already been solved and are considered to be negligible. RDA has already obtained CCD's approval of the environmental impact assessment on March 17, 2006 and 4m in height of navigation clearance on September 12, 2006. To obtain the construction permit from CCD, the bridge and causeway have been designed to minimize environmental impacts.

2-2-1-4 Policy on Construction and Procurement

(1) Working Condition

Most people in Mannar are Tamils and Moors. Common labour can be recruited relatively easily from Mannar but special technique is required for the implementation of the Project. Engineers and special technicians required for the Project are available in Colombo but they have no intention to work in Mannar due to many opportunities to work for highway projects in the south and security problems in the north. Therefore, expatriates from surrounding countries should be employed for the construction of cast-in-place concrete piles and erection of PC girders. The employers shall conform to the Sri Lankan Labor Law (enacted in 2004).

(2) Procurement of Machines and Materials

1) Cement

According to the hearing survey from manufacturers, two cement factories are operating in the west and south regions of Sri Lanka. Cement is now in great demand due to the current execution of projects for the restoration of Tsunami disaster. Normal Portland cement manufactured in India and South Africa can be procured in Sri Lanka. There are seven cement suppliers in Colombo. Ten ready mixed concrete suppliers with batching plants are operating in Sri Lanka, but only in Colombo and the southern area. Therefore, the batching plant should be procured in Colombo and installed at this site.

2) Reinforcing Bars/Steel Materials

Reinforcing bars and steel members will be procured from Singapore but PC strand and anchors, which are not produced in Singapore, and tensioning jacks will be imported from Japan.

(3) Sand, Stones and Borrow Materials

Sand will be procured from private suppliers at Kalar. The sand price is fluctuating due to transportation cost and security control of the Army. Concrete and pavement aggregate and stones for retaining walls and slope protection will be procured from the suppliers operating a crushing plant at Madukanda or Mihintale. Borrow material for embankment will be procured from the borrow pit in government land at Madhu.

(4) Bridge Accessories

According to the procurement survey at the local site, bearings and expansion joints are not produced in Sri Lanka; therefore, they will be procured from Japan.

(5) Construction Machines

Construction equipment for road work can be rented in Sri Lanka. However, truck cranes with over 80ton lifting capacity, all casing bored pile machine, and erection girder for PC concrete girders and portal crane cannot be procured in Sri Lanka and Singapore. They will be procured from Japan. Crushing plant will not be provided at the site so all materials produced from stones will be procured from local suppliers.

2-2-1-5 Procurement of Local Contractors

Local contractors in Sri Lanka have experience in the construction of PC bridges but they are not interested in working in Mannar. Subcontractors for cast-in-place concrete pile and PC girder erection may be mobilized from Japan.

2-2-1-6 Policy on Capability of Implementation Institute as to Management and Maintenance

(1) Implementation Institute

The implementation institute of the Project is the Ministry of Highways (MOH) and the Road Development Authority (RDA). MOH controls the highways section in Sri Lanka and RDA is responsible for the construction and maintenance of roads and bridges as shown in

Figure 2-1. For this Project, RDA is the implementation agency under the control of MOH. RDA is composed of 14 bureaus, 1 project office and 9 PMUs. RDA has a total staff of approximately 2,730.

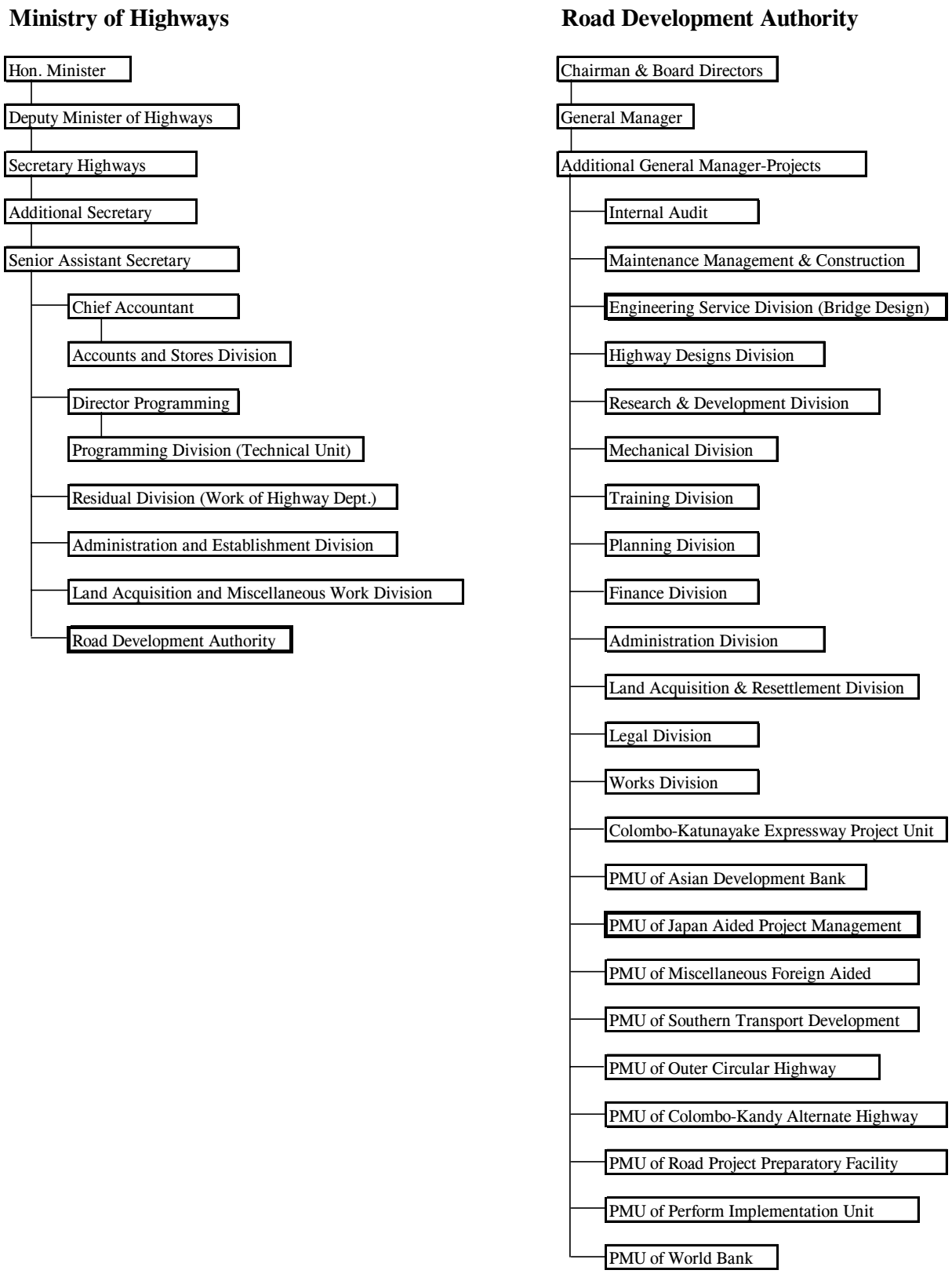


Figure 2-1 Organization of MOH and RDA

(2) Maintenance Organization

As shown in Figure 2-2, RDA, which is responsible for the maintenance of roads and bridges under the Board of Directors, has 9 provincial and 24 regional offices and is operating with the maintenance budget. RDA Mannar Office is responsible for the maintenance of the new Mannar Bridge and causeway and contracts with private repair agencies for routine maintenance works. RC&DC (Road Construction & Development Corporation) undertakes directly periodical maintenance and rehabilitation works under contract with RDA. However, in order to ensure that periodical maintenance requiring technical knowledge such as bridge repair and replacement of expansion joints can be conducted appropriately, the following measures will be taken:

- The bridge and causeway will be so designed as to minimize and facilitate maintenance works after their construction.
- Maintenance engineers in RDA will learn the inspection and maintenance management systems for the new bridge and causeway through a training programme in Japan during the construction stage.

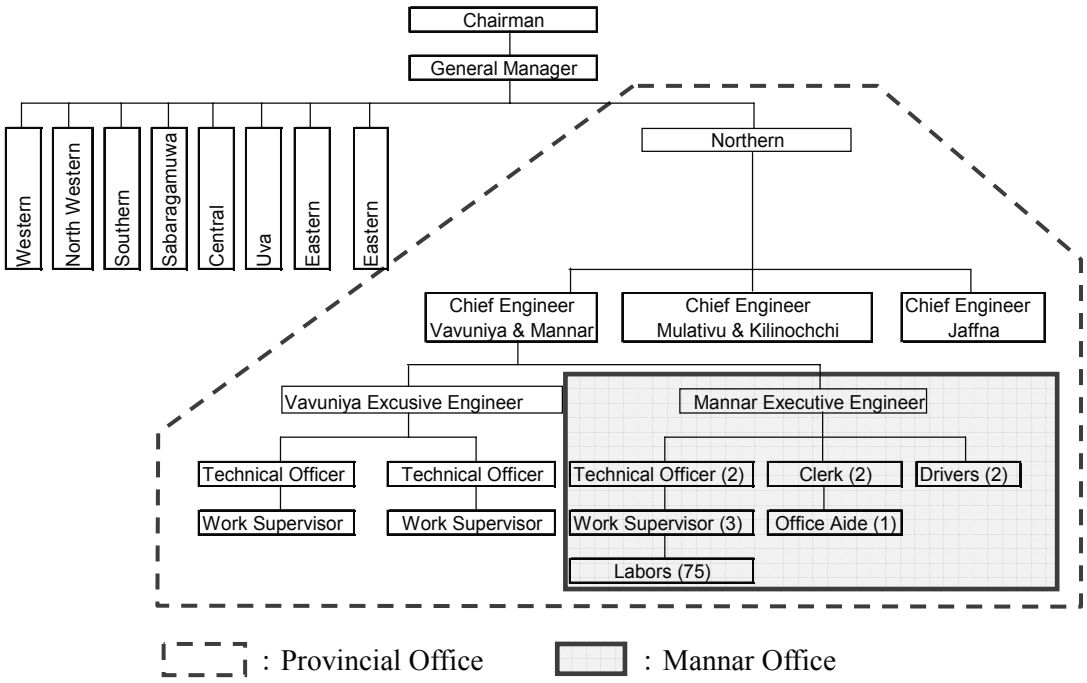


Figure 2-2 Organization of RDA for Road Maintenance

2-2-1-7 Policy on the Grade of Facilities and Equipment

(1) Design Standards

Sri Lankan design standards and manual are applied for the design of bridge and causeway to determine the suitable and economic scale of facilities for the Japan Grant Aid Project. But expansion joints, rubber shoes will be procured from Japan considering the lower quality of local products and the severe site conditions suffering damage by salty water.

(2) Policy on Reconstruction of Bridges and Causeway

The Mannar Bridge was blasted in 1990 and is now in a severely dilapidated condition presenting a risk of collapse due to the traffic of heavy vehicles. The new bridge construction policy is that a temporary bridge will be provided for the transportation of equipment and materials for bridge works, and the existing bridge will be used only for the general traffic. Most bridge works including foundations will be executed on the temporary bridge.

On the other hand, the existing causeway structure is still relatively sound but its width is narrow and deteriorated in some section. The causeway widening policy is that part of the existing causeway will be used as a detour road with a single traffic way for both construction vehicles and general traffic during the construction and then will be incorporated into the new causeway which has been widened toward the western side.

The reconstruction of the bridge and causeway is designed with a view of providing sufficient safety against the past maximum high tide level and an appropriate navigation clearance (20m wide and 4m height). Considering the site conditions such as scouring, waves and canal erosion, both abutments will be moved back from the existing location.

The abutment and slope protections are designed to be flexible to alleviate the critical damage due to waves by following the deformation of seabed and bank slope. Therefore, periodical maintenance shall be conducted to protect the bridge and causeway structures, and subsidiary structures.

(3) Consideration of Traffic Safety

The Mannar Bridge is located at the entrance of Mannar city where a provincial capital and administrative, educational and business center exist. It is predicable that the number of pedestrians and bicycles passing on the bridge will increase after its construction. Therefore, safety facilities should be provided for pedestrians to ensure their safety and sidewalks for pedestrians should be considered in the bridge design.

2-2-1-8 Policy on Construction Method and Construction Period

The causeway passes on a lagoon (tidal land) where is sandy mud, very soft on the seabed and less than 1.0m of water depth in the raining season. In such site conditions, a permanent cofferdam with steel sheet piles is required for the execution of the widening causeway such as soft soil displacement, construction of a retaining wall and embankment in the section of 1.5km from the existing Mannar Bridge. The execution length of one section is necessary to be shorten and repeating the same procedures transferring equipment and labour for cost saving and traffic safety. The construction of widening causeway will be carried out while keeping one traffic lane for vehicles. The construction period of the widening causeway is approximately 25 months which is on the critical pass.

Before the construction of bridge is commenced, a temporary bridge will be constructed between the existing bridge and the new bridge for transportation of materials and equipment. The pile bent type is selected for piers to avoid costly submarine work, therefore all foundation and substructure works will be executed by equipment on the

temporary bridge. In parallel with the foundation and substructure works, PC girders will be cast at the fabrication yard. PC girders will be pulled out by winches from the fabrication yard to the erection site behind the abutments and then erected by means of erection girder. The construction period of the new bridge including the temporary bridge is approximately 21 months. Shortly after the completion of the bridge, RDA shall demolish the steel truss bridge that fell in the sea to ensure safe navigation of fishing boats during the construction period.

Considering the above conditions, the construction of the Project will commence in October, 2007 with the mobilization in the end of the rainy season and both bridge and causeway works will be carried out at the beginning of the dry season. The total construction period is estimated to be 29 months.

2-2-2 BASIC PLAN

2-2-2-1 Overall plan

(1) Adopted Design Specifications

The following standards and manuals have been referred to in the basic design of the structures:

- RDA Geometric Design Standard of Roads, 1998
- RDA Bridge Design Manual
- A Guide to the Structural Design of Roads under Sri Lankan Conditions

Detailed specifications are shown in Table 2-2 and Table 2-3respectively.

1) Road Design Conditions

Table 2-2 Road (Causeway) Design Conditions

Items		Design Condition	Notes
Class of Road (Type of Road)		A (R3)	RDA Geometric Design Manual
Classification of Road Location		Local	Site Conditions
Location		Plain	Site Conditions
Design Speed	Road	70km/hr	RDA Geometric Design Manual
	Vicinity of Junction	60km/hr	
Cross Fall	Carriageway (DBST)	3.0%	RDA Geometric Design Manual
	Shoulder (DBST)	3.0%	
Maximum Super Elevation		6.0% (3.0%)	RDA Geometric Design Manual
Minimum Radius	Road	185m	RDA Geometric Design Manual
	Vicinity of Junction	130m	
Minimum Radius with Adverse Cross Fall	Open	1,105m	RDA Geometric Design Manual
	Built-up	810m	
Minimum Length of Spiral Curve	Road	40m	RDA Geometric Design Manual
	Vicinity of Junction	35m	
Vertical Maximum Gradient		4.0% (0.5%)	RDA Geometric Design Manual
Critical Length of Gradient	i=3.0%	480m	RDA Geometric Design Manual
	i=4.0%	330m	
Minimum Vertical Curve Length for Appearance		60m	RDA Geometric Design Manual
Minimum Vertical Curve	Crest	3,000m	RDA Geometric Design Manual
	Sag	1,300m	

2) Bridge Design Conditions

Table 2-3 Bridge Design Conditions

Items		Design Condition		Notes
Navigation Clearance		Height : 4.0m, Width : 20.0m		refer to 2.3.2
Design Loads	Live Load	HA Load, B Load : 30 Unit		BS5400 Part 2, 1978
	Wind Load	60 miles/hr.		RDA Bridge Design Manual
	Temperature	33.8~2.9℃		RDA Bridge Design Manual
	Impact	P=0.1 x W x V	P=Impact (ton) W=Weight of Ship (9ton) V=Speed of Ship (20m/sec)	RDA Bridge Design Manual and Site Conditions
	Seismic Load	Zero		RDA Bridge Design Manual
Design Strength of Concrete		PC I-Girder	50N/mm^2	RDA Bridge Design Manual
		Cross Beam	50N/mm^2	
		RC Slab	40N/mm^2	
		Concrete in the Air	40N/mm^2	
		Cast-in-place Concrete Pile and Pile Bent	50N/mm^2	
		Leveling Concrete	25N/mm^2	
Concrete Coverage		PC I-Girder	40mm	RDA Bridge Design Manual
		Cross Beam	40mm	
		RC Slab	50mm	
		Concrete in the Air	50mm	
		Cast-in-place Concrete Pile and Pile Bent	55mm	
		Leveling Concrete	-	

(2) Road Width Plan

The new Mannar Bridge and causeway, which is a vital connection road between the Mannar Island and the mainland of Sri Lanka, will be reconstructed to have a two-lane carriageway taking into account the forecast of traffic increasement on the A14. The road width has been determined in conformity with the above-mentioned road design conditions. As the bridge is located at the entrance of Mannar city with a population of 50,000, it should be provided with foot walks on both sides for pedestrians and bicycles.

1) Bridge Width Structure

The cross section applied for the new Mannar Bridge is as shown in Figure 2-3 based on the RDA Bridge Manual. The bridge and causeway, which will be constructed on the R14, are classified in Class-A, Rural and Flat. Based on the above criteria, two 3.7m wide carriageways and 1.2m wide foot walk/cycle have been applied as a minimum standard. The foot walks on the both sides are 1.5m wide of mount-up type, composing of 1.2m wide foot walk/cycle and a space of 0.3m for concrete hand railing for safety of pedestrians. The total width of the bridge is 10.4m

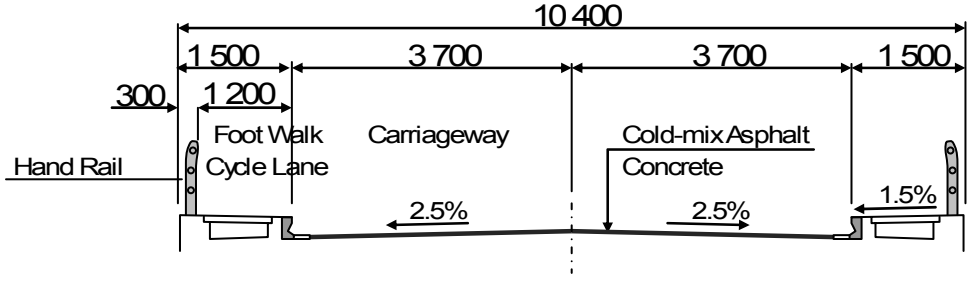


Figure 2-3 Standard Bridge Cross Section

2) Causeway Width Structure

The cross section of causeway is as shown in Figure 2-4 based on the same classifications as the bridge. The minimum width of structure is as follows:

- Carriageway = 7.4m (3.7m x 2 lanes)
- Foot walk/cycle = 1.8m (Foot walk/cycle = 1.2m and top of retaining wall)

According to the RDA Geometric Design Standard of Roads, 1998, the width of foot walk is 1.8m in minimum but it is maintained to be the same (1.2m) as that of the bridge and a space of 0.6m on the top of the retaining wall is used for the installation of guard stones in the section of the causeway for minimizing the construction cost. The width of the causeway is 11.0m in total. On the top of the retaining wall, guard stones will be provided for traffic safety.

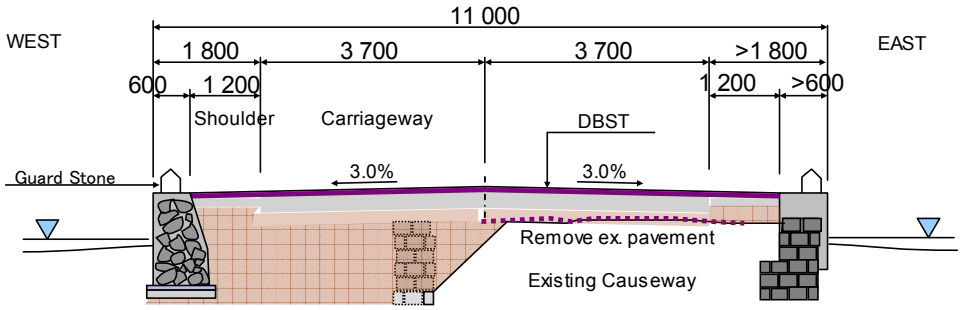


Figure 2-4 Standard Road Cross Section

a) Approach Road Width Structure

The cross section of approach roads is as shown in Figure 2-5 based on the RDA Geometric Design Standard of Roads, 1988 with the same features as the causeway. On the section of the approach roads, guard rails will be provided for traffic safety.

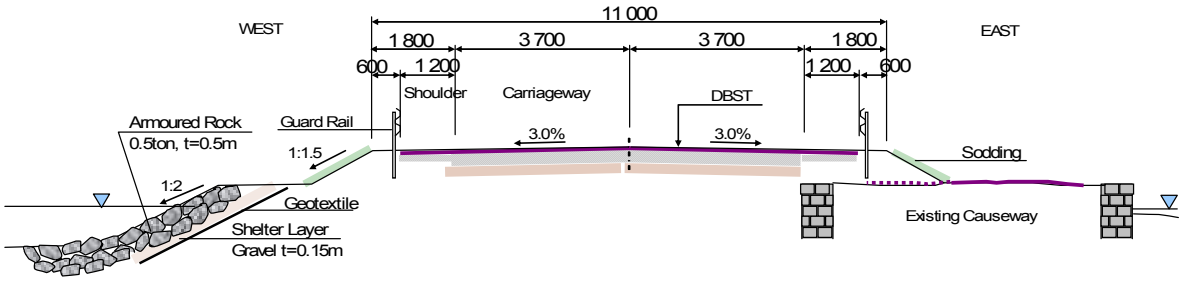


Figure 2-5 Standard Approach Road Cross Section

2-2-2-2 Facility Plan

(1) Bridge Center Line

To select the location of the reconstructed bridge, the following three alternatives have been taken into consideration:

Route- A : 20m on the western side of the existing bridge

Route- B : The same as that of the existing bridge

Route- C : 20m on the eastern side of the existing bridge

The route-A had been studied by RDA and agreed with stakeholders. In this basic design report, Route-A has been verified only to determine whether it is most appropriate or not.

1) Evaluation from the Social Environment Viewpoint

In the Route-A, it is necessary to replace the existing gasoline stand and two deserted houses, but RDA has already discussed with the Agents concerned and found the places for their relocation. Both habitants' resettlement and land acquisition for the two deserted houses have also been solved. For these reasons, the Route-A does not present negative issues at present in the environmental aspect.

2) Evaluation from the Viewpoint of Impact on Existing Life Facilities

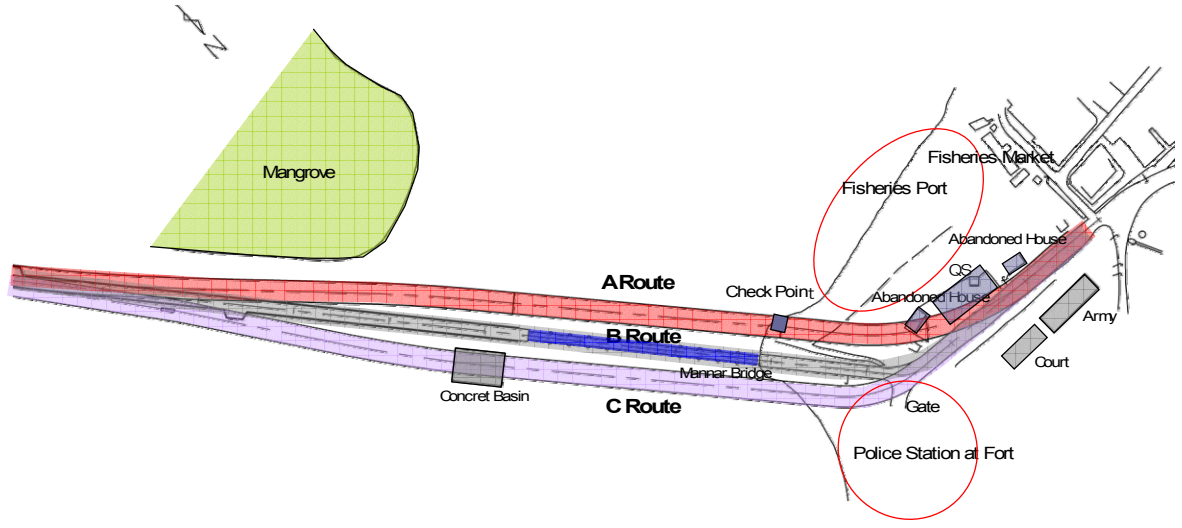
As the existing bridge and water supply pipe can be maintained during the construction in the case of Route-A, the impact on the residents' life style is the smallest compared to the Route-B and Route-C.

3) Evaluation from the Viewpoint of the Bridge Plan

In the Route-C, it is not appropriate to divert the road alignment to the end junction with the minimum radius. If a bigger radius is applied in the alignment, the military and police facilities are affected. The road alignment in the cases of Route-A and Route-B satisfies the RDA Geometric Design Standard of Roads.

The overall construction cost for the Route-B is the highest compared to that of other alternatives because it is necessary to construct a new detour bridge for traffic and pedestrians as well as a temporary bridge for construction purpose. In conclusion, the Route-A is the best route from the social environment and economical viewpoints. A comparison of these aspects is shown in Table 2-4.

Table 2-4 Alternative Plans of Bridge Center Line

Route		Evaluation
A	20m to the west of existing bridge	• Big radius can be provided at the end junction, so traffic can move to the junction smoothly. • Easy access to police office is provided. Movement of gasoline stand and demolish of 2 abandoned houses have already been agreed with the Government Agents concerned. • RDA has studied this route and concluded that it is economical and acceptable. **Good**
B	Same alignment as existing bridge	• Road alignment is almost same as the existing road and bridge, so the impact on the existing facilities is minimized. • Construction of the new bridge is carried out only after a detour bridge is constructed and the existing bridge and wreckage of steel truss bridge are removed, so the construction period is longer and the cost is higher compared with other alternatives. • Construction of a temporary bridge for construction works is also required, so it is not economical. **Fair**
C	20m to the east of existing bridge	• Only small radius can be aligned at the end of junction, so the road alignment is out of design criteria. • The water supply pipe on the eastern side of the existing road is affected by the bridge construction. • A detour road is required for the existing road to the fort. • Military check point and police facilities are affected by the alignment. **Bad**
		

(2) Bridge and Causeway Plan

The new Mannar Bridge and causeway are designed as shown below.

1) Newly Constructed Bridges

The existing bridge has a total length of 121.2m, a 38.0m long center span and 4 10.4m long spans on both sides. As the existing bridge was constructed with a relatively short length, local scouring occurred around the abutments. It is considered that the hydraulic condition of the canal will be unchanged, although the existing bridge will be demolished after the construction of the new bridge. In the design of the new bridge, both abutments are set back from the existing abutments to minimize the risks of local scouring and waves caused by the southwestern wind in the monsoon season.

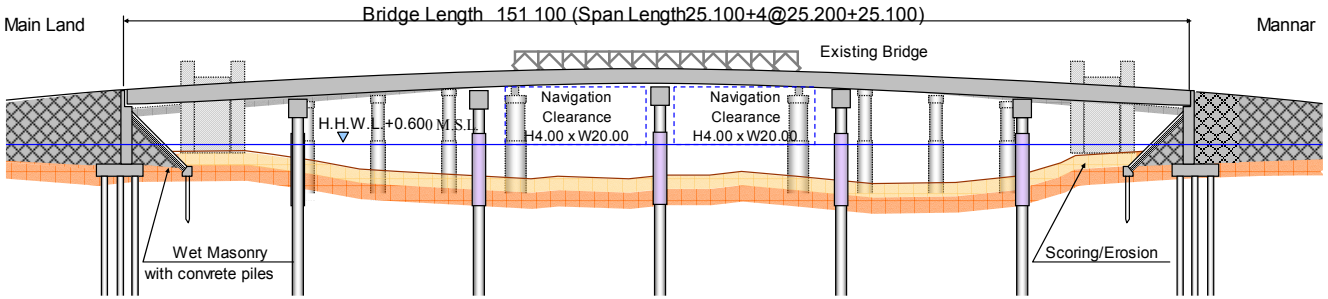
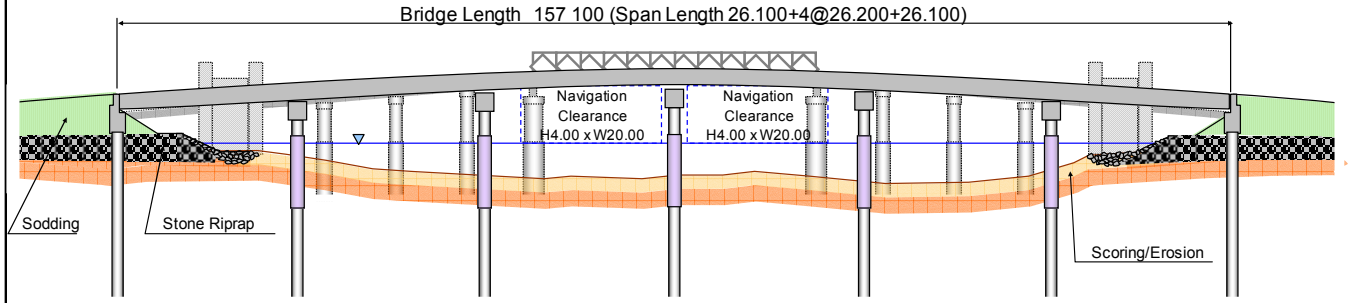
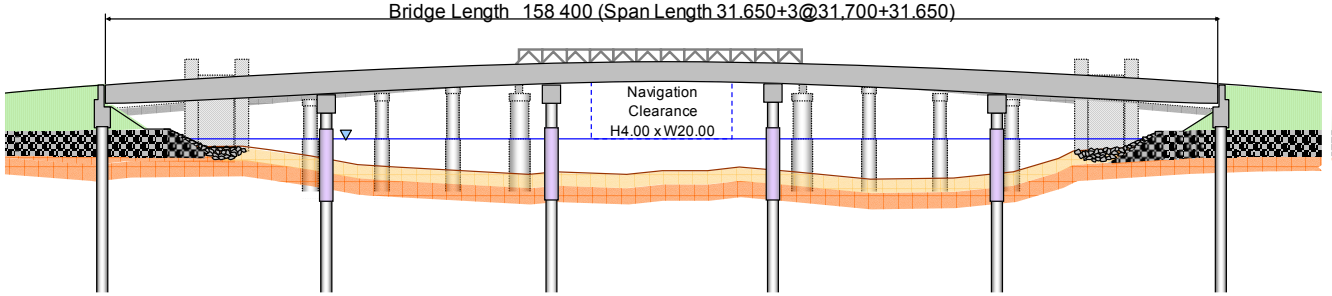
The navigation clearance of 4.0m height and 20.0m width has been agreed with the agencies concerned. Based on this clearance, the minimum length of the center span is over 22.0m. The use of prestressed concrete girder type for the bridge is reasonable and economical considering its durability against salty breezes at the seashore.

On the center line of the new bridge (20m on the western side from the existing bridge), both abutments will be constructed in sea water and therefore affected by waves. Slop protection and revetment should be strong enough to withstand waves but low construction cost and easy maintenance should be ensured.

Based on the above conditions, three alternatives have been evaluated in the following aspects i) Structural aspect; ii) Cost/constructability; and iii) Maintenance as shown in Table 2-5. Alternative-B (bridge length: 157.1m, girder length: 26.0m, 6 spans of continuous PC I-Girders) has been selected as the most appropriate from the following viewpoints:

- In the case of span length of 25.1m for Alternative-A and 26.1m for Alternative-B, the difference of bridge cost is negligible because girders have the same height and the same erection equipment is used for their erection. On the other hand, Alternative-A requires large abutments to set the footing under the sea bed and it is necessary to provide strong revetment and slope protection leading to uneconomical design:
- In Alternative-C, the number of spans can be reduced by providing longer girders of 30m. But for 30m spans, the PC T-Girder type should be applied, which results in an increase in the construction cost. Alternative-C would also require large foundation, substructure and girders and therefore large equipment should be used.
- For Alternative-B it has been planned to construct abutments on a wide mound so as not to be affected by waves. The filled mound will be protected by stone riprap and revetment, which can be easily maintained by RDA Mannar Office.

Table 2-5 Alternative plans of span Arrangement

Profile	Evaluation
Alternative -A, Bridge Length 151.6m, (girder Length 2.05m), 6-spans Connection PC-I Girder + Wet Masonry Protection 	**Structural Point（Erosion）** To shorten bridge length, protection with wet masonry (Slope 1:1)to protect erosion is provided. ○ **Economic and Construction** Scale of abutments, slope protection and foundation and costs are bigger than Alternative-B, although bridge length is shorter ○ **Evaluation** In maintenance of scoring and ersion are difficult. ○
Alternative-B Bridge Length 157.10m (Span 26.6m) 6 Spans Connection PC I-Bridge + Stone Riprap Protection 	**Structural Point（Erosion）** Both abutments are set back on mound filled and protected by stone riprap to make easy mentenance. ◎ **Economic and Construction** Scale of abutments, slope protection and foundation are smaller than Alternative-A, and cost is lowest among them ◎ **Evaluation** In maintenance of scoring and ersion are easy. ◎
Alternative-C Brige Length 158.40m (Girder Length 31.5m), 5-Span, Connection PC T-Girder + Stone Riprap 	**Structural Point（Erosion）** Both abutments are set back on mound filled and protected by stone riprap to make easy mentenance. ◎ **Economic and Construction** Scale of abutments, slope protection and foundation are smaller than Alternative-A, and cost is lowest among them ○ **Evaluation** Constructability and cost are inferior among 3 alternatives ○

2) Widening of Causeway

Causeway widening should be planned to incorporate the existing causeway to minimize the construction cost. The causeway widening alternatives are i) Widening to the western side, ii) Widening to the eastern side; and iii) Widening on both sides. Based on the result of site survey, the alternative of widening to the western side utilizing the eastern retaining wall has been considered the most appropriate from the following viewpoints:

- The western retaining wall is damaged more seriously than the eastern retaining wall;
- The alignment of the existing eastern retaining wall is relatively straight, therefore modification of the road alignment is limited;
- In the case of widening on both sides, the construction cost increases because it requires the construction of new retaining walls on both sides and a traffic detour road;
- As the centerline of the new bridge is shifted 20m to the west, connection of the bridge alignment with the alignment of the westward widened causeway is smooth; and
- As an existing water supply pipe is laid under the eastern shoulder, the eastern retaining wall should be maintained to enable future inspection and repair of this water supply pipe.

A basic plan of the causeway widening to the western side is shown in Figure 2-6.

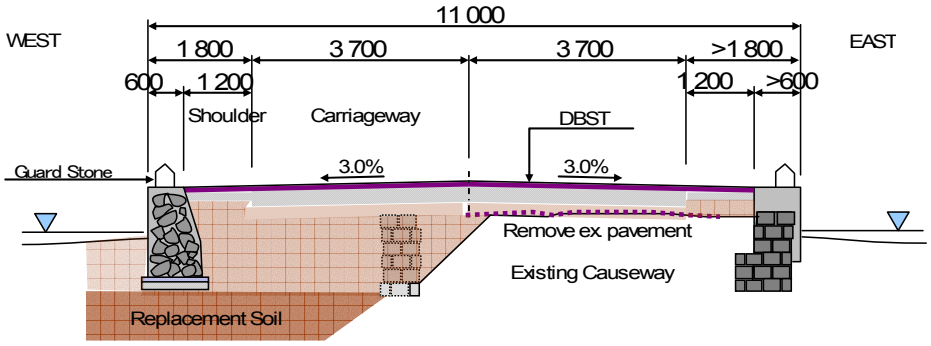


Figure 2-6 Basic Plan for Causeway Widening to the Western Side

(3) Basic Structures of Bridges and Causeways

1) Superstructure Type

Considering the designed bridge length of 157.1m and the span length of 26.10m, the following three alternatives: i) Connection PC I-Girder (PC I-Girder), ii) Connection PC T-Girder (PC T-Girder), and iii) Continuous Steel I-Girder (Steel I-Girder) have been considered for superstructure design as shown in Table 2-6.

a) PC I-Girder

The economical span length of I-shaped PC girder is 20m to 30m, therefore the designed span length of 26.1m is reasonable. PC I-Girders are planned to be produced at the fabrication yard near the bridge site and erected by truck cranes (truck crane method) or by erection girder (erection girder method). However, as the erection site crosses over a sea canal, the erection girder method is more appropriate considering the difficulty to carry I-girders under the erection span. PC I-Girders are connected to each other on the piers to make a continuous structure. In such a way, expansion joints on the piers and maintenance are not required.

b) PC T-Girder

The economical span length of T-shaped PC girder is 25m to 40m. The designed span length of 26.1m is also acceptable but not so economical. On the other hand, the construction period is shortened because no concrete slabs are required. Considering the same condition as PC I-Girders as mentioned in item a) above, the girder erection method is applied for PC T-Girders. However, the weight of a PC T-Girder is approximately 80 tons, so larger fabrication yard and erection facilities are required. PC T-Girders are connected to each other on the piers to make a continuous structure. In such a way, expansion joints on the piers and maintenance are not required.

c) Steel I-Girder

The economical span length of steel I-Girders is 25m to 45m. Steel I-Girders are manufactured only in a neighboring country (Thailand) and have to be transported by ships and trucks to the construction site in Sri Lanka. The transportation cost is very high. As steel girders can be fabricated in parallel with the construction of foundation and substructure, the construction period can be minimized. However, steel girders are subject to corrosion and deterioration due to sea water, so the maintenance cost including painting is higher.

d) Overall Evaluation

The use of steel I-Girders is not viable from the economical and maintenance viewpoints. In comparison between PC I-Girders and PC T-Girders, the PC T-Girder type would be more preferable in view of its shorter construction period. The critical path in the construction schedule is on the causeway construction but not on the bridge construction. In conclusion, the PC T-Girder is superior to other alternatives in the structural, constructability, economical and maintenance aspects.

2) Pier and Foundation Type

The sea water depth at the location of piers is 5~6m. A relatively hard clay layer is found at 10 to 20m from the ground surface but the sand stone layer deeper than 20m is considered as the bearing layer for bridge piles. Based on such conditions, four alternative types, i.e. i) Wall type pier + Spread footing, ii) Circular column pier + Cast-in-place concrete pile, iii) Caisson foundation pier, and iv) Pile bent foundation pier have been considered.

a) Wall Type Pier + Spread Footing

The wall type pier type does not obstruct the water current and is strong against collision by ship. However, cofferdams made of steel sheet piles are required for execution of deep seabed excavation. Spread foundation on relatively hard clay is not acceptable for pier foundation considering the consolidating settlement of clay and local scouring. Spread foundation requires low construction cost but high maintenance cost. In the comprehensive cost comparison, the spread foundation type is not economical.

b) Circular Column Pier + Pile Foundation (Cast-in-place Concrete Pile)

The circular column pier type obstructs the water current but has good appearance. Considering the deep scouring depth, the pile foundation type is applied for the circular column pier. For this type, it is also necessary to provide cofferdams as same as mentioned in item a) above for construction of pile caps and cast-in-place concrete piles, which leads to cost increase. The construction period of this type is the longest among the four alternatives.

c) Caisson Foundation Pier

The caisson foundation pier was applied for the existing Mannar Bridge. Its diameter is normally about 3m in Sri Lanka. To minimize the construction cost of caisson foundation, construction of filled cofferdams is required for working areas in the sea. The filling for cofferdams in the deep sea canal is not acceptable for environment reason. If filled cofferdams are not provided, mechanical excavation for large diameter piles is very costly because it needs large size equipment and it is also difficult to procure such equipment and casing pipes.

d) Pile Bent Foundation Pier

The pile bent diameter is the same as that of the column of substructure, therefore so both works can be proceeded in continuity. It is not necessary to provide cofferdams for construction of pile-bents, therefore the construction period and cost are drastically minimized. The diameter of pile bents is only 1.2m which presents no obstruction to navigation but they may be damaged by ship collision. The pile bent concrete should be protected with steel pipe used for concrete placing of pile bents. The pile bent pier is a structure with heavy load on the top of pier, so the horizontal displacement at the bearing shoes tends to be large. To solve this problem, the following measures are adopted;

- Simple PC I-Girders will be connected continuously on the pier, so as to prevent them from falling even when the displacement becomes large; and
- The diameter of the pile bents will be over 1,200mm in order to secure high stiffness of bridge piers.

e) Overall Evaluation

In case those piers are constructed in the sea canal, construction conditions such as current, tide, and waves are complicated and may lead to construction problems. All pile bent foundation works are executed by means of construction equipment and machines on the temporary bridge, therefore the construction period and cost can be minimized. In the area considered not being subject to seismic force, the horizontal load is relatively small and the vertical load due to the reaction force from the superstructure is steadily supported by long pile bents penetrated into the sand rock layer. Therefore, the pile bent pier type is the most appropriate from the structural and economical viewpoints as shown in Table 2-7.

3) Abutment and Foundation Type

Abutments are constructed in the shallow sea. The depth of sea water becomes deeper near the canal but erosion of the canal slope is not observed. The abutment on the Mannar Island side may be affected by waves. Based on such conditions, two alternative types, i.e. i) Reversed T-type abutment, and ii) Pile bent abutment have been considered.

a) Reversed T-type Abutment

Abutments of this type are structurally stable because their footing is constructed under the seabed. On the other hand, as the abutment is subject to horizontal loadings due to a large earth pressure. The scale of the abutment will be larger and the number of piles be increased. Although the total bridge length can be shortened, both abutments should be protected with strong concrete slope protection and this leads to cost increase. If such consolidated concrete slope protection is damaged due to waves, their maintenance and repair by the RDA Mannar Office are difficult and limited.

b) Pile Bent Abutment

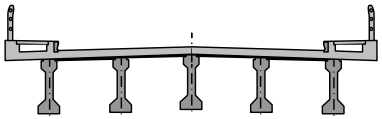
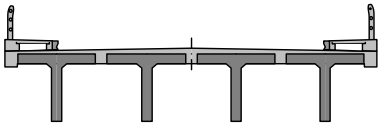
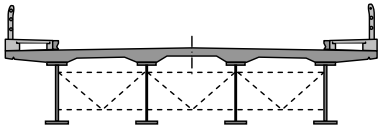
In this type, small abutments supported by pile bents are constructed on a filled mound around the abutments at a level not affected by waves. The slope of the mound is protected by stone riprap and revetment, so the slope maintenance is simple and can be

easily conducted by the RDA Mannar Office. In the case of small earth pressure, the abutment size may be smaller and the number of piles may be decreased. Although the total bridge length will be longer resulting in an increase in the cost of superstructure, the total construction cost decreases because the costs of foundation, substructure, slope protection and revetment are lower.

c) Overall Evaluation

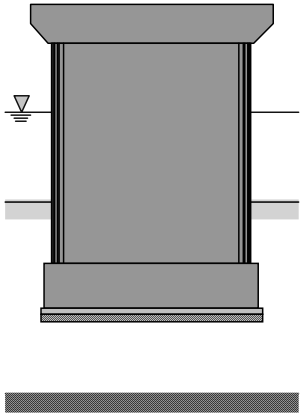
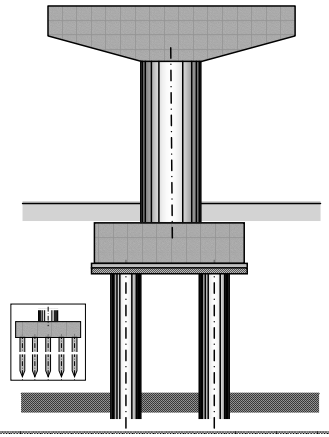
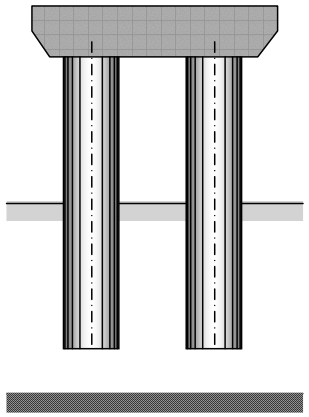
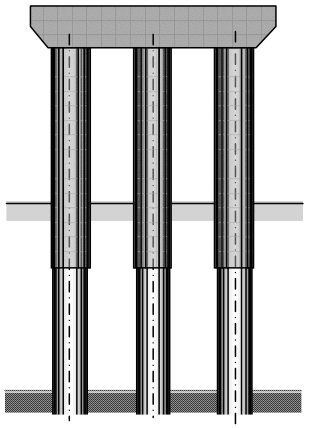
The pile bent abutment type is the most appropriate from the structural, economical and maintenance viewpoints as shown in Table 2-8.

Table 2-6 Comparative Study for Bridge Superstructure

Description	**Alternative-B** **Post-tensioned connected PC I-Girder**	**Alternative-C** **Post-tensioned PC T-Girder**	**Alternative-D** **I-shaped Steel Girder with RC Slab**
Plan View of Cross Section			
Structural Condition	- Post-tension PC I shaped girder is applied for the span of 20~30m. ◎	- Post-tension PC girder is applied for the span of 25~40m. - Height of the girder will be higher than I-girder, so elevation will raise. ◎	- Steel I shaped girder is applied for the span of 25~45m. - Steel will be seriously affected by the sea water △
Construction Condition	- Post-tension PC girder is fabricated and stressed in the construction site near the bridge and then erected by erection girder or two heavy track cranes (80- - 100ton). Erection girder or track cranes can be hired in Singapore. ◎	- Post-tension PC girder is fabricated and stressed in the construction site near the bridge and then erected by erection girder or two heavy track cranes (more than 100ton). - Erection equipment shall be large due to heavy weight of girder. ○	- Steel girders are procured from the third countries and transport ship and trailer through Colombo, so the transport cost is relatively high. △
Procurement of Material and Erection	- Bridge site condition is limited, so erected by erection girder is recommended for safety. ◎	- Condition is same as the I-girder. But girder is heavier than I-girder, heavy equipment should be used for erection. ○	- Two track cranes of around 40~50ton lifting capacity are required for erection. ○
Maintenance	- Maintenance of bridge is not necessary exception of cleaning of drain, expansion joint, bearing and incidentals. ○	- Maintenance of bridge is not necessary exception of cleaning of drain, expansion joint, bearing and incidentals. ○	- It is required to inspect and maintenance periodically for the painting. △
Economical Aspects	- PC post tension I-girder of 25~30m is economical and light of weight, so erection equipment will be minimize than T-girder - Erection girder can be hired in Singapore. ◎	- Concrete bridge is reasonable to use natural resources mainly. - Equipment shall be larger than the construction of I-girder. ○	- Steel material and fabrication cost of steel girder is extremely high compared with concrete girder mainly consists of local product material △
Overall Evaluation	Most reasonable bridge type ◎	○	The steel girder use is not reasonable for high cost and main material imported from third countries. △

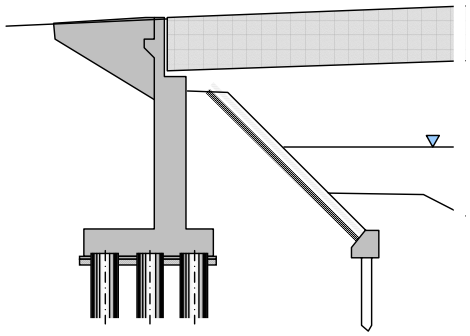
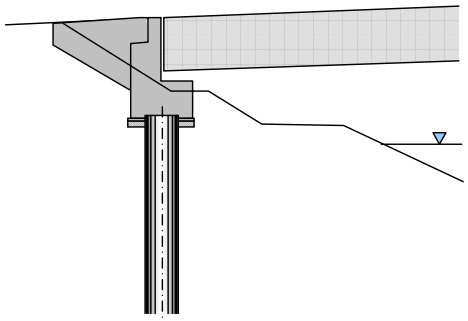
◎ : Very Good ○ : Good △: Poor

Table 2-7 Comparative study for Bridge Superstructure

Description	**Alternative-A** **Wall with Spread Foundation**	**Alternative-B** **Column with Cast-in-situ Pile** **/Pre-fabricated Concrete Pile**	**Alternative-C** **Beam with Cylinder Caisson**	**Alternative-D** **Pile Bent**
Ground/Construction Condition	1) Depth of water level is high (5~6m depth to seabed) 2) Seabed layer is sediment sand 3) Basement layer is sand rock and depth from seabed is around 20m 4) Temporary jetty is required any foundation type to choose due to construction way to construction yard at Mannar Island, foundation work in the deep water and navigational clearance for fisheries' boats			
Plan View of Cross Section				
Hydrology Characteristics	- Minimize the affected structure area in the water course ◎	- Opening width is reduced due to a bold column in the water course △	- Opening width is reduced due to bold columns of caisson in the water course △	- Minimize the affected structure area in the water course ○
Construction Ability	- Spread footing is located below water level, huge cofferdam is necessary to install in the seabed so the construction period is extended. △	- Pile cap with more than 4 cast-in-place piles reach to the sand rock layer. - or more than 6 pre-fabricated concrete piles. - Pile cap is located below water level, sheet pile cofferdam is necessary to install so the construction period is extended. △	- Traditional method of RC cylinder caisson of dia. 2.5~3.0m in Sri Lanka Construction of caisson is necessary - to build costly sand bank higher level than the water level. Depth of caisson in the coarse sand layer must be deep due to avoid - settling ○	- Pilling work be done from temp. platform extended from the jetty with rotary power drilling machine transferred from the third country. - Permanent steel tubular pipe is required concreting in the water and protection from the impact by the fisheries' boat Piling work is faster than any other - foundation. ◎
Maintenance	- Maintenance of seabed scoured around wall is necessary periodically. ○	- Maintenance of seabed scoured around column and pile cap is necessary periodically ○	- Maintenance of seabed scoured around caissons is necessary periodically ○	- Maintenance of seabed scoured around piles is necessary periodically. ○
Economical Aspects	- Construction costs are showing a tendency to rise due to installation of cofferdam of steel sheet piles. △	- Construction costs are showing a tendency to rise due to installation of both of cofferdam and jetty. △	- Construction costs are showing a tendency to rise due to long construction period △	- Less of the temporary structure is most economical method of the foundation ◎
Overall Evaluation	- Due to installation of cofferdam, cost up and construction period is extended. △	Due to installation of cofferdam, cost up and construction period is extended. △	Due to installation for casted concrete step by step, construction period is extended. ○	It is a suitable pier type aiming at cost down ◎

◎ : Very Good ○ : Good △: Poor

Table 2-8 Comparative Study for Abutment Substructure/Foundation

Description	**Alternative-A** **Inverted T-type Abutment**	**Alternative-B** **Pile Bent Abutment**
Plan View of Cross Section		
Structural Futures	- As Pile cap is installed below sea bed, abutment is not affected by local scoring due to waves. - As large earth pressure forces to the abutment, the number of piles showing a tendency to increase. - The type of abutment is strongly resistance to horizontal force (earthquake).	- As Pile cap is installed on the mound not to affect sea. The mound is filled widely and protected by stone riprap. - As light earth pressure forces to the abutment, the number of piles showing a tendency to reduce. - The type of abutment is flexibly resistance to horizontal force (earthquake).
Construction Ability/Period	- As Pile cap is installed below sea bed, cofferdam is necessary to construct the piles and abutment. - Volume of excavation and concrete of abutment become large, so that the construction period extends long. △	- Construction of piles is easy to undertake on the ground above water level. - Volume of excavation and concrete of abutment become small, so that the construction period shortens. ○
Maintenance	- Concrete or wet masonry protection is applied against scoring and waves. - These protection is difficult to repair and maintain in case of defect for RDA Mannar office Construction costs are showing a tendency to increase because abutment is large and . ○	- Slope protection around the mound is necessary to inspect periodically, but maintenance is easy with simple repair of stone placing. - Construction costs are showing a tendency to reduce because excavation, number of piles and concrete volume of abutments are relatively small. ○
Economical Aspects	- Construction costs are showing a tendency to increase because abutment is large and coffer-dam for protection of the slope. - This type of abutment is not suitable for this project to minimize construction cost and maintenance in future although it is reliable △	- Construction costs are showing a tendency to reduce because excavation, number of piles and concrete volume of abutments are relatively small. - This type of abutment is suitable for this project to achieve the cost reduction and easy maintenance after construction. ◎
Overall Evaluation	This type of abutment is not suitable for this project to minimize construction cost and maintenance in future although it is reliable for scoring. △	This type of abutment is suitable for this project to achieve the cost reduction and easy maintenance after construction. ◎

◎ : Very Good ○ : Good △: Poor

(4) Structure of Causeway

The causeway structure is of embankment type with slope protection and retaining wall type composed of vertical filling. Protection of this embankment type is the same as for the approach roads (refer to Figure 2-5) such as wet or dry masonry and stone riprap. The vertical filling is protected by reversed T-type or gravity type retaining wall. Both types have advantages and disadvantages but the same type as the existing retaining walls (vertical filling type) has been selected because the existing eastern retaining wall will be used as the new eastern wall of the widened causeway after being reinforced. Based on the 1~2 year probability inundation on the existing causeway, the inundation level is estimated at MSL+1.2m and the proposed height of the improved causeway is set up at MSL+1.4m providing an allowance of 20cm which is the thickness of the base course.

1) Type of Retaining Wall

There is no record of large scale repair of the causeway since the Netherlands constructed it in 1918. The RDA Mannar Office is repairing the retaining walls damaged by heavy traffic applying RDA's standards. The Study Team judged that the type of retaining wall constructed by the Netherlands is suitable for the site conditions in Mannar in both technical and economical aspects. However, the Study Team inspected and studied the damaged retaining walls and found the causes of damage. Based on the Team's findings, the new retaining wall has been classified by four types for each height, and designed referring to the RDA Bridge Design Manual, 1997 and BS5400 Part 2, 1978.

a) Retaining wall under 1.0m (Type-A), 1.0~3.5m (Type-B and Type-C)

The retaining walls of Type-A, Type-B and Type-C, which are a gravity type with a wet masonry as shown in Figure 2-7, are stable against earth pressure and are economical. These retaining walls have been adopted in the design in consideration of the RDA standard retaining wall. The front of retaining walls is covered with reinforced concrete (15cm thick) to prevent damage to the surface of wet masonry.

b) Retaining Wall over 3.5m (Type-D)

The retaining wall of Type-D, which is a reversed T-type concrete wall as shown in Figure 2-7, has been selected for a height of over 3.5m. Placing of pre-cast blocks may be applied for the reversed T-type concrete wall but it is costly due to the use of heavy concrete blocks. Cast-in-place concrete in the dry condition at the site is more economical considering the construction schedule with work concentration in the dry season.

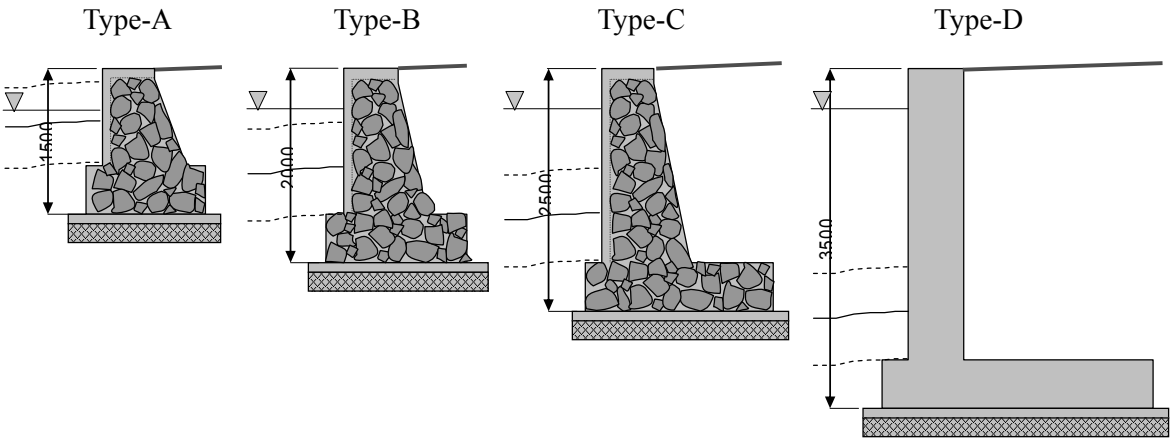


Figure 2-7 Types of Retaining Walls

2) Culverts

The causeway has 2 stone arch culverts and 6 pipe culverts connecting the lagoon (tidal land) on both sides. To maintain the existing ecological system, the culverts will be rehabilitated. They have been designed with the same existing features. The type, size, state of damage of culverts and their rehabilitation method are shown in Table 2-9.

Table 2-9 Existing Conditions and Rehabilitation Method of the Culverts

	Type	Size	State of Damage	Rehabilitation Method
1	Pipe Culverts	2x ϕ 0.60m	Good condition	Extension of pipe culverts
2	Stone Arch Culverts	2x ϕ 2.1xH1.2m	Some key stones are moved at top of arch	Extension of culvert and repair at top with RC concrete
3	Pipe Culverts	12x ϕ 0.90m	Relatively good condition	Extension of pipe culverts
4	Stone Arch Culvert	2x ϕ 1.6xH0.85m	Relatively good condition	Extension of culvert and repair at top with RC concrete
5	Pipe Culverts	4x ϕ 0.60m	Deteriorated and clogged pipes	Removal of old pipes and installation of new pipes in same number and size
6	Pipe Culverts	4x ϕ 0.60m	Deteriorated and clogged pipes	Removal of old pipes and installation of new pipes in same number and size
7	Pipe Culverts	4x ϕ 0.60m	Deteriorated and clogged pipes	Removal of old pipes and installation of new pipes in same number and size
8	Pipe Culverts	4x ϕ 0.60m	Clogged pipes	Removal of old pipes and installation of new pipes in same number and size

3) Settlement Measure

From the results of the centerline survey on the causeway, it was found that settlement occurred along the causeway. As a very soft layer of 2~3m thick is deposited on the seabed of the lagoon, necessary measures dealing with settlement should be taken for the widening area before embankment. The considered measures against settlement include i) Pre-loading Method, ii) Displacement Method, iii) Drain Method, and iv) Concrete Slab Method, as described below:

a) Pre-loading Method

The pre-loading method is a standard and economical method for settlement but it takes long time to consolidate and complete the settlement on soft ground. This method is not applicable in the limited construction period and space which leads to ineffective surcharge and compaction. It is also uneconomical because the surcharged material is not re-used for the other construction.

b) Displacement Method

The displacement method that consists in excavating and replacing the soft ground with good embankment material is a reliable measure against settlement. However, construction of cofferdams with steel sheet piles is required for excavation of soft ground, resulting in cost increase. To minimize the cost, coffering works should be carried out during the low tide in the dry season to provide small scale cofferdams. The displacement method presents no problem even within a limited construction period because consolidation period is not concerned.

c) Sand Drain Method

Prior to applying the pre-loading method, drain pipes are excavated and filled with sand to accelerate consolidation of soft ground. The sand drain method can reduce the construction period in comparison with the pre-loading method but still cause a little

problem with regard to the construction period due to the import and inland transportation of sand drain machines, and low working efficiency in the limited place.

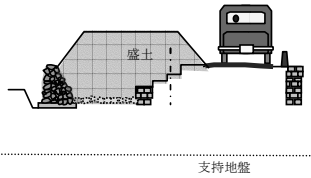
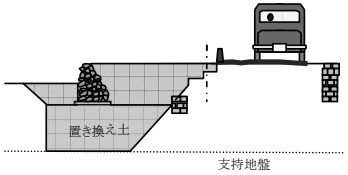
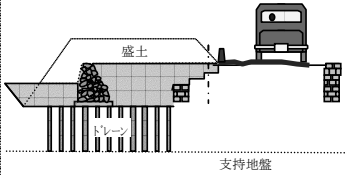
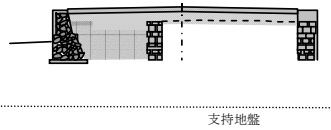
d) RC Concrete Slab Method

The RC slab method is suitable for structural and economical aspects because the existing retaining wall and new retaining wall are used for slab pedestals. However, repair and maintenance of damaged RC slabs is difficult for the RDA Mannar Office. Slab pedestals are not durable against settlement.

e) Overall Evaluation

The construction of the widened causeway consists of application of counter-measures for settlement, embankment of retaining walls and pavement in a continuous sequence on the critical path. Considering the construction period of 29 months, the displacement method and RC concrete slab method are deemed appropriate. However, the displacement method is reliable against settlement and is economical in view of cost reduction by concentrating coffering works during the low tide in the dry season. The overall evaluation of the settlement measures is summarized in Table 2-10.

Table 2-10　Comparative Table for Measure of Settlement on the Causeway

Description	**Alternative-A** **Pre-loading**	**Alternative-B** **Displacement**	**Alternative-C** **Drain**	**Alternative-D** **RC Concrete Slab**
Plan				
Procedure	①Move existing retaining wall ②Construct new retaining wall ③Embankment ④Pre-loading ⑤Pre-loading period ⑥Remove pre-loading ⑦Pavement	①Move existing retain wall ②Cofferdam with sheet piles ③Excavation ④Displacement with soil or gravel ⑤Construct new retaining wall ⑥Embankment ⑦Pavement	①Move existing retaining wall ②Drilling and execute sand drain ③Surcharge of embankment ④Remove of excess soil ⑤Construct new retaining wall ⑥Embankment ⑦Pavement	①Construct new retaining wall ②Embankment ③RC concrete slab
Execution Period	It takes long time to consolidate although cost is low △	It takes short time to execute the procedure because no need to wait for consolidation. ◎	Although It can shorten the consolidation time to provide sand drains, it is still not enough ○	It takes time to execute RC concrete along causeway. ○
Effectiveness Settlement	Short pre-loading time and limited loading height are ineffective for consolidation. Settlement is expecting in future. △	Displacement (2-3m) with selected soil checking bearing strata is effective. ◎	Settlement can be minimized due to drains to shorten consolidation time. ○	There is a risk on cracks on RC slab due to the settlement of new retaining wall △
Cost	It is a popular method with the lowest cost ◎	Cost is relatively higher than other plans due to cofferdam. But, execution is concentrated in dry season to minimize cost. ○	Cost is relatively higher than other plans due to cofferdam. But, execution is concentrated in dry season to minimize cost. △	RC Concrete Slab is the most expensive in the alternatives. Maintenance cost is relatively high. △
Overall Evaluation	Although it is the lowest cost, it is expecting to the decline of retaining wall and cracks on pavement with short pre-loading. △	It is the most reliable method for measure of settlement. Cost can be reduced to concentrate on coffering works in dry season. ◎	Settlement can be minimized but execution time is longer than displacement method. ○	Risk of cracks on slab due to settlement and its difficulty of maintenance are not acceptable. △

◎ : Very Good　○ : Good　△: Poor

(5) Structure of Pavement

Asphalt pavement is more popular than concrete pavement for road construction in Sri Lanka. Except a part of the main road, double bituminous surface treatment (DBST) will be applied for the road surface as stipulated in RDA Pavement Manual. There is no asphalt plant operating in the northern area and road repair is done by penetration macadam. In view of such a situation in the northern area, DBST has been selected for surface pavement considering extensive accomplishments by this method in Sri Lanka, its economical and easy application and the experience of the RDA Mannar Office in the maintenance of this kind of pavement.

1) Standard of Pavement

The pavement of causeway and approach road has been designed with a CBR value determined from the geotechnical survey results. The new pavement on the widened section of the causeway and the raising and overlay on the existing pavement have been designed on the basis on the Guide to the Structural Design of Roads under Sri Lankan Condition. The design life of pavement has been determined to be 10 years considering the future traffic volume stated the above Guide.

2) Cumulative Number of Standard Axles

The cumulative number of standard axles that will traverse the road in the course of its design life is estimated with the factors such as daily traffic volume, rate of traffic growth by vehicle type, equivalent standard axle (ESA), as shown in Table 2-11. The applied rates of traffic growth by vehicle type are the average rates stipulated in RDA Guideline (A Guide to the Structural Design of Loads under Sri Lankan Condition, April 1999). According the RDA Guideline, the cumulative number of standard axles (3.66 x 10^6) is classified as T5.

Table 2-11 Cumulative Number of Standard Axles

Vehicle Type	Daily Traffic Volume	Traffic Growth Rate by Vehicle Type (%)	Equivalent Standard Axle	Cumulative Number of Standard Axles (x 10^6)
Heavy Vehicle	446	5.5	1.88	2.13
Medium Vehicle	368	5.5	1.17	1.10
Light Vehicle	944	3.5	0.01	0.01
Long Bus	486	4.0	0.30	0.34
Mini Bus	371	4.0	0.09	0.08
Total	2,615			3.66

3) Design of Pavement Thickness

The pavement thickness has been designed using the Structural Catalogue given in the RDA Guideline, based on the cumulative number of standard axles and the quality or CBR of the selected materials. From the results of material survey in the vicinity area, it was designed that the road surface is treated by the DBST method, the base course consists of crushed aggregates from Madukanda, the sub-base course consists of laterite with a CBR value of over 20%, and the subgrade consists of silty laterite with a CBR value of 8%. Based on the CBR of subgrade, the following 3 types of pavement have been designed for the causeway and approach road as shown in Figure 2-8 and the detailed classification by sections is shown in Appendix-C

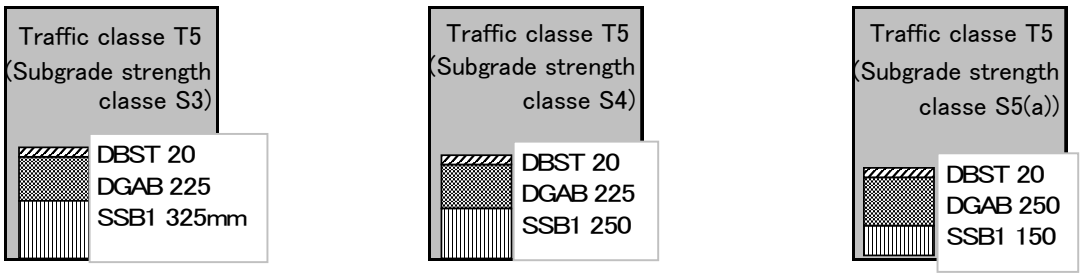
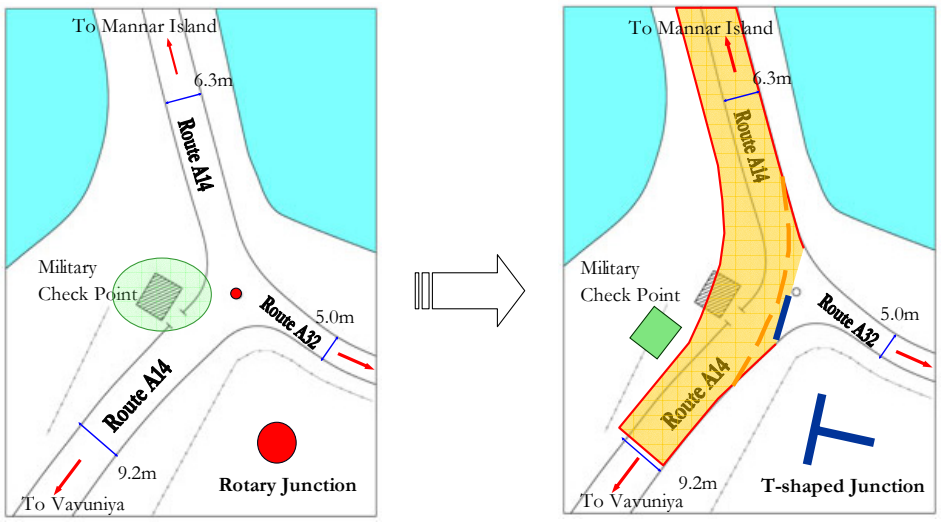


Figure 2-8 Pavement Thickness for Causeway and Approach Road

(6) Improvement of Junction at the Beginning Point

In the stakeholder meeting, the RDA Mannar Office requested to improve the small rotary junction at the beginning point. According to the result of directional traffic survey, almost all traffics are between Vavuniya and Mannar and the traffic between Jaffna and Mannar is very limited. The Study Team proposed to apply the T-type junction to improve the traffic flow between Vavuniya and Mannar at the existing junction as shown in Figure 2-9. The difference of elevation between the existing junction and the causeway is also moderated to make smooth vertical alignment and improve the traffic condition.

In the meeting with the Army Headquarters in Mannar, the Army side has confirmed that checkpoint facilities will be moved out of the right-of-way of the junction and agreed with the above junction improvement plan for smoothing traffic flow between Vavuniya and Mannar.



(Exiting Condition of Junction) (Plan of Improvement of Junction)

Figure 2-9 Improvement Plan of Junction at Beginning Point

(7) Traffic Safety Facilities and Ancillary Facilities

1) Pre-cast Concrete Hand railing

Pre-cast concrete handrails consisting of posts and railings will be provided on the bridge for protection of pedestrians from falling. Handrails have been designed applying RDA standards.

2) Kerb Stones

Kerb stones will be provided on the bridge for preventing vehicles from running onto the foot walk that is a special device used by RDA. Kerb stones are made of pre-cast concrete according to RDA standards.

3) Guardrails

As the height of embankment behind abutments is approximately 6.0m, steel guardrails with steel posts embedded in ground will be provided for protection of pedestrians from falling. Guardrails will be installed on the embankment sections higher than 2.0m on both sides of the approach road.

4) Guard Stones

Guard stones will be provided on the causeway for preventing vehicles from falling into the lagoon. Concrete guard stones of the same type as that installed on the existing causeway will be placed on the top of retaining walls at 2.5m intervals.

5) Expansion Joints

Expansion joints designed according to RDA standards are of simple steel fabrication used for small bridges and are not good for long bridges like the Mannar Bridge and not suitable for use at the seashore. It is necessary to use imported expansion joints suitable for long bridges and durable against salty water. Therefore, the expansion joints to be used for the Mannar Bridge will be imported from Japan and fabricated according to the Japanese quality standards.

6) Bridge Drainage

The average annual rainfall at the bridge site is not high at about 980mm, therefore it is not necessary to provide drain pits, which are difficult to clean and remove debris for maintenance. Only drain pipes designed according to RDA standards will be provided.

7) Illumination on Bridge

Illumination will be provided only for the bridge section to ensure safety for passing ships under it. The illumination on bridge has been designed according to RDA standards and AASHTO standard. Electric power required for the illumination will be supplied from the low voltage power line near the gasoline station in the Mannar Island.

(8) Facility Plan

The facilities designed in accordance with the basic policy are described in Table 2-12 and Table 2-13.

Table 2-12 Mannar Bridge and Approach Road

Item	Mannar Bridge	Approach Road
Improvement Method	The bridge will be reconstructed.	The approach road will be reconstructed.
Class of Road	Class-A, Local, Plain	Class-A, Local, Plain
Design Speed	70 Km/hr	70 km/hr Near Junction:60km/hr
Cross Section	Carriageway: 3.7m x 2= 7.4m Shoulder (Foot walk): 1.5 (1.2)m x 2 Total width: 10.4m	Carriageway: 3.7m x 2= 7.4m Shoulder (Foot walk): 1.8 (1.2)m x 2 Total width: 11.0m
Total Length of Bridge and Approach Road	157.1 m	Junction at beginning point: 140 m Bridge on Mannar Island side: 158m Bridge on Mainland side: 155 m
Span (Girder Length)	6 spans (26.2m)	-
Type of Structure Superstructure Substructure Foundation	Concrete Bridge PC precast I-Girder (30 girders) 5 Bridge piers: pile bent 2 Bridge abutments: pile bent Cast-in-place concrete pile (ϕ 1.2m): 627m	Approach to abutment with embankment
Pavement	Asphalt concrete pavement Min. 50mm (Cold mixed type)	Carriageway: DBST: 20mm Shoulder: DBST: 20mm
Falling Protection	Pre-cast concrete hand railing : 310m	Steel guardrail: 160m
Slope Protection	Stone riprap: 720m^3	Sodding
Illumination Facilities	Bridge section: 157.1m(H=10m), one side	—

Table 2-13 Causeway

Item	Western Side		Eastern Side	
Improvement Method	Widening of causeway toward the west			
Class of Road	Class-A, Local, Plain			
Design Speed	70 Km/hr			
Cross Section	Carriageway: Shoulder (Foot walk): Total width:	3.7m x 2= 7.4m 1.5 (1.2)m x 2=3.0m 10.4m		
Total Length of Causeway	3,140m			
Retaining Wall	New construction		Repair and new construction	
Embankment Volume	37,700m^3		1,400m^3	
Displacement Volume	9,200m^3		-	
Pavement: Type-A Type-B Type-C	 Carriageway: Shoulder: Carriageway : Shoulder: Carriageway : Shoulder:	 1,700m^2 760m^2 4,700m^2 2,200m^2 5,200m^2 2,400m^2	 - Carriageway: Shoulder: -	 11,600m^2 3,800m^2
Falling Protection	Concrete guard stone :	1,300nos	Concrete guard stone:	1,300nos

2-2-3 BASIC DESIGN DRAWINGS

The basic design drawings are provided in Appendix-1

2-2-4 IMPLEMENTATION PLAN

2-2-4-1 Implementation Policy

The Project Implementation Plan has been worked out based on the guideline of Japan Grant Aid and considering the site conditions. The policies of implementation of the Project are summarized below:

- To activate the regional development and generate job opportunity, local labour and construction materials should be used to the maximum extent for the Project. Considering an acute shortage of professional and skilled labour, technology transfer is necessary for local people to accelerate the work progress in the early stage of the construction.
- The construction of the bridge and causeway is implemented on the condition that peace is maintained during the construction stage. Working hours are from 8:00 AM to 17:00 PM and no night work is allowed for safety reason.
- Both sites of the bridge and causeway are under control of the Army and check is carried out currently at the junction of the beginning point and the Mannar bridge site. It is predicted that such strict check for labour, materials and equipment will affect the work progress. Therefore, the respective parties shall have meetings and take measures for the smooth in-and-out control of labour, materials and equipment.
- It was learned from hearing survey that the tide level is high in the rainy season (November to February) and the lagoon is covered with sea water. On the other hand, the lagoon on the mainland of Sri Lanka side has tendency to become dry in the dry season due to low tide. Implementation of the Project should be reasonably scheduled considering the fluctuation of the tidal levels between the rainy season and the dry season.
- The inspection and maintenance management systems for the new bridge and causeway will be included in the Project and the maintenance manuals should be prepared in coordination among the Client, consultants and contractors through a training programme in Japan and at site during either the detailed design stage or the construction stage.

2-2-4-2 Implementation Condition

The important notices for the implementation plan are described below:

(1) Labor Law

The Contractor shall manage labors properly with an adequate safety control plan and shall prevent conflicts with local labors. In all circumstances, he shall abide by the labor laws and regulations in force in Sri Lanka.

(2) Environmental Consideration during Construction

RDA has already acquired the approval of Environment Considerations with conditions on March 13, 2006. The Project can be started under the admission by the Coastal Conservation Department (CCD). If there are any conditions to follow in the environmental aspect for the admission, they will be taken into consideration in the implementation plan.

(3) Permission to Labour, Materials and Equipment in site

To minimize and smooth the security control during the construction at the junction of the beginning point on the mainland side and beside of the Mannar bridge, the following measures shall be taken:

- ID cards will be issued by the Army in Mannar to and carried by all staffs working in the site;
- Japan ODA logo marks will be stuck on all equipment operating in the site to distinguish between the general and construction vehicles.

(4) Evacuation of the site

The construction works will be implemented on the condition that peace is maintained during the construction stage. However, if the situation will be severely changed in the vicinity of the site, all staffs should evacuate from the construction site immediately. Methods, ways and places of evacuation shall be discussed among the Agencies concerned.

(5) Traffic Safety and Security Measures

The Project is mainly divided into bridge and causeway sections. The existing bridge will be used only for general traffic. A temporary bridge will be constructed between the existing and new bridges and in parallel with the existing bridge for the construction purposes. Guard offices will be constructed at the gateways from the existing road to provide security guard policemen to control the equipment and construction workers.

In the causeway section, the reconstructed (widened) causeway and culverts will be sited at the same location as the existing causeway and structures. Traffic on the causeway should be maintained during the construction. Only one traffic lane of approximately 4.0m wide will be provided, and cars have to pass in turn in each direction. Against this condition, the following measures are taken into consideration:

To control traffic vehicles and construction equipment including dump trucks:

- To lead bicycles and pedestrians smoothly.
- To indicate the construction site at night time.

Traffic control policemen will be stationed at the construction points to control traffic smoothly and to avoid accidents between traffic vehicles and construction equipment. Traffic safety facilities, such as traffic safety plates, information boards of detour, and simple night-lighting facilities will be installed in the construction sites and stipulated in the construction contract to be executed by contractors in order to minimize traffic accidents.

(6) Importance of Concrete Quality Control

As concrete structures in the Project are constructed near or in the sea or lagoon (tidal land), the quality of concrete has a great influence on life of the concrete structures (especially the bridge). Concrete in seawater is subjected to many effects such as battering of waves and tides, wetting and drying, corrosion of reinforcing bar and temperature variations. The above potentially harmful effects can be controlled by the use of normal cement along with sound non-relative aggregates that are properly proportioned to produce strong impermeable concrete. Reinforcing bars should be properly protected from corrosion by minimum coverage of concrete from the crack width in accordance with the RDA Bridge Design Manual. It is important to produce high quality and durable concrete to reduce cracks. To produce high quality concrete, selection of concrete materials such as

aggregate, sand, water and cement, low W/C, air contained calibration of concrete plant, regulation on transportation and placing of concrete should be given utmost attention.

2-2-4-3 Scope of Works

The scope of works to be undertaken by the Japanese Government as well as the Sri Lankan side is as follow;

Table 2-14 Scope of works to be undertaken by the Japanese Government and Sri Lankan side

Works and Facilities to be Provided by the Japanese Government	Works and Facilities to be provided by the Sri Lankan side
- Consulting services for detailed design, preparation of tender documents, assistance to Sri Lankan side in tender process, and construction supervision including environmental control plan. - Construction of the new Mannar Bridge and improvement of causeway selected in the basic design study. - Installation and removal of temporary facilities (temporary bridge, camp yard and temporary construction yards) - Illumination on the bridge and installation of the rack of water supply pipe, agreed by the Japanese Government. - Safety measures required for traffic and construction in the execution of works. - Measures for prevention of environmental pollution during execution of construction works. - Procurement, import, and transport of equipment/ materials required for the reconstruction works and re-export of imported equipment.	- Free provision of site (land) for construction, temporary facilities other construction activities required in execution of construction works - Preparation of Environmental Considerations and acquisition of environmental permit from CCD. - Removal and relocation of the existing utilities and public facilities (water supply pipes and telephone lines, signboards) - Payment of bank service charges for banking arrangement (B/A) and authorization to pay (A/P). - Free provision of land for camp yards and temporary construction yards - Free provision of borrow pit and waste disposal area in the government land - Disposition of full time security management policemen at camp yard - Exemption of consultants and contractors from taxes, customs duties and other levies charged in Sri Lanka for execution of construction works - Arrangement for visas, certification and other privileges to Japanese nationals and third country personnel relating to and required in execution of construction works. - Monitoring of water quality during construction - Removal of the wreck of steel trusses in the sea after completion of the Project. - Removal of the existing bridge after completion of the Project

2-2-4-4 Consultant Supervision

(1) Supervision

The engineering services for construction supervision will begin with the acceptance of the construction contract and the issuance of a Notice to Proceed (N/P) to the Contractor.

The Consultant shall perform his duties in accordance with the criteria and standards applicable to the construction works and shall exercise the powers vested in him as the Engineer under the Contract to supervise the field works by the Contractor.

The Consultant within his capacity as the Engineer shall directly report to RDA and JICA Colombo about the field activities and shall issue field memos or letters to the Contractor regarding various matters, including progress, quality, safety and payment for the works under the Project. After one year from the completion of the construction, the Consultant will conduct the final inspection for defects reliability as the final task of the Consultant.

(2) Implementation Organization

A Resident Engineer will basically stay at the construction site and conduct both construction supervision and project management. The necessary specialists for each stage are as follows:

- Team Leader : Coordination and liaison for all the project activities to ensure smooth progress and management in all technical aspects
- Bridge Engineer : Technical and quality control of bridge works
- Road Engineer : Technical and quality control of causeway and approach road

2-2-4-5 Quality Control Plan

The design of the Project was carried out according to the relevant Sri Lankan standards for roads and bridges. Highway and bridge design manuals are available in Sri Lanka. However there is no specific quality control plan in Sri Lanka. Consequently, the quality control plan for the Project has been formulated based on the design concepts as shown in Table 2-15.

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Table 2-15 Quality Control Tests Plan

Item			Test Method	Frequency
Crushed Rock	Mixed Material		Liquid Limit, Liner Shrinkage (< Sieve No.4) Sieve Gradation	Each site/Crushing plant
			Abrasion Loss	
			Aggregate Density	
			Maximum Dry Density	
	Paving		Field Density (Compaction)	Daily
Prime Coat and Tack Coat	Material	Bitumen	Quality Certificate	
			Applied Volume/Weight	Every 500m^2
Cold Mix Asphalt	Material	Bitumen	Quality Certificate & Chemical Analysis	Every material
		Aggregate	Sieve Gradation	Every mixing
			Water Absorption	Every material
			Abrasion Loss	
	Mix Requirement		Marshall Stability	Every mixing
			Marshall Flows	
			Air Voids	
			Voids in Material Aggregate	
			Indirect Tensile Strength	
			Immersion (Strength) Index	
			Bitumen Content	
	Compaction		Temperature in Mixing	Each site
			Temperature in Compaction	Each site
			Sampling (Marshall Test)	Each site
Concrete	Material	Cement	Quality Guarantee, Chemical & Physical Analysis	Every material
		Water	Chemical Analysis	Every material
		Admixture	Quality Guarantee, Chemical Analysis	Every material
		Fine Aggregate	Bulk Specific Gravity Dry	Every material
			Sieve Gradation, Finesse Modulus	
			Clay and Friable Particles	
		Coarse Aggregate	Bulk Specific Gravity Dry	Every material
			Flakiness Index	
			Sieve Gradation	
			Sodium Sulfate Soundness	
	Mixing Test		Calibration of Batching Plant	Before starting concrete works
	Pouring		Slump	Daily
			Concrete Temperature before Pouring	Daily
	Strength		Compressive Strength at 7 & 28 days	Daily or every 50m^3
Re-bar/PC strand	Material		Quality Certificate	Each lot
PC Stressing	Prestressing Equipment		Calibration of Hydraulic Jacks and Pump	Before starting prestressing works
	Control of Prestressing		Graph of Prestressing Control	Each stressing
Grouting	Mixing Test		Calibration of Mixer	Before grouting works
	Pouring		Consistency, Temperature	Every mixing
	Strength		Compressive Strength at 7 & 28 days	

2-2-4-6 Procurement Plan

Bridge construction materials such as steel, reinforcing bar, PC cable, etc. cannot be procured inside Sri Lanka, but are available in Singapore. However, PC cable and its anchors including tensioning jack, rubber bearings and expansion joints will be imported from Japan to ensure good quality and durability against saline water. Construction equipment such as PC girder erection machine (erection girder method) and all casing bored pile machine is not available in Sri Lanka and Singapore, so this equipment will be procured from Japan.

There is no a concrete plant in Mannar but it is available in Colombo. To control the quality of concrete effectively, concrete plants will be procured from Colombo and installed inside the camp yard.

Aggregates and stones will be purchased from the suppliers having crushing plants located at Madukanda and Mihintale. Principal construction materials can be procured as shown in Table 2-16 and. Table 2-17.

Table 2-16 Construction Materials Procurement Table

Materials	Sri Lanka	Japan	Third Country	Reason	Import Route
Portland Cement	○				
Aggregate/Sand	○				
Reinforcing Bar	○				
Steel/Sheet Pile		○			
PC Strand and Anchorage		○		No production in Sri Lanka	Marine transportation
Admixture	○				
Wood/Plywood	○				-
Bituminous Material	○				-
Fuel (Diesel and Gasoline)	○				-
Rubber Bearing Shoes		○		No production in Sri Lanka	Marine transportation
Expansion Joint (Rubber)		○		ditto	ditto
Plaque Plate		○		ditto	ditto

Table 2-17 Indicative Procurement of Construction Equipment

Items	Procurement	Sri Lanka	Japan	Third Country	Route of Transport
Bulldozer	lease	○	-	-	Inland transport from Colombo
Backhoe	lease	○	-	-	ditto
Dump Truck	lease	○	-	-	ditto
Truck Crane	lease	○	-	-	ditto
Motor Grader	lease	○	-	-	ditto
Road Roller	lease	○			ditto
Tire Roller	lease	○			ditto
Asphalt Distributor	lease	○	-	-	ditto
Concrete Plant	lease	○			ditto
Agitator Truck	lease	○			ditto
Vibration Hammer	lease	○			ditto
Breaker with Crawler Crane	lease	○			ditto
All Casing Bored Pile Machine	lease		○		Sea transport from Japan to Colombo
Casing Pipe ϕ 1200mm	lease		○		ditto
Hammer Grab	lease		○		ditto
Gantry Crane	lease		○		ditto
PC Tendon/Jack and Pump	lease		○		ditto
Erection Girder	lease		○		ditto
4-wheel Drive Vehicle	lease		○		ditto

2-2-4-7 Implementation Schedule

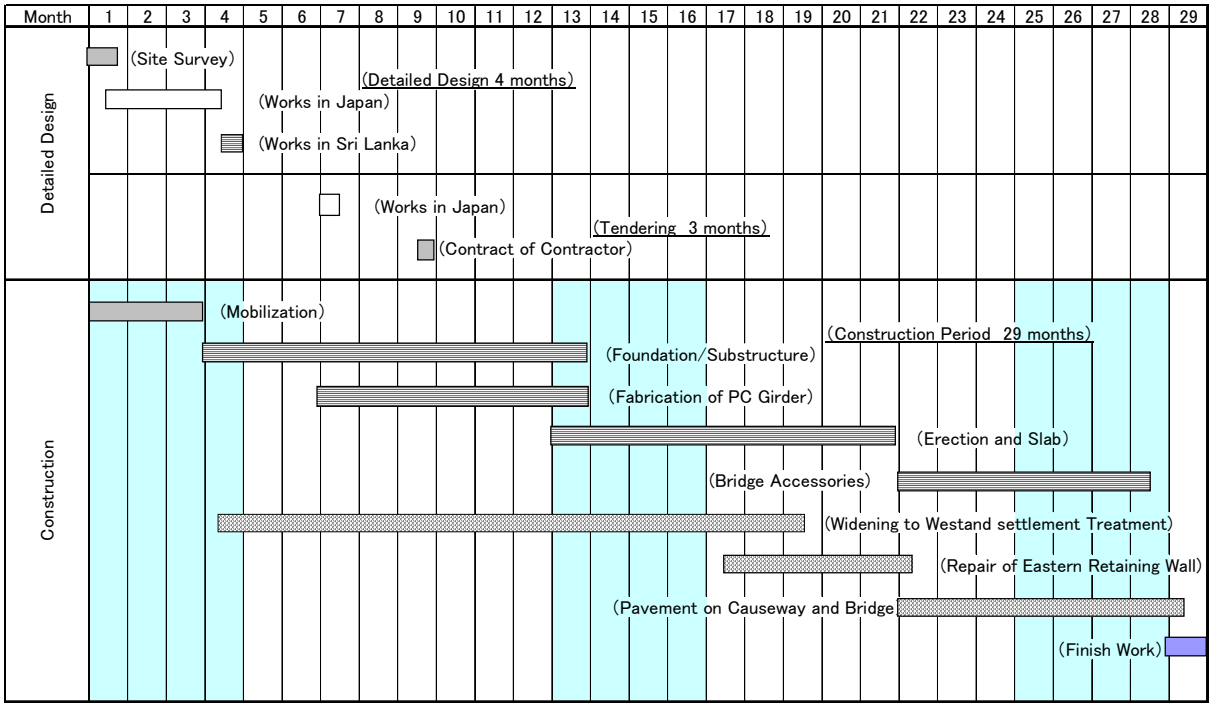
The Construction period is estimated at 29 months considering interruption or inefficient execution of works in the rainy seasons. The budgetary year of Japan would be applied to the Project implementation in accordance with the Japan Grant Aid Guideline.

The consulting services will be commenced under the Grant Aid Project only after the Exchange of Notes (E/N) covering the detailed design, tendering, construction supervision and civil works has been signed.

At the beginning of the services, the Consultant will carry out site surveys to confirm the basic design along with the existing landscape for 3 weeks and then detailed design including preparation of the tender documents will follow in Japan for 4 months. All designs and documents will be approved by RDA at the end of the detailed design. Tender activities such as prequalification of contractors, tender evaluation, selection of the contractor, etc. will be carried out under assistance concept, and it will take about 2.5 months. After selection of the contractor through competitive bidding, the Government of Sri Lanka will sign the civil works contract with the selected contractor after verification of the contract.

The works will be commenced simultaneously for the bridge and causeway after the raining season. The total construction period including mobilization and demobilization is 29 months. A Tentative Implementation Schedule is shown in Table 2-18.

Table 2-18　Tentative Implementation Schedule



2-3 OBLIGATIONS OF THE RECIPIENT COUNTRY

2-3-1 COMMON ITEMS OF JAPAN'S AID SCHEME

For smooth implementation of the Project, the Government of the recipient country shall fulfill the following undertakings:

- To provide the necessary data and information for implementation of the Project;
- To secure land necessary for the site of the Project (for the approach road, camp yard and storage of materials and equipment);
- To clear, level and reclaim the land prior to commencement of the Project;
- To open a bank account in the name of the Government in a bank in Japan (B/A) and issue the authorization to pay (A/P);
- To ensure all the expenses and prompt execution for unloading, customs clearance;
- To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies which will be imposed in the recipient country with respect to the supply of the products and services under the verified contracts;
- To accord Japanese nationals, whose services may be required in connection with the supply of the products and services under the verified contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work;
- If necessary, to issue the permission and any other authorization for the Project implementation,
- To ensure proper maintenance, management and preservation of the facilities provided by Japan's Grant Aid;
- To bear all expenses, other than those to be borne by the Grant Aid, necessary for the construction of the facilities as well as for the transportation and installation of the equipment.

2-3-2 SPECIAL ITEMS OF THE PROJECT

- Relocation of the gasoline stand and 2 abandoned houses affected by the works : By the End of August 2007;
- Provision and clearance for the main camp yard and temporary construction yards at both bridge sides：By September 2007;
- Relocation of a water supply pipe affected by the works at the site during construction;
- Relocation of telephone lines affected by the works at the site during construction;
- Provision and clearance for the main camp yard：By September 2007.
- Provision of the soil disposal and construction waste areas：By September 2009.
- Issue ID cards to all staffs and security stickers on all vehicles and equipment : By November 2007
- Assignment of security policemen on full time basis at the camp yard and the construction yards：From October 2007 to February 2010.

2-4 PROJECT OPERATION PLAN

The Maintenance Management & Construction Division of RDA is responsible for maintenance and operation of roads and bridges and RDA Regional Offices execute them under the control of RDA Provincial Offices in Sri Lanka. After completion of the Project, the operation of maintenance works of the Mannar Bridge and Causeway will be carried out by the RDA Mannar Office under the Northern Provincial Office of RDA.

The operation and maintenance works, such as clearing of drains, cutting grass, pothole repair are carried out by a private repair agency under contract with the Mannar Office. Urgent repair of damaged bridges and periodical repairs at every 2, 5 and 10 year are also carried out by RC & DC under contract with RDA.

The operation and maintenance works for the bridge and causeway after completion of the Project shall be carried out in accordance with the following schedule;

2-4-1 YEARLY MAINTENANCE

Ordinary inspection for the bridge and causeway:

- Removal of debris and cleaning of drain pits and ditches and around bearing shoes
- Maintenance of traffic safety such as repainting lane marks and guardrails.
- Change of lighting bulbs for illumination poles
- Patching repair on pavement
- Leveling of the scoured areas along the retaining wall
- Cutting grass on slope of embankment and road shoulders.

2-4-2 PERIODICAL MAINTENANCE

- Repair of revetment around abutments and retaining walls after cyclone (at every two years)
- Overlay of surface layer of bridges, causeway and approach roads at every 5 years
- Repair of bearing shoes and expansion joints at every 10 years

2-5 COST ESTIMATE

2-5-1 TOTAL PROJECT COST

The total cost of the Project to be borne by the Japan's Grant Aid is estimated at Japanese Yen 1,878 million as summarized in Table 2-19. The Project cost required for fulfilling the undertakings to be borne by the Government of Sri Lanka is shown in Table 2-20.

These cost estimates are provisional and will be further examined by the Government of Japan for the approval of the Grant.

(1) Project Cost to be borne by Japan's Grant Aid

Table 2-19 Project Cost to be borne by Japan's Grant Aid

Items			Cost (million Japanese Yen)	
Construction Facilities	Bridge (Length :157.1m)	Temporary bridge Foundation Substructure Superstructure Bridge surface work	646	1,739
	Causeway (Length :3.14km)	Earthwork Settlement work Retaining wall Pavement Traffic safety facilities	1,001	
	Approach Roads (Length :0.45km)	Earthwork Pavement work Traffic safety facilities	92	
Detailed Design and Construction Supervision				139
			Total	1,878

(2) Project Cost to be borne by Sri Lankan Side

Table 2-20 Project Cost to be borne by Sri Lankan Side

Items	Cost (Thousand Rupees)	Yen Equivalent (Thousand Yen)
1) Relocation of gasoline station and 2 abandoned houses, environmental monitoring.	1,010	1,160
2) Relocation of telephone lines	150	170
3) Relocation of water supply pipe	2,250	2,570
4) Land preparation for temporary camp yard	360	410
5) Provision of policemen for guard at temporary camp yard and construction yard	1,620	1,850
6) Issue of ID cards and security stickers for vehicles and equipment	400	460
7) Demolition of the wreckage of the steel truss bridge in the sea.	910	1,040
8) Demolition of the existing bridge including temporary steel Bailey bridge	8,300	9,500
9) Payment of bank service charges for banking arrangement (B/A) and authorization to pay (A/P)	1,900	2,170
Total	16,900	19,330

(3) Condition of Cost Estimate

- Estimate Time 2006 : Average rate of 6 months before the end of July
- Exchange Rate : 1.0 Rs = 0.0098 US$ (= 1.1443 Yen)
  : 1.0 US$ = 116.77 Yen
- Construction Period : 29 months

The Project will be implemented under the Japan's Grant Aid scheme. The above project costs would be revised by the Japanese Government before issuing the Exchange of Notes (E/N).

2-5-2 MAINTENANCE COST

RDA is required to bear the maintenance costs of about 980,000 Rs (1.125 million Yen) annually as well as 110,000 Rs (130,000 Yen) every 2 years for repair of river structures, 4.150 million Rs (4.750 million Yen) every 5 years for overlay of pavement and 1.150 million Rs (1.310 million Yen) every 10 years for repair of bearing shoes and expansion joints. The average of these annual maintenance costs is about 1.010 million Rs (1.158 million Yen).

On the other hand, the annual maintenance budget for roads and bridges of RDA is 1.990 billion Rs (2.283 billion Yen) in total. Hence, the annual maintenance cost for the reconstructed bridge and causeway by the Project as estimated in Table 2-21 corresponds to only 0.11% of the RDA's total annual maintenance budget. Therefore it is financially possible for RDA to continue the maintenance of the reconstructed bridge and causeway.

Table 2-21 Maintenance Cost Estimate

Classification	Frequency	Component	Work Items	Approximate Cost (,000)		Note:
				Rupees	Yen Equivalent	
Cleaning of Drainage	Twice a year	Bridge Drain	Removal of debris	10	11	
		Bridge Footway	Removal of debris	30	34	
Traffic Safety	Once a year	Road Surface	Marking, guardrail, and change of lighting Bulbs	830	950	
Road Maintenance	Twice a year	Bank Slope, Road Surface	Patching on pavement, Cutting grass	110	130	
Annual Maintenance Cost 1				980	1,125	
Revetment Protection	After cyclone (Once two years)	Retaining Wall of Causeway	Repair on scored parts along causeway	110	130	2% of the designed quantities
Pavement	Once every 5 years	Bridge and Road Surface	Overlay of pavement	4,150	4,750	20% of the designed quantities
Re-painting of Steel Surface	Once ever 10 years	Steel Surface	Re-painting of lighting Poles etc,	650	740	Painting by hand
Change of Bridge Accessories	Once every 10 years	Shoes & Expansion Joints	Replacement or repair	500	570	10% of purchase cost
Average Annual Maintenance Cost 2				1,010	1,158	
Total Annual Maintenance Cost				1,990	2,283	

Note: Exchange Rate 1.0Rs＝1.144Yen. The indirect cost is estimated to be 30% of the direct construction cost.