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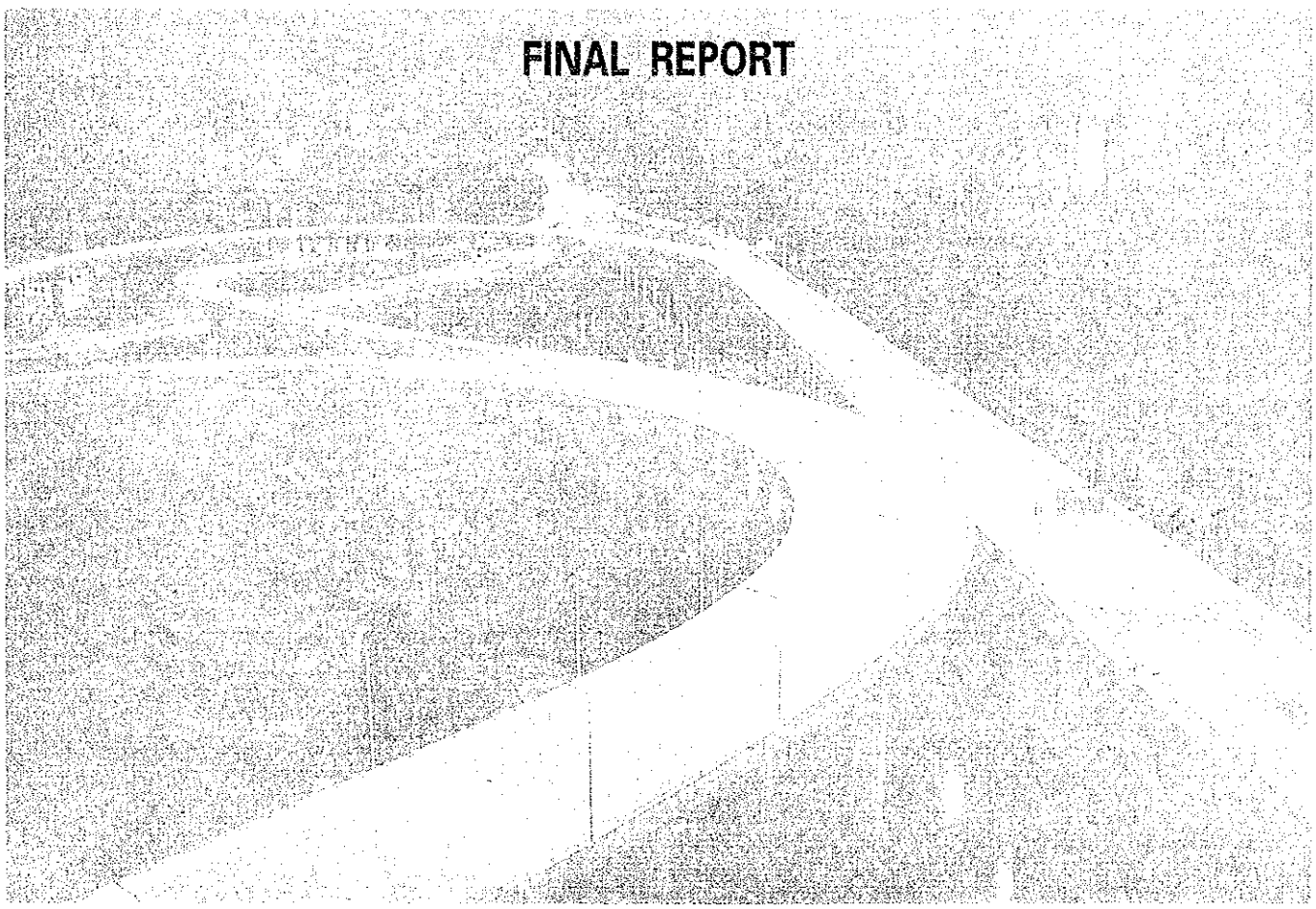
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE EXPRESSWAY AND RAPID TRANSIT AUTHORITY OF THAILAND
KINGDOM OF THAILAND

# THE STUDY ON INSPECTION AND MAINTENANCE SYSTEM FOR THE EXPRESSWAY IN THE KINGDOM OF THAILAND



## FINAL REPORT

DECEMBER 1994

ORIENTAL CONSULTANTS
PACIFIC CONSULTANTS INTERNATIONAL

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct 'The Study on Inspection and Maintenance System for the Expressway in the Kingdom of Thailand', and entrusted the study to the Japan International Cooperation Agency (JICA).

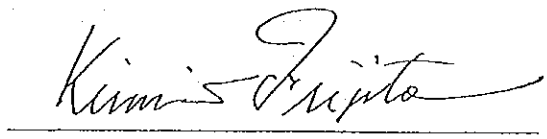
JICA then sent to Thailand a study team headed by Mr. Kazuro Yanagida, and composed of members of Oriental Consultants and Pacific Consultants International, from July 1993 to September 1994.

The team held discussions with the officials concerned of the Government of Thailand, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

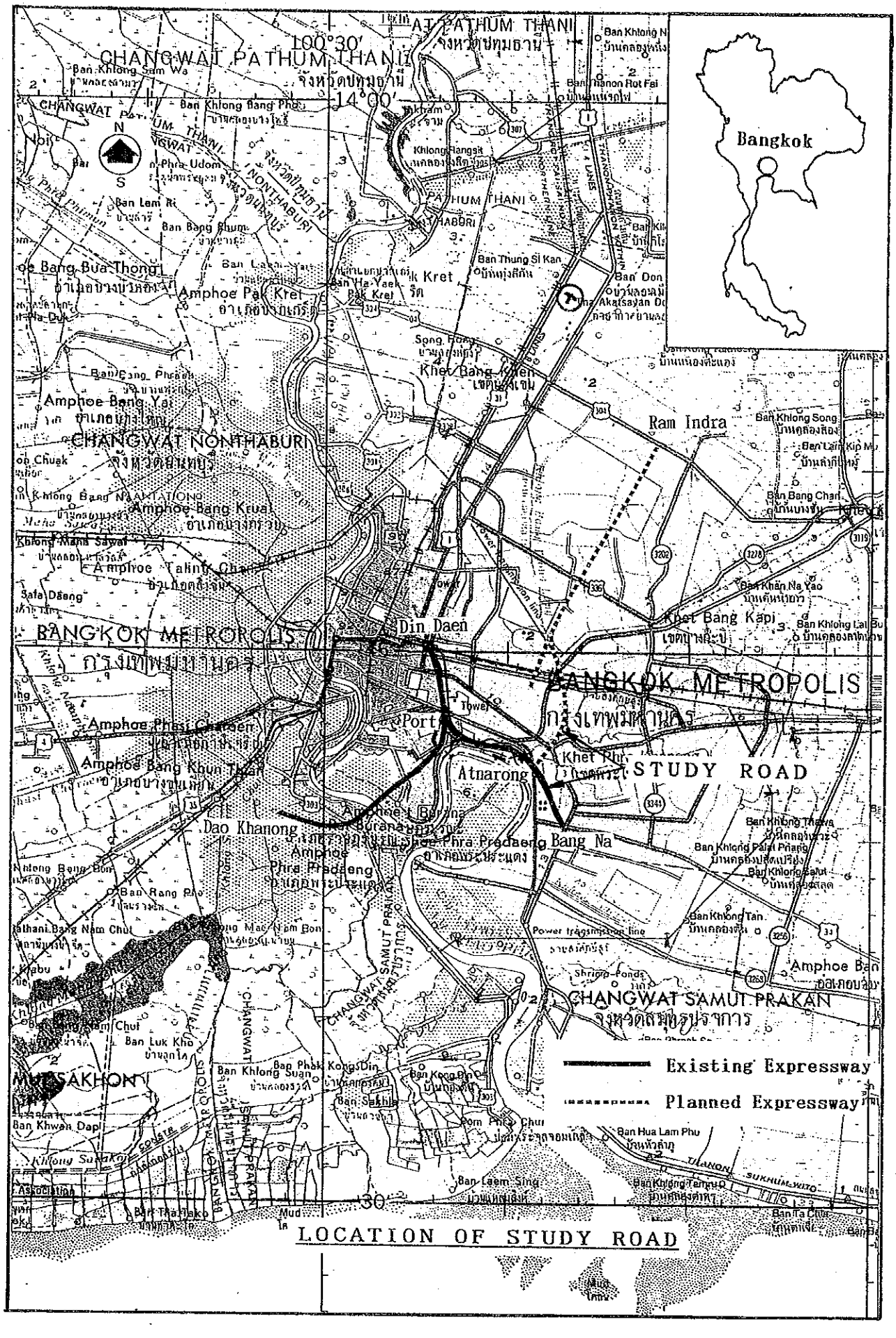
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

December 1994



Kimio Fujita
President
Japan International Cooperation Agency




LOCATION OF STUDY ROAD

THE STUDY ON
INSPECTION AND MAINTENANCE SYSTEM FOR THE EXPRESSWAY

FINAL REPORT

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# CHAPTER 1

# INTRODUCTION

# Chapter 1 Introduction

## 1.1 Objectives of the Study

### 1.1.1 Background

The existing expressway system in Bangkok, which is operated and managed under the authority of the Expressway and Rapid Transit Authority of Thailand, has been constructed and opened for public traffic in three phases; Din Daeng-Port section of 8.9 km in October 1981, Bang Na-Port section of 7.9 km in January 1983, Dao Khanong-Port section of 10.3 km in November 1987. The present total service length is thus 27.1 km long and serves as a major vehicle traffic route in the Bangkok metropolitan area.

Yearly traffic volume was less than one million at the beginning; however, there have been sharp increases since then due to the very rapid economic growth and increase of number of vehicles in the Bangkok metropolitan area. Nowadays, average daily number of vehicles of using the ETA expressway exceeds more than three hundred thousand. Based on this, it can be said that the existing expressway system is playing an important role as a main artery for vehicular traffic in the Bangkok metropolitan area, however its road structures and facilities are being damaged by the large traffic volume.

It is predicted that damage to the existing road structures and facilities of the expressway will escalate with an increase in traffic volume, the ratio of heavy vehicles and the number of age-worn structures and facilities. In order to manage expressway systems adequately and carry out timely remedial works for these structures and facilities, the availability of an inspection and maintenance system is of great importance to road administrators. Exchange of opinions and coordination among related divisions in the ETA are essential for the successful implementation of the Study.

### 1.1.2 Objectives of the Study

The objectives of the Study are as follows:

1) to formulate an inspection and maintenance system for the ETA expressway by doing the following:

   - developing a database system with the aid of a micro-computer,
   - preparing an inspection manual,
   - preparing a repair manual,
   - compiling a road inventory database,
   - making recommendations on the organization of maintenance, and

2) to transfer technology to ETA counterparts in the course of the implementation of the Study.

### 1.1.3 Study Road

The study road covers the whole existing ETA expressway network, where total length is 27.1 km. In addition, a database system was designed to be applicable of compiling the information on the Ramindra-Atnarong Expressway, which has been undertaken by ETA. Figure-1.1.1 shows the study road network.

The inspection and maintenance system covers superstructures, piers of the bridge, pavements, traffic safety devices and part of the street lighting facilities, which can be visually inspected.

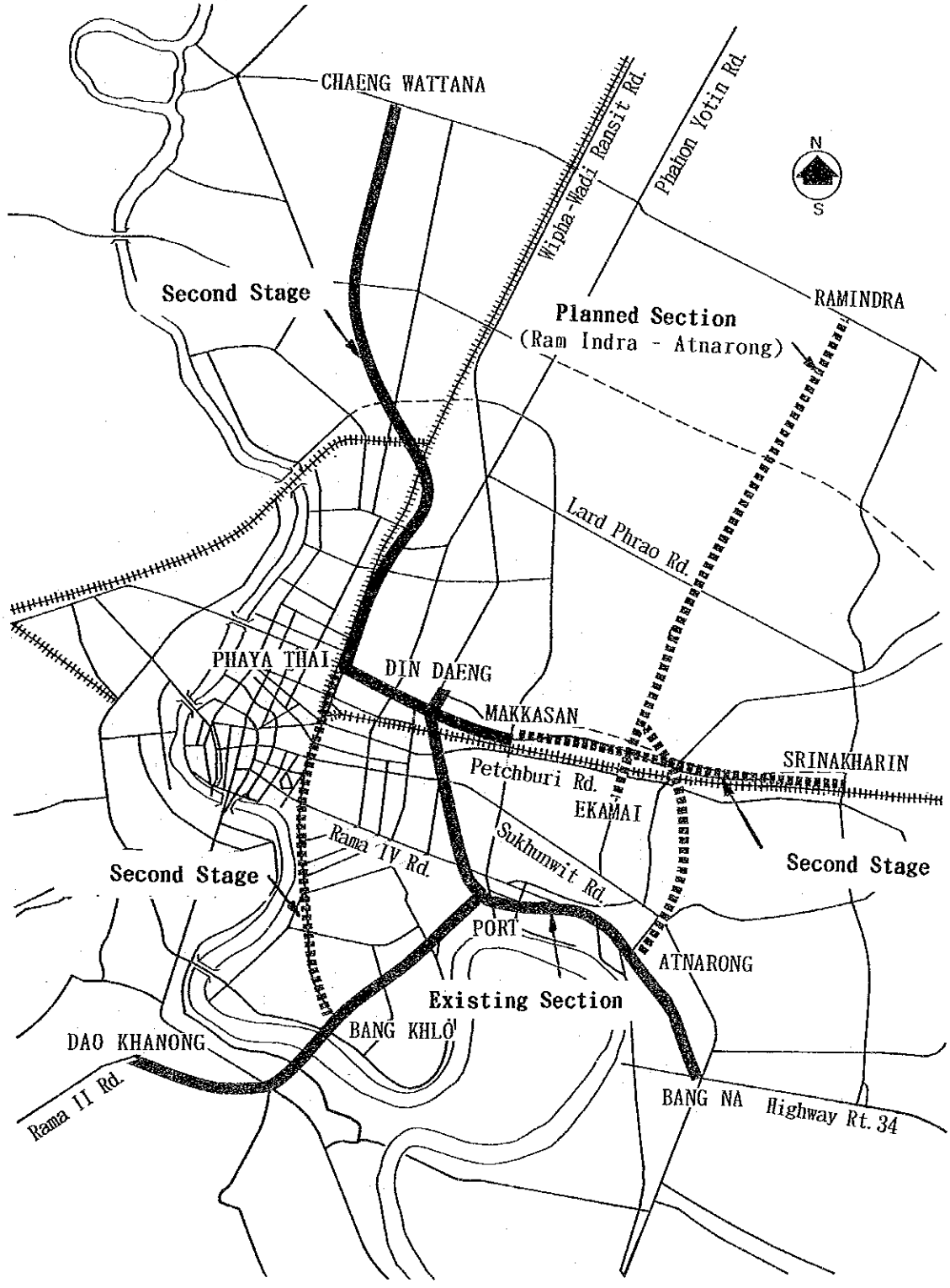



Figure-1.1.1 Study Road Network

## 1.2 Study Plan Conducted

### 1.2.1 Study Flow

The Study commenced in June 1993 and is scheduled to be completed in November 1994. Figure-1.2.1 shows the general flow of the Study, which is comprised of the following seven steps:

Step-1: preparatory work for the Study in design of study approach and drawn up of the Inception Report, which was carried out in Japan,

Step-2: survey and review of the ETA expressway system to formulate basic system concepts,

data and information collected are shown in Appendix-A.002 to Appendix-A.007,

Step-3: survey and review of maintenance systems in Japan and the drawing up of a preliminary system design,

Step-4: design and formulation of an inspection and maintenance system for the ETA expressway, including the drawing up of inspection and repair manuals and establishment of a road inventory database,

the Progress Report was submitted in the middle of this work step,

the Interim Report and manuals on inspection, maintenance and repairs were submitted in the end of this work step, and the Workshop was held to present and demonstrate the developed system,

Step-5: tentative application of the developed system to the ETA expressway,

Step-6: review and modification of the developed system and recommendations on ETA's maintenance system, and the Draft Final Report and revised manuals were submitted in the end of this work step,

Step-7: preparation of a final report is carried out by the end of November 1994 for the Study.

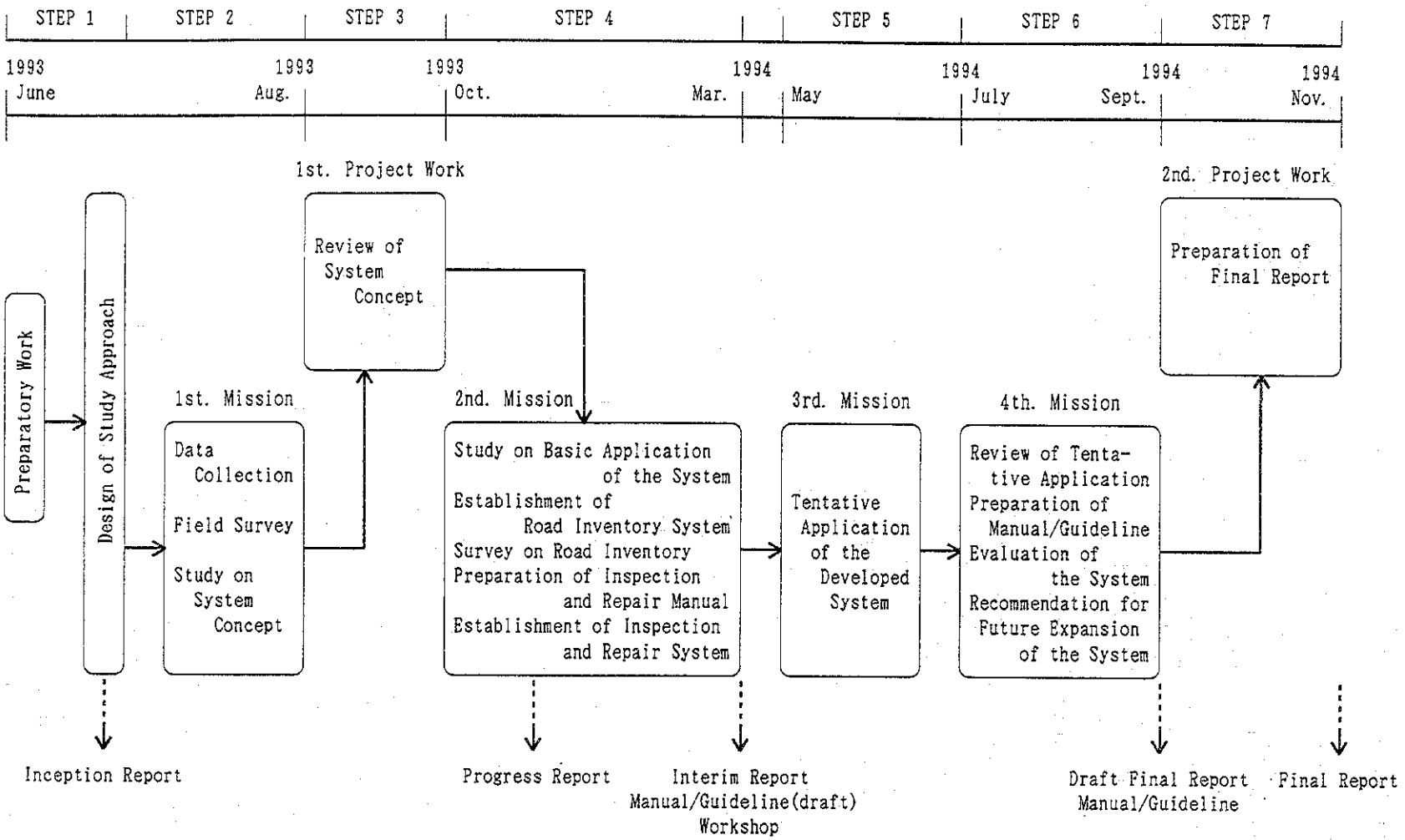



Figure-1.2.1 General Flow of the Study

The Workshop program is attached in Appendix-A.001.

This Final Report describes the basic concepts on the developed inspection and maintenance system for the ETA expressway and progress has made since the submission of the Inception Report.

The Study Team submitted the following results as a final version:

- Database System Program (dBASE4/MS-DOS)
- Road Inventory Database

Manuals in both Thai and English:
- Inspection Manual for the Land Section
- Inspection Manual for the Rama IX Bridge Section
- Maintenance and Repair Manual

- Database System Users Manual (English)

### 1.2.2 Study Organization and Participants

The Study was carried out by a Study Team composed of consultant team from JICA and their Thai counterparts. JICA has also organized the Advisory Committee. Figure-1.2.2 shows the study organization.

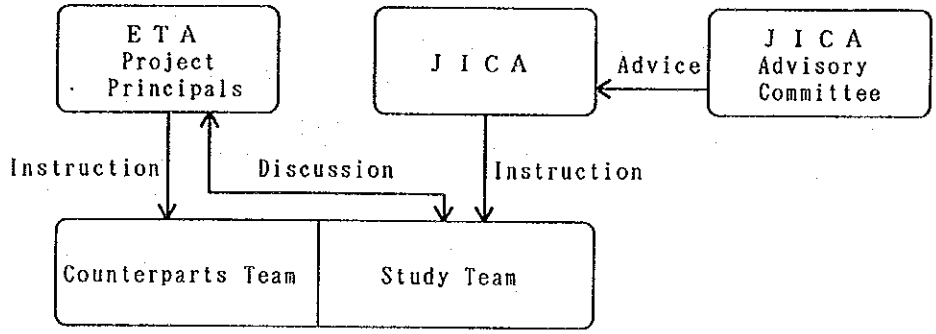



Figure-1.2.2 Study Organization

Table-1.2.1 lists the ETA project principals, members of the JICA Study Team, counterparts to the JICA Study Team, and members of the JICA Advisory Committee.

Table-1.2.1 List of Study Participants

| | |
|---|---|
| ETA PROJECT PRINCIPALS: | |
| Mr. Vatanachai Suvagondha | Project Director |
| Mr. Nopakun Leungvititgoon | Deputy Project Director |
| Mr. Booying Yaitavorn | Deputy Project Director |
| JICA STUDY TEAM: | |
| Mr. Kazuro Yanagida | Team Leader |
| Mr. Koji Wada | Deputy Team Leader |
| Mr. Keigo Konno | Concrete Engineer |
| Mr. Junnosuke Mori | Steel Engineer |
| Mr. Masashi Oshitari | Steel Engineer |
| Mr. Takashi Oki | Pavement Engineer |
| Mr. Yutaka Yamazaki | Pavement Engineer |
| Mr. Torao Tokozumi | Facility Engineer |
| Mr. Kunawut Atthasis | System Engineer |
| Mr. Yoshiki Miyazaki | System Engineer |
| ETA COUNTERPARTS: | |
| Mr. Vichit Dilokvilas | Technical Assistant |
| Mr. Somsak Mungkarak | Technical Assistant |
| Mr. Pongsak Parkpibul | Technical Assistant |
| Mr. Sombat Paneiam | Technical Assistant |
| Mr. Withawat Sirichanya | Technical Assistant |
| Mr. Pibulsak Aungsuthara | Deputy Technical Assistant |
| Mr. Chakkrit Ruamsilp | Deputy Technical Assistant |
| Mr. Arnurut Treehirankul | Deputy Technical Assistant |
| Lt.Jg. Sanaw Puthawong | Deputy Technical Assistant |
| Ms. Thanistha Mangrak | Project Officer |
| Ms. Jongdee Rakdej | Project Officer |
| JICA ADVISORY COMMITTEE: | |
| Mr. Hiroaki Yanagi | Committee Chairman |
| Mr. Fukashi Kogure | Committee Member |
| Mr. Masanori Tanaka | Committee Member |

Note: as of September 1994

# CHAPTER 2

# OUTLINE OF THE EXPRESSWAY

# Chapter 2 Outline of the Expressway

## 2.1 The Expressway in Service

### 2.1.1 Routes of Expressway

A total of 27.1 km of expressway are currently in service and are the responsibility of the Expressway and Rapid Transit Authority of Thailand (hereinafter referred to as ETA). They are officially called "the Chlerm Maha Nakorn Expressway", but are commonly referred to as the First Stage Expressway (FSE). It is the only existing expressway in Thailand, i.e. a fully access-controlled highway, except for the Second Stage Section (which was constructed using the B.O.T. system).

FSE was constructed in section, with the first section connecting Din Daen and the Port for a length of 8.9 kilometers. This section was opened in January 1982 and leads to Don Muang International Airport and the national highways No.1 and No.2, which extend to the north and northeast of Thailand.

The second section connected Bang Na to the Port was opened in January 1983. At Bang Na, the expressway joins two highways. One leads to the heavily industrialized area of Samut Prakarn, while the other ultimately leads to Trat and also links up with a highway that goes to the deep-sea port of Sattahip on the eastern seaboard. This section is 7.9 kilometers long.

The last section was opened to traffic in 1989 to connect Dao Khanong to the Port for a length of 10.3 kilometers. It links the expressway with the western side of the Chao Phraya River and also with Highway No.35, which stretches to Pak Tho and joins with highway No.4 (which leads to the South of Thailand and Malaysia). The Rama IX Bridge, which had been the longest cable-stayed bridge in the world until recently, is located on this section and is used for crossing the Chao Phraya River.

FSE basically has six-lane carriageways, except for the four-lane carriageway from Prachauthit to Dao Khanong. The expressway has three toll plazas at each end of its three routes and ten on-off ramps in the middle of these routes.

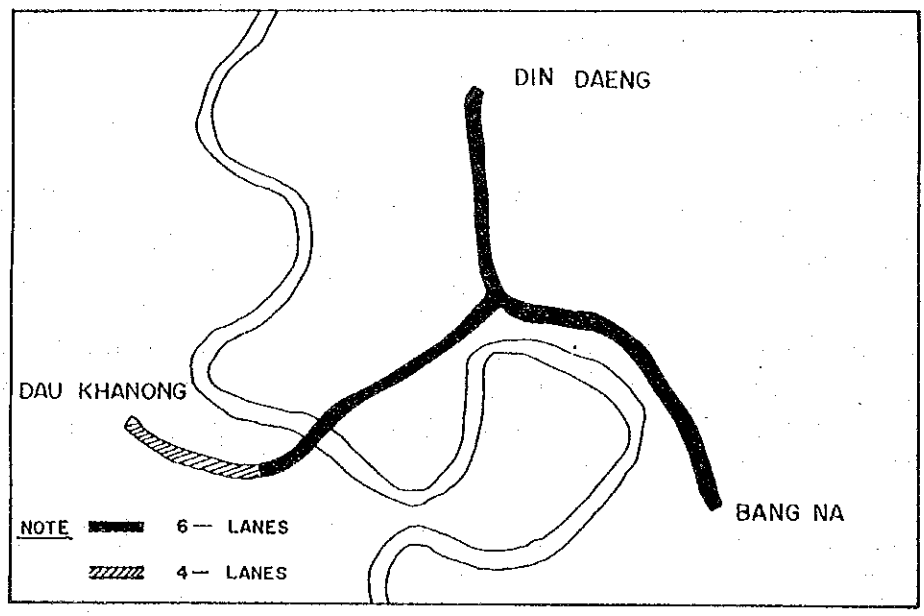



Figure-2.1.1 Number of Lanes

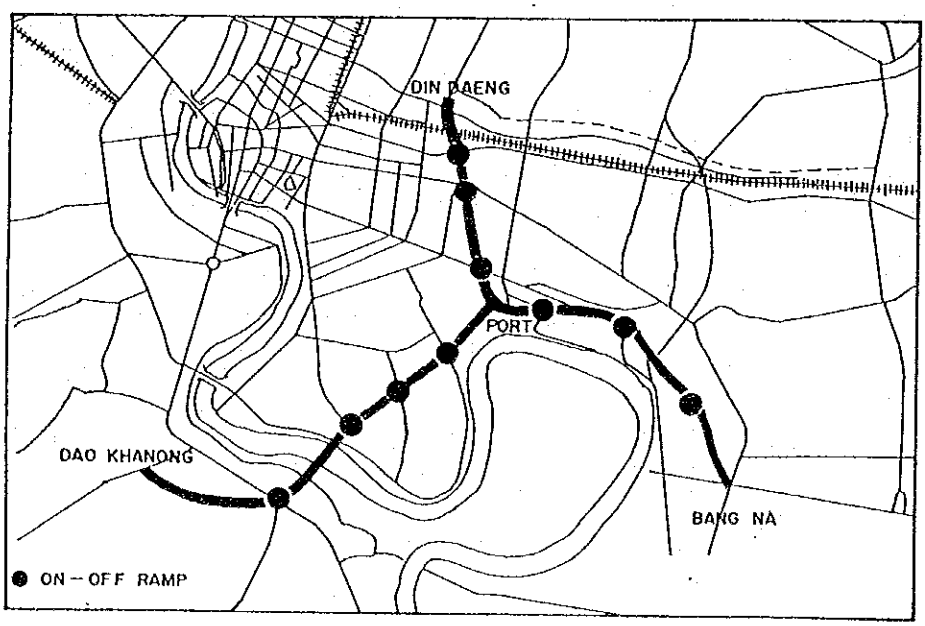



Figure-2.1.2 Location of On-Off Ramps

## 2.1.2 Road Structures and Facilities

### 1) Land Section

#### a) Design Criteria

Geometric standards were defined for an expressway with full access control, i.e., a divided arterial highway with all intersecting roads grade separated and all entering and exiting accomplished by high-speed merging and diverging maneuvers. The principle criteria are as follows:

| | | | |
|---|---|---|---|
| - Design Speed | : Expressways | 80 km/h |
| | : BMA's Road | 60 km/h |
| | : Major Existing Roads | 50 km/h |
| | : Minor Existing Roads | 30 km/h |
| - Superelevation | : Maximum | 7% |
| - Gradients | : Maximum for expressways | 4% |
| | : Maximum for all other roads | 5% |
| - Vertical Clearance | : Minimum for all roads | 5.0 m |
| | : Minimum for navigable Khlongs (or the same present clearance) | 3.5 m |

The minimum values of alignments are indicated in Table-2.1.1 and 2.1.2.

Table-2.1.1 Minimum Values for Horizontal Alignment

| Speed (km/h) | Minimum Radius (m) | | Radius (m) | | | |
|---|---|---|---|---|---|---|
| | | | Normal | | Minimum | |
| | Without Super-elevation (SE) | With Transition Curve for Adverse Camber | 4% SE | 7% SE | 4% SE | 7% SE |
| 80 | 1,800 | 1,200 | 500 | 300 | 270 | 240 |
| 60 | 1,200 | 600 | 320 | 200 | 170 | 150 |
| 50 | 600 | 300 | 180 | 110 | 82 | 80 |
| 30 | 300 | 160 | 80 | 50 | 40 | 35 |

Table-2.1.2 Minimum Values for Vertical Alignment

| Speed (km/h) | Min."k" for Stopping Comfort | Min.Vertical Curve Length (m) | Min.Overtaking Distance (m) | Min.Stopping Distance (m) |
|---|---|---|---|---|
| 80 | 25 | 50 | 370 | 130 |
| 60 | 10 | 40 | 300 | 100 |
| 50 | 6 | 30 | 215 | 60 |
| 30 | 1 | 20 | 150 | 40 |

"k" value for the formula L = kA; where "L" equals the minimum length of the parabolic curve and "A" equals the algebraic difference of gradients.

As for structural design standards, AASHTO specifications were used with MS 18 loading.

b) Structural Type

The expressway is comprised of three types of structures: viaducts, embankments, and river crossings. Viaducts make up most of the expressway, with embankments coming next. Sections with river crossings, on the other hand, only make up a very small part of the expressway. Figure-2.1.3 shows the locations of these structures on FSE.

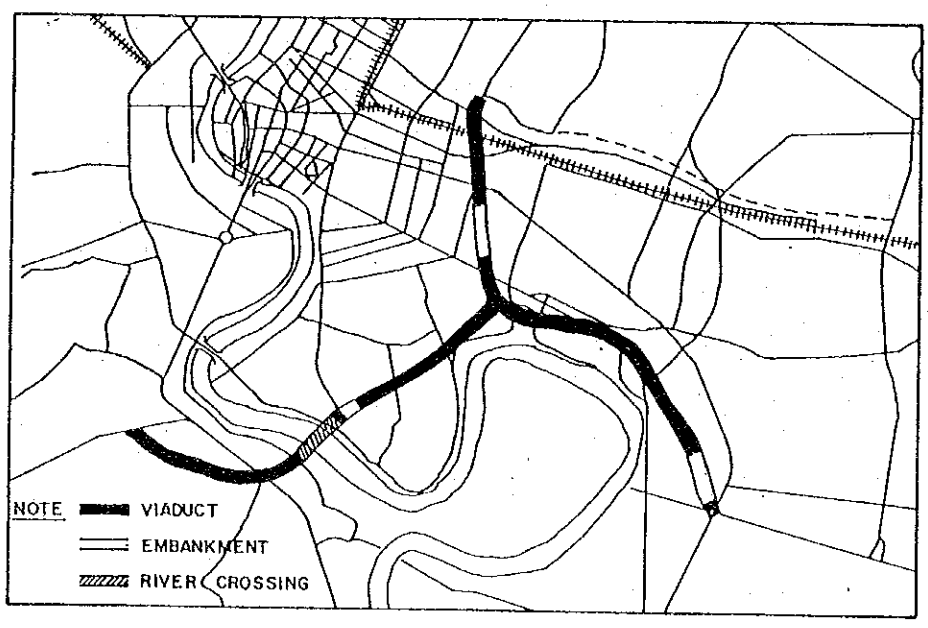



Figure-2.1.3 Type of Structures

Viaducts are classified into two types of structures. One is a standardized structure, while the other is a rather long pre-stressed concrete T-section girder at the approaches to both sides of the Rama IX Bridge.

Standard Viaducts

The standard viaduct is composed of 20 meter long pretensioned I beams and cantilever beams, which are rigidly connected to twin columns or a single octagonal column. The total length of the cantilever beams, which are evenly balanced on the top of the column(s), varies from 5.0 to 15.0 meters.

The cantilevers are either reinforced-concrete solid beams up to 6.0 meters in length or reinforced-concrete haunched cellular beams up to 15.0 meters in length, with both having the same edge distance for aesthetic reasons. The I beams were designed with halved joints at their ends to rest in between these cantilevers. As shown in Figure-2.1.4, the span length of a viaduct ranges from 20 meters up to 35 meters when the above-mentioned lengths of the I beams and relevant cantilevers are considered.

Precast beams were made from concrete with a 28-day cylinder strength of 350 kg/cm2 and pretensioned with 12.4 mm deflected strands.

Without exception, concrete piles were used to support piers and pile caps. The piles for the standard viaduct are as follows:

- Hollow cylindrical post-tensioned pile, 60 cm in diameter
- Hollow cylindrical pretensioned pile, 60 cm in diameter
- Hollow cylindrical post-tensioned pile, 50 cm in diameter
- Hollow cylindrical pretensinoed pile, 50 cm in diameter
- Square-sectioned r.c. pile, 45 cm in side
- Square-sectioned r.c. pile, 35 cm in side

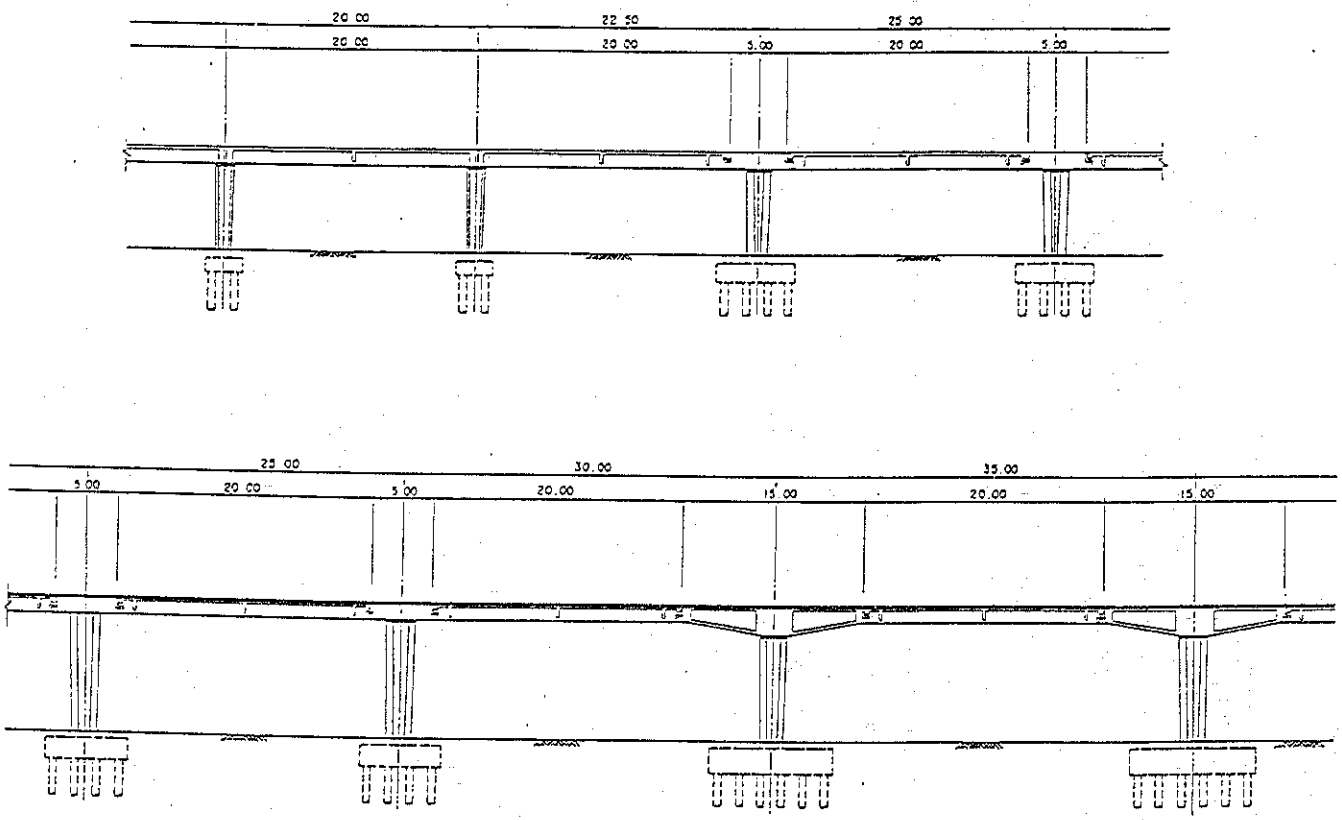
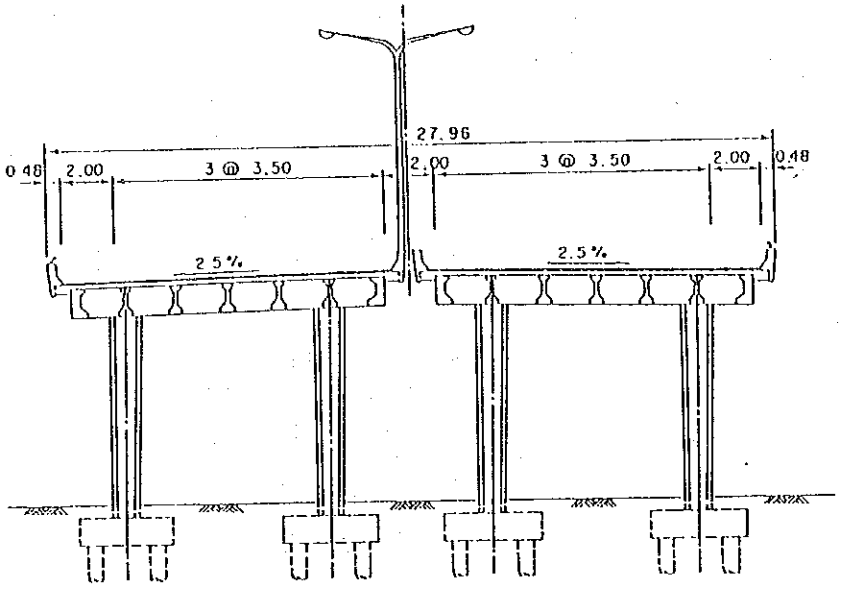
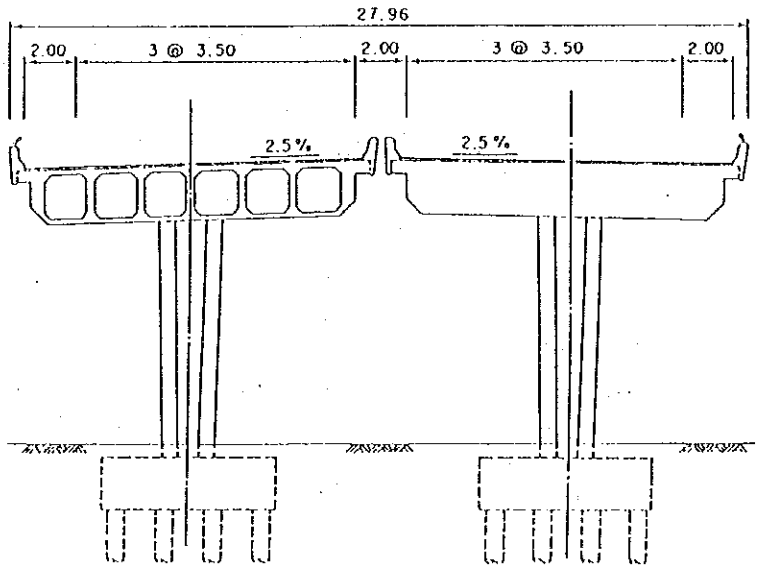



Figure-2.1.4 Typical Profile of Viaduct




CROSS SECTION ( SPAN LENGTH 20 – 25 m. )




CROSS SECTION ( SPAN LENGTH 30 – 35 m. )

Figure-2.1.5 Typical Viaduct Cross-section

The Rama IX Bridge Approach Viaducts

The approach viaducts for the Rama IX Bridge are dual double-T post-tensioned viaducts supported by concrete girders. There are 13 spans on each side of the river, all 50.0 meters long except for two spans connecting to the Rama IX Bridge with the Thon Buri side, which are 40 meters long.

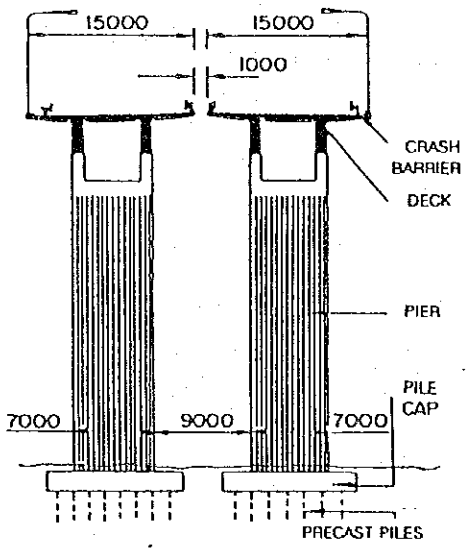



Figure-2.1.6 Typical Cross-section of Approach Viaduct

The post-tensioned girders were made from concrete with a 28-day cylinder strength of 350 kg/cm2.

The piers are made from box-sectioned reinforced concrete. The reinforced concrete piers and pile caps are supported on drivén 0.525 x 0.525 meter concrete piles 20-25 meters in length. Steel raking H-section piles, which are $0.356^{m}$ x $0.368^{m}$ and 27-30 meters long, were used to withstand earthquakes and other horizontal loads.

Embankments

Embankment sections account for around 20 percent of the total length of FSE. The height of most embankments is low and less than 1.6 meters.

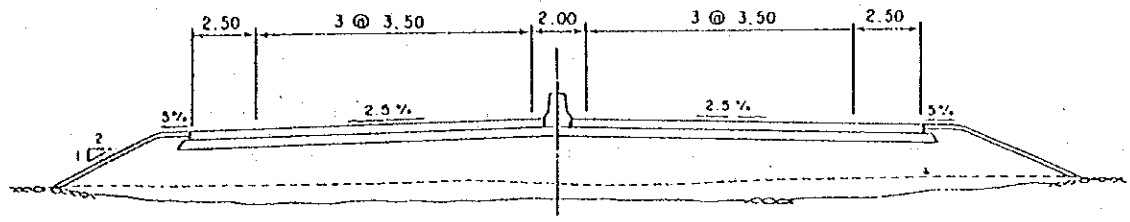



Figure-2.1.7 Typical Embankment Cross-section

c) Facilities

Crash Barrier

Standard viaduct: To deal with car crashes, reinforced-concrete parapets with mild steel railing are installed.

The Rama IX Bridge approach viaducts: Special barriers, consisting of two hollow steel rails, are installed in stead of the concrete parapets as outer and median crash barriers. In addition, steel handrails are installed outside the outer barriers to protect inspection personnel using the narrow walkway.

Embankment: No barrier is installed and fences are built outside of the carriageway.

Median Barrier

Standard viaduct: For the standard dual three and two-lane expressway, a separate viaduct is provided for each carriageway with a 240 mm gap between, so no median barrier is needed.

The Rama IX approach viaduct: No median barrier is installed based on the same reason mentioned above.

Embankment: In principle, a median barrier made from reinforced concrete is installed.

Bearings

Standard viaducts: Rubber pads are used.

The Rama IX Bridge approach viaducts: Steel bearings are used, and the performance requirements for them are as follows:

-Vertical Maximum Load: 600 t
-Transverse Maximum Load: 40 t
-Longitudinal Maximum Load: 40 t
-Longitudinal Movement Capacity: + 10 mm, - 60 mm

Expansion Joints

Standard viaducts: Buried expansion joints were provided at the ends of all precast spans to cater for movements due to a temperature changes of ± 15 degrees Celsius.

The Rama IX Bridge approach viaducts: Movement requirements for expansion joints are shown in Table-2.1.3.

Table-2.1.3 Movement Requirements for Expansion Joints

| Stage | 50 meters | | 40 meters | |
|---|---|---|---|---|
| | Movement | Gap | Movement | Gap |
| At time of casting | 12.5 | 25 | 12.5 | 25 |
| After stressing | 21.5 | 34 | 20 | 32.5 |
| Long term | 57.5 | 70 | 48.5 | 61 |
| Long term and temperature fall | 65.5 | 78 | 54.5 | 67 |
| Long term and temperature rise | 49.5 | 62 | 42.5 | 55 |

Note: Unit is millimeters

Drainage

Standard viaducts: Free-flow drainage is used in those areas where the surrounding area is of no concern. To accommodate

free-flow drainage, 100 mm plastic pipes are cast through the deck adjacent to the parapets. These pipes have a cast-iron inset placed into the road surface.

The Rama IX Bridge approach viaducts: Drainage occurs at side inlets. These then feed into plastic pipes cast into the concrete on the cantilever slab deck beyond the edge beam. The pipes then empty into other pipes cast into the piers. The whole arrangement is completely invisible in the finished structure.

Lighting

| | | |
|---|---|---|
| Type of lighting | : | High-Pressure Sodium |
| Illumination Level | : | Expressway --- 2 candela/square meter |
| | | Slip Road----- 1 candela/square meter |
| | | Toll Plaza---- 3.2 candela/square meter |

Traffic Signs

Permanent traffic signs for the expressway are as follows:

| | | |
|---|---|---|
| Signboards | : | Overhead Signboards |
| | : | Roadside Signboards |
| Regulatory Signs | : | Speed limit |
| | : | Stop |
| | : | No Right Turn |
| | : | No Left Turn |
| | : | Turn Left Ahead |
| | : | Turn Left |
| | : | No Entry |
| | : | Bicycle, Three-wheeled Motorcycle, and Carts Prohibited |
| Warning Signs | : | Merging Traffic |
| | : | Left Curve |
| | : | Right Curve |

2) Rama IX Bridge

a) Design Criteria

Geometric standards for the bridge are the same as those for a standard viaduct except for the gradient. To satisfy the navigational clearance of 41 meters, a maximum gradient of 5% is adopted.

The design criteria of the cable-stayed bridge is based on German standards. The basic standards applied to this design are DIN 1072, DIN 1073, DIN 1075, DIN 1079, DIN 4101, DIN 4114, and DIN 4119.

DIN 1072 : Design Loads
DIN 1073 : Steel Load Bridge (Bases of Design)
- Materials
- Principles for calculation
- Design loads
- Proofs required
- Special features for certain type of structure
- Structural connection
- Allowable stresses

DIN 1075 : Concrete Bridges
DIN 1079 : Steel Road Bridges (Construction Principles)
DIN 4101 : Welded Steel Bridges (Design and Structural Details)
DIN 4114 : Steel Structures (Stability-Buckling, Overturning)
DIN 4119 : Building in German Earthquake Areas

The allowable stress of structural steel conforms with that contained in Table-5 of Chapter 8 of DIN 1073.

Table-2.1.4 Allowable Stress of Structural Steel

| | ST-37 | | ST-52 | |
|---|---|---|---|---|
| | H | HZ | H | HZ |
| Axial tension and bending tension | 1,600 | 1,800 | 2,400 | 2,700 |
| Axial compression and bending compression | 1,400 | 1,600 | 2,100 | 2,400 |

Note Unit: kg/cm2
H : loading case of sum of principle loads
HZ : loading case of sum of principal and additional loads

The allowable stress of locked-coil cable conforms with that of Chapter 6 section 5 of DIN 1073.

$$H = 0.42Bn$$
$$HZ = 0.46Bn$$

H : where, allowable stress of a cable in the loading case H
HZ: allowable stress of a cable in the loading case HZ
Bn: nominal strength of cable wire.

To deal with ground subsidence problems, the design allows for pylon piers to sink up to 20 cm and anchor span piers to sink up to 2.5 cm.

b) Structural Description

The Rama IX Bridge is a single plane cable-stayed bridge that crosses over a 500-meter wide section of the Chao Phraya River at Watsai. The main dimensions of the bridge are as follows:

| | | |
|---|---|---|
| Bridge Length | : 781.20 m | |
| Span Length | : Main span | 450.00 m |
| | : Back span | 165.60 m (61.20+57.60+46.80) |
| Width of Bridge | : varies between 31.00 and 33.00 m | |

Superstructure

The main section of the bridge deck is a three-cell steel box girder 21.8 meters wide and 4.0 meters deep at the center. The central cell houses the cable anchorages of the bridge deck. As for the anchor spans, the width of the bridge deck increases from 31 meters to 33 meters in order to pass the pylons with sufficient clearance. The bridge deck is supported on piers by pendel supports (pin connection).

The 87-meter high pylons pass through the bridge deck without a structural connection. The pylons are held down on the pylon piers by long high tensioned reinforcement bars.

The bridge deck is supported by four sets of 17 locked coil cables with diameters varying from 121 to 167 mm. The cables are anchored into the pylons by simple hammer head sockets. In the bridge deck, the cables are anchored by cylindrical sockets with supporting collars.

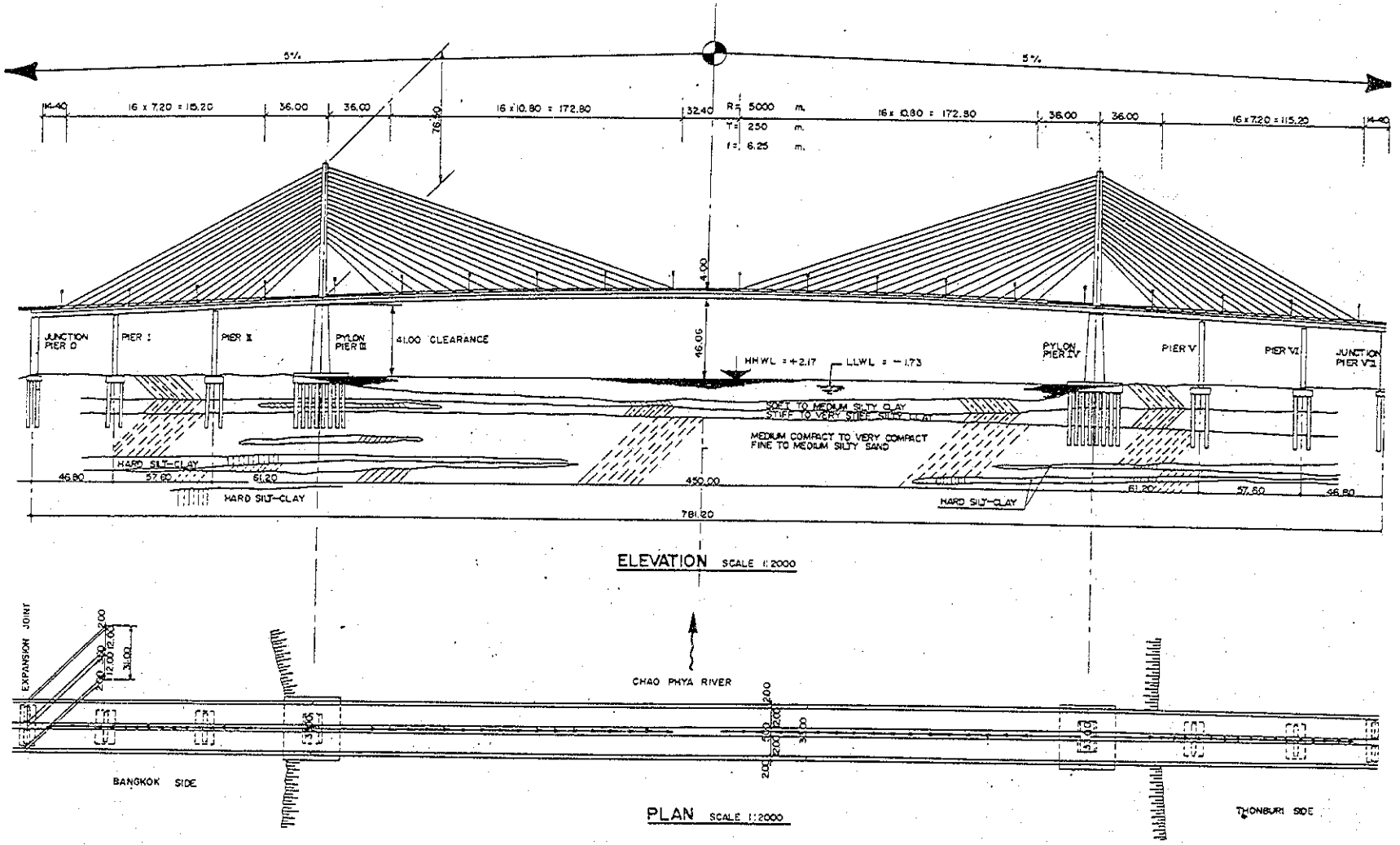



Figure-2.1.8 General View of Rama IX Bridge

To absorb wind-induced oscillation, tuned mass dampers are installed in the bridge deck and at the top of the pylons.

Substructure

The pylon piers are hollow reinforced-concrete structures with a height of 29.7 meters. The anchor span piers are of solid reinforced concrete to act as counterweights to hold down the deck.

The pylon piers and pile caps are supported by 64 bored piles with a diameter of 2 meters. The tips of these piles are embedded about 30 meters below the mean sea level on the Bangkok side and 35 meters on the Thon Buri side.

The anchor span piers and one junction pier on the Thon Buri side are placed on eight or ten of the same type of bored piles. A junction pier on the Bangkok side is placed on driven piles.

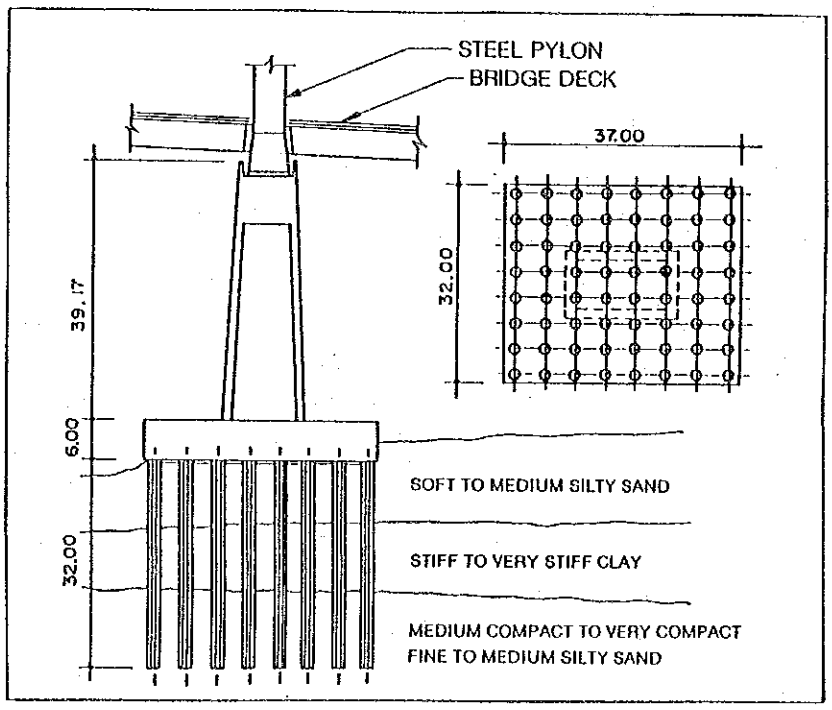



Figure-2.1.9 Pylon Pier and Foundation

c) Facilities

Crash Barrier, Median Barrier

A special barrier with two hollow steel rails and a steel handrail are installed in the same way as in the case of an approach viaduct.

Bearings

The bridge is supported vertically by pendel bearings with 400 mm in diameter pinned connections at each end, and is supported horizontally by steel and rubber pot-type bearings with sliding surfaces as required. The bridge is restrained against all horizontal movement at the Thon Buri pylon pier, and is restrained against transverse movement with longitudinal expansion permitted at all of the other piers.

Expansion Joints

"Rolling-shutter" type waterproof expansion joints have been installed at the two junction piers.

Drainage

The roadway drainage gullies feed into galvanized steel drain-pipes which run through the girder discharging at the pylon and junction piers.

Lighting, Traffic Signs

Design concepts on the arrangement of lighting and traffic signs are as same as those for a standard viaduct section.

## 2.2 Future Expressway to be Studied

### 2.2.1 Route of Ramindra-Atnarong Expressway

The Ramindra-Atnarong Expressway System (RAE) is to be 18.7 kilo-meters long with dual three-lane carriageways. RAE will start from the junction with Highway No.304 in the vicinity of Ramindra and run southward to Highway No.336 (Lad Phrao Road) and Rama IX Road. It then will turn southeast and pass through Ramkhamhaen Road and Sukhumvit Road and connect with the First Stage Expressway (FSE). The route alignment of RAE is shown in Figure-1.1.1.

Along the route, nine on-off ramps and three interchanges (including one for future construction) are planned.

### 2.2.2 Road Structures and Facilities

1) Design Concepts

Basic concepts in designing RAE structures, which are mentioned below, are almost the same as those for FSE structures except for a few changes.

- The expressway shall be grade-separated from BMA roads,
- Structures type shall be standardized as much as possible,
- Structures shall be made from concrete to be maintenance free,
- For aesthetical reasons, girder depth shall be constant.

A major change is that the superstructure, which is statically determinate in FSE, is statically indeterminate in RAE.

2) Structural Type

a) Superstructure

A viaduct will run throughout the route without exception. The viaduct can be basically sorted into two types. One type is composed of precast prestressed concrete girders and a cast in-situ deck. The other type is composed of precast prestressed concrete girders, cast in-situ decks, and continuity decks with reinforced concrete columns.

In the case of the former type, the cast in-situ deck is linked (girders are not linked) up to six spans at a maximum over the top of the column crosshead. In the case of the latter type, girders are linked together through the continuity decks, which are made from reinforced concrete solid haunched cantilever beams and a column. The cantilever beams are evenly balanced at the top of the column. The length of a continuity deck varies from 6.28 meters to 20.28 meters (refer to figures-2.2.1 and 2.2.2).

A combination of the two viaduct types is also possible, with the standard span being 36 meters long and the maximum span 54 meters long.

For a standard viaduct section, a separate viaduct is provided for each carriageway with a 400 mm gap between the viaducts.

b) Substructure

Pre-tensioned concrete piles are used to support columns and pile caps and no spread foundation is used. The dimension of the piles are shown below.

- Hollow cylindrical pretensioned pile, 60 cm in diameter
- Square-sectioned pretensioned pile, 40 cm in side
- Hollow cylindrical pretensioned pile, 30 cm in diameter

3) Equipped Facilities

a) Crash Barrier

Reinforced concrete parapets with mild steel railing, the same type as that for FSE, are used on the outer sides and either median side of a deck.

b) Median Barrier

No median barrier is to be installed.

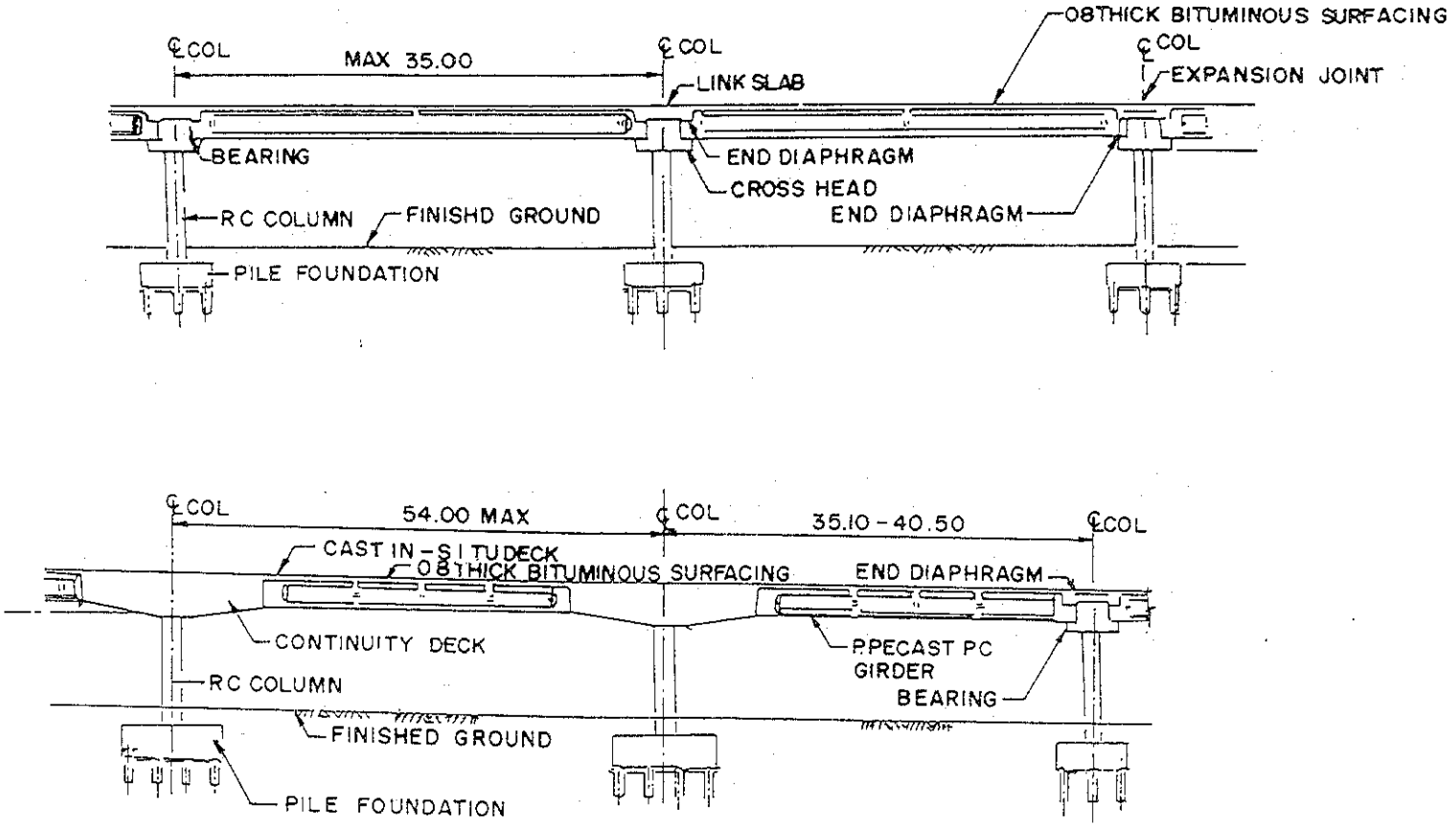



Figure-2.2.1 Typical Profile of Viaduct

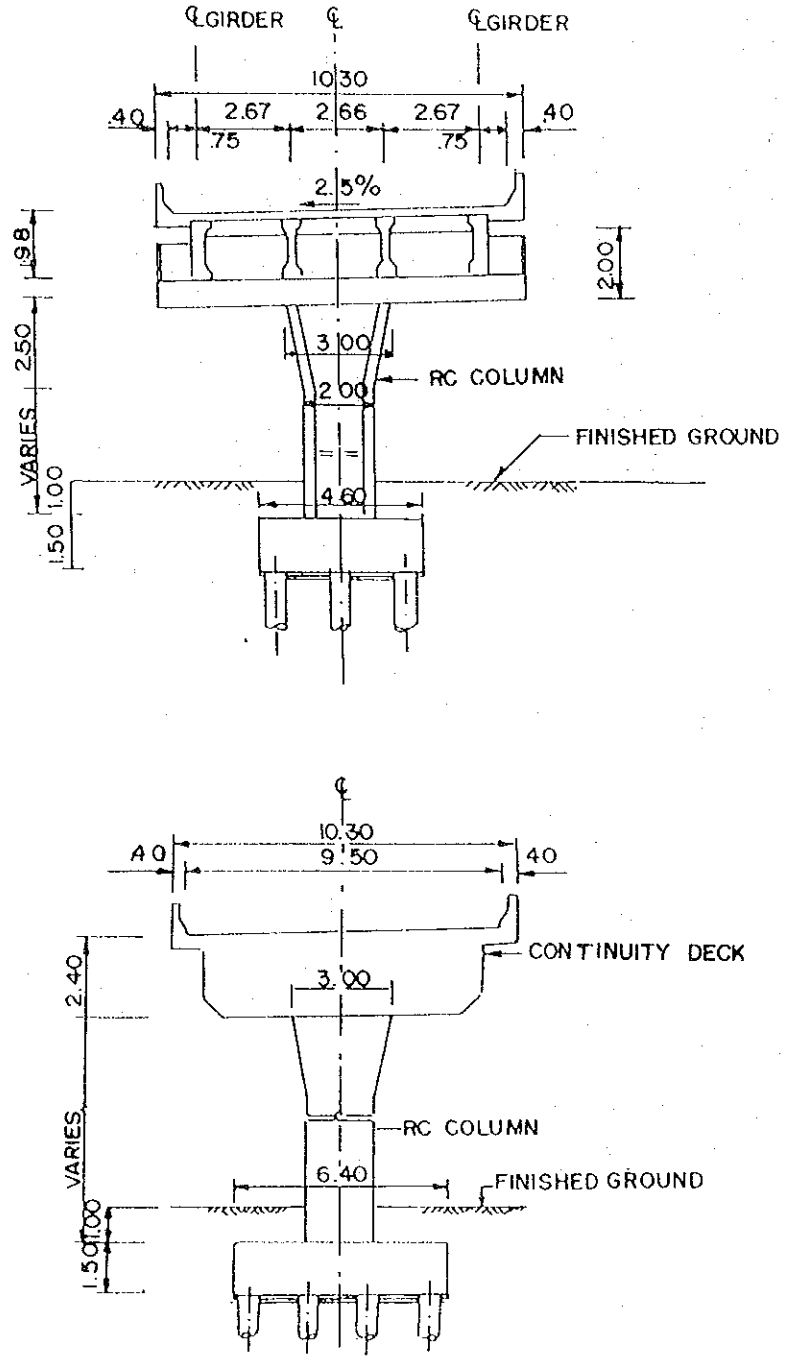



Figure-2.2.2 Typical Cross-section of Viaduct

c) Bearings

Rubber pads with steel luminated plates are recommended in detailed design. Rough bearing performance requirements are shown below.

- Maximum vertical load : 1060 kn
- Minimum vertical load : 400 kn
- Longitudinal Movement(reversible) : ±8 -- ±29 mm
  (irreversible) : -6 -- -23 mm

d) Expansion Joints

As a result of using continuous decks, the longitudinal movement requirements for expansion joints are much bigger in comparison with those of the FSE. To absorb this movement, two types of metallic and elastomeric expansion joints are planned to be installed.

e) Drainage

In those areas where the surrounding area is of no concern, free-flow drainage is adopted.

In areas where free-flow drainage is inappropriate, drainage will be via a side entry inlet. Water on the carriageway surface will feed into leading pipes cast into the pier columns, with the whole arrangement being completely invisible in the finished structure.

f) Lighting

As for viaduct lighting, the same system as that used for the FSE is adopted.

g) Traffic Sign

RAE traffic signs are designed with the same concept applied in designing FSE's traffic signs.

# CHAPTER 3

# PRESENT INSPECTION AND MAINTENANCE SYSTEM

# Chapter 3 Present Inspection and Maintenance System

## 3.1 Numbering System

### 3.1.1 Common and Land Section

ETA uses the following numbering system to identify objects and their locations in order to carry out maintenance work and manage the expressway:

- Route name:
  a main route and branch routes at junctions are named in the following manner;
  Din Daeng - Port section : "DD-P",
  one branch at Port junction: "DD-BN" (Din Daeng - Bang Na),

- Direction of traffic:
  the direction of traffic on main routes is distinguished by the letters "A" and "B",

- Name of ramp:
  provides information on the access to other roads, with the in and out functions of a ramp used to distinguish the location and direction of a ramp's traffic,

- Chainage:
  expressway chainage is set along the control line, which has been established in the planning stage of the expressway; for instance, in the case of the Port-Bang Na section, chainage starts at Port at 10+000.000 and ends at 18+259.100 in Bang Na,

- Numbering of piers:
  chainage is used to number piers; however, there is no numbering to distinguish the existence of two or more columns on the same chainage,

- Numbering of expansion joints:
  chainage is used to number every expansion joint,

- Lighting pole:
  a unique number is assigned to every lighting pole; however, some poles do not have a number.

- Identification of road segments on embankment sections:
  on embankment sections where there is no specified sign, chainage is subdivided into 100 meter road segments; and these segments are then used to identify of embankments, pavement, and attached road facilities within the segments themselves.

In order to manage information on the structures and facilities of a roadway by means of a database system, it is necessary to identify each object on the roadway with its own unique code number. For this reason, structures and facilities that have not yet been identified by the current ETA numbering system will have to be cataloged by the said numbering system.

### 3.1.2 Rama IX Bridge Section

In addition to the expressway numbering system, a special numbering system has been established to identify some of the bridge members of the cable-stayed bridge to assist with its special maintenance work. The types of numbers used are as follows:

- Lot numbers for the main girders:
  to identify girder and pavement location on the bridge at intervals of one lot length.

- Lot numbers for pylons:
  to identify the location of a pylon at intervals of one lot length.

- Cable numbers:
  to identify each cable on the bridge with its own unique unit number.

- Pier numbers:
  to identify piers and the location of attached facilities such as pendel bearings.

It is also necessary to identify each structure and facility on the bridge with its own unique number. In the same manner as the land section, structures and facilities that have not been identified by the current numbering system, review and rearrangement on numbering system for them will be essential for the database system.

## 3.2 Inspection Work

### 3.2.1 Land Section

1) Inspection Manual

Since the expressway is a new concept for transportation in Thailand, ETA requested the Japanese Government to send experts under the auspices of JICA to assist ETA in formulating a maintenance system. JICA then sent a series of experts to assist ETA's the Expressway and Right-of-Way Maintenance Division. Since then, the following reports and manuals on maintenance work for the expressway have been prepared by said JICA experts:

- An Approach to the Systematic Maintenance of the Structure on Operated Expressway (Mikitake Ishizuka, May 1987)

- Inspection Manual for Expressways (Mitsuo Hara, March 1990)

- Final report on an Approach to the Database of Maintenance Work for Urban Expressway (Hiromi Kosaka, August 1992)

The above manuals resulted from a close collaboration between the JICA experts and ETA staff. These manuals are currently used for inspection work by ETA; however, some parts of them have been revised by ETA itself.

2) Inspection Work

Present inspection work is divided into three types as shown below.

- Routine Inspection:
  a daily inspection that consists of examining the expressway visually or using simple equipment (such inspection is performed only twice a week for one route),

- Periodic Inspection:
  a regular inspection carried out on major structures, such as superstructure and piers, at predetermined intervals of time using special equipment in some cases, and

- Special Inspection:
  an inspection that supplements the routine and periodic inspections, and which is carried out when accidents or disasters occur.

Inspection items are categorized into the following eleven (11) items; some items are broken down into more detailed items. All of the detailed items are tabulated in Table-3.2.1.

Table-3.2.1 Inspection Work Items for Land Section

| No. | Work Items | | Kind of Inspection |
|---|---|---|---|
| 1 | General condition | | Routine |
| 2 | Shoulder and drainage system | | Periodic |
| 3 | Control system building and toll building | | Periodic |
| 4 | Sanitary and sanitary ware of all building | | Periodic |
| 5 | Metal work & welded facilities | Handrails | Periodic |
| | | Pedestrian crossings | Periodic |
| | | Guardrails and fences | Periodic |
| | | Traffic signs | Periodic |
| 6 | Painting | Handrails | Periodic |
| | | Pedestrian crossings | Periodic |
| | | Guardrail and fences | Periodic |
| | | Traffic signs | Periodic |
| | | Buildings | Periodic |
| 7 | Toll booth | | Periodic |
| 8 | Expansion joints | Buried | Periodic |
| | | Exposed (Nitta, Sho Bond, Thorma) | Periodic |
| 9 | Pavement | Asphalt | Periodic |
| | | Concrete | Periodic |
| 10 | Road markings | | n.a. |
| 11 | Expressway structure | | Periodic |

### 3.2.2 Rama IX Bridge Section

1) Inspection Manual

Inspection work is executed in accordance with the inspection manual prepared by ETA. The manual suggests inspection methods, requisite equipment for inspection, required number of personnel, inspection frequency, etc. (refer to Appendix-A.004).

In addition, there is the English language "Manual for Inspection of the Rama IX Bridge", which was prepared in 1990 by a JICA expert dispatched to assist ETA's Expressway Maintenance Division.

2) Inspection Work

Inspection work for the Rama IX Bridge is divided into the same three types of work as that for the Land Section.

- Routine Inspection
- Periodic Inspection
- Special Inspection

Inspection items are categorized into sixteen (16) items, with some broken down into greater detailed. All of the detailed items are as tabulated in Table-3.2.2.

Table-3.2.2 Inspection Work Items for Rama IX Bridge

| No. | Work Items | | Kind of Inspection |
|---|---|---|---|
| 1 | Bridge body (Inside) | Bolt-connected sections | Periodic |
| | | Welded sections | Periodic |
| | | General sections(color) | Periodic |
| 2 | Bridge body (Outside) | Top | Routine |
| | | Profile of bridge | Periodic |
| | | Bottom and sides | Periodic |
| 3 | Pylons (Inside) | Bolt-connected sections | Periodic |
| | | Welded sections | Periodic |
| | | General sections(color) | Periodic |
| 4 | Pylons (Outside) | Displacement of pylon | Periodic |
| | | General sections(color) | Periodic |
| 5 | Cables | Tension | Periodic |
| | | Sockets | Periodic |
| | | Anchorage | Periodic |
| | | Cable cover & coating | Periodic |
| | | Miscellaneous | Periodic |
| 6 | Pendel anchored cables | Tension | Periodic |
| | | Anchorage | Periodic |
| 7 | Bearings | Pendel | Periodic |
| | | Wind shoes | Periodic |
| | | Neo pots | Periodic |
| 8 | Drainage | Inside bridge & piers | Periodic |
| 9 | Expansion joints | Roller-shutter type | Routine |
| 10 | Dampers | Cable dampers | Periodic |
| | | Pylon dampers | Periodic |
| | | Bridge dampers | Periodic |
| 11 | Maintenance gantry | | Periodic |
| 12 | Cradles | Pylon cradles | Periodic |
| | | Cable cradles | Periodic |
| 13 | Lifts | | Routine |
| 14 | Permanent instruments | | Routine |
| 15 | Piers | Settlement | Routine |
| | | Cracking & other damage | Periodic |
| 16 | Pavement | | Routine |

## 3.3 Damage to Structures and Facilities

### 3.3.1 Land Section

1) Damage to Structures

The existing expressway has been open to public traffic for more than ten years, and there is damage and deterioration to the structures and facilities especially due to the vehicle traffic load. However, almost all of the structures are relatively in good condition in spite of the heavy traffic. Current damage is as listed below.

- Pavement rutting and cracking
  Paved embankment sections are prone to damage from road bed settlement, which is supported by the soft clay ground in Bangkok, and rutting, faulting and cracking are caused by uneven road bed settlement together with heavy traffic loads.

  On viaduct sections, some rutting of pavement occurs due to the liquefaction of the asphalt, especially on curved sections and at up-grades.

- Cracking along buried joints
  Expansion joints, which are buried-type joints, have been damaged through out the expressway due to the direct wheel loads of vehicles.

- Settlement of retaining wall
  Retaining walls with no pile foundation, were found to have settled in 20 cm due to the soft ground bed.

- Lateral movement of viaduct
  The superstructure of one span on the Bang Na-Port section has experienced a lateral movement of 6 cm at the road surface level. It is assumed that the bridge pier is displaced by lateral ground movement due to the effects of the earthworks beside the expressway.

- Cracking at half joints of cantilever beams
  Some cracking at the half joints of the superstructure have been reported; however, deterioration of the superstructure seems to be small in scale.

2) Damage to Facilities

- Damage to parapets, median barriers, fences, noise barriers, and traffic signs
  Most damage has been caused by car crashes that occur when drivers try to unreasonable overtake another vehicle via the emergency lane.

- Damage to drainage
  Drainage pipes have been damaged by the uneven settlement of the ground at embankment sections.

### 3.3.2 Rama IX Bridge Section

Damages and defects found in the Rama IX Bridge after being opened to traffic, except for those to pavement, were mainly minor in nature. Current damages and defects as listed below.

1) Bridge, Pylons and Cables

- Missing "High-strength friction grip bolt":
  Some bolts were broken or missing, and the cause of breakage was not clear.
- Loss of bolt tensile force.
- Rusting of bolt tip.
- Blistering of painting inside girders.
- Rusting inside girders and pylons.
- Rusting at welded corners of girders and inside pylons.
- Minor corrosion at welded corners and inside girders.
- Corrosion of painting.
- Piles of dust on the bottom plate of girders.

According to the Bridge Profile Survey, which was conducted one year after the completion of the bridge in 1988 by the contractor, the bridge profile deviated from the expected elevation due to the settlement of the pylon piers. The deviation was not big enough to be critical at that stage, for the bridge structure (refer to Appendix-A.005). However, an urgent follow-up survey has been recommended by a JICA expert to confirm the tendency of pylon sinking.

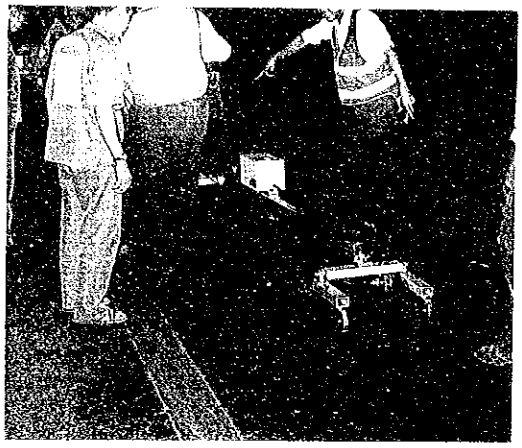
2) Pavement

Shortly after opening to traffic, the pavement of the Rama IX Bridge caused problems particularly in the slow lane. Since then, it has needed constant repair. The cause of these problems is still under research.

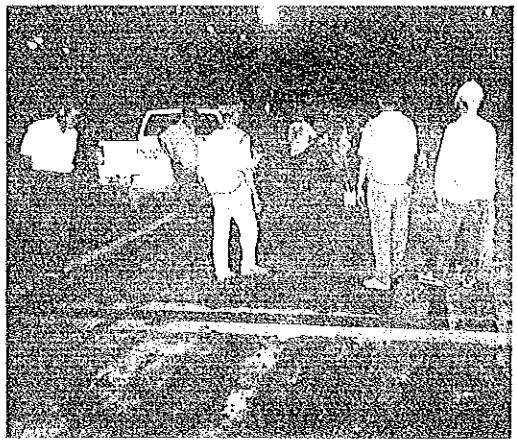
3) Attached Facilities

- Damage to barriers from car crashes.
- Damage to handrails from car crashes.

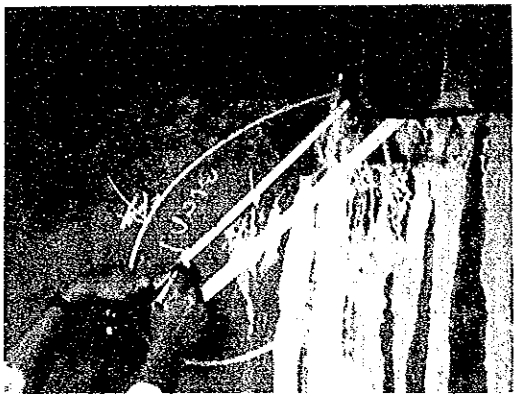
Photographs in inspection work and typical damages to structures and facilities are shown below on the next pages.



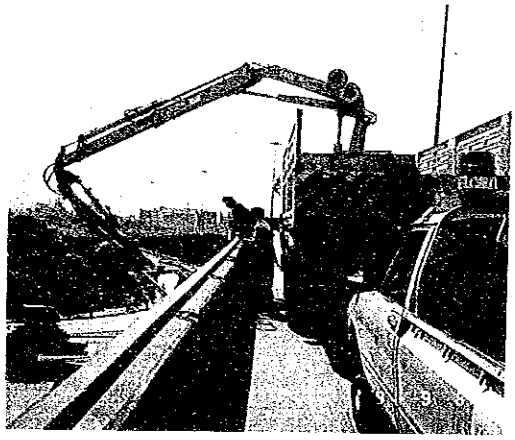
Inspection on Pavement
Using Profilo-Meter



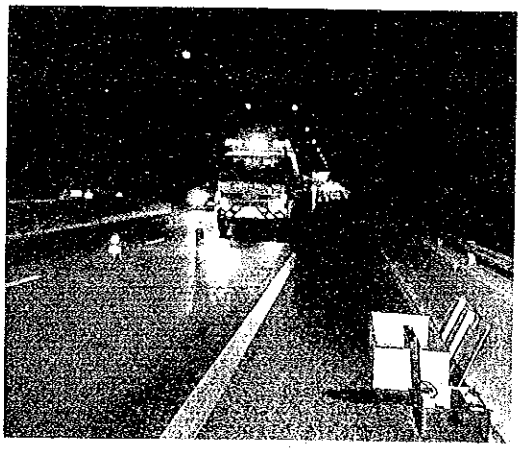
Visual Inspection
on Pavement



Measuring Cracks on Pier

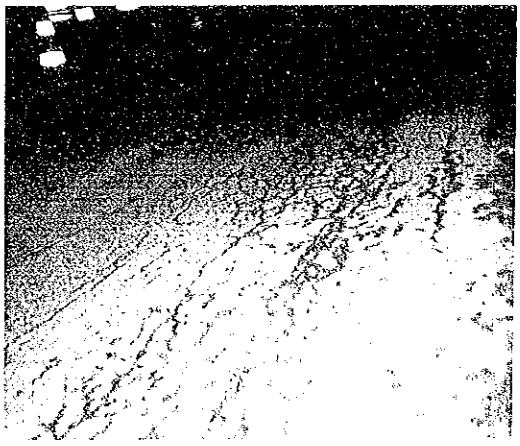


Inspection Work Using
Inspection Car



Traffic Regulations for
Maintenance Work (1)

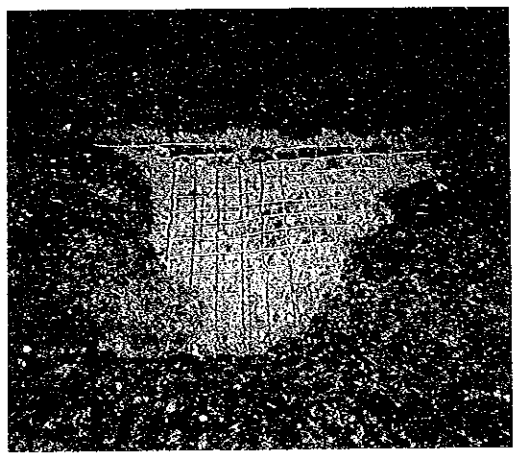
Traffic Regulations for
Maintenance Work (2)



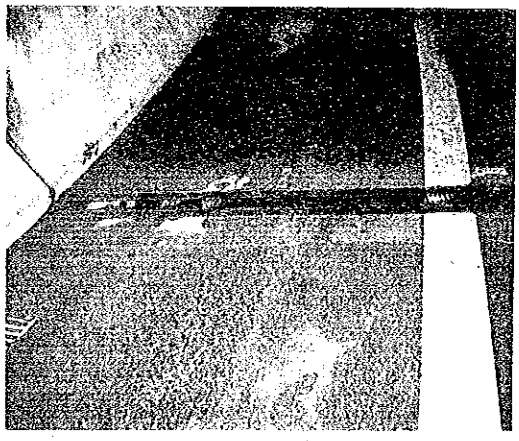
Cracks on Pavement
on Embankment

Rutting of Pavement
on Rama IX Bridge

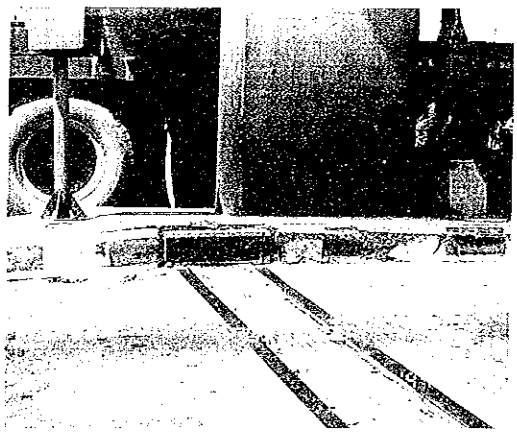
Potholes on Pavement



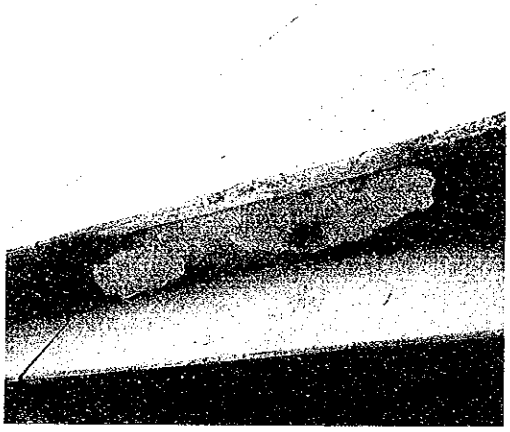
Abrasion of Pavement



Damage to Expansion Joint (1)

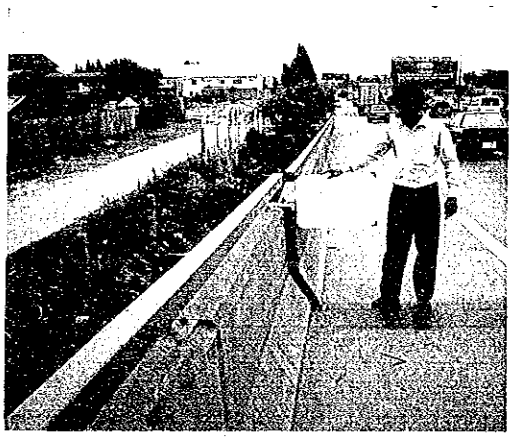


Damage to Expansion Joint (2)

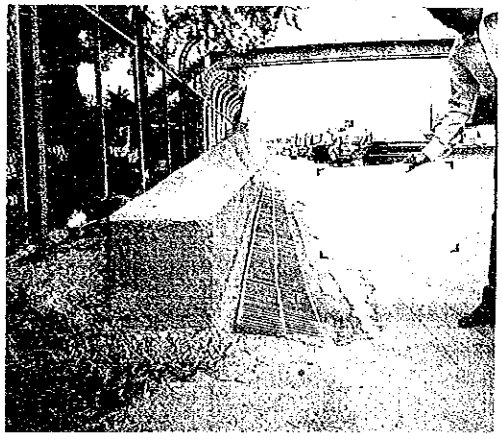


Fire Damage to Viaduct

Cracks on Concrete Pier

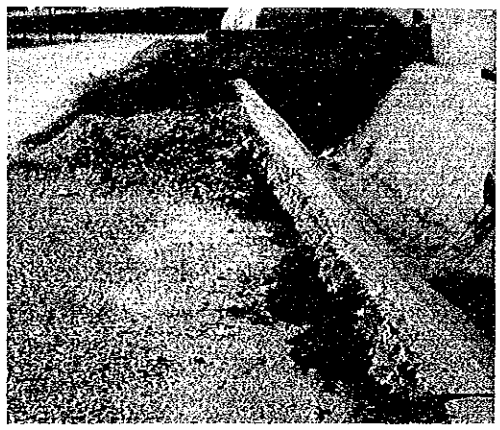


Displacement of Retaining Wall



Subsidence on Edge of Embankment

Subsidence of Drain at Embankment



Subsidence of Shoulder at Embankment

## 3.4 Repair Work

### 3.4.1 Land Section

Road structures and facilities on the expressway, other than these of the embankment sections, are in good condition thanks to the appropriate maintenance work by ETA and the occurrence of few defects. Repair and maintenance work for the expressway is conducted in accordance with the present repair manual.

On the repair and maintenance work expenditures in fiscal year 1992, approximately half were pavement related and a quarter each were for expansion joints and cleaning.

Repair work is classified into two categories: force-account and contract. Force-account repairs have been recorded in detail in a repair book and on report sheets. The recording started in 1986 in ETA's Maintenance Section. The repair records of the expressway for 1986 and 1987 were lost due to the lack of an inventory system. The approximate number of repair records can be calculated from the number of repair sheet shown in Table-3.4.1 below.

Table-3.4.1 Number of Repair Sheets

| Fiscal Year | Number of Repair Sheets |
|---|---|
| 1988 | 3,000 |
| 1989 | 2,400 |
| 1990 | 1,800 |
| 1991 | 1,200 |
| 1992 | 1,800 |
| 1993 | 1,200 |

In the case of contract repair, it is obligatory for the contractor to have the records in the Division as specified in the contract. However, only major repair work, such as pavement and expansion-joint repairs, can be easily accessed. The repair records on expansion joints and pavement are shown in Appendix-A.006.

According to the repair experiences of ETA, it was found that structures requiring frequent repair were asphalt pavement on the land section and expansion joints. Maintenance work for the land section, except for the pavement and expansion joints,

was mainly routine and consisted of such work as cleaning, patching, and painting.

The present repair methods in ETA are as follows :

- Concrete structure (superstructure, substructure and retaining wall)

  Cracks : Patching with cement mortar and epoxy mortar.
  : Pressure injection and epoxy resin mortar.
  Spalling or cavity : Patching with cement and epoxy mortar.
  Damage to slab : Concrete placing.

- Expansion Joints

  Minor damage : Filling with asphalt or epoxy mortar.
  Major damage : Replacement for Thorma joints.

- Slope

  Erosion, heaving, subsidence : Repair or reconstruction.

- Pavement

  Cracks : Sealing, filling with asphalt.
  Rutting : Milling, overlay, or reconstruction.
  Exfoliation : Patching, partial reconstruction.
  Pot holes : Patching, partial reconstruction.
  Irregularities in the vicinity of structure :
  Patching, partial reconstruction.

- Drainage

  Dirt or debris : Cleaning and removal.
  Water leakage : Repair.
  Breakage : Replacing or reconstruction.

- Traffic Safety Facilities (traffic signs, guard rail, etc)

  Rusting or peeling : Spot painting.
  Loose or missing anchor : Replacing or correcting bolt/nut.
  Broken lamp : Replacing.
  Damage or defects (deformation, cracks, corrosion, etc.)
  : Repair (metal work, welding, etc)

Damage to road markings : Repainting and reconstruction.

### 3.4.2 Rama IX Bridge Section

The recording of repairs was started in 1986 by ETA's Expressway Maintenance division for viaduct sections and in 1989 for the Rama IX Bridge sections.

Repair work is classified into two categories in the same manner as that of the land section. The approximate number of repair records by repair sheet are shown in Table-3.4.2.

Table-3.4.2 Number of Repair Sheets for Rama IX Bridge

| Fiscal Year | Number of Repair Sheets |
|---|---|
| 1989 | 90 |
| 1990 | 130 |
| 1991 | 150 |

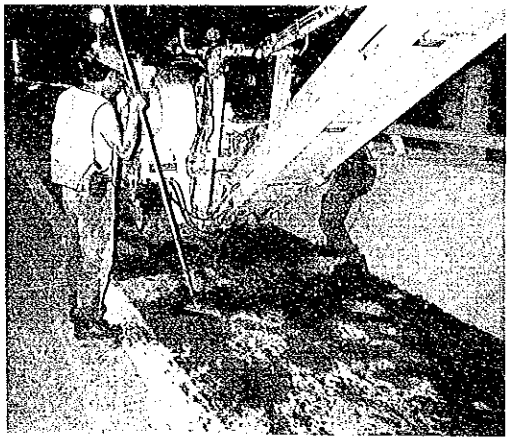
In the case of contract repair, it is obligatory for the contractor to keep records at the Division.

Force-account repair is for simple repair work or emergency work, such as pavement patching, spot painting, replacement or retention of bolts, fixing or replacement of barriers and handrails. The procedure for force-account repair is as follows:

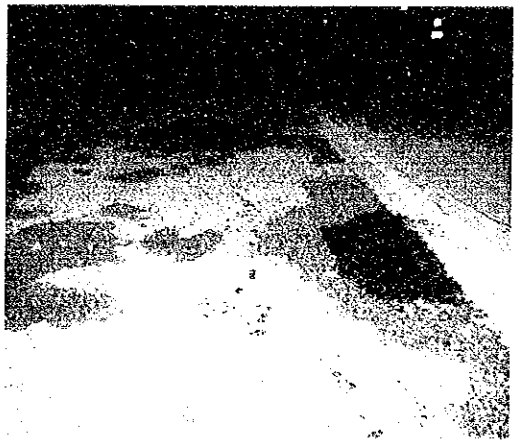
- site inspection,
- damage report to office,
- consideration of repair measures by engineer,
- assignment to responsible unit,
- make fill out repair sheet,
- make repairs,
- monitoring, and
- make a report to office including actual cost calculations.

Contract repair is for jobs beyond the capability of ETA or non-emergency work.

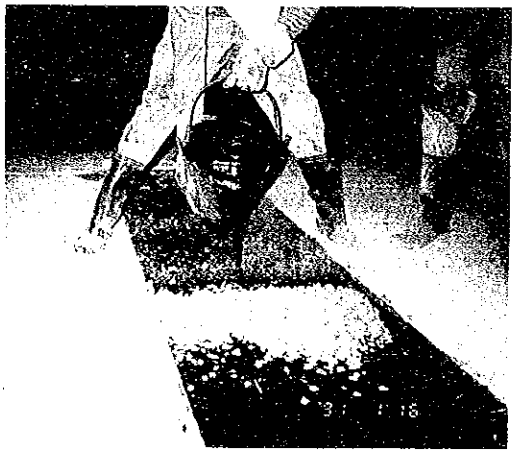
Photographs of repair works of the ETA expressway are attached below on next page.



Pavement Repair
(Milling Work)

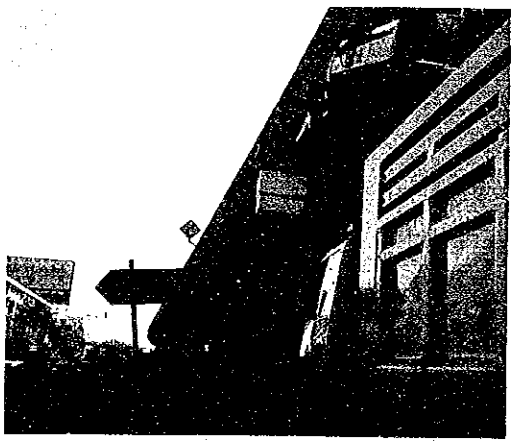


Pavement Repair (Patching)

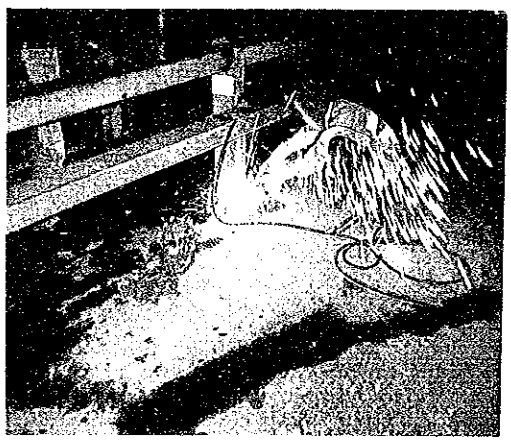


Repairs for Expansion Joints

Injection to Crack
on Concrete Pier



Injection Works under
Viaduct



Restoration of Guardrail
on Rama IX Bridge

## 3.5 Traffic Conditions

### 3.5.1 Traffic Volume

The number of vehicles that used the expressway in 1983 was 26 million, which increased to 123 million in 1992 as shown in Table-3.5.1. Traffic volume increased sharply due to the extensions of the expressway in 1983 and 1988, and it is predicted to increase sharply due to the socioeconomic development of Bangkok and its vicinity in the future.

Table-3.5.1 Number of Vehicles Using the Expressway

| Fiscal Year | No. of Vehicles (1,000 vehicles) | No. of Average Daily Vehicles (1,000 vehicles) | Operating Length (km) |
|---|---|---|---|
| 1982 | 9,290 | -- | 8.9 |
| 1983 | 26,777 | 73 | 16.8 |
| 1984 | 40,068 | 109 | 16.8 |
| 1985 | 45,301 | 124 | 16.8 |
| 1986 | 49,162 | 134 | 16.8 |
| 1987 | 55,460 | 151 | 16.8 |
| 1988 | 76,629 | 209 | 27.1 |
| 1989 | 91,290 | 250 | 27.1 |
| 1990 | 104,185 | 285 | 27.1 |
| 1991 | 113,807 | 311 | 27.1 |
| 1992 | 123,026 | 337 | 27.1 |

### 3.5.2 Ratio of Heavy Vehicles

According to statistics compiled at toll plazas, the number of four-wheel vehicles using the expressway in 1991 was 100 million, with heavy vehicles accounting for 12 million of these vehicles or 11%.

### 3.5.3 Traffic Accidents

The number of traffic accidents on the expressway increased sharply from 80 in 1982 to 1,331 in 1990 in proportion with the increase in traffic volume. Damage to structures or facilities of the expressway from car crashes cost ETA more than 2 million baht in 1990.

Table-3.5.2 Number of Traffic Accidents

| Fiscal year | No. of Accidents | Damage to expressway property (1,000 bahts) |
|---|---|---|
| 1982 | 80 | 314 |
| 1983 | 262 | 413 |
| 1984 | 424 | 1,051 |
| 1985 | 390 | 824 |
| 1986 | 309 | 654 |
| 1987 | 619 | 650 |
| 1988 | 1,124 | 1,338 |
| 1989 | 1,348 | 2,465 |
| 1990 | 1,331 | 2,272 |

## 3.6 Organization for Maintenance

### 3.6.1 Organization and Charge

The organization of ETA is as shown in Figure-3.6.1, and was effective from the beginning of October 1993. The "Expressway Maintenance Division" is under the "Expressway Maintenance Department", and is divided into two sections; that is to say, the "Roadway Maintenance Section" and "Bridge Maintenance Section".

The main responsibilities of the "Expressway Maintenance Division" are as follows:

- to analyze, research, plan and develop the expressway maintenance system,
- to investigate and provide solutions for expressway maintenance problems (repair, prevention etc.),
- to draw up maintenance work manuals,
- to draw up specifications for maintenance work,
- to provide specifications for equipment, machines, vehicles, etc. for the "Expressway Maintenance Division" and "Equipment Maintenance Division"

Two sections of the "Expressway Maintenance Division" have the responsibilities listed below:

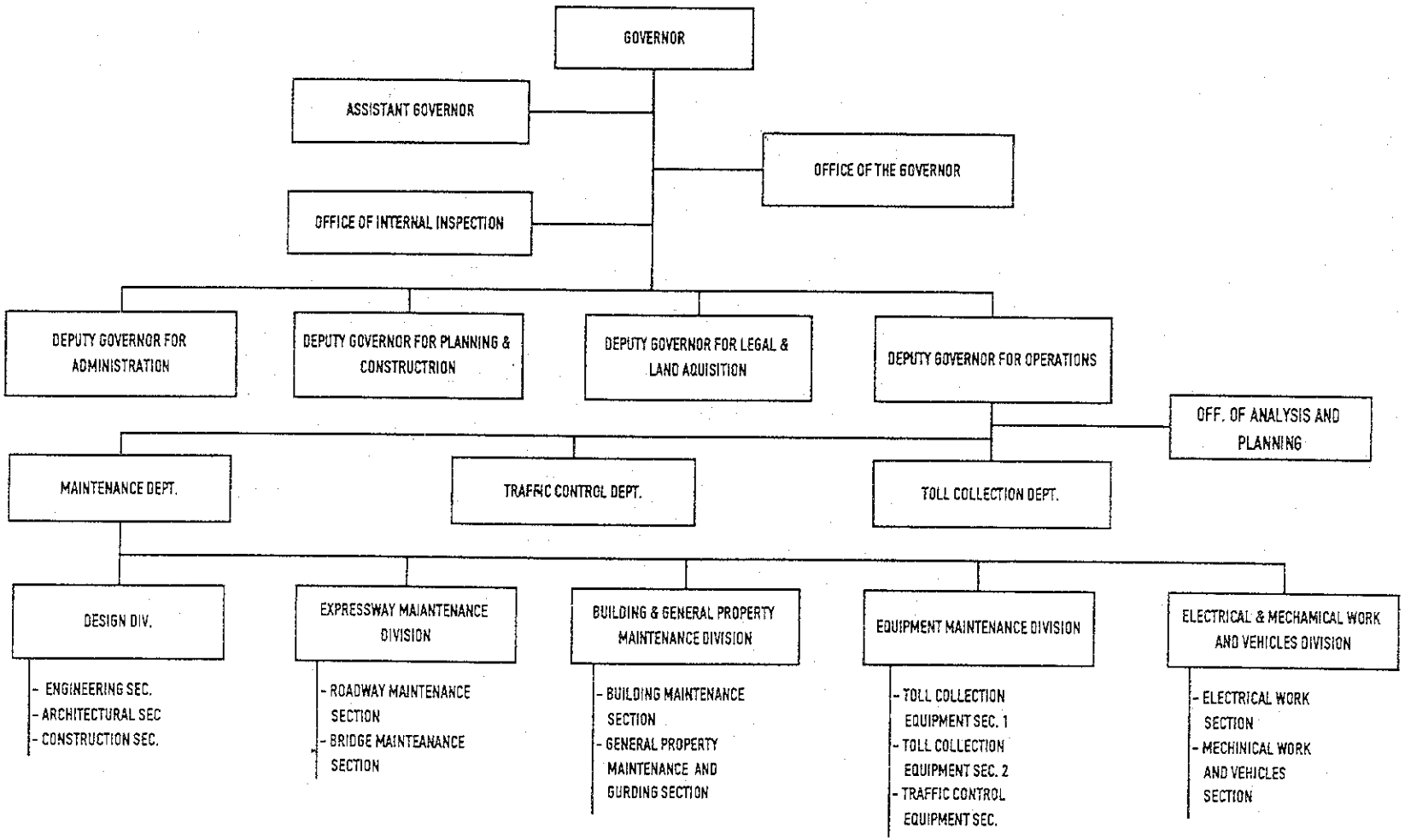



Figure-3.6.1 Organizational Chart of ETA

Road Maintenance Section

- inspection and maintenance of roadways, buildings and all civil works,
- inspection of roadway structures, pavement, shoulders etc,
- provision of maintenance plans and records,
- employment and supervision of contracted works,
- estimation of roadway damages due to car accidents,
- analysis and development of work systems and equipment,
- provision of emergency repair work, and
- other work assigned.

Bridge Maintenance Section

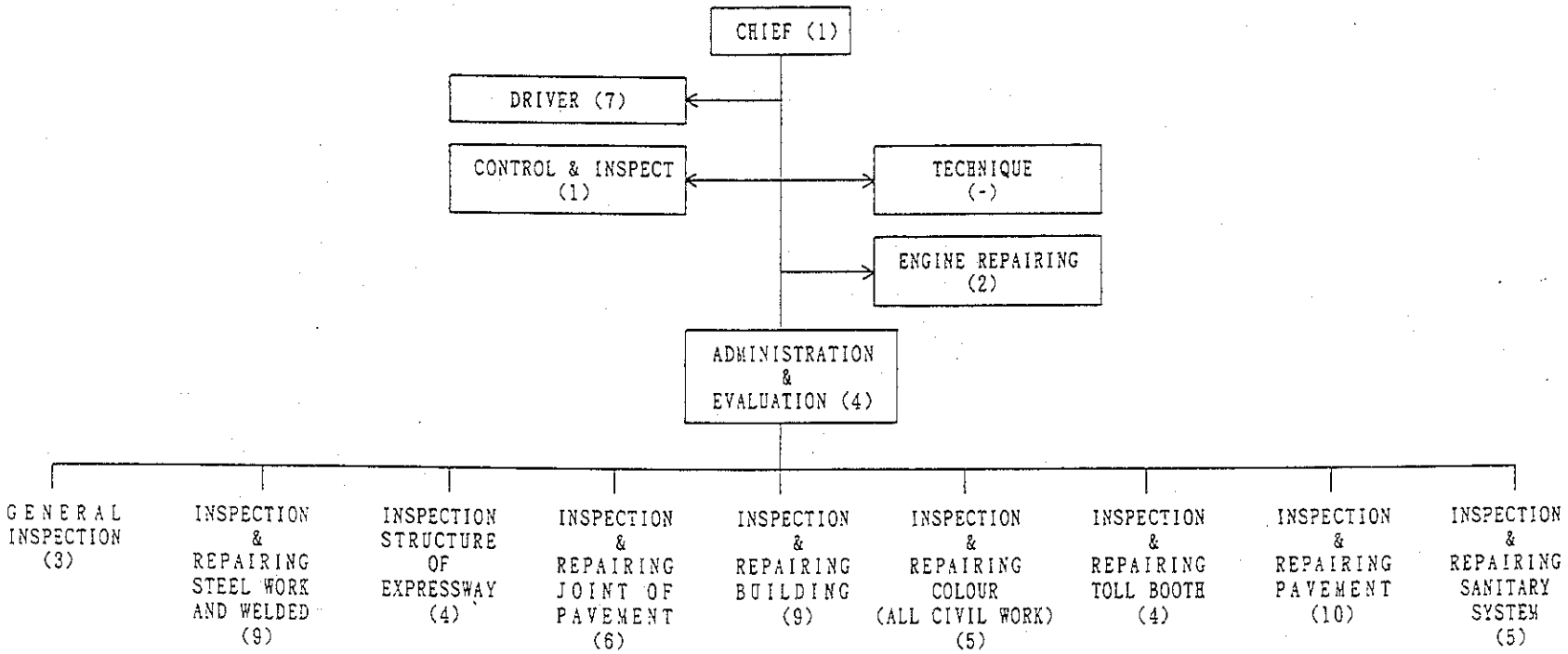
- inspection and maintenance of bridge structures including foundation,
- inspection of bridge cables,
- provision of maintenance plans and records,
- employment and supervision of contracted work,
- provision of emergency repair work,
- estimation of damages to bridge due to car accidents, and
- other work assigned.

### 3.6.2 Manpower for Maintenance

A total of 111 personnel belonged to the "Expressway Maintenance Division" as of 1992 (refer to Table-3.6.1, Figure-3.6.2 and Figure-3.6.3).

Table-3.6.1 Manpower of Expressway Maintenance Division

| Job Category | Central Administration | Roadway Maintenance Section | Bridge Maintenance Section |
|---|---|---|---|
| Director | 1 | | |
| Head | - | 1 (Engineer) | 1 (Engineer) |
| Engineer | - | - | - |
| Technicians | - | 10 (+1 temporary) | 4 |
| Labors | - | 44 | 22 |
| (permanent) | - | (26) | (9) |
| (temporary) | - | (16) | (13) |
| Drivers | 2 | 6 | 1 |
| Temporary Drivers | - | 3 | 4 |
| Equipment Operators | - | 2 | - |
| Others: | | | |
| -Administrators | - | 2 | - |
| -Clerk | 3 | 2 | 2 |
| -Janitor | 1 | - | - |
| Total | 7 | 70 | 34 |




REMARKS:() = MAN POWER

Figure-3.6.2 Organizational Chart of Roadway Maintenance Section

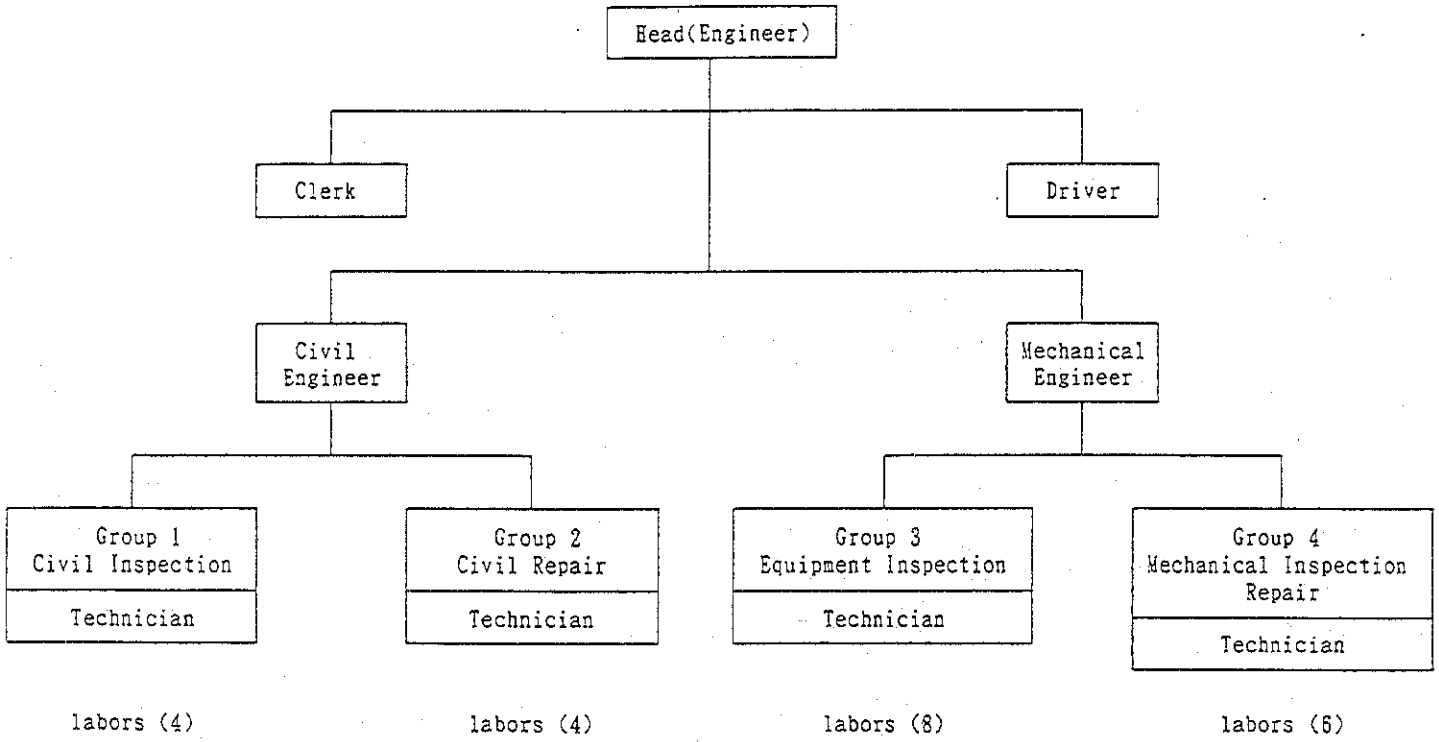



Figure-3.6.3 Organizational Chart of Bridge Maintenance Section

### 3.6.3 Equipment and Materials for Maintenance

At present, maintenance work carried out by the "Expressway Maintenance Division" is mostly light work, such as cleaning and the repair of pavement, expansion joints, and car barriers. Accordingly, the equipment and materials for maintenance that belong to the Division are also simple and light as shown in Table-3.6.2 and Table-3.6.3.

Table-3.6.2 Equipment for Roadway Maintenance

| No. | Equipment | Total No. |
|---|---|---|
| 1 | Pickups | 8 |
| 2 | Trucks | 4 |
| 3 | Pavement grinding cars | 1 |
| 4 | Vibration compactors (800kg) | 1 |
| 5 | Concrete cutters | 1 |
| 6 | Concrete vibrators | 1 |
| 7 | Concrete mixers | 2 |
| 8 | Vibration compactors | 2 |
| 9 | Jumping compactors | 1 |
| 10 | Sealing cutters | 2 |
| 11 | Miller-welding machines | 1 |
| 12 | Gas-welding machines | 2 |
| 13 | Air painting machines | 1 |
| 14 | Field generators | 3 |
| 15 | Air-drilling machines | 2 |
| 16 | Asphalt boilers | 1 |
| 17 | Torch blowers | 1 |
| 18 | Microcomputers & printers | 2 |
| 19 | Cameras | 2 |
| 20 | Binoculars | 2 |
| 21 | Concrete test hammers | 1 |
| 22 | Re-bar locations | 1 |
| 23 | Ultrasonic testers (Concrete) | 1 |
| 24 | Vibration compactors (8 Ton) | 1 |
| 25 | Back-hoes & loaders | 1 |
| 26 | Trucks with lifting cages | 1 |
| 27 | Radio transceivers | 13 |

Table-3.6.3 Equipment for Bridge Maintenance

| | Equipment | Total No. |
|---|---|---|
| 1 | Permanent instruments for dynamic behavior | |
| | -Bridge dampers | 8 |
| | -Temperature sensors | 3 |
| | -Wind speed detectors | 1 |
| | -Pylon dampers | 1 |
| 2 | Lifts | 2 |
| 3 | Maintenance gantries | 1 |
| 4 | Pylon cradles | 2 |
| 5 | Cable cradles | 2 |
| 6 | Vehicles | |
| | -Trucks | 1 |
| | -Pickups | 1 |
| | -Cars | 1 |
| | -Station wagons | 1 |
| 7 | Welding machines | 1 |
| 8 | Field generators | 2 |
| 9 | Ultra sonic testers (welding) | 1 |
| 10 | Cable-tension meters | 1 |
| 11 | Microcomputer printers | 2 |
| 12 | Cameras | 2 |
| 13 | Binoculars | 2 |
| 14 | Radio transceivers | 12 |
| 15 | Magnetic coating thickness gauges | 1 |
| 16 | Thermometers | 2 |
| 17 | High-tension bolt meters | 1 |

## 3.7 Budget and Expenditure for Maintenance

Changes over time in ETA maintenance budget are shown in Table-3.7.1 by work item. In addition, road maintenance expenses are also shown in Figure-3.7.1.

Table-3.7.1 Budget for Expressway Maintenance

| Items | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|
| Roadway & Bridge | 8,400 | 2,960 | 6,890 | n.a | n.a | 38,750 | 39,200 |
| - Joints | -- | -- | -- | n.a | n.a | 17,250 | 11,810 |
| - Pavements | -- | -- | -- | n.a | n.a | 19,500 | 22,750 |
| - Road Markings | -- | -- | -- | n.a | n.a | 1,400 | 2,025 |
| - Steel Works | -- | -- | -- | n.a | n.a | -- | 465 |
| - Traffic Signs | -- | -- | -- | n.a | n.a | -- | 1,300 |
| - Toll Booths | -- | -- | -- | n.a | n.a | 500 | 750 |
| - Equipment(rent) | -- | -- | -- | n.a | n.a | 100 | 100 |
| Cleaning of Expressway | -- | -- | -- | 5,579 | 5,220 | 8,505 | 9,710 |

Note : Unit is thousands of baht.

As shown in Figure-3.7.2, pavement repairs account for around half of the total maintenance expenditures, then comes repairs for expansion joints and cleaning.

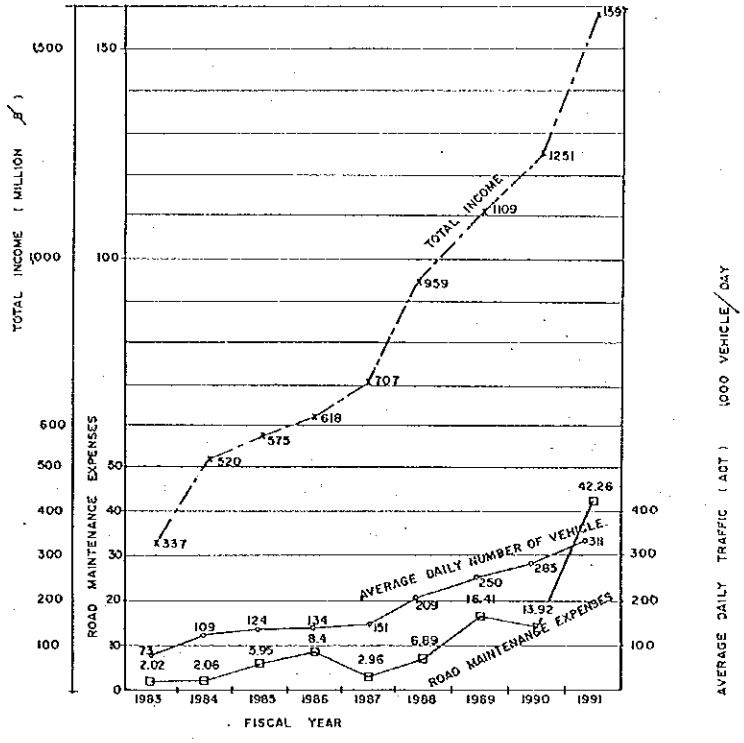



Figure-3.7.1 Relation between Average Daily Traffic (ADT) and Road Maintenance Expenses

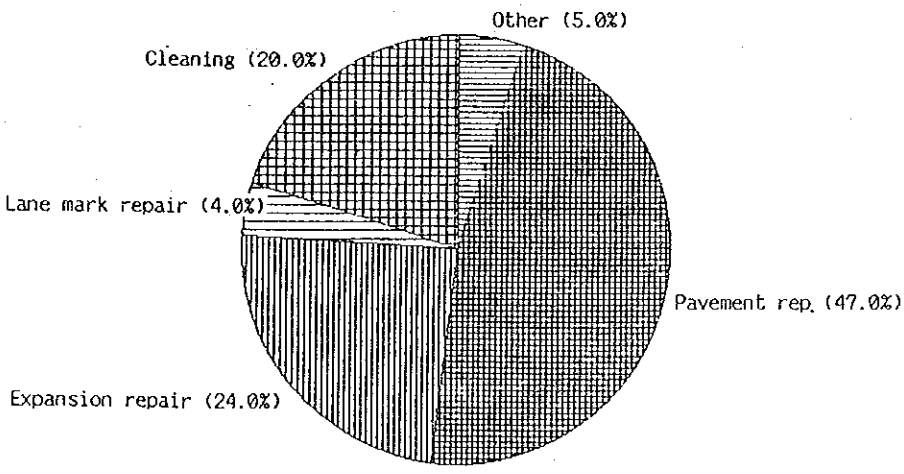



Figure-3.7.2 Maintenance Expenses

## 3.8 ETA Information System

### 3.8.1 Existing Hardware and Software

Main Frame System

A DEC computer (model 11/34A) was introduced at ETA's head office to store data and report on toll revenues. This system is connected with terminals at toll booths on the expressway, and manages toll fees on a real-time basis. Capacity and the installed software are as shown in Table-3.8.1.

Workstation

A RISC/6000 workstation (MODEL-530H) was initially introduced for the database task in 1993. This machine has ample disk storage capacity and adequate operating speed, and is supported by system software which facilitates database tasks. This machine is accessible for common engineering work in ETA's three offices, ie, the maintenance section of the Rama IX Bridge, the Klongtoey office, and the maintenance center. Capacity and installed software are presented in Table-3.8.1. "Informix" is a relational type database management system, and the database established by informix is accessed by its own command language, C-language and COBOL.

Two sets of the Intergraph RISK/Technology model have also been introduced to facilitate geographic information processing in engineering tasks and database management in informix.

Microcomputer

A number of microcomputers were introduced as shown in Table-3.8.1. They are used in various sections of ETA for database processing, word processing, toll management, and engineering tasks.

### 3.8.2 Future Concepts for Information System

ETA has some of the following fundamental concepts for the introduction and up-grading of information systems:

Hardware and software

- Introduction of some hardware to assist in engineering work, such as an A0-size scanner, digitizer, A0-size plotter, and additional workstation terminals in offices.
- Up-grading and introduction of the latest software, such as Graphic User Interface, WINDOWS, etc.

Communications network

- In order to share information within ETA, the LAN (Local Area Network) system will be introduced to interconnect computers in ETA offices.

Usage plan of information systems

- To broaden the usage of information systems to include tasks such as traffic analysis, manpower management, personnel administration, supply administration.
- To revise the established database system for inspection and maintenance of the expressway operated in dBASE4 to more a functional database management system, such as informix or ORACLE.

## Table-3.8.1 Existing Computer System in ETA

| SYSTEM | Name of Computer | QTY | CPU Memory<br>Outer Memory | Language | Application Programs | Major Usage | OS |
|---|---|---|---|---|---|---|---|
| - Main-Frame<br>Mini-computer | - DEC<br>Model 11/34 A | 1 | 64 KB | ASSEMBLY | TOLL COLLECTION<br>REALTIME SUMMARY | STORAGE DATA and<br>CREATE REPORT FOR<br>TOLL REVENUE<br>SYSTEM | RSX 11S |
| - WORKSTATION | 1. RISC/6000<br>MODEL 530H | 1 | 128 MB | FORTRAN,<br>COBOL | Informix | Database<br>Management System | AIX |
| | 2. Intergraph<br>RISC Technology | 2 | 32 MB | —— | Informix, GIS<br>(Microstation, MGA,<br>Insite, Inroad) | Geographic<br>Information<br>System | CLIX |
| - MICROCOMPUTER | 1. ACER<br>Acer Power386/ | 11<br>32 | 4 MB<br>(HDD 80 MB) | —— | dBASEⅢ, Fox-Pro | Database<br>Management System | MS-DOS 5.0<br>WINDOWS 3.1 |
| | 2. DEC 11/73 | 1 | 1 MB | FORTRAN,<br>ASSEMBLY | TOLL COLLECTION<br>REALTIME SUMMARY | STORAGE DATA and<br>CREATE REPORT FOR<br>TOLL REVENUE<br>SYSTEM | RSX 11M |
| | 3. Unknown | 35 | 1MB-4MB<br>HDD 30-120MB | —— | dBASEⅢ, Fox-Pro<br>Excel, Word Perfect | - Word-Processing<br>- DBMS | |

# CHAPTER 4

# INSPECTION AND MAINTENANCE SYSTEM CONCEPTS

# Chapter 4 Inspection and Maintenance System Concepts

## 4.1 Objective Road Structures and Facilities

### 4.1.1 Land Section

The inspection and maintenance system defines its objective structures, facilities and the damage they may sustain, in order to standardize information management and work procedures for the effective maintenance of the expressway. For this reason, objective road structures and facilities are classified considering their functional, material, damage, and maintenance characteristics. Information on maintenance shall also be subjected to this classification to correspond with other information concerning such things as inventory and inspection.

The inspection and maintenance system covers superstructures, bridge piers, pavement, and expressway appurtenances, such as traffic safety devices and street lighting facilities. Objective road structures and facilities are classified into the following 15 types as shown in Figure-4.1.1 for the Land Section:

- superstructures : main girders, cross girders and slabs,
- piers : columns and beams,
- retaining walls : at high embankments,
- embankments : embankment shoulders and masonry walls,
- pavement : with lane markings,
- guard walls : reinforced concrete walls at both bridges and embankments, as well as median walls that are common to bidirectional traffic,
- drainage : composed of inlets and water leading pipes and ditches,
- expansion joints : buried and rubber joints,
- bearings : rubber pads,
- lighting : with poles and lights,
- traffic signs : with poles, signboards and lights,
- handrails : at the guard walls of bridge sections,
- guardrails : at embankments,
- fences : to resist intrusion and protect falling and glare, and
- noise barriers : support columns and panels.

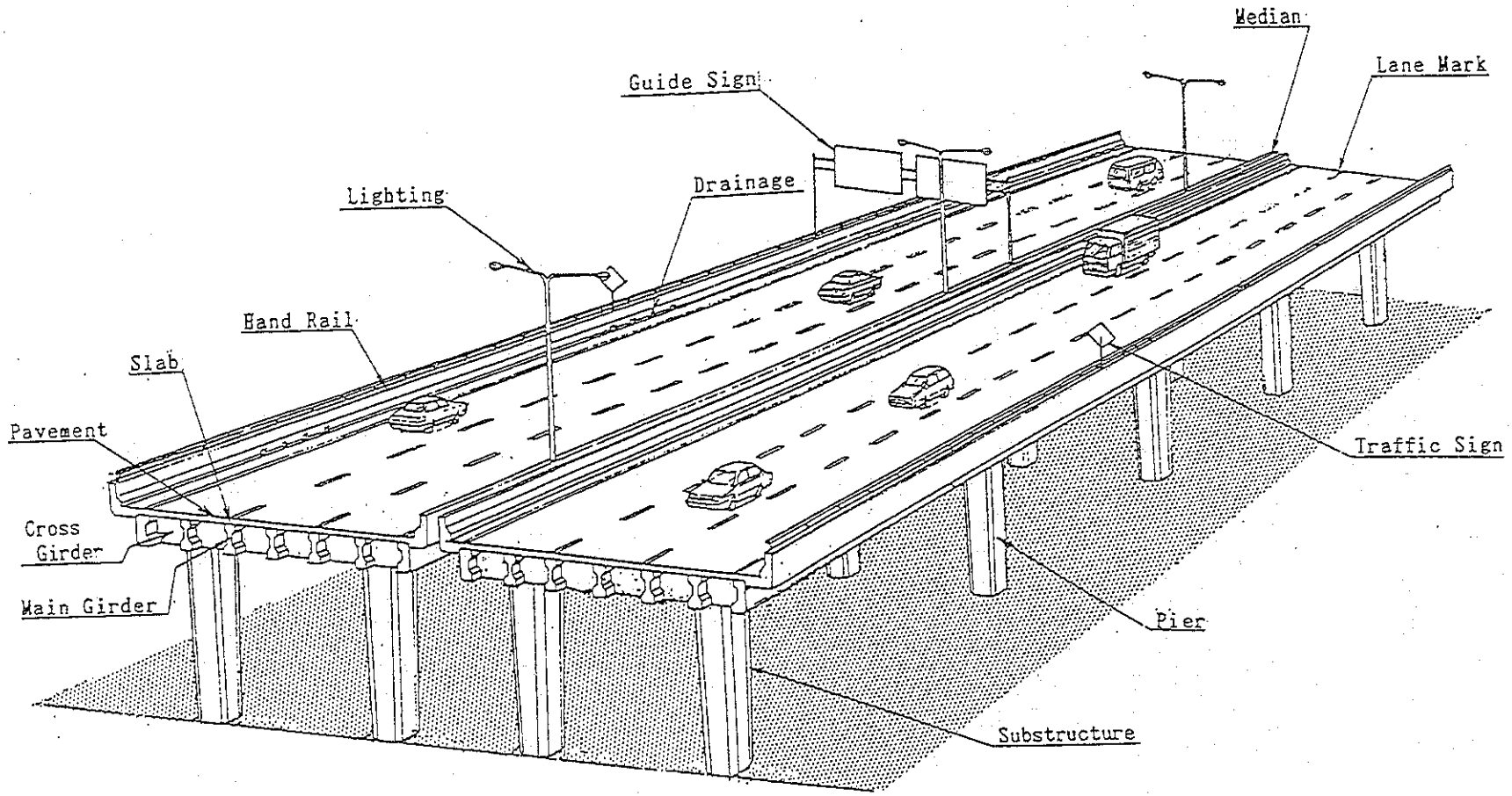



Figure-4.1.1 Objective Structures and Facilities for Land Section

### 4.1.2 Rama IX Bridge Section

Objective road structures and facilities of the Rama IX Bridge Section are determined to consist of 14 members, taking into account the special characteristics of the cable-stayed bridge, and are as follows:

- main girders : including upper decks, lower decks or flanges, web plates, and cross beams,
- stay cables : cables, cable coverings, cable anchorage at both sides of girders and pylons,
- pylon : on pylon piers,
- pavement : asphalt pavement and lane markings,
- piers : high concrete piers of the bridge,
- guard barriers : to prevent vehicles from falling off bridge,
- handrails : mostly outside guard fences for maintenance work,
- drainage : inlets and water leading piers,
- bearings
  - pendel bearings : on each pier,
  - neo-pot bearings : on pylon piers,
  - wind bearings : on junction piers,
- expansion joints : roller-shutter-type joints at both ends of the bridge,
- dampers
  - pylon dampers : tuned mass dampers on pylon piers
  - girder dampers : tuned mass dampers on girders
  - cable dampers : oil dampers at the end of each cable in box girder,
- maintenance facilities
  - girder gantry : maintenance gantries under girders,
  - pylon lift : electric lifts in pylons,
  - pylon ladder : ladders in pylon towers,
  - pylon gondola : gondolas outside pylons,
  - cable gondola : gondolas for stay cables
- lighting : poles and lights, and
- traffic signs : poles, signboards and lights.

Figure-4.1.2 shows objective Structures and facilities for the Rama IX Bridge Section.

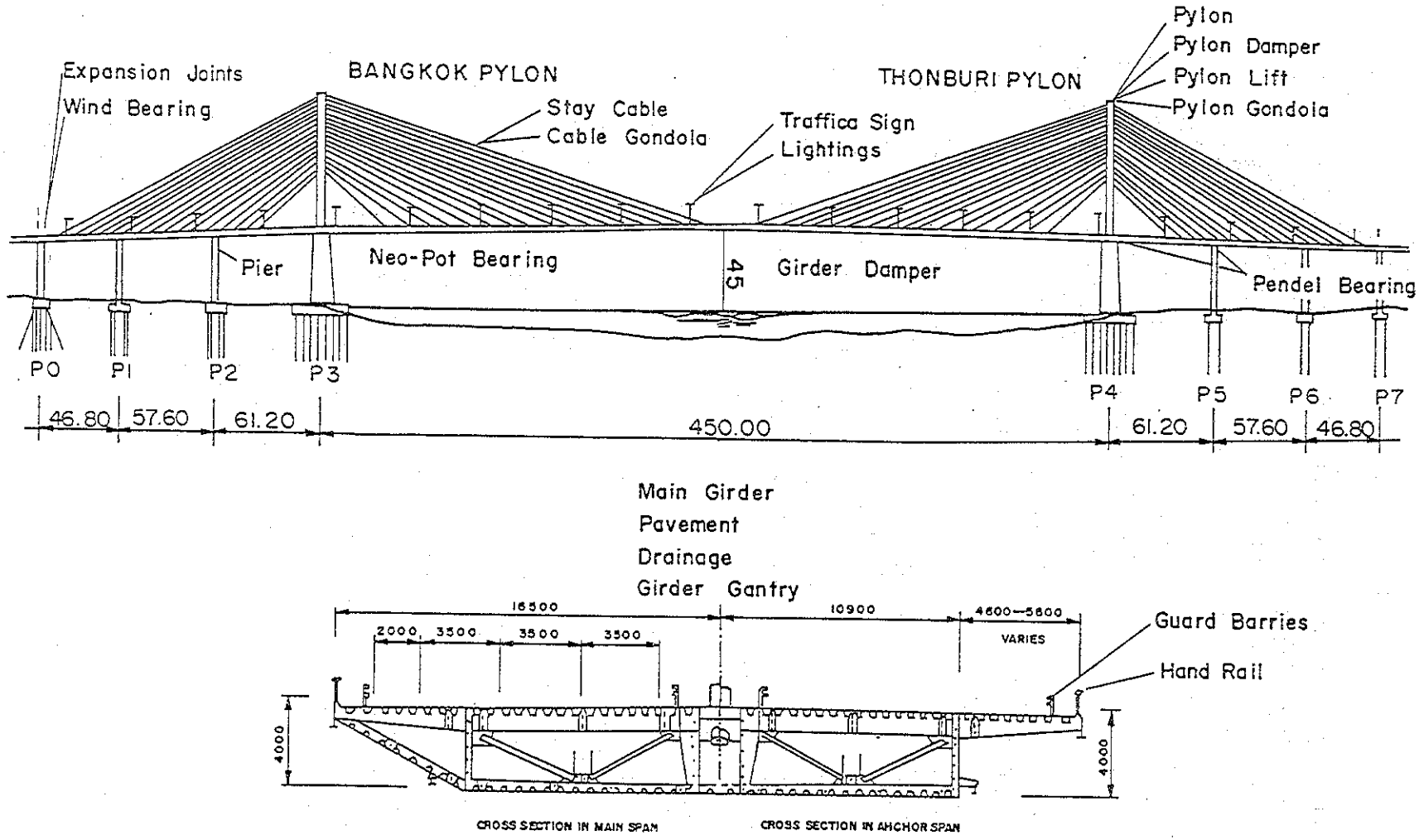



Figure-4.1.2 Objective Structures and Facilities for Rama IX Bridge Section

## 4.2 System Framework

### 4.2.1 Inspection and Repair Concepts

#### 1) Objects of Systematization of Maintenance

Inspection work is implemented using an inspection manual, which is insufficient for providing adequate support for inspection work. Results of inspections are presented in report form and kept on file. Repair plans are carried out based on the inspection reports, and repair work is either executed by ETA itself or farmed out to an outside construction firm.

Currently, the above maintenance situation of the expressway is not such a problem now, since it seems that damage to road structures and facilities is only minor at present. In the near future, though, as this damage becomes increasingly serious with the increase of heavy vehicles and age-worn structures, the inadequacy of the current maintenance practices will pose difficult problems.

The maintenance work flow with systematization using the database system is improved to the work flow shown in Figure-4.2.1.

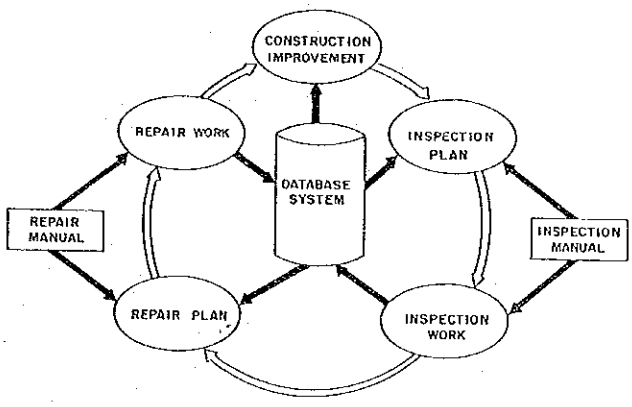



Figure-4.2.1 Systematized Maintenance Work Flow

Inspection and repair plans will be supported with output information from the databases. The output information will provide a list of structures or facilities to be inspected or repaired in terms of existing damage to road structures and facilities. This will enable engineers to decide on inspection or repair plans more easily using information stored in the

databases.

An inspection and repair manual will also support inspection and repair work and cover methodology, equipment, work methods, reporting, and inputting information into the databases.

The inspection and maintenance system formulated in this study will provide a broad base of support for the maintenance and management work of the expressway, and it will improve work procedures and methods that will result in higher efficiency and less incidental damage to structures.

2) Inspection and Maintenance Work Framework

Maintenance work on road structures and facilities is conducted to keep them in good condition in order to achieve smoother vehicle traffic flows and to preserve public property for a longer period of time. Maintenance work is composed of inspec-

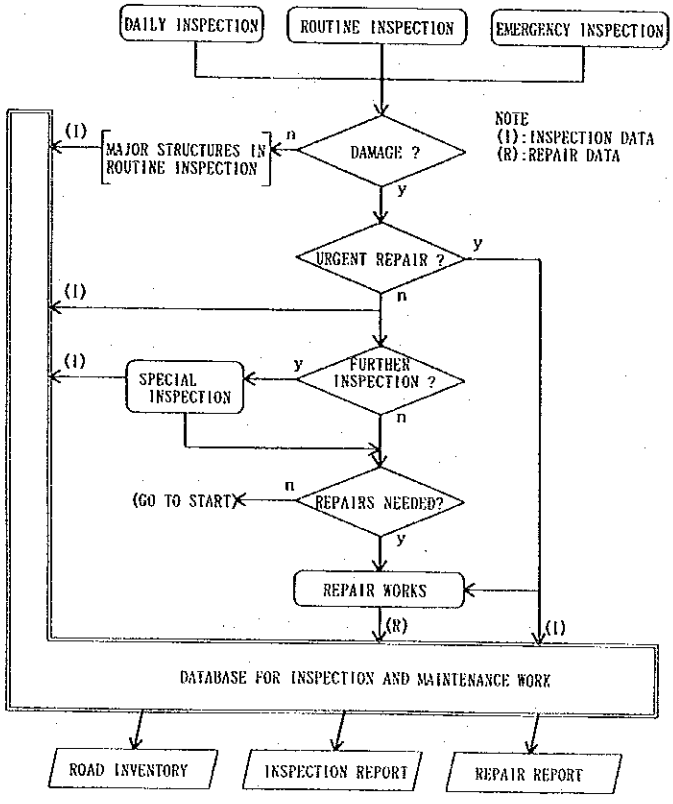



Figure-4.2.2 Inspection and Maintenance Procedures

tion and repair work, and is shown in the flow chart of Figure-4.2.2.

An inspection is first carried out to grasp the condition of road structures and facilities, which influences further measures such as the repairs to be taken for damaged structures or facilities. Therefore, attention must be given not only to damage, but also to the causes of damage and their effects on vehicular traffic.

Daily inspection is performed over the entire expressway every day and is based on the inspection manuals. Results of observations are written on inspection sheets and inputted into the daily inspection database file by inspectors after coming back to the office. In the case of discovering serious damage that adversely affects traffic, urgent repairs shall be performed immediately and the results of the inspection and repair work inputted into the database file.

Routine inspection forms the basis of the inspection manuals, and it is carried out as a preventive maintenance measure for the major structures and facilities of the expressway. When damage or deterioration is found by a routine inspection, the work procedure differs by member as below.

All inspection results on the major members of the viaducts, such as the superstructure, pavement, expansion joints and piers, are stored in the database, even when no damage or defect are found. Inspection results of the other above-mentioned structures and facilities are compiled in the database system when damage is greater than that of Rating C.

When damage or deterioration is as serious as that of Rating A, urgent repairs shall be performed as soon as possible prior to inputting observations into the database.

In the case where damage on a major structure such as a superstructure or pier is as serious as that of Rating B, further investigations shall usually be carried out to clarify the causes and influences of the damage by special inspection work by means described in the inspection manuals.

When damage or deterioration is that of Rating B, repairs shall be based on the basic concepts for damage ratings, which gives

priority to the following 4 functions:

- influences on traffic and third parties,
- the functionality of structures or facilities,
- the durability of structures or facilities, and
- the annual repair plan, budgets, repair methods, etc.

Observations from inspections and repairs are stored in databases based on measures and procedures described in the manuals on inspection and maintenance repair, as well as on procedures described in the System Users Manual for the operation of the database system. Users can retrieve and output information stored in the databases in form of a road inventory and inspection and repair reports on a daily, monthly, and yearly basis to assist them with their maintenance work.

### 4.2.2 Inspection and Maintenance System Framework

#### 1) System Components

The expressway's inspection and maintenance system plays an important role for road administrators in the road's maintenance, management and operation. In order to apply the system effectively for the practical maintenance work of the road's structures and facilities, the system is subdivided into subsystems as shown in Figure-4.2.3.

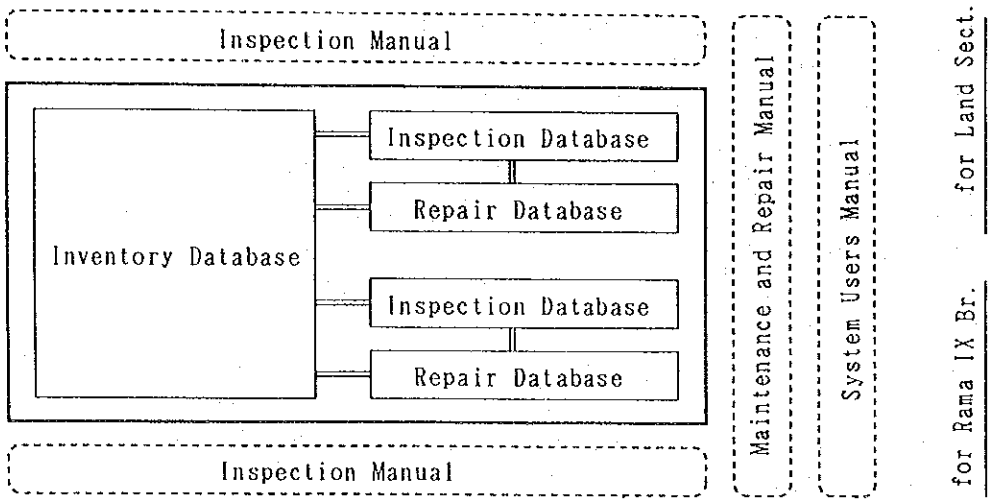



Figure-4.2.3 System Framework

The inspection and maintenance system for the ETA expressway system consists of a database to manage maintenance information and manuals to assist ETA engineers with inspection and maintenance work and the operation of database system.

Inspection manuals are handled out to assist inspection engineers with daily, routine, and special inspection work for the expressway. Since the Rama IX Bridge Section is maintained differently than other parts of the expressway by an exclusive maintenance section in ETA, a separate inspection manual is prepared for the Rama IX Bridge for this maintenance section for exclusive use.

The Maintenance and Repair Manual has been drawn up so it can be applied to the whole expressway, i.e. the Land Section and the Rama IX Bridge Section, which is useful because of its comprehensiveness. A system users manual is also drawn up for ETA engineers to assist them with the operation of the database system.

The database system, which is composed of inventory, inspection, and repair databases for the same reason mentioned above, subdivides the last two databases into the Land Section and a section for the Rama IX Bridge. The inventory database, on the other hand, is designed for the whole expressway and it is subdivided into 11 database files.

2) Database Framework

In a database system, detailed information on inventory and inspection/repair, which can not be stored in a single database, are compiled in separate database files for effective computer usage and to avoid the duplication of information stored. Therefore, including a code database that is used for all the database files, 19 database files are developed as shown in Figure-4.2.4.

Although these databases are formulated separately, the system is designed in such a way that the related databases for maintenance work can be interfaced with key identifiers.