EXPRESSWAY AND RAPID TRANSIT AUTHORITY OF THAILAND
MINISTRY OF INTERIOR
KINGDOM OF THAILAND

FINAL REPORT ON AN APPROACH TO THE DATABASE OF MAINTENANCE WORK FOR URBAN EXPRESSWAY

AUGUST 1992

PREPARED BY

HIROMI KOSAKA
EXPERT
ON
MAINTENANCE OF URBAN EXPRESSWAY
AND
CABLE-STAYED BRIDGE

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request by the Government of the Kingdom of Thailand, the Government of Japan dispatched an expert on maintenance for expressways and a cable-stayed bridge, Mr. Hiromi KOSAKA to Expressway and Rapid Transit Authority of Thailand (ETA), Ministry of Interior, in August, 1990.

The background of the request is as follows:

> "The ETA has been assigned to implement urban expressway systems in the Kingdom of Thailand. In December, 1987, the first stage expressway with total length of 27.1 km was completed and opened for traffic. Among this, there exists the world longest cable-stayed bridge, Rama IX Bridge, which has central span of 450 meters. The first and the second section of the expressways were opened to public in 1981 and 1983, respectively. So the importance of maintenance work on the expressways and the bridge has increased in order to maintain smooth traffic operation. Therefore an experienced expert in expressway and bridge maintenance is by all means required to ETA."

The main duties for which the expert was responsible

a) To prepare repair work manuals both for the cable-stayed bridge and ordinary expressways making use of past repair examples.

b) To set up a maintenance data recording system for systematic maintenance work.

c) To carry out a periodic inspection work of the cable-stayed bridge.

e) To give advice, comments or information on the re-surfacing project of the cable-stayed bridge.

The expert performed his duties with the counterparts in the office of expressway management department for two years.

This report complies the works that have been done on the main duties, and also includes some recommendation deemed to be necessary for the maintenance work.

Finally, the expert would like to express his sincere appreciation for the cooperation and supports which were given from many persons during his term in the Kingdom of Thailand.

HIROMI KOSAKA
Expert on Maintenance for Urban Expressways
Japan International Cooperation Agency

1. Inspection and Maintenance System of the Metropolitan Expressways

1.1 General

The Metropolitan Expressways are motorways constructed for the purpose of contributing to cultural and industrial development of the metropolice. The expressway can isolate the living environment along the route within the city from a mass flow of extraneous vehicles while, on the other hand, enhancing travel and time benefits of the motor vehicle traffic. The Metropolitan Expressways also play an important role as an extension to interurban expressways. For example, the Metropolitan Expressway Route No.3 connects to the Tomei Expressway while Route No.4 to the Chuo Expressway (See Fig.1-1).

The first Metropolitan Expressway was opened in December, 1962 for a distance of 4.5 km from Takara-cho, Chuo Ward to Kaigan-dori, Minato Ward in central Tokyo and it is still today a vital part of the present Route No.1. As of April, 1991, the total length of the expressway in service 220.0 km, with a traffic volume increasing from approximately 1.15 million vehicles/year in 1962 to 404.47 million vehicles/year in 1990. Namely, for approximately 49-fold increase of the length in service, the traffic volume showed an increase by approximately 350 times.

The traffic volume per km has increased by approximately 700 times, from approximately 250,000 vehicles/km/year in 1962 to 1.84 million vehicles/km/year in 1990. In particular, the structural change in the transport industry has brought about higher percentage of large trucks, with the percentage of truck rising from 2.7% in 1962 to 19.7% in 1991. As it is evident from Table 1-1 and Fig.1-2, the length in service and traffic volume have undergone chronological growth, but traffic volume per km has edged down in rate of growth. This means that traffic volume per km has reached the road capacity in these ten years in view of recent traffic congestion and the strict traffic control on the expressways.

On the other hand, with a history of 30 years since the commencement of service, The Metropolitan Expressways contain approximately 40.7% of 20 years or more old portion, 49% of 15 years or more old portion and 63% of 10 years or more old portion as of March 1991 (See Fig. 1-3).

THE METROPOLITAN EXPRESSWAY NETWORK

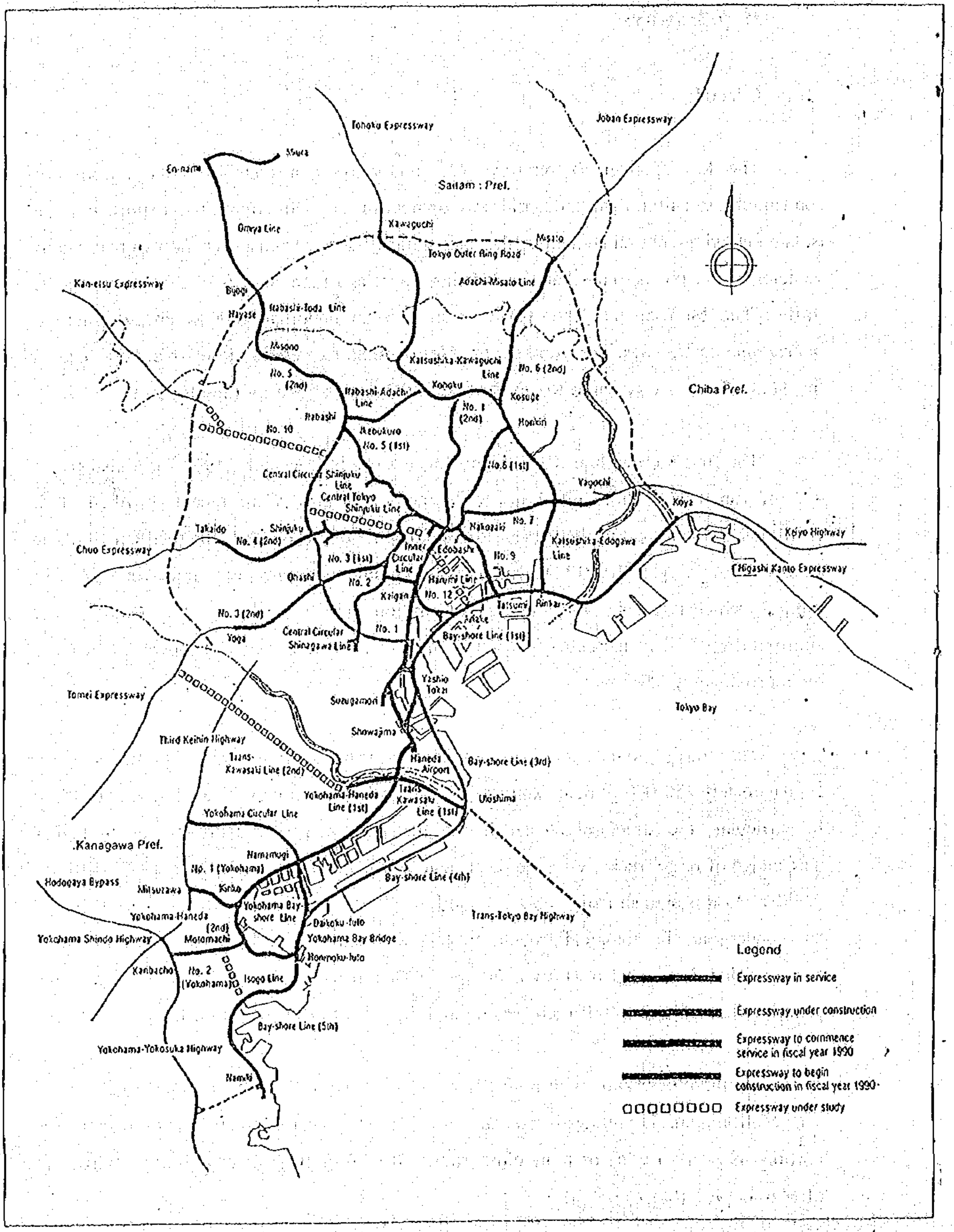


Table 1.1 Trend of Lenght in Service and Traffic Volume

Year	Length in service (km)	Traffic volume (Million/year)	Traffic volume per km (Million/km/year)
1962	4.5	1.15	0.25
1963	13.4	7.19	0.54
1964	32.8	22.35	0.68
1965	32.8	28.63	0.87
1966	34.9	30.85	0.88
1967	47.2	48.03	1.02
1968	60.9	77.43	1.27
1969	71.3	117.96	1.65
1970	89.6	134.19	1.50
1971	97.5	166.37	1.71
1972	101.3	181.32	1.79
1973	107.8	192.21	1.78
1974	107.8	188.99	1.75
1975	107.8	191.65	1.78
1976	111.3	202.81	1.82
1977	131.7	217.84	1.65
1978	131.7	251.26	1.91
1979	138.7	257.84	1.86
1980	138.7	268.15	1.93
1981	145.6	281.24	1.93
1982	157.6	284.10	1.80
1983	160.8	280.02	1.74
1984	173.2	291.48	1.68
1985	173.2	305.07	1.76
1986	173.2	312.99	1.81
1987	200.9	339.79	1.69
1988	200.9	365.70	1.82
1989	217.4	381.26	1.75
1990	220.0	404.47	1.84

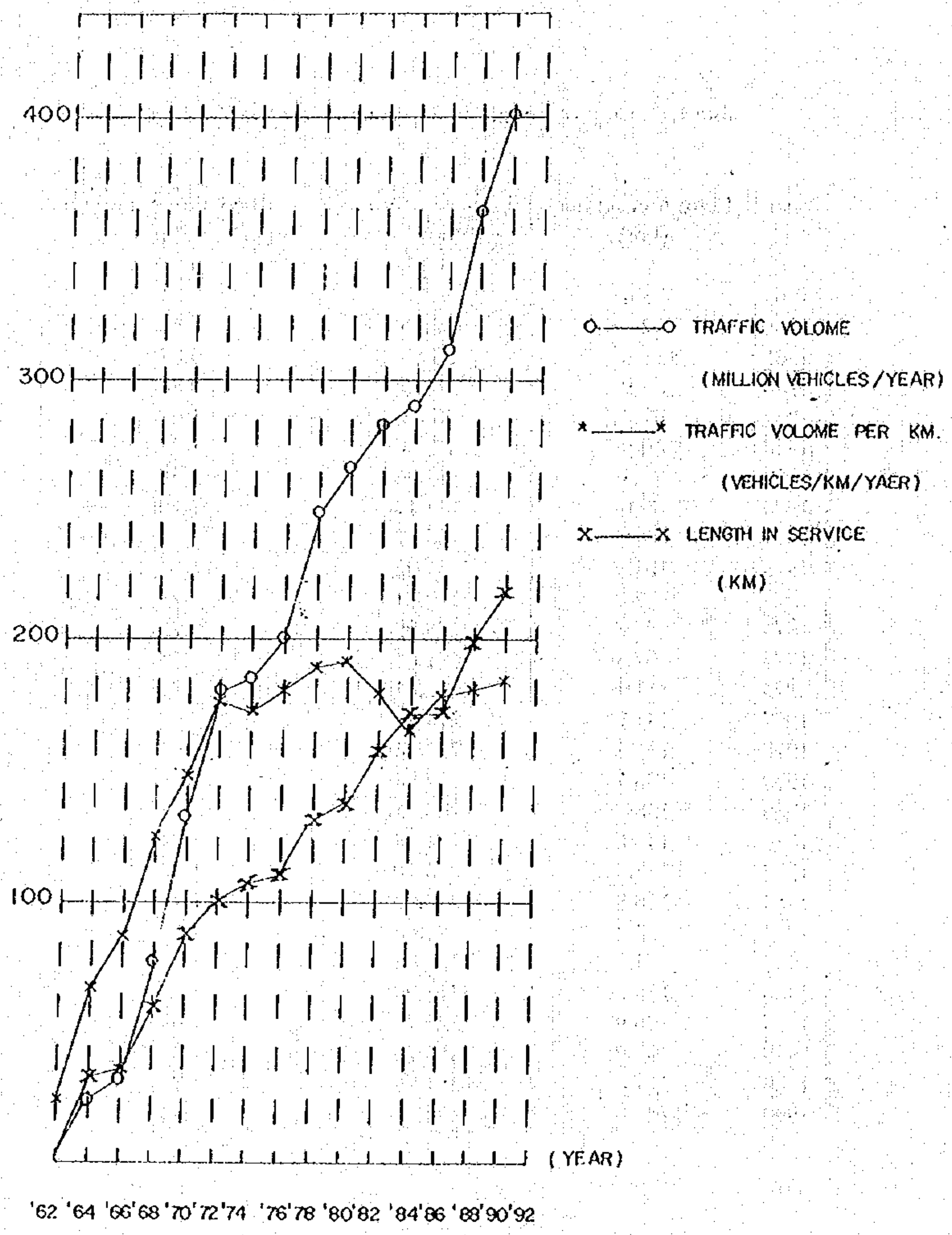


FIG. 1-2 CHRONOLOGICAL TREND OF LENGTH IN SERVICE AND TRAFFIC VOLUME

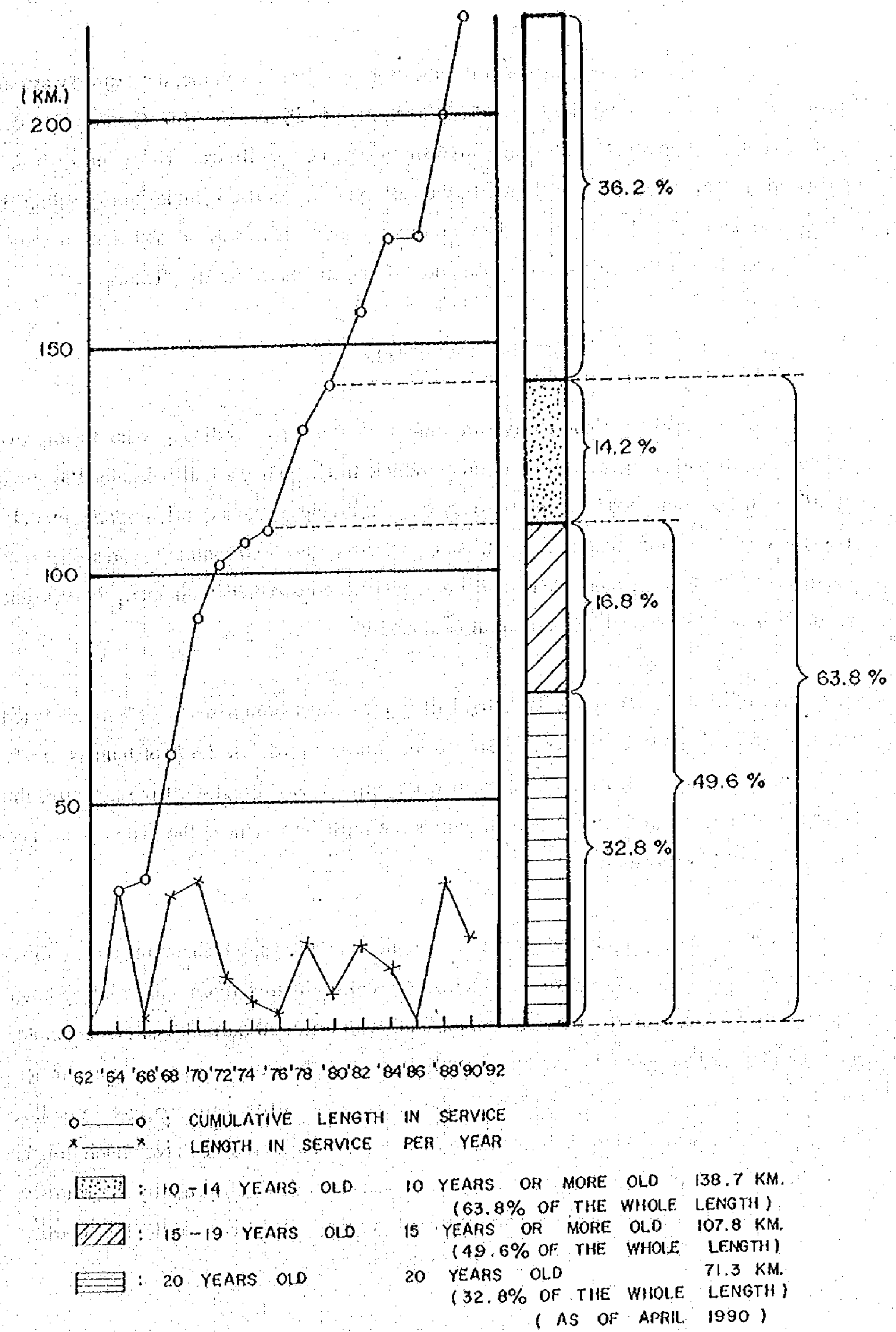


FIG. 1-3 CHRONOLOGICAL OUTDATED STOCK PERCENTAGE

Finally, to ensure safe and smooth flow of giantic traffic volume, the expressways are provided with highly sophisticated road administrative facilities, i.e., traffic safety devices, traffic control system and other most diversified attached facilities. These must be well maintained to preserve their functions. In view of overload traffic volume for exceeding the initial estimation, chronological deterioration, unique characteristic and administration business has become more and more complicated and increased its significance.

1.2 Structure Type of Metropolitan Expressways

The Metropolitan Expressways are built separately from ordinary roads to improve safety, comfortability and speed of the motor vehicle traffic. They are also designed to avoid at grade intersections with ordinary roads by employing viaducts, bridges and tunnels. Because of its particular feature as an urban expressway, the Metropolitan Expressway runs mostly on top of roads and rivers and consequently constructed with many curves and accommodates geometrical and structural complexity.

As of April 1991, the total length of expressways comprises 85.4% of elevated structure (68.9% for steel girders and 16.5% for concrete girders), 3.9% of tunnels, 5.9% of dug-out portion and 4.8% of plain earth work portion (See Fig.1-4). Consequently, the measures to be taken for the elevated structures are most important in the maintenance and administration of expressways.

Steel girders, steel piers and cast-in-place pile foundations, which are the most typical expressway structures, are shown in Fig.1-5. As shown in this figure, the Metropolitan expressways are made up from various components with different durabilities. For example, road markings which have the shorter durability are erased within a year while expansion joints and pavement require replacement in about ten years. Girders are expected to endure for 50-70 years while piers and foundation piles are considered to have much longer durability. Durability of toll highways is generally determined at 60 years by the Ministry of Finance and 40 years by the Economic Planning Agency. In the case of the Metropolitan

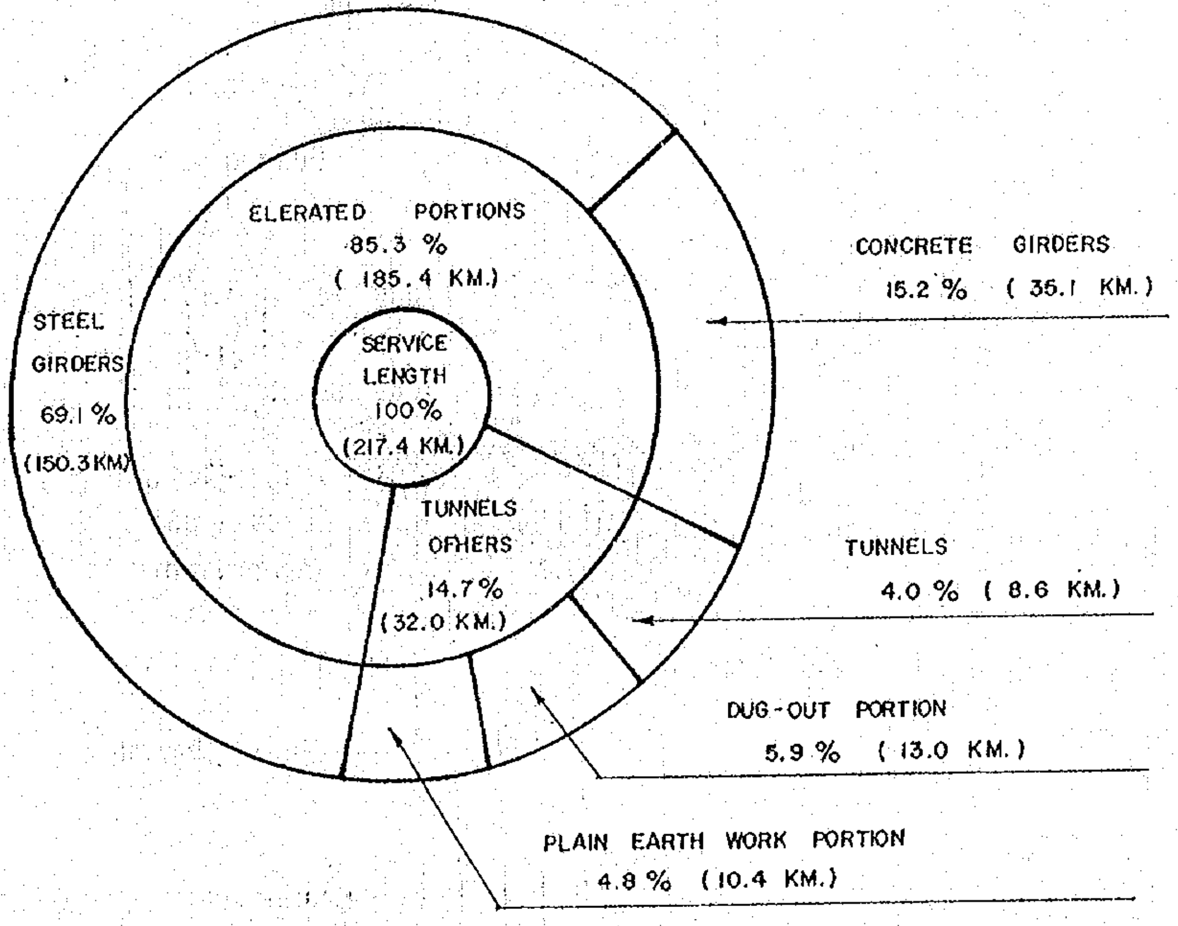


FIG. 1-4 PERCENTAGE OF STRUCTURE TYPES IN THE TOTAL LENGTH IN SERVICE

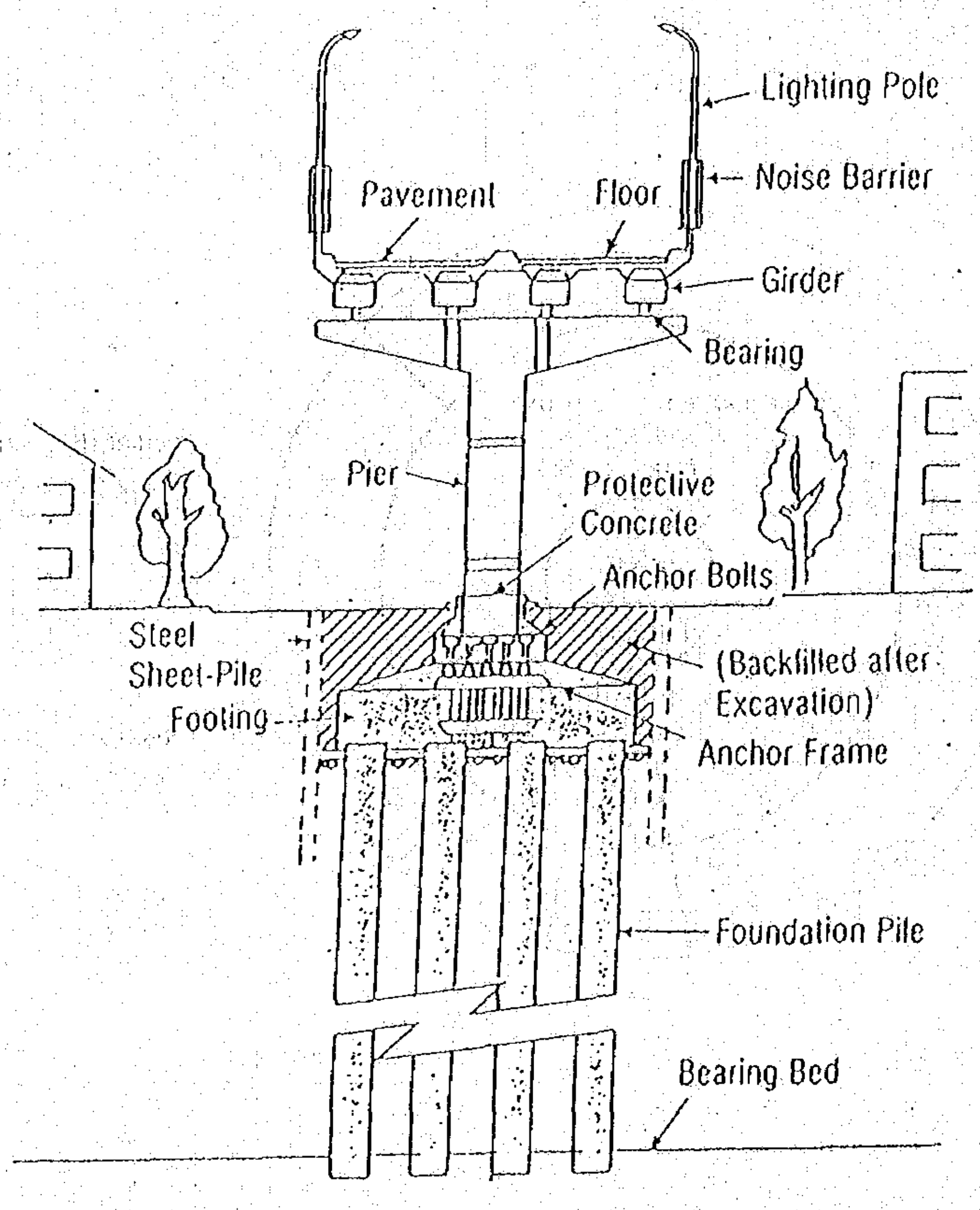


FIG. 1-5 TYPICAL STRUCTURE OF THE EXPRESSWAY

expressways, however, a substantial difference arises depending on which section has been selected as a reference. Accordingly it is impossible to determine the durability in a strict sense of the word which applies to the expressway as a whole.

At present, the Metropolitan expressways are in a phase requiring partial reinforcement of floor slabs and girders. For locations with longer durability, it is important to prolong the service life through maintenance, inspection and repair. In addition, the maintenance and administration of the Metropolitan expressways must be executed with due consideration and checking on any change of not only visible above-ground members(piers, girders, floor slabs, road surface, lighting apparatus, etc.), but also underground members (anchors, bearing bed).

A list of the expressway facilities is shown in Table 1-2 and primary design specifications for the Metropolitan expressways are as follows:

* Geometric standards for highways (Japan Road Association)
* Specifications for highway bridges (Japan Road Association)
  - part I : common specifications
  - part II : steel bridges
  - part III : concrete bridges
  - part IV : substructures
  - part V : seismic design

1.3 Maintenance and Administration Organization

Proper execution of maintenance and administration is possible only when the system and organization are established with required manpower and machinery effectively and reasonably arranged.

Roughly speaking, following three kinds of business are necessary in order to maintain and administer the Metropolitan expressway section currently in service:

1) Collection of tolls and other related business
2) Traffic control
3) Maintenance and repair

Table 1-2 Summary of Equipments Belonging to M.E.P.C.

No.	Equipment		Tokyo	Kanagawa	Total
1	Emergency exit	(place)	451	112	563
2	Emergency parking area	(place)	249	66	315
3	Variable message sign board on streets	(face)	166	28	194
4	Graphic information boards on streets	(face)	3	0	3
5	Variable regulatory sign	(face)	119	23	142
6	Graphic information board	(face)	15	3	18
7	Loop type vehicle detector	(place)	9	0	9
8	Ultrasonic wave type vehicle detector	(place)	1505	310	1815
9	Vehicle detector at toll gates	(lane)	258	58	316
10	Closed circuit TV for surveillance	(unit)	368	192	560
11	Character information board	(place)	296	75	371
12	Emergency telephone	(place)	916	198	1114
13	Lighting on roads				
	mercury lamp		11800	3216	15016
	sodium lamp		1353	0	1353
	Lighting in tunnels				
	mercury lamp		2599	2820	5419
	sodium lamp		1519	0	1519
	fluorescent lamp		13346	3363	16709
14	Roadside radio broadcasting device	(place)	2	0	2
15	Anemoscope/anemometer	(place)	9	5	14
16	Vehicle speed monitoring device	(place)	9	3	12
17	Tunnel ventilator				
	jet fan	(place)	0	12	12
	other fan	(place)	99	9	108
18	Drainage pump	(place)	83	14	97
19	Axle-load scale	(place)	160	42	202
20	Camera for axle-load scale	(place)	143	37	180
21	De-icing facility	(place)	4	0	4
22	Toll gate	(place)	107	23	130

ORGANIZATION

- Administrative Committee
- President
  - Vice-President
    - Director-Generals
      - Secretariat
      - Auditor's Office
      - General Planning & Coordination Office
      - General Affairs Deprtment
        - General Affairs Division
        - Accounting Division
        - Public Information Division
      - Personnel Department
        - Personnel Division
        - Labor Division
        - Welfare Division
      - Finance Department
        - Finance Division
        - Fund Division
        - Contract Division
        - Property Division
      - Management Department
        - Road Management Division
        - Business Management Division
        - Economic Survey Division
      - Traffic Management Department
        - Traffic Management Division
        - Traffic Control Facilities Division
        - Traffic Control Engineering Division
      - Planning Department
        - Planning Management Division
        - First Planning Division
        - Second Planning Division
        - Environmental Engineering Division
        - Survey & Research Division
      - Land Acquisition Department
        - Right-of-Way Management Division
        - Land Appraisal Division
        - Compensation Division
      - Engineering Department
        - Engineering Management Division
        - Construction Management Division
        - Construction Guidance Division
        - Design & Research Division
      - Maintenance & Facilities Department
        - Maintenance Management Division
        - Maintenance Engineering Division
        - Architectural Division
        - Facilities Division
        - Electricity & Telecommunication Division
      - Construction Works Inspection Office
      - First Construction Department
        3-2-4 Iwamoto-cho, Chiyoda-ku, Tokyo 101
        Phone: 03 (3861) 8171
      - Second Construction Department
        1-2-13 Yoyogi, Shibuya-ku, Tokyo 151
        Phone: 03 (3370) 2171
      - Third Construction Department
        2-14-4 Hachobori, Chuo-ku, Tokyo 104
        Phone: 03 (3553) 1231
      - Bay-shore Route Construction Bureau
        1-11-11 Shiba, Minato-ku, Tokyo 105
        Phone: 03 (5232) 6761
      - Kanagawa Construction Bureau
        2-25 Masago-cho, Naka-ku, Yokohama City, Kanagawa 231
        Phone: 045 (662) 1151
      - Tokyo First Management Department
        2-16-3 Hirakawa-cho, Chiyoda-ku, Tokyo 102
        Phone: 03 (3264) 8200
      - Tokyo Second Management Department
        6-1-1 Kiba, Koto-ku, Tokyo 135
        Phone: 03 (3646) 1151
      - Tokyo Maintenance Department
        1-1-3 Shintomi, Chuo-ku, Tokyo 104
        Phone: 03 (3552) 1441
      - Kanagawa Management Department
        1-3-4 Higashikanagawa, Kanagawa-ku, Yokohama City, Kanagawa 221
        Phone: 045 (461) 2021
      - Parking Lot Management Department
        1-13, Nihombashi Kabuto-cho, Chuo-ku, Tokyo 103
        Phone: 03 (3667) 3357
- Auditor

(Head Office)
1-4-1 Kasumigaseki
Chiyoda-ku, Tokyo 100
Tel. 03 (3502) 7311

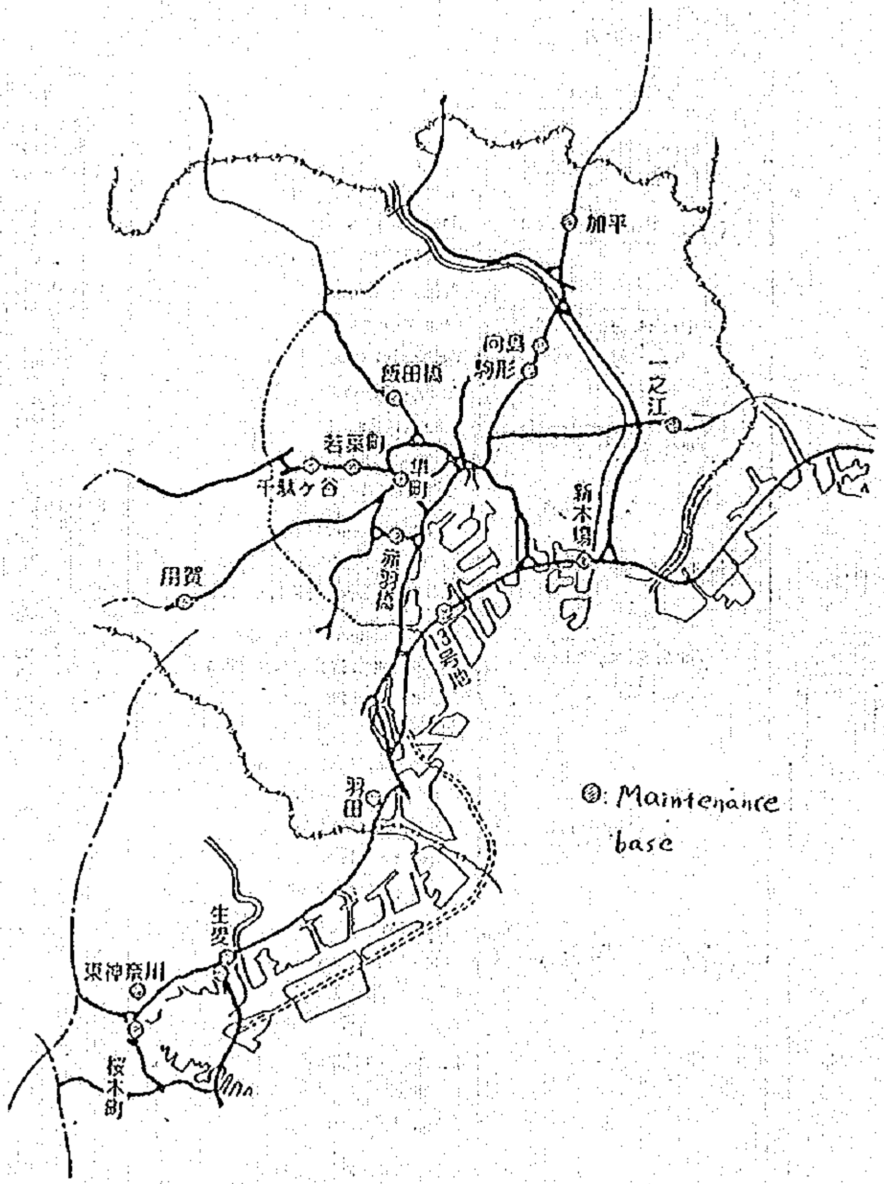


FIG. 1-7 LOCATION OF MAINTENANCE BASE

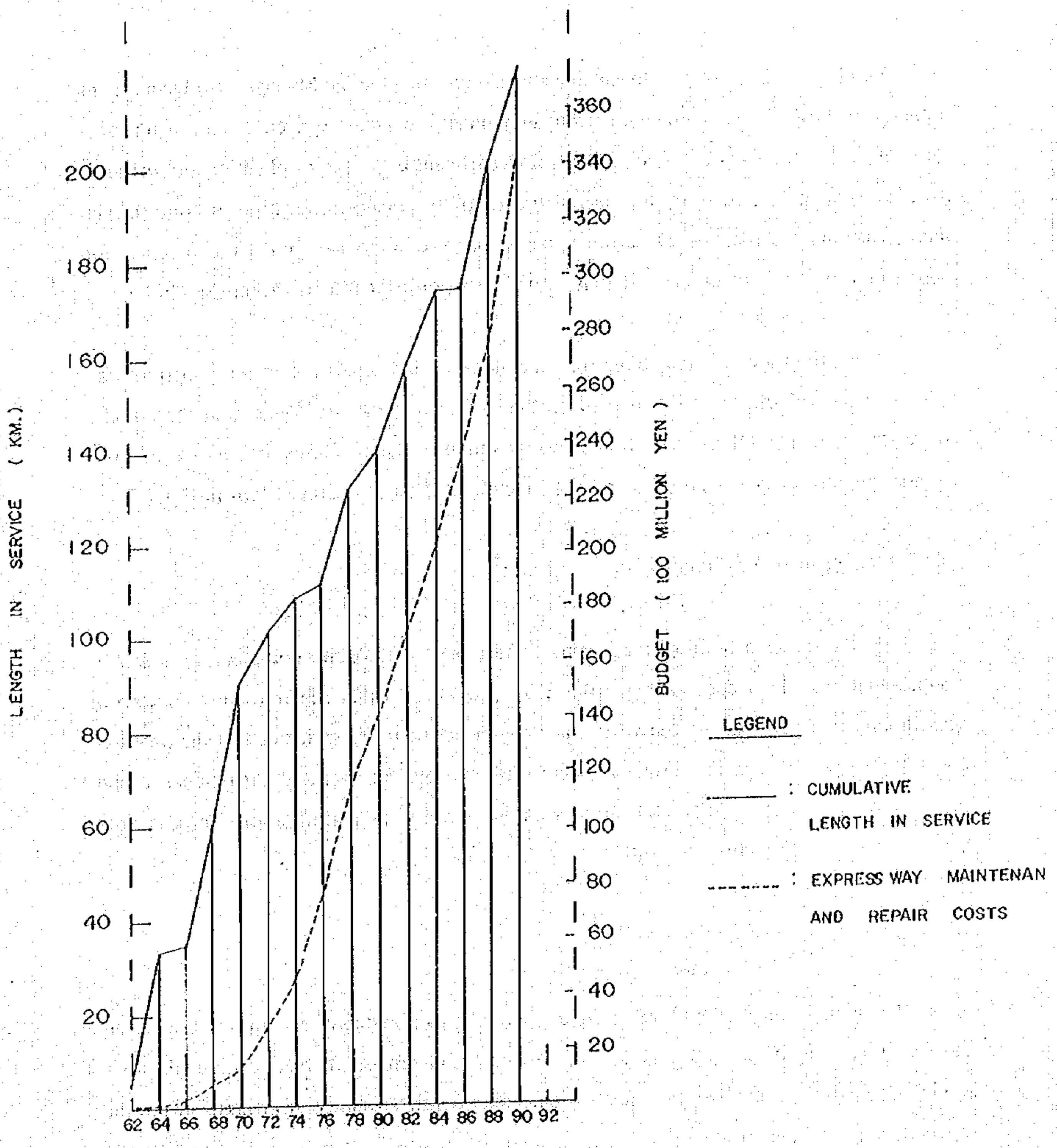


FIG. I-8 TREND OF LENGTH IN SERVICE AND MAINTENANCE & REPAIR COST FOR THE METROPOLITAN EXPRESSWAYS

Head office departments to execute above duties include the Management Department in charge of property management (occupancy under elevated road, etc.) and of business (toll collection, etc.) and the Traffic Control Department in charge of planning and research of traffic control system, improvement of traffic safety devices, execution of control. The Maintenance and Equipment Department takes charge of road maintenance and repair for preservation of road's original functions as well as of disaster rehabilitation (See Fig.1-6).

Direct field jobs related to the road maintenance and repair are under control of one equipment control office and five maintenance offices, which are lower branches of the Tokyo Maintenance Office and Kanagawa Operation Office. Bases in charge of civil engineering and repair of facilities are also erected in 15 locations as shown in Fig.1-7.

1.4 Maintenance and Repair Cost

Fig.1-8 shows a trend of maintenance and repair cost. A chronological trend shows a substantial growth in cost starting from 1971. This means that repair requirement grew substantially in approximately ten years since commencement of service or that the time has come for large-scale repair. Principal factors responsible for increased maintenance and repair cost of the Metropolitan expressways are increased stock and inflation. These factors are expected to exert substantial influence in future too.

1.5 Description of Maintenance Duty

The maintenance as a whole of the expressways can be classified into the servicing and repair and the incurred business. The servicing and repair are further divided into a servicing duty and a repair duty. The servicing duty consists mainly of cleaning while the repair duty repair and improvement. The repair is subdivided into maintenance and repair. (See Fig.1-9).

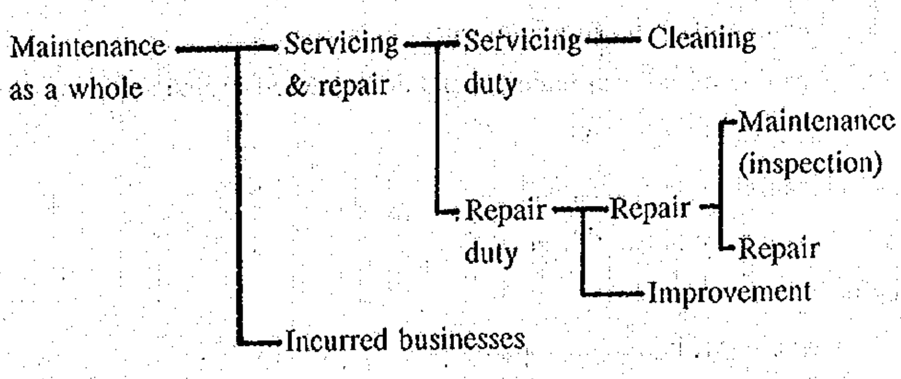


Fig. 1-9 Classification of the Maintenance Business

Servicing and repair of the Metropolitan expressways include following jobs:

1) Servicing

(1) Road Structures

a. Cleaning of road surface

Cleaning by hand and machines, removal of fallen obstacles

b. Cleaning of tunnel

Cleaning of tiled surface and all sections by hand and machines

c. Cleaning of guard rails

Cleaning of guard rails on expressways and bridges by hand and machines

d. Cleaning of drainage equipment

Cleaning of galleys, underground and elevated drainage pipes, lateral ditches

e. Cleaning of traffic signs

f. Cleaning of noise barrier

(2) Facilities

a. Cleaning of lighting apparatus

Cleaning of various lighting apparatus

b. Cleaning of mechanical facilities

Cleaning of surface drainage tank, purification tank, receiving tank, hydrant, fire extinguisher lamp

c. Cleaning of buildings

Cleaning of toll gates and offices

2) Repair

(1) Road Structures

a. Inspection of structures

Patrol inspection, inspection of structures, check of concrete structures for any crack and other fluctuations, inspection inside tunnel, measurement of settlement of structures at fixed points, inspection of special structures (oil damper, etc.)

b. Repair of coating

c. Repair of expansion joints

d. Repair of drainage facilities

e. Repair of pavement

f. Repair of structures

Reinforcement of floor slabs, repair of shoes, repair of protector (handrails, guard rails, fences, noise barriers)

g. Road markings and traffic signs

h. Emergency counteraction in case of disaster

Measures in case of accident, removal of fallen obstacles, countermeasure against snow damage

i. Conservation of green belt

(2) Facilities

a. Lighting facilities

Repair of road lighting apparatus and facilities

b. Drainage facilities

Servicing and repair of pumps and attached machine repair facilities

c. Traffic signs

Repair of traffic signs

d. Ventilation equipment

Servicing and repair of tunnel ventilation equipment and attached equipment

e. Power receiving and distribution facilities

Servicing and repair of power receiving equipment, substations, power generator, remote monitoring and control system, high tension lines, electric manholes

f. Telecommunication facilities

Repair of microwave radio, crime preventive radio, telecommunication line, telephone sets

g. Other electrical equipment

Maintenance of cathodic protection equipment, anti-freezing equipment, electrical equipment

h. Fire fighting equipment

Servicing and repair of foaming extinguisher, CO_2 gas extinguisher, fire detector, water spray

i. Traffic control system

Installation, servicing, inspection, and repair of variable message signs, vehicle detectors, and ITV, and maintenance of traffic control facilities

j. Toll gates and attached buildings

Repair of toll gates, booths, account office, ventilation room, and other buildings and repair of base buildings

k. Axle load measuring system

Servicing and repair of axle load meters and cameras

l. Improvement of tunnel disaster preventive equipment

Installation of fire detector and monitoring TV, water spray system, and alarm boards

m. Pilot lamps

Installation and repair of pilot lamps in curved sections

n. Electrical repair and improvement

Installation of internal illumination sign plates and low voltage switching board, demurring of mercury lamps, improvement of remote monitoring and control system, and improvement of inverter system

o. Improvement of buildings

Improvement of toll gates and booths as well as base buildings

p. Mechanical improvement

Improvement of tunnel ventilation control system

Above listed are road maintenance items and various related jobs. Since 85.4% of the entire Metropolitan expressways is occupied by the elevated section, the maintenance and administration have a long-term significance. In this view, the inspection duty and repair duty for concrete and steel structures in particular are described below together with the outline of job and necessary precautions.

The repair duty begins with inspections. The patrol Inspection helps early detection of deteriorated or damaged portion of road, followed by emergency countermeasure (if necessary) to secure safe and smooth traffic and to keep road facilities intact.

Inspection, by its nature, can be classified into routine inspection, periodical inspection, and special inspection (See Fig.1- 10 and Table 1-3).

[1] Routine inspection

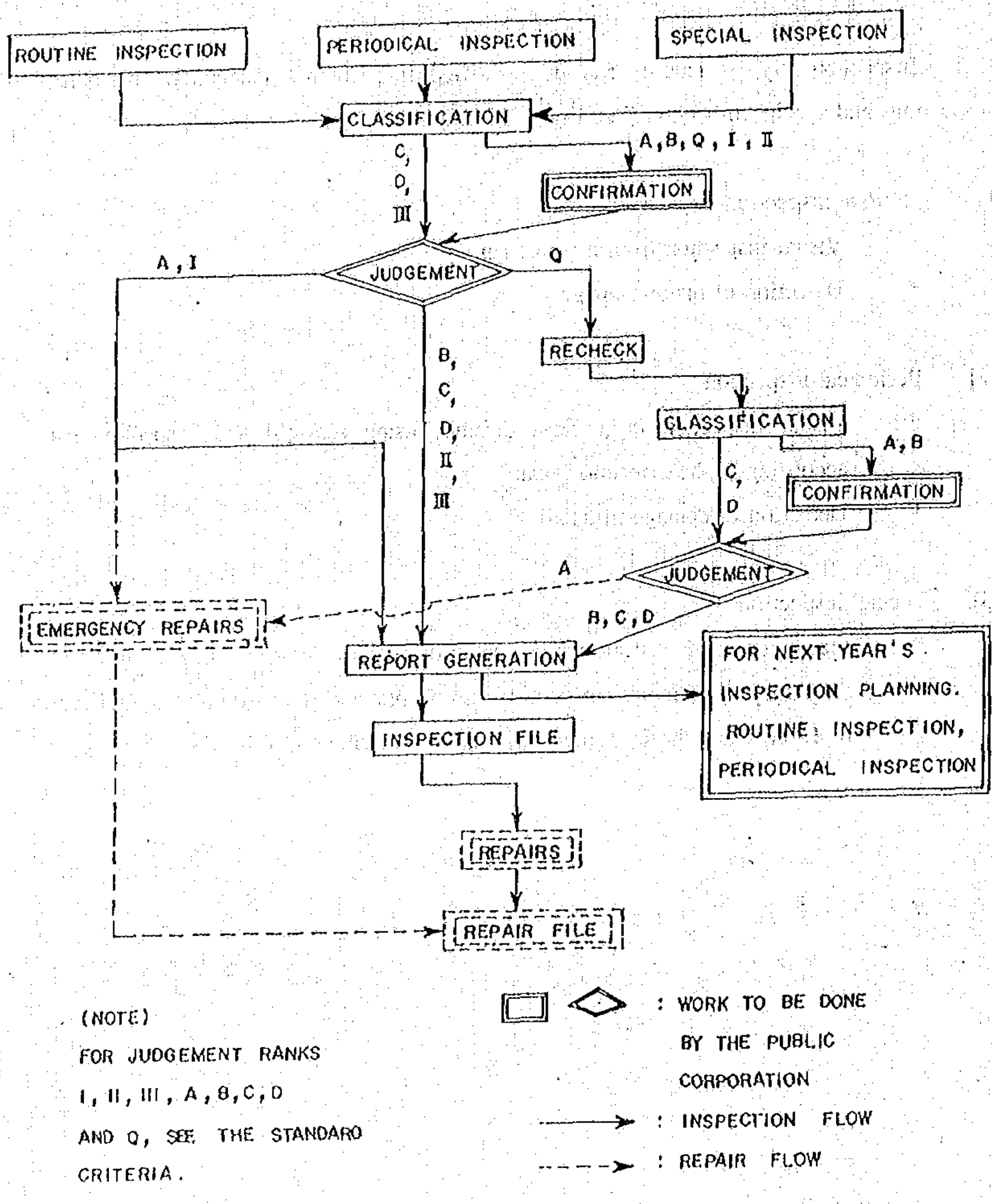
* Visual inspection from a patrol car
* Detection of major damage

[2] Periodical inspection

* Visual inspection in a close distance using scaffold and inspection car according to the inspection plan
* Detection of damage in detail

[3] Special inspection

* Inspection conducted after unexpected disaster or damage. The method and frequency of periodical inspection on concrete and steel structures are shown in Table 4 and the judgement criteria are described in Table 1-5.



(NOTE)
FOR JUDGEMENT RANKS
I, II, III, A, B, C, D
AND Q, SEE THE STANDARD
CRITERIA.

FIG. 1-10 STRUCTURAL INSPECTION FLOW CHART

Table 1-3 The standard criteria

Judgement of routine inspection

Judgement	Condition
I	Damage considered to be serious. Largely influencing traffic and 3rd parties. Emergency repair required.
II	Damage is medium in size has some influence on the environment, but not causing any serious threat to traffic. Repair work may be necessary.
III	Damage is small with no influence at present to traffic nor deterioration of structural function. Structure should be inspected on a daily basis for the progress of damage.

Standard criteria for periodical and special inspection

Condition	Judgement
Structure is damaged to a serious degree. Largely influencing traffic and 3rd parties. Emergency repairs are required.	A
Damage is observed and Normal, not emergency, repairs need to be taken. Structure needs to be strengthened. Repair work should be carried out to such an extent that there is not detrimental influence to traffic or the environment.	B
Damage found but only at the stage to be recorded	C
No damage or minor damage which needs no record.	D
Damage is seen but its degree cannot be clearly determined, or abnormal damage which should be examined using another method.	Q

When damage is classified as being of the Q type, the reason for the judgement should be clearly recorded.

Table 1-4 Periodical Inspection on Concrete and Steel Structure

Inspection from scaffold	Visual inspection in a close distance or with measuring instruments, using scaffold used in coating repair or floor slab reinforcement work. Frequency: Each time the scaffold is erected.
Inspection of Piers and girders	Visual inspection in a close distance or with measuring instruments, using scaffold or inspection car, on girder end cross girder, floor slab end, support, and expansion joint around pier or pier girder. Frequency: Every five years
Inspection while Walking under viaduct	Visual inspection or inspection with a binocular while walking under viaduct, for the purpose of early detection of excessive damage or structure, fallen obstacles possibly affecting any third party, abnormal sound. Frequency: Once a year
Inspection inside the box girder	Inspection for any flaw or crack particularly in floor slabs while entering directly into the box girder through existing hole. Frequency: Every five to seven years
Inspection of concrete girders using photo	Inspection for any damage using photos of girders taken by a photographing engineer under direction of an inspection (engineer and inspector forming a team). Photographic accuracy must enable judgement of crack of around 0.1 - 0.2 mm. Frequency: Every five to seven years
Dynamic inspection of concrete	Inspection to grasp development of flaw and crack in concrete requiring follow-up by measuring variation of flaw and crack with a contact gauge, etc. Frequency: Twice a year
Inspection of high-tension bolts	Visual inspection of FHT for any missing bolt or crack by hammering or ultrasonic flaw detection. Frequency: Every ten years

Table 1-5 **Judgement Criteria for Inspection from Scaffold, Inspection of Pier and Girder, Inspection inside Box Girder and Inspection of High-tension Bolts**

Judgement Rank / Item	Emergency Repair Necessary	Repair Necessary	Recording Necessary	Recording Not Necessary	Re-check According to Different Method
Crack	* Concrete breakage, possibly causing obstruction to traffic safety or any third party.	* Max. width 0.3 mm for RC and 0.2 mm or more for PC, with depth more than 2/3 of sectional dimension in a cracking direction. * Max. width 0.3 mm or more, with a crack interval less than 50 cm. * Max. width 0.3 mm or more, with scale on reinforcement.	* Max. width 0.2 mm for RC and 0.1 mm for PC, with depth more than 1/2 of sectional dimension in a cracking direction and with a crack interval less than 50 cm.	* Max. width 0.2 mm for RC and less than 0.1 mm for PC or no cracking	* Damage not clearly identifiable and abnormal damage requiring different method for inspection.

Table 1-5 **Judgement Criteria for Check from Scaffold, Check of Pier and Girder, Check Inside Box Girder and Check of High-tension Bolts (Cont'd)**

Judgement Rank / Item	Emergency Repair Necessary	Repair Necessary	Recording Necessary	Recording Not Necessary	Re-check According to Different Method
Break-off and exposed steel members	* Concrete breakage, possibly causing obstruction to traffic safety or any third party.	* Concrete reinforcement, PC steel, and PC sheath. * Exposed anchorage of PC steel members. * Corrosion of steel members.	* With break-off but without exposure.	* Without break-off and exposure of reinforcement.	* Damage not clearly identifiable and abnormal damage requiring different method for inspection.
Deterioration and discoloration	- ditto -	* Possible scaling of reinforcement and resulting break-off of concrete. * Insufficient strength due to Schmidt hammer, etc.	* With deterioration but insufficient strength.	* Without deterioration.	- ditto -

Table 1-5 Judgement Criteria for Inspection from Scaffold, Inspection of Pier and Girder, Inspection Inside Box Girder and Inspection of High-tension Bolts (Cont'd)

Judgement Rank / Item	Emergency Repair Necessary	Repair Necessary	Recording Necessary	Recording Not Necessary	Re-check According to Different Method
Cavity, honeycomb	* Concrete breakage, possibly causing obstruction to traffic safety or any third party.	* Exposed inforcement, PC steel members, and PC sheath. * Cavity and honeycomb near anchorage of PC steel members.	* With cavity, but without exposed steel member.	* Without cavity and honeycomb.	* Damage not clearly identifiable and abnormal damage requiring different method for inspection.
Water leak	* With possible obstruction to any third party.	* Water leaking from crack concrete placement joint.	* With water leak, but without possible corrosion of steel members.	* Without water leak.	
Damaged member	* With possible breakage or break-off of member and with abnormal sound possibly affecting traffic and any third party.	* With breakage causing deterioration of load carrying capacity	* With damage, but not presenting major problem.	* Without damage or with minor damage.	
Deformed members		* With deformation causing deterioration of load carrying capacity	* With deformation, but not presenting major problem.	- ditto -	

Table 1-5 Judgement Criteria for Inspection from Scaffold, Inspection of Pier and Girder, Inspection Inside Box Girder and Inspection of High-tension Bolts (Cont'd)

Judgement Rank / Item	Emergency Repair Necessary	Repair Necessary	Recording Necessary	Recording Not Necessary	Re-check According to Different Method
Missing or loose HT bolt	* With possible breakage or break-off of member and with abnormal sound, possibly affecting traffic and any third party.	* One or more missing or broken bolt per one connection.	—	* Without damage or with minor damage.	* Damage not clearly identifiable and abnormal damage requiring different method for inspection.
Missing or loose rivet		- ditto -	—	- ditto -	
Corrosion		* Sectional loss due to corrosion.	—	- ditto -	
Water seepage and leak		* Water seepage or leak inside box girder and pier.	—	- ditto -	
Abnormal sound		* Abnormal knocking sound between	—	- ditto -	
Others		* Functional abnormality	—	- ditto -	

The Metropolitan expressway are facing not only deterioration of structures, but also increased and complicate attached equipment. And thus the inspection duty requires increased in work amount, sophistication of technology, or high-level specified knowledge.

To ensure rational and efficient inspection, strengthening of the field organization, development of better inspection practice, standardization of judgement criteria, compiling of inspection result in good order, and other improvements must be made. Currently a computer system and achievement suitable solution.

Following is a list of conventional instruments and tools for inspection.

- For routine inspection

  A pain of binoculars, steel measure, ruler, test-hammer, plumb bob, camera

- For periodical inspection

  A pain of binoculars, steel measure, ruler, magnifying glass, slide calipers, clearance gauge, wire blush, test-hammer, plumb bob, plumb line, camera, blackboard

- For both occasion

  Inspection vehicle, traffic control device, torch, ladder Special instruments are used for specific purpose of inspection

- Crack measuring instrument

  Contact gauge, crack gauge, eye gauge, special point clearance gauge

- Deformation/settlement measuring instrument

  Level, theodolite, incline gauge

- Concrete strength measuring instrument

  Schmidt hammer

- High-tension bolt inspection instrument

  Torque wrench, ultrasonic flaw detector

- Pavement measuring instrument

  Surface photographing vehicle, profile meter 3.6 m long ruler

Any damage found in the road inspection must be repaired. Basic requirements for repair are as follows:

1) Repair must satisfy the strength requirement.
2) The repair method must be reasonable in terms of engineering.
3) Repair must not inflict any damage to the main body (structural system, design conditions).
4) The repair method must be economically feasible.
5) Due consideration must be paid on appearance after repair.

For the Metropolitan expressways, the repair of road and bridges is of most importance. The outline is shown in Table 1-6.

Table 1-6 The outline of repair work

<table>
<tr><th>Type</th><th>Work Method</th><th colspan="3"></th></tr>
<tr><td rowspan="4"></td><td>Repair</td><td colspan="3">* Executed only when crack does not directly cause deterioration of load carrying capacity, for the purpose of recovery of water-proof performance and durability of concrete.
* In general, epoxy resin is used for surface treatment, injection, or filling of portions with crack, honeycomb, exposed reinforcement, water leak.</td></tr>
<tr><td rowspan="2">Reinforcement</td><td>Direct method</td><td colspan="2">* Method, in which integration with existing concrete is made to reinforce damaged member.
* Method, in which actual stress is reduced by dispersing stress (through increase in section using concrete, steel plate, PC steel member) and by applying a force opposite to acting force.</td></tr>
<tr><td>Indirect method</td><td colspan="2">* Method, in which stress is dispersed by inserting different members (additional girders, etc.).</td></tr>
<tr><td>Replacement</td><td colspan="3">* Removal of existing members and replacement with new equivalent members where the repair is ineffective because of excessive deterioration or where replacement because of traffic and location conditions. There are a partial replacement and a whole replacement.</td></tr>
<tr><td rowspan="5"></td><td>Emergency measure</td><td rowspan="5">* Executed in case of buckling, cracking, cutting, deformation, loss, corrosion of steel structures, by welding or bolting of new steel members.</td><td>Temporary support, etc.</td><td rowspan="5">* The steel structure has thin members. Due attention must be paid to prevent deviation of the initial structure system from design conditions (and thus stress concentration in unexpected point), which is caused by cutting of drilling of member as well as accidental removal or addition of members during when welding or bolting reinforcement members due consideration must be directed to variation of existing girder under stress of traffic.</td></tr>
<tr><td>Rehabilitation</td><td>Replacement of members</td></tr>
<tr><td>Reinforcement</td><td>Installation of cover plate, reinforcement member</td></tr>
<tr><td>Improvement</td><td>Change to new structure</td></tr>
<tr><td>Corrosion prevention</td><td>Cleaning, anticorrosive coating</td></tr>
</table>

1.6 Present Problem Factors in Maintenance

Details and organization of the maintenance and administration corresponding to the unique structure of the Metropolitan expressways have been described. What is specifically different from ordinary roads may be considered as the elevated structure running over roads and rivers, linear and structural complexity with lot of curved sections, high utilization factor (because of trunk line) with traffic volume nearly reaching the capacity, and most diversified accessories like traffic control equipment, traffic safety equipment, etc. for smooth and safe operation of giantic traffic. It is now evident that these elements have greatly affected maintenance and administration. Essential points to be taken into consideration at present and in future concerning maintenance and administration are described below. These points may also lead to increased maintenance and repair cost.

The first point is outdated stock. In 30 years since commencement of service, the 10-year or more old portion has now occupied 63% (as of April, 1991) of the whole of the Metropolitan expressways. Outdated stock causes increase in maintenance and inspection work cost, with individual jobs growing in scale and requiring more and more care. Moreover, growing outdated stock as time passes by makes re-coating, re-pavement, and other repairs necessary in increasing degree.

The Metropolitan expressways comprises various components with different durability. For example, road markings are erased within one year while expansion joints and pavement require replacement in approximately ten years. Girders are expected to have durability of 50-70 years while piers and foundation piles much longer durability. Consequently the currently applied maintenance and administration are wide ranging, including not only cleaning, but also various inspections, bolt replacement, coating repair, repair of drainage facilities, repair of pavement, repair of expansion joints, and other jobs related to lighting, electrical and telecommunication facilities. Concurrently the job amount is growing. Now the time is approaching for repair of structures themselves, such as partial replacement of concrete floor alabs, partial reinforcement of girders, etc. In future, this type of repair will surely increase steadily.

Factors responsible for accelerated deterioration of roads include traffic volume far exceeding the initial estimate, larger size vehicles, increased overload vehicles, etc. As a result, fatigue and wear of roads are much heavier than expected from the age, with cumulative increase in durability maintenance and repair costs. Reinforcement of floor slabs and girders has made necessary because utilization exceeded greatly the initial expectation. For example, vehicles have become so large that the initial floor slab design standard has becomes insufficient and floor slabs have to be reinforced to meet the present design standard.

Natural environment is also responsible for accelerating deterioration. Air pollution promote deterioration of concrete and coastal roads are expected suffer salt damage, with increased repair frequency.

The second point is that the Metropolitan expressways are equipped with intricate and sophisticated accessories to execute road administration. These accessories require high level knowledge and technology with increased cost. It is also necessary to take balance of technological development of equipment between old and new routes. Replacement work thus required causes further increase in working days and expenditures.

The third point is the environmental control measure and disaster preventive measure. The Metropolitan expressways comprises mainly elevated section built in the heavily populated urban area, thereby presenting environmental problems such as noise vibration, exhaust gas, hindrance sunshine, radio wave disturbance,etc. And the well-considered counteraction to these problems is the most important subject in planning, construction, and management of the Metropolitan expressways. For example, more and more noise barriers have come to be installed in response to demand from inhabitant along the route, resulting in increased maintenance and repair costs. Another examples are the improvement of girder fall preventive equipment to meet earthquake condition and installation of water spray to prevent disaster inside tunnels.

The fourth point is a state making effective maintenance and repair job impossible. The Metropolitan expressways have two lanes on one side and the maintenance and repair have to be made during night time because of heavy traffic volume. On the other hand, any job accompanying large noise has to be avoided during midnight, greatly limiting the time available for job. Besides, the possibility of realizing effective combination of various kinds of jobs (e.g., job with large noise and that with small noise) is limited, making the job inefficient. These also contribute to pushing up costs.

The fifth point is the soaring personnel expense because of shortage of manpower, new investment for mechanization of the work to offset above shortage and accompanying maintenance and repair costs. These may be expected newly in the future aging society.

Finally, there may be a problem of controlling vast information concerning roads. Namely, it is important to classify past repair frequency, repair time, repair cost, and ground conditions for future reference to ensure proper repair planning and reasonable execution. For this purpose, a computer has been introduced since 1981 and the detail will be mentioned in chapter five.

2. Inspection and Maintenance Work of the Expressway and Rapid Transit Authority of Thailand

2.1 General

The Expressway and Rapid Transit Authority of Thailand (ETA) is responsible for planning, study, design, construction and operation of the expressway system in Thailand. Up to now, ETA has carried out the construction of the expressway system in Bangkok, namely Chalerm Maha Nakorn Expressway, consisting of three sections which are the Din Deang-Port section (8.9 km), the Bang Na-Port section (7.9 km), and the Dao Khanong-Port section (10.3 km) as shown in Fig. 2.1. The first two sections have been opened to traffic for ten years (October 29, 1981) and nine years (January 17,1983) respectively, while the Dao Khanong-Port section including a long span cable stayed bridge, named the Rama IX Bridge, was opened to public use on December 5, 1987 in order to commemorate His Majesty the King's 60th Birthday Anniversary.

The expressway system is the most important links connecting business districts of Bangkok each other and it also serves at the artery connecting Bangkok with the rest of the country including the increasing industrializing eastern Seaboard. The total length of the expressway in service is 27.1 km at the present with a traffic volume increasing from approximately 9.29 million vehicles/year in 1982 to 104.19 million vehicles/year in 1990 (See Table 2-1). The traffic volume showed an increase by approximately 11 times for about 3-fold increase of the length in service.

The traffic volume per km has increased by approximately 4 times from 1,050,000 vehicles/km/year in 1982 to 4,200,000 vehicles/km/year in 1990 and it is still keeping the rate of growth. The percentage of large trucks is around 9% in 1988.

Maintenance work on the expressway system is still in an early stage as the system is only ten years old. However the maintenance will gradually become a major concern of the ETA as the system gets older. It carries more than 300,000 vehicles per day. If the

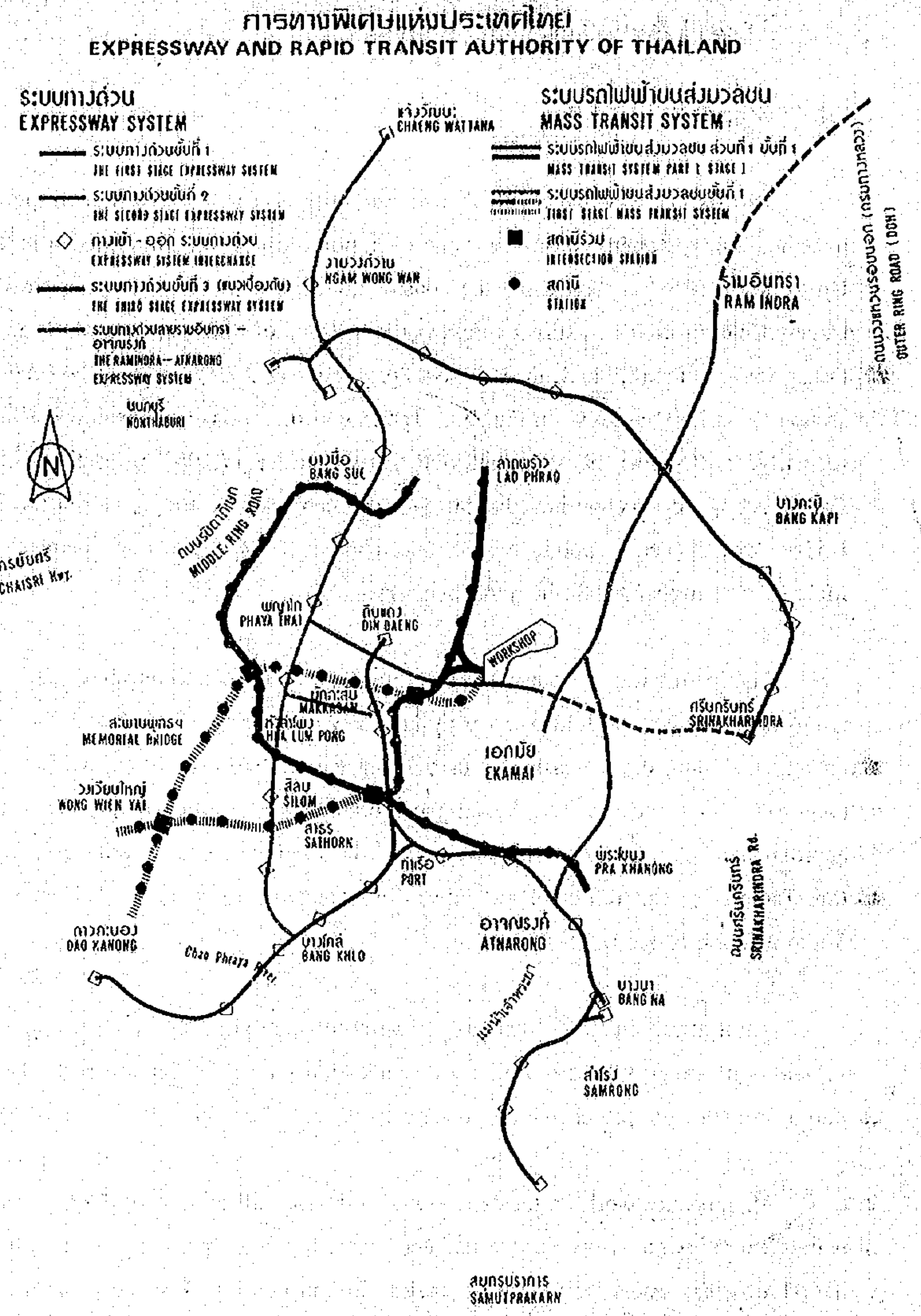

การทางพิเศษแห่งประเทศไทย
EXPRESSWAY AND RAPID TRANSIT AUTHORITY OF THAILAND
EXPRESSWAY SYSTEM
MASS TRANSIT SYSTEM
CHAENG WATTANA
NGAM WONG WAN
NONTHABURI
RAM INDRA
OUTER RING ROAD (DOH)
BANG SUE
LAD PHRAO
BANG KAPI
MIDDLE RING ROAD
BANGKOK NOI - NAKORNCHAISRI Hwy.
PHAYA THAI
DIN DAENG
WORKSHOP
MAKKASAN
MEMORIAL BRIDGE
HUA LUM PONG
SRINAKHARINDRA
EKAMAI
WONG WIEN YAI
SILOM
SATHORN
PHETKASEM Rd.
PORT
PRA KHANONG
SRINAKHARINDRA Rd.
ATNARONG
DAO KANONG
BANG KHLO
Chao Phraya River
BANG NA
SAMRONG
SAMUTPRAKARN

Fig 2-1

Table 2–1 NO. OF VEHICLES USING THE CHALERM MAHA NAKHORN EXPRESSWAY: FYs 1982–1990

(Unit: Vehicle)

Month	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total	9,289,544	26,777,037	40,068,084	45,301,533	49,161,878	55,459,800	76,628,839	91,289,594	104,185,044
October	38,887	1,004,279	3,268,854	3,409,938	3,943,309	4,243,636	5,022,862	7,186,233	8,074,776
November	571,043	1,054,690	3,653,398	3,615,275	4,059,652	4,292,966	5,250,314	7,340,332	8,337,090
December	733,505	1,145,592	3,528,122	3,643,686	4,075,039	4,569,956	6,523,759	7,616,262	8,649,945
January	805,289	1,597,678	3,436,407	3,700,264	4,171,991	4,578,649	6,477,319	7,556,760	8,649,690
February	758,302	2,184,589	3,116,669	3,458,950	3,805,107	4,221,396	6,243,208	6,859,813	7,968,232
March	901,990	2,588,996	3,429,505	3,906,929	4,295,437	4,821,329	6,755,426	7,882,235	9,112,581
April	880,238	2,607,581	3,206,270	3,903,868	4,152,993	4,597,027	6,442,031	7,411,672	8,360,533
May	853,417	2,658,276	3,312,481	4,045,327	3,991,815	4,659,131	6,516,039	7,772,845	8,931,849
June	899,286	2,760,423	3,222,811	3,848,023	4,090,480	4,783,500	6,711,216	7,786,300	8,885,171
July	925,735	2,914,239	3,260,593	3,951,012	4,198,516	4,952,248	6,674,588	7,829,203	9,065,901
August	956,014	3,033,028	3,378,886	3,945,536	4,249,450	4,964,622	6,982,580	8,113,303	9,299,978
September	975,838	3,227,396	3,251,088	3,872,725	4,128,089	4,775,340	7,029,497	7,934,636	8,849,298

expressway system fails to function, the entire economy of Thailand would suffer a terrible setback. The proper maintenance of the expressway system is and will be of vital importance to Thailand.

2.2 Structure Type of ETA

Structures of the expressway system in Bangkok are mainly classified into the next two types.

1) The Rama IX Bridge section (steel girder)

The Rama IX Bridge is a single plane cable-stayed bridge at Watsai crossing over the 500 m wide Chao Phraya River.

Type of bridge	:	Single plane fan type cable-stayed bridge with steel box girder
Span length	:	Main span 450 m
		Back span 165.60 m (61.20 + 57.60 + 46.80)
Bridge length	:	781.20 m
Width of bridge	:	31 m - 33 m
Gradient	:	5.0 %
Crossfall	:	2.5 %

Navigation clearance through the main span : 41 m

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

2) Other sections except The Rama IX Bridge (concrete girder) The most typical expressway structures are shown in Fig. 2.2 As shown in this figure, The basic design consists of a 20 m span constructed from pre-tensioned I beams with in situ cross beams at either end constructed within the depth of the longitudinal beams. These cross beam rest on rubber bearings which in turn are carried on discrete columns. The joint between the spans are waterproofed by deck flashing, with a second line of defence over columns in an attempt to avoid unsightly staining. The asphalt surfacing is then carried over the joints.

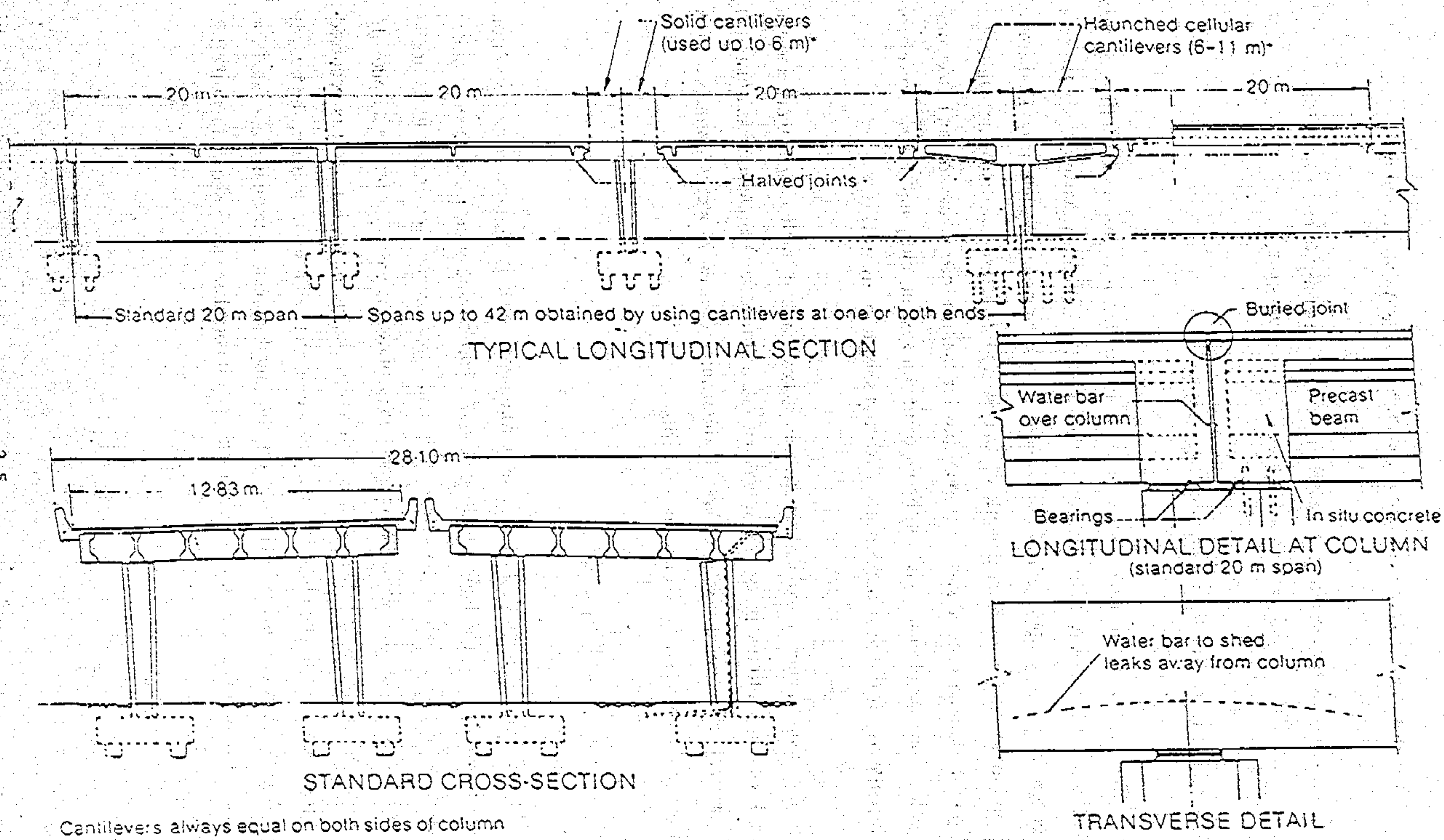


FIG. 2-2 BASIC VIADUCT (SHOWING POSSIBLE RANGE OF SPANS)

The primary design specifications for the expressways are as follows,

* A Policy on Design of Urban Highway and Arterial Streets, AASHTO
* Standard Specifications for Highway Bridges, AASHTO

2.3 Maintenance and Administration Organization

The current maintenance work of ETA is divided into the responsibility of two divisions; the Expressway Maintenance Division and the Equipment Maintenance Division under the Expressway Management Department. The Expressway Maintenance Division is responsible for the maintenance work of expressway structure and cleaning while the Equipment Maintenance Division is responsible for maintenance of electric and electronic equipment, such as electric light, toll booth operation system, etc., and electric power for the expressway. The organization chart of ETA is shown in Figure 2.3.

The maintenance of expressway structure takes a bulk of maintenance work and the work is separated into two parts; bridge maintenance and roadway maintenance as illustrated in Figure 2.4. However the Right of Way Maintenance (General Property Maintenance) is included in the Expressway Maintenance Division.

2.4 Maintenance and Repair Cost

For the budget request, the Expressway Maintenance Division prepares an inspection and repair work plan. The budget is divided into 3 parts; inspection, force account repair and contract repair. The budget for inspection and force account repair are likely to be increased by 50% annually while the contract repair budget is based on the actual plan. In the case of the Rama IX Bridge, which is four years old, no major damage has occurred except pavement repair. Therefore, its maintenance budget has been included in the budget of the Expressway Maintenance Division due to the small amount. The budget allocated for the Expressway Maintenance Division since 1982 and its breakdown are shown in Table 2-2 and 2-3.

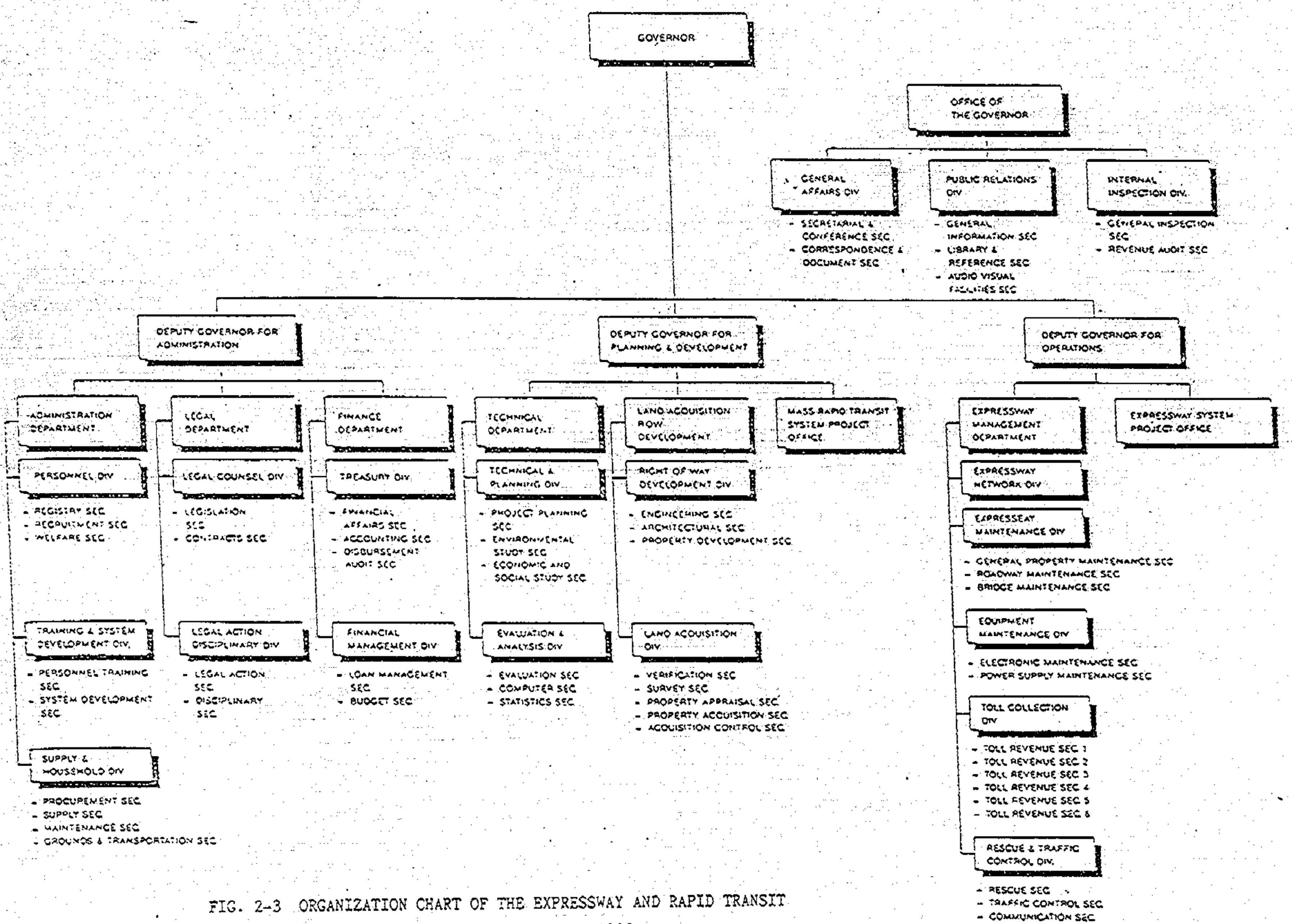
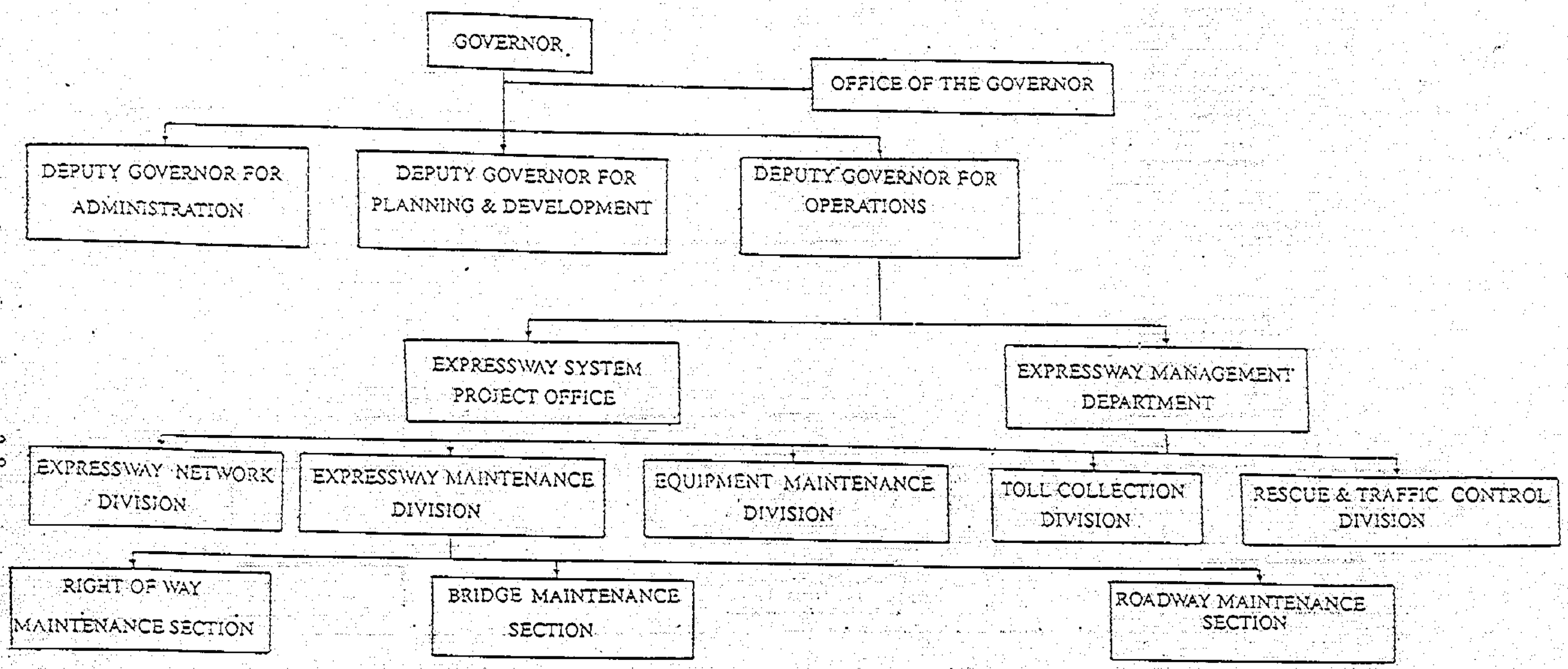


FIG. 2-3 ORGANIZATION CHART OF THE EXPRESSWAY AND RAPID TRANSIT AUTHORITY OF THAILAND: FY 1990

MAINTENANCE ORGANIZATION STRUCTURE



- Inspection and Maintenance of Bridge Structure & Foundation
- Inspection of Bridge Cables
- Provision of Maintenance Plan & Record
- Employment & Supervision of Contract Works
- Provision of Repairing Work In Case of Emergency
- Estimation of Bridge Damage Costs Due to Accidents
- Other Relevant Works

- Inspection & Maintenance of Roadway, Building & All Civil Works
- Inspection of Roadway Structure, Pavement, Shoulder, Etc.
- Provision of Maintenance Plan & Record
- Employment & Supervision of Contract Works
- Estimation of Roadway Damage Costs Due to Accidents
- Analysis & Development of Work System & Equipment
- Provision of Repairing Work in case of emergency
- Other Relevant Works.

FIG. 2-4 MAINTENANCE ORGANIZATION STRUCTURE

Table 2-2 THE CHALERM MAHA NAKHORN EXPRESSWAY OPERATING EXPENSES: FYs 1982-1990

(Unit:Millions of Baht)

Month	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total	2.22	21.61	37.81	57.91	63.22	57.76	83.01	104.29	130.55
Administration Expenses	0.34	11.75	18.75	22.67	25.06	26.78	39.94	49.26	58.12
Toll Operation Expenses	1.61	7.84	11.98	13.40	12.08	11.18	22.43	24.11	24.96
Road Maintenance Expenese	0.27	2.02	2.06	5.95	8.40	2.96	6.89	16.41	13.92
Equipment Maintenance Expenses	–	–	5.02	4.80	5.82	2.67	2.10	1.66	5.22
Investment Expenses(1)	–	–	–	11.09	11.86	14.17	11.65	12.85	28.33

Note : Investment expenses include land and construction cost,durable articles cost, reserved money for urgent matter and reserved money for changed price.

Table 2-3 Break of Budget for Expressway Maintenance

unit : Baht

No.	Item \ Fy	1986	1987	1988	1989	1990	1991	1992
1	Roadway & Bridge	8,400,000	2,960,000	6,890,000	n.a.	n.a.	38,750,000	39,200,000
	1.1 Joint	–	–	–	"	"	17,250,000	11,810,000
	1.2 Pavement	–	–	–	"	"	19,500,000	22,750,000
	1.3 Road Marking	–	–	–	"	"	1,400,000	2,025,000
	1.4 Steel work	–	–	–	"	"	–	465,000
	1.5 Traffic Sign	–	–	–	"	"	–	1,300,000
	1.6 Toll Booth	–	–	–	"	"	500,000	750,000
	1.7 Equipment(Rent)	–	–	–	"	"	100,000	100,000
2	Cleaning of expressway	–	–	–	5,578,930	5,220,000	8,505,000	9,710,000

2.5 Inspection and Repair Work

The Expressway Maintenance Division is responsible for the inspection and repair of the expressway. Since the expressway is a new concept of transportation in Thailand. ETA has requested the Japanese Government to send experts under a cooperation of the Japan International Cooperation Agency (JICA) to assist in formulating a maintenance system. JICA has sent a series of experts to assist the Expressway Maintenance Division and several reports and manuals for maintenance work of expressway have been prepared by JICA experts.

Following the study results by a close collaboration of JICA experts and ETA staff, a maintenance work plan was set up comprising of inspection and repair work as described below:

1) Inspection

There are three kinds of inspection such as routine inspection, periodic inspection and special inspection.

- routine inspection; daily inspection by eyes or simple equipment
- periodic inspection; regular inspection for a specified time period which may need special equipments in some cases
- special inspection; to supplement the routine inspection and the periodic inspection or in case of emergency such as accident or disaster.

The inspection items for the expressway and the Rama IX Bridge are categorized into the following 11 and 17 items respectively.

- the Rama IX Bridge

1. Girder (inside)
2. Girder (outside)
3. Pylon (inside)
4. Pylon (outside)
5. Cables
6. Pendel cable
7. Bearing, pendel and wind-shoe
8. Drainage system

- the expressway

1. General condition
2. Shoulder and drainage
3. Building
4. Sanitary
5. Metal works
6. Painting
7. Toll booth
8. Expansion joint

9. Expansion joint
10. Damper
11. Maintenance gantry
12. Cradle
13. Lift
14. Permanent instrument
15. Pier and abutment
16. Concrete deck
17. Pavement

9. Pavement
10. Road marking
11. Expressway structure

2) Repair

The repair work can be classified into 2 categories ; force account-repair and contract-repair. Force account-repair is for simple repair works or emergency work, such as pavement pitching, painting, etc. On the other hand, contract-repair is for the jobs which are beyond the capability of ETA or non-emergency work such as asphalt paving, road marking, guardrail installation, etc.

The procedure for force account-repair as follows;

- site inspection
- damage report to office
- repairing consideration by engineer
- assignment to responsibility unit (if it is not over the capability)
- record to the repair book
- repair
- monitoring
- report to office including actual cost calculation

All the above processes are recorded in the following form which is an experimental form since 1986.

According to the repair experiments of ETA, it was found that structures of the expressway, which frequently required the repairing, are asphalt pavement of at-grade section and expansion joint. There are 2 sections of roadway that were constructed

The Expressway and Rapid Transit
Authority of Thailand

Experimental Form
07/00/80

REPAIR SHEET
(TRANSLATION)

No. ....

◯ Electronics	◯ Water & Sanitary	◯ Concrete	Job No. ....
◯ Electric Power	◯ Building	◯ Metal & Sign	Sec. ....
◯ Mechanics	◯ Pavement	◯	Div. .... Dept. ....

1. Repair Oder
Receiving Date.../.../...Time......
Starting Date.../.../... Time......
Material................................
....
....
No. ....
Location ....

Description of Damage...................
....
....
....
....
Repair Method...........................
....
....
Odered by ....

2. Repair
Company ....
Evidence..........No. .....
ETA
Working ....Hours

Name	Signature	Position
Chief 1.	....	....
2.	....	....
3.	....	....
4.	....	....
5.	....	....

3. Repair Note ....
....
....
....
....

4. Repair Time
Starting Date .../.../... Time.......
Finishing Date .../.../... Time......

5. Remarks (After Complete) Normal
Others..................................
....

6. Be Noticed of Repair by
Signature ....
(.........................)
Position ..../.../...

7. Summery of Cost	Total Amount	Remarks
7.1 Meterial Cost		Deltails on the back
7.2 Labor cost		Deltails on the back
7.3 Others		Deltails on the back
Total		Deltails on the back

8. Inspection Note ....

....

Inspector ....

(..........................)

Position ..../.../...

9.Approve

Signature.......................

(......................)

Sect. Chief................ .../.../...

7.1 Meterial Cost

No.	Item	Date	Amount	Unit Cost	Total	Remark
1						
2						
3						
4						
5						
6						
&						
9						
10						
11						
12						
13						
14						
15						
		Total Amount				

7.2 Labor Cost

No.	Name	Normal		Over Time		Total	Remarks
		Hr.	Baht	Hr.	Baht		
1							
2							
3							
4							
5							
	Total Amount						

7.3 Others

No.	Item	Total	Remarks
1			
2			
3			
	Total Amount		

Reporter ....

(..............................)

Position ..../.../...

on the ground level: in Khlong Toey and Bang Na. As the soil condition of Bangkok is soft clay, the different settlement of pavement and drainage system for these sections are also a major problem for maintenance. The repair work for the Rama IX Bridge, except for the pavement of bridge, were mainly simple repairs caused by accidents such as painting, guardrail repairing, etc.

Due to the lack of equipment and manpower, the inspection and repair work could not be implemented as planned. The routine inspection can be conducted while the periodic inspection is indifficult situation especially for the Rama IX Bridge. It needs more special equipment and skilled staff such as a qualified engineer.

2.6 Data Availability and Processing Capability

1) Inspection Records

Due to the lack of equipment and manpower, only the routine inspection can be done at present. For the periodic inspection needs not only the equipment and staff for inspection but also inventory system. As of now, ETA has only an inventory of expansion joints of expressway, which shows the location and maintenance record of expansion joint, that was a part of the conditions of the construction contract. However, the Roadway Maintenance Section has just started to make an inventory system for the other structures of the expressway such as beam, pavement, girder, column and etc. The inspection forms for each structure have already prepared.

2) Repair Records

As the repair work is classified into 2 categories ; force account and contract, the force account repair details have been kept in the repair book and the report form (as shown in page 2-13-15) which has no summary for the results or used budget. The recording has been started in 1986 for the Roadway Maintenance Section and 1989 for the Rama IX Bridge Maintenance Section which were kept in the cartons at each section. The repair record of the expressway in 1986 and 1987 were lost due to the lack of inventory system.

The approximate numbers of repair records by repair sheet of each section which can be roughly translated as numbers of repair by force account are shown below ;

Number of Repair Sheet

Section\Year	1988	1989	1990	1991
Road Maintenance	3,000	2,400	1,800	1,200
Bridge Maintenance	---	90	130	150

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 can be easily found such as pavement and expansion joint repair.

The asphalt pavement maintenance and expansion joint repair records are shown below :

Pavement Maintenance Record (Asphalt Concrete)

Chainage	Direction	Lane No.	Repair Area (sq.m.)	Repair Date
Roadway				
1+559-1+639	DD-P	1	243.60	02/01/89
1+559-1+734	P-DD	1	612.50	"
2+550	P-DD	1	4.80	"
5+100	P-DD	1	29.40	"
5+550	P-DD	3	38.15	"
6+250-5+920	P-DD	1	1436.05	"
"	P-DD	2	1436.05	"
"	P-DD	3	1436.05	"
--	--	-	1683.00	"
--	--	-	52.20	"
10+420	P-BN	2	53.90	"
10+420	BN-P	3	237.30	"
--	--	-	3493.40	"
20+403-8+720	DK-P	1	2100.00	"
--	DK-P	-	2667.00	"

Pavement Maintenance Record (Asphalt Concrete) (Con't)

Chainage	Direction	Lane No.	Repair Area	Repair Date
Roadway (Con't)				
8+504	DK-P	1	41.65	02/01/89
--	--	-	35.00	"
--	P-BN	Eme. +1	79.80	"
--	--	-	732.90	"
--	--	-	341.25	"
--	P-BN	1	70.00	"
--	--	-	56.00	"
20+212-20+123	DK-P	3	380.00	18/04/91
20+117-20+044	DK-P	3	277.20	"
20+014-8+769	DK-P	3	111.96	"
20+212-20+069	DK-P	2	474.95	"
20+077-8+760	DK-P	2	490.00	"
20+373-20+209	DK-P	1	572.25	"
8+760-8+050	DK-P	2	172.90	"
8+772-8+746	DK-P	3	177.08	"
8+042-10+000	P-BN	1	570.15	"
8+390-8+495	P-BN	2	536.20	"
8+042-8+415	P-BN	3		"
10+000-10+083	P-BN	1	268.45	"
8+495-10+083	P-BN	2	395.85	"
8+435-8+475	P-BN	3	104.20	"
8+435-10+063	P-BN	3	331.35	"
10+358-10+476	P-BN	2	359.01	"
10+383-10+565	P-BN	1	601.44	"
10+563-10+799	P-BN	1	795.20	"
10+313-10+563	P-BN	2,3	709.70	"
10+476-10+751	P-BN	2	670.07	"
Rama IX Bridge				
1-10 BKK	Left	BKK-THB	503.64	18/04/91
12-15 BKK	Left	BKK-THB	146.36	"
16-17 BKK	Left	BKK-THB	50.56	"
19-21 BKK	Left	BKK-THB	113.04	"
26-31 BKK	Left	BKK-THB	207.36	"
25-31 BKK	Left	BKK-THB	240.12	"
3-8 BKK	Left	THB-BKK	312.12	"
17-18 BKK	Left	THB-BKK	46.26	"
20-24 BKK	Left	THB-BKK	194.22	"

Note : P = Port, DD = Din Dang, BN = Bang Na, DK = Dao Khanong
BKK = Bangkok, THB = Thonburi

Pepair Record of Expension Joint

No.	type of Joint	Contractor	Contract No.	Completed
1	Thorma	TES	2/85	6 Jan 1985
2	Thorma	TES	6/86	27 Mar 1986
3	Thorma	Marino	5/89	12 May 1989
4	Thorma	Marino	11/90	11 Nov 1990
5	Thorma	Marino	13/90	25 Dec 1990
6	Thorma	TES	6/91	4 Jul 1991

Note : TES = Traffic Engineering System Limited
Mario = Mario Co., Ltd.

3. Inspection System

3.1 General

As Mr. Hara, former JICA Expert to ETA, mentioned in the final report, inspection is classified into the following three types :

1) Routine Inspection

Daily inspection checking road condition while staying in a vehicle. This inspection is made to grasp road and traffic condition, to know how maintenance work has been done and to decide whether appropriate measure or repair work is needed by finding malfunction of road and damage at an early stage. In case that continuous observation is needed for the damage which has been found by inspection, attention should be paid to the damaged point considering its nature and influence to the third party.

2) Periodic Inspection

Regular inspection on foot, approaching objective structure as close as possible. The main purpose of the periodic inspection is to grasp the condition of the bridge and judge the necessity of repair by rating the defects which cause deterioration. This inspection is made for elements on which routine inspection is insufficient and should be performed schematically in the best season since it is the inspection for the elements which routine inspection cannot cover. In addition, having the quantitative distribution of defects or damages, inspection data are to be used for setting up repair work schedule.

3) Special Inspection

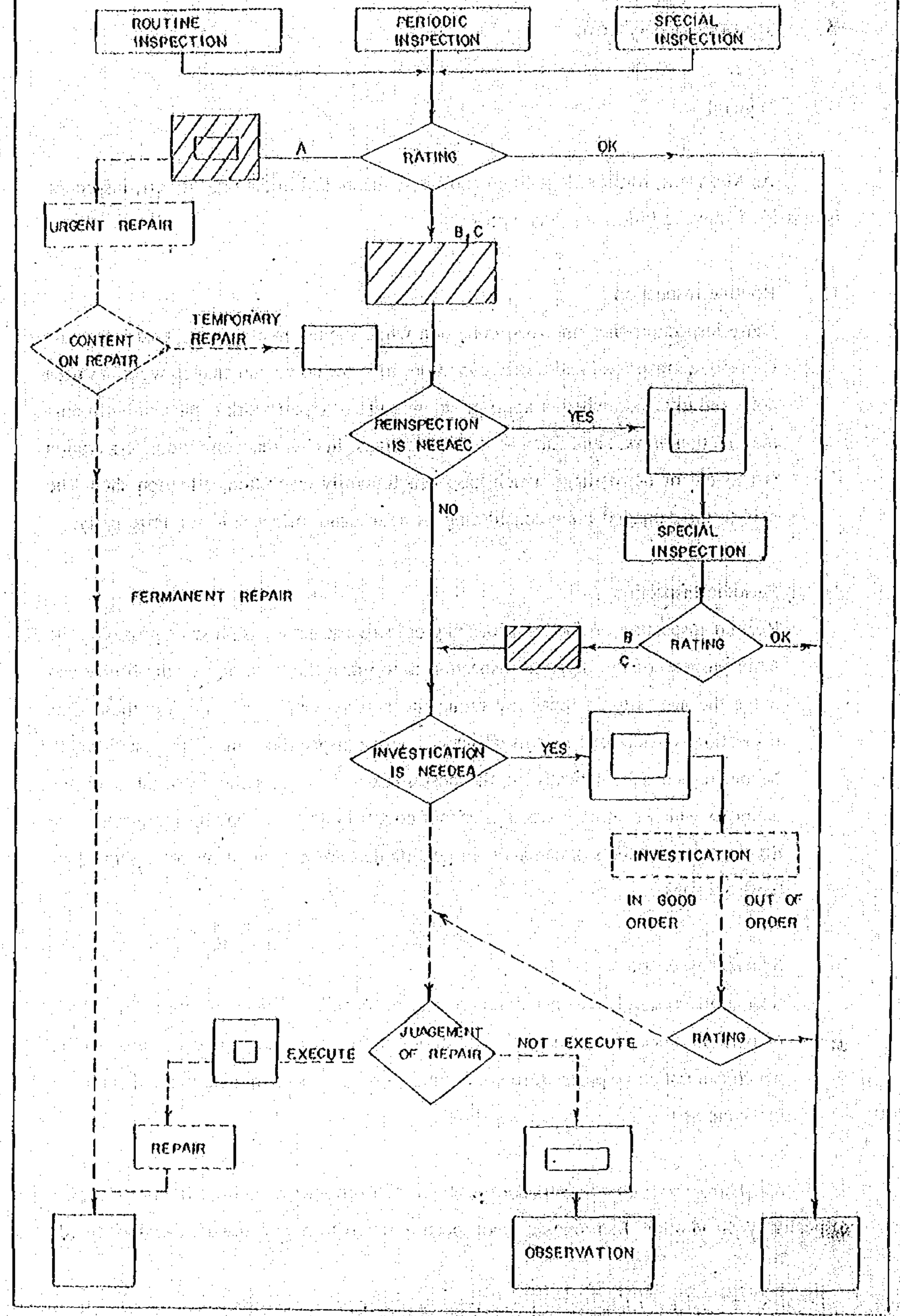
Special inspection is conducted temporarily in order to supplement routine inspection or periodic inspection and to check important factors or unusual stress distribution which can not be inspected through ordinary visual inspection. The method is almost the same as that of periodic inspection.

Mr. Hara also prepared inspection manual for expressways and the Rama IX Bridge respectively. In addition, he proposed the inspection report form and how to keep the record.

PROCEDURE OF INSPECTION WORK

STANDARD PROCEDURE OF INSPECTION WORK IS AS FOLLOWS :

FIGURE 3-1



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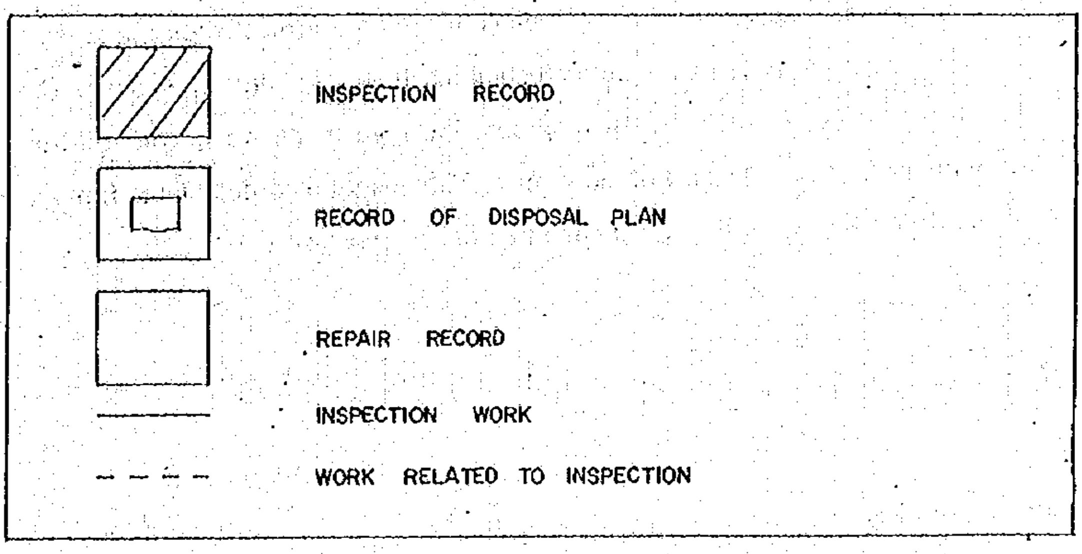


But, he has not mentioned about pavement inspection.

3.2 Pavement

The surface of the road should be investigated to understand its condition, and the processes and causes of damage to it.

1) Rutting and Raveling

The following methods of measuring rutting and raveling are recommended.

(1) Measurement Using a Transverse Profilometer

The profilometer is installed on the surface in a position so that the meter strides over the expressway and moves at a right angle to the direction of the traffic lane. The profile of the surface is recorded by moving the profile recorder as shown in Fig.3-2. The recorded profiles are classified by comparing the heights of the center of the ruts and the heights of the surface at both sides.The amount of ruts, D1 and D2, are obtained as shown in Fig.3-3. The larger value is defined as the rutting depth of the cross-section. The average of the measured values of the rutting depth is taken as the rutting depth of the investigated section.

(2) Measurement Using a Rut Measuring Vehicle

When the investigation of a long section is involved, or when detailed information is necessary, lines or points of light are projected on the surface of the expressway using a light projection machine installed on a vehicle. The profile of the line of light is photographed at regular intervals, synchronized with the motion and speed of the vehicle. The images recorded on the film are used to investigated the rutted condition of the expressway.

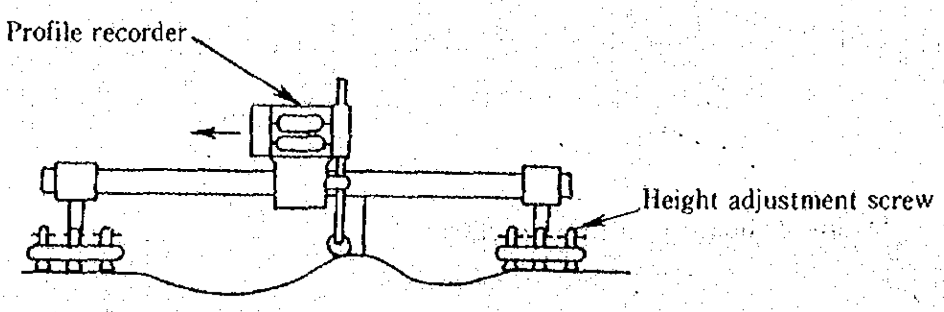
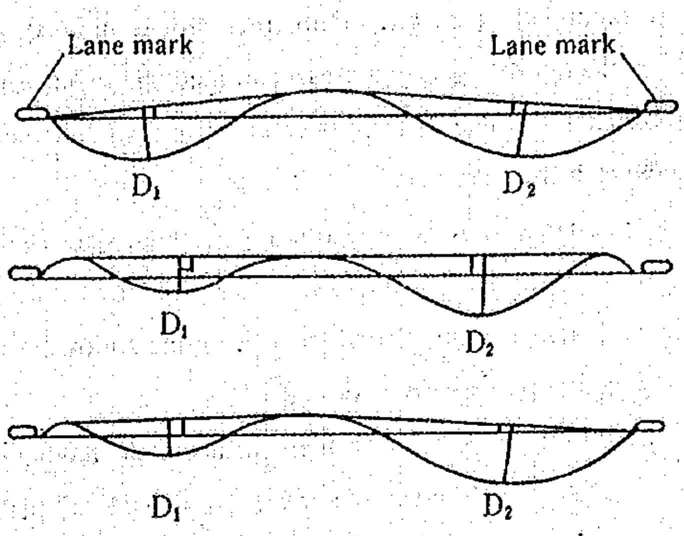


Fig.3-2 Measurement Using a Transverse Profilometer

(1) When the highest point in the center is higher than the line connecting both sides



(2) When the highest point in the center is lower than the line connecting both sides

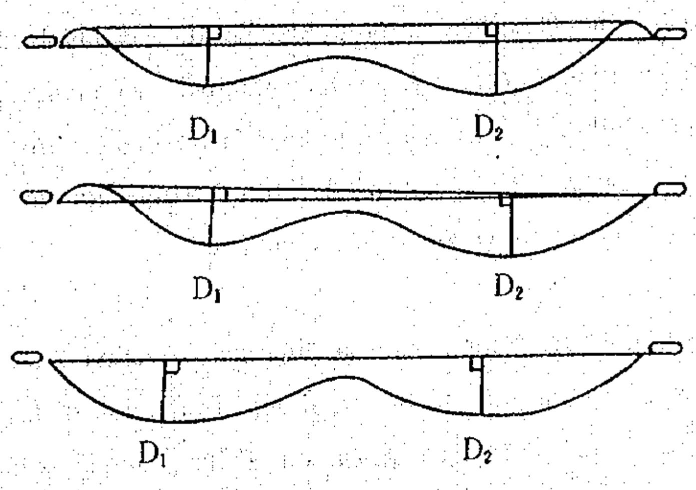


Fig.3-3 Process of Recording Data

2) Cracks

The investigation of cracks is indispensable for understanding the level of damage to the pavement, and for determining the timing, method, and thickness of overlay and/or replacing the damaged area. The methods of measuring cracks include those using sketches and that of using a crack measuring vehicle.

(1) Sketch Measurements

The road surface is divided into grids with sizes of 0.5mX0.5m, and sketches of the conditions of cracks are made for each traffic lane. The computation of the cracking ratio is conducted using the following formula:

Cracking ratio = {(Cr+P)/A}X100 (%)

where Cr = Sum of gridded surface areas having cracks (m2)
The surface area is to be 0.15 m2 per grid, if one crack exists in the grid; and 0.25 m2 per grid, if more than one crack exist.

P = Patched area (m2)

A = Total area of the investigation (m2)

(2) Measurement Using Crack Measuring Vehicle

When the investigation of a long section is involved, or when detailed information is necessary, a vehicle equipped with a device for taking pictures and a lighting device is used to take continuous pictures of the surface of the expressway. The speed of the film feeder and the lighting device are synchronized to the speed of the vehicle.

3) Roughness and Corrugation in the Longitudinal Direction

Roughness and corrugation in the longitudinal direction of the road are measured using a longitudinal profilometer, or a longitudinal roughness measuring vehicle.

(1) Measurement Using a Longitudinal Profilometer

The longitudinal profilometer is manually drawn over the road, as shown in Fig.3-4, to record the roughness of the road surface.

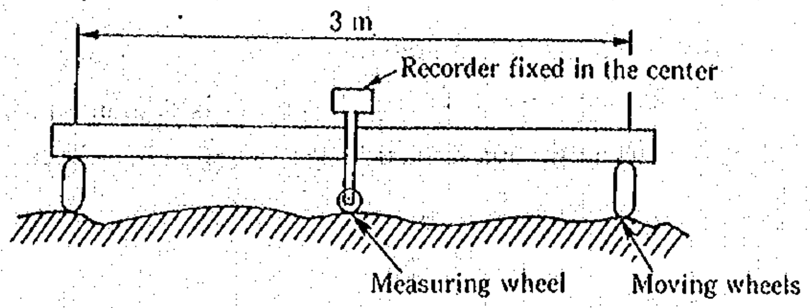


Fig.3-4 Longitudinal Profilometer

The measurement is conducted along the rutting line in the lane, with the results of the measurement being read every 1.5m. The standard deviation of these values is taken as the value of the longitudinal roughness.

(2) Measurement Using a Longitudinal Roughness Measuring Vehicle

When the investigation of a long section is involved, or detailed information is necessary, a longitudinal roughness measuring vehicle is used. Two types of the vehicle are available; a contact measuring vehicle with a fifth wheel, and a non-contact measuring vehicle using a laser beam. The front and rear wheels of the former vehicle correspond to the moving wheels of the longitudinal profilometer, and the fifth wheel, which corresponds to the measuring wheel of the profilometer, deals with recording the irregularities of the expressway. The latter vehicle is equipped with a non-contact-type laser displacement meter, in a position which corresponds to that of the moving and measuring wheels, in order to record the roughness of the expressway surface. The recorded data is processed similarly to that obtained by the longitudinal profilometer.

4) Faulting

Faulting is measured at the deepest point or at three different points in one lane, with the maximum value, D(mm), taken as the fault value, as shown in Fig.3-5. The length of the leveling cord should be 15 m for expressways.

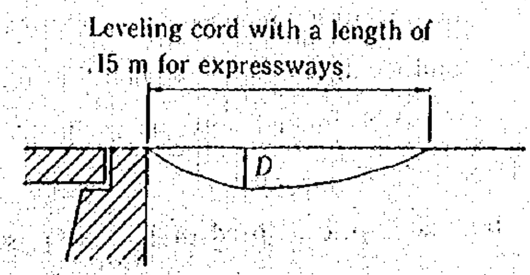


Fig.3-5 Method of Measuring Faulting

Pavement inspection on the expressway as mentioned above will cause traffic congestion because of a lane closure. In such a case, it is desirable to inspect by taking pictures from the moving inspection vehicle. Fig.3-6 shows one model of this kind of inspection vehicle.

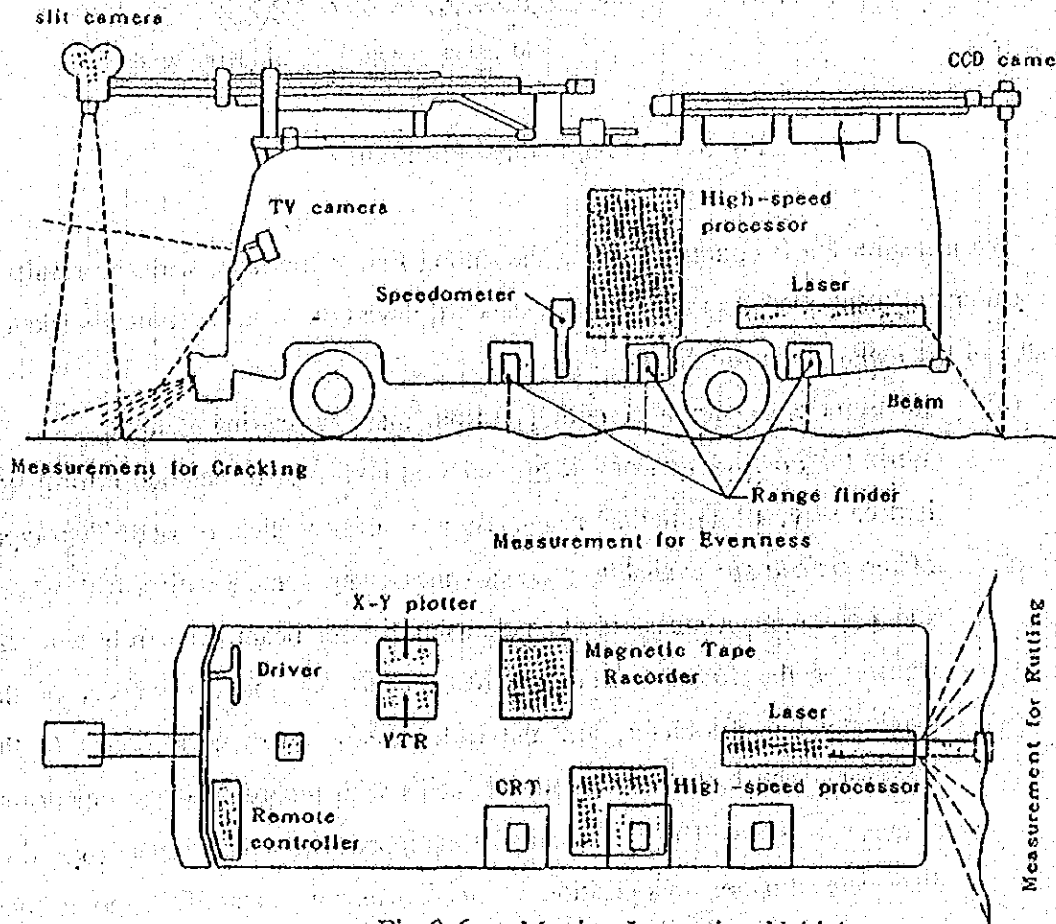


Fig.3-6 Moving Inspection Vehicle

This system has various kinds of features as follows:

* Rutting, cracking, and roughness are measured simultaneously, and all data for one lane is recorded in a single run.
* A non-contact speedometer provides presice system control and high speed measurement.
* All measurements are controlled by a single speedometer so that coordinated data for all three characteristics can be obtained.
* An on board video camera records mileposts and other markings on the road shoulder for detection and identification of structural differences in the road.
* Measurements can be reviewed immediately, using the TV monitor and X-Y plotter installed on board.
* Measurements can be made up to a speed of 80 km/hr, so that traffic flow reminds unobstructed.

It is desirable to inspect pavement condition in a manner as mentioned above once a year and to evaluate them quantitatively.

3.3 Non destructive testing

Non destructive testing is to investigate the internal defect, its extent and condition without breaking. The purposes of non destructive testing are quality control, quality evaluation and maintenance inspection, and the procedure of non destructive testing is as follows,

To suppose kind of defect and occurence area in the material

To select appropriate test method and test condition

To measure

To estimate existance of defect and its extent

To make a judgement on the degree of herm

Non destructive testing is classified as in Fig.3-7.

- Non destructive testing
  - detection of defect
    - surface area
      - magnetic particle inspection
      - liquid penetrant test
      - electromagnetic induction test
      - electric resistance test
    - internal part
      - radiation penetra test
      - ultrasonic wave test
  - measurement of strain
    - strain of certain point
      - mechanical method
      - electrical method
      - X-ray stress measuring method
    - stress distribution
      - photoelastic method
      - brittle coating
      - moire' method
      - copper gilding method

Fig.3-7 Classification of Non Destructive Testing

1) Radiation penetra test

Radioactive rays such as X-rays, r-rays and so on have the characteristics to penetrate an object and it is called radiation penetra test to inspect the internal condition of object using this characteristics.

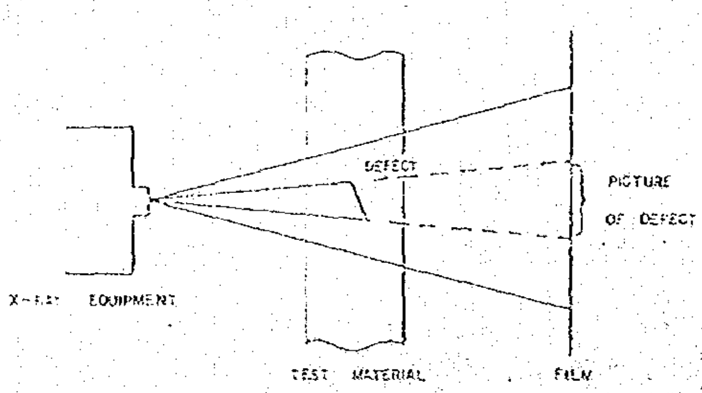
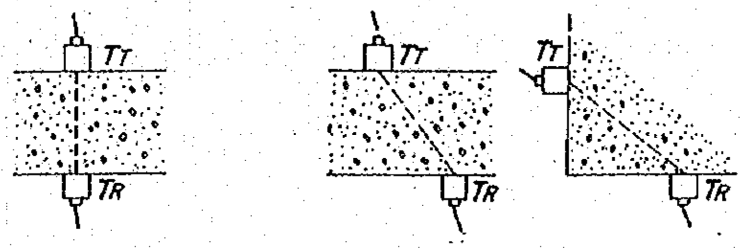


Fig.3-8 Radiation Penetra Test

Radiation penetra test is appropriate for detecting internal defect and applicable to all materials. It is possible to confirm directly the shape of defect and easy to detect even small defect. Furthermore, it is possible to keep the record in pictures, but necessary to pay attention in handling them because of ill effects to the human body.

2) Ultrasonic Wave Test

Ultrasonic wave has the characteristics to propagate into the object and to reflect at the discontinuous part such as defect. It is called ultrasonic wave test to inspect the internal condition of object using this kind of characteristics. If ultrasonic wave is transmitted into the object, the probe will also receive echo in case of existence of defect. Echo reflects the size and shape of defect, and it is measured on the screen to know the velocity of pulse-echo applied on the already-known distance and the intensity. There are two types of transmission such as vertical and diagonal one.



vertical type diagonal type

Fig.3-9 Two Types of Transmission in Ultrasonic Wave Test

Ultrasonic wave test is appropriate for detecting internal defect and applicable to all kinds of materials, but it is required a lot of experiences to make judgement through measurement of echo.

3) Magnetic Particle Inspection

When the metal such as iron, nickel, etc. has magnetization, lines of magnetic flux are disturbed by the defect that exists on the surface or near the surface. It is called magnetic particle inspection to find defect using this characteristics. When the test piece is placed in the magnetic field that coil and magnetic material form as a result of being induced by current through them, the test piece is magnetized, the disturbance in lines of magnetic flux arise and it is easy to find defect, because this magnetic flux leakage will cause the adsorption of magnetic powder and make magnetic powder layers.

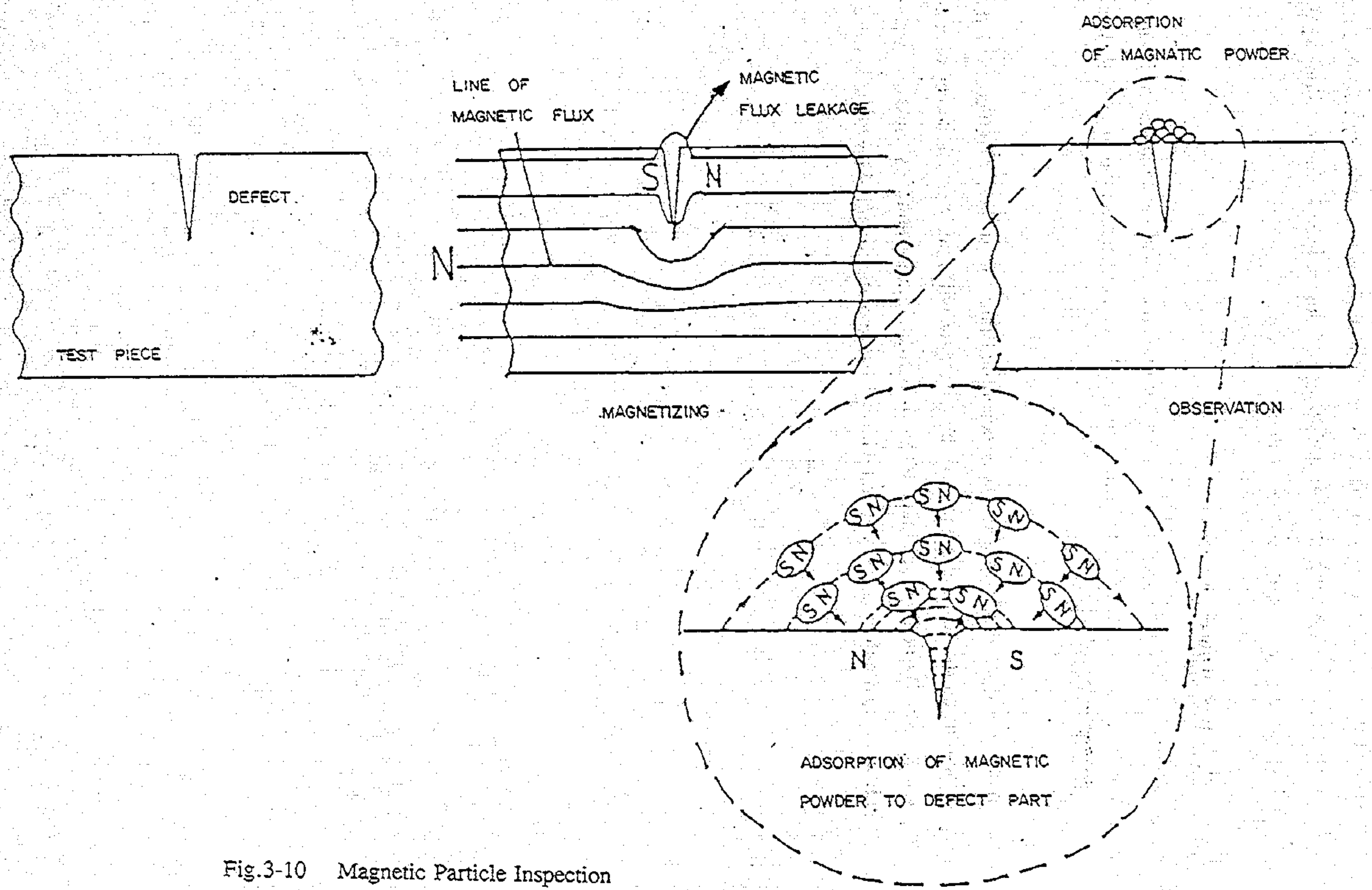


Fig.3-10 Magnetic Particle Inspection

This test is appropriate for finding defect on the surface and of the part just beneath it, but it is applicable only to magnetic material such as iron, etc. By this test, it is possible to see directly the size and shape of defect except that of along depth direction and not possible to find scattered defects.

4) Liquid Penetrant Test

A liquid has the characteristics to penetrate into cracks and gaps (capillarity), and it is called liquid penetrant test to find defect such as crack, etc. on the surface of object using this characteristics.

After a special liquid (penetrant) is penetrated into the surface of object and the penetrant on the surface is removed, the penetrant will remain in the defect such as crack, etc. By adding developer to the penetrant, the penetrant is sucked out and diffused, and defect is easily found with the fringe pattern coming up to the surface.

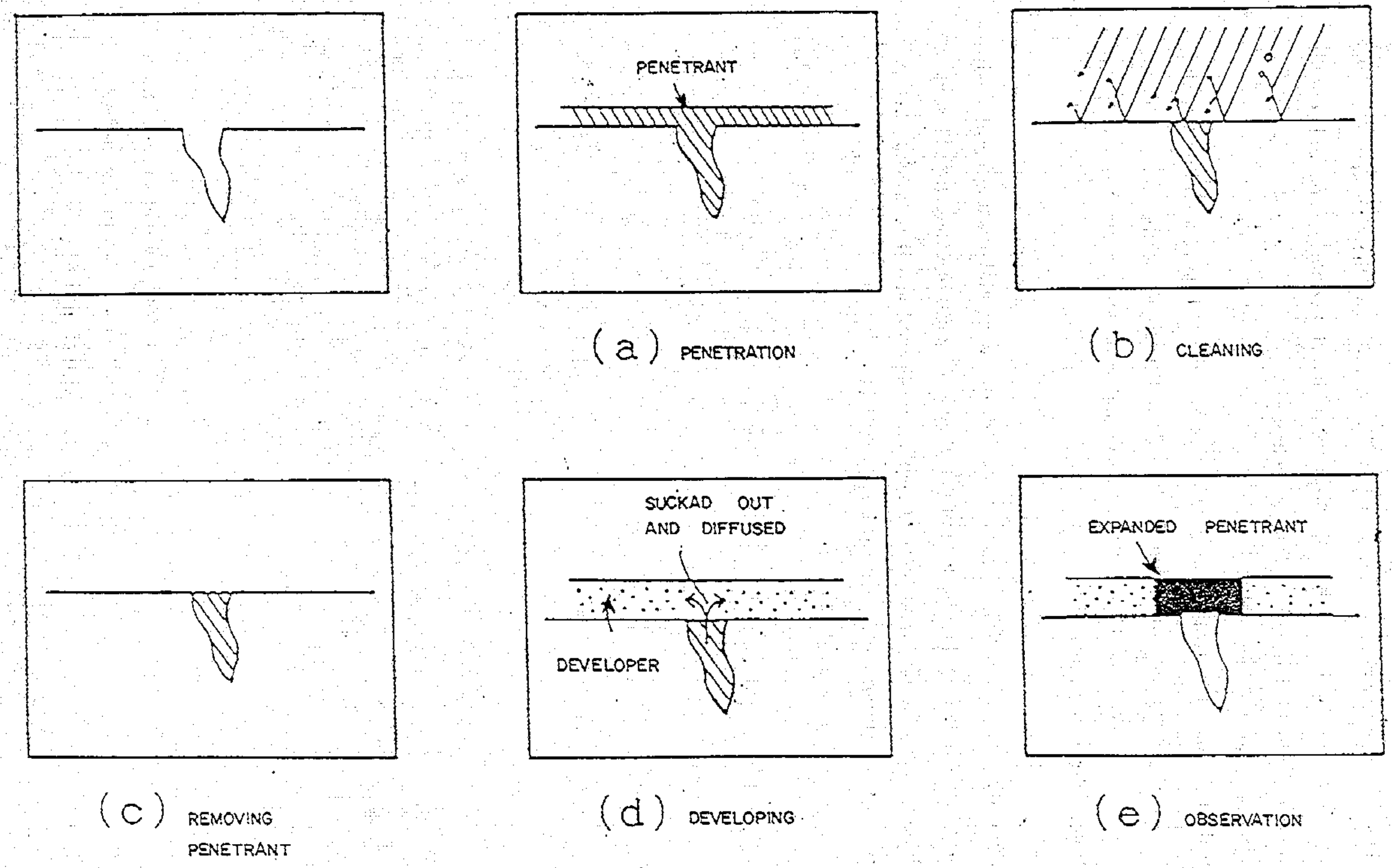


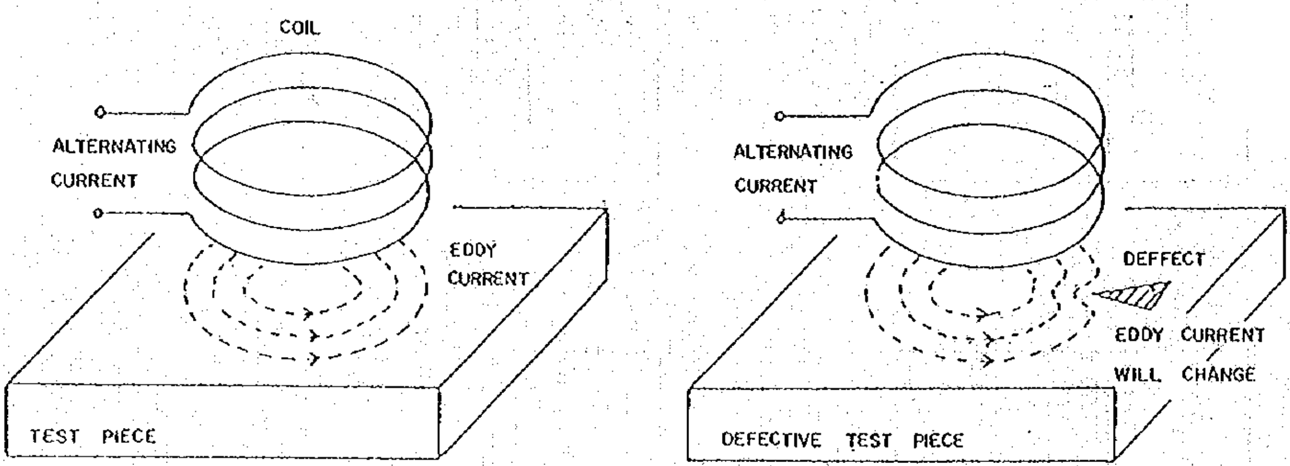
Fig.3-11 Liquid Penetrant Test

This test is applicable to a nonmetal, but not appropriate for the material absorbing water and the porous material. It is possible to find only the open defect on the surface and to see directly the size and shape of defect, but not possible to know the size and shape of defect along depth direction.

5) Electromagnetic Induction Test

If the coil running alternating current approaches the test piece such as iron, etc., current (eddy current) will be induced in the test piece due to the electromagnetic induction theory. It is called electromagnetic induction test to find defect with this change of eddy current.

The eddy current induced by approaching the coil running alternating current will change depending on the existence of defect and the shape of conductor. This eddy current affects the change of current running in the coil and it is possible to find defect by measuring the current running in the coil.



If the eddy current change, the current running in the coil will also change.

Fig.3-12 Electromagnetic Induction Test

This test is appropriate for finding defect on the surface and of the part just beneath it, and it is possible to get the information such as defect depth. This test is applicable only to conductor and in general, it is possible to test without touching material with high speed.

6) Electric Resistance Test

This is the test method to use the characteristics that the impedance between any two points in the metal will change with the existence of defect between those points.This test is appropriate for finding defect on the surface and of the part just beneath it, and it is possible to get the information such as defect depth. Test method is quite easy and applicable to repeat at the same point.

7) Test using Infrared Rays

This is the method to measure thermal distribution by infrared photography using the characteristics that the thermal distribution of object will change due to the existence of defect or structure of the object.

8) Test Using Microwave

If the microwave (frequency is ranging from 300MHz to 3000GHz) is radiated to the material such as plastic,etc., it reflects itself at the point of defect and the discontinuous phase of the internal part and it is the method of test to find defect using this characteristics.

9) Test Using Acoustic Emission

It is called acoustic emission phenomena that the elastic wave such as ultrasonic wave, etc, arises, when the external force is applied to the metal and the metal is deformed plasmically. In this test, the occurrence of crack and its size in the test piece under the external force is detected by measuring this elastic wave.

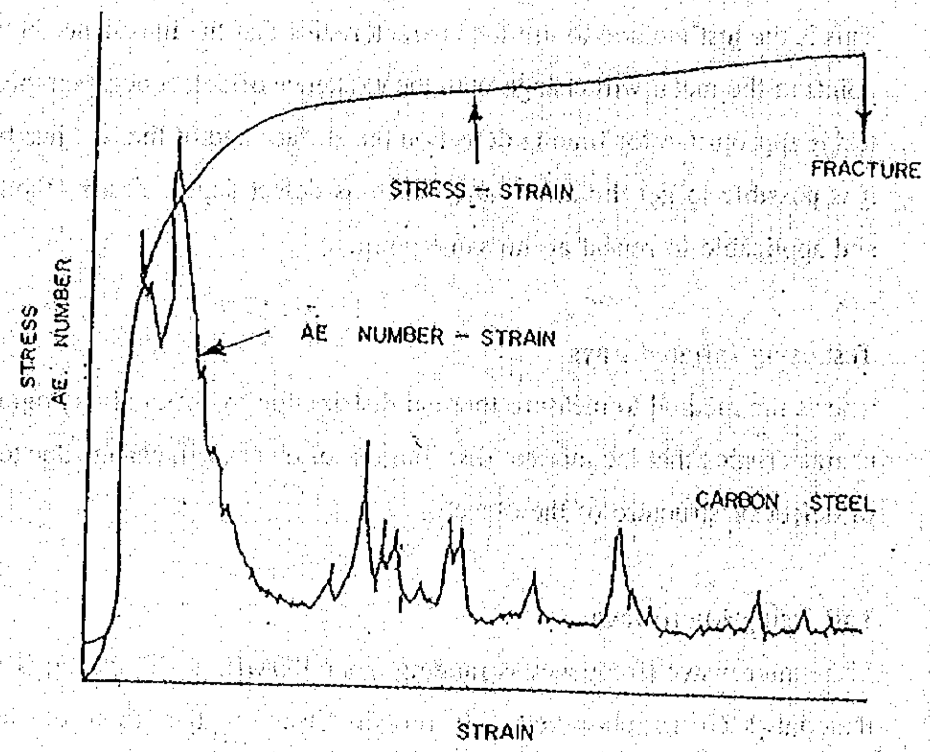


Fig.3-13 An Example of Occurrence of Acoustic Emission and the Deformation of Carbon Steel

4. Evaluation and Repair System

4.1 The Rama IX Bridge

1) General

The Rama IX Bridge is a single plane cable-stayed bridge constructed at Watsai, where the 10.3 km Dao Kanong-Port section, a part of the 27.1 km First Stage Expressway System in Bangkok, crosses over the 500 m wide Chao Phraya River. The requirement for navigation passage are that piers are not to be extended into water deeper than 2 m below lowest-low water level and vertical clearance throughout the main span is to be 41 m above highest high water level (See Fig. 4-1).

The design criteria of the cable-stayed bridge is based on the German Standards (DIN). The basic standards applied to this design are enumerated below. Other related standards, regulations and instructions are taken into consideration according to the field of application.

DIN 1072 Road and Foot Bridge (Design Loads)

- Principal loads (Dead loads, Pre-stressing, Traffic design loads, Stresses set up by probable ground movement, etc.)
- Additional loads (Temperature effects, Wind loads, Braking load, etc.)
- Special loads

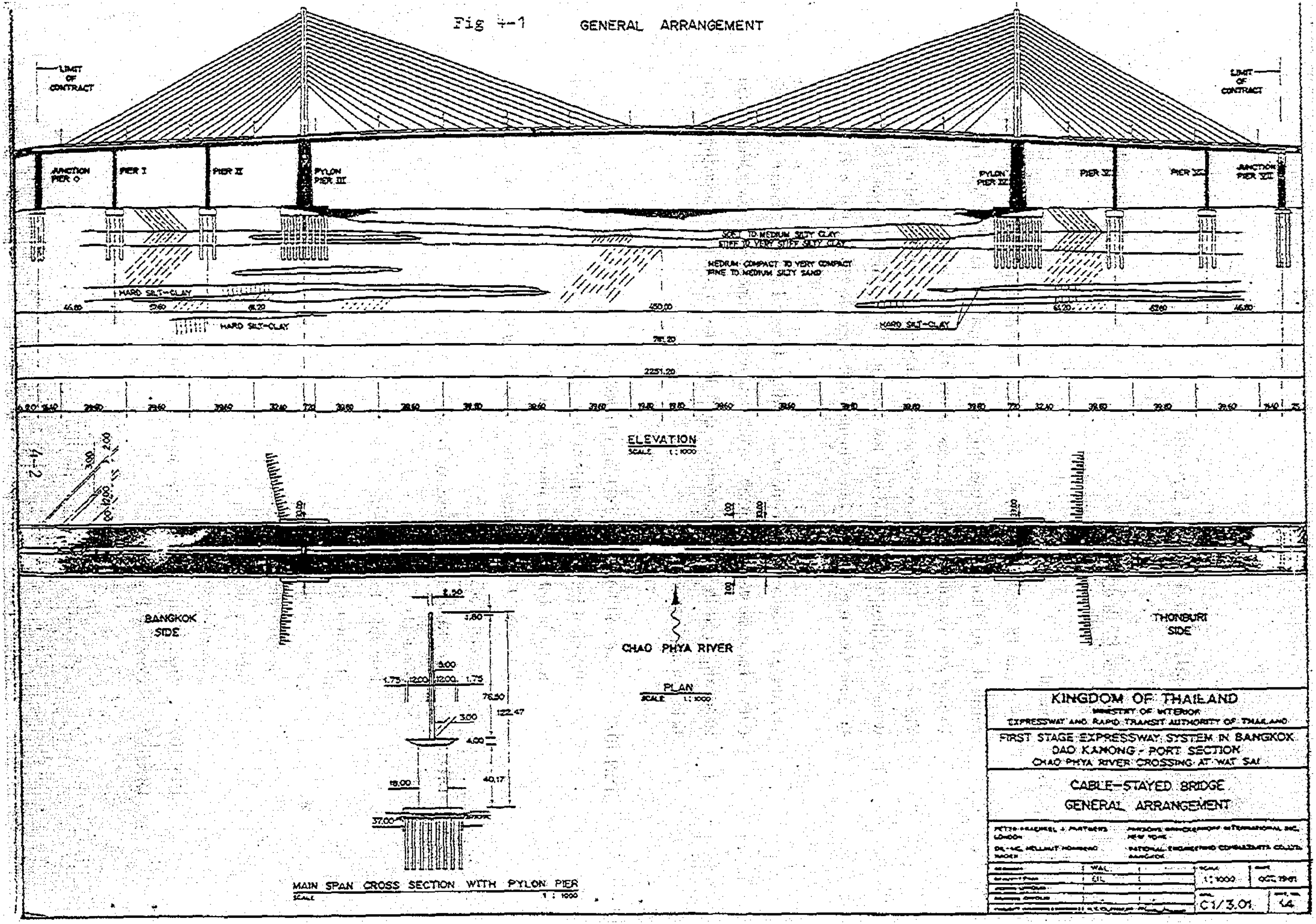
DIN 1073 Steel Road Bridge (Bases of Design)

- Materials
- Principles for calculation
- Design loads
- Proofs required
- Special features for certain types of structure and parts
- Structural connections
- Allowable stresses

DIN 1079 Steel Road Bridges (Construction Principles)

DIN 1075 Concrete Bridges

Fig 4-1 GENERAL ARRANGEMENT



DIN 4101 Welded Steel Road Bridges (Design and Structural Details)

DIN 4114 Steel Structures (Stability-Buckling, Overturning)

DIN 4119 Building in German earthquake areas (Guide to Dimensioning and Execution)

Materials of superstructure are selected according to specifications of DIN 1073 Steel Road Bridges (Bases of Design) Steel for bridge and pylon structure:

St52-3 (DIN 17100-General structural steels: Quality specifications)

Steel for less important structure (Handrails, guardrail, etc.):

St37-2 (DIN 17100)

Cast steel for cable stay head:

GS52 (DIN 1681-Cast steel for general application: Quality specifications)

High strength steel pre-stressing bar anchoring pylon base to pier caps:

St110/125 Dia. 32mm (Dywidag or Peine)

Allowable stresses of structural steel follow Table 5 in Chap.8 of DIN 1073 (Steel road bridges-bases of design).

	ST37		ST52	
	H	HZ	H	HZ
Axial tension and bending tension	1600	1800	2400	2700
Axial compression and bending compression	1400	1600	2100	2400

unit : Kg/cm^2

where H means loading case of sum of principal loads (Hauptlasten) and HZ means loading case of sum of principal and additional loads (Zusatzlasten)

Allowable stresses in weld follow table 2 in Chap. 4 of DIN 4101 and allowable stresses of locked coil cable follow Chap. 6.5 of DIN 1073.

$$H = 0.42B_N$$
$$HZ = 0.46B_N$$

where H means allowable stress of a cable in the loading case H and HZ means allowable stress of a cable in the loading case HZ, and B_N means nominal strength of wires of cable.

The main section of the bridge deck is a three-cell steel box girder 21.8 m wide and 4 m deep at the center. In the anchor spans the width of the bridge deck increases from 31 m to 33 m in order to pass the pylons with sufficient clearance. The longitudinal stiffening of the bridge deck is generally by U-shaped ribs welded to the insides of the plates. In the main span a sloping web extends from the base of the box girder to the outer edge of the 5.6 m deck panels to form the aerodynamically streamlined shape.

The 78 m high pylons pass through the bridge deck without structural connection. The pylons have flared bases which are held down on the 6 m thick caps at the heads of the pylon piers by long tensioned high strength bars. The four high yield steel plates which constitute the base section are 100 mm thick. The thickness of the plates reduces with height to 15 and 20 mm at the pylon top.

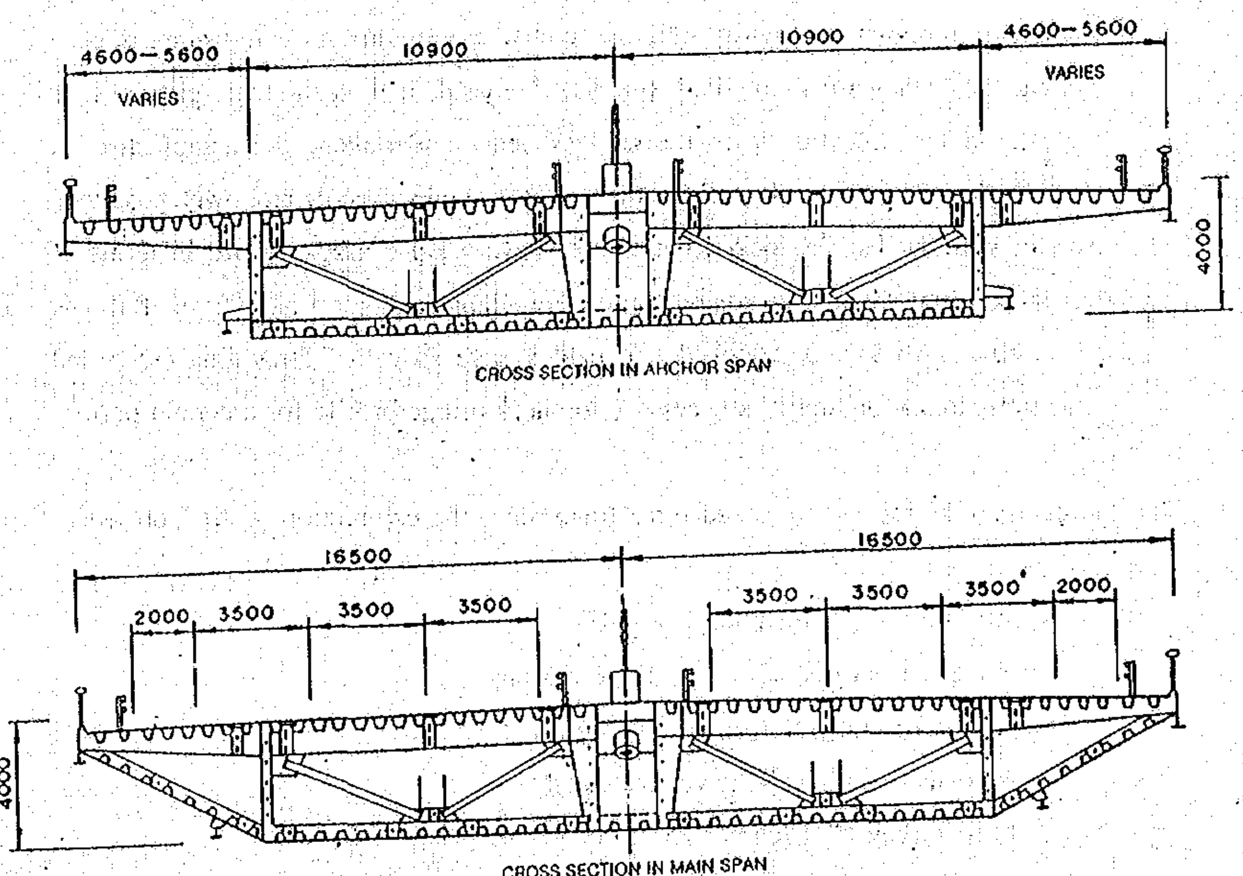


Fig.4-2 Main girder cross sections

2) Bridge Profile

The bridge design, which was undertaken between 1980 and 1981, drew heavily on Dr. Homberg's previous well known cable-stayed bridges, and in particular on the Friedrich Ebert Bridge in Boon of which it is in many respects a magnified version. As it is a well known fact that heavy structures tend to sink in the Bangkok area, the design allowed for relative settlement of the pylon piers of up to 20 cm and up to 2.5 cm of the anchor span piers. Greater settlement can be accommodated by adjustment of the special rocker supports which connect the piers to the bridge deck. There are currently two methods of making prefabricated large cables. The individual high strength cold drawn steel wires are either coiled spirally during manufacture (locked coil cables) or they are simply laid straight side by side in a plastic tube (parallel wire cables). At the time the detail design was being undertaken, the manufacture of suitably large diameter of locked coil cables became feasible at lower cost than parallel wire cables. As locked coil cables have a better track record in terms of resistance to fatigue and corrosion, they were adopted for the final design. But it is also well known fact that locked coil cables have so called long time creep and structural-elongation and it is necessary to check bridge profile for a certain period.

Bridge profile has been checked three times since the completion of erection work.

* The first survey (September 21, 1987)
  It was carried out just after the bridge closing.
* The second survey (November 14, 1987)
  It was conducted after the pavement finish.
* The third survey (November 25, 1988)
  It was surveyed one year after the completion.

According to these surveys and comparing the third survey result with the second one, the deck elevations of the third survey shows higher elevations at the back span and lower elevations at the main span.

This was surely caused by the settlement of the pylon piers. Because back span elevation cannot move upward judging from the reaction force of the back span piers.

Therefore the third survey result is revised considering the pylon pier settlements. Fig.4-3 shows the profile considering the pylon settlement and deviations from the expected elevations.

From the result shown in Fig.4-3, the maximum deviation is 69 mm (over level) at the main span and 55 mm at the back span. This is rather small for this class of cable-stayed bridge and it is also recommended to take account of thickness change (from 80mm to 72mm) of asphalt pavement layer.

According to the inspection manual, bridge profile should be surveyed once a year, but unfortunately, survey has not yet been done because of absence of the permanent bench marks which used to be located at the ground level near P3 and P4 and because of the lackness of man power.

<u>It is urgently recommended to make a survey as soon as possible and to check bridge profile of the present stage.</u>

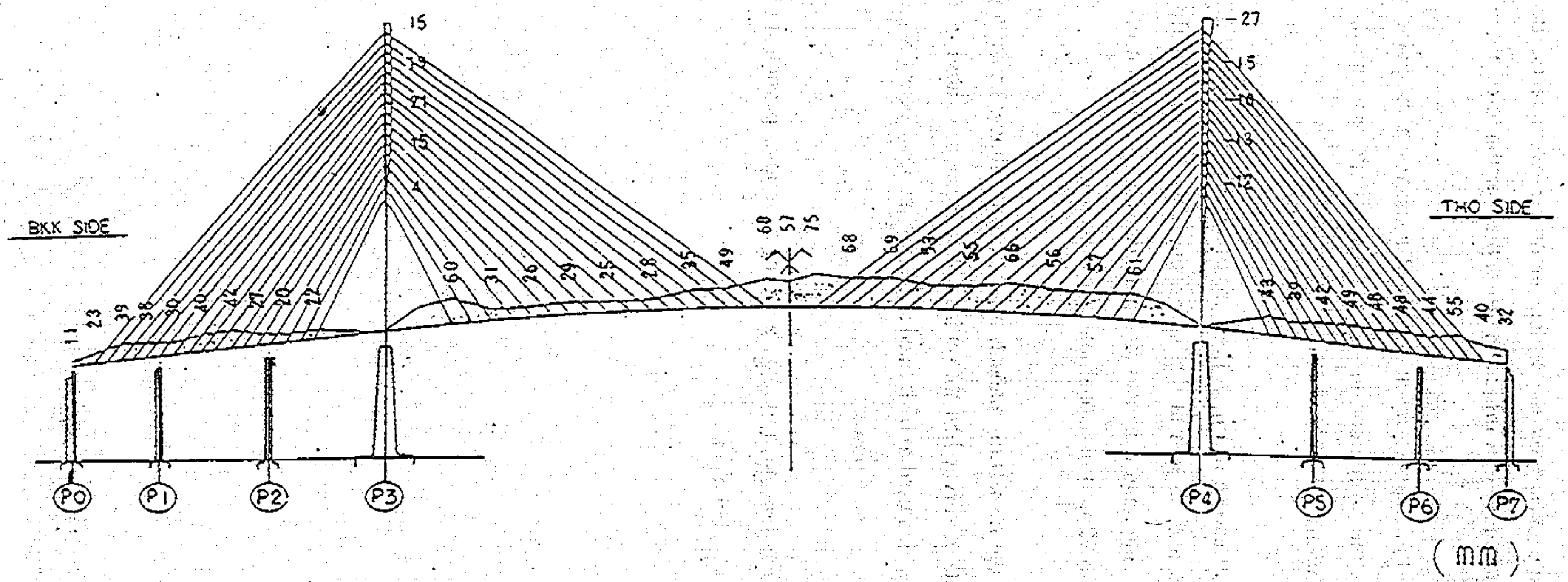


FIG. 4-3 DEVIATION OF BRIDGE PROFILE

(REVISED ELEVATION CONSIDERING THE PYLON SETTLEMENT)

3) Cable

The bridge deck is supported by four sets of 17 cables with diameters varying from 121 mm (the shortest) to 167 mm (the longest). The minimum breaking load of the 167 mm cables is 2800 tonnes. These are, in terms of cross sectional area and breaking load, about twice as big as any previously used and the main span of the bridge is designed to carry traffic loading to the German Standard DIN 1072, bridge class 60, in addition to its own weight (about 10000 tonnes). This design standard gives a higher loading than would be obtained from any comparable national standard and it is unlikely to be exceeded in any actual traffic situation. Even at this design loading, cables are strained to only 45% of their tested breaking load.

The corrosion protection system of the ropes consists of inner and outer corrosion protection. The inner corrosion protection consists of the hot dip galvanized surface of all wires and a corrosion protection compound added during stranding operations. The active corrosion protection compound consists of polyurethane oil with a high content of zinc dust filler. The outer corrosion protection consists of a multiple thick layer paint coat which is applied after erection.

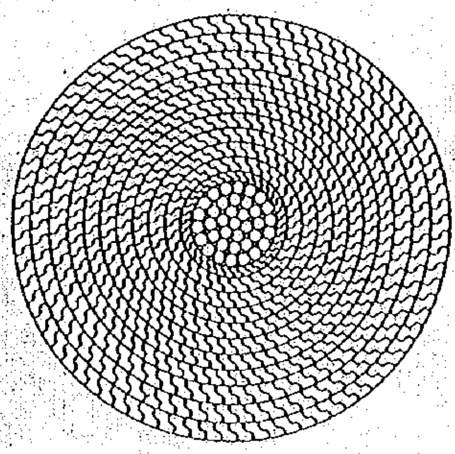


Fig.4-4 Cross section of rope diameter 167 mm

Japan International Cooperation Agency (JICA) provided the Cable Tension Meter to ETA in August 1991 according to the request by JICA expert. This measuring instrument was developed for estimating the tension of cables built in structures, especially bridge cables accurately and in a short time. A microcomputer in the tension meter automatically analyzes signals from the accelerometers, and calculates the cable tension. You can find the detail about how to use it in Appendix.

Photo 4-1 - 3 and Table 4-1 show the results of cable tension measurent.

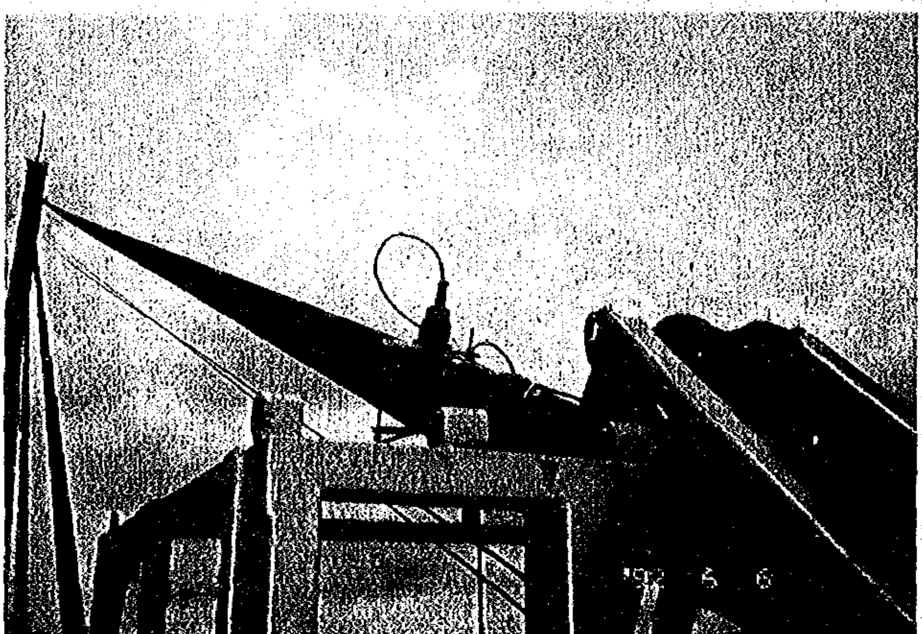


Photo 4-1

Photo 4-2

Photo 4-3

Table 4-1

Input Data

Cable No.	DIA (0)	R (t/m³)	E (t/m²)	L (m)	A (m²)	EI (t.m)	W (t/m)	TNS (tf)	TMAX (tf)	O (DEG)	REMARK
166	167	8.50047	1.71012	175.40	0.02094	590	0.178	1281	1310	29.05	BACKSPAN BKK.
167	167	8.50047	1.71012	167458	0.02094	590	0.178	1259	1310	29.34	
168	167	8.50047	1.71012	159.75	0.02094	590	0.178	1263	1310	29.65	
169	167	8.50047	1.71012	151.856	0.02094	590	0.178	1252	1310	30.00	
170	167	8.50047	1.71012	144.09	0.02094	590	0.178	1250	1310	30.38	
171	167	8.50047	1.71012	136.283	0.02094	590	0.178	1223	1310	30.81	
172A	139	8.48806	1.67189	128.49	0.01508	269	0.128	896	930	31.29	
172B	139	8.48806	1.67189	120.70	0.01508	269	0.128	890	930	31.83	
173A	139	8.48806	1.67189	112.92	0.01508	269	0.128	904	930	32.45	
173B	139	8.48806	1.67189	105.14	0.01508	269	0.128	902	930	33.16	
174A	134	8.50	1.67306	97.32	0.01400	250	0.119	826	890	33.99	
174B	134	8.50	1.67306	89.57	0.01400	250	0.119	825	890	34.96	
175	121	8.50168	1.61341	81.795	0.01188	173	0.101	673	690	36.11	
176	121	8.50168	1.61341	74.130	0.01188	173	0.101	685	690	37.51	
177A	121	8.50168	1.61341	66.465	0.01188	173	0.101	691	690	39.24	
177B	121	8.50168	1.61341	58.888	0.01188	173	0.101	670	690	41.41	
178	121	8.50168	1.61341	51.28	0.01188	173	0.101	675	690	44.22	

Table 4–1 (Continued)

Input Data

Cable No.	DIA (0)	R (t/m^3)	E (t/m^2)	L (m)	A (m^2)	EI (t.m)	W (t/m)	TNS (tf)	TMAX (tf)	O (DEG)	REMARK
179	160	8.50077	1.67890	223.80	0.01941	540	0.165	1157	1200	18.90	MAINSPAN BKK.
180	160	8.50077	1.67890	212.66	0.01941	540	0.165	1168.	1200	19.16	
181	160	8.50077	1.67890	201.53	0.01941	540	0.165	1171	1200	19.47	
182	160	8.50077	1.67890	190.42	0.01941	540	0.165	1169	1200	19.82	
183	160	8.50077	1.67890	179.31	0.01941	540	0.165	1165	1200	20.22	
184	160	8.50077	1.67890	168.23	0.01941	540	0.165	1135	1200	20.68	
185A	134	8.50	1.67306	157.07	0.01400	250	0.119	845	890	21.22	
185B	134	8.50	1.67306	146.03	0.01400	250	0.119	848	890	21.84	
186A	134	8.50	1.67306	135.01	0.01400	250	0.119	863	890	22.58	
186B	125	7.62398	1.63607	123.77	0.01351	198	0.103	741	760	23.46	
187A	125	7.62398	1.63607	112.85	0.01351	198	0.103	718	760	24.52	
187B	125	7.62398	1.63607	101.96	0.01351	198	0.103	712	760	25.83	
188	121	8.50168	1.61341	91.06	0.01188	173	0.101	661	690	27.47	
189	121	8.50168	1.61341	80.268	0.01188	173	0.101	664	690	29.56	
190A	125	7.62398	1.63607	69.64	0.01351	198	0.103	660	690	32.32	
190B	125	7.62398	1.63607	59.308	0.01351	198	0.103	633	690	36.09	
191	125	7.62398	1.63607	49.07	0.01351	198	0.103	616	690	41.46	

Table 4－1 (Continued)

Input Data

Cable No.	DIA (0)	R (t/m^3)	E (t/m^2)	L (m)	A (m^2)	EI (t.m)	W (t/m)	TNS (tf)	TMAX (tf)	O (DEG)	REMARK
192	160	8.50077	1.67890	223.80	0.01941	540	0.165	1164	1200	18.90	MAINSPAN THON.
193	160	8.50077	1.67890	212.66	0.01941	540	0.165	1148	1200	19.16	
194	160	8.50077	1.67890	201.53	0.01941	540	0.165	1170	1200	19.47	
195	160	8.50077	1.67890	190.42	0.01941	540	0.165	1167	1200	19.82	
196	160	8.50077	1.67890	179.31	0.01941	540	0.165	1161	1200	20.22	
197	160	8.50077	1.67890	168.23	0.01941	540	0.165	1129	1200	20.68	
198A	134	8.50	1.67306	157.07	0.01400	250	0.119	839	890	21.22	
198B	134	8.50	1.67306	146.03	0.01400	250	0.119	841	890	21.84	
199A	134	8.50	1.67306	135.01	0.01400	250	0.119	858	890	22.58	
199B	125	7.62398	1.63607	123.77	0.01351	198	0.103	736	760	23.46	
200A	125	7.62398	1.63607	112.85	0.01351	198	0.103	727	760	24.52	
200B	125	7.62398	1.63607	101.96	0.01351	198	0.103	722	760	25.83	
201	121	8.50168	1.61341	91.06	0.01188	173	0.101	667	690	27.47	
202	121	8.50168	1.61341	80.268	0.01188	173	0.101	670	690	29.56	
203A	125	7.62398	1.63607	69.64	0.01351	198	0.103	680	690	32.32	
203B	125	7.62398	1.63607	59.308	0.01351	198	0.103	656	690	36.09	
204	125	7.62398	1.63607	49.07	0.01351	198	0.103	652	690	41.46	

Table 4–1 (Continued)

Input Data

Cable No.	DIA (0)	R (t/m^3)	E (t/m^2)	L (m)	A (m^2)	EI (t.m)	W (t/m)	TNS (tf)	TMAX (tf)	O (DEG)	REMARK
205	167	8.50047	1.71012	175.40	0.02094	590	0.178	1274	1310	29.05	BACKSPAN THON.
206	167	8.50047	1.71012	167.458	0.02094	590	0.178	1271	1310	29.34	
207	167	8.50047	1.71012	159.75	0.02094	590	0.178	1269	1310	29.65	
208	167	8.50047	1.71012	151.856	0.02094	590	0.178	1263	1310	30.00	
209	167	8.50047	1.71012	144.09	0.02094	590	0.178	1251	1310	30.38	
210	167	8.50047	1.71012	136.283	0.02094	590	0.178	1222	1310	30.81	
211A	139	8.48806	1.67189	128.49	0.01508	269	0.128	895	930	31.29	
211B	139	8.48806	1.67189	120.70	0.01508	269	0.128	886	930	31.83	
212A	139	8.48806	1.67189	112.92	0.01508	269	0.128	898	930	32.45	
212B	139	8.48806	1.67189	105.14	0.01508	269	0.128	892	930	33.16	
213A	134	8.50	1.67306	97.32	0.01400	250	0.119	808	890	33.99	
213B	134	8.50	1.67306	89.57	0.01400	250	0.119	805	890	34.96	
214	121	8.50168	1.61341	81.795	0.01188	173	0.101	668	690	36.11	
215	121	8.50168	1.61341	74.130	0.01188	173	0.101	692	690	37.51	
216A	121	8.50168	1.61341	66.465	0.01188	173	0.101	661	690	39.24	
216B	121	8.50168	1.61341	58.888	0.01188	173	0.101	635	690	41.41	
217	121	8.50168	1.61341	51.28	0.01188	173	0.101	622	690	44.22	

Table 4–1 (Continued)

Output of Results

Cable No.	f1 (Hz)	f2 (Hz)	T1 (tf)	T2 (tf)	T1/TNS (tf)	T2/TNS (tf)	REMARK
166	0.69	1.39	1054.43	1067.63	0.8231	0.8334	BACKSPAN BKK.
167	0.72	1.40	1042.98	991.54	0.8284	0.7875	
168	0.76	1.52	1053.66	1066.08	0.8342	0.8440	
169	0.78	1.56	999.87	1004.60	0.7986	0.8023	
170	0.83	1.64	1015.20	1001.71	0.7449	0.8013	
171	0.84	1.68	927.33	941.94	0.7582	0.7701	
172A	0.90	1.80	688.80	689.80	0.7687	0.7690	
172B	0.96	1.91	688.24	685.04	0.7733	0.7697	
173A	1.05	2.01	723.46	663.88	0.8002	0.7343	
173B	1.09	2.20	672.67	685.24	0.7457	0.7596	
174A	1.17	2.35	613.57	624.10	0.7428	0.7555	
174B	1.28	2.54	617.88	612.92	0.7489	0.7429	
175	1.41	2.86	528.69	551.90	0.7855	0.8200	
176	1.56	3.15	534.46	548.40	0.7802	0.8005	
177A	1.81	3.61	572.87	576.09	0.8290	0.8337	
177B	1.98	3.98	538.13	545.42	0.8031	0.8140	
178	2.25	4.53	519.88	529.70	0.7534	0.7847	

Table 4-1 (Continued)

Output of Results

Cable No.	f1 (Hz)	f2 (Hz)	T1 (tf)	T2 (tf)	T1/TNS (tf)	T2/TNS (tf)	REMARK
179	0.56	1.10	1030.32	1017.47	0.8905	0.8794	MAINSPAN BKK.
180	0.58	1.14	995.79	983.79	0.8525	0.8422	
181	0.61	1.20	1002.66	975.60	0.8562	0.8331	
182	0.63	1.25	937.20	941.89	0.8017	0.8057	
183	0.66	1.32	937.12	934.81	0.8043	0.8024	
184	0.68	1.33	859.84	838.47	0.7575	0.7387	
185A	0.72	1.43	606.28	605.62	0.7174	0.7167	
185B	0.79	1.57	635.87	635.77	0.7498	0.7497	
186A	0.90	1.74	700.76	667.00	0.8120	0.7728	
186B	0.99	1.98	613.91	624.37	0.8284	0.8426	
187A	1.04	2.08	565.80	574.66	0.7880	0.8003	
187B	1.10	2.22	518.05	527.66	0.7275	0.7410	
188	1.26	2.52	527.52	532.28	0.7980	0.8052	
189	1.46	2.92	545.05	553.05	0.8208	0.8335	
190A	1.66	3.31	540.53	539.91	0.8189	0.8180	
190B	1.92	3.95	522.43	551.32	0.8253	0.8709	
191	2.42	4.94	562.35	585.67	0.9129	0.9507	

Table 4−1 (Continued)

Output of Results

Cable No.	f1 (Hz)	f2 (Hz)	T1 (tf)	T2 (tf)	T1/TNS (tf)	T2/TNS (tf)	REMARK
192	0.55	1.08	1012.19	981.25	0.8696	0.8430	MAINSPAN THON.
193	0.57	1.12	978.78	958.35	0.8526	0.8348	
194	0.61	1.19	986.55	959.56	0.8432	0.8201	
195	0.63	1.24	952.03	926.99	0.8158	0.7943	
196	0.64	1.29	882.29	900.06	0.7600	0.7752	
197	0.68	1.34	859.84	850.99	0.7616	0.7537	
198A	0.74	1.46	640.04	635.39	0.7629	0.7573	
198B	0.78	1.55	620.11	619.86	0.7374	0.7371	
199A	0.88	1.74	670.32	663.21	0.7813	0.7730	
199B	0.99	1.95	613.91	608.84	0.8341	0.8272	
200A	1.05	1.81	582.04	431.67	0.8006	0.5938	
200B	1.17	2.29	585.17	561.34	0.8105	0.7775	
201	1.30	2.60	561.22	566.47	0.8414	0.8493	
202	1.44	2.93	530.28	556.84	0.7915	0.8311	
203A	1.64	3.24	527.64	517.24	0.7759	0.7606	
203B	1.96	3.96	544.39	556.97	0.8299	0.8490	
204	2.32	4.69	516.67	524.86	0.7924	0.8050	

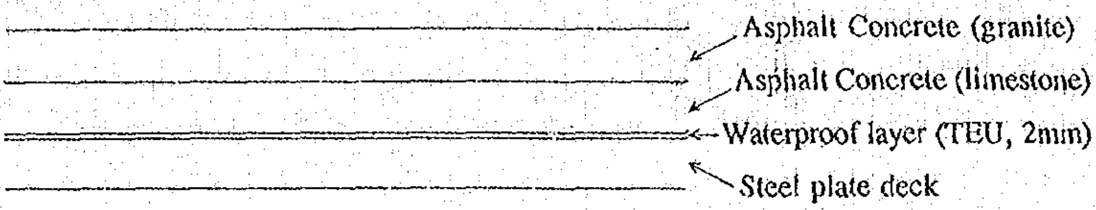
Table 4–1 (Continued)

Output of Results

Cable No.	f1 (Hz)	f2 (Hz)	T1 (tf)	T2 (tf)	T1/TNS (tf)	T2/TNS (tf)	REMARK
205	0.69	1.37	1039.49	1044.90	0.8159	0.8201	BACKSPAN THON.
206	0.73	1.44	1071.65	1048.41	0.8431	0.8248	
207	0.75	1.48	1013.10	1004.59	0.7983	0.7916	
208	0.79	1.57	1012.55	1017.44	0.8017	0.8056	
209	0.82	1.65	991.17	1007.79	0.7923	0.8056	
210	0.84	1.69	938.29	953.10	0.7678	0.7799	
211A	0.90	1.80	688.80	692.89	0.7696	0.7742	
211B	0.98	1.92	716.81	692.18	0.8090	0.7812	
212A	1.02	2.03	676.77	677.06	0.7536	0.7539	
212B	1.08	2.16	660.54	660.65	0.7405	0.7406	
213A	1.17	2.35	613.57	624.10	0.7594	0.7724	
213B	1.25	2.50	589.46	593.78	0.7322	0.7376	
214	1.42	2.83	536.18	540.41	0.8027	0.8090	
215	1.60	3.21	562.00	569.46	0.8121	0.8229	
216A	1.78	3.60	554.09	572.90	0.8383	0.8667	
216B	2.00	4.02	549.03	556.49	0.8646	0.8764	
217	2.21	4.49	501.58	520.29	0.8064	0.8365	

4) Pavement

The Rama IX bridge has orthotopic steel plate deck and its original surfacing is as follows,



Asphalt penetration originally used in the mix is 80-100 and aggregate gradation is shown in the next table.

Sieve Size	Percent Passing by Weight	
	Binder Course	Wearing Course
37.5 mm	100	
25.0 mm	78 - 100	
19.0 mm	-	100
12.5 mm	56 - 80	80 - 100
6.3 mm	40 - 64	-
4.75 mm	-	54 - 72
3.35 mm	30 - 52	-
2.36 mm	-	42 - 58
1.0 mm	18 - 38	34 - 48
600 um	-	26 - 38
425 um	11 - 25	-
300 um	-	18 - 28
150 um	5 - 15	12 - 20
75 um	3 - 7	6 - 12
Asphalt Content % by Weight of Total Mix	4.0 - 8.0	5.0 - 7.5

Shortly after the opening to the traffic, pavement of the Rama IX bridge has failed particularly in the slow lane and since then, it has needed constant repair. Unfortunately, there is no exact data on how many square meters have been repaired so far. A lot of study have been also done to find causes of failure by ETA, supervising consultant and contractor respectively.

As a rule, the successful design of bridge deck surfacing on long span steel bridges is a complicated task. It is a problem which can not be solved correctly without performance testing in a laboratory or field conditions similar to the actual operating requirements for the completed bridge.

Unlike many other design tasks, selection of asphalt pavement for a steel deck structure must be considered as a unique problem requiring a unique solution. In this case, it is wise to follow a traditional design sequence for solving new problems. In general this process should include the following steps:

1. Establish the Design Concept - or method and general characteristics required of the surfacing system.
2. Establish or identify the conditions affecting the Design.
3. Establish the preliminary structural design concept.
4. Selection of the material to be used for surfacing.
5. Conduct trial laying of the materials.
6. Prepare standards and specifications.
7. Establish practical methods of construction.

The success or failure of any design can only be measured against the design concepts and expected performance. Most important is that the materials selected be suitable for the functions they must perform.

The Purpose of Surfacing Systems

The surfacing system on a steel deck bridge must provide smooth riding conditions comfortable and safe for operation of the vehicles that will use the bridge. It must be able to transfer the traffic loads to the deck surface, protect the deck surface from impact loads and protect the steel surface from corrosion.

In order to design a surfacing system which will meet these requirements, several conditions must be considered in detail.

1. Traffic Conditions
   a. Wheel loads - Maximum in tons
   b. Wheel contact area - Average in cm2
   c. Dynamic loads
   d. Vehicle speed of heavy trucks - Average in km/hr
   e. Loading period of vehicle load - seconds per load
   f. Traffic volume - Number of vehicles per period

2. Meteorological Conditions
   a. Temperature - Maximum and Minimum
   b. Precipitation

3. Bridge Surface and Structure
   a. Minimum bending radius
   b. Deformation characteristics
   c. Degree of composite effect desired
   d. Plate thickness
   e. Structural characteristics
   f. Road gradient

4. Expected life of bridge and pavement

Consideration in Selection of Materials

All materials considered for use in the surfacing system must be measured according to the design concept and conditions for the bridge.

1. Waterproofing layer must provide impermeability and adhesion to the steel deck surface.

2. Binder course is the foundation for the pavement. It provides structural strength and gives a level surface. It must contribute to a strong bond within the layers of the surface, if the benefits of composite action are expected.

3. Wearing course should have the same physical characteristics as the binder course, so that it can act compositely. In addition, the wearing course must have special characteristics to resist skidding and abrasion associated with the type of vehicles that will use the bridge.

Evaluating the Performance of Pavement

In cases that problems occur in pavement on steel deck bridges after construction, there are three major areas for evaluation and investigation.

1. Determine if actual conditions are the same as the those used in the design criteria.
   a. Are temperatures, wheel loading, traffic volume and traffic characteristics the same as expected?

2. Determine how the actual performance of materials differs from the expected performance.
   a. Is the bond between layers in the system performing as expected?
   b. What bond strength was required and what strength was achieved?
   c. What characteristics of the bidder material were expected at the operating temperatures?

d. What was the expected structural strength of the asphaltic material compared to the actual loads experienced?
e. What stability was expected of the pavement at the temperatures required
f. Was the mix design in accordance with the design requirements?
g. Is the traffic load the same as expected?

3. Determine if construction was in accordance with the specified requirements.
   a. Examine records of all tests made during construction to determine compliance with the requirements.
   b. Conduct a representative sampling procedure to determine the condition of the bridge surface.

Success or failure of any physical system can only be determined in comparison to the expectations for that system. In case of asphalt pavement, design life is the simplest test for success. If failure occurs prematurely, normal engineering procedure requires that the operating conditions be examined in comparison to the design assumptions. If no significant changes have occurred, the design and results of material performance testing should be reviewed. If no discrepancies can be found, the materials used in construction should be carefully tested and analyzed. Unless there is a clear difference in any of the above areas, the cause of failure will usually be found to be the result of many factors adding together.

In case of the Rama IX bridge, trial section was paved in April, 1992 using two kind of materials, which are "Sealoflex 2"-SBS polymer modified bitumen and "Bolideck ZOK"-polyurethane system under the supervision of Overseas Projects Corporation of Victoria (OPCV) Ltd., Melbourne, Australia. Before applying these materials to trial section, ETA and OPCV have discussed for a long time what kind of material should be used on the Rama IX bridge after OPCV has reviewed the existing materials and tested some materials in the laboratory.

We have to see the performance of trial section, at least, six months until October 1992. But it is quite difficult to estimate the life of trial section, because there is no data about traffic condition, weather, mix properties just after placement and so on.

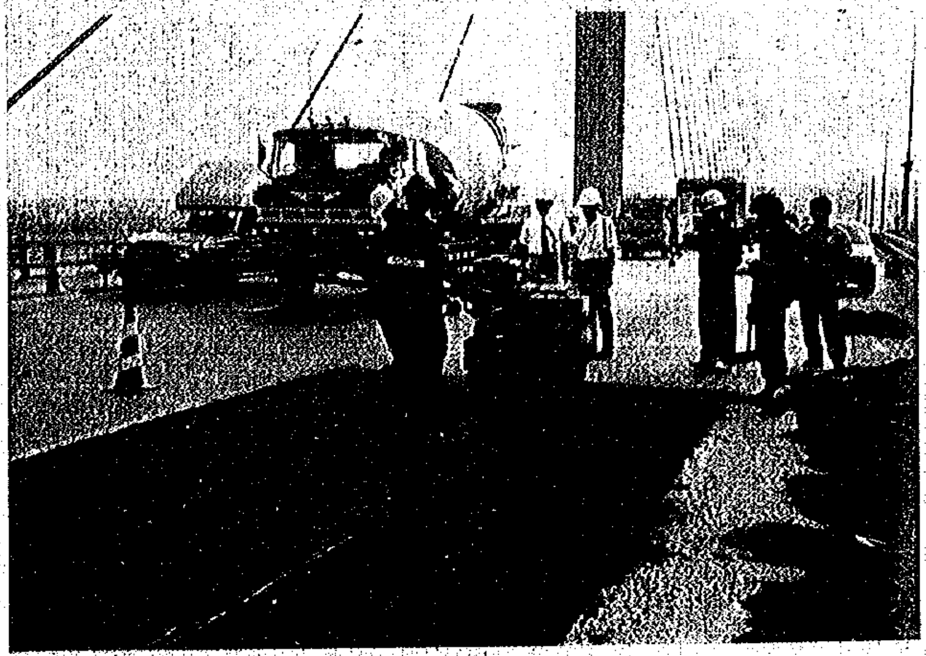


Photo 4-4

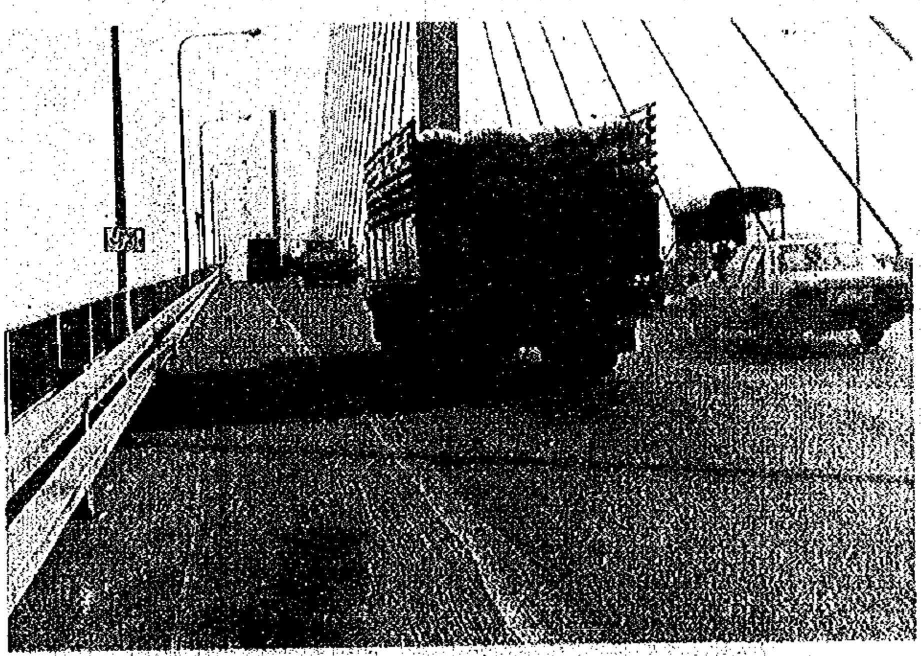


Photo 4-5

Photo 4-6

Photo 4-7

5) High Strength Friction Grip Bolt

The types and sizes of high tensile bolt that was used in construction of Rama IX bridge are as follows,

* High strength hexagon bolt
  M16 L=55-60, M20 L=55-115, M22 L=60-80, M24 L=65-105
  M27 L=80-140, M30 L=100-180, M36 L=190-205
* High strength torque control bolt
  M20 L=55-115, M22 L=60-80, M24 L=65-105

and the bolt grade is F10T (tensile strength 100-120 kg/mm). Since the completion of the Rama IX bridge, some bolts were broken and dropped down into the water. The cause of breakage is not clear, but number of the broken bolt is not so many and all of them have been already replaced.

In Japan, high strength friction grip bolts have been used for structural steel-works since Japanese Industrial Standard (JIS), JIS B 1186-1964, has been established. A major characteristic of the high strength friction grip bolted joints is able to be introduced a high stress into the bolts up to 82.5% of minimum yield point of an effective screwed area of the bolts instructed by JIS. Accordingly, a decrease of axial force of bolts due to creep at screwed parts of bolts and nuts, stress relaxation for bolts was found in actual joints of structural members.

In addition, in case of the metropolitan expressways, high strength friction grip bolts have been used since 1968 and among them, a lot of breakage of F11T has been found since March 1979 because of so called " delayed failure ". On the other hand, in Hanshin area the high strength bolt, F13T class 4 used on the joints have been developed in accordance with JIS B 1186-1964 and these bolts have been also broken due to delayed failure soon after the completion of construction since 1964. Several kinds of investigations for looking for the cause were conducted on the damaged bolts by testing and comparing with characteristics between damaged and undamaged bolts sampled at the place around damaged bolts found out. All results gave that every sample on the damaged bolts shows a grain-breakage with no plastic deformation on properties of a fracture. The breakage on the bolts was concluded to be caused by the delayed fracture because of typical characteristics on the properties of a fracture.

The sensibility for delayed failure will mainly relates to the following items.

* Degree of tensile strength and its uniformity
* Corrosive environments
* Deviation in the process of heat treatment during manufacturing bolts.

Ultra sonic wave test, which is well known as a non-destructive test for the soundness of steel material, is normally applied to check the breakage of the high strength bolts. In this test, inspection procedure is simple and it is not required much time to obtain the test result, but it is very hard to keep test data at the site and inspection engineer will be required very long time experience because test result quite depends on his judgement.

As a general repair method for breakage and looseness of the bolts, a nylon safety net is unavoidably applied at the place where a bolt might drop down. In addition, an improved inspection system is being provided so that a complete inspection can be introduced for that in the future.

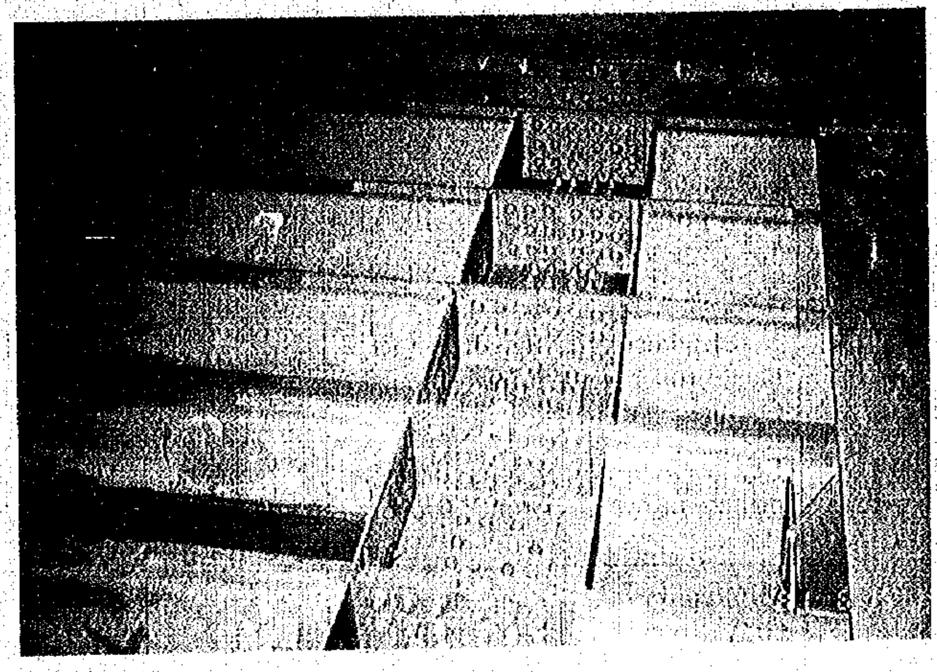


Photo 4-8 An example of broken bolt

6) Paint

Painting specification for the Rama IX bridge is as follows.

Table 4-2 External Surface - Minimum Total Dry Film Thickness 270 micron

	Description	Brand name	Application number	Average of Dry film thickness (micron)
Shop primer (before temporary assembling)	Inorganic zinc shop primer	SD zinc primer ZE No. 1000	1	20
1st coat (after temporary assembling)	Red lead/epoxy blast primer Orange	Epomarine RL primer Orange	1	45
2nd coat (after temporary assembling)	Red lead/epoxy primer Brown	Epomarine RL primer Brown	1	75
3rd coat (after temporary assembling)	MIO/epoxy Grey	Kanpe ferrodor EPX -34 Bridge Gray	1	75
Edge protection stripe coat	Red lead : MIO (60:40)/epoxy Brown	Kanpe ferrodor EPX (EPC)	1	(40)
4th coat (after temporary assembling or site)	Polyurethane Silver Grey	Retan No.60000	1	55

Note: Incase of brush coating, application number shall be the number of times to be able to keep the required dry film thickness.

Table 4-3 Internal Surface - Minimum Total Dry Film Thickness 210 Micron

	Description	Brand Name	Application Number	Average of Dry Film Thickness (Micron)
Shop primer (before temporary assembling)	Inorganic zinc shop primer	SD zinc primer ZE No. 1000	1	20
1st coat (after temporary assembling)	Red lead/epoxy blast primer Orange	Epomarine RL primer Orange	1	50
2nd coat (after temporary assembling)	MIO/epoxy Grey	Kanpe ferrodor EPX - 34 Bridge Grey	1	70
Edge protection stripe coat	Red lead: MIO (60:40)/epoxy Brown	Kanpe ferrodor EPX (EPC)	1	(40)
3rd coat (after temporary assembling or site)	MIO/epoxy Light Grey	Kanpe ferrodor EPX - 33 Silver Grey	1	70

Table 4-4 Galvanized Surface - Minimum Total Dry Film Thickness 105 Micron

	Description	Brand Name	Application Number	Average of Dry Film Thickness (Micron)
Touch up coat	Zinc/epoxy primer	SD zinc primer ZE No. 500	1	40
1st coat	Red lead/epoxy primer	Epomarine RL primer Brown	1	50
Finish coat	Polyurethane Silver Grey	Retan No.6000	1	55

Note: In case of brush coating, application number shall be the number of times to be able to keep the required dry film thickness.

Table 4-5 Painting System of Joint Parts

1) Internal Surfaces

	1st Coat	2nd Coat	3rd Coat	4th Coat	Edge Protection Stripe Coat	5th Coat
Description	Zinc/epoxy primer	Red lead/epoxy primer	Red lead/epoxy primer	MIO/epoxy	Red lead:MIO (60:40)/epoxy	Polyurethane
Brand Name	SD Zinc primer ZE No. 500	Epomarine RL primer (Orange)	Epomarine RL primer (Brown)	Kanpe ferrodor EPX - 34 (Grey)	Kanpe ferrodor EPX(EPC) (Reddish) Grey	Retan No. 6000 Grey
Where applied	Site	Site	Site	Site	Site	Site
How applied	Brush	Brush	Brush	Brush	Brush	Brush Airless Spray
Dry film thickness (microns)	50 (Splice plate: touch up)	50	50	65	(40)	50

Table 4-5 Painting System of Joint Parts

2) External Surfaces

	1st Coat	2nd Coat	3rd Coat	Edge Protection Stripe Coat	4th Coat
Description	Zinc/epoxy primer	Red lead/epoxy primer	Red lead/epoxy primer	Red lead:MIO (60:40)/epoxy	MIO/epoxy
Brand Name	SD Zinc primer ZE No. 500	Epomarine RL primer (Orange)	Kanpe ferrodor EPX - 34 (Grey)	Kanpe ferrodor EPX(EPC) (Reddish Grey)	Kanpe ferrodor EPX - 33 (Silver Grey)
Where applied	Site	Site	Site	Site	Site
How applied	Brush	Brush	Brush	Brush	Brush Airless Spray
Dry film thickness (microns)	50 (Splice plate:Touch up)	50	50	(40)	60

Table 4-6 Painting System of Cable

1) Paint System for Stay Cable

Cable			
	Priming Coat	1st Coat	Finish Coat
Description	Solvent free Polyurethane zinc chromate primer	Solvent free Polyurethane MIO cover coat	Solvent free Polyurethane MIO cover coat
Brand Name	RETAN CABLE PRIMER	RETAN CABLE COAT	RETAN CABLE COAT
Where applied	Site	Site	Site
How applied	Brush	Brush	Brush
Dry film thickness	160 microns	150 microns	150 microns

2) Paint System for Stay Cable

Lower Region of Cable up to 10 Meters Above Carrigeway

Cable				
	Priming Coat	1st Cover Coat	2nd Cover Coat	Finish Coat
Description	Solvent free Polyurethane zinc chromate primer	Solvent free Polyurethane MIO cover coat	Solvent free Polyurethane MIO cover coat	Solvent free Polyurethane MIO cover coat
Brand Name	RETAN CABLE COAT	RETAN CABLE COAT	RETAN CABLE COAT	RETAN CABLE COAT
Where applied	Site	Site	Site	Site
How applied	Brush	Brush	Brush	Brush
Dry film thickness	160 microns	150 microns	150 microns	150 microns

The frequency of inspection for painting is as follows:

Bridge (inside) ------- every year
Bridge (outside) ------ every day
Pylon (inside) -------- every year
Pylon (outside) ------- every month
Cable ----------------- every 2 weeks (Routine inspec.)
every 2 years (Period inspec.)

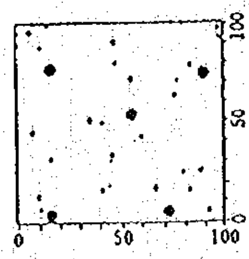
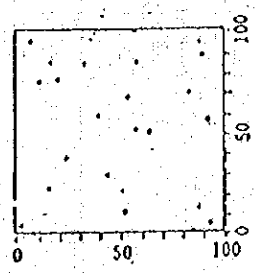
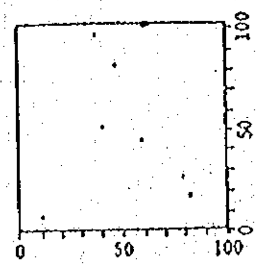
In regard to the condition of members of the bridge, it is judged according to rating standard in table 4-6. Inspection results are classified into five grades from A to Q due to grade of detects or damage.

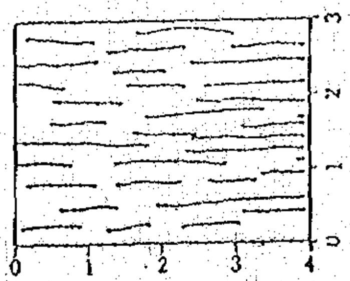
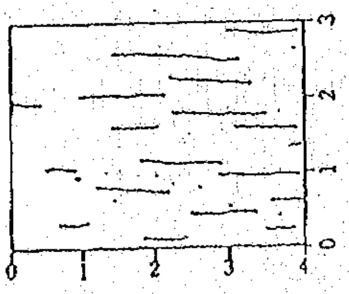
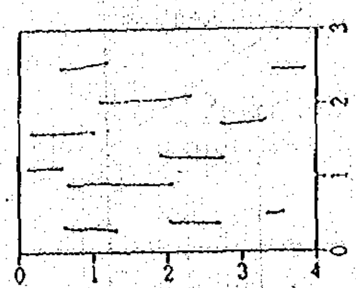
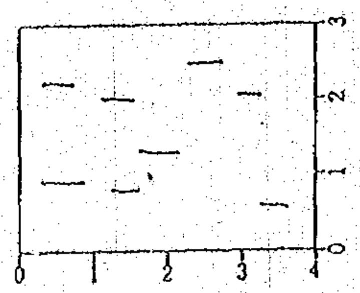
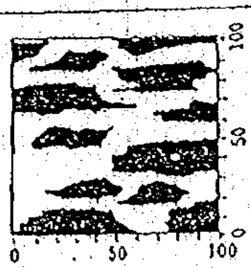
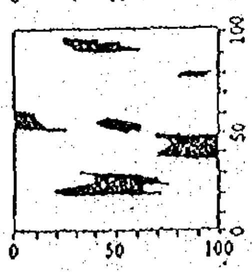
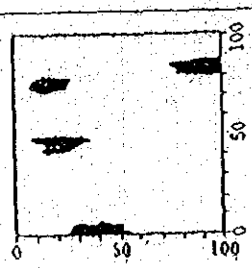
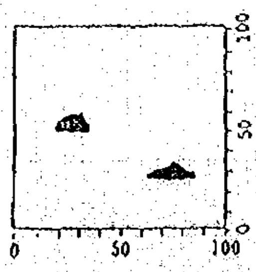
Table 4-7 Standards for rating of defects and failures (Painting inspection excluded)

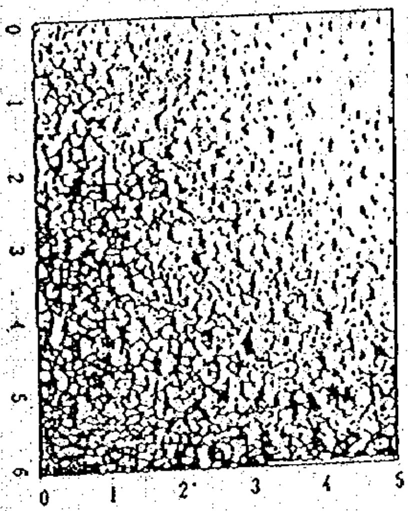
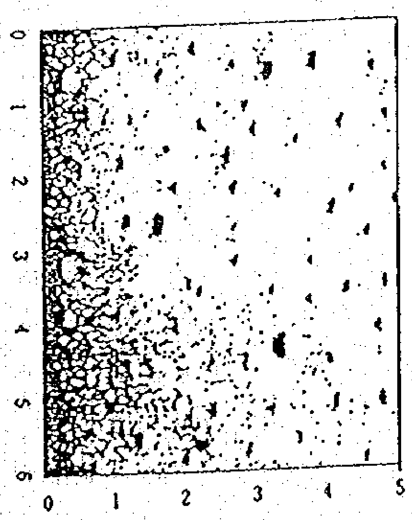
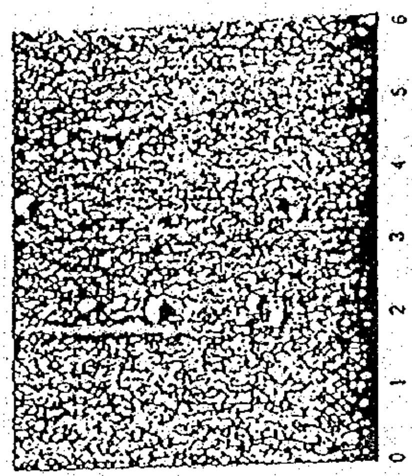
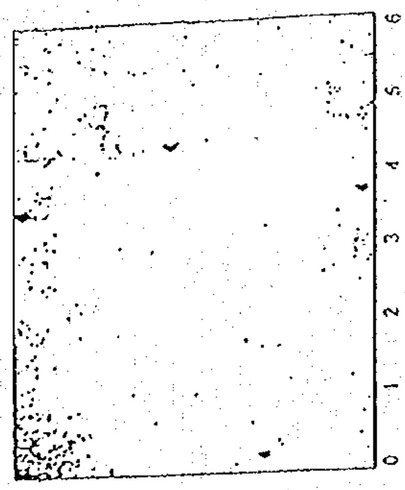
Rating	Standards of Rating
A	This stage has serious defects or failures which may affect on vehicle driving or on safety of third body. This needs urgent stiffening or closing of traffic.
B	This stage has significant defects or failures which may proceed to decrease the bridge function. This needs prompt treatments.
C	Defects are light. This needs continuous inspection.
OK	Normal stage.
Q	Rating is difficult by general means This needs re-inspection by other methods.

Standards for rating in painting inspection are as follows.

Table 4-7 Standards for rating in painting inspection

Condition \ Rating		B	C
Rust	General surface	  (mm)	 (mm)
	Edge	Continuous rust along edge line	Discontinuous rust along edge line

Rating / Condition	B	C
Cracking	  (cm)	  (cm)
Flaking peeling	  (mm)	  (mm)

Rating / Condition	B	C
Blisterling	  (cm)	  (cm)

Repainting is one of the methods to repair steel structures and essential for them to keep in good condition for a long time. Repainting is classified into three methods such as whole area repainting, partially repainting and spot repair and selection of repainting method depends on rating in painting inspection. It is generally recommended to use the same paint as original one in repainting work.

Cleaning is very important process in repainting work and cleaning class depends on painting system and rating in painting inspection. Cleaning class is normally classified into four classes from I to IV.

7) Damper

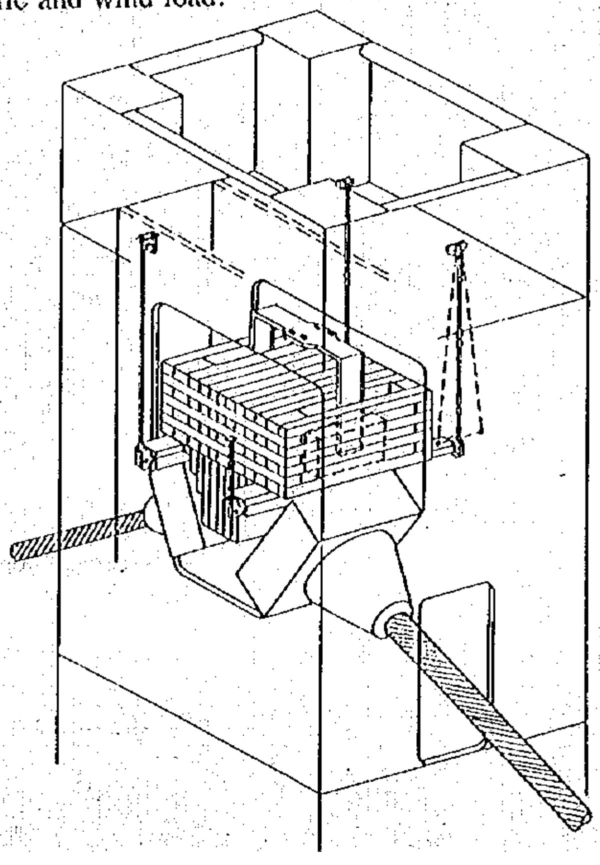
The aerodynamic effects of wind on the bridge deck and pylons were studied in wind tunnel tests and records of wind speed and direction at 50 meters above Mean Sea Level were also made during the construction period.

The tests were conducted using models of the bridge deck and pylons and limited oscillations of the deck model were observed only with wind blowing with an upward component. These oscillations would not be dangerous for the bridge, but it was thought that, if they occurred, they might become noticeable or uncomfortable to users, and might possibly cause traffic accidents. To avoid any possibility of this happening, it was decided to install tuned mass dampers in the bridge deck.

The tuned mass dampers consists of a mass hanging grom tension springs with "viscodampers" attached. They are tuned to the natural frequency of the bridge, and if wind induced oscillations begin , they reduce the amount of movement of the bridge by themselves moving and so absorbing energy.

There is one damper in each of the pylons, immediately above the top cable anchorages. The deck contains eight torsion dampers and eight bending dampers each with a weight of five tonnes. There is also viscous cable damper in each stay cable to reduce the vibration caused by traffic and wind load.

Fig.4-5 Pylon damper



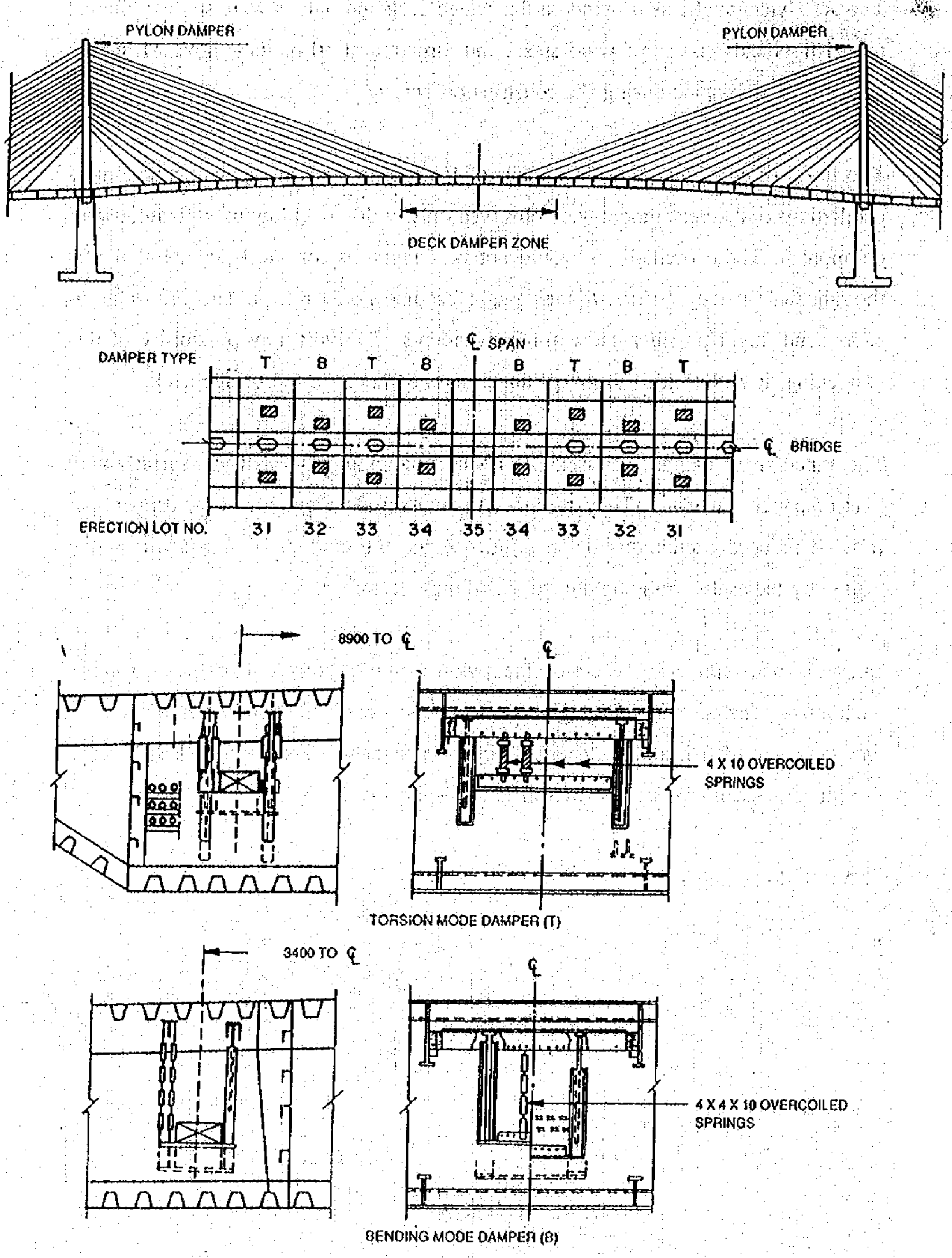


Fig.4-6 Aerodynamic dampers

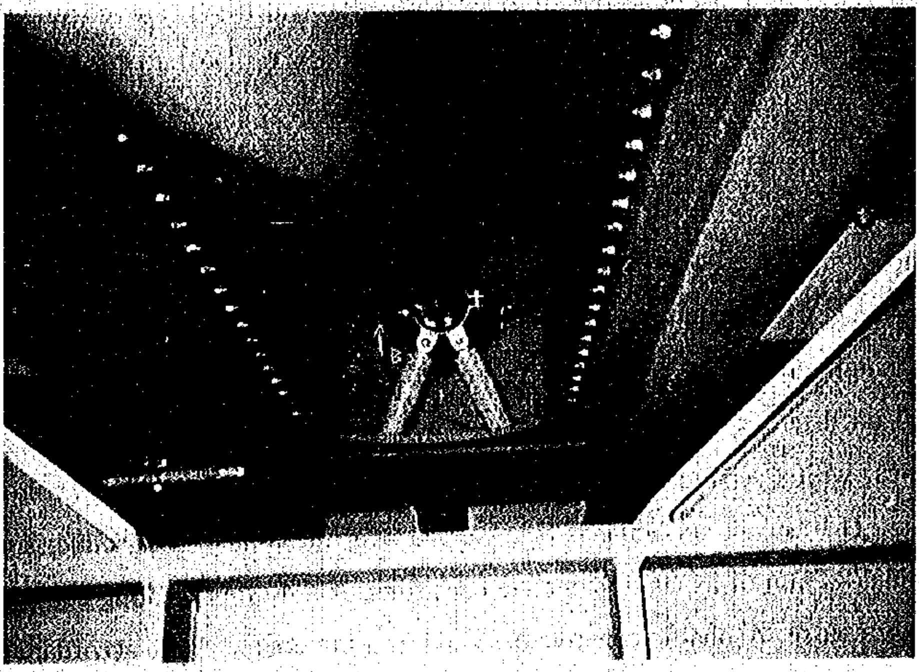


Photo 4-9 Cable damper

It will be needed to check actual behavior of these dampers by dynamic test on the bridge in near future and it is better to compare those behavior with theoretical one.

4.2 Expressways

1) General

A total length of the first stage expressway system is 27.1 km and most of structures except Rama IX bridge crossing over Chao Phraya River are concrete viaducts. AASHTO specification is generally used for highway bridge in Thailand with MS 18 loading. They have however been compared with British and other standards and these have been used where AASHTO has been found wanting.

As shown in Fig.2-2 the basic design consists of a 20 meter span constructed from pretensioned I beams with in situ cross beams at either end constructed within the depth of the longitudinal beams. These cross beams rest on rubber bearings which in turn are carried on discrete columns. The joints between the spans are waterproofed by deck flashings, with a second line of defence over columns in an attempt to avoid unsightly staining. The asphalt surfacing is then carried over the joints. The viaduct surfacing is a nominal 80 mm of asphaltic concrete consisting of a 40 mm wearing course and a 40 mm base course. Asphaltic concrete base and wearing course are in accordance with the Thai Department of Highways specification, with the exception that the aggregate forming wearing course has been specified to British Standards to improve the skid resistance properties of the surfacing. Buried expansion joints are provided at the ends of all the precast spans to cater for movements due to a temperature range of $\pm 15^{\circ}C$. In addition, all points vulnerable to staining are protected by a water bar cast into the adjacent faces of concrete at all expansion joints. These water bars are not designed to permanently stop water that leaked through the buried joints, but to deflect it away from areas such as columns, where leaks will cause staining.

Where a span greater than 20 meters is required or where single column piers are desirable, the precast beams are constructed with a halved joint at either end and a section of in situ deck is cast over the columns.

2) Concrete Structure

For the concrete structures, crack is inevitable and it is very important to check crack existence and its propagation in order to keep concrete structures in good condition. According to the recommendation for the investigation and repair of cracks in concrete structures prepared by Japan Concrete Institute, a general process of investigation and repairing work of cracks will be done in accordance with Fig.4-7 . The word of "Start" in the flow chart means a discovery of the crack and these steps of the flow chart are for normal cracks on the concrete structures which caused by normal performance in design, material, construction and operation.

To clear up the cause of cracks is very important to get necessary information for estimating a sound judgement of the structure for the use in comfort and for deciding a necessity of the repairing work and process for supposing the causes of cracks should be based on the Preliminary or Detailed investigation.

The judgement for the necessity of repairing work will be divided into two major considerations as follows:

(1) Useability of the structure (Safety and Functionability)

The judgement for the necessity of repairing work on the crack, in principle, should be conducted in response to a purpose of the best possible use of the structure. Because of this, a different standard for the judgement against even if for the same kind of cracks, comes up in practical depending on making the best use of the structure.

In general, useability of the concrete structure can be classified as follows:

- Useability
  - Safety
    - Proof-stress
    - Durability
    - The others
  - Functionability
    - Waterproof
    - Aesthetic sense (Beauty)
    - Airtightness
    - The others

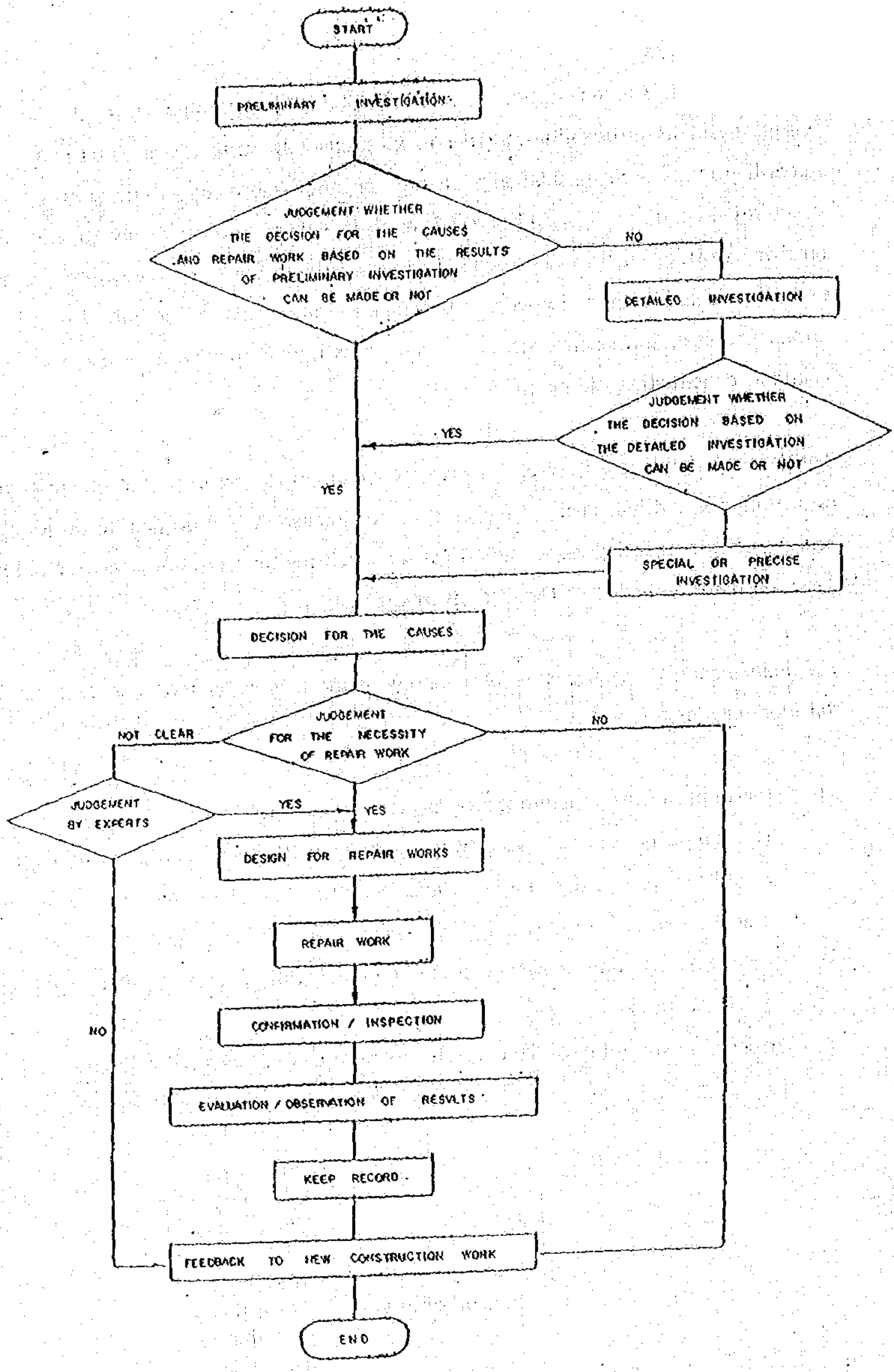


Fig 4-7 Flow Chart for Investigation and Repair work of Cracks

- Proof-stress will give a judgement whether the structure can maintain safety at present while the investigation is being done or not.
- Durability will take account of the safety to be covered for the whole service life of the structure. A consideration for durability should be extended over for not only a possible condition of a present safety but also an ultimate possibility of the long-term-safety caused by the cracks.
- Functionability has to be considered for the whole service life of the structure not only at present.

(2) The final judgement for the necessity of repairing work should be considered including practical means instead of actual repairing works as follows,

- Decrease in load (To control superimposed load)

  When the decrease of safety to the specified load has been confirmed due to the occurrence of cracks, the loading such as traffic load should be controlled within the limits which would not infringe safety service to the users.
- Change of the using purpose

  In very rare cases, the using purpose can be changed keeping the safety for the specified load.
- Reinforcement of the structure

  Sometimes a major reinforcement of the structure which was damaged by cracks will be needed, when the enough safety of the structure due to repairing work on the cracks can be not be guaranteed or when a future repairing work will be needed again.
- Reconstruction or demolition

  When the safety of the structure can not be predicted after repairing works, or when a huge investment will be needed for the reinforcement on the structure, a reconstruction or demolition of the structure must be considered.

Mainly two major factors such as durability and water-proof on the concrete structures should be considered for judgement in accordance with Table 4-9 and the judgement for the necessity of repairing works can be made comparing with the width of cracks between that given from the investigation and that as shown in Table 4-9 .

Class	1) Other Factor / 2) Environmental Condition	View from Durability: Serious	View from Durability: Medium	View from Durability: Not Serious	View from Water-tight
	(Power of Influence)	Over than	Over than	Over than	Over than
(A) Crack-Width to be repaired (mm)	Large	0.4	0.4	0.6	0.2
	Medium	0.4	0.6	0.8	0.2
	Small	0.6	0.8	1.0	0.2
	(Power of Influence)	Less than	Less than	Less than	Less than
(B) Crack-Width to be not repaired (mm)	Large	0.1	0.2	0.2	0.05
	Medium	0.1	0.2	0.3	0.05
	Small	0.2	0.3	0.3	0.05

Table 4-9 Standard Width of Cracks for the Judgement of the Necessity of Repair Works

1) The other factors means the degree of harmfulness for durability and water-proof on concrete structures.
Pattern and depth of crack, amount of concrete cover, covering material on the surface of the concrete, material and mix proportion of the concrete, condition of the construction joints and others can be taken into consideration.

2) This means an environmental condition mainly from point of view of the condition for the rust of reinforcements.

When more structural factors such as proof-stress, beauty, airtightness and others on the structure will be needed in consideration, the judgement can be made by experts.

The most adequate method, after grasping the conditions of the crack, should be selected to meet the purpose of a repair. Before doing the repair work, the design for the repair should be completed with necessary factors involved such as scope, scale of the work, methods, materials, period, necessary equipments and adequate time for the work.

In general, there are three kinds of typical repairing methods on the cracks as follows,

(1) Surface-treatment Method

This involves, putting a coat along the crack and is useful for crack widths less than 0.2 mm, as shown in Fig.4-8. This will not repair the structural strength of damaged structures. A material for the coat should be selected for the specified purpose; for instance 1 epoxy resins or glass clothes with resins for general purpose; 2 tar-epoxy for the water-proof when the crack will change the width. Before commencing surface-treatment method of any surface on the concrete structure, any foreign things such as oil, grease, dust, leakage-lime, rust and corroded or fragile parts of the concrete have to be removed by suitable means (1: to scour the surface with a wire-brush for making roughness of the surface, 2: to wash extraneous matter away from the surface, and 3: to ensure the concrete is dry). Also before applying the coat, more attention has to be paid for filling into the hole like a void or an air bubble on the surface of the concrete by putty resins. Mortar blow method instead of filling of resins or asphalt paint method for only purpose of water-proof as one of surface-treatment methods have been applying on the actual structures.

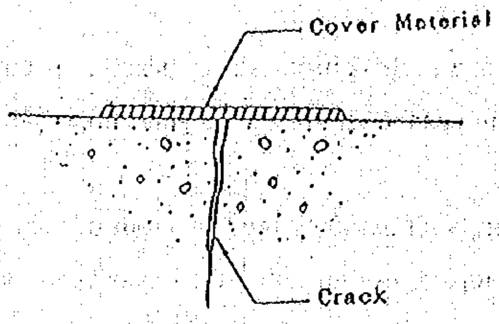


Fig.4-8　Surface-treatment Method

(2)　Grout Injection Method

The method of filling of resins or inorganic materials into each and every crack, is useful for the purpose of not only water-proof but also recovering the strength of the structure if the epoxy resin was applied.

* Filling-up method

This will be applied when the surface-treatment method will be not sufficient for protecting the wear or corrosion in the long period. Typical form of this method is to apply resins, cement-mortar and asphalt material into the inside of the groove. In normal, two kinds of groove can be formed V-shape for resins and U-shape for mortar (to protect from exfoliation of materials after operation), as shown in Fig.4-9. After cutting the groove, any fragile concrete parts or foreign things must be removed and, the groove has coated with a primer before filling. After the material has hardened,surface treatment by grinder or disc sander can be applied if necessary.

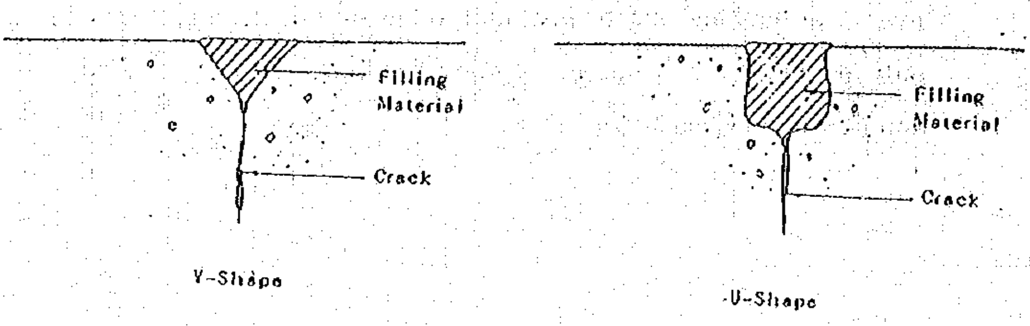


Fig.4-9　Filling-up Method

* Grouping method

This is a method to inject a viscous fluid into the deep part of the crack. A typical material is a low-viscous epoxy resin. A normal process for the grouping method is as follows:

- To make the groove with V-shape along the crack. The center of the groove is to be at the center of the crack.
- To install grout pipes along the crack as necessary.
- To seal entirely the mouth of the groove with a cover material or adhesive tape so that the resin filled in will not come out.
- To fill the resin into the pipe by means of electric, hand, or treadle pump.

Before filling the resin, it is important to clean inside the crack by first blowing air and fill the resin into crack, slowly and slowly, under an adequate pressure. If the grout pressure is too high, the result of work will not be satisfactory because not only will the resin fail to penetrate not smoothly deep into the crack, but also, in the worst case, the pressure will expand the crack-width. Careful attention should be given to selecting pressure-value.

The most applicable condition of the grouping method is for crack width over than 0.2 mm on the surface. If the crack-width is smaller than 0.2 mm, it is very difficult to apply this method, skillfully, because of "plugging". If the method applied to the crack which has a suitable width for its application, however, a good result with a careful performance can be provided up to crack width of 0.05 mm.

A possible range to be able to be filled by one grouping pipe is depending on factors such as crack-width, viscosity of the resins, and temperature during construction. Accordingly, the space of the grouping pipes to be set along the crack should be adjusted due to factors, but a normal space will be 10 to 30 cm. Filling works should start from the pipe located on the lowest or left most side of the cracks, continuing until it is confirmed that resin overflows from the next pipe. After finishing the work at applied to the next pipe in the sequence.

(3) Reinforcing Method

This will be mainly divided into two groups : Steel anchor method and Prestress method as follows:

* Steel anchor method

This is a method to fasten the crack with steel anchors of clamp shape as shown in Fig.4-10. The purpose of this method is not only to repair the cracks but also reinforces of the structure due to stitching it up together. Holes for the clamps should be provided by drilling and fastening with cement-mortar or resin-mortar. The desired number of steel anchors should be provided by the request in design under service load-conditions and should be carefully installed in the similar direction of the main stress-distribution along the crack. If it is possible, all of installed things including the area up to crack ends should be covered by resin-mortar to obtain protection against rust and water.

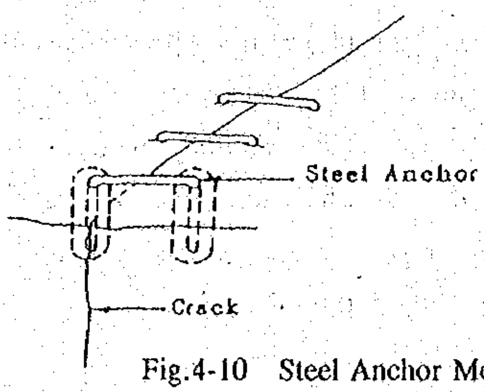


Fig.4-10 Steel Anchor Method

* Prestress method

This is a method to fasten the area of the structure affected by putting designed prestress bars, which they cross at right angles to each other as shown in Fig.4-11. The holes for the prestress bar will normally be provided by boring through the structure. It is normal to insert resins into the holes after fastening the prestress bars.

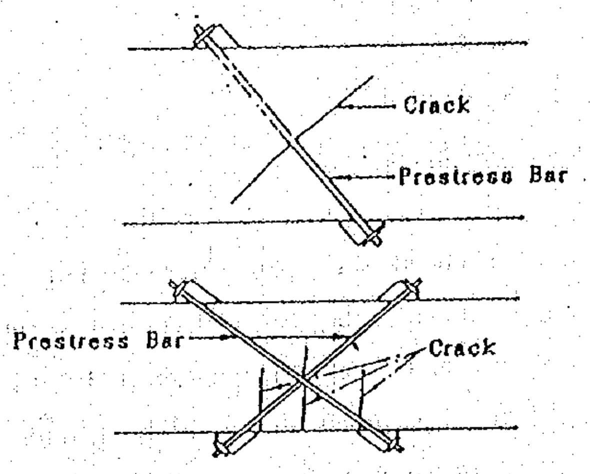


Fig.4-11 Prestress Method

As special method for repair of cracks, there are two other methods as follows,

- Replacing method

  After removing all the fragile parts of concrete in the crack location, new concrete is added together with proper arrangement of reinforcement.
- Reinforced method

  After preparing a steel plate along the crack, it is struck on to the structure by an adhesive agent, to recover the decrease of the structural strength.

3) Pavement

After the conditions of the road surface have been investigated, an overall evaluation of the surface is conducted for each investigated section or route. The evaluation is to be quantitative. In Japan, each authority has their own evaluation standard, for instance, for the Metropolitan Expressways the maximum rut depth and cracking ratio should be 20 mm and 20 % respectively, and for national highways the Maintenance Control Index (MCI) has been adopted as an index to evaluate the conditions of the surfaces.

$$MCI = 10 - 1.48C^{0.3} - 0.29D^{0.7} - 0.47G^{0.2}$$

where MCI=Maintenance Control Indexes

C=Cracking ratio (%)

D=Rutting depth (mm)

G=Longitudinal roughness (mm)

It is reasonable to conduct maintenance and repair corresponding to the MCI value shown in Table 4-10. However, occasionally, the road surface may be subject to repair even though its MCI value is higher than the value shown Table 4-10. It is desirable to repair damage in its early stage, before it becomes serious. Early attention to the damage may result in reductions in the cost of maintenance and repair in the long run.

Table 4-10 MCI and Its Corresponding Maintenance Level

MCI	Necessary Level of Maintenance
5 MCI 10	Routine maintenance
3 MCI 5	Minor repair
MCI 3	Major repair

The process of maintenance should be selected on the basis of past experience and overall judgement of the maintenance and repair method. The purpose of maintenance methods is not to thoroughly repair damage to the pavement, but to maintain the serviceability of the pavement through temporary repair. The maintenance methods for asphalt pavement are classified as follows:

* Patching
* Sealing and filling cracks
* Surface treatment

The purpose of repair methods is to cope with drastic repairs. Major methods include overlay, milling and overlay, reconstruction and in-place recycling. But, overlay is not suitable repair method for the elevated structure because of limitation of dead load.

With the milling and overlay method, the part of the asphalt mixture of the existing pavement which has developed damage is removed and overlay is applied to the surface. There are two methods available, the replacement of the new asphalt mixture with an equal thickness of the removed mixture, and the addition of an overlay having the necessary thickness to the replaced layer.

If the damage is judged to be too serious for temporary repair to maintain a pavement with sufficient quality, the pavement is to be replaced. Since this method is the most expensive one among the repair methods, it should be adopted after taking full consideration.

* Level 1: The pavement has nearly perfect serviceability and will only need routine maintenance.
* Level 2: The pavement has nearly perfect serviceability, although partial maintenance and repair are needed.
* Level 3: The pavement needs to be applied with overlay or major should be conducted.

The purpose of In-place recycling is for the effective use of resources and prevention of wastes arising during repair operations. It may be used in any situations where overlay, milling and overlay, or reconstruction are necessary, with existing pavement materials being able to be recycled. In-place recycling includes two methods: The in-place surface course recycling method, which aims at reinforcing the structure of the pavement through restoring the quality and original shape of the damaged surface course, and the in-place base course recycling method, which crushes the asphalt mixture and granular materials of the damaged pavement and stabilizes them for the construction of the base course in repair operations. For the expressway carrying heavy traffic, in-place surface course recycling is recommended.

4) Expansion Joint

In a long elevated type of structure, expansion joints are essential components in order to adjust displacements in bridges caused by such factors as temperature variations, as well as creep and shrinkage to maintain road levelness to ensure trouble-free travelling of vehicles, but the joints will make one of the weakest point in the bridge structure. There are many kinds of expansion joints that can be used at the both ends of the girder for the purpose of keeping road-continuity and of accommodating allowable movement due to temperature change or live load. It is, however, rather difficult to provide a high quality joint to satisfy the requirements sufficiently.

The durability of a joint relates many factors such as bridge type, load of vehicle, traffic volume, environmental conditions, and so on. Since there are a few data concerning such factors, it is difficult to decide the durability of a joint clearly. According to Japanese investigation of the number of replaced joint and an accumulated traffic volume of large vehicle, the number of replacement increases quickly when an accumulated traffic volume of large vehicle reaches 2 to 5 million for rubber joints, 5 to 10 million for steel reinforced elastomer, and more than 10 million for finger joints. The major reasons of replacement are an abrasion of joint body and damage of post-cast concrete.

In the first stage expressway system, the life of some joint is less than four years and expected to be more than five years. Because, not only the frequent replacing costs more, but also the replacing expansion joint causes traffic congestion during its work under the present heavy traffic volume. I found some joint is still keeping good condition even after more than 5 years since experimental installation. The cost of that joint is more expensive than the other common type of joint. But the life of joint is longer and total cost (initial cost + maintenance cost) is much more inexpensive. It is the time for ETA to rethink the way of selection of expansion joint.

5) Bearing

Damages of bearings are produced as a result of mixing of various causes in many cases. Therefore, the estimation of the cause of damages must be made with utmost care.

Main causes leading to a damage can be classified into the following 3 categories,

* Lack of consideration in design
* Defective manufacture or execution
* Insufficient maintenance or management

The reparatory measures shall not only restore the original functions of the bearings , but also prevent recurrence of similar damages in the future with their execution in principle. The repairing method shall be determined based on an examination from a global viewpoint of field condition, condition of damage, cause of damage, workability, influence on passing vehicles, influence on bridge structure, etc.

Since the bearings are located in narrow places, the repair work of bearings must be executed under very difficult conditions in many cases. There are various measures to be taken depending on the condition of damage, the situation of surroundings, the cause of damage, etc. in order to try to adopt the most effective method by accurately grasping the cause of the damage and to avoid deciding the method of repair works easily by considering the workability only.

An ideal reparatory measure is to remove the main cause of the damage of bearings. Therefore, there are often cases where reparatory measures must be taken not only for the bearings themselves, but also for other portions such as superstructure, substructure, foundation, expansion device, etc. and a careful consideration is required. The repair work must be executed in such a way that the repaired part may continue to deploy its functions smoothly for a long time.

However, in the case of a damage due to an unusual displacement of the substructure, large-scale works are sometimes required and it is also necessary to take a flexible approach of making a temporary repair work only and continue watching the situation, for example, in a place where there is a high possibility of repetition of similar displacements in the future.

From the viewpoint of stability and safety of bridge, the time of temporary supporting with a jack and a temporary supporting work, etc. should preferably be as short as possible. It is therefore desirable to select the repair method with due attention to method and procedure of execution as well as materials used to shorten the period of temporary supporting as much as possible in repair works requiring a temporary supporting.

When the damage of bearing is attributed to breaking of expansion device, etc. it is desirable to adjust the time of execution of repair work to the time of rust proofing work of the bearings as much as possible. However, at points of works involving jacking up (raising) and jacking down (lowering) of girder such as partial replacement of bearing, etc., it is recommended to execute the repair works of expansion devices at an earliest possible time after the execution of the repair work of bearings in view of the flatness of the road face.

As for the period and the time zone of execution, it is requested to select a season and a time zone in which the influence of the works on the traffic may be kept to the minimum and that the works may have the least influence on the bridge structure and the temporary supporting works.

5. Maintenance Database

The maintenance database usually consists of; basic information of each portion of the expressway, such as drawing, map, etc., history of maintenance and inspection works, and possibly containing work plan for maintenance and inspection. It is an important information for maintenance system which will secure the expressway in a good condition for all operating period. The maintenance system will not be able to work without information supporting from the database. The database can tell present conditions of the expressway and can also be used to predict future conditions of the expressway via their historical data. Beside of maintenance purpose, the database can also be used for other purposes such as planning and administration.

There are various types of maintenance database system which were tailored to suit with their purpose of use and maintenance system to be used together. However, they normally have the same basic structure and contain similar basic information. The Tokyo Metropolitan Expressway Authority has also developed its own maintenance database system for using together with its maintenance system. It is currently using in the authority for maintenance purpose.

5.1 Maintenance Database of the Tokyo Metropolitan Expressways Authority

The maintenance database of the Tokyo Metropolitan Expressways Authority was established in order to use with the maintenance system of the authority. It was basically developed on the micro-computer. However, the capability of micro-computer is limited, therefore, some parts, such as drawings, have to be developed on the mainframe computer and then linked together.

According to the capability of the micro-computer, the maintenance database was separated into two major parts; database and drawing. The database containing basic information, historical data, and etc., was developed on the micro-computer using 'Dbase III plus' which is convenient for updating. In the case of drawing, it needs to be developed on the mainframe computer due to a large memory and graphical presentation requirement, it was, therefore, developed under CAD system (Computer Aided Design). It is normally available as a result of design works. The contents of the database are shown in the Table 5.1.

5.2 Maintenance Database of the ETA

ETA has not developed the maintenance database system yet due to that the age of the First Stage Expressway (FES) is in the early stage. In order to develop the maintenance system for the ETA, the maintenance database availability in the ETA was investigated in comparison to the database of the Tokyo Metropolitan Expressways Authority. The following are discussions on the results of investigation.

5.2.1 Procurement Record File

- Procurement Records

The procurement records for construction and repair of the FES have been kept in each responsible division and also kept in the Procurement Section of Supply and Household Division. They are currently not kept in system yet due to staff shortage.

- Contracts

The contracts for both construction and repair work are in the Expressway System Division. The contracts for the First Stage Expressway was separated by route alignment into 4 sections as follows:

1. Bang Na - Port Section
2. Din Daeng - Port Section
3. Dao Kanong - Port Section (Portion of the Chao Phya River Crossing Excluded)
4. Dao Kanong - Port Section (Chao Phya River Crossing at Wat Sai)

Table 5.1 Contents of Maintenance Database of the Tokyo Metropolitan Expressway Authority

File	Sub-file	Type
1. Procurement Record File	Procurement, Contrcat, Modification	Database
2. Structure File	2.1 Base File Basic alignment, accesories	Database
	2.1.1 Basic management drawing	CAD
	2.2 Floor File Basic structure, floor stringer, edge reinforce, railing reinforce, railing paint, drainage repair	Database
	2.2.1 Floor reinforce drawing 2.2.2 Railing reinforce drawing	CAD CAD
	2.3 Superstructure File Basic structure, flexible joint, ant-fall device, support pod	Database
	2.3.1 Steel floor file 2.3.2 HTB file 2.3.3 Anti-fall maintenance drawing 2.3.4 RC beam photo file	Database Database CAD Database
	2.4 Foundation File Basic structure	Database
	2.4.1 RC pillar photo file	Database
	2.5 Accesories File Noise barrier, noise absorbant board, central divider, fence	Database
	2.5.1 Accesories maintenance drawing	CAD
	2.6 Attached Facility File Emergency exit, open space, emergency staircase, weaving section, emergency parking, toll booth, sign posts	Database
	2.6.1 Sign posts maintenance drawing	CAD
	2.7 Cleaning Work File	Database
	2.8 Green Area File	Database

File	Sub-file	Type
3. Maintenance Work File	3.1 Pavement File Pavement structure, history	Database
	3.1.1 Pavement management drawing 3.1.2 Pavement work order management drawing	CAD CAD
	3.2 Paint File Paint structure, history	Database
	3.2.1 Paint drawing Latest paint structure	CAD
	3.3 Damage Repair File Damage data	Database
4. Inspection Work File	4.1 RC Floor Inspection File Photoes, details	Database
	4.2 Steel Structure Inspection File Floor, superstructure, pillar	Database
	4.2.1 Fatique damage file	Database
	4.3 RC Structure Inspection File Superstructure, pillar	Database
	4.4 Support Pod Inspection File	Database
	4.5 Sign Post Inspection File	Database

(1) Bang Na - Port Section

There are 6 contracts for the Bang Na - Port Section as follows:

Contract no. 1 from Kasemraj Road to Sukhumvit 50

Contract no. 2 from Sukhumvit 50 to Bang Na

Contract no. 3 Bang Na Interchange

Contract no. 4 Toll Buildings

Contract no. 4/1 Central Administration Building

Contract no. 5 Electric and Mechanics for Toll Booth

Contract no. 6 Lighting and Signals

(2) Din Daeng - Port Section

There are 6 contracts as follows:

Contract no. 1 from Din Daeng to Makasan

Contract no. 2 Makasan to Rama IV

Contract no. 3 Port Section

Contract no. 4 Toll Buildings

Contract no. 5 Electric and Mechanics for Toll Booth

Contract no. 6 Lighting and Signals

(3) Dao Kanong - Port Section

There are 6 contracts as follows:

Contract no. 1 from Nang Linchi to Sathu Pradit

Contract no. 2 from Sathu Pradit to Bangkok Approach of Rama IX Bridge

Contract no. 3 from Suksawat Interchange to Dao Kanong

Contract no. 4 Dao Kanong Interchange

Contract no. 4A Dao Kanong Interchange Addendum

Contract no. 5 Electric and Mechanics for Toll Booth

Contract no. 6 Lighting and Signals

(4) Dao Kanong - Port Section (Chao Phya River Crossing at Wat Sai)

There are 4 contracts as follows:

Contract no. 1 Cable-Stayed Bridge
Contract no. 2 Thonburi Approach Bridge
Contract no. 3 Bangkok Approach Bridge
Contract no. 4 Suksawat Interchange

All contracts are kept in the Supply and Household Division.

Each contract has attached drawing called contract drawing. During the construction period, some contract drawings, such as utilities, at grade expressway, access road, and etc., have been modified in correspondence to the actual construction works.. These modified drawing called as-built drawings and they have been used as reference instead of contract drawing.

Sections 1, 2, and 3 are under the responsibility of the Expressway Maintenance Section of the Maintenance Division. Whilst section 4 is under the Rama IX Bridge Maintenance Section. The drawings of each section are, therefore, kept at the Administration Office of each section according to their responsibilities. However, These drawings were prepared by the consultant in two sizes; half size and full sized. The half size drawings have rather been used due to their convenience for carrying. They are kept in the Expressway System Project Office and in each relevant division.

Apart of these drawings, there are drawings for repair contracts such as pavement repair, repainting, traffic sign installation, and etc. They were also kept in the same places as those major contract drawings.

- Modifications

There are one on-ramp and one off-ramp added to the First Stage Expressway at Rama IV road which led to the modifications of the drawing of Din Daeng - Port Section. The modified drawings have been attached to the original drawings as addendum.

Sample drawings are illustrated in the Appendix 6.

5.2.2 Structure File

- Base File

Basic alignments are illustrated in the as-built drawing of each route as a key plan, while the accessories are in lay out plan by each type of accessories.

Basic Management Drawing has not been used in the ETA yet.

- Floor File

The basic structure, floor stringer, edge reinforce, railing reinforce, and drainage repair are shown in the as-built drawing of each route in the structural drawing part. The railing paint is none existent.

The reinforce drawing for floor are illustrated in as-built, but railing for FES is guardrail, therefore, no reinforcement is needed.

- Superstructure File

Basic structure, flexible joint, and support pod are in as-built drawing while anti-fall device is not applied for the expressway in Thailand.

There is only one steel floor section on the Rama IX bridge, it has illustrated in as-built drawing of the bridge section.

The HTB file is kept in the Rama IX Bridge Maintenance Section.

The anti-fall has not been used in the FES.

The RC beam photo has not been prepared.

- Foundation File

Basic structures are in the as-built drawings of each route.

The RC pillar photo file has not been prepared.

- Accessories File

Noise barrier exists in the as-built drawing of each route as concrete barrier or median barrier. Noise barrier will be constructed more in accordance with noise pollution level occurring.

Noise absorbent board has not been used in the FES.

Central divider is in the as-built drawings in island details section.

Fence is in fencing details of as-built drawing.

Accessories maintenance drawing has not been prepared.

- Attached Facility File

Emergency exit, open space, emergency staircase, weaving section, emergency parking, toll booth, and sign post are illustrated in plan view of as-built drawing without details.

Sign posts maintenance drawing are in the contract drawing for maintenance work.

- Cleaning Work File

They have been kept in the Right of Way Maintenance Division.

- Green Area File

They have been kept in the Right of Way Maintenance Division.

5.2.3 Maintenance Work File

- Pavement File

There is only inventory of pavement joint has been prepared as an obligatory of the contractors. It contains location, type, and history of repair. In the case of pavement, the repair records have also been kept since they were done under contract basis.

There is no pavement management drawing and pavement work order management drawing.

- Paint File

There is no record of paint data and drawing.

- Damage Repair File

It is result of inspection work which has been kept in the repair form. However, there is no filing system for damage repair records.

5.2.4 Inspection Work File

There are inspection work file and photo for almost all type of structure but there is no filing system for these inspection results yet.

5.3 An Approach to Maintenance Database of the ETA

As discussed in the prior section that the ETA has no maintenance database forming as system yet and most of the data have not been kept in the way that can be found easily. It is, therefore, necessary to introduce maintenance database of the ETA into step-wise as immediate plan, medium term plan, and long term plan as follows:

5.3.1 Immediate Plan

The immediate plan is to establish an inventory system of all devices of the FES, such as beam, pavement, joint, girder, bearing unit, foundation, parapet, lighting, traffic sign, pavement marking, toll booth, and etc. The location, type, current condition, history of repair, and etc., would be collected and filed.

The following are sample inventory forms for traffic sign and lighting.

Apart of these inventory system, the drawings should be prepared in corresponding to each inventory file (structure). These drawings will be attached to the inventory as reference.

The inspection and maintenance should be included in the inventory of each file and also separated as inspection and maintenance file for each structure for easily planning of inspection and maintenance works.

5.3.2 Medium Term Plan

The medium term plan is to introduce the computer based system such as semi-computerized inventory system. It will provide effective utilization, accuracy and will reduce the amount of works on updating the database. This computerized database will be useful and necessary to the maintenance system.

At this stage, a micro-computer would be appropriate for establishing the system. The software package such as Dbase III plus or Dbase IV can be use as a tool. All the inventory will be coded and input into the computer while the drawings are on the paper. But, however, the serial number of drawing is needed for input in the computer.

The following are sample computer coding forms for above inventory forms.

5.3.4 Long Term Plan

A fully computerized system would be introduced. The drawings will be kept in the computer file such as CAD which would require a high capacity computer. The mainframe or mini-computer may be needed for developing the system. It will be fully interfaced with maintenance system and other systems. The appending, altering, and deleting works for both database and drawing will be able to be done automatically.

This system will require a large budget and will take long time to complete the system. However, when the expressway system is expanded in the near future, this system will be needed. In addition to that the labor force shortage would be continued and even more severe in the future.

Table 5.2 Traffic Sign Inventory Form

Route No.

Control Section-Subsection ______

Subdivision ______

Division-District ______

Installed Road ______

Location Name ______

POLE DATA					SIGN DATA													INSPECTION DATA									
Kilo-Post (9999m)	Type of Pole	Number of Sign Installed	Material	Heights (9.9m)	Type	Sign Placement	Color	Width of Board (999cm)	Heights of Board (999cm)	Material	Clearance-V (9.9m)	-H (9.9m)	Installed Date (yymm)	Visibility-Daytime	-Night time	Condition of Pole	Condition of Sign	Inspected Date (yymm)	Condition of Pole	Condition of Sign	Inspected Date (yymm)	Condition of Pole	Condition of Sign	Inspected Date (yymm)	Condition of Pole	Condition of Sign	Inspected Date

Remarks	Character in Sign	Name of Manufacturer	Remarks

Table 5.3 Road Lighting Inventory Form

Route No. ________ Division-District ________

Control Section-Subsection ________

Subdivision ________ Chainage from (m) ________ Location Name ________

to (m) ________ Type of Location ________

POLE DATA		LAMP DATA		ELECTRICITY	
Type of Pole		Type Lamp		Type of Switch Board	
Heights (9.99m)		No. of Lamp		Type of Branching	
No. of Pole		Type of Regulator		Type of Main Switch	
Installed Location		Type of Switch		Type of Sub-Switch	
Type of Paint		Luminous Intensity	(lux)	Rates per Month	(kwh)
Paint Area (m^2)		Consumption per Lamp	(w)	Type of Contract	
Maker Name		Maker Name		Contract Number	
Installed Date	(yymm)	Remarks		Remarks	
Remarks					

SIDE ELEVATION

PLAN

REPAIR DATA			
Repair Date	Type of Works	Repair Costs	Cause of Repair

Route Number :
Control Section-Subsection :
Subdivision :
Chainage (m) from :
to :
Length of Section (m) :
Region-Division-District :
Location (1;Roadway 2;Intsct) :

No. of Guide Signs :
Warning Signs :
Regulatory Signs :
Other Signs :
Signs in Total :

Coded by : ______________
Date : ____/____/____

INSPECTION RECORDS (No. of Signs)

Date	to be Repaired				to be Improved				to be Renewed				to be Installd				Remarks
	G	W	R	O	G	W	R	O	G	W	R	O	G	W	R	O	
/																	
/																	
/																	
/																	
/																	
/																	

REPAIR RECORDS

Date	Repaired				Improved				Renewed				Installed				Cost
	G	W	R	O	G	W	R	O	G	W	R	O	G	W	R	O	
/																	
/																	
/																	
/																	
/																	
/																	

NOTE
G ; Guide Sign R ; Regulatory Sign
W ; Warning Sign O ; Other Sign

Figure 5.1 Traffic Sign

Route Number ;
Control Section-Subsection ;
Subdivision ;
Chainage (m) from ;
to ;
Region-Division-District ;
Length of Section (m) ;
Location (1;Roadway 2;Intsct) ;

Type of Lamp ;
Pole ;
No. of Lamps ;
No. of Poles ;
Height of Pole (m) ;

Electricity Consumption
Lamp (W) ;
Total (KW) ;
Rates per Month (KWH) ;
Average Luminous
Intensity (Lux) ;
Installed Date ;

Coded by : ____________________

Date : ______/______/______

REPAIR RECORDS

Date	Type of Works	Cost	Remarks
/			
/			
/			
/			
/			
/			

Lamp Type Code
1 ; Low-Pressure Sodium (Yellow)
2 ; High-Pressure Sodium (Orenge)
3 ; Mercury Vapor (White)
4 ; Flourescent (White)

Pole Type Code
1 ; Y-Shape Pole
2 ; T-Shape Pole
3 ; Overhanged Pole
4 ; Straight Pole
5 ; Others

Repair Work Code
1 ; Improvement
2 ; Reinforcing
3 ; Circuit Repair
4 ; Circuit Parts Renewal
5 ; Bulb Renewal
6 ; Adjustment
7 ; Other Works

Figure 5.2 Road Lighting

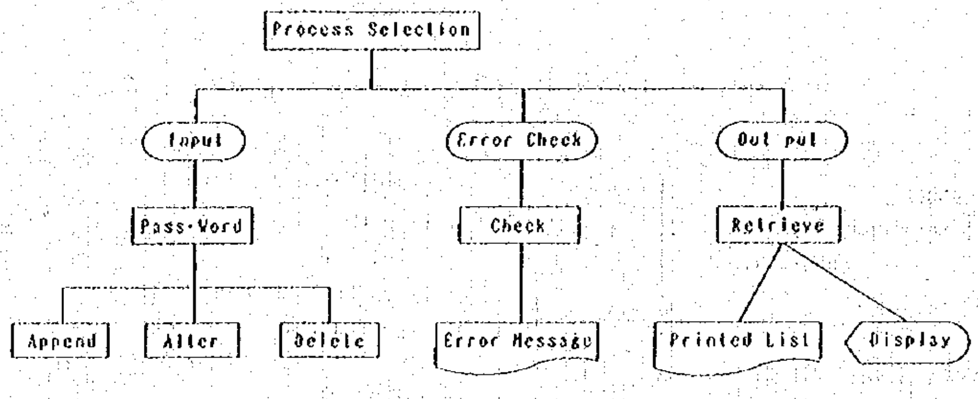


Figure 5.3 Operation Flow For Medium Term Plan

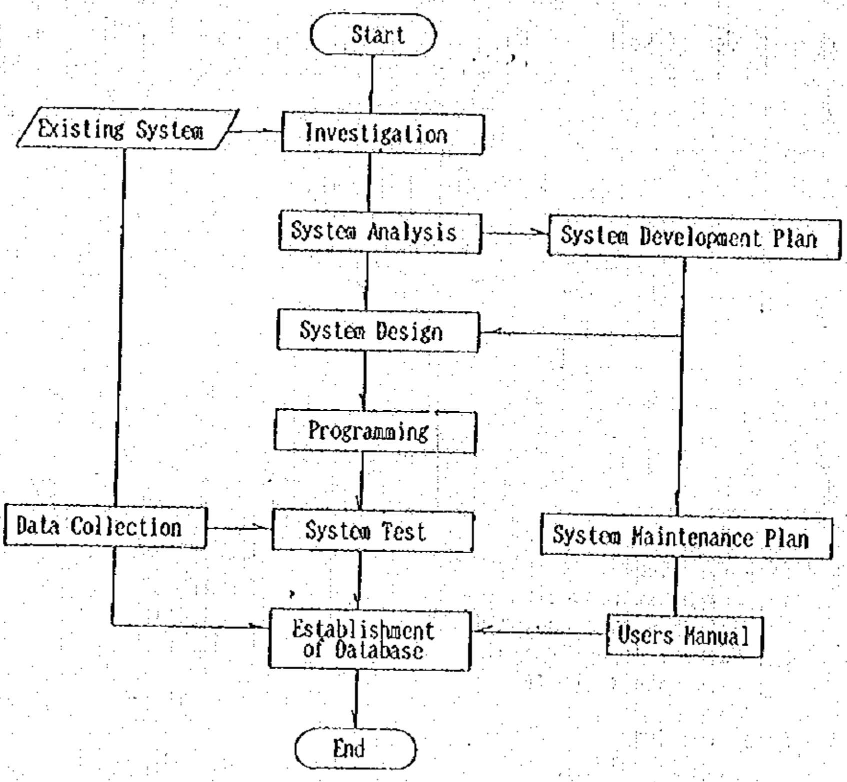


Figure 5.4 System Development Flow For Medium Term Plan

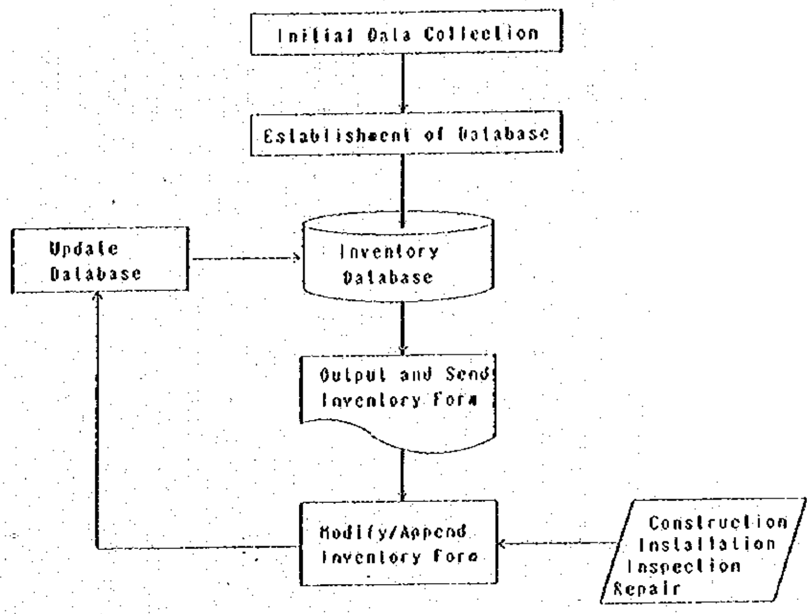


Figure 5.5 Data Maintenance Flow

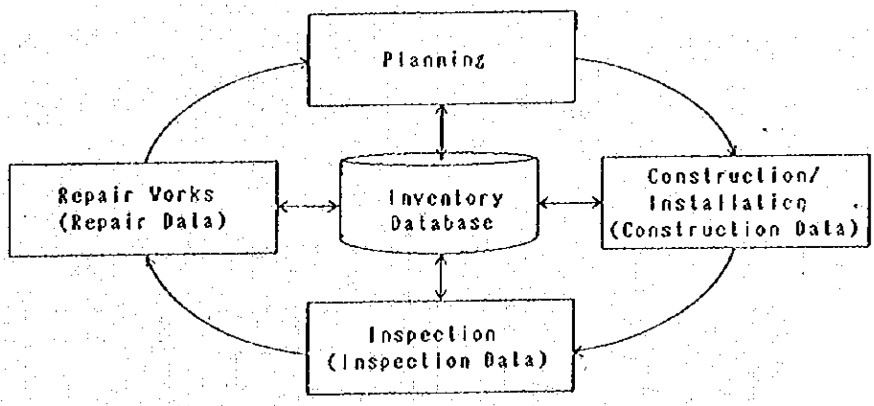


Figure 5.6 Circulative Relation of Database