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THE KINGDOM OF THAILAND

BANGKOK METROPOLITAN ADMINISTRATION

STUDY ON ROAD IMPROVEMENT, REHABILITATION AND TRAFFIC SAFETY IN BANGKOK

FINAL REPORT

VOLUME III PAVEMENT REHABILITATION

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF ABBREVIATIONS

BMA	Bangkok Metropolitan Administration
CPD	City Planning Division, BMA
CMD	Construction and Maintenance Division, BMA
DD	Design Division, BMA
PPD	Policy and Planning Division, BMA
PPSd	Public Works Planning Sub-division, BMA
DPW	Department of Public Works, BMA
DDS	Department of Drainage and Sewerage, BMA
TED	Traffic Engineering Division, BMA
MOI	Ministry of Interior
OARD	Office of Accelerated Rural Development, MOI
OCMRT	Office of the Committee for the Management Road Traffic, MOI
OPP	Office of Policy and Planning, MOI
PWD	Public Works Department, MOI
TCPD	Town and Country Planning Department, MOI
TPD	Traffic Police Division, MOI
LDPD	License Division of Police Department, MOI
MOC	Ministry of Communications
DOH	Department of Highways, MOC
DLT	Department of Land Transport, MOC
ETA	Expressway and Rapid Transit Authority of Thailand
NESDB	National Economic and Social Development Board
SRT	State Railway of Thailand
MEA	Metropolitan Electricity Authority
AIT	Asia Institute of Technology
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
BS	British Standards
CAB	Cable Box
CBD	Central Business District
HCM	Highway Capacity Manual
MCI	Maintenance Control Index
MSL	Mean Sea Level
MTS	Mass Transit System
NECO	National Executive Council Order
PCU	Passnger Car Unit
PSI	Present Serviceablility Index
RAL	Richtlinien für die Anlage von Landstraßen
SSES	Second Stage Expressway System
STTR	Short Term Urban Transport Review

PAVEMENT REHABILITATION

1. PAVEMENT REHABILITATION

1.1 Introduction

The pavements suffer damages from traffic loads, weathering conditions or superannuation of pavements themselves, and these damages would cause decrease in serviceability of pavements as well as disturbance for the smooth and safe traffic flows, if proper rehabilitation would not be carried out. In order to avoid these situations, it is necessary to rehabilitate the damage of pavement at appropriate timing and using suitable rehabilitation method.

Timing and method, as well as the necessity, of rehabilitation used to be determined entirely based on the judgment of experienced engineers. This, however, sometimes lacked quantitative basis. Hence, establishment of quantitative evaluation method of pavement condition was desired.

Original rating method to evaluate the pavement condition quantitatively is the "Present Serviceability Index", P.S.I., which was developed from the result of AASHO ROAD TEST, 1962, U.S.A. This method was developed based on the correlation between the results of the pavement condition surveys, concerning such factors as cracking, rutting and longitudinal roughness, and the result of visual evaluation of pavement condition from the viewpoint of present serviceability by road engineers at the same road sections.

In Japan, P.S.I. for asphalt pavement was developed by using the similar way of original P.S.I. in order to evaluate the pavement condition.

Lately, however, numbers and volume of pavement rehabilitation works have greatly increased due to increase of vehicles' weight and mounting of public demand for higher level of pavement condition. Hence, it was desired to develop a new rating method to consider not only the serviceability for traffic but also the degree of necessity for rehabilitation and the its scale and method of rehabilitation.

In such circumstances, the concept of "Maintenance Control Index", M.C.I. was developed in Japan and it is widely used in the country now. The M.C.I. was developed based on the correlation between two types of data i.e. the results of pavement condition surveys and the result of visual evaluation of pavement condition from the viewpoint of the degree of necessity and scale of rehabilitation as well as the serviceability for traffic by road engineers at the same road sections.

In this study, a rating method was developed mainly by modifying the current rating methods employed in Japan where pavement condition and axle load of vehicles are considered similar to those in Bangkok.

This rating method was prepared for asphalt pavement and cement concrete pavement, respectively.

It was examined as to whether M.C.I. or P.S.I., developed in the study, is more suitable to evaluate the asphalt pavement condition in Bangkok.

In addition, rehabilitation plannings for selected five (5) road sections are presented, respectively.

1.2 Development of Pavement Rating Method

Figure 1.2.1 shows the procedure for developing the Pavement Rating Method in the study and the major work items are summarized below.

1.2.1 Pavement Survey

(1) Surveys

The following types of pavement surveys, which were necessary for the development of Pavement Rating Method were carried out at selected 111 road sections in the study area.

- Cracking survey
- Longitudinal roughness survey
- Rutting depth survey
- Visual evaluation of pavement condition by 5 ranks

After inspections of the roads in the study area, 111 road sections were selected as survey sites in such a way that they could represent various pavement conditions of the road network in the study area. In selecting these road sections due considerations were also paid to the types of pavement (asphalt or cement concrete), conditions of pavement, and traffic volumes as well as number of lane. The type of pavement at the selected sections and their locations are presented in Figure 1.2.2, respectively.

1) Cracking survey

Crackings were surveyed by sketching and with an ordinary camera as a supplemental means. Figure 1.2.3 shows typical examples of crackings on asphalt and cement concrete pavements.

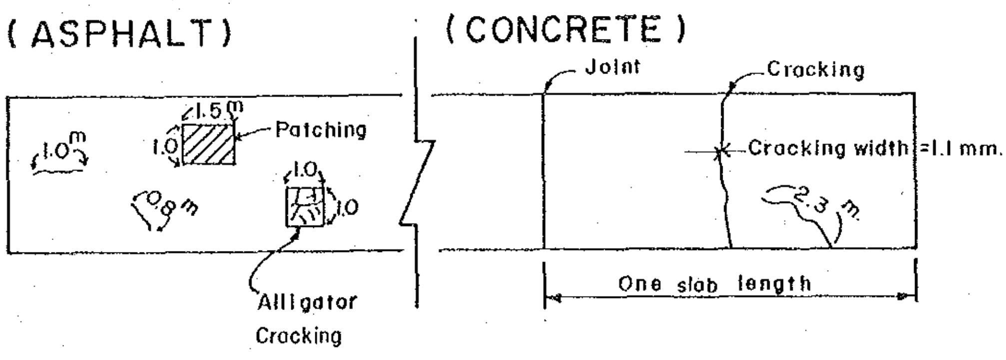

Figure 1.2.3 Example of Crackings

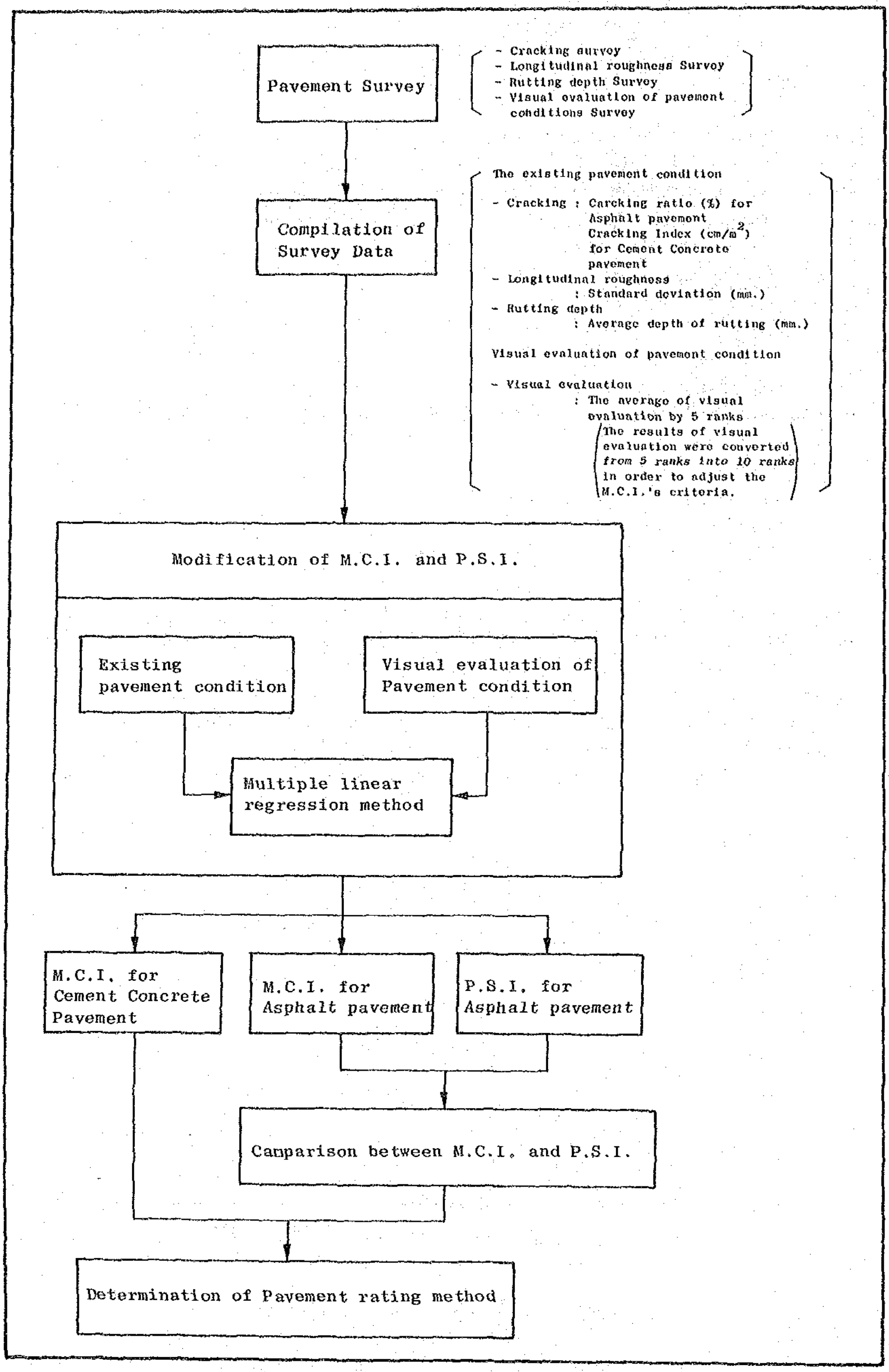

Figure 1.2.1 Procedure for Development of Pavement Rating Method

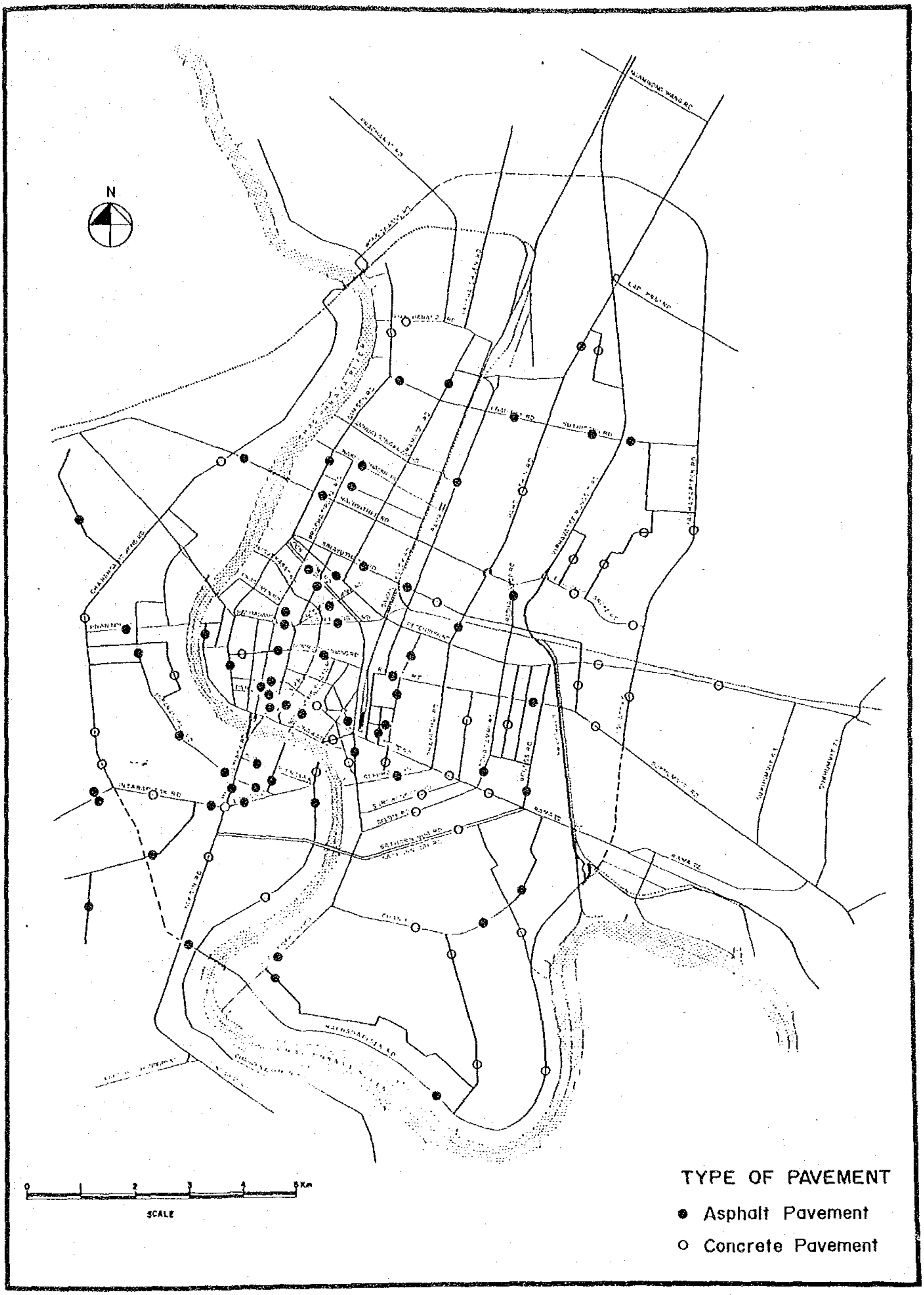

Figure 1.2.2 Locations of Pavement Survey Sites

The results of field surveys at asphalt pavement were compiled in terms of cracking ratio, while the results of cement concrete pavement are compiled in terms of cracking index as defined by the following formulae.

Cracking ratio (%)

$$= \frac{\text{Patching area } (m^2) + \text{Cracking area } (m^2)}{\text{Area of survey site } (m^2)} \times 100$$

$$\text{Cracking index } (cm/m^2) = \frac{\text{Cracking length (cm)}}{\text{Area of survey site (m2)}}$$

2) Longitudinal roughness survey

A profilemeter (3m type) was employed to measure longitudinal roughness at the survey site along the dotted line in Figure 1.2.4.

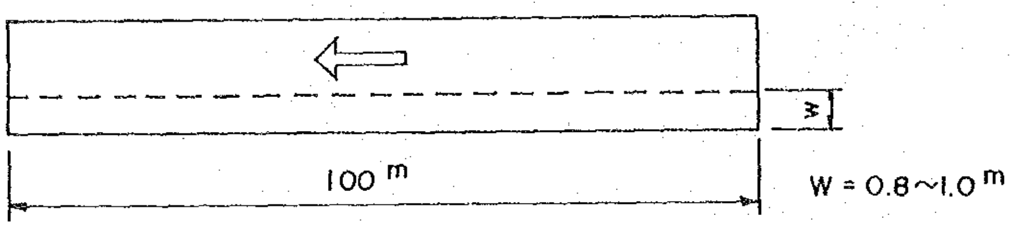

Figure 1.2.4 Longitudinal Roughness Survey Line

During the measurements irregular points such as manhole, joint were marked on graph paper of profilemeter for consideration in the course of data analyses.

A longitudinal roughness of pavement surface is defined by the value of the standard deviation of all recorded roughness measurements over the entire stretch of a survey site.

3) Rutting depth survey

A profilemeter for cross section measuring type was used to measure rutting depth along the transverse lines at intervals of 20 m as shown in Figure 1.2.5.

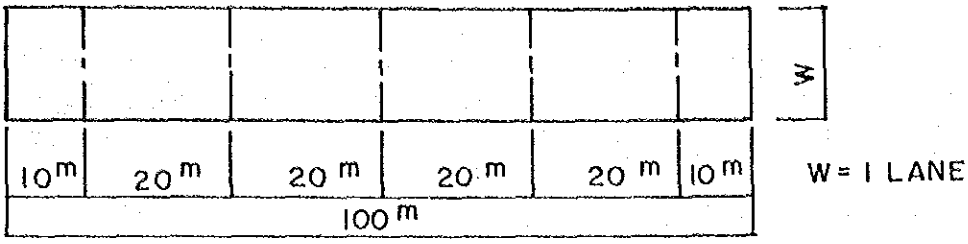

Figure 1.2.5 Rutting Depth Survey Line

The rutting depth at each cross section is defined by a bigger value between D1 and D2 (see Figure 1.2.6). The rutting depth at a survey site can be represented by an average value of all the data of rutting depth measured at interval of 20 m over the entire stretch of a survey site.

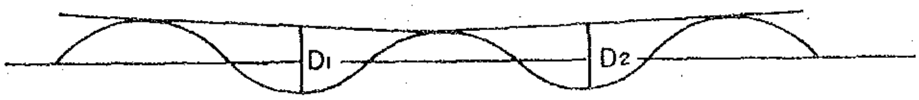

Figure 1.2.6 Rutting Depth

4) Visual evaluation of pavement conditions

The visual evaluation of pavement conditions were carried out by 7 engineers at 111 survey sites. The pavement conditions were evaluated to fall into 5 ranks of index as shown in Table 1.2.1 based on the judgments by the engineers as to the check items presented in Table 1.2.2.

Table 1.2.1 Pavement Evaluation

Index	Level of Evaluation
5	no defect, perfection, good
4	a little defect but be considered as good
3	several defects but need not to be repair
2	need slight repair (patching, partial seal coat)
1	needs large scale repair (overlay, replacing)

The average of visual evaluation by 5 ranks obtained as the result of the visual evaluation of pavement condition were calculated, then they were subdivided into 10 ranks for application to the M.C.I. criteria.

(2) Survey results

The survey results are shown graphically in Figures 1.2.7 to 1.2.12 and their characteristics are summarized below.

Table 1.2.2 Check Items of Visual Evaluation

Check Items	Condition
Surface of Texture	coarse, smooth
Equality of Surface	good, irrugular
Contents of Asphalt	flashed, a little flashed good, coarse
Slipperliness	slippery, not slippery
Rutting and Deformation	deep rutting, plastic flow, no rutting
Longitudinal Roughness	waves, no waves
Pot Hole or Scaling	many pot holes or scaling, no hole or scaling
Wear of Surface	much weared, no wear
Cracking	many alligator's or net shaped cracking, line cracking, no cracking
Joint (Concrete)	good, joint-sealing compound is filled up or not, joint is broken or not

1) <u>Cracking survey results</u>

The cumulative frequency distribution of cracking ratio of asphalt pavement and that of cracking index of cement concrete pavement are shown in Figure 1.2.7 and Figure 1.2.8.

The characteristics of the survey results are summarized below.

- In Figure 1.2.7, the cracking ratio (%) of asphalt pavement of ten percent (10%) or less counts for about eighty percent (80%) of the total data, and approximately half of them (40%) have the cracking ratio of zero percent (0%). The distribution pattern of the cracking ratio is almost same to that of national highways in Japan.

- In Figure 1.2.8, the cracking index of cement concrete pavement of five ($5cm/m^2$) or less counts for eighty percent (80%) of the total data, and approximately half of them (40%) have the cracking index of zero ($0cm/m^2$) and there are no cracking indices greater than thirty ($30cm/m^2$). In this survey, crack widths were measured at the same time. The crack width is defined by the maximum width of one crack. Crack widths more than 0.5mm counts for one third of the total data and the maximum crack width recorded was 20mm observed on Petburi Road. When the crack width widens, load transmission becomes worse and water can easily seep in and affects pavement performance.

2) <u>Longitudinal roughness survey results</u>

The cumulative frequency distribution of longitudinal roughness of asphalt pavement and that of cement concrete pavement are shown in Figure 1.2.9 and Figure 1.2.10.

The Characteristics of these survey results are summarized below.

- In Figure 1.2.9, the longitudinal roughness of asphalt pavement of 4mm or less counts for about eighty percent (80%) of the total data. This value is a little larger than that of Japan.

- In Figure 1.2.10, the longitudinal roughness of cement concrete pavement of 4mm and less counts for eighty percent (80%) of the total data.

3) <u>Rutting depth survey results</u>

The cumulative frequency distribution of rutting depths of asphalt pavement and cement concrete pavement are shown in Figure 1.2.11 and Figure 1.2.12.

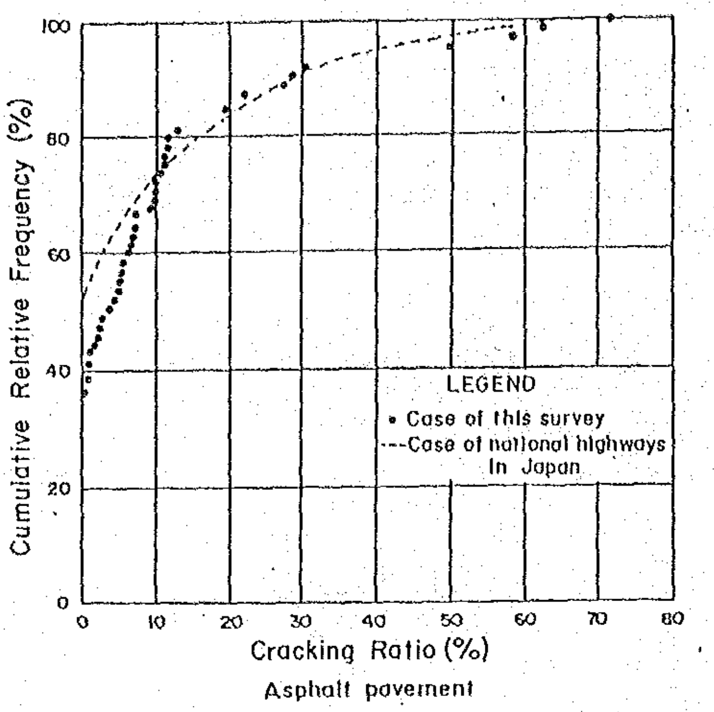

Figure 1.2.7 Cumulative Relative Frequency Distribution of Cracking Ratio

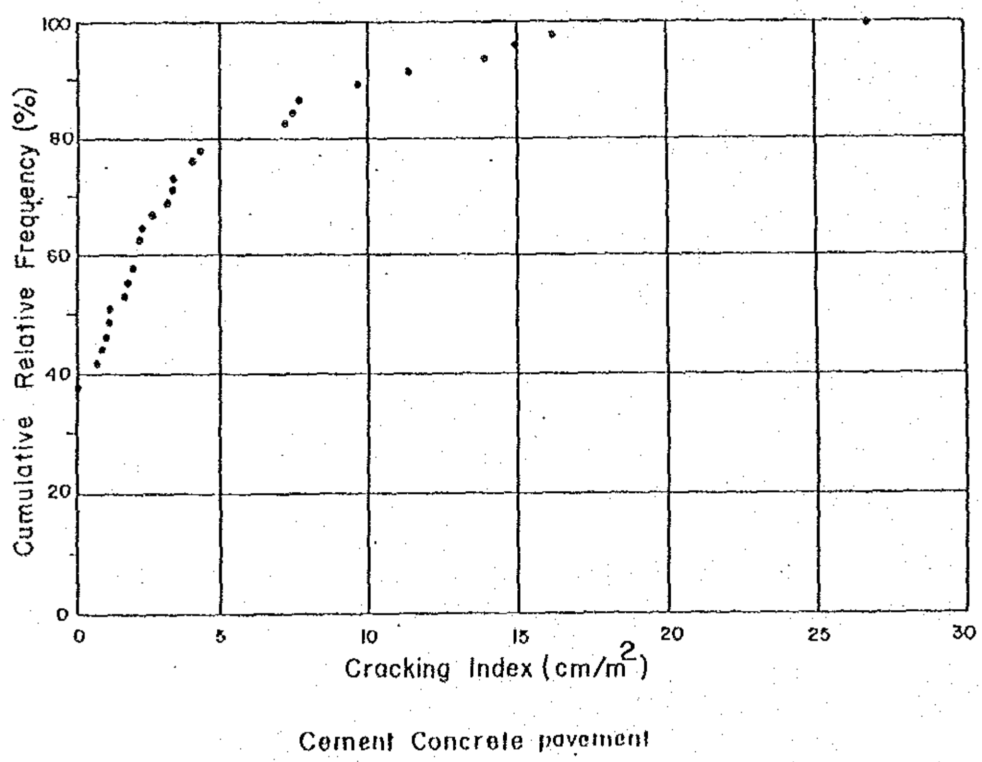

Figure 1.2.8 Cumulative Relative Frequency Distribution of Cracking Index

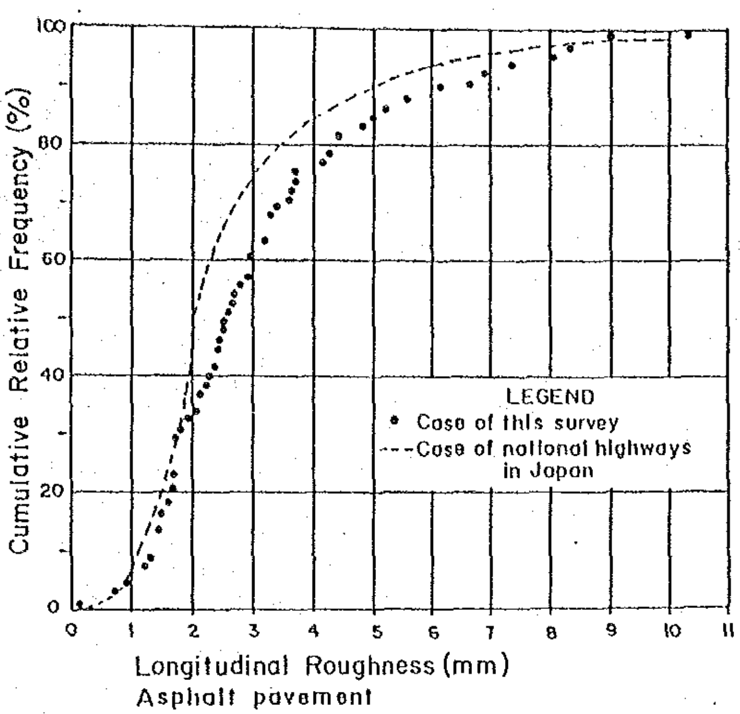

Figure 1.2.9 Cumulative Relative Frequency Distribution of Longitudinal Roughness

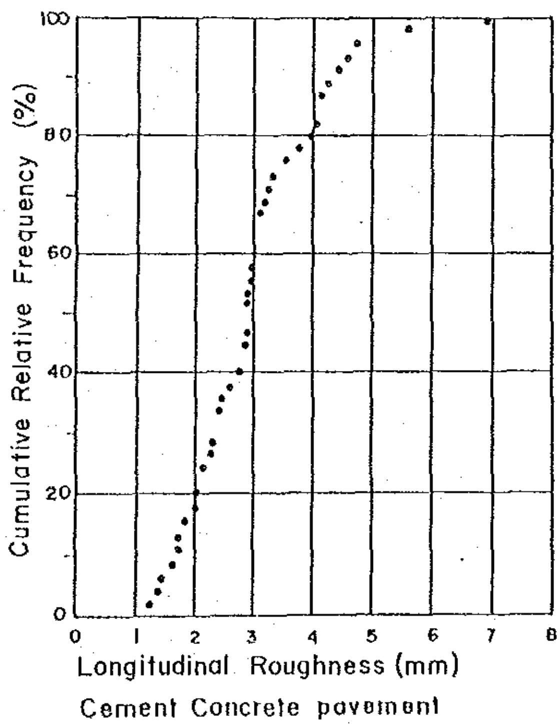

Figure 1.2.10 Cumulative Relative Frequency Distribution of Longitudinal Roughness

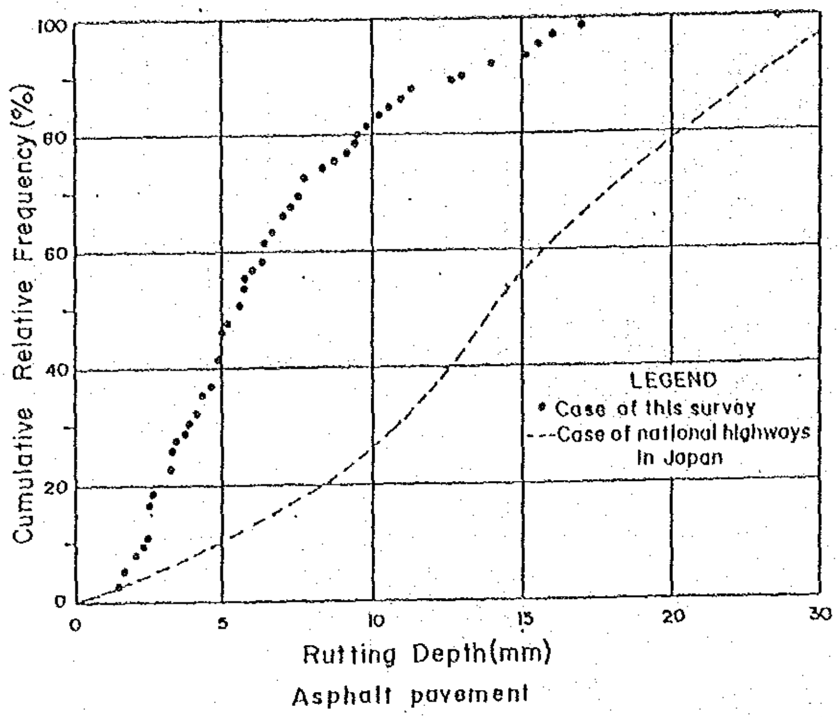

Figure 1.2.11 Cumulative Relative Frequency Distribution of Rutting Depth

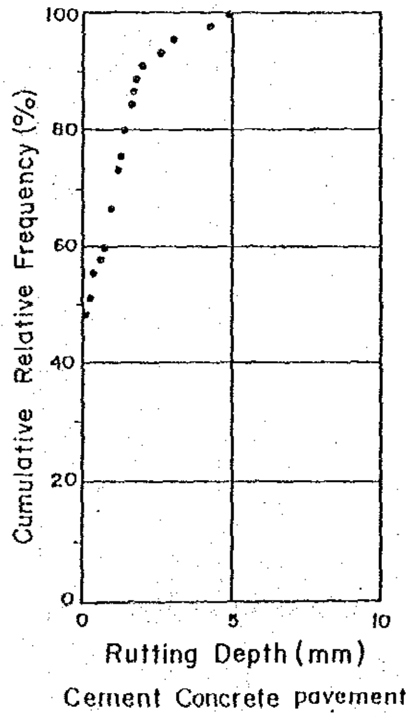

Figure 1.2.12 Cumulative Relative Frequency Distribution of Rutting Depth

The characteristics of these survey results are summarized below.

- In Figure 1.2.11, rutting depth of asphalt pavement of 15mm or less counts for ninety percent (90%) of the total data. These values are smaller than those of Japan.
- In Figure 1.2.12, rutting depth of cement concrete pavement of negligible 2 mm counts for about ninety percent (90%) of the total data and maximum value is 5 mm.

1.2.2 Modification of M.C.I. and P.S.I.

The development of rating method in the study was attempted so that the M.C.I. and the P.S.I. formulae employed in Japan as described in Section 1.1 were to be modified to comply with the prevailing pavement conditions in Bangkok. The M.C.I. and the P.S.I. formulae employed in Japan are shown below.

$$M.C.I. = 10 - 1.48C^{0.3} - 0.29D^{0.7} - 0.47\sigma^{0.2}$$

where C : cracking ratio (%)
σ : standard deviation of longitudinal roughness (mm)
D : average depth of ruttings (mm)

$$P.S.I. = 4.53 - 0.518\log\sigma - 0.37\sqrt{C} - 0.174D^2$$

where σ : standard deviation of longitudinal roughness (mm)
C : cracking ratio (%)
D : average depth of rutting (mm)

In order to correlate the indices of pavement condition, such as cracking, rutting depth and longitudinal roughness, and visual evaluation of pavement condition by engineers, the coefficients of each term of M.C.I. and P.S.I. formulae were modified by using multiple linear regression method, based on both the results of pavement surveys and visual evaluation of pavement condition carried out at 111 survey sites in the study area. The results of the modification of formulae are shown below.

For Asphalt Pavement :

$$M.C.I. = 10 - 0.88C^{0.3} - 2.03\sigma^{0.2} - 0.22D^{0.7} \quad (R = 0.83)....(1)$$

$$P.S.I. = 3.64 - 0.22\sqrt{C} - 0.90\log\sigma \quad (R = 0.79)....(2)$$

where C : cracking ratio (%)
σ : standard deviation of longitudinal roughness (mm)
R : multiple correlation coefficient

For Cement Concrete Pavement :

$$M.C.I. = 10 - 0.83C^{0.3} - 2.65\sigma^{0.2} \quad (R = 0.59)......(3)$$

where C : cracking index (cm/m^2)

σ : standard deviation of longitudinal roughness (mm)

R : multiple correlation coefficient

Term of rutting depth in P.S.I. formula for asphalt pavement and M.C.I. formula for cement concrete pavement were not taken into this modification because of its negligible influence, which have can verified by statistical test.

Therefore, pavement condition can be evaluated without taking into account the rutting depth in case it is rather small. On this basis, a new formula for asphalt pavement was developed adopting only the cracking ratio and standard deviation of longitudinal roughness as the following:

$$M.C.I.o = 10 - 0.97C^{0.3} - 2.61\sigma^{0.2} \quad (R = 0.81)......(4)$$

where C : cracking ratio (%)

σ : standard deviation of longitudinal roughness (mm)

The values of multiple correlation coefficient R indicate that these formulae are statistically satisfactory.

1.2.3 Comparison between M.C.I. and P.S.I. on Asphalt Pavement

Figure 1.2.13 shows comparison of characteristics of M.C.I. and P.S.I for asphalt pavement. Each curve indicates the value of terms in M.C.I. formula and P.S.I. formula corresponding to the level of cracking ratio and longitudinal roughness. Rate of curve A (cracking of M.C.I.) is steeper than that of curve B (cracking of P.S.I.) where cracking ratio is small (0% - about 10%). Hence, curve A can be regarded as more sensitive than curve B.

In fact, the scale of damages on asphalt pavement in the study area is generally small (the average cracking ratio : 10%, the average longitudinal roughness : 4 mm).
Besides, multiple correlation coefficient R of M.C.I. is higher than that of P.S.I. as shown in 1.2 (2) (see formulae (1), (2)).

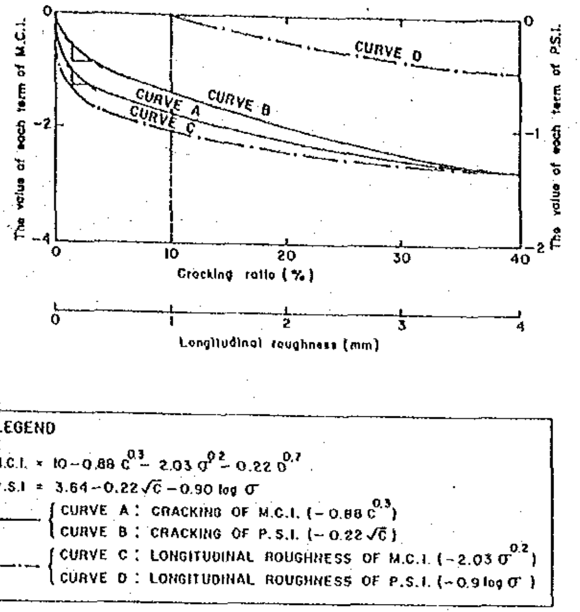

Figure 1.2.13 Comparison of Characteristics of M.C.I. and P.S.I.

Moreover, rating method using the P.S.I. is mainly to concern about the serviceability for traffic, while rating method using the M.C.I. is to deal with not only the traffic serviceability but also the extent of pavement rehabilitation.

As the result, it is desirable to employ M.C.I. formula for the evaluation of asphalt pavement condition in Bangkok.

1.2.4 Determination of Rating Method

As the conclusion, the following formulae were employed as the pavement rating methods for the roads in Bangkok.

For Asphalt Pavement :

$$M.C.I. = 10 - 0.88C^{0.3} - 2.03\sigma^{0.2} - 0.22D^{0.7} \quad ....(1)$$
$$M.C.I._o = 10 - 0.97C^{0.3} - 2.61\sigma^{0.2} \quad ....(4)$$

where C : cracking ratio (%)

σ : standard deviation of longitudinal roughness (mm)

D : average depth of rutting (mm)

The first formula (1) should be basically used for the evaluation. However, if the value of rutting depth at certain road section is small, the second formula (4) can be used for practical application.

For Cement Concrete Pavement :

$$M.C.I. = 10 - 0.83C^{0.3} - 2.65\sigma^{0.2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where C : cracking index (cm/m^2)

σ : standard deviation of longitudinal roughness (mm)

1.3 Evaluation of Pavement Condition by M.C.I. at Selected Road Section

M.C.I. formulae have been developed in order to evaluate the pavement condition of the roads in Bangkok quantitatively and, thus, to determine the needs for rehabilitation. In practice, it is used in the following procedure for both asphalt and cement concrete pavement;

- To decide whether damaged pavement should be rehabilitated or not.
- To decide extent of rehabilitation.
- To indicate the priority of rehabilitation.

Table 1.3.1 describes the extent of rehabilitation required to the pavement condition evaluated by the M.C.I. values.

Table 1.3.1 Evaluation of Pavement Condition by M.C.I. Values

MCI Value	Required Extent of Rehabilitation
MCI ≧ 5.0	Unnecessary to repair
4.0 ≦ MCI < 5.0	Maintenance
3.0 ≦ MCI < 4.0	Partial repair
MCI < 3.0	Full scale repair

Since the formulae of M.C.I. were determined taking into account the judgment of multiple number of engineers, M.C.I. value can be regarded to indicate the judgment of an "average engineer" on the necessity and the extent of rehabilitation. The Road section where the M.C.I. value is between five and ten can be regarded as to render tolerable traffic serviceability without pavement rehabilitation for the time being. If the M.C.I. value of road section is below 4.0, some rehabilitation work should be done according to the order of smaller M.C.I. value considering the extent of the work, method of rehabilitation and economical aspects.

The pavement conditions at selected road sections in the study were evaluated by M.C.I. method and the results are shown in Figure 1.3.1.

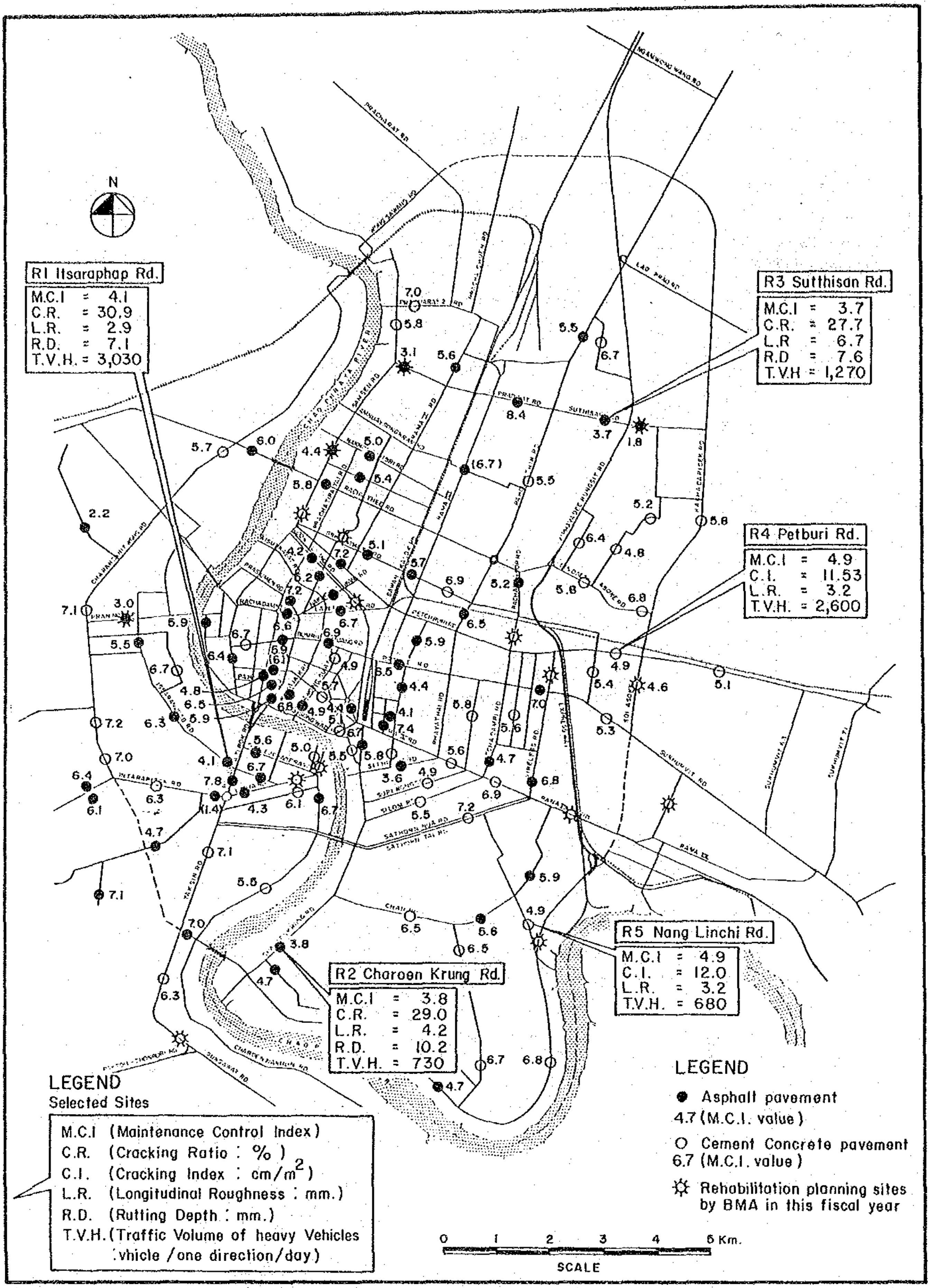

Figure 1.3.1 Evaluation of Pavement Condition by using M.C.I. and Locations of Road Sections

1.4 Rehabilitation Planning

In order to demonstrate application of the rehabilitation methods, five (5) road sections in study area were selected out of 27 candidate sections which need pavement rehabilitaiton identified by the newly developed rating method, M.C.I.

Procedure of rehabilitation planning is summarized below.

- To select damaged road sections where rehabilitation are needed.
- To evaluate extent of damaged condition of pavement.
- To select rehabilitation method taking into account the result of above evaluation.
- To execute pavement design for rehabilitation based on the supplemental survey and design criteria.

1.4.1 Selection of Road Sections for Pavement Rehabilitation Plans

According to the results of evaluation of pavement condition using M.C.I. at 111 surveyed sections, 27 road sections are identified to require rehabilitation which are broken down as follows;

a) Maintenance required ($4.0 \leqq$ M.C.I. < 5.0)		
- Asphalt pavement	:	15 road sections
- Cement concrete pavement	:	5 road sections
b) Repair required (M.C.I.<4.0)		
- Asphalt pavement	:	7 road sections
- Cement concrete pavement	:	nothing
total	:	27 road sections

And five (5) road sections for rehabilitation plans were selected from above 27 road sections, taking into account the rehabilitation methods, traffic volume of heavy vehicles and type of pavement, in order to demonstrate typical rehabilitation plans.

Selected five (5) road sections are shown in Figure 1.3.1.

1.4.2 Evaluation of Pavement Condition at Selected Road Sections

(1) Pavement evaluation

In order to select the suitable rehabilitation method for damaged road sections, it is necessary to evaluate the existing pavement and to grasp the traffic condition (traffic volume of heavy vehicles and its weight) on its road.

The general evaluation of pavement condition shall be carried out by application of M.C.I. method which can grasp the general conditions of pavement on road sections, but tends to neglect independent type damages, such as pot holes and bumps.

Therefore, in order to supplement the general evaluation and to pinpoint independent type damages, it is necessary to conduct the evaluation by using damage type criteria as shown in Table 1.4.1 and 1.4.2.

Table 1.4.1 Damage Type Criteria for Rehabilitation (Asphalt Pavement)

Item / Road Classification	Rutting Depth (mm)	Bump (mm)		Skid Resistance Coefficient	Longitudinal Roughness (mm)	Cracking Ratio (%)	Pot Hole Diameter (cm)
		Abutment	Culvert Box				
Highways with Heavy Traffic	30-40	60	60	0.25	4.0-5.0 (σ) (3 m profile)	30-40	20
Other Highways	40	60	-	-	-	40-50	20

Table 1.4.2 Damage Type Criteria for Rehabilitation (Cement Concrete Pavement)

Item / Road Classification	Rutting Depth (mm)	Bump (mm)	Skid Resistance Coefficient	Longitudinal Roughness (mm)	Cracking Index (cm/m^2) (Develop the bottom of the slab)	Joint Damage
Highways with Heavy Traffic	30-40	15	0.25	5.0 (σ) (3 m profile)	30	If the damage can be found
Other Highways	40-50	-	-	-	50	

(2) Evaluation of pavement condition at selected road sections

The results of pavement evaluation by using M.C.I. method and damage type criteria at selected five (5) road sections are shown in Table 1.4.3.

As shown in Table 1.4.3, it is necessary to rehabilitate the existing

Table 1.4.3 Evaluation of Pavement Condition at Selected Road Sections

Rehabilitation No.	Road Name	Pavement Condition					Evaluation	
		M.C.I. value	Cracking	Longitudinal Roughness	Rutting depth	Traffic volume 1)		
R 1	Itsaraphap Rd.	4.1	30.9%	2.9 mm	7.1 mm	3,030	by M.C.I. value	maintenance is required
							by damage type criteria	Rehabilitation of cracking is required
R 2	Charoen Krung Rd.	3.8	29.0%	4.2 mm	10.2 mm	730	by M.C.I. value	Partial repair is required
							by damage type criteria	Rehabilitation of longitudianal roughness is required
R 3	Sutthisan Rd.	3.7	27.7%	6.7 mm	7.6 mm	1,270	by M.C.I. value	Partial repair is required
							by damage type criteria	Rehabilitation of longitudinal roughness is required
R 4	Petburi Rd.	4.9	11.5cm/m^2	3.2 mm	-	2,600	by M.C.I. value	maintenance is required
							by damage type criteria	-
R 5	Nang Linchi Rd.	4.9	12.1cm/m^2	3.3 mm	-	680	by M.C.I. value	maintenance is required
							by damage type criteria	-

Note: 1) Traffic volume: Present one way daily traffic volume of heavy vehicles pavement at selected five (5) road sections, respectively. The details of the rehabilitation planning of these sections are discussed in the following section.

1.4.3 Selection of Rehabilitation Method for Selected Road Sections

It is necessary to determine the suitable rehabilitation method taking into consideration of all the following factors.

- the result of evaluation by M.C.I. value (Table 1.4.3),
- the result of evaluation by damage type criterion (Table 1.4.3),
- rehabilitation methods by type of damages (Table 1.4.4 and 1.4.5),
- rehabilitation method which can be determined by the relationship between the cracking ratio and the traffic volume of heavy vehicles (Figure 1.4.1) and
- rehabilitation method which can be determined by the relationship between the cracking index and deflection (Figure 1.4.2).

Based on above consideration, the following methods were chosen for the selected sections.

(1) Itsaraphap Road

As the main rehabilitation method, overlay was selected considering the followings.

- There are many parts patched by hot mix and line and/or alligator cracks spreading over the whole road surface at the first lane heading to Phran Nok Road.
- There are some small sized pot holes on the site.
- The traffic volume of heavy vehicles is large (3,030 vehicles/day/one direction).
- M.C.I. value is 4.1.

(2) Charoen Krung Road

Overlay was chosen as the rehabilitation method mainly based on the following considerations.

- There are many alligator cracks over the site.
- There are some small sized pot holes on the site.
- The value of longitudinal roughness is slightly larger than its critical value.
- M.C.I. value is 3.8.

Table 1.4.4 Rehabilitation Methods for Asphalt Pavement by Type of Damage

Type of Damages	Rehabilitation Methods
Hair cracking Line cracking	. Seal in cracking, Fog seal, Seal coat
Roughness near to a surface	. Patching . Partial reconstruction
Rutting	. Cutting of ruts . Overlay or carpet coat after cutting ruts . Cutting and reconstruction of surface course . Reconstruction depending on surface condition
Longitudinal roughness Corrugation	. Armer coat, . Carpet coat
Flush	. Scattering of crushed or coarse sand
Ravelling	. Patching, . Armer coat, . Carpet coat, . Overlay
Polishing	. Seal coat, . Armer coat, . Carpet coat, . Grooving . Resinous surface treatment
Scaling	. Patching, . Partial reconstruction
Pot hole	. Patching, . Partial reconstruction
Stripping Weathering	. Seal coat, . Armer coat, . Fog seal, . Slurry seal, . Carpet coat, . Overlay
Alligator cracking	. Armer coat, . Carpet coat, . Overlay, . Cutting and reconstruction . Reconstruction

Table 1.4.5 Rehabilitation Methods for Cement Concrete Pavement by Type of Damages

Type of Damage	Rehabilitation Methods
Cracking which undevelop to the bottom of concrete slab	. Seal by paraffin, Synthetic rubber, Resin, Asphalt emulsion
Roughness near to a structure and Bump between slabs	. Injection method, . Patching, . Overlay, . Reconstruction
Longitudinal roughness	. Injection method, . Patching, . Overlay, . Reconstruction
Ravelling	. Patching, . Surface treatment, . Overlay
Polishing	. Resinous seal coat, . Overlay, . Grooving
Scaling	. Patching, . Surface treatment, . Overlay
Damage of joint-sealer	. Excision of joint sealing, . Injection of joint sealer
Damage on edge of joint	. Patching by cement mortar, . Resinous mortar or cement concrete
Perforation	- ditto -
Cracking which develop to the bottom of concrete slab	. Injection method, . Partial reconstruction, . Overlay, . Patching
Blow-up	. Reconstruction
Crashing	. Patching, . Reconstruction

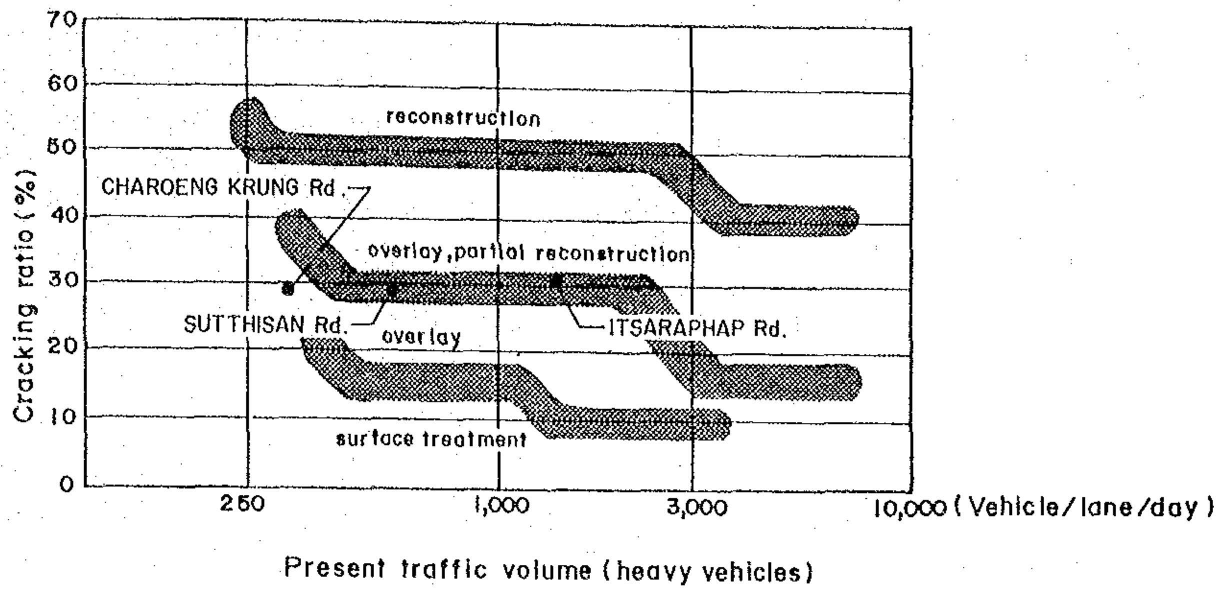

Figure 1.4.1 Rehabilitation by Cracking Ratio - Heavy Vehicle Traffic Volume (Asphalt Pavement)

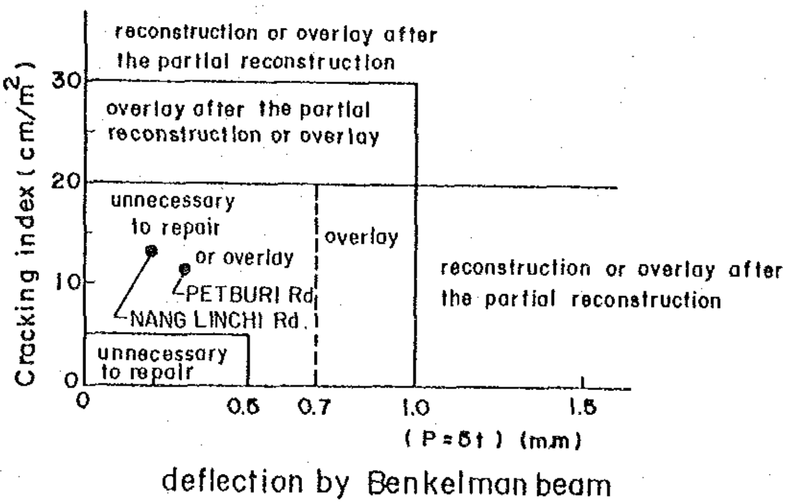

Figure 1.4.2 Rehabilitation Method by Cracking Index - Deflection (Cement Concrete Pavement)

(3) Sutthisan Road

Overlay was adopted as the rehabilitation method in considering of the followings.

- There are many parts patched by hot mix and line and/or alligator cracks over the entire road surface.
- The value of longitudinal roughness is larger than its critical value.
- The traffic volume of heavy vehicle is large (1,270 vehicles/day/one direction).
- M.C.I. value is 3.7.

(4) Petburi Road

As the major rehabilitation method, injection of joint sealer into damaged joints and cracking spots was adopted based on the following considerations.

- There are several longitudinal cracks which develop to the bottom of the concrete slab.
- There are some joints which had lost joint sealers.
- M.C.I. value is 4.9.

(5) Nang Linchi Road

As the main rehabilitation method, patching and reconstruction were selected based on the following considerations.

- Some spalling and scaling are seen at the edge of concrete slab.
- There are some transverse cracks (crack widths are less than 0.5 mm).
- There are some transverse cracks which develops to the bottom of the slab on a certain slab.
- M.C.I. value is 4.9.

1.4.4 Application of Pavement Design Method

In this study, the pavement design method is applied for execution of pavement rehabilitation at five (5) selected road sections, as described in Chapter 2 of this Volume TECHNICAL GUIDELINE FOR PAVEMENT REHABILITATION.

The design work is based on supplemental surveys at the selected sections and the design criteria to be dealt with in the following paras.

(1) Supplemental surveys

Supplemental surveys which are preriquisite to the actual pavement design works were carried out at the selected road sections. The survey items were deflection, CBR test in laboratory and core boring, and these surveys were aimed at the followings.

- Deflection : for design of overlay thickness
- CBR test in laboratory and Core Boring :
  for design of overlay thickness and investigation of present pavement composition

The results of these surveys are incorporated to the pavement design works for five (5) selected road sections.

(2) Design criteria

1) Design traffic volume

As the first step, the one-way daily traffic volume of heavy vehicles in 5 years was estimated to determine pavement design classification of the road sections by traffic volume as shown in Table 1.4.6.

Table 1.4.6 Pavement Design Classification by Traffic Volume

Classification	One Way Daily Traffic of Heavy Vehicles
L	Less than 100
A	100 to 250
B	250 to 1,000
C	1,000 to 3,000
D	More than 3,000

The design traffic volume of heavy vehicles at five (5) selected road sections and their classifications are shown in Table 1.4.7.

2) Standard axle load

According to information by DLT, standard axle load of heavy vehicles in Thailand are between 6.8 ton and 9.1 ton as shown in Appendix 1.4.1.

Table 1.4.7 Design Traffic Volume at Selected Road Sections

Rehabilitation No.	Road Name	Present Traffic Volume One way daily traffic of Heavy Vehicles	Design Traffic Volume One way daily traffic of Heavy Vehicles in 5 years *	Classification by Traffic Volume
R 1	Itsaraphat Road	3,030	3,150	D
R 2	Charoen Krung Road	730	760	B
R 3	Sutthisan Road	1,270	1,320	C
R 4	Petburi Road	2,600	2,700	C
R 5	Nang Linchi Road	680	710	D

* The 5-year traffic volume growth rate : 1.04 is determined based on Peak Period Traffic Growth (person-trips) from 1994-2001 in Short Term Urban Transport Review (STTR).

On the other hand, result of heavy vehicle survey at a weighing station on National Highway Route 1 shows that the axle load of heavy vehicles are almost within range of the standard axle load as shown in Figure 1.4.3. Therefore, the standard axle load in this study was set at 10 tons (while, wheel load is 5 ton).

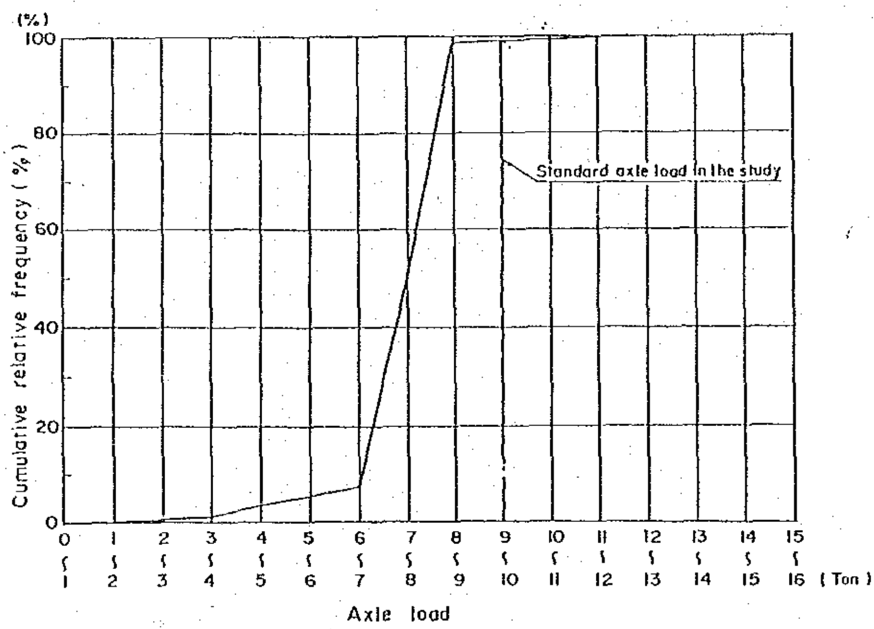

Figure 1.4.3 Distribution of Axle Load (at National Highway Route 1)

3) Design CBR

For the design of pavement thickness, subgrade soils are sampled to determine the design CBR. Design CBR shall be determined based on the CBR value obtained from CBR test in laboratory. It is desirable to take the samples for CBR test from the rehabilitation sites. However, in this study it was impossible to take the samples due to the traffic condition at the site or roadside condition.

Therefore, CBR test in laboratory was carried out using the samples obtained from the spots along the middle ring road, and core boring was carried out at the selected three road sections, on Itsaraphap Road, Charoen Krung Road and Sutthisan Road.

Design CBR at above three road sections were estimated based on the reviews on the results of CBR test, water contents and gradation obtained from core boring, and on engineering judgment including Bangkok soil.

1.4.5 Rehabilitation plans for selected road sections

(1) Itsaraphap Road

The design methods for overlay thickness are classified into two types i.e. design of overlay thickness by design CBR and by deflection value. The designs of overlay thickness applying above two methods are demonstrated below.

1) Design of overlay thickness by design CBR

Design conditions

- Design traffic volume : 3,150 vehicles/day/one direction
  D : Classification by Traffic Volume
  (see Table 1.4.7)
- Design CBR = 3
- Present pavement composition is as shown below.

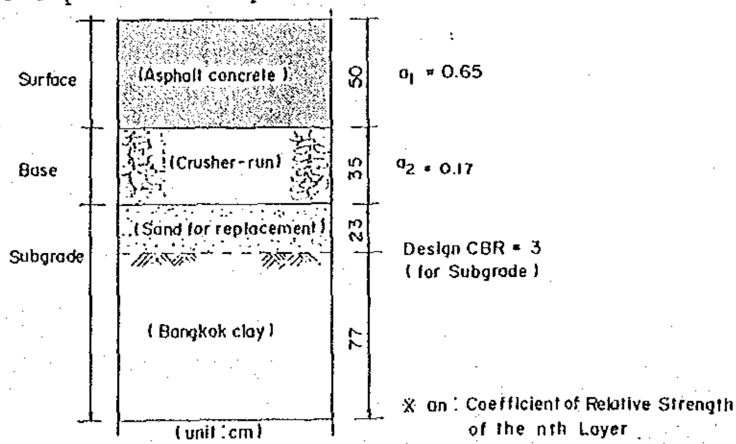

Figure 1.4.4 Present Pavement Composition at Itsaraphap Road

Procedure of design of overlay thickness

a) Calculation of T_{AO}

The existing pavement condition is evaluated by T_{AO} as described below.

$T_{AO} = \Sigma\ a_{no} \cdot Tn = 0.65x50 + 0.17x35 = 38$ cm

where T_{AO} : thickness of hot bituminous mixture for surface course converted from the total pavement thickness which is reduced according to the evaluation of each layer shown in Table 1.4.8.

a_{no} : coefficient of relative strength of the n th layer. (see Table 1.4.8)

Tn : thickness of the n th layer (cm)

b) Determination of T_A

Required thickness T_A is determined based on the traffic volume (heavy vehicle volume) and subgrade strength (Design CBR value) as described in design conditions. According to Table 1.4.9, T_A is determined as shown below.

$T_A = 45$ cm

Table 1.4.9 T_A Target Value by Design CBR and Classification by Traffic Volume

Design C B R	T_A by Classification of Traffic Volume (cm)				
	L	A	B	C	D
more than 2	17	21	29	39	51
more than 3	15	19	26	35	45
more than 4	14	18	24	32	41
more than 6	12	16	21	28	37
more than 8	11	14	19	26	34
more than 12		13	17	23	30
more than 20				20	26

c) Calculation of overlay thickness

Overlay thickness is calculated by the following equation.

$t = T_A - T_{AO}$ (cm) $= 45 - 38 = 7$ cm

where t : required overlay thickness

Table 1.4.8 Coefficient of Relative Strength of Each Layer (a_{no})

	Material of Existing Pavement	Level of Damages on Pavement	Coefficient	Remark
Binder and Surface Course	Hot asphalt mix	Present level is 1, but it might be worsen to be level 2	0.9	
		Present level is 2, but it might be worsen to be level 3	0.85 - 0.6	
		Present level is 3	0.5	
Base	Hot asphalt mix statilization		0.8 - 0.4	The coefficient is determined depending on the condition of damaged, under the consideration that the maximum coefficient is utilized for bases which is admitted to secure the same strength as newly constructed bases.
	Cement stabilization		0.55 - 0.3	
	Lime stabilization		0.45 - 0.25	
	Graded crushed stone		0.35 - 0.2	
Sub Base	Pit-run gravel crusher-run		0.25 - 0.15	
	Cement Stabilization, Lime Stabilization		0.25 - 0.15	
Cement Concrete Slab	Cement Concrete	Present level is 1 or 2	0.9	
		Present level is 3	0.85 - 0.5	

Note: Level of damages on pavement
Level 1 : Service level is good (Cracking ratio is less than 15%)
Level 2 : Service level is almost good, however partial repair is required (Cracking ratio is between 15 and 35%)
Level 3 : Overlay or large scale repair is required (Cracking ratio is more than 35%)

T_A : thickness of hot bituminous mixture for surface course converted from the total pavement thickness

T_{AO}: as mentioned above

2) Design of overlay thickness by deflection value

Overlay thickness can also be determined by the deflection value (D) of existing road surface. The results of deflection survey are shown in Appendix 1.4.2.

Procedure of design of overlay thickness

a) Adjustment of measured deflection value

It is necessary to adjust deflection value according to the pavement temperature, because deflection depends on pavement temperature. Deflection is adjusted using the following equation.

$$D = (d + 2\sqrt{V}) \times f$$

where D : adjusted deflection (mm)

d : the average of measured value of deflection (wheel load = 5t)

$\sqrt{V}$: unbiased standard deviation of measurement value

f : adjusted coefficient of temperature which is determined by Figure 1.4.5.

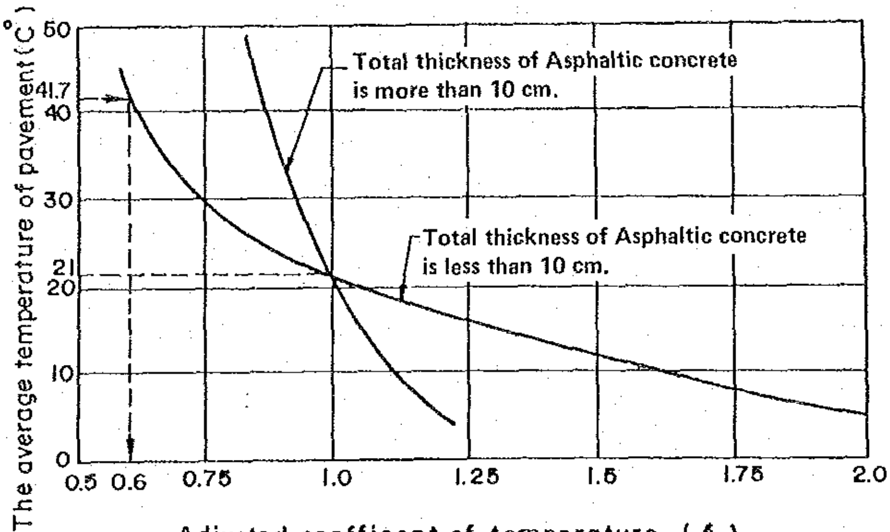

Figure 1.4.5 Adjusted Coefficient by Temperature for Deflection Value

From the results of the supplemental survey, the average of measured deflection value, d and its unbiased standard deviation, $\sqrt{V}$ are determined as below.

$d = 0.78$ mm, $\sqrt{V} = 0.252$ mm.

The average temperature of pavement is 41.7°C, then from Figure 1.4.5,

$f = 0.6$

Therefore, adjusted deflection is as follows:

$D = (d+2\sqrt{V}) \times f = (0.78 + 2 \times 0.252) \times 0.6 = 0.8$ mm

b) Determination of overlay thickness

- Design Traffic Volume

  D : classification by traffic volume (see Table 1.4.7)

According to Table 1.4.10, overlay thickness is determined as 8 cm.

Table 1.4.10 Required Overlay Thickness by Deflection Value

Adjusted Deflection on existing road surface D (mm)	Overlay thickness by Classification of Traffic Volume (cm)				
	L	A	B	C	D
less than 0.6	-	-	-	4	4
more than 0.6	-	-	4	6	8
more than 1.0	-	4	6	10	12
more than 1.5	4	6	10	12	15
more than 2.0	6	10	12	15	-

3) Overlay thickness at Itsaraphap Road

As calculated above the overlay thickness for this road section was recommended to be 8 cm. The recommended thickness was chosen within the range between the two values described in previous sections, and was determined based on the engineers judgment considering the site condition, reliability of the data and conservativeness. The following attentions shall be paid upon the implementation of overlay work.

- The tapering of surface between curb and carriageway should be carried out to secure the desirable height of curb (minimum 10 cm) at shoulder. (see TECHNICAL GUIDELINE Figure 2.3.4)
- Pot hole and concave of road surface shall be covered with hot mix before implementation of overlay work in order to secure the level of road surface.
- As the pavement condition in this section is different on each lane, overlay shall be carried out on the first left lane heading to Phran Nok Road but on the other lanes, only patching shall be needed.

(2) Charoen Krung Road

1) Design of overlay thickness by design CBR

Design conditions

- Design Traffic Volume : 760 vehicles/day/one direction
  B: Classification by Traffic Volume
- Design CBR = 6
- Present Pavement Composition is shown below.

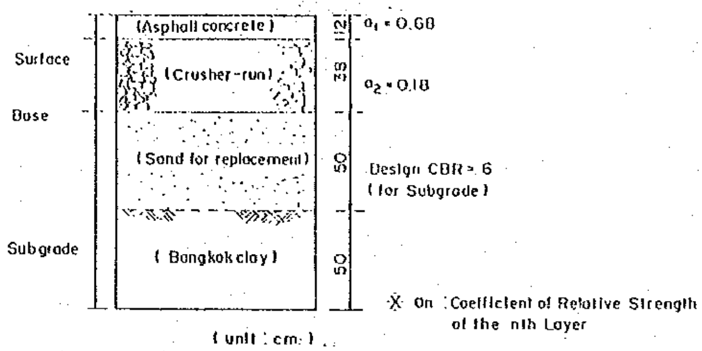

Figure 1.4.6 Present Pavement Composition at Charoen Krung Road

Procedure of design of overlay thickness

a) Calculation of T_{AO}
   $T_{AO} = \Sigma\, a_{no} \cdot T_n = 0.68 \times 12 + 0.18 \times 38 = 15$ cm

b) Determination of T_A
   $T_A = 21$ cm (determined from Table 1.4.9)

c) Calculation of overlay thickness
   $t = T_A - T_{AO} = 21 - 15 = 6$ cm

2) Design of overlay thickness by deflection value

a) Adjustment of measured deflection value

According to the results of survey (see Appendix 1.4.2) the average of measured deflection value, d and its unbiased standard deviation, $\sqrt{V}$ are determined as below.

$d = 0.62$ mm, $\sqrt{V} = 0.226$ mm.

The average temperature of pavement is 33.4°C, then from Figure 1.4.5,

$f = 0.68$

Therefore, adjusted deflection is as follows:

$D = (d + 2\sqrt{V}) \times f = (0.62 + 2x0.226) \times 0.68 = 0.7$ mm

b) Determination of overlay thickness

- Design Traffic Volume
  B : Classification by traffic volume

According to Table 1.4.10, overlay thickness is determined as 4 cm.

3) Overlay thickness at the Charoen Krung Road

As the adopted overlay thickness for this road section was 6 cm. Following attentions shall be paid upon implementation.

- Tapering of overlay shall be carried out so that the surface around the manhole and inlet shall be very smooth without any gaps, as shown in Figure 2.3.4 in the TECHNICAL GUIDELINE.
- Pot hole shall be covered by hot mix before implementation of overlay work.
- Leveling work, especially for longitudinal direction of road, should be carefully carried out before overlay work.

(3) Sutthisan Road

1) Design of overlay thickness by design CBR

Design conditions

- Design Traffic Volume : 1,320 vehicles/day/one direction
  C : Classification by Traffic Volume
- Design CBR = 4
- Present Pavement Composition is shown below.

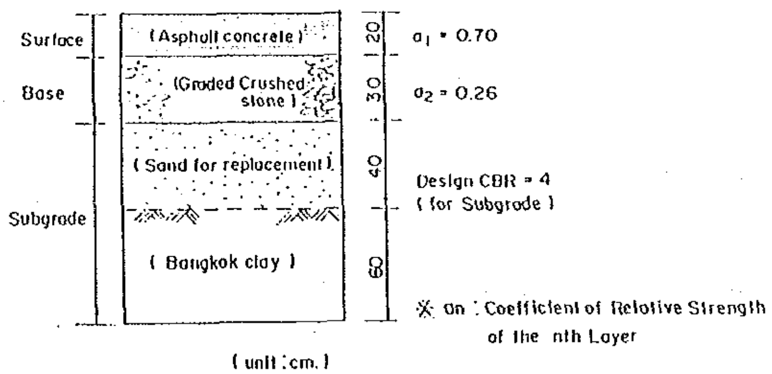

Figure 1.4.7 Present Pavement Composition at Sutthisan Road

Procedure of design of overlay thickness

a) Calculation of T_{AO}
$T_{AO} = \Sigma\, a_{no} \cdot T_n = 0.70x20 + 0.35x30 = 25$ cm

b) Determination of T_A
$T_A = 32$ cm (determined from Table 1.4.9)

c) Calculation of overlay thickness
$t = T_A - T_{AO} = 32 - 25 = 7$ cm

2) Design of overlay thickness by deflection value

a) Adjustment of measured deflection value

According to the results of survey (see Appendix 1.4.2), the average of measured deflection value, d and its unbiased standard deviation, $\sqrt{V}$ are determined as below.

$d = 0.58$ mm, $\sqrt{V} = 0.209$ mm

The average temperature of pavement is 31.1°C, then from Figure 1.4.5,

$f = 0.73$

Therefore, adjusted deflection is as follows:

$D = (d + 2\sqrt{V}) \times f = (0.58 + 2x0.209) \times 0.73 = 0.7$ (mm)

b) Determination of overlay thickness

- Design Traffic Volume
  C : Classification by traffic volume

According to Table 1.4.10, overlay thickness is determined as 6 cm.

c) Overlay thickness at the Sutthisan Road

As the recommended overlay thickness for this road is 7 cm, following attentions shall be paid upon implementation of overlay work.

- Leveling work should be fully carried out before overlay work.
- Curb shall be raised to secure the desirable height of curb at this section.
- Tapering of overlay shall be carried out so that the surface around the manhole and inlet shall be very smooth without any gaps, as Figure 2.3.4 in the TECHNICAL GUIDELINE.

(4) Petburi Road

1) Rehabilitation method for longitudinal cracking which develops to the bottom of the concrete slab

The widths of longitudinal cracks on this section were measured to be 12 mm - 20 mm.

In general, if the cracking width is wide, it is necessary to check a void between the concrete slab and the base course. If the void is found in the base course, it is necessary to apply the injection method (see TECHNICAL GUIDELINE 2.4.3.(1) 5))

Injection of the joint sealer into the cracks is recommended for this type of cracking. The injection shall be carried out as shown in Figure 1.4.8. Usually, the material of joint sealer is made of bituminous material mixed with rubber.

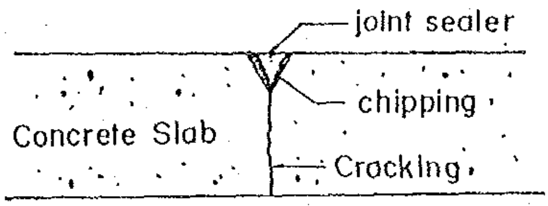

Figure 1.4.8 Example of Injection for Longitudinal Cracking

2) Rehabilitation method for cracks which has not developed to the bottom of the concrete slab

It is necessary to fill the cracking which has not reached to the bottom of the concrete slab by sealing material. The details of this process is shown in TECHNICAL GUIDELINE.

3) Rehabilitation method for damaged joint

There are some joints which had lost joint sealers on this section. As the deficiency of joint sealers can be the cause of spalling, it is necessary to repair the damaged joints immediately by injecting the joint sealers.

The following attentions shall be paid upon implementation of injection.

- To clean the damaged joint by jet water
- To take out the old joint sealer, and

- To dry up the joint before injection

Usually, the joint sealer for repair shall be same as the damaged one.

(5) Nang Linchi Road

1) Rehabilitation method for spalling and scaling

Usually, patching is used for repair of spalling and scaling. Patching is classified into three types, i.e. by cement, asphalt and resin.

Patching by asphalt is recommended because it allows the road to be reopened quickly. Patching is applicable to between the slab Ⓐ and Ⓑ (see Figure 1.4.9).

The implementation is similar to patching on asphalt pavement described in TECHNICAL GUIDELINE 2.3.3.

Tapering of patching area shall be carried out carefully at the execution.

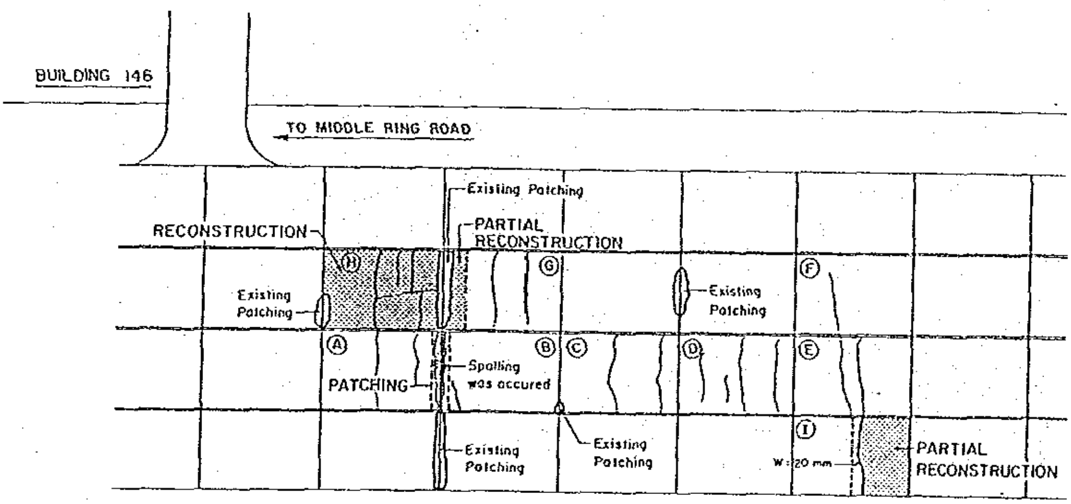

Figure 1.4.9 Pavement Condition and Rehabilitation Method at Nang Linchi Road

2) Rehabilitation method for transverse cracking

There are some transverse cracking on the road surface (see Figure 1.4.9 slab Ⓐ,Ⓒ-Ⓕ).
According to the result of observation, these cracking widths are small (cracking width is less than 0.5 mm) and undeveloped to the bottom of the

slab. Based on above consideration, the crackings shall be covered with sealing materials.

3) Rehabilitation method for cracks which develops to the bottom of the slab at a certain slab

There are some slab which have cracks developing to the bottom of slab (see Figure 1.4.9 slab Ⓖ, Ⓗ and Ⓘ).

The rehabilitation methods for these damaged slabs are recommended as follows.

Slab Ⓖ : Injection of joint sealer into cracking spots shall be recommended.

Slab Ⓗ : Reconstruction over the whole slab shall be recommended.

slab Ⓘ : Partial reconstruction according to Figure 1.4.9 shall be recommended.

The execution of partial reconstruction is described in TECHNICAL GUIDELINE 2.4.3.(2).

TECHNICAL GUIDELINE
FOR
PAVEMENT REHABILITATION

2. TECHNICAL GUIDELINE FOR PAVEMENT REHABILITATION

This technical guideline is prepared for pavement rehabilitation planning for asphalt pavement and cement concrete pavement in general. Pavement design for new construction is also presented in this study since the design process for pavement reconstruction is almost same as new construction.

2.1 General

2.1.1 Objectives of Pavement Rehabilitation

There are three major objectives in pavement rehabilitation

- To secure the structural function of pavement and to ensure the durability of pavement.
- To ensure the rideability i.e. safe and comfortable driving.
- To prevent deterioration of the roadside environment caused by bad pavement condition.

2.1.2 Pavement Rehabilitation Works

Pavement rehabilitation works[1/] can be classified into two types, maintenance and repair.

Maintenance works mainly consist of improvement of surface smoothness, while repair works consist of structural strength improvement.

1/ The word "rehabilitation" is sometimes used to refer a large scale repair work such as reconstruction of pavement.
However, in this study the word "rehabilitation" has been used to mean only maintenance and repair work.

(1) Maintenance

Maintenance works are classified into the following two types.

a) Work to be executed immediately
- patching
- to fill up the pot hole
- to taper bumps

b) Work to be executed at appropriate timing
- surface treatment
- to cover partial crackings
- to eliminate rutting
- to increase skid resistance

(2) Repair

Repair work should be carried out with the following works from the long term view point.

- overlay
- reconstruction

2.1.3 Pavement Damage

In general, damages of pavement are classified into two types as shown in Table 2.1.1. One type is mainly damages of pavement surface and the other is damages of structural function of pavement.

2.1.4 Basic Procedure of Pavement Rehabilitation Works

Basic procedure of pavement rehabilitation works is illustrated in a flow chart in Figure 2.1.1.

Table 2.1.1 Classification of Pavement Damage

Type of damage		Asphalt pavement	Cement concrete pavement
Damages on pavement surface	Partial cracking	. Hair cracking, . Line cracking	Cracking which undevelop to the bottom of concrete slab
	Bump	. Roughness around a structure	Roughness around a structure and Bump between slabs
	Deformation	. Rutting . Longitudinal roughness, . Corrugation, . Flush	Longitudinal roughness
	Abrasion	. Ravelling, . Polishing, . Scaling	Ravelling, Polishing Scaling
	Damages	. Pot hole, . Stripping, . Weathering	
	Damage of joint		Damage of joint-sealing, Damage on edge of joint
	Others	. Tire mark, . Scratch	Perforation
Damages of structural function of pavement	Alligator cracking	. Alligator cracking	Cracking which develop to the bottom of concrete slab
	Buckling		Blow-up Crashing

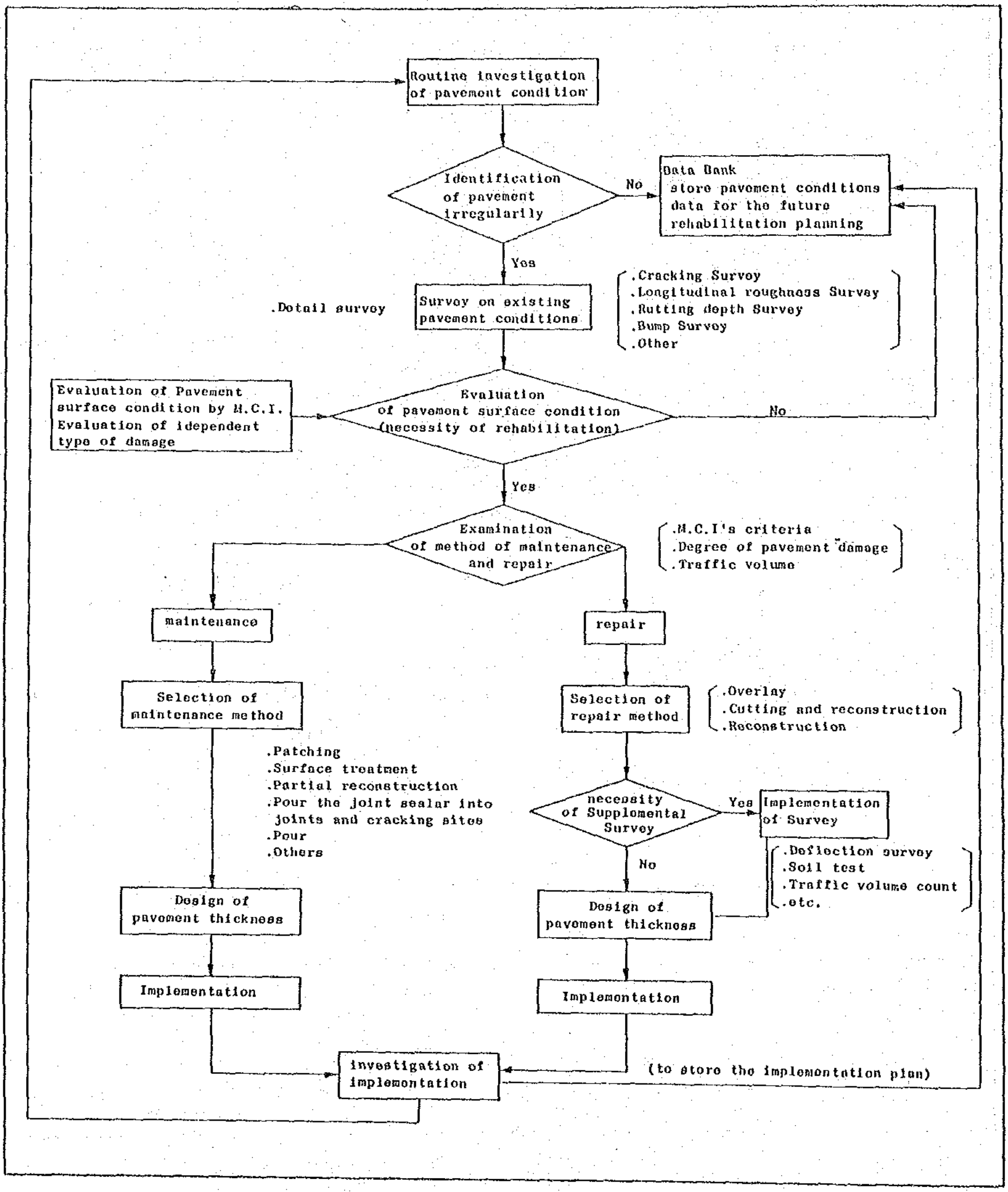

Figure 2.1.1 Basic Flow of Rehabilitation Works

2.2 Survey for Evaluation of Pavement Condition

2.2.1 Introduction

In general, surveys to assess the condition of pavements are classified into two types,i.e. the visual assessment and the detailed pavement survey.

The visual assessment is a part of the routine investigation of road in which engineers visually assess the condition of pavement.

The detailed pavement survey is a special assessment of pavements and it is occasionally carried out by using special survey equipments for the road sections with irregular pavement conditions.

It is desirable to carry out this detailed survey once in three years at selected road sections in order to prepare the future pavement rehabilitation plannings. If the survey results are to be used for making the rehabilitation plan such as overlay or reconstruction, the surveys should be carried out before implementation.

2.2.2 Survey Items

(1) Visual assessment

By the visual assessment, cracking and roughness on pavements (including bumps) are mainly assessed.

(2) Detailed pavement survey

To select the rehabilitation method for damaged pavement, it is necessary to carry out the detailed pavement survey.
There are several types of pavement damages as shown in Table 2.1.1. In fact, it is impossible to measure every type of damage.

Therefore, the following items are measured in the detailed pavement surveys.

- Cracking
- Longitudinal roughness
- Rutting depth
- Bump (if necessary)
- Deflection (if necessary)

Survey procedure and compilation of survey results are presented in Appendix 2.2.1.

2.3 Rehabilitation of Asphalt Pavement

2.3.1 Evaluation of Pavement Condition

Evaluation of pavement condition can be classified into two types, i.e. evaluation by M.C.I. method and evaluation by damage type criteria for rehabilitation.

(1) Evaluation of pavement condition by M.C.I. method

In order to secure good condition of pavement, it is necessary to rehabilitate the damage of pavement at appropriate timing. It is desirable to use the M.C.I. rating method for evaluation to determine the necessity and extent of the rehabilitation for the pavement. The following formulas were employed to evaluate the asphalt pavement condition in the study. The details of the formulas are shown in Chapter 1 Pavement Rehabilitation of this volume.

$$M.C.I. = 10-0.88C^{0.3} -2.03\sigma^{0.2} -0.22D^{0.7} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$M.C.I._{o}= 10-0.97C^{0.3} -2.61\sigma^{0.2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where C : Cracking ratio (%)

σ : Standard deviation of longitudinal roughness (mm)

D : Average depth of rutting (mm)

The first formula (1) should be basically used for the evaluation. However, if the value of rutting depth at certain road section is small, the second formula (2) can be used for the evaluation.

M.C.I. formulae have been developed in order to evaluate the pavement condition of the roads quantitatively and, thus, to determine the needs for rehabilitation. In practice, it is used in the following procedure for asphalt pavement;

- To decide whether damaged pavement should be rehabilitated or not.
- To decide necessity and extent of rehabilitation.
- To indicate the priority of rehabilitation.

Table 2.3.1 describes the extent of rehabilitation required to the pavement condition evaluated by M.C.I. values.

Table 2.3.1 Evaluation of Pavement Condition by M.C.I. Values

M.C.I	Required Extent of Rehabilitation
MCI ≧ 5.0	Unnecessary to repair
4.0 ≦ MCI < 5.0	Maintenance
3.0 ≦ MCI < 4.0	Partial repair
MCI < 3.0	Full scale repair

(2) <u>Evaluation of pavement condition by damage type criteria for rehabilitation</u>

In order to secure the good condition of pavement, it is necessary to rehabilitate the independent type of pavement damages, such as bumps and pot holes, regardless of M.C.I. value, if they are severe.

Hence, it is also necessary to evaluate the extent of damages taking into account damage type criteria for rehabilitation.

Table 2.3.2 shows damage type criteria for rehabilitation for asphalt pavement.

Table 2.3.2 Damage Type Criteria for Rehabilitation
(Asphalt Pavement)

Item / Road Classification	Rutting Depth(mm)	Bump (mm)		Skid Resistance Coefficient	Longitudinal Roughness(mm)	Cracking Ratio(%)	Pot hole diameter (cm)
		Abutment	Culvert Box				
Highways with heavy traffic	30 - 40	60	60	0.25	4.0 - 5.0(σ) (3 m profile)	30 - 40	20
Other highways	40	60	-	-	-	40 - 50	20

2.3.2 <u>Selection of Rehabilitation Method</u>

In order to select the suitable rehabilitation method for damaged pavement, the comprehensive consideration of the following items are necessary.

- M.C.I. value (Table 2.3.1)
- Damage type criteria for rehabilitation (Table 2.3.2)
- Rehabilitation methods by type of damages (Table 2.3.3)
- Rehabilitation method which can be determined by relationship between

cracking ratio and heavy vehicle traffic volume (Figure 2.3.1).

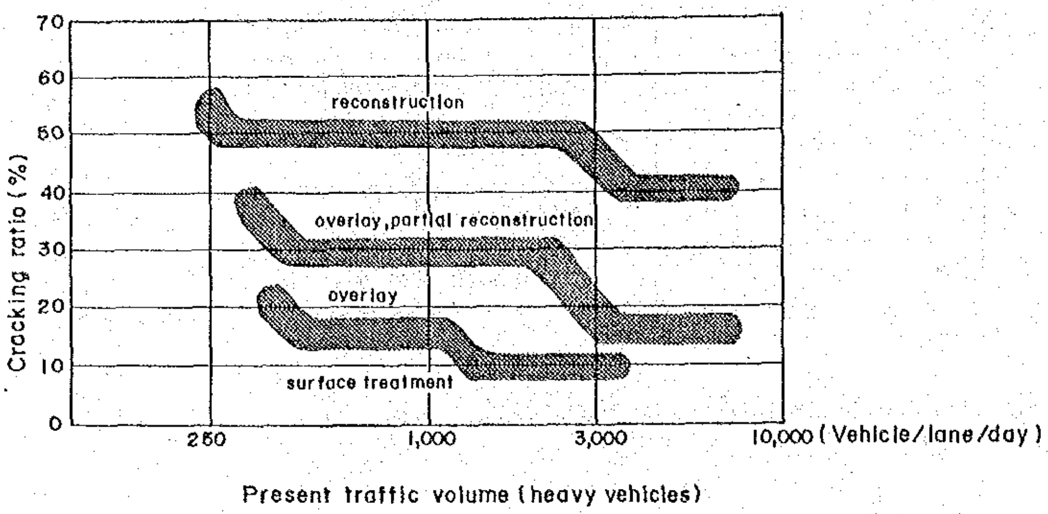

Figure 2.3.1 Selection of Rehabilitation Method by Cracking Ratio - Heavy Vehicle Traffic Volume

2.3.3 Rehabilitation Method

The rehabilitation methods are classified into two types i.e. the maintenance method and repair method. Maintenance methods are carried out in order to secure the pavement performance, while repair methods are mainly carried out in order to extend the pavement life by strengthening the pavement structure.

The typical maintenance methods are shown below.

- Patching
- Surface treatment
- Partial reconstruction
- Cutting
- Grooving

The types of repair methods are shown below.

- Overlay
- Cutting and Reconstruction
- Reconstruction

The summary of each method are presented below.

Table 2.3.3 Rehabilitation Methods for Asphalt Pavement by Type of Damages

Type of Damage	Rehabilitation methods
Hair cracking Line cracking	. Seal in cracking, Fog seal, Seal coat
Roughness near to a surface	. Patching, . Partial reconstruction
Rutting	. Cutting of ruts . Over-lay or carpet coat after cutting ruts . Cutting and reconstruction of surface course . Reconstruction depending on surface condition
Longitudinal roughness Corrugation	. Armer coat, . Capet coat
Flush	. Scattering of crushed or coarse and
Ravelling	. Patching, . Armer coat, . Capet coat . Overlay
Polishing	. Seal coat, . Armer coat, . Capet coat, . Grooving, . Resinous surface treatment
Scaling	. Patching . Partial reconstruction
Pot hole	. Patching . Partial reconstruction
Stripping Weathering	. Seal coat, . Armer coat, . Fog seal, . Slurry seal, . Capet coat, . Overlay
Alligator cracking	. Armer coat, . Capet coat, . Overlay . Cutting and reconstruction . Reconstruction

(1) Maintenance method

1) Patching

In order to repair damaged pavement such as pot hole, bumps, local cracking etc., this method should be applied. In general, this methods are subdivided into two types i.e. hot mixing method and cold mixing method.

Hot mixing method: The materials used in the hot mixing method have extremely good adhesion, durability, and high stability, and are therefore suitable for roads with heavy traffic roads.

Cold mixing method: The materials used in the cold mixing method can be used at the prevailing temperature, since it can be easily transported.

2) Surface treatment

When damage occurs locally on the surface of asphalt pavement, such as cracking, deformation (rutting, longitudinal roughness) and abrasion (ravelling), the relatively thin layer (less than 2.5cm) should be placed on damaged pavement.

Usually, surface treatment is subdivided into the method as shown in the following.

- Seal coat and armer coat
- Carpet coat
- Fog seal
- Slurry seal
- Resin surfacing

a) Seal coat and armer coat

Seal coating is the process in which bituminous material is spread over existing road surface and then sand or crushed rock are spread on road surface.

Armer coat is repeatation of the above process more than two times.

b) Carpet coat

The hot mixture is spread over the surface and is compacted in 1.5 - 2.5 cm thickness. This method is suitable for heavy traffic road because it allows the road to be reopened quickly.

c) Fog seal

A water-diluted asphalt emulsion is spread on the surface in order to cover the little cracking and void of surface.

d) Slurry seal

Cold mixing which is slurry made of asphalt emulsion is spread evenly on road surface. This method does not require rolling.

e) Resin surfacing

Resin surfacing consists of the spraying or painting of synthetic resin on the road surface, followed by the application of special aggregate. This method can be expected to increase the skid resistance on the road surface.

3) Partial reconstruction

Where the severe damage occurs on the surface partially, and other repair method can not be used, this method is used to reconstruct the surface and base course, and sometimes the subgrade. It is important that the cause of damage should be investigated in detail before implementation.

The shape of reconstruction is recommended to form a rectangular in parallel with the center line of the road and its width shall be more than 2.5m in order to get the best workability of the equipment to be used for such reconstruction. Since the reconstructed area tends to sink after the road reopened to traffic, it is recommended to design pavement thickness about 0.5 - 1.0 cm higher than the height of existing surface.

4) Cutting

If continuous or intermittent roughness are occurred on the surface, cutting should be carried out to repair the damaged sites.

It is often used to remove rutting and deformations caused by flow of the asphaltic mixture which occurs on road surface at intersection approach, and to improve skid resistance.

5) Grooving

Grooving is used to cut the surface either in parallel or perpendicular to the direction of the road in order to increase the frictional coefficient when the surface is wet. Generally, grooves' depth is 3 mm.

(2) Repair method

1) Overlay

If the condition of pavement becomes such as described below, overlay works are required.

- There are many crackings on the surface.
- Maintaining of the good pavement serviceability is expected to be difficult in the near future if temporary repairings are done.
- Pavement thickness become insufficient for increasing traffic volume.

There are two types of thickness design methods for overlay, as described below.

Design of overlay thickness by design CBR

This method is applied as a pavement thickness design method for new construction (see 2.5.1). Procedure of this method is shown below.

a) The existing pavement condition is evaluated by T_{AO} as described below.

$T_{AO} = \Sigma a_{no} \cdot Tn$ ....(3)

where T_{AO} : thickness of hot bituminous mixture for surface course converted from the total pavement thickness which is reduced according to the evaluation of each layer shown in Table 2.3.4.

a_{no} : coefficient of relative strength of the n th layer (see Table 2.3.4).

Tn : thickness of the n th layer (cm)

b) Required thickness T_A is determined based on the traffic volume (heavy vehicle volume) and subgrade strength (Design CBR value) as shown in Table 2.3.5 and 2.3.6.

c) Overlay thickness is calculated by the following equation.

$t = T_A - T_{AO}$ (cm)........................(4)

where t : required overlay thickness

Table 2.3.4 Coefficient of Ralative Strength of Each Layer (a_{no})

	Material of existing pavement	Level of damages on pavement	Coefficient	Remark
Binder and Surface course	Hot asphalt mix	Present level is 1, but it might be worsen to be level 2	0.9	The suitable coefficient for intermediate level of damages (in level 2) can be determined under the consideration that the maximum and minimum coefficient level are utilized if the condition of damages is almost similar to that of in level 1 and level 3 respectively.
		Present level is 2, but it might be worsen to be level 3	0.85 - 0.6	
		Present level is 3	0.5	
Base	Hot asphalt mix stabilization		0.8 - 0.4	The suitable coefficient is determined depending on the condition of damages, under the consideration that the maximum coefficient is utilized for bases which is admitted to secure the same strength as newly constructed bases.
	Cement Stabilization		0.55 - 0.3	
	Lime Stabilization		0.45 - 0.25	
	Graded crushed stone		0.35 - 0.2	
Sub base	Pit-run gravel crusher-run		0.25 - 0.15	
	Cement Stabilization Lime Stabilization		0.25 - 0.15	
Cement Concrete slab	Cement Concrete	Present level is 1 or 2	0.9	
		Present level is 3	0.85 - 0.5	

Note : Level of damages on pavement
Level 1 : Service level is good (Cracking ratio is less that 15%)
Level 2 : Service level is almost good, however partial repair is required (Cracking ratio is between 15 to 35%)
Level 3 : Overlay or large scale repair is required (Cracking ratio is more than 35%)

T_A : thickness of hot bituminous mixture for surface course converted from the total pavement thickness

T_{AO} : as mentioned above

Table 2.3.5 Pavement Design Classification by Traffic Volume

Classification	One Way Daily Traffic of Heavy Vehicles*
L	Less than 100
A	100 to 250
B	250 to 1,000
C	1,000 to 3,000
D	More than 3,000

*Heavy Vehicles refers to buses, mini-buses, truck with over 6 wheels, trailers and tractors.

Table 2.3.6 T_A Target Value by Design CBR and Classification by Traffic Volume

Design CBR	T_A by Road Classification (cm.)				
	L	A	B	C	D
more than 2	17	21	29	39	51
more than 3	15	19	26	35	45
more than 4	14	18	24	32	41
more than 6	12	16	21	28	37
more than 8	11	14	19	26	34
more than 12		13	17	23	30
more than 20				20	26

[For example]

Example of overlay thickness design is shown below.

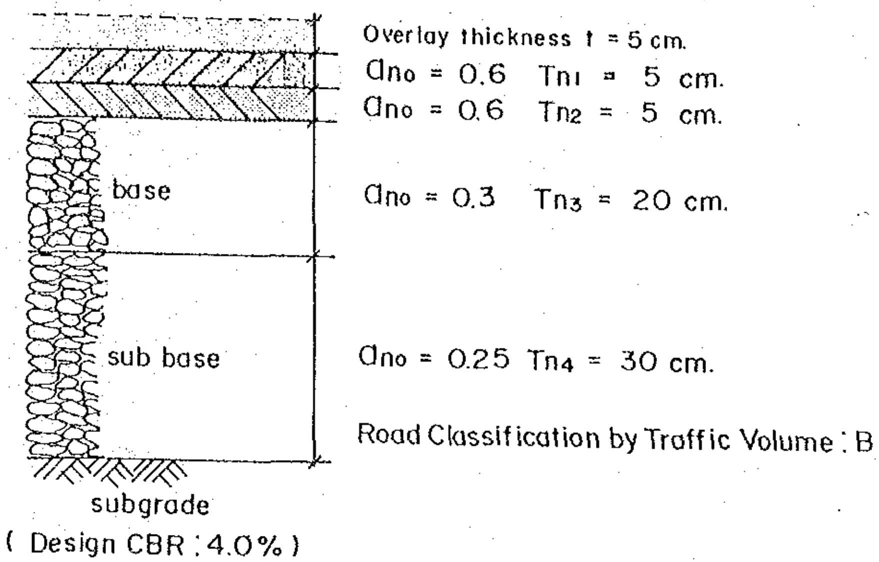

Figure 2.3.2 Example of Pavement Composition and Design Conditions

T_{AO} is calculated by following equation.

$T_{AO} = \Sigma an \cdot Tn$
$= 0.6x5 + 0.6x5 + 0.3x20 + 0.25x30$
$= 19.5$ cm

Required thickness : T_A is determined based on Table 2.3.6.
As the result, $T_A = 24$ cm

$t = T_A - T_{AO} = 24 - 19.5 = 4.5 \text{ cm} \fallingdotseq 5 \text{ cm}$

Design of overlay thickness by deflection value

Overlay thickness can also be determined by the deflection value (D) of existing road surface as shown in Table 2.3.7.

Table 2.3.7 Required Overlay Thickness by Deflection Value

Deflection on existing road surface D (mm)	Overlay Thickness by Road Classification (cm.)				
	L	A	B	C	D
less than 0.6	-	-	-	4	4
more than 0.6	-	-	4	6	8
more than 1.0	-	4	6	10	12
more than 1.5	4	6	10	12	15
more than 2.0	6	10	12	15	-

The measurements of deflection value shall be carried out at 10m intervals on the wheel path in each section (see Appendix 2.2.(1) 7) Deflection survey).

It is necessary to adjust deflection value according to the pavement temperature, because the deflection is depends on pavement temperature.

The deflection is adjusted using the following equation.

$$D = (d + 2\sqrt{V}) \times f \quad \ldots\ldots (5)$$

where D : adjusted deflection (mm)

d : the average of measured value of deflection (wheel load = 5t)

$\sqrt{V}$: unbiased standard deviation of measurement value

f : adjusted coefficient of temperature

f is determined by Figure 2.3.3.

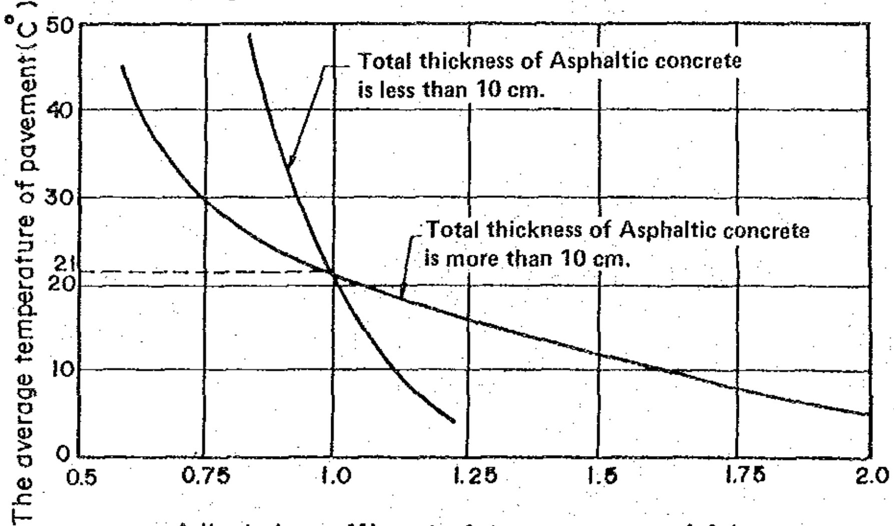

Figure 2.3.3 Adjusted Coefficient by Temperature for Deflection Value

If it is impossible to measure the average temperature, deflection measurement should be carried out between 8 to 10 am which is regarded to assume the average pavement temperature.

Implementation of overlay work

Prior to the implementation of overlay work, it is necessary to repair the damaged points on existing pavement according to its degree.

Thus, where the pavement damage is caused by defect of subgrade or base course in partially, partial reconstruction is adopted and seal coating is used at the location where there is cracking on the surface.

Procedure of implementation of overlay work is shown below.

a) Cleaning the pavement surface
b) Tack coating
c) Leveling work
   In order to secure the level of road surface leveling work is necessary prior to the overlay work, by filling the hot mix into concave or rutting spots on the existing road surface.
d) Execution of overlay
e) Improvement of the height of road structure
   Height of road structure (gutter, manhole, guard rail) should be improved according to height of overly surface, if necessary. The example of height adjustment by tapering between the roadside structure and surface of carriageway is shown in Figure 2.3.4.

   If the overlay thickness is more than 10 cm, the gutter should be raised to secure the desirable height of curb.

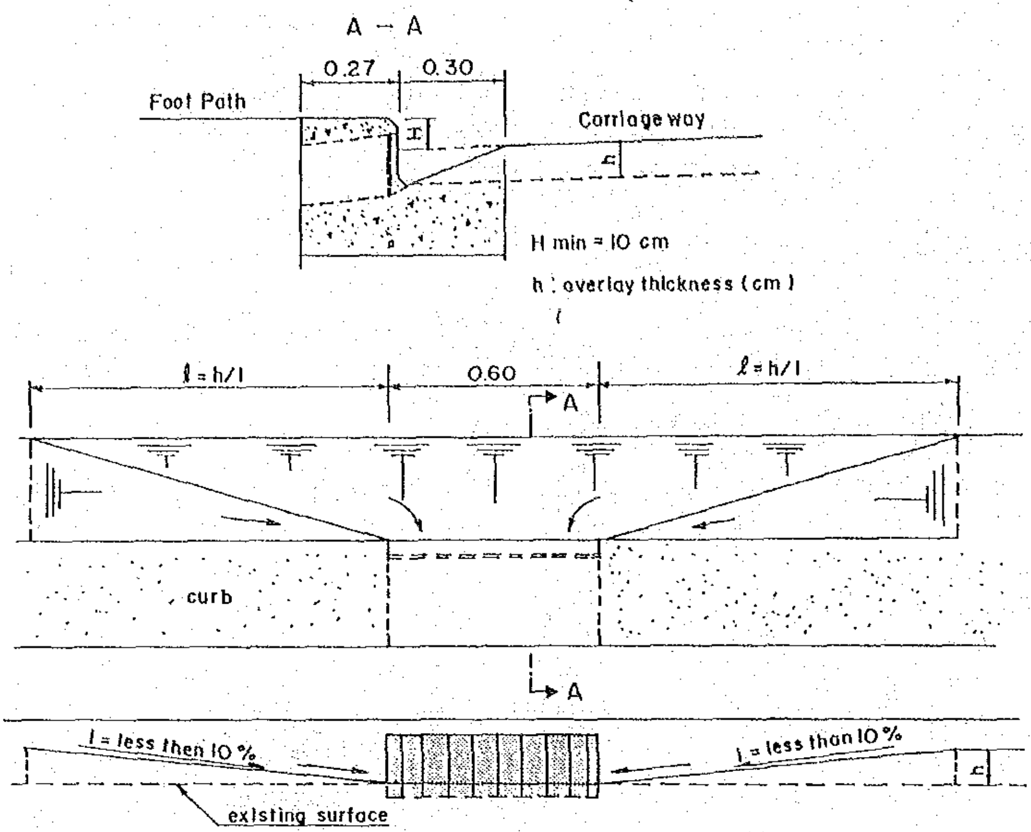

Figure 2.3.4 Example of Tapering Around the Inlet

2) Cutting and reconstruction

This method is to cut the existing surface and then overlay is carried out. When this method is planned, it is necessary to consider the degree of pavement damage and also the land use condition along the road.

In order to design the pavement thickness for reconstruction, the survey of subgrade condition should be carried out and design of pavement thickness shall be decided based on the design of overlay thickness.

3) Reconstruction

This method should be carried out when the pavement damage is remarkable and it cannot be repaired by any other methods such as overlay.

This method is expensive, and hence, a decision should be made after careful investigation and study on the damaged site and cause of damages.

The following items shall be investigated in order to determined the design of reconstruction.

- CBR value of subgrade