PART B
STUDY ON LOW-CLASS PAVEMENTS

CHAPTER 7

LOW-CLASS PAVEMENT IN THE PHILIPPINES

7.1 TYPE OF LOW-CLASS PAVEMENT

Low-class pavement, as defined in this Study, refers to pavements which serve for low to medium traffic roads (less than 1,000 vehicles per day). Asphalt Concrete Pavement (AC) and Portland Cement Concrete Pavement (PCC) are generally not considered as low-class pavements. However, AC pavement of 5 cm or less and PCC pavement of 20 cm or less are classified as low-class pavements in this study.

7.1.1 Pavement Types in the Philippines

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(1) Existing Pavement Types

Of a total of 158,000 kms. of public roads in the Philippines, 86% are gravel/earth roads and only 6% are paved with PCC and 8% with bituminous surfaces as shown in Table 7.1-1. About 24% of national roads are paved with PCC, 22% with bituminous surfaces while the rest are still gravel/earth surfaces. About 89% of provincial roads are still gravel/earth surfaces and only 2.5% are paved with PCC and 8.9% with bituminous surfaces. Most of barangay roads (99%) are gravel/earth roads. In general, the majority of rural roads are still gravel/earth roads.

TABLE 7.1-1 ROAD LENGTH IN 1987 BY TYPE OF PAVEMENT IN THE PHILIPPINES

	Type of Pavement				
	PCC	Bituminous	Gravel	Earth	Total
National Road	6,179.7 (23.6%)	5,829.3 (22.3%)	13,400.3 (51.3%)	734.4 (2.8%)	26,143.7 (100%)
Provincial Road	714.1 (2.5%)	2,584.4 (8.9%)	20,477.9 (70.6%)	5,215.0 (18.0%)	28,991.4 (100%)
City Road	649.4 (16.3%)	2,006.0 (50.3%)	1,164.5 (29.3%)	164.7 (4.1%)	3,984.6 (100%)
Municipal Road	1,676.4 (13.0%)	1,574.5 (12.3%)	6,383.0 (49.6%)	3,224.8 (25.1%)	12,858.7 (100%)
Barangay Road	229.1 (0.3%)	557.7 (0.7%)	84,828.9 (99.0%)	- (-)	85,685.7 (100%)
Total	9,518.7 (6.0%)	12,551.9 (8.0%)	126,254.6 (80.1%)	9,338.9 (5.9%)	157,664.1 (100%)

Source: 1988 DPWH Infrastructure Atlas

There is no statistical data on what types of bituminous surfaces were used. However, the DPWH road inventory of national roads suggests the types of bituminous surfaces as follows (see Table 7.1-2 and Figure 7.1-1):

Thickness of Bituminous Surface from Road Inventory (cm)	Percentage (%)	Assumed Type of Bituminous Surface
0.5 - 2.0	13.6	SBST or DBST
2.1 - 4.0	13.4	DBST or thin AC
4.5 - 5.5	38.8	AC (one layer)
6.1 - 8.5	17.7	AC (one or two layers)
9.0 - 10.0	16.5	AC (two layers)

It could be said that asphalt concrete surface of about 5 cm is most commonly used among bituminous surfaces, followed by asphalt concrete surface of 6-10 cm thickness and single or double bituminous surface treatment has still low share.

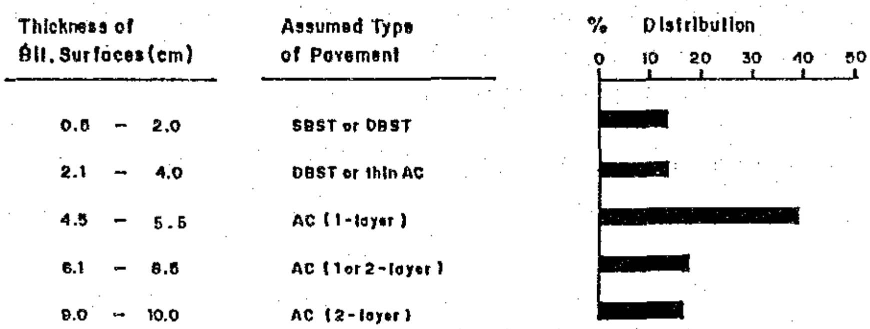


FIGURE 7.1-1 BITUMINOUS PAVEMENT THICKNESS DISTRIBUTION

(2) Pavement Types Suggested by DPWH/DLG Design Guidelines

DPWH Design Guidelines (1984) and DLG Interim Design Guidelines (1981) suggests pavement types for the respective ranges of traffic volume as shown in Table 7.1-3.

TABLE 7.1-2 THICKNESS OF BITUMINOUS SURFACING ON NATIONAL ROARS

As of January 1980-June 1989

THICKNESS (cm) / REGION	LENGTH (km)									
	0.5-1.0	1.2-2.0	2.1-2.54	2.7-4.0	4.5-5.0	5.1-6.0	6.1-7.5	8.0-8.5	9.0-10.0	(0.5-10.0 TOTAL)
R - I					126.876	54.422	130.677		205.473	517.448
C A R			2.640	1.332	170.642				81.737	256.351
R - II			0.300		11.712		15.681	9.378	32.101	69.172
R - III	961	12.415		123.847	143.216	3.710	6.914		89.093	380.156
N C R		0.550			209.363	9.994	33.938	5.400	26.398	285.643
R - IV A	16.995		12.548	14.754	512.983	74.757	29.672	9.240	85.363	756.312
R - IV B		121.124			188.348		0.300	1.140	5.794	316.706
R - V		96.207	92.252		73.771	10.027	2.933		40.704	315.894
R - VI		0.244	56.886	128.927	199.816	81.923	92.127	88.584	125.460	773.967
R - VII	1.505	238.713		0.752	68.884	134.067	10.472		40.180	494.573
R - VIII					18.719	3.890			4.116	26.725
R - IX		135.511	112.826		25.467	0.477	6.774			281.055
R - X	0.982	39.109	53.943	34.449	101.734	38.636		3.584	34.413	306.850
R - XI				18.577	34.061				22.29	74.932
R - XII					1.800	0.809			8.87	11.476
TOTAL	20.443	643.873	331.395	322.638	1,887.394	412.712	329.488	117.326	801.99	4,867.262
%	0.4	13.2	6.8	6.6	38.8	8.5	6.8	2.4	16.5	100.0
Cumulative %	0.4	13.6	20.4	27.0	65.8	74.3	81.1	83.5	100.0	

SOURCE : 1989 DPWH ROAD INVENTORY

TABLE 7.1-3 PAVEMENT TYPES AND TRAFFIC VOLUME

Guidelines	Range of Traffic Volume (AADT in Opening Year)				
	Under 50	50 - 400	400 - 1,000	1,000 - 2,000	More than 2,000
DPWH Design Guidelines	.Gravel (natural or crushed) .Bit. Preservative Treat. .SBST .DBST .Bit. Macadam Pavement		.Bit. Macadam Pavement .Dense or Open Graded Plant Mix Surface Course .Bit. Concrete Surface Course	.Bit. Concrete Surface Course .PCC Pavement	.Bit. Concrete Surface Course .PCC Pavement
DLG Interim Design Guidelines	.Natural Gravel	.Crushed Gravel	.Surface Treatment		

(3) Pavement Types in DPWH Standard Specifications

Pavement types, whose specifications are described in the 1988 and 1972 DPWH Standard Specifications, are listed in Table 7.1-4.

TABLE 7.1-4 PAVEMENT TYPES IN DPWH STANDARD SPECIFICATIONS

1988 Standard Specifications	1972 Standard Specifications
.Aggregate Surface Course .Bituminous Surface Treatment .Bituminous Penetration Macadam Pavement .Bituminous Road-Mix Surface Course .Bituminous Plant-Mix Surface Course, Cold-Laid .Bituminous Concrete Surface Course, Hot-Laid .Portland Cement Concrete Pavement	.Aggregate Surface Course .Bituminous Surface Treatment .Bituminous Macadam Pavement (Hot Asphalt Type and Emulsified Asphalt) .Dense Graded Plant-Mix Surface Course .Open-graded Plant-Mix Surface Course .Bituminous Concrete Surface Course .Bituminous Preservative Treatment .Portland Cement Concrete Pavement .Rock Asphalt Bound Surface Course

(4) Pavement Types in the Philippines and Low-class Pavements

Based on the discussion in (1), (2) and (3) above, pavement types which are commonly adopted or suggested by the Design Guidelines, can be summarized to be the following six (6) types:

a) Gravel Surface
b) Single Bituminous Surface Treatment (SBST)
c) Double Bituminous Surface Treatment (DBST)
d) Bituminous Macadam Pavement (BMP)
e) Asphalt (or Bituminous) Concrete Pavement (AC)
f) Portland Cement Concrete Pavement (PCC)

As suggested by the DPWH Design Guidelines, pavement types a) through d) are generally applied to low traffic roads of which AADT in the opening year is less than 400 vehicles per day, and thus considered low-class pavement. AC pavement is suggested for roads with AADT of more than 400 vehicles per day. Thin AC pavements of about 5 cm are most commonly used among bituminous surfaces. Therefore, AC pavements of 5 cm or less in thickness are considered as low-class pavement in this Study. Although PCC pavement is suggested for roads with AADT of more than 2,000 vehicles per day, this type of pavement is commonly used for much lesser traffic roads in the country due mainly to availability of materials, equipment requirement, durability of the pavement and lesser maintenance requirement. PCC pavements of no more than 20 cm in thickness are considered low-class pavements in this Study.

7.1.2 *General Description of Low-Class Pavement*

General descriptions of low-class pavements are given in Table 7.1-5.

(1) Gravel Surfacing (GR)

Used for low-volume traffic roads

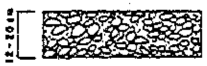
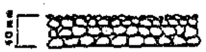
On a prepared sub-base, a course of selected quality of sandy gravel or crushed rock/gravel is laid and compacted. The finished thickness is usually 12 to 20 cm depending on the subgrade bearing capacity and traffic condition.

(2) Single Bituminous Surface Treatment (SBST)

Used for low-volume traffic roads

A single layer of liquid asphalt is sprayed, which is immediately followed by spreading and rolling uniform-size stone chippings. The finished thickness is usually 6 to 10 mm. Not durable under wet climatic conditions.

TABLE 7.1-5 GENERAL DESCRIPTION OF LOW-CLASS PAVEMENTS

Surface Course (Illustration)	Pavement Structure (Examples)	Traffic Volume	Descriptions	Materials / Equipment	Remarks
Gravel Surfacing 	GR Surface 12-20cm Sub-base (10cm) Subgrade	Low	• On a prepared sub-base, a course of selected sandy gravel or crushed rock/ gravel is laid and compacted • Finished thickness; usually 12-20cm	• Material Well graded sandy gravel and/or crushed gravel/rock with light silt • Equipment Road grader, Rollers	A good gravel surfaced road is only attained by continous maintenance operation
Single Bituminous Surface Treatment  Base	SBST Surface 6mm Base 10-15cm Sub-base (12cm) Subgrade	Low	• A single layer of liquid asphalt is sprayed and immediately uniform size stone chippings are spread and rolled • Not so durable under wet climatic condition • Finished thickness: usually 6-10mm.	• Material Cut-back/Emulsified asphalt stone chipping 5-10/10-15mm • Equipment Asphalt distributor or Asphalt sprayer, Chip spreader, Broomer, Rollers	Production/preparation of uniform chippings, Well equiped asphalt distributor or asphalt sprayer, Uniform spraying of asphaltic binder, are necessary.
Double Bituminous Surface Treatment  Base	DBST Surface Base 10-15cm Sub-base (15cm) Subgrade	Low to Medium	• Two course surface treatments are placed. The size of second treatment chippings is about the one-half of the first one. • Finished thickness: 12-16mm about the nominal size of the first course • Durable under certain climatic condition.	• Material Cut back/Emulsified asphalt Stone chipping 5-10/10-15/20mm • Equipment Asphalt distributor or Asphalt sprayer, Chip spreader, Broomer, Rollers	
Bituminous Penetration Macadam  Base	BMP Surface 40 mm Base 10-15cm Sub-base (15cm) Subgrade	Low to Medium	• First, base stone course is placed. Then liquid asphalt is sprayed and penetrates into base stone course and key stones are spread and rolled. Asphalt sprayed and cover stones spread. rolled. Seal coat is followed. • Finished thickness: usually 30-60mm depend on the first base stone course thickness. • Durable under certain climatic condition	• Material Straight/Cut-back/Emulsified asphalt Crushed stone 5-10/10-20/20-30mm • Equipment Asphalt distributor or Asphalt sprayer (Chip spreader), Broomer, Rollers	
Asphalt Concrete  Base	HAC Surface 50 mm Base 10-15cm Sub-base (15cm) Subgrade	Medium to Heavy	• Smooth and durable surface is attained for all seasons. • Surface thickness: 40mm or 50mm	• Material Crushed stone 5-10/10-20mm, sand, Mineral filler • Equipment Straight asphalt, asphalt paver, Rollers	Stationary asphalt mixing plant is necessary.
Portland Cement Concrete  Sub-base	PCC Surface 18 cm Sub-base (15cm) Subgrade	Medium to Heavy	• Stable pavement is attained. • Surface thickness: 15-20cm	• Material Portland cement Gravel 5-25/25-40mm, Sand, Water • Equipment Concrete mixer, Vibrator, Forms	

(3) Double Bituminous Surface Treatment (DBST)

Used for low to medium traffic roads

Two courses of surface treatments are placed. The size of chips used for the second treatment is about one-half of the first one.

The finished thickness is 12 to 16 mm which is about the nominal size of the first one. Provided with a seal coat, this treatment is durable under proper climatic conditions. This type of pavement has been mainly applied to ADB/ IBRD funded provincial road improvement projects. Since this pavement construction requires a well equipped asphalt distributor, chip spreader, and trained skill to achieve a uniform rate of asphaltic binder spraying and chip spreading, DBST has seldom been used for locally funded projects.

(4) Bituminous Penetration Macadam Pavement (BMP)

Used for medium traffic roads

After the first base stone layer is placed, liquid asphalt is sprayed so that it penetrates into the base stone layer, and key stones are then spread and rolled. This is followed by the spraying, spreading and rolling of asphalt and cover stones. Finally a seal coat is laid.

The finished thickness is usually 30 to 60 mm depending on size and thickness of the first base layer stones. This type is durable under proper climatic conditions and traffic volume.

This pavement had been widely used, however, it is seldom used for new construction in recent years because it requires complicated construction process such as spreading and rolling of cover stones with different size in three to four layers and spraying of asphalt in each layer as well as trained skills for these works.

BMP is sometimes used for repairs or minor rehabilitations of existing bituminous pavements.

(5) Asphalt Concrete Pavement (AC)

Used for medium to heavy traffic roads

The hot mix consists of asphalt, crushed stones, sand and mineral filler is placed over the base course and rolled. The finished thickness is usually 4 to 5 cm. The structure is composed of a single AC layer with a granular base. A smooth and durable surface is maintained for all seasons. A stationary asphalt mixing plant is necessary for the production of the asphalt concrete mixture.

(6) **Portland Cement Concrete Pavement (PCC)**

Used for medium to heavy traffic roads

Portland cement concrete is placed and cured for 2 weeks, before the opening of road to traffic. The thickness of PCC slabs for low to medium traffic roads is usually 15 to 20 cm. The standard pavement structure consists of a PCC slab with a sandy gravel subbase. A stable pavement is maintained for all seasons. Where plenty of good quality gravels and sands are available, PCC pavement proves generally to be economical and is used widely.

7.2 PAVEMENT SURFACE CONDITION SURVEY AND EVALUATION

7.2.1 Approach

(1) Basic Concept

The pavement surface condition survey was conducted to establish the procedures/ criteria for evaluating the functional performance of pavements (mainly for low-class pavement in rural roads) and identify road sections requiring rehabilitation or reconstruction.

The functional performance of a pavement concerns how well the pavement serves the user. To quantify it, the "serviceability-performance" concept developed by AASHTO was adopted in this study. The serviceability-performance concept is based on five (5) fundamental assumptions, which are summarized below:

- Highways are for the comfort and convenience of the travelling public (User).

- Comfort, or riding quality, is a matter of subjective response of the opinion of the User.

- Serviceability can be expressed by the mean of the ratings given by all highway Users and is termed the serviceability rating.

- There are physical characteristics of a pavement which can be measured objectively and which can be related to subjective evaluations. This procedure produces an objective serviceability index.

- Performance can be represented by the serviceability history of a pavement.

The evaluation method developed here will be used for evaluation and analysis of performance of the experimental pavement.

(2) Study Flow

The study flow on the pavement surface condition survey is shown in Figure 7.2-1.

The study is divided into the following four (4) steps:

Step 1 : Pavement Surface Condition Survey
- Present serviceability rating
- Rehabilitation requirement rating
- Roughness measurement
- Pavement deterioration survey

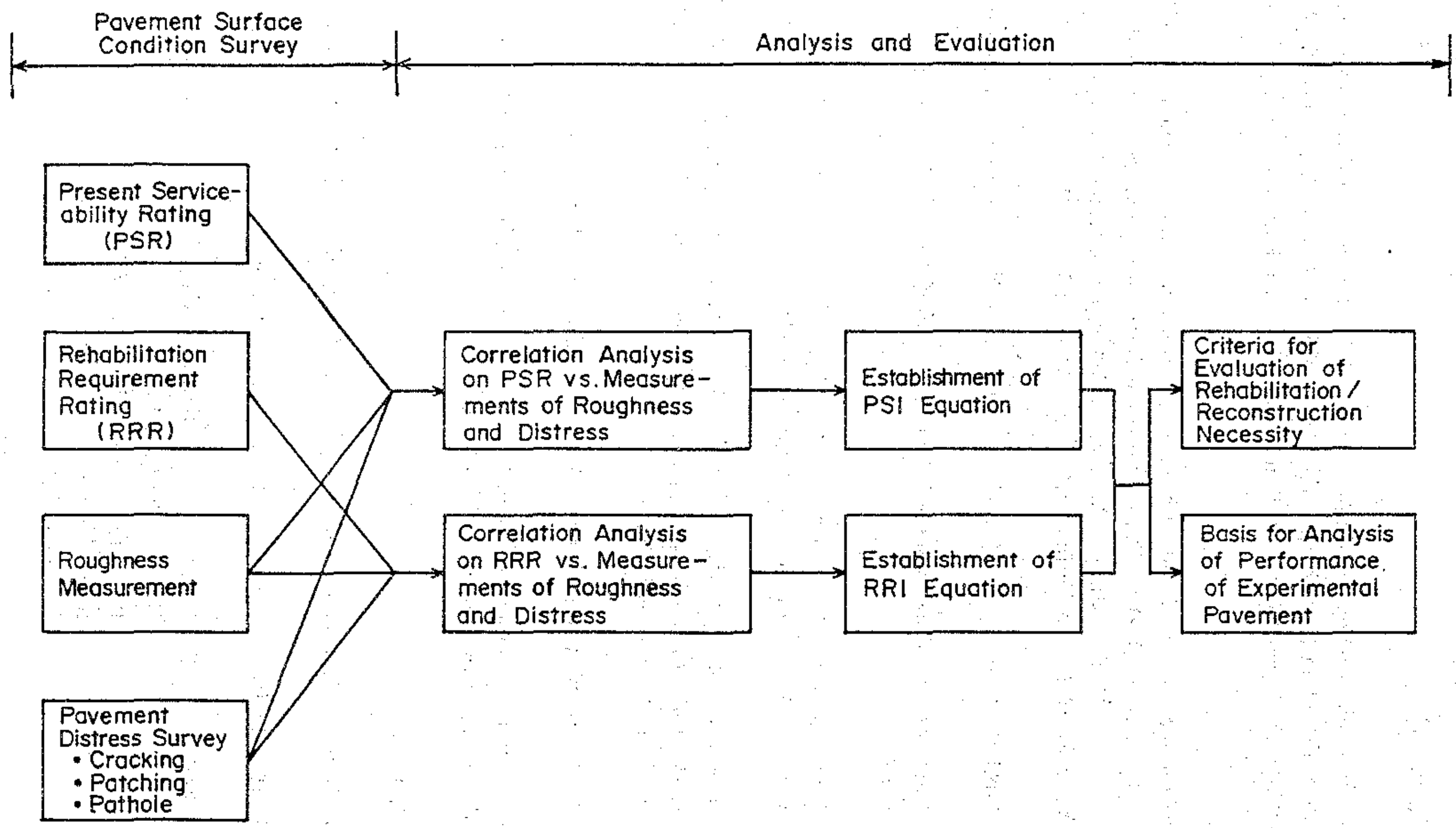


FIGURE 7.2-1 STUDY FLOW ON PAVEMENT SURFACE CONDITION SURVEY AND EVALUATION

Step 2 : Correlation Analysis on:

- Present Serviceability Rating (PSR) vs.
  - Roughness
  - Cracking
  - Patching
  - Pothole
- Rehabilitation Requirement Rating (RRR) vs.
  - Roughness
  - Cracking
  - Patching
  - Pothole

Step 3 : Establishment of Evaluation Equation

- Present Serviceability Index (PSI)
- Rehabilitation Requirement Index (RRI)

Step 4 : Criteria for Evaluation of Rehabilitation/Reconstruction Necessity Terminal Serviceability Index (Pt)

7.2.2 Study Road Sections

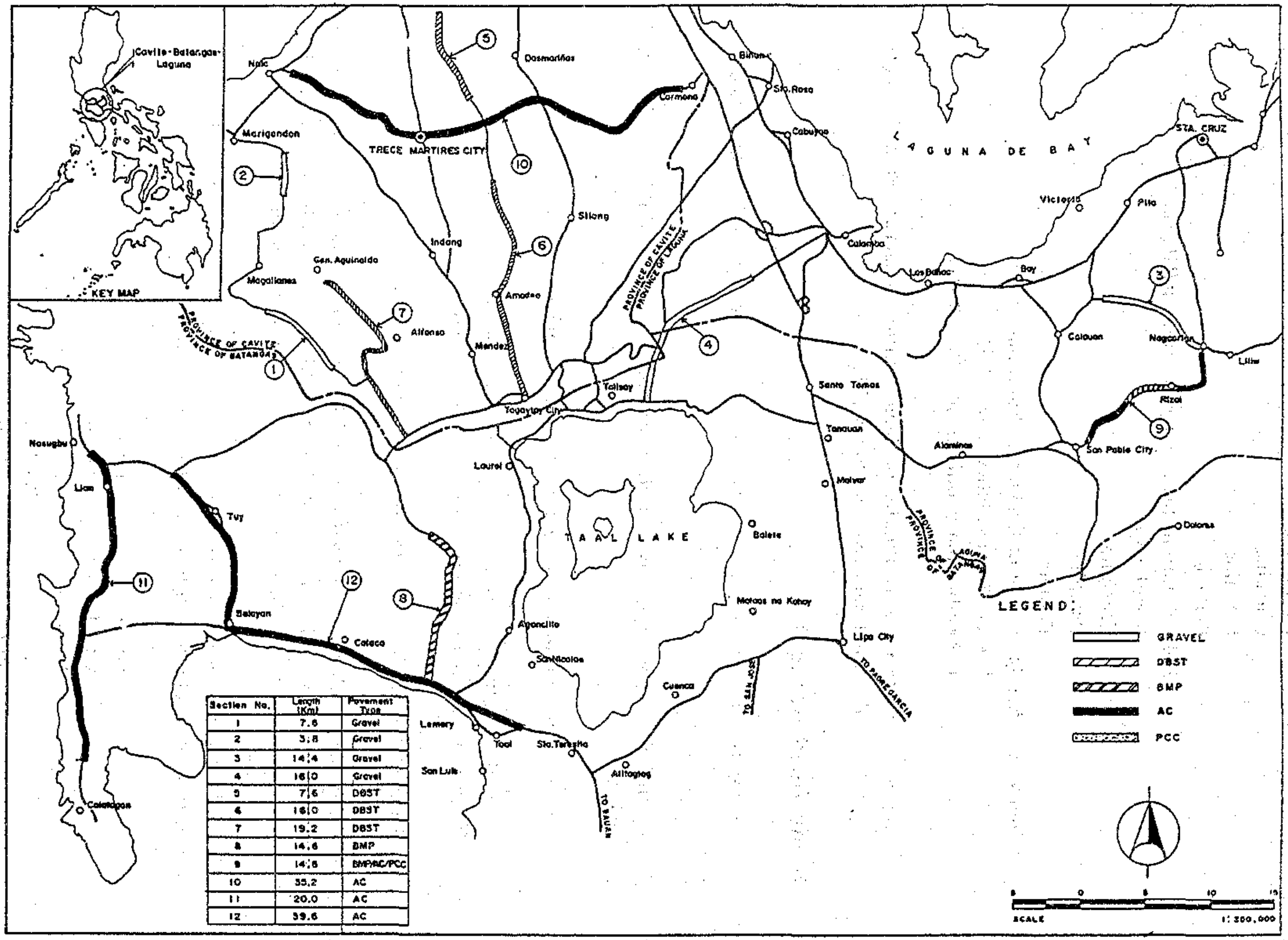
In selecting the study road sections, the following factors were taken into consideration:

- To include various types of low-class pavements; Gravel, SBST, DBST, BMP and AC.
- To cover a wide range of surface conditions for each type of pavement.
- To omit peculiarly localized conditions such as extremely strong subgrades, frequent inundations, peculiar traffic conditions, etc.
- To be preferably located in the vicinity of Metro Manila.

The study road sections were selected in accordance with the above criteria. However, gravel road in good condition and SBST road could not be found because gravel road is easily aggravated and SBST has seldom been used in the Philippines.

Figure 7.2-2 shows the selected road sections, and Table 7.2-1 presents survey of their characteristics. Total length by type of pavement is as follows:

Grave	41.8 km
DBST	42.8 km
BMP	17.8 km
AC	105.2 km
PCC	1.0 km
Total	208.6 km



Section No.	Length (Km)	Pavement Type
1	7.6	Gravel
2	3.8	Gravel
3	14.4	Gravel
4	16.0	Gravel
5	7.6	DBST
6	16.0	DBST
7	19.2	DBST
8	14.6	BMP
9	14.8	BMP/AC/PCC
10	35.2	AC
11	20.0	AC
12	39.6	AC

FIGURE 7.2-2 ROAD SECTIONS FOR PAVEMENT SURFACE CONDITION SURVEY

TABLE 7.2-1 ROAD SECTIONS FOR PAVEMENT SURFACE CONDITION SURVEY

Section No.	Location	Province	Class of Road	Section Lenght (km)	Type of Pavement	Road Widht (m)	Surface Condition
1	Jct. Alfonso-Magallanes	Cavite	Provincial	7.6	Gravel	6.2	bad
2	Magallanes-Maragondon	Cavite	Provincial	3.8	Gravel	6.2	bad
3	Nagcarlan-Calauan	Laguna	National	14.4	Gravel	9.9	fair-bad
4	Tagaytay-Laguna via Calamba	Batangas/ Laguna	National	16.0	Gravel	6.0	bad-very bad
5	Amadeo-Gen. Trias	Cavite	Provincial	7.6	DBST	6.2	fair-bad
6	Amadeo-Gen. Trias	Cavite	Provincial	16.0	DBST	6.2	fair-bad
7	Jct. Alfonso-Gen Aguinaldo	Cavite	Provincial	19.2	DBST	6.0	good-fair
8	Tagaytay Jct.-Lemery	Batangas	National	14.6	BMP	6.0	good-fair
9	San Pablo-Rizal	Laguna	National	14.6	BMP/AC/PCC	6.0	good-very bad
10	Trece Martirez-G.M. Alvares	Cavite	National	35.2	AC	6.2	good-bad
11	Calatagan-Nasugbu	Batangas	National	20.0	AC	7.0	very good-fair
12	Calaca-Balayan	Batangas	National	39.6	AC	6.0	very good-good
Total				208.6			

7.2.3 Pavement Surface Condition Survey

(1) Survey Items and their Application

Table 7.2-2 shows the survey items and their application to each type of pavement.

TABLE 7.2-2 SURVEY ITEMS AND THEIR APPLICATIONS

	Gravel	DBST	BMP	AC
Present Serviceability Rating (PRS)	0	0	0	0
Rehabilitation Requirement Rating (RRR)	X	0	0	0
Roughness	0	0	0	0
Cracking, class 2	X	X	X	0
Cracking, class 3	X	X	X	0
Patching	X	0	0	0
Pothole	X	0	0	0

Note : X not applicable

It is to be noted that :

- Since, in the Philippines, rutting is rarely found in pavements it was not included in the survey.

- Neither does the survey include cracking in DBST and BMP for the reason that cracks quickly develop into potholes and are therefore hard to identify.

(2) Present Serviceability Rating (PSR)

Present Serviceability is defined as the ability of a specific section of pavement to serve high-speed, high volume, mixed (truck and automobile) traffic in its existing condition.

It is understood that the basis of judgment may be swayed by the tolerableness of the road users, national characters as well as economic conditions of the country since comfort or riding quality is a matter of subjective response or the opinion of the users. Each country, therefore, may have their own rating.

In order to ascertain the basis in the Philippines, the assessment of the present serviceal.ility was conducted in November, 1989.

i) Rating Panel

7 - Filipino road users (including 2-drivers) and
1 - Japanese Highway Engineer

ii) Rating Method

Each member of the rating panel was asked to rate the serviceability/comfort using their own judgment on every 200 m of the road and record it in the form as shown in Figure 7.2-3, while the survey vehicles were travelling at 60 kph.

The ratings range from 0 to 5, as shown below:

5-4 Very Good
4-3 Good
3-2 Fair
2-1 Poor
1-2 Very Bad

iii) Present Serviceability Rating (PSR)

PSR, defined as the mean of the individual ratings, was calculated for every 200 m of the study road sections.

iv) Acceptability

Each member of the rating panel was further asked to indicate whether or not the pavement being rated is acceptable.

(3) Rehabilitation Requirement Rating (RRR)

Since the present serviceability rating is a subjective assessment by the road users using their own guideline and judgment, the rating does not necessarily identify the sections where the rehabilitation works are needed, when judged from the engineering point of view.

To assess the rehabilitation needs, a rating panel composed of only experienced engineers was set up to conduct the survey based on the ocular survey on the pavement conditions with emphasis placed on pavement deterioration such as cracking and potholes. The survey was carried out in December 1989.

TABLE 7.2-3 INDIVIDUAL PRESENT SERVICEABILITY RATING FROM

Rator : ______________ Date : ______________

Road Section : ______________ Vehicle : ______________

Km	Surface Condition Rating					Acceptable ?		
	5	4	3	2	1 0	YES	NO	Un-decided
—								
—								
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Rating		Condition
5 − 4	:	Very Good --- Very Comfortable
4 − 3	:	Good --- Comfortable
3 − 2	:	Fair --- Acceptable
2 − 1	:	Poor --- Uncomfortable
1 − 0	:	Very Poor --- Very Uncomfortable

i) Rating Panel

4 - Filipino highway engineers in charge of design, construction and maintenance, and

1 - Japanese highway engineer

ii) Rating Method

While riding on a survey vehicle running at 20 kph, each engineer was asked to rate his engineering judgement on every 200 m of the road, the resulting ratings being then recorded on a form similar to that used for PSR.

The criteria for rating are as follows:

5-4	:	No deficiencies
4-3	:	Little deficiencies
3-2	:	Considerable deficiencies
2-1	:	Severe deficiencies needing immediate treatment
1-0	:	Immediate reconstruction required

iii) Rehabilitation Requirement Rating (RRR)

RRR, defined as the mean of the individual ratings, was calculated for every 200 m of the study road sections.

(4) Roughness Measurement

The roughness of the road surface of each direction along the study road sections was measured by the Bump Integrator loaded on a Toyota Land Cruiser of the Department of Public Works and Highways in December 1989.

The bump integrator is a device which produces an electric impulse for a particular amount of movement of an axle relative to the frame of the test vehicle. The pulses are counted and expressed as a total amount of movement per length of road.

i) Survey Method

A survey engineer of DPWH with a long experience in roughness survey conducted this survey. The test vehicle was driven at the speed of 30 kph most suited to measurement. The intensity of the integrator was recorded at every 200 m. The survey was conducted three (3) times for each direction.

ii) Roughness Value

Roughness value (R) cm/km was calculated as follows

$$R(\text{cm/km}) = \frac{\text{Reading for 200m(inches)} \times 2.54(\text{cm/inch})}{0.2\ (\text{km})}$$

$$= 12.7 \times \text{Reading}$$

(5) Pavement Deterioration Survey

Measurements of the physical deterioration of pavement were conducted in order to provide the factors for predicting the subjective ratings (PSR/RRR).

i) Survey Panel

Experienced highway engineers (same member as in Rehabilitation Requirement Rating)

ii) Pavement Deterioration Surveyed

Among various types of pavement deterioration, the following items were selected:

- : Class 2 cracking
- : Class 3 cracking
- : Patching
- : Pothole

Rutting in the wheelpaths was not found in the study road sections.

The definitions of pavement deterioration surveyed are as follows:

Class 2 cracking	:	Cracking which has progressed to the stage where crack shave connected together to form a grid-type pattern.
Class 3 cracking	:	Cracking in which the bituminous surfacing segments have become loose.
Patching	:	Repair of pavement surface by skin patching or deep patching.
Pothole	:	Bowl-shaped hole of various sizes in pavement.

iii) Survey Method

The area of each deterioration was roughly estimated for every 200 m of the road and recorded in percent of total pavement surface.

(6) Results of Survey

Major survey results including present serviceability rating (PSR), rehabilitation requirement rating (RRR), roughness, patching and pothole are plotted in Figure 7.2-3, together with PSI/RRI values which will be described in Section 7.2.5.

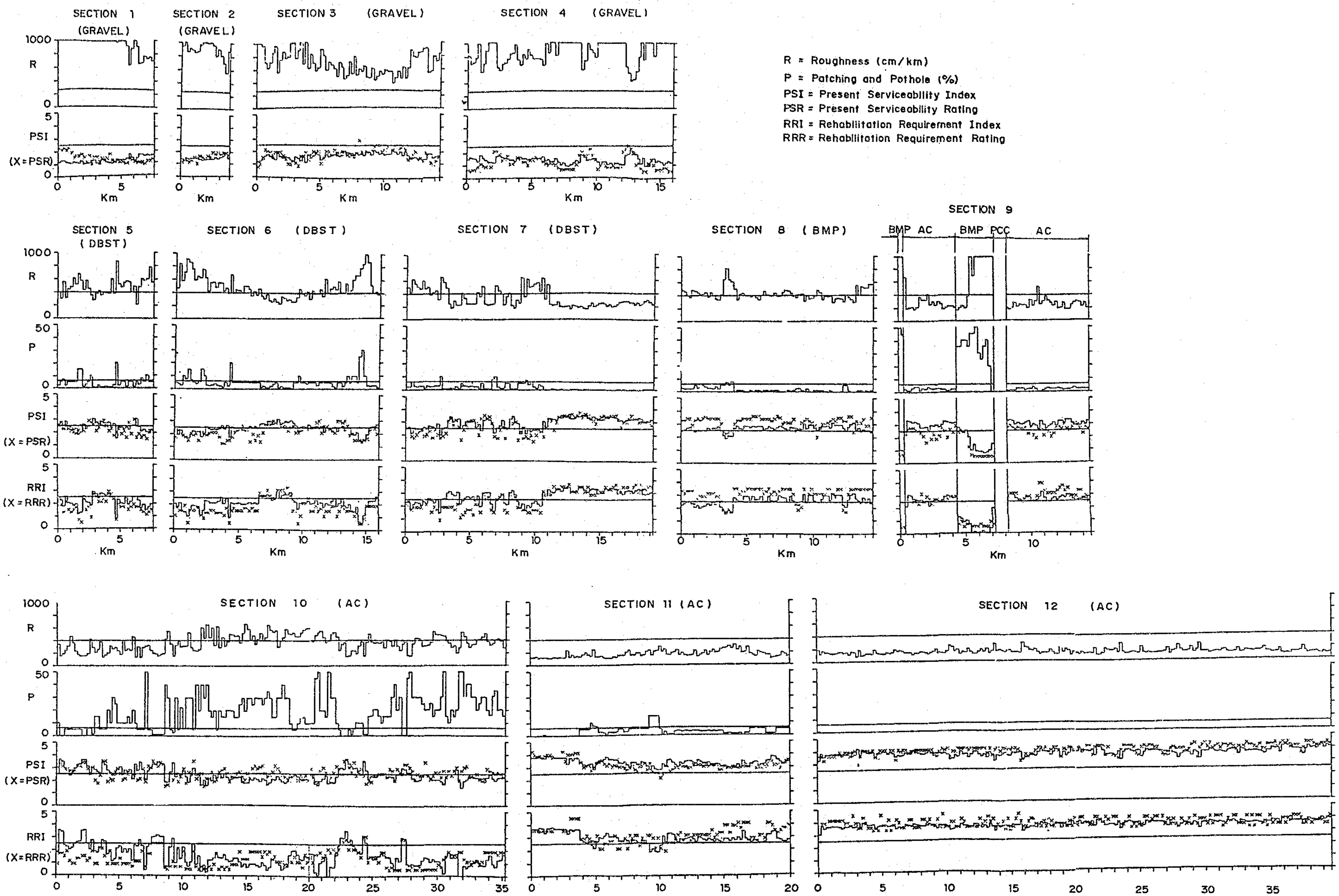


FIGURE 7.2-3 PAVEMENT SURFACE CONDITION OF STUDY ROAD SECTIONS

7.2.4 Correlation Analysis on Ratings and Physical Measurements

As the first step in the formulation of the present serviceability index (PSI) and rehabilitation requirement index (RRI) that would predict the subjective ratings, the correlations between PSR/RRR and physical measurements should be analyzed. Such analysis makes it possible to determine which measurements might be the most predictable and which might be negligible.

Figures 7.2-4 through 7.2-7 show the relation between the physical measurements and PSR/RRR.

The correlation coefficient of each two variables is shown in Table 7.2-4.

The following characteristics were observed from the above figures and tables:

Abbreviation : PSR = Present serviceability rating
RRR = Rehabilitation requirement rating
R = Roughness
P = Patching plus pothole
C = Class 2 and class 3 cracking

- Gravel
  - A correlation is found between R and PSR, but is not so high.
- DBST
  - R is more closely correlated with PSR than with P.
  - R and P show the same degree of correlation with RRR.
- BMP
  - Both R and P are closely correlated with PSR.
  - As regards the correlation with RRR, P is higher than R.
- AC
  - R, P and C show, in this order, higher correlation with PSR.
  - R, P and C are correlated with RRR in almost the same degree.

- Common characteristics:

  - Among physical measurements, R has the closest correlation with PSR.
  - R and P are correlated with RRR in almost the same degree.
  - Mutual correlation between physical measure ments is not high.

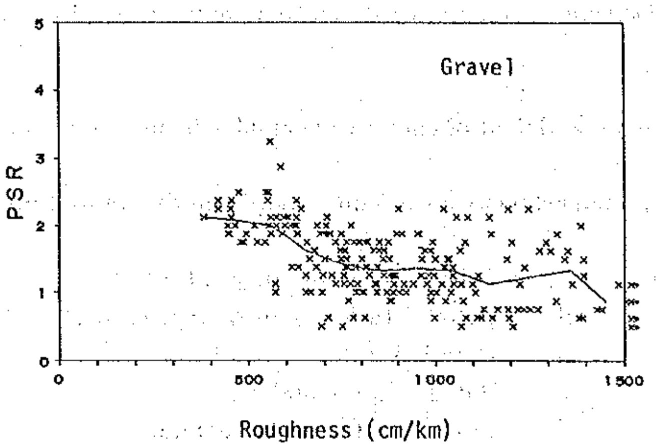


FIGURE 7.2-4 PSR vs ROUGHNESS : GRAVEL

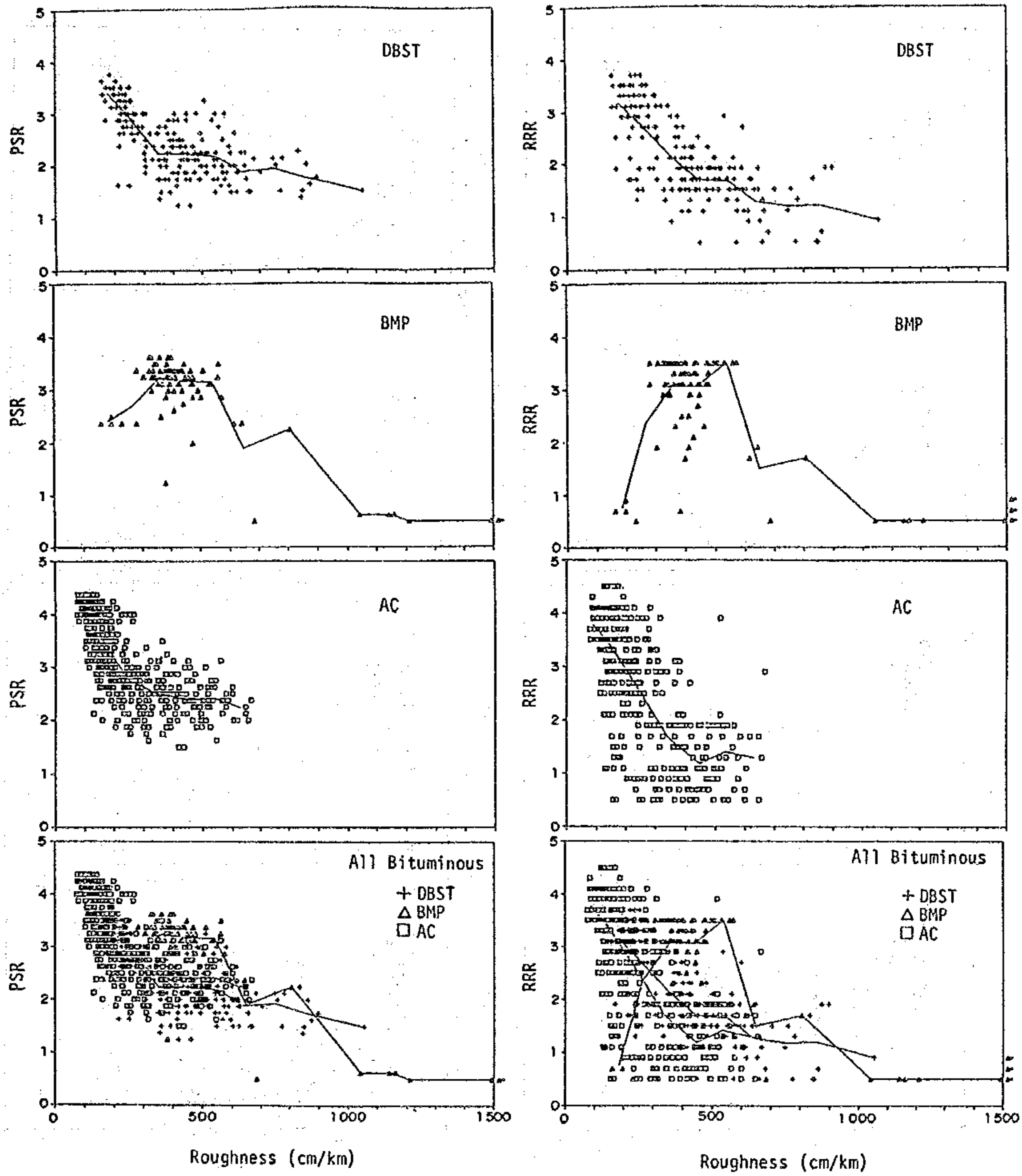


FIGURE 7.2-5 PSR/RRR vs ROUGHNESS : BITUMINOUS PAVEMENT

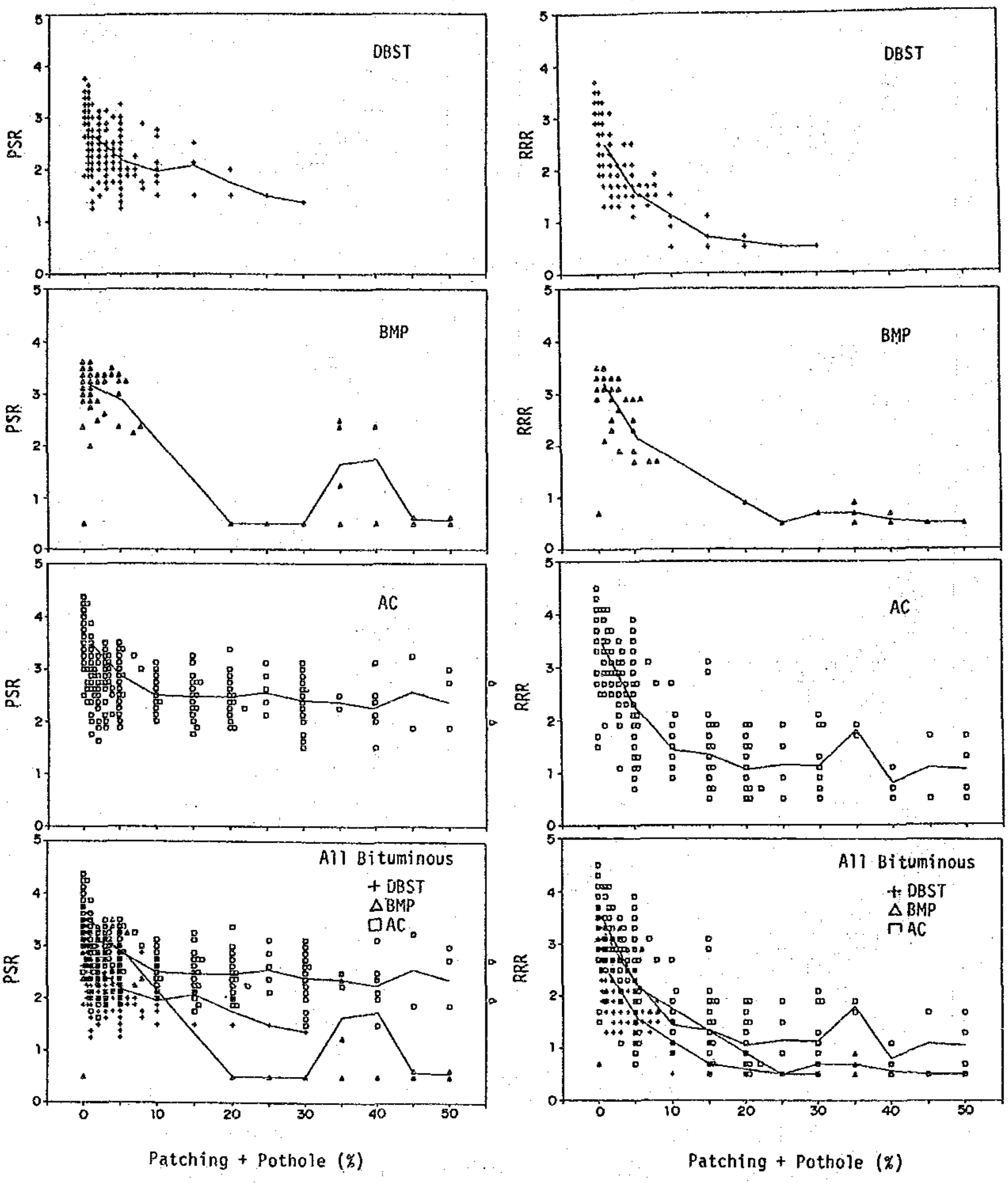


FIGURE 7.2-6 PSR/RRR vs PATCHING + POTHOLE : BITUMINOUS PAVEMENT

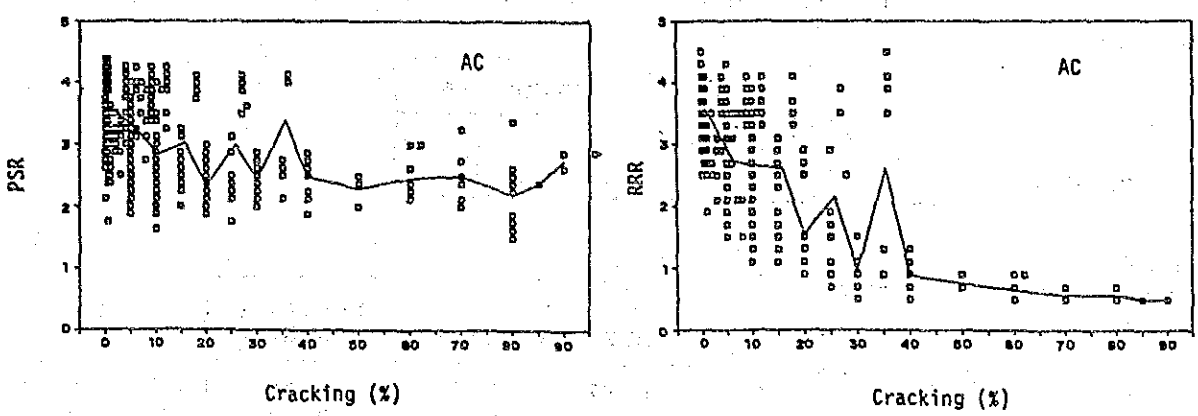


FIGURE 7.2-7 PSR/RRR vs CRAKING : AC

TABLE 7.2-4 CORRELATION COEFFICIENT BETWEEN TWO VARIABLES AMONG RATINGS AND PHYSICAL MEASUREMENTS

Gravel

	PSR	Roughness
PSR	1.00	- 0.51
Roughness		1.00

DBST

	PSR	RRR	Roughness	Patching + Pothole
PSR	1.00	0.67	-0.67	-0.49
RRR		1.00	-0.70	-0.71
Roughness			1.00	0.65
Patching + Pothole				1.00

BMP

	PSR	RRR	Roughness	Patching + Pothole
PSR	1.00	0.85	-0.83	-0.80
RRR		1.00	-0.62	-0.88
Roughness			1.00	0.49
Patching + Pothole				1.00

AC

	PSR	RRR	Roughness	Patching + Pothole	Cracking
PSR	1.00	0.75	-0.72	-0.58	-0.43
RRR		1.00	-0.71	-0.72	-0.69
Roughness			1.00	0.66	0.45
Patching + Pothole				1.00	0.53
Cracking					1.00

All Bitumious (DBST, BMP, AC)

	PSR	RRR	Roughness	Patching + Pothole	Cracking
PSR	1.00	0.76	-0.72	-0.49	-0.15
RRR		1.00	-0.59	-0.66	-0.45
Roughness			1.00	0.42	0.01
Patching + Pothole				1.00	0.46
Cracking					1.00

7.2.5 Establishment of Equations for Condition Evaluation

(1) Establishment of PSI/RRI Equations

a) Present Serviceability Index (PSI) and Rehabilitation Requirement Index (RRI)

PSI and RRI are defined as mathematical combinations of values obtained from certain physical measurements so formulated as to predict the present serviceability rating (PSR) and rehabilitation requirement rating (RRR), respectively.

Those indices could be used to evaluate both the performance history of the experimental pavement in particular and to assess the serviceability of other pavements in general, instead of conducting individual ratings.

b) Selection of Predictors

The following physical measurements were selected as predictors:

R = Roughness (cm/km)
P = Patching plus pothole (%)
C = Class 2 and 3 cracking (%)

c) Transformation of Physical Measurements

As shown in Figures 7.2-4 through 7.2-7, physical measurements are correlated with PSR/RRR curvilinear. To formulate a suitable model for PSI/RRR, it is necessary to transform the physical measurements so as to obtain a straight line relationship with PSR/RRR as much as possible. Based on a preliminary analysis, the following linearizing transformations were selected:

$$\log R$$

$$\sqrt{P}$$

$$\sqrt{C}$$

The general form of PSI/RRI equations was assumed to be:

$$PSI/RRI = A_0 + A_1 \log (R+A_2)+A_3 \sqrt{P+A_4} + A_5 \sqrt{C+A_6}, \text{ or}$$
$$PSI/RRI = A_0 + A_1 \log (R+A_2)+A_3 \sqrt{P+A_4 C + A_5}$$

where, A_0 to A_6 coefficients are to be determined by the least squares regression analysis.

d) Proposed PSI/RRI Equations

Various alternative PSI/RRI equations were derived by the least squares regression analysis as shown in Table 7.2-5.

TABLE 7.2-5 VARIOUS PSI/RRI FORMULAS

PSI	Gravel	$PSI = 7.49-2.06 \log R$	d = 0.357, r = 0.542
		$PSI = 4.73-1.21 \log (R-309)$	d = 0.357, r = 0.552
	DBST	$PSI = 7.76-1.99 \log R-0.11\sqrt{P}$	d = 0.312, r = 0.739
		$PSI = 5.35-1.16 \log (R-135)-0.11\sqrt{P}$	d = 0.307, r = 0.752
	BMP	$PSI = 9.80-2.46 \log R-0.25\sqrt{P}$	d = 0.277, r = 0.917
		$PSI = 6.68-0.63 \log (R-608)-0.44\sqrt{P+60}$	d = 0.235, r = 0.940
	AC	$PSI = 7.32-1.68 \log R-0.14\sqrt{P}$	d = 0.348, r = 0.817
		$PSI = 8.23-2.08 \log R-0.06\sqrt{P+C}$	d = 0.366, r = 0.799
		$PSI = 7.28-1.65 \log R-0.13\sqrt{P}-0.02\sqrt{C}$	d = 0.348, r = 0.818
		$PSI = 5.78-1.10 \log (R-64)-0.13 P-0.01\sqrt{C}$	d = 0.340, r = 0.826
	Common to DBST BMP/AC	$PSI = 7.83-1.92 \log R-0.14\sqrt{P}$	d = 0.351, r = 0.739 (DBST)
			d = 0.529, r = 0.911 (BMP)
			d = 0.350, r = 0.817 (AC)
			d = 0.369, r = 0.821 (All)
		$PSI = 6.84-1.57 \log (R-42)-0.14\sqrt{P}$	d = 0.350, r = 0.742 (DBST)
			d = 0.549, r = 0.910 (BMP)
			d = 0.344, r = 0.823 (AC)
			d = 0.368, r = 0.822 (All)
RRI	DBST	$RRI = 6.22-1.29 \log R-0.51\sqrt{P}$	d = 0.309, r = 0.874
		$RRI = 4.81-0.81 \log (R-125)-0.51\sqrt{P}$	d = 0.303, r = 0.877
	BMP	$RRI = 5.80-0.89 \log R-0.42\sqrt{P}$	d = 0.302, r = 0.917
		$RRI = 3.74-0.29 \log (R-571)-0.42\sqrt{P+1}$	d = 0.285, r = 0.932
	AC	$RRI = 6.04-1.12 \log R-0.39\sqrt{P}$	d = 0.454, r = 0.859
		$RRI = 7.25-1.56 \log R-0.26\sqrt{P+C}$	d = 0.446, r = 0.872
		$RRI = 5.51-0.76 \log R-0.31\sqrt{P}-0.17\sqrt{C}$	d = 0.382, r = 0.094
		$RRI = 5.56-0.74 \log (R-14)-0.30 P-0.19\sqrt{C+1}$	d = 0.381, r = 0.904
	Common to DBST BMP/AC	$RRI = 6.61-1.40 \log R-0.38\sqrt{P}$	d = 0.421, r = 0.872 (DBST)
			d = 0.570, r = 0.912 (BMP)
			d = 0.457, r = 0.858 (AC)
			d = 0.460, r = 0.851 (All)
		$RRI = 4.47-1.35 \log (R-9)-0.38\sqrt{P}$	d = 0.422, r = 0.873 (DBST)
			d = 0.569, r = 0.912 (BMP)
			d = 0.457, r = 0.858 (AC)
			d = 0.460, r = 0.851 (All)

Note : PSI = Present Serviceability Index
RRI = Rehabilitation Requirement Index
R = Roughness (cm/km)
P = Patching + Pothole (%)
C = Cracking, class 2 and class 3 (%)
d = Average difference bwteen PSR/RRR and PSI/RRI (calculated value)
r = correlation coefficient

From among them, the following equations were selected, which are of a simple form while being in relatively higher accuracy than others:

PSI	:	Gravel	:	$PSI=7.49-2.06 \log R$	(r=0.542)
		DBST	:	$PSI=7.76-1.99 \log R-0.11 \sqrt{P}$	(r=0.739)
		BMP	:	$PSI=9.80-2.46 \log R-0.25 \sqrt{P}$	(r=0.917)
		AC	:	$PSI=7.32-1.68 \log R-0.14 \sqrt{P}$	(r=0.817)
RRI	:	DBST	:	$RRI=6.22-1.29 \log R-0.51 \sqrt{P}$	(r=0.874)
		BMP	:	$RRI=5.80-0.89 \log R-0.42 \sqrt{P}$	(r=0.917)
		AC	:	$RRI=6.04-1.12 \log R-0.39 \sqrt{P}$	(r=0.859)

where,
- PSI = Present Serviceability Index
- RRI = Rehabilitation Requirement Index
- R = Roughness (cm/km)
- P = Patching plus pothole (%)
- r = Correlation coefficient

PSR/RRR vs PSI/RRI calculated by the above formula are plotted in Figure 7.2-8 and 7.2-9.

(2) PSI/RRI Equations in Other Studies

a) PSI/RRI Equations for Rigid Pavement in the Philippines

In the Feasibility Study of the Road Improvement Project on the Pan-Philippines Highway, 1987, a similar study was undertaken on the Pan-Philippine Highway in Sta. Rita-Aritao Section and Calamba-Calauag Section. The Study Road is paved with portland cement concrete (PCC).

The PSI/RRI equation for PPC was established as shown below:

$$PSI = 5.75-2.0 \log R-0.06 \sqrt{C+P}$$
$$RRI = 7.53-1.5 \log R-0.11 \sqrt{C+P}$$

where,
- R : Roughness (cm/km)
- C : Class 3 and Class 4 cracking ($m/1,000\ m^2$)
- P : Patching ($m^2/1,000\ m^2$)

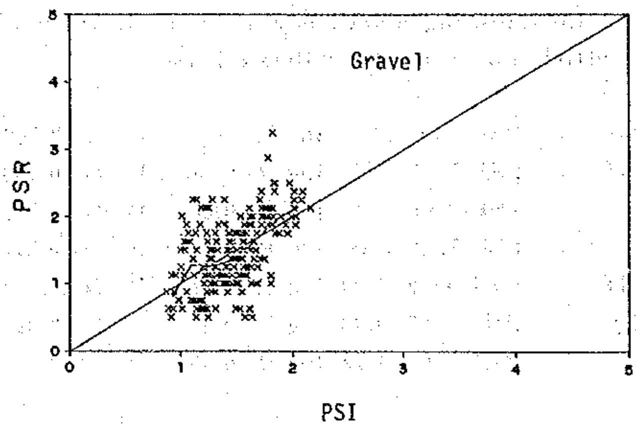


FIGURE 7.2-8 PSR vs PSI : GRAVEL

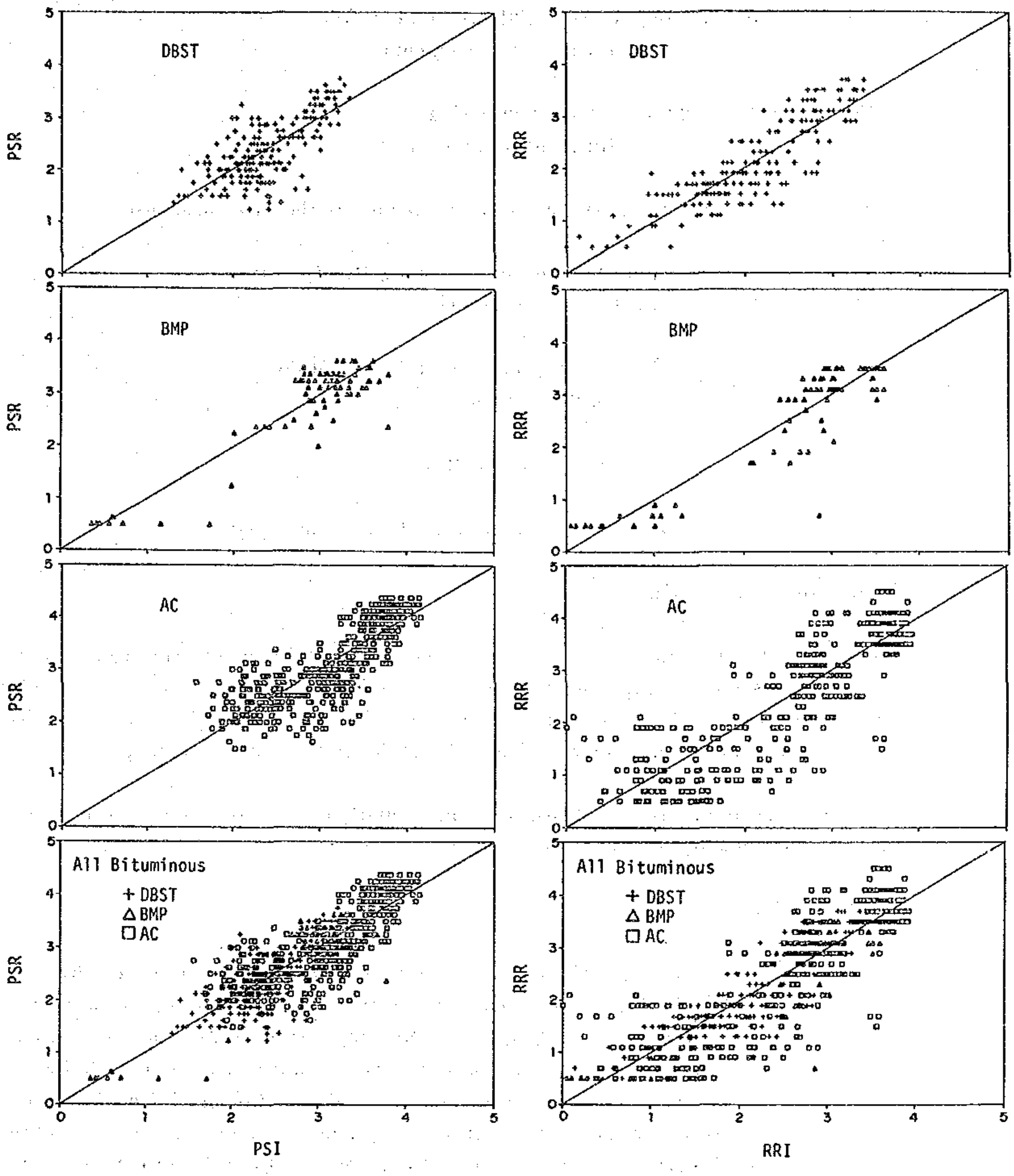


FIGURE 7.2-9 PSR/RRR vs. PSI/RRI : BITUMINOUS PAVEMENT

b) ASSHO's PSI Equation

The following equation was established by the AASHO Road Test staff in 1957.

$$PSI = 5.03-1.91 \log (1+\overline{SV})-0.01 \sqrt{C+P}-1.38\, RD^2$$
(for flexible pavement)

$$PSI = 5.41-1.80 \log (1+\overline{SV})-0.09 \sqrt{C+P}$$
(for rigid pavement)

where, $\overline{SV}$: the mean of the slope variance in the two wheelpaths

C : class 2 and class 3 cracking ($ft^2/1,000\ ft^2$) (for flexible pavement)

C : class 3 and class 4 cracks ($ft^2/1,000\ ft^2$) (for rigid pavement)

P : Patching ($ft^2/1,000\ ft^2$)

RD : a measure of rutting in the wheelpaths (in)

(3) Characteristics of PSI/RRI

To examine the relationship between roughness and pavement deterioration, corresponding roughness values and total values of patching, pothole and cracking are plotted in Figures 7.2-10 (1) and (2) for each type of pavement including the AASHTO Road Test pavement for reference. These figures include the lines showing:

i) Average relationship between roughness and pavement deterioration obtained by the least squares regression analysis.

ii) PSI/RRI contours

Note : In the AASHTO Road Test, roughness was measured by the longitudinal profilometer, while in this Study, the bump integrator was used. Although no authentic relationship between the two different types of measurements of the two studies have been established as yet, the AASHTO longitudinal profilometer measurements were converted into those of roughness obtained by the bump integrator based only upon every loose relation between multi-wheeled profilometer and bump integrator measurements shown in the "Design and Performance of Road Pavements, TRRL, 1977". This conversion was made to plot them on the same scale for sake of comparison.

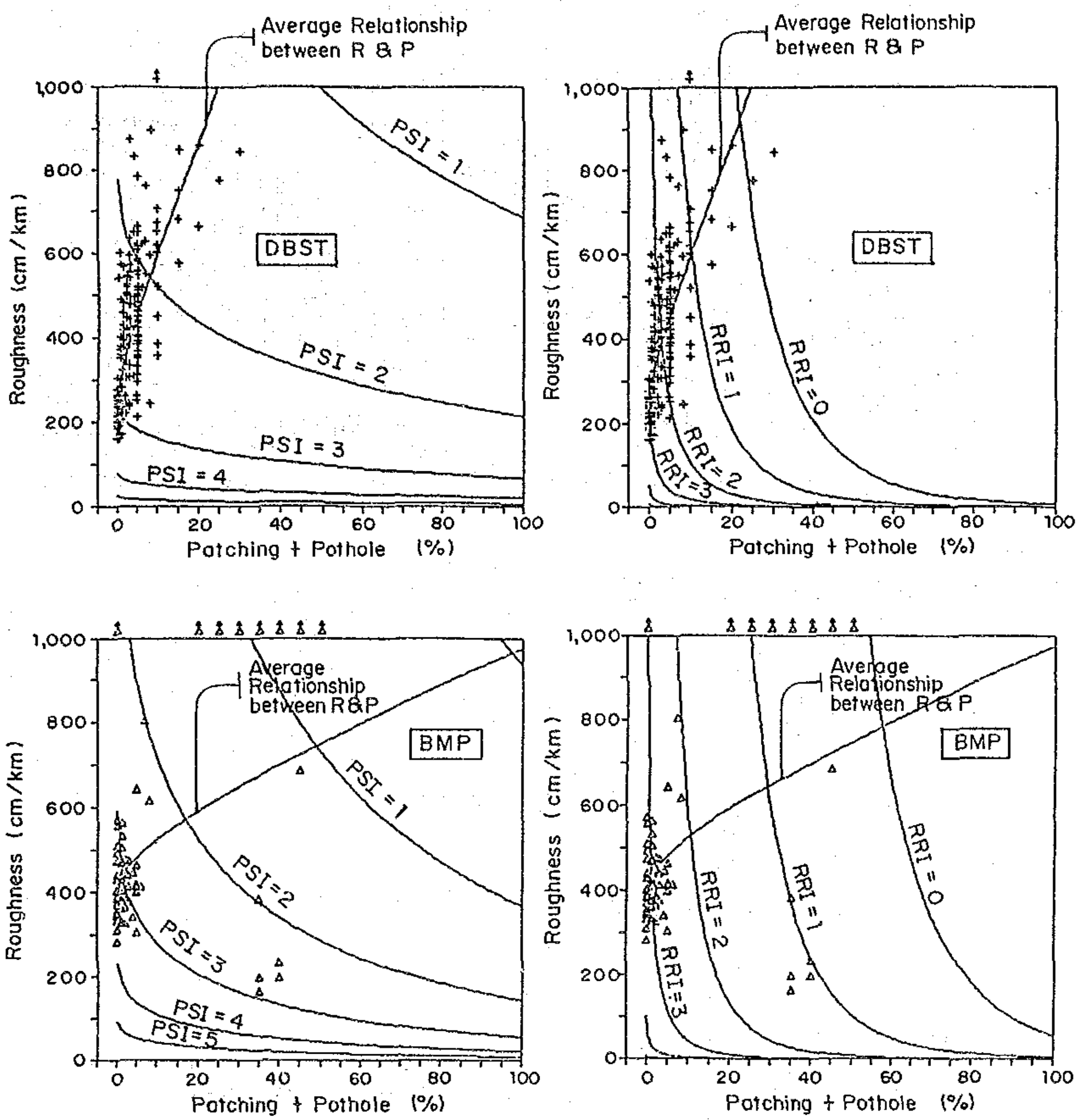


FIGURE 7.2-10 (1) AVERAGE RELATIONSHIP BETWEEN ROUGHNESS (R) AND PATCHING + POTHOLE (P)

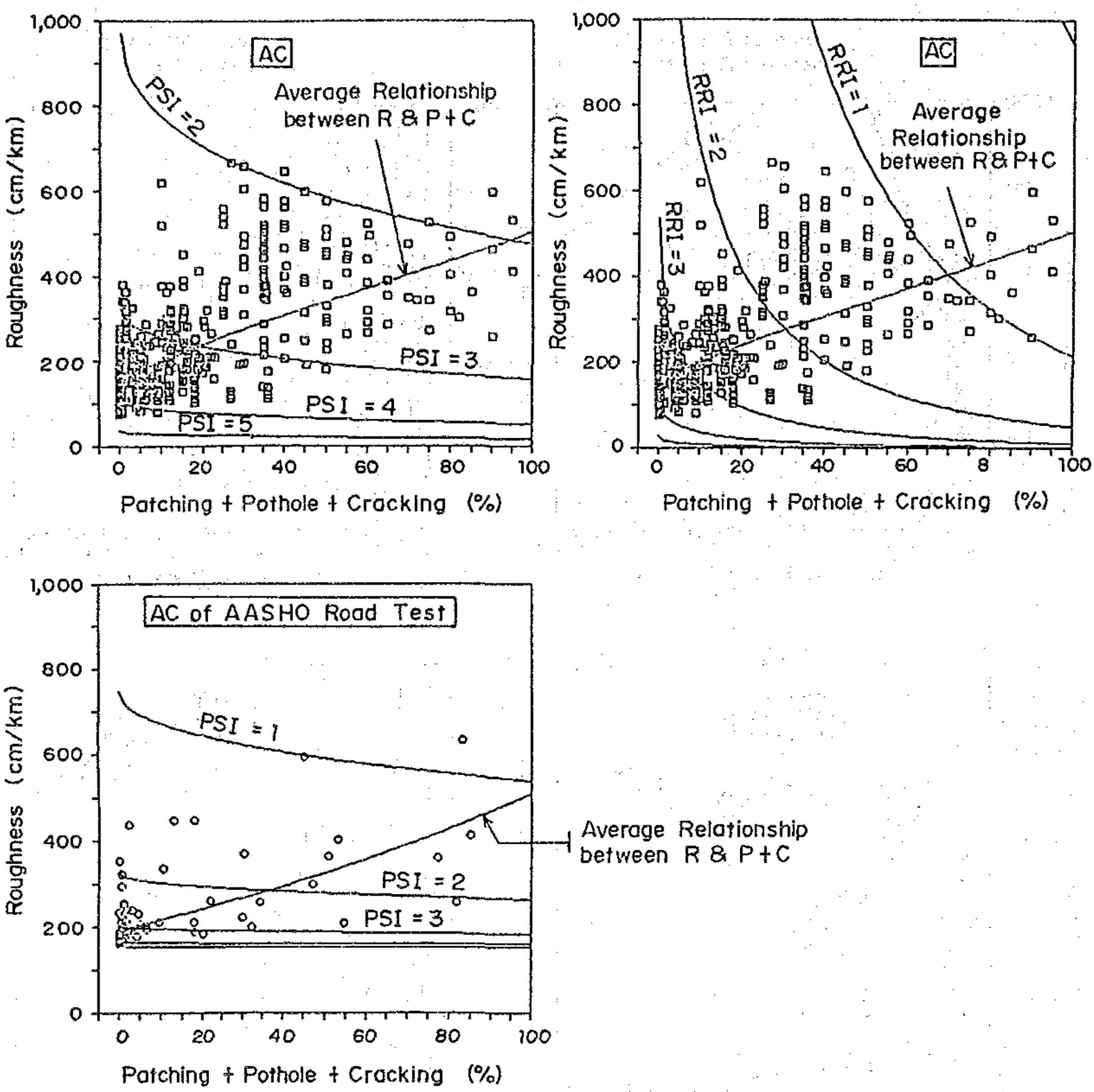


FIGURE 7.2-10 (2) AVERAGE RELATIONSHIP BETWEEN ROUGHNESS (R) AND PATCHING + POTHOLE + CRACKING (P+C)

The following characteristics of PSI/RRI are found from these figures:

i) The dominant factor in determining PSI is roughness, except for BMP where roughness and pavement deterioration are almost equally related to PSI.

ii) The dominant factor in determining RRI is pavement deterioration, except for AC where roughness and pavement deterioration are almost equally related to RRI.

iii) RRI is lower than PSI. It might be interpreted as follows:

- The lowest acceptable levels as a rural road for road users might not be so high.

- Earlier rehabilitation might be necessary even when the surface condition is still acceptable to road users.

iv) The AASHTO's PSI is lower than the PSI in this Study. It might be due to difference in class of road as well as in national characteristics.

7.2.6 Criteria for Evaluation of Rehabilitation/Reconstruction Necessity

(1) Criteria of AASHTO Guide 1986

The terminal serviceability index (Pt) is the lowest acceptable level before resurfacing or reconstruction becomes necessary. The AASHTO Guide for Design of Pavement Structures, 1986 recommends the following values:

- Major highways	: 2.5 or 3.0
- Highways with a lower classification	: 2.0
- Minor highways when economic considerations dictate that expenditures be kept low	: 1.5

Acceptability opinions in the AASHTO Road Test were as follows:

Present Serviceability Rating	Percent of People Stating Acceptable
3.0	88
2.5	45
2.0	15

(2) **Criteria recommended in the Feasibility Study of the Road Improvement Project on the Pan-Philippine Highway**

In the captioned study, the criteria for evaluation of rehabilitation necessity are recommended as follows:

Major highway	: RRI = 2.5
Highway with a lower classification	: RRI = 2.0
Minor highway	: RRI = 1.5

(3) **Survey in this Study**

Each member of the rating panel was asked to indicate whether the pavement being rated is acceptable or not. The relationship between acceptability opinions and PSI is graphically shown in Figure 7.2-11.

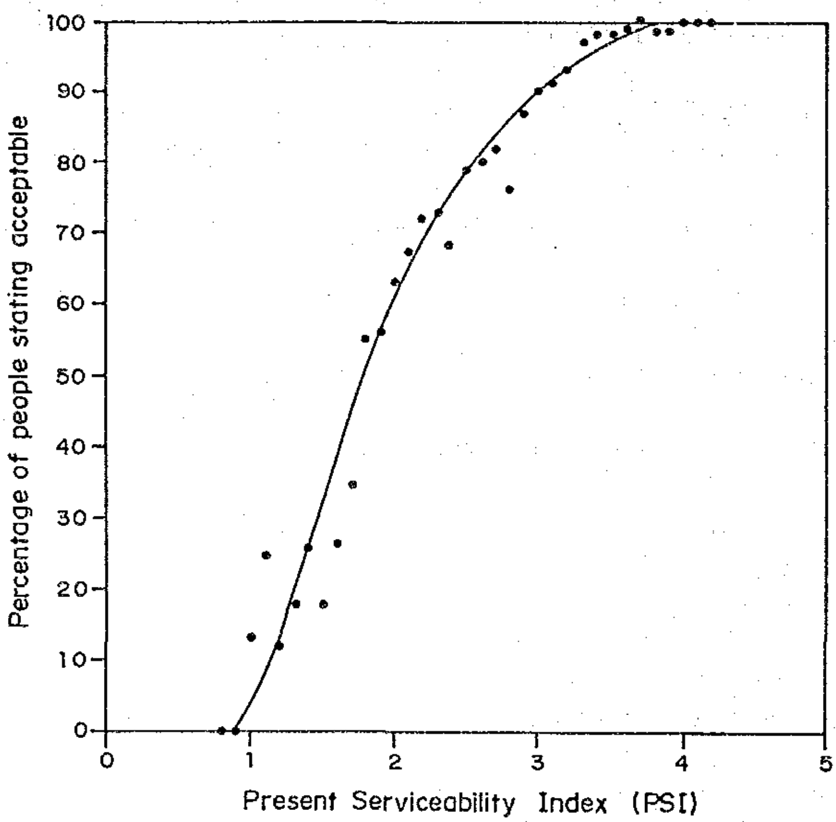


FIGURE 7.2-11 ACCEPTABILITY vs PSI

The results are summarized in Table 7.2-6

TABLE 7.2-6 ACCEPTABILITY OPINIONS

PSI	Percent of People Starting Acceptable
3.0	90
2.5	80
2.0	60
1.8	50
1.5	30

Acceptable percentage for every level of PSI is higher than that of the AASHTO Road Test. It might be due to difference in class of road surveyed as well as in national characteristics.

(4) Proposed Criteria for Evaluation of Rehabilitation/Reconstruction Necessity

Based on the results of the acceptability survey, the following terminal serviceability (Pt : lowest acceptable serviceability) are proposed for the Rural Road Network Development Project:

Pt = 2.0 for major roads, and
Pt = 1.5 for minor roads,

according to the road class as defined in the Project.

7.3 ANALYSIS OF LOW-CLASS PAVEMENT DETERIORATION

7.3.1 Approach

The general approach is shown in Figure 7.3-1. Typical sections for pavement deterioration analysis were selected. Various pavement surveys were conducted on the selected sections to investigate causes of pavement deteriorations. Based on the data obtained, pavement deteriorations were analyzed. On the other hand, theoretical analysis was conducted to obtain the most influencing factors for pavement serviceability performance. Based on the above, causes of pavement deteriorations were identified.

7.3.2 Selection of Sections for Deterioration Analysis

Criteria for selection of sections for deterioration analysis were established so as:

- To include various types of low-class pavements
- To cover a wide range of surface conditions for each type of pavement
- To cover various service periods after the opening of road to traffic
- To be free from peculiarly localized conditions such as extremely strong subgrade, frequent inundation, peculiar traffic condition, etc.
- To be preferably located in the vicinity of Metro Manila.

The following fifteen (15) sections were selected, which consist of four (4) types of pavement and two (2) to three (3) surface conditions for each type of pavement.

Pavement Type	Number of Location	Pavement Surface Condition
Gravel Surface	3	Good (1), Fair (1), Bad (1)
Double Bituminous Surface Treatment	6	Good (2), Fair (2), Bad (2)
Bituminous Penetration Macadam	3	Fair to Bad (2), Bad (1)
Asphalt Concrete	3	Very Good (1), Fair to Bad (2)

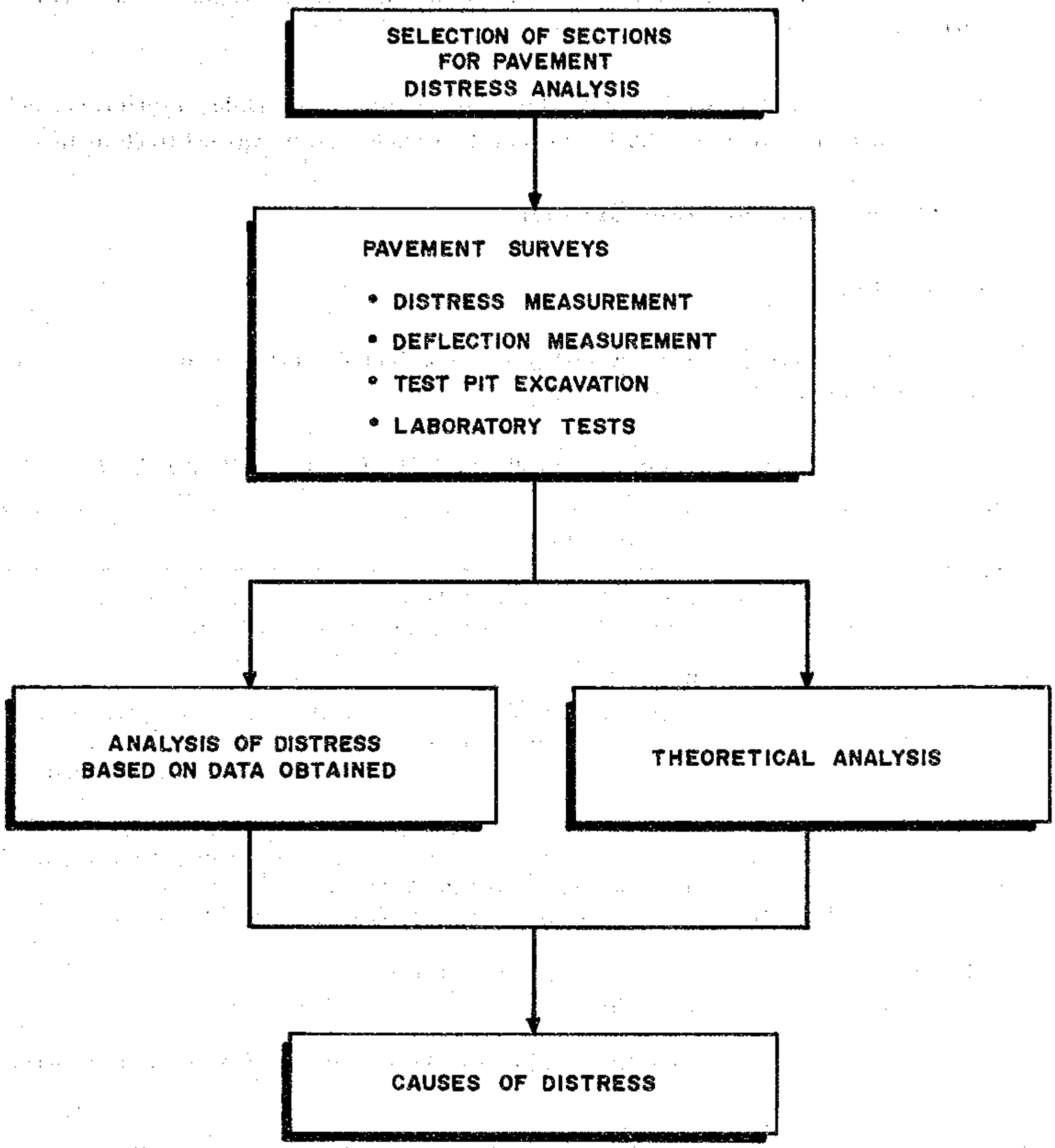


FIGURE 7.3-1 GENERAL APPROACH

Sections with single bituminous surface treatment were not found in the vicinity of Metro Manila.

Locations of selected sections are shown in Figure 7.3-2 while descriptions of the sections are given in Table 7.3-1. The length of each section was set to 50 meters.

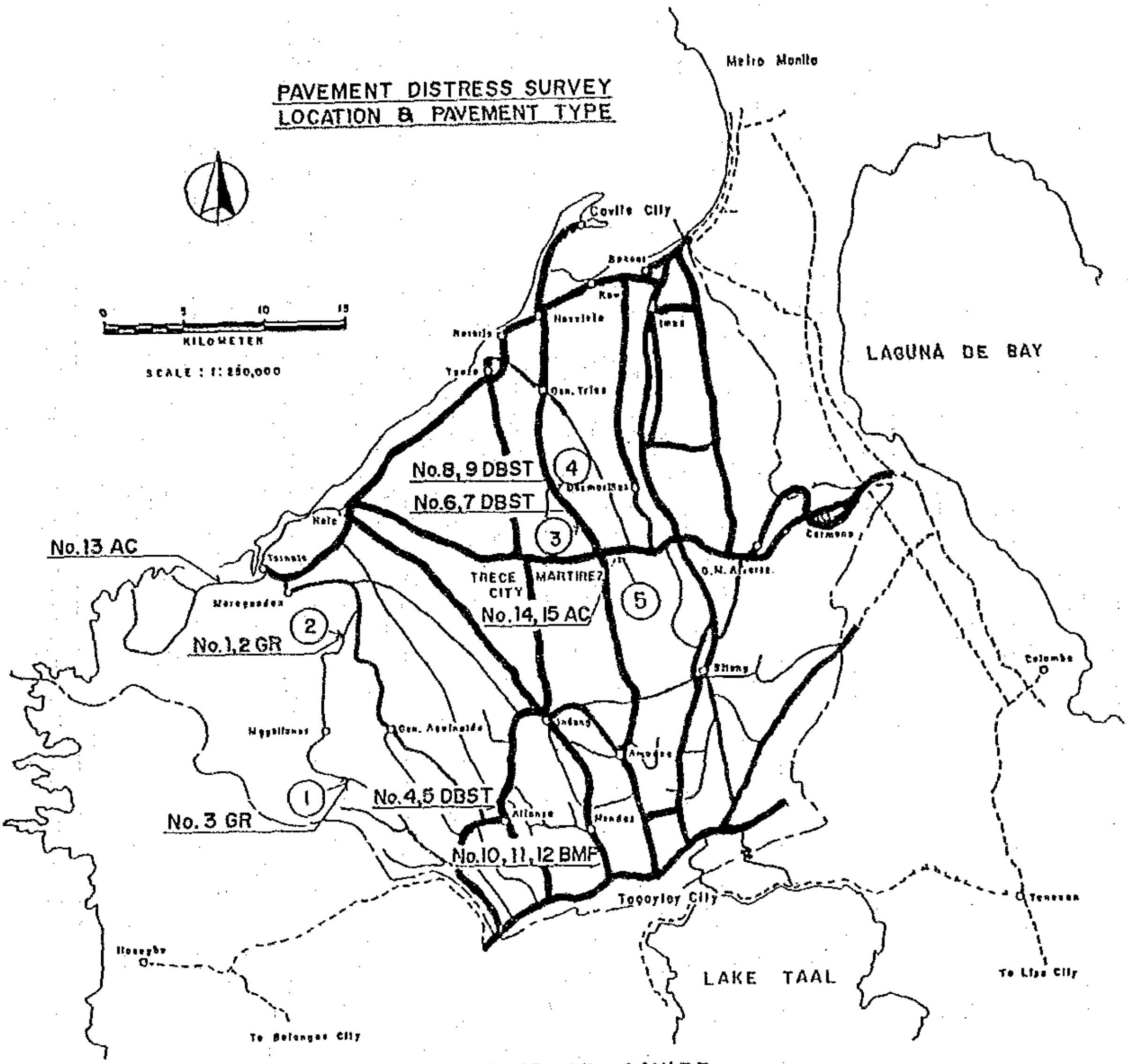
7.3.3 Pavement Deterioration Surveys

(1) Survey Items

For each of selected section, a survey was conducted based on the items and data listed in Table 7.3-2.

TABLE 7.3-2 SURVEY ITEMS FOR PAVEMENT DETERIORATION ANALYSIS

Items	Remarks
Construction record	Construction data: Maintenance and repair record
Road inventory	Road cross section
Traffic	Daily traffic, vehicle type composition Commercial vehicle: percentage/axle load distribution
Pavement structure	Thickness and materials: surface/ base/sub-base
Shoulder	Thickness and materials
Drainage condition	Road side ditch/gutter, water table
Deterioration	Type and severity
Surface condition	Roughness, Crack %, Patching %
Structural Adequacy	Surface (Benkelman beam: Deflection mm)
Test Pit Excavation	Pavement Composition observation Sampling/test: Subgrade soil, pavement layer materials



PROVINCE OF CAVITE

LEGEND :

TRAFFIC VOLUME : AADT

- (thick line) > 400
- (medium line) 200 - 400
- (thin line) < 200

PROPOSED EXPERIMENTAL PAVEMENT CONSTRUCTION SECTIONS

SECT. NO.	TRAFFIC VOLUME ADT *	SUBGRADE CONDITION	TYPE OF EXPERIMENTAL PAVEMENT
1	106	GOOD	GR SBST DBST BMP
2	80	POOR	GR SBST DBST BMP
3	654	GOOD	DBST BMP HAC(4cm) HAC(5cm)
4	654	POOR	DBST BMP HAC(4cm) HAC(5cm)
5	2068	GOOD	HAC (5cm) PCC (18cm)

* AS OF NOVEMBER 1989

REMARKS :

GR : GRAVEL SURFACING
SBST : SINGLE BITUMINOUS SURFACE TREATMENT
DBST : DOUBLE BITUMINOUS SURFACE TREATMENT
BMP : BITUMINOUS PENETRATION MACADAM
HAC : HOT MIX ASPHALT CONCRETE
PCC : PORTLAND CEMENT CONCRETE

FIGURE 7.3-2 LOCATION OF SECTIONS FOR PAVEMENT DETERIORATION ANALYSIS

TABLE 7.3-1 DESCRIPTION OF SECTIONS SELECTED FOR PAVEMENT DETERIORATION SURVEY AND ANALYSIS

Section No.	Pavement Type	Pavement Condition	Road and Survey Section	Traffic Volume (ADT)	Survey Section Environment	Pavement Const. Year
1 2	GR GR	Good Fair	Provincial Rd. Magallanes to Maragondon On EPC Sec. No. 2	Low (114)	Rising slightly from flat to hill area. Vegetated, some portion being rice field.	Unknown
3	GR	Bad	Provincial Rd. JCT. Alfonso to Magallanes on EPC Sec. No. 1	Low (106)	Ridge of high land, Plantation area for coconut, pineapple, coffee and banana.	Unknown
4 5	DBST DBST	Good Good	Provincial Rd. Alfonso to Gen. Aguinaldo	Low (268)	Highland, residential and coffee plantation.	Oct. 1983
6 7	DBST DBST	Fair Fair	Provincial Rd. Gen. Trias to Amadeo on EPC Sec. No. 3	Medium (654)	Flat and alvium area surrounded with wide rice field, some portion along the road is residential area.	Aug. 1983
8 9	DBST DBST	Bad Bad	Provincial Rd. Gen. Trias to Amadeo on EPC Sec. No. 4	Medium (654)	Flat and alvium area surrounded with wide rice field, some portion along the road is residential area.	Aug. 1983
10 11 12	BMP BMP BMP	Fair to Bad Fair to Bad Bad	National Rd. Tagaytay to Mendez	Medium (669)	Highland, grassy and pasture land.	1981
13	AC	Very Good	National Rd. Ternate to Puerto Azul, Jct. to Puerto Azul	High (1338)	Highland, grassy and and residential.	1981
14 15	AC AC	Fair to Bad Fair to Bad	National Rd. Trece Martirez to G.M. Alvarez on EPC Sec. No. 5	High (2068)	Hill and grass land alvium area.	1978

Length of each survey location = EPC Sec.: Experimental pavement construction section

(2) Classification of Deterioration

Deteriorations were classified as shown in Table 7.3-3.

TABLE 7.3-3 CLASSIFICATION OF DETERIORATION

Type of Pavement	Types of Deterioration: Surface Deterioration	Types of Deterioration: Structural Deterioration
Gravel Surface Road	a) Surface Cracks b) Deformation . Rutting . Longitudinal unevenness . Corrugation c) Potholes	a) Alligator Cracks b) Depressions
Bituminous Pavement	a) Cracks . Transverse cracks . Longitudinal cracks . Shrink cracks b) Deformations . Rutting . Longitudinal unevenness . Corrugation (washboarding) c) Abrasion d) Potholes e) Bleeding	a) Alligator Cracks b) Depressions

Definitions of the above deteriorations are presented in Appendix 7-1.

(3) Pavement Deterioration Measurements

Measurements of deterioration were carried out by the following methods:

a) Crack Area

For the cracked area, the surface was divided into 0.5 m × 0.5 m grids marked with white chalk on the surface of the pavement, measured and recorded. The Cracking Ratio was computed by using the following formula.

$$\text{Cracking Ratio} = (Cr/A) \times 100\ (\%)$$

where : Cr = Sum of grid surface area having cracks (sq. m.). The surface area is to be 0.15 sq.m. per grid, if one crack exist in the grid, and 0.25 sq.m. per grid, if more than one crack exist.

A = Total surveyed area

b) Area for Patching, Pothole, Abrasion (Ravelling), Deformation and Depression

The actual area for each patching, pothole, abrasion, deformation was measured and divided by total surveyed area to obtain the ratio.

c) Longitudinal Roughness

Measurements were taken along the inner wheel path line on each lane using a 3.0 m straight edge. The straight edge was placed on the surface at every 1.5 m interval and the maximum gap between the surface and straight edge (maximum wave height) was measured and recorded.

The standard deviation of the measured value was computed as the value of the longitudinal roughness.

(4) Pavement Surface Deflection by Benkelman Beam

The magnitude of pavement deflection under wheel load is an indicator of the ability of the pavement to withstand traffic loading. In order to evaluate the adequacy of the bearing capacity of the existing pavement, Benkelman Beam deflection measurements were taken in accordance with the following procedure.

a) Loading:

Dump truck having a 8.16 ton rear axle load, and inflated tire pressure of 80 psi.

b) Measured location:

At 10 m. intervals both on inner and outer wheel path on each lane.

c) Measured Value:

$$V = (\sigma / \overline{X}) \times 100$$

where:

$\overline{X}$ = Mean value of individual rebound deflection (0.01mm)
σ = Standard deviation
V = Variation coefficient (%)

Beside each 50 m. survey location, the deflection measurements, (50 m. interval), were conducted at the following locations.

Pavement Type	Condition	Measured Length	Remarks
GR	Good to Fair	800 m	EPC Sec. No. 2
DBST	Good	400 m	
DBST	Good to Fair	800 m	EPC Sec. No. 3
DBST	Bad	800 m	EPC Sec. No. 4
BMP	Bad	400 m	
AC	Fair to Bad	400 m	EPC Sec. No. 5

EPC Sec: Experimental Pavement Construction Section

(5) Test Pit Excavation

For each survey location, one test pit (60 cm. × 60 cm., depth up to subgrade) was excavated at a point showing a representative deterioration condition. The thickness and material quality of pavement component layers were measured, observed and recorded. Samples of the base course and subgrade soil were taken to analyze pavement deterioration.

Sample materials were tested at the Bureau of Research and Standards.

(6) Sample Tests

The following laboratory tests of materials sampled from test pits were conducted at the laboratory of the Bureau of Research and Standards:

- Water content
- Sieve analysis
- Liquid and plastic limits
- CBR

(7) Summary of Survey Results

All survey results were recorded in the Survey Report Sheet (see Table 7.3-4).

Table 7.3-5 summarizes the surface conditions and Benkelman Beam deflection measurements. Laboratory test results of materials sampled from test pits are shown in Table 7.3-6.

The results of Benkelman Beam deflection measurements and those of deterioration measurements as well as the survey report sheets for all sections are presented in Appendices 7-2, 7-3, and 7-4, respectively.

TABLE 7.3-4 LOW-CLASS PAVEMENT CONDITION AND DETERIORATION SURVEY REPORT SHEET:

: No. 8 Survey Date, Dec. 8-23, 1989

Pavement Type	Pavement Construction Year	Location	Trafic Data and Characteristics as of Nov. 1989.	Environmental condition	
☐ GRAVEL ☐ SBST ☐ DBST ☐ BMP ☐ AC	August, 1983	Province : Cavite Provincial Road Gen. Trias to Amadeo (EPC Section No. 4) Station : 0+ 350— 0+ 400	Both Direction ADT : 654 Trucks : 37 Buses : 2		Flat area Both sides of road are rice field
				Drainage condition	Surface drainage : grassy side ditch Underground water table : Not observed

Pavement Existing Condition Rating *	Type of deterioration, Severity	Probable Cause of Deterioration	Maintenance operation	
☐ Very Good ☐ Good ☐ Fair ☐ Bad ☐ Very Bad * See, Rating Sheet	Alligator Cracks : Mostly not segreggated, some are become potholed and patched Abrasion : Longitudinal streak ravelling of seal coat and DBST layers	Alligator cracks : Mostly structural failure due to weak subgrade and weak subbase Abrasion : Inadequate skills for asphalt binder spraying and cover aggregate spreading		Potholes patching * AC overlay is scheduled for rehabilitation of this pavement road.

Road Cross Section

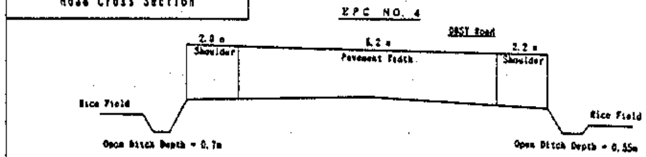


Photo showing representative condition

Surface Condition				R	L
Roughness	$\bar{X}$	mm	:	5.9 *	7.3 *
	σ	mm	:	3.3	2.2
	Crack	%	:	20.6	9.4
	Patching	%	:	3.0	4.2
	Pothole	%	:	1.5	1.2
	Abrasion	%	:	12.9	20.1
	Depression	%	:	0	6.5

Benkelman Beam Deflection (mm)		
n	:	24
Range	:	208-152
x	:	179.8
s	:	16.8
v (%)	:	9.3

Pavement Cross Section

Layer	Material
(Surface)	DBST with Seal coat
15cm Base	Crushed stone, sand and silt
10cm Subbase	Silty sand with and gravel
Subbase	Silty fine sands or clayey fine sands

Pavement Material Properties

Surface : In some portion, under size and contaminated aggregates were used

Base : Well graded aggregate Material

W(n) %	Max size mm	2.0 mm pass %
	37.5	31

0.074 mm pass %	PI,	CBR
10	NP	67

Subbase : Fine graded, lack of Material coarse aggregates

W(n) %	Max size mm	2.0 mm pass %
	19.0	63

0.074 mm pass %	PI,	CBR
17	NP	17.9

Subgrade Soil Properties

Soil Classification ML or MH

W(n)	%	:	31.8
Max. size	mm	:	2.0
0.074mm pass	%	:	54
	LL	:	NP
	PL	:	NP
	PI	:	NP
	CBR	:	4

Evaluation	
1. Serviceability Performance	1. Bad : Rather severely cracked, some craked portions are already become potholed and were patched, Bumpy riding.
2. Design Adequacy	2. For high underground table, weak subgrade condition that is close to rice field section, more thicker pavement design wpould be required.
3. Materials Quality	
4. Construction Skills	4. Not well trained skills for asphalt binder spraying and cover aggregate spreading
5. Necessary Measures for Maintenance	5. Partial replacement of pavement, then AC overlay

* Some Potholes and Depressed area were patched and roller comopacted by soil-rock fragments aggregates several day before.

TABLE 7.3-5 SUMMARY OF SURFACE CONDITION AND BENKELMAN BEAM DEFLECTION MEASUREMENTS

Survey No.	Pavement Type	Condition Rating	Pavement Deterioration						Roughness	Deflection Value		
			Cracks %	Potholes %	Patching %	Abrasion %	Deformation %	Depression %	σ mm	X 0.01mm	σ 0.01mm	V %
1	GR	G - F	-	-	-	-	-	8.6	5.2	86	22	25.2
2	GR	G - F	-	-	-	-	-	9.0	9.4	112	26	22.8
3	GR	B	8.9	-	-	-	33.6	40.3	11.9	132	36	27.5
4	DBST	G	-	-	-	5.6	-	-	2.4	64	24	36.9
5	DBST	G	-	-	-	12.5	-	-	1.5	74	7	9.7
6	DBST	F	21.9	0.2	-	6.5	-	-	3.9	85	18	20.1
7	DBST	F	8.7	0.1	-	20.3	-	-	2.8	83	14	16.6
8	DBST	B	10.0	1.4	4.0	16.5	-	3.3	2.8	179	17	9.3
9	DBST	B	10.3	1.4	3.9	22.6	-	8.0	3.6	162	32	19.4
10	BMP	F - B	5.9	-	7.3	-	-	7.6	4.3	138	47	34.2
11	BMP	F - B	4.6	-	4.0	-	4.5	7.6	5.7	131	44	33.8
12	BMP	B	10.5	-	23.4	4.1	-	14.6	7.1	233	35	14.8
13	AC	VG	-	-	-	-	-	-	0.9	75	15	19.9
14	AC	F - B	22.7	-	9.5	-	-	15.9	7.7	113	19	17.0
15	AC	F - B	25.5	-	5.4	-	-	13.8	6.4	124	37	29.2

* Some Potholed and Depressed area were patched and roller compacted several days before

TABLE 7.3-6 (1) TEST RESULTS OF SAMPLES FROM CONDITION SURVEYED PAVEMENTS

Survey No.		1	2	3	4	5	6	7	8
Type		GR	GR	GR	DBST	DBST	DBST	DBST	DBST
Pavement Condition		Good to Fair	Good to Fair	Bad	Good	Good	Fair	Fair	Bad
Road Section		EPC Section No. 2	EPC Section No. 2	EPC Section No. 1	Alfonso to Gen. Aguinaldo		EPC Section No. 3	EPC Section No. 3	EPC Section No. 4
Base Course Material Type		Gravel Surfacing	Gravel Surfacing	Gravel Surfacing	Crushed stone, Sand and silt	Crushed stone, Sand and silt	Crushed stone, Sand and silt	Crushed stone, Sand and silt	Crushed stone, Sand and silt
Grading	37.5 mm	97	93	93	100	Not tested	100	100	100
	19	68	77	81	79		63	76	72
	4.75	49	69	61	52		40	47	44
	2.00	42	61	54	40		27	32	31
	0.425	20	37	40	20		14	17	19
	0.075	9	17	22	11		7	8	10
	LL	NP	NP	NP	NP		NP	NP	NP
	PI	NP	NP	NP	NP		NP	NP	NP
	CBR %	29	18	14	106		82	75	67
Subbase Course Material Type		No Subbase	No Subbase	No Subbase	Crushed stone, Sand and silt	Crushed stone, Sand and silt	Sand and silt with pea gravel	Sand and silt with pea gravel	Silty sand with pea gravel
Grading	37.5 mm				100	Not tested	100	99	100
	19				89		77	91	96
	4.75				69		56	74	80
	2.00				55		42	58	63
	0.425				23		21	32	32
	0.075				14		12	19	17
	LL				NP		NP	NP	NP
	PI				NP		NP	NP	NP
	CBR %				29		11	16	17
Subgrade Soil Soil Type		Silty fine sands	Silty fine sands	Clayey and silty fine sands	Silty sands with pea gravel	Silty sands with pea gravel	Sands and silty fine sands	Sands and silty fine sands	Silty or clayey fine sands
Grading	19 mm	100	83	100	95	93	99	92	-
	4.75	96	72	95	84	79	85	81	95
	2.00	83	63	89	67	62	75	71	91
	0.425	60	37	75	35	32	55	51	74
	0.075	45	23	54	15	13	31	23	54
	LL	41	29	50	NP	NP	NP	NP	NP
	PI	13	7	12	NP	NP	NP	NP	NP
	W(n) %	21.5	9.1	45.1	13.9	13.2	19.2	17.9	31.8
	CBR %	4	6	4	17	11	8	9	4

EPC Section No. : Experimental Pavement Construction Section No.

TABLE 7.3-6 (2) TEST RESULTS OF SAMPLES FROM CONDITION SURVEYED PAVEMENTS

Survey No.	9	10	11	12	13	14	15
Type	DBST	BMP	BMP	BMP	AC	AC	AC
Pavement Condition	Bad	Fair to Bad	Fair to Bad	Bad	Very Good	Fair to Bad	Fair to Bad
Road Section	EPC Section No. 4		Tagaytay to Mendez		Puerto Azul	EPC Section No. 5	EPC Section No. 5
Base Course Material Type	Crushed stone, Sand and silt	Macadam stone base	Macadam stone base	Macadam stone base	Crushed stone, Sand, silt-clay	Crushed stone, Sand, silt-clay	Rock fragments, Sand-silt-clay
Grading 37.5 mm	100	81	83	80	90	100	93
19	79	46	51	41	74	80	83
4.75	49	25	20	21	55	51	56
2.00	38	18	18	15	47	43	45
0.425	23	10	7	6	30	27	26
0.075	9	5	4	2	16	14	16
LL	NP	NP	NP	NP	NP	NP	NP
PI	NP	NP	NP	NP	NP	NP	NP
CBR %	78	-	-	-	61	45	37
Subbase Course Material Type	Silty sand with pea gravel	Rock fragments, Sand and silt	No Subbase	No Subbase	Silty sand with gravel	Crushed rock, Sand and silt	Silty sands with pea gravel
Grading 37.5 mm	100	100			92	95	95
19	97	65			78	87	85
4.75	82	45			57	73	69
2.00	80	35			41	67	51
0.425	39	16			21	40	30
0.075	18	11			11	16	14
LL	NP	NP			NP	NP	NP
PI	NP	NP			NP	NP	NP
CBR %	15	20			29	11	19
Subgrade Soil Soil Type	Silty or clayey fine sands	Silty fine sands	Silty or clayey fine sands	Silty fine sand	Silty fine sands	Silty fine sands	Silty or clayey fine sands
Grading 19 mm	100	85	96	95	93	99	100
4.75	94	74	93	78	77	91	96
2.00	86	64	88	70	68	85	92
0.425	64	44	76	57	48	70	83
0.075	43	30	66	46	31	53	71
LL	NP	NP	NP	NP	NP	NP	42
PI	NP	NP	NP	NP	NP	NP	12
W(n) %	23.6	20.0	44.0	20.1	8.3	32.1	31.6
CBR %	6	10	7	5	8	6	5

7.3.4 Analysis of Pavement Deterioration

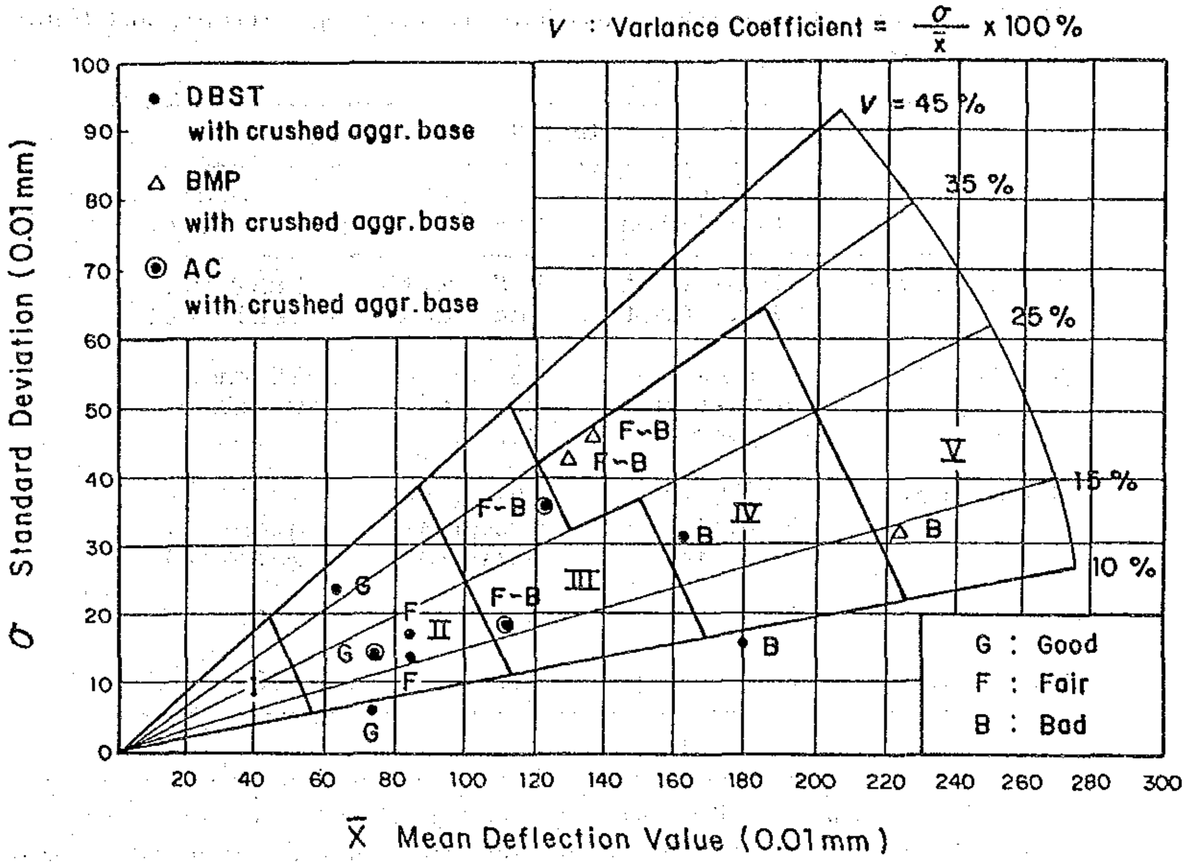
(1) Relationship Between Pavement Deterioration and Deflection

Deflection measurement was carried out on good, fair and bad sections of DBST, BMP and AC pavements to evaluate the structural performance of the existing pavement. The mean value, standard deviation and variance coefficient were computed based on the measured deflection value, while relationship between the surface condition rating and deflection was obtained as shown in Figure 7.3-3.

The pavement having less deterioration and good surface condition shows low deflection, while pavement having severely deteriorated surface and bad surface condition shows greater deflection. On pavements under longer period of traffic repetition, greater deflection value are mostly occurred.

The table shown below summarises the relationship between deflection and structural performance.

Surface Condition	Deflection Value (0.01 mm)	Structural Performance
Good to Fair	< 100	Adequate
Fair to Bad	100 - 140	Requires maintenance work according to deterioration condition, by sealing, seal coat, AC patching, or partial replacement.
Fair to Bad	140 - 200	Requires partial replacement of deteriorated portions, then followed by an AC overlay.
Bad	> 200	Requires total reconstruction.



Evaluation on the Surveyed Pavements

Zone	Structural Performance Evaluation
I	Maybe no existence or over design
II	Shows adequate structural performance
III	Requires sealing, seal coat, AC patching partial replacement according to distres level.
IV	Requires partial replacement of structural distressed portion, then AC overlay
V	Requires total reconstruction

FIGURE 7.3-3 EVALUATION OF PAVEMENT STRUCTURAL PERFORMANCE BY BENKELMAN BEAM DEFLECTION VALUE

The deflection characteristics of DBST pavements are analyzed in further detail. The DBST pavements of surveyed sections have the following structural and traffic characteristics:

	DBST Pavements in		
	Good Condition	Fair Condition	Bad Condition
Surface Course	DBST with Seal Coat	DBST with Seal Coat	DBST with Seal Coat
Base Course	15 cm Crushed Stone	15 cm Crushed Stone	15 cm Crushed Stone
Subbase Course	10-15 cm granular material	10-15 cm granular material	10-15 cm granular material
CBR	8 %	5-8 %	3-5 %
Traffic (ADT)	268	948	948

The cumulative percentage curves obtained by Benkelman Beam deflection for good, fair and bad surface condition are shown in Figure 7.3-4. From this figure, the relationship between the surface condition and deflection value can be summarized as follows:

Surface Condition	Structural Adequacy	$\overline{X}$	σ	$\overline{X}$ + S
Good	Adequate, Repair not required.	68.8	18.2	87.0
Fair	Needs sealing, seal coat, AC patching	84.0	17.3	101.3
Bad	Needs overlay with AC, replacement for structurally deteriorated portion.	166.5	26.4	192.9

$\overline{X}$: mean value in 0.01 mm

σ : standard deviation in 0.01 mm

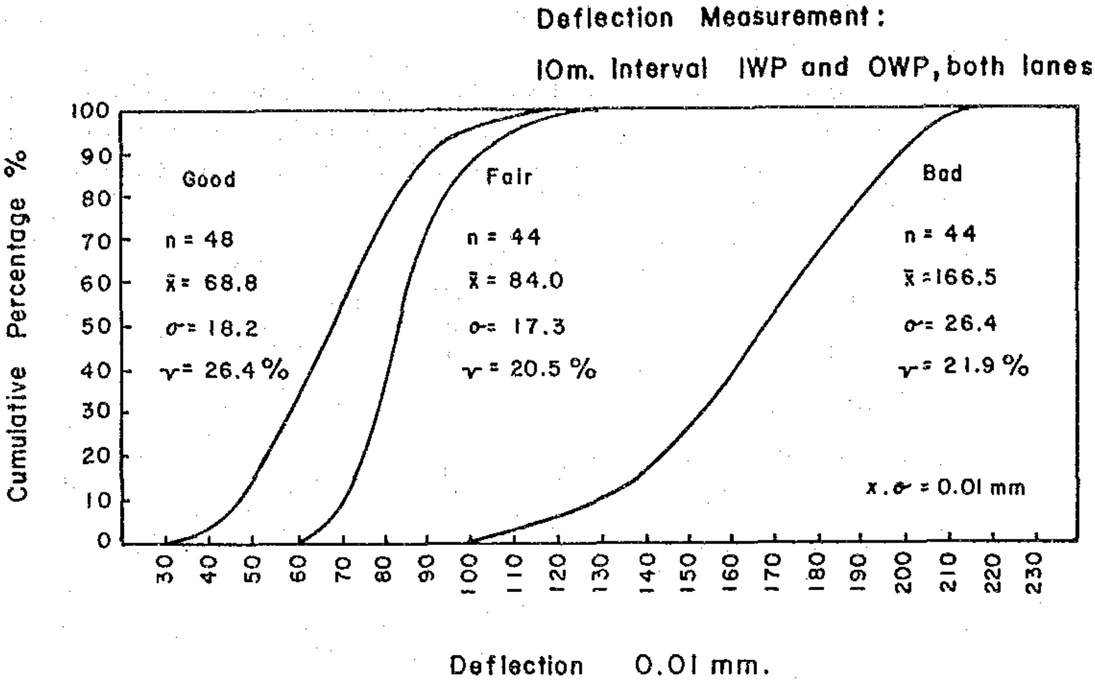


FIGURE 7.3-4 CUMULATIVE PERCENTAGE CURVES OF BENKELMAN BEAM DEFLECTION FOR DBST GOOD, FAIR, BAD PAVEMENTS

Surveyed DBST Pavement Surface Conditions

Surface Condition Rating		Good	Fair	Bad
Survey Location		Alfonso to Gen. Aguinaldo Road	Gen. Trias to Amadeo Road EPC Sec. No 3	EPC Sec. No. 4
Survey Length		2 @ 50 m	2 @ 50 m	2 @ 50 m
Surface Distress	Cracks	– %	15.3 %	10.1 %
	Potholes	– %	0.2 %	1.4 % *
	Patching	– %	– %	4.0 %
	Abrasion	7.1 %	13.4 %	19.6 %
	Depression	– %	– %	9.7 % *
Longitudinal Roughness σ	Right Lane	2.9, 1.9 mm	4.5, 2.8 mm	3.3, 2.2 mm *
	Left Lane	1.4, 1.7 mm	3.3, 2.8 mm	2.2 4.0 mm *
ADT as of June 1988		268	948	
DBST Pavement Road Construction Completion Year		Oct. 1983	Aug. 1983	

* Some potholes and depressions were patched and roller compacted several days before.

(2) Relationship Between Roughness and Deflection

The relationship between the degree of roughness and the magnitude of deflection is shown in Figure 7.3-5. Here greater deflection demonstrates greater roughness in bad condition surfaces while less roughness is revealed by smaller deflection values in good pavement surface.

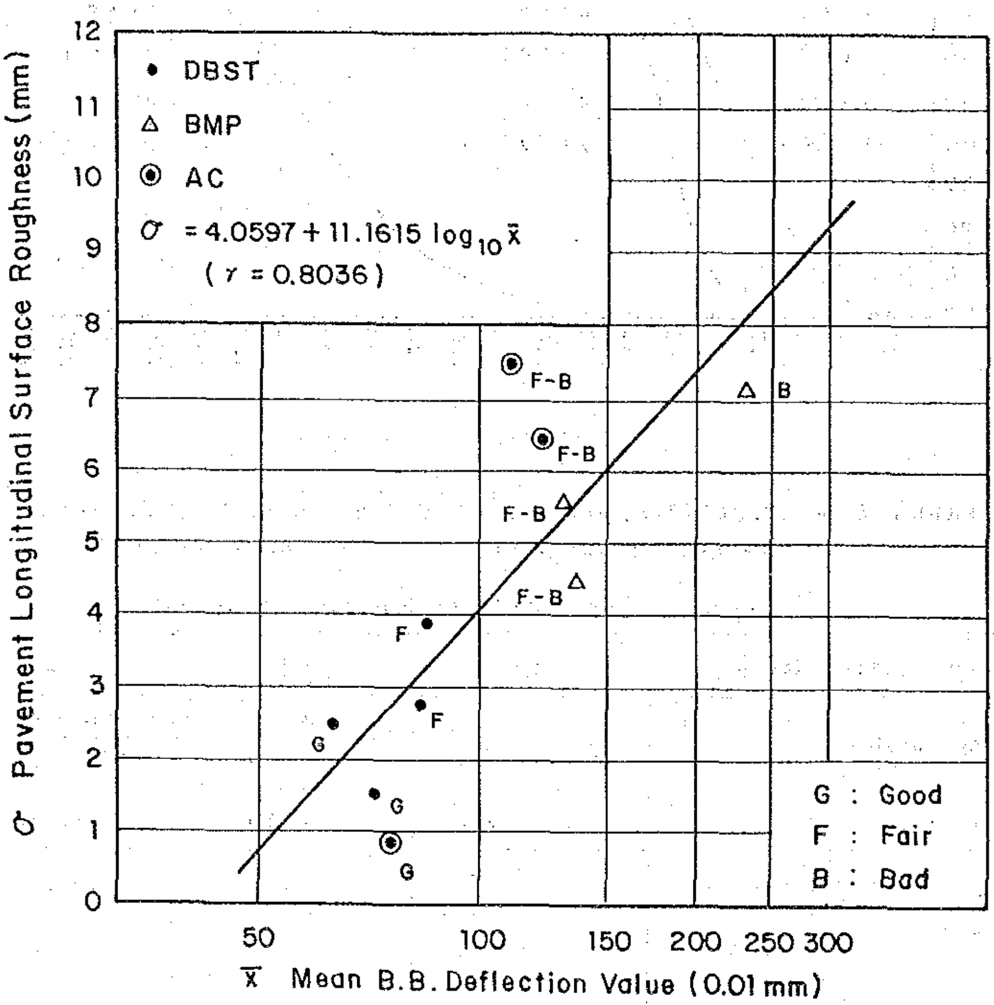


FIGURE 7.3-5 RELATION BETWEEN LONGITUDINAL SURFACE ROUGHNESS OF PAVEMENT AND B.B. DEFLECTION VALUE

(3) Pavement Serviceability Performance

Factors influencing the decrease of serviceability of a pavement are traffic, subgrade soil condition, age and climate. In this section, some examples of decrease in pavement serviceability due to traffic repetition and the soil supporting values of subgrades are analyzed by using the AASHTO Basic Design Equation for Flexible Pavements.

The following typical pavement models were theoretically analyzed to identify the pavement performance characteristics:

PAVEMENT STRUCTURE AND STRUCTURAL NUMBER SN

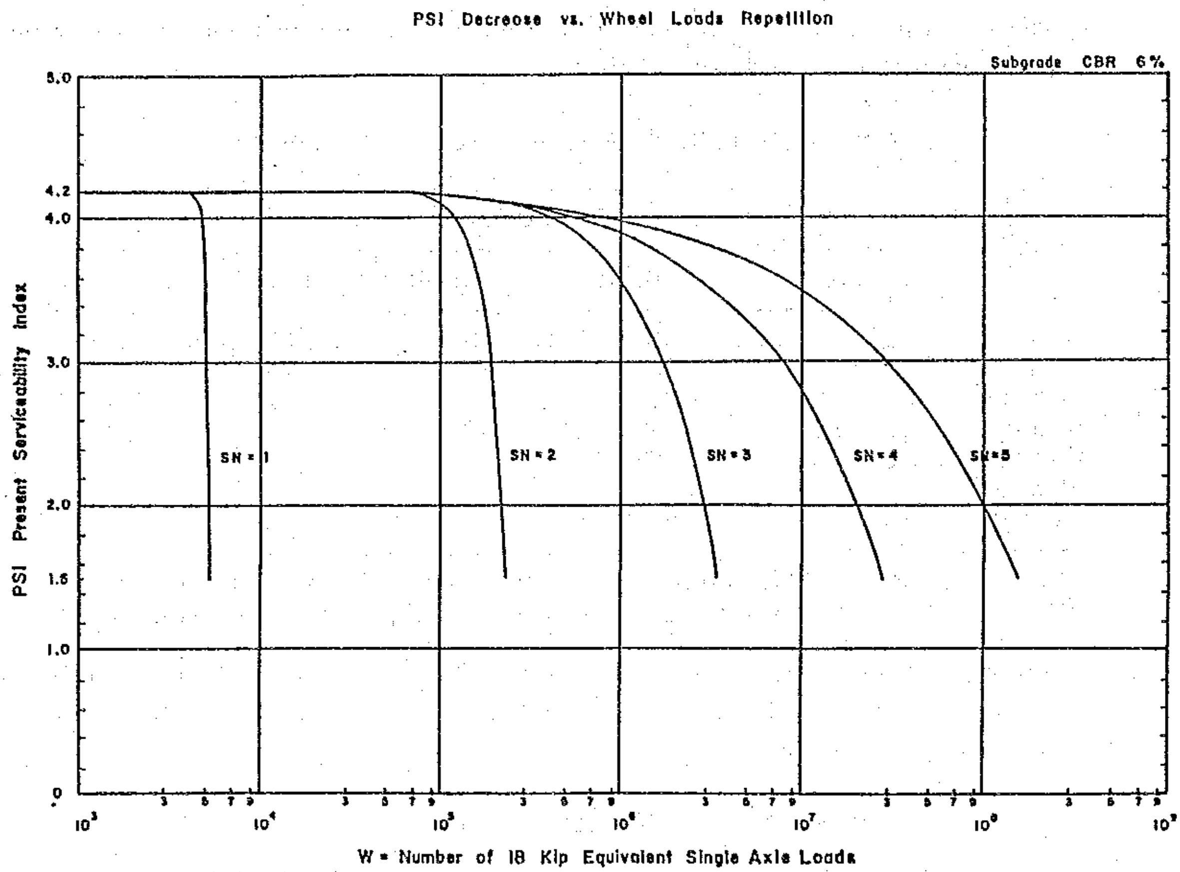
Traffic	Pavement Structure			Total Thickness	SN
	Surface	Base	Subbase		
Low	DBST 1.5cm	CS 10cm	AG 10cm	21.5cm	1.0
Low	DBST 1.5	CS 15	AG 10	26.5	1.5
Medium	AC 5	SC 15	AG 10	31	2.0
Heavy	AC 10	SC 15	AG 10	35	3.0
Heavy	AC 10	ATB 15	AG 10	40	4.0
Extra Heavy	AC 10	ATB 15	CTSB 15	46	5.0

CS : Crushed stone base ATB: Asphalt treated base
AG : Aggregate subbase CTSB: Cement treated subbase

Figure 7.3-6 shows PSI decrease curves and Table 7.3-7 the relationship between structural number (SN) and number of ESAL for the respective terminal serviceabilities of 2.5 and 1.5.

TABLE 7.3-7 STRUCTURAL NUMBER AND ESAL

SN	Number of ESAL (W)			
	(1) W Pt=2.5	(2) W Pt=1.5	(3) W Pt=1.5−W Pt=2.5	(3)/(1)*100
1.0	5.18×10^3	5.26×10^3	0.08×10^3	1.5
1.5	4.05×10^4	4.25×10^4	0.20×10^4	4.9
2.0	2.09×10^5	2.34×10^5	0.25×10^5	12.0
2.5	7.09×10^5	9.91×10^5	2.01×10^5	25.4
3.0	2.37×10^6	3.46×10^6	1.09×10^6	46.0
4.0	1.38×10^7	2.79×10^7	1.41×10^7	102.1
5.0	6.10×10^7	1.54×10^7	9.30×10^7	152.5



PSI = 2.5 Level Rehabilitation Work such as Bituminous Over Lay will be required for Main Highways
PSI = 2.0 Level Rehabilitation Work such as Bituminous Over Lay will be required for Rural Roads
PSI = 1.5 Level Reconstruction will be required

Example of Pavement Structure and Structure Number SN

SN = 1.0 — DBST Low Traffic Pavement

Layer	Thickness	$t_i \times a_i$	SN
DBST		1.5 x 0.20	
Aggr. Base	10 cm	10 x 0.14	
Aggr. Subbase	8 cm	8 x 0.10	
			2.50/2.54 = 1.0

SN = 1.5 — DBST Low Traffic Pavement

Layer	Thickness		SN
DBST		1.5 x 0.20	
Aggr. Base	15 cm	15 x 0.14	
Aggr. Subbase	14 cm	14 x 0.10	
			3.80/2.54 = 1.5

SN = 2.0 — Medium Traffic Pavement

Layer	Thickness		SN
As. Con.	5 cm	5 x 0.40	
Aggr. Base	15 cm	15 x 0.14	
Aggr. Subbase	10 cm	11 x 0.10	
			5.10/2.54 = 2.0

SN = 3.0 — Heavy Traffic Pavement

Layer	Thickness		SN
As. Con.	4 cm	4 x 0.40	
As. Con.	6 cm	6 x 0.40	
Aggr. Base	15 cm	15 x 0.14	
Aggr. Subbase	10 cm	15 x 0.10	
			7.60/2.54 = 3.0

SN = 4.0 — Heavy Traffic Pavement

Layer	Thickness		SN
As. Con.	4 cm	4 x 0.40	
As. Con.	6 cm	6 x 0.40	
		15 x 0.14	
As. Treated Base	15 cm	15 x 0.10	
			10.10/2.54 = 4.0

SN = 5.0 — Extra Heavy Traffic Pavement

Layer	Thickness		SN
As. Con.	4 cm	4 x 0.40	
As. Con.	6 cm	6 0.40	
		15 0.30	
As. Treated Base	15 cm	21 0.20	
			12.70/2.54 = 5.0
Cem. Treated Subbase	21 cm		

FIGURE 7.3-6 FLEXIBLE PAVEMENT SERVICEABILITY DECREASE CURVE BASED ON AASHTO BASIC DESIGN EQUATION

The above analysis reveals a tendency of the serviceability of low-SN pavements, dropping quite rapidly which indicates the necessity of earlier and more timely strengthening of pavement in order to maintain and prolong a proper serviceability level. The remaining life of low-SN pavement is shorter than that of higher SN pavements.

Figure 7.3-7 shows the influence of the soil supporting value of the subgrade on pavement serviceability decrease. The pavement structure of SN=1.5, for example, will be greatly influenced by the supporting value of such subgrades as shown below:

CBR of Subgrade	Nember of ESAL at Pt=1.5	
3%	8.51×10^3	(1.00)
6%	42.5×10^3	(4.99)
10%	139×10^3	(16.3)

(4) Structural Failure of Flexible Pavements

The functions of the surface course are to provide resistance to wear and stress due to traffic loads, to provide an even and non-skid surface with comfortable riding quality and to prevent water from penetrating into the pavement structure.

The base and subbase course play an important role in distributing the traffic loads, and reducing the loading intensity until the subgrade will be able to support the distributed load without failure.

Based on the above functions needed for a pavement structure, deterioration in a pavement may be classified into the two (2) following categories:

- Deterioration due to structural failure
- Deterioration due to failure of surface course

a) Structural Failure

Structural failure is defined as a collapse of the structure, or breakdown of one or more of the structural components, that is due to traffic loads and that make the structure incapable of sustaining the loads imposed on its surface.

The general relationship between stress and depth within a flexible pavement structure is shown in Figure 7.3-8.

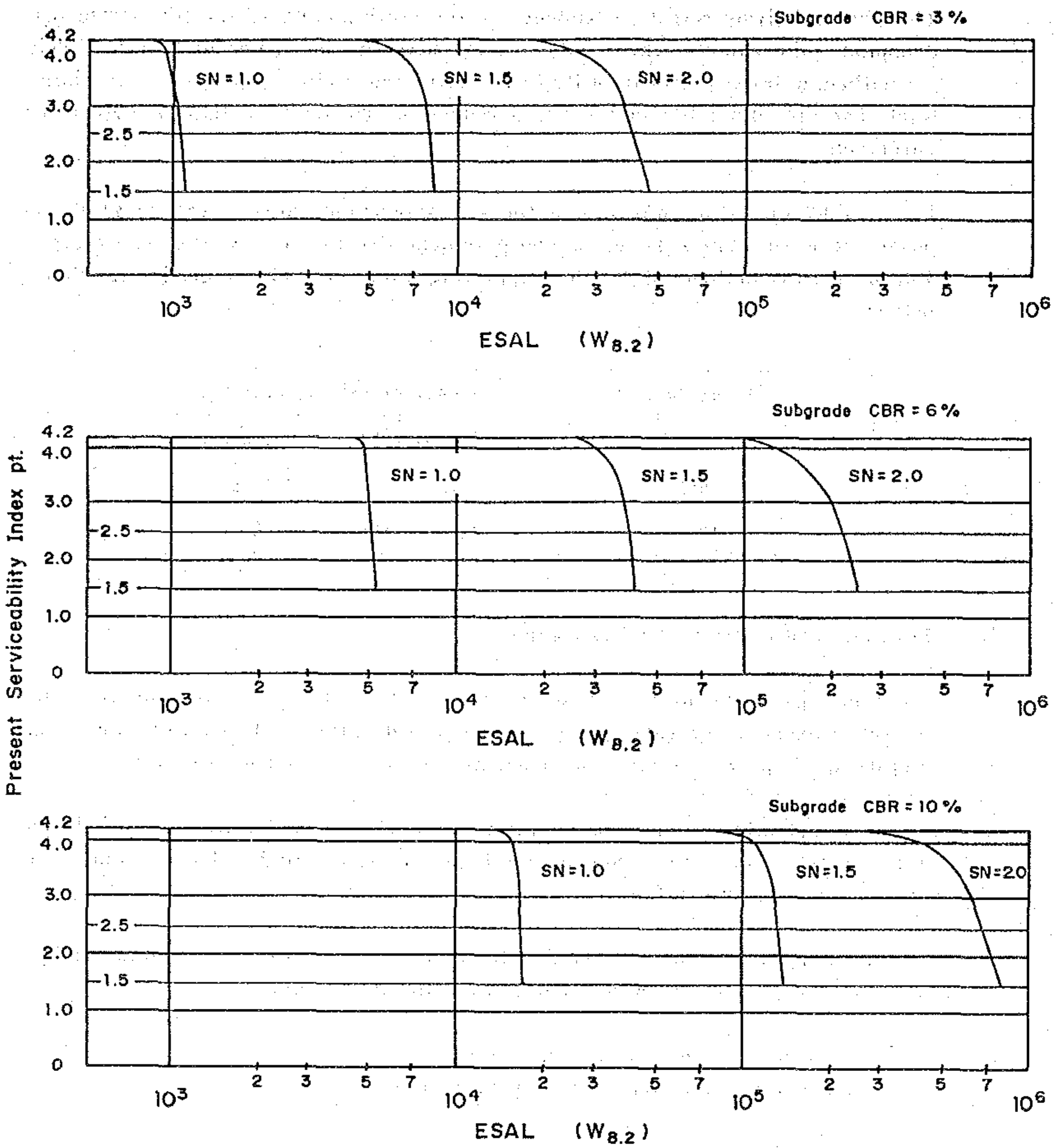


FIGURE 7.3-7 PAVEMENT SERVICEABILITY DECREASE WITH CUMULATIVE NUMBER OF 8.2 TON STANDARD AXLES (ESAL $W_{8.2}$) BASED ON AASHTO FLEXIBLE PAVEMENT DESIGN EQUATION.

Pt=2.5 Rehabilitation will be required for main highways
Pt=2.5 Rehabilitation will be required for rural roads
Pt=2.5 Rehabilitation will be required

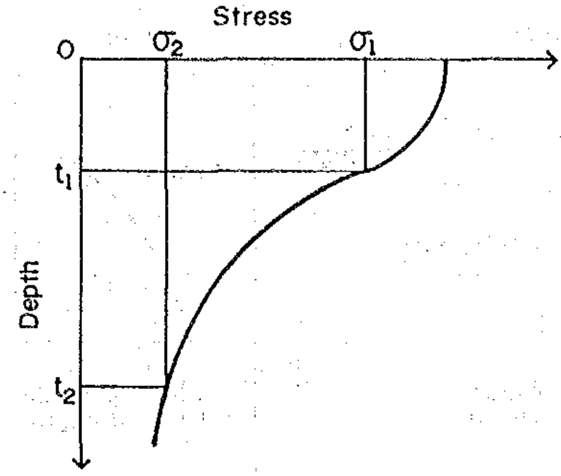


FIGURE 7.3-8 DISTRIBUTION OF STRESS WITH DEPTH OF FLEXIBLE PAVEMENT

Stresses caused by vehicle loads are largest near the surface and decrease with the depth. At depth t_1, the stress caused by the vehicle is σ_1, and at a depth t_2 the stress is σ_2. If the pavement is to be constructed on a very strong subgrade soil with a strength greater than or equal to σ_1, then the total thickness of pavement required would be t_1. If a weak subgrade soil with a strength equal to σ_2 is encountered, a thickness of at least t_2 would be required to prevent shear failure in the subgrade.

Since stress decreases with depth, the highest quality materials should be placed in the upper portion of the pavement near the surface. Lower quality materials can be used in the lower portions of the pavement near the subgrade.

From a basic structural viewpoint, a pavement structure should be designed so that layers with increased strength or higher quality are placed from the subgrade toward the pavement surface. This is conceptually illustrated in Figure 7.3-9 (a). The high quality layer becomes the base course for pavements with a bituminous surface.

Use of high quality materials over the total pavement thickness would be uneconomical as shown in Figure 7.3-9 (b). Figures 7.3-9 (c) and 7.3-9 (d) illustrate subgrade failure and base failure conditions, respectively.

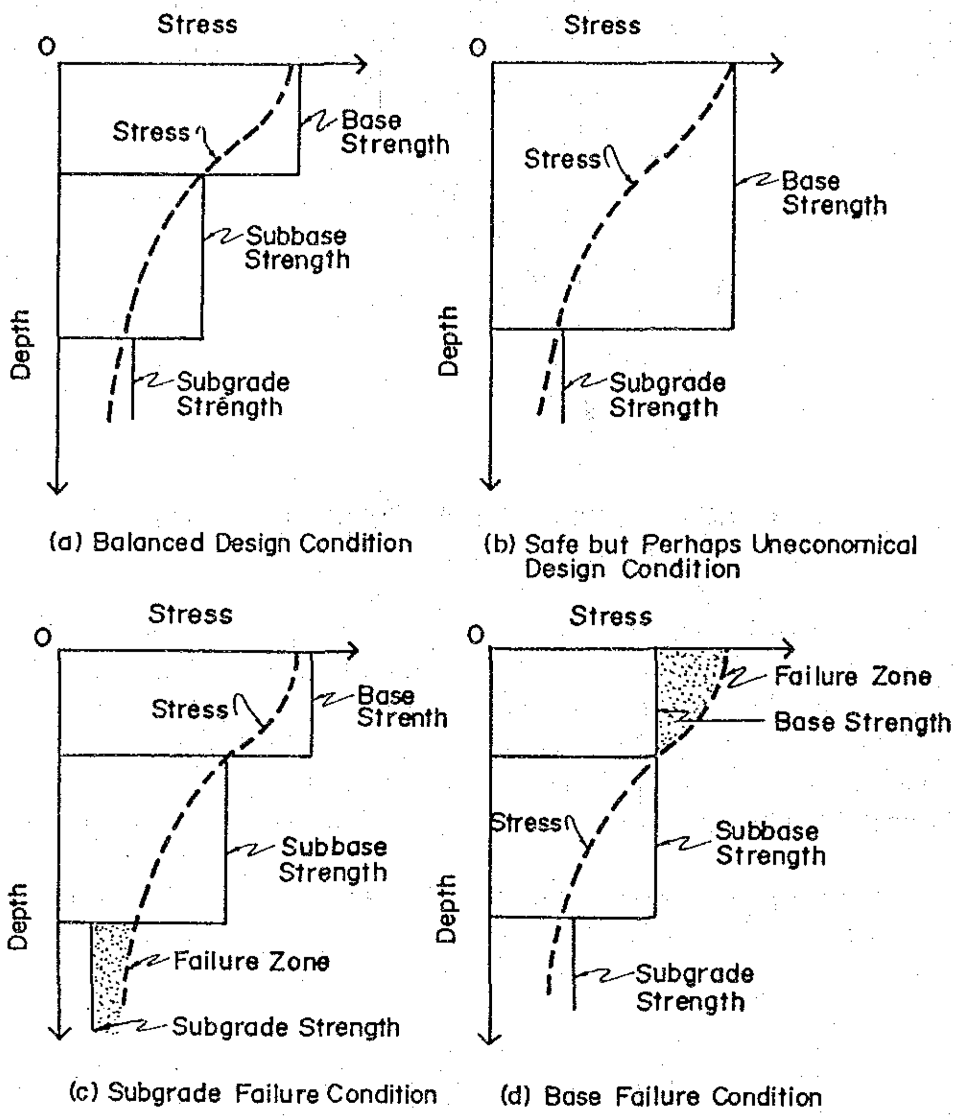


FIGURE 7.3-9 FLEXIBLE PAVEMENT STRESS-STRENGTH CONSIDERATION

b) Failure of Surface Course

The fundamental characteristics needed for the surface course are: stability or shear resistance to vehicle load actions directly imposed on the surface, a waterproof layer on the surface to minimize surface water infiltration into the base/subbase course and subgrade soil, and durability to maintain the required material characteristics of the surface course under the climatic conditions without deterioration.

(5) Causes of Pavement Deterioration

Pavement failure and deterioration and their causes are discussed individually for the surveyed pavements in the following section.

a) Gravel Surfaced Road

i) Pavement Structure

For the surveyed three (3) locations, the thickness of the gravel layer range from 7cm to 15cm. The CBR value varies from 3% to 6%. Quite irregular and bumpy surface conditions were observed at survey location No. 3.

ii) Properties of gravel layer aggregates

The test results for survey location No. 3 are as follows:

TEST RESULTS FOR GRAVEL SURFACE MATERIALS

Item		Gravel Surface No. 3	DPWH Spec. 300 Grading
Max. size		50 mm	25 mm
Gravel	<4.75 mm	31 %	35 - 65 %
Sand	4.75 - 0.07 mm	31 %	
Silt/Clay	0.075 mm	22 %	4 - 15 %
LL		NP	< 35
PI		NP	4 - 9
CBR		14 %	-

The following two important characteristics are of high importance for materials for use in gravel surfaced roads.

- Grading of particles, that is the mix proportion of gravel, sand and silt/clay.

- Plasticity properties of the fines passing through a 0.425 mm sieve screen.

Well-graded aggregates with a proper amount of fine particles having considerable plasticity demonstrate an adequate shear strength, frictional strength and cohesion to withstand vehicle loads and tire action directly imposed on the surface of the aggregate layer.

iii) Cause of Deterioration

- Surface Cracks (less than 2 mm):

  Shrinkage cracks due to an excessive amount of fines, under the spell of dry days.

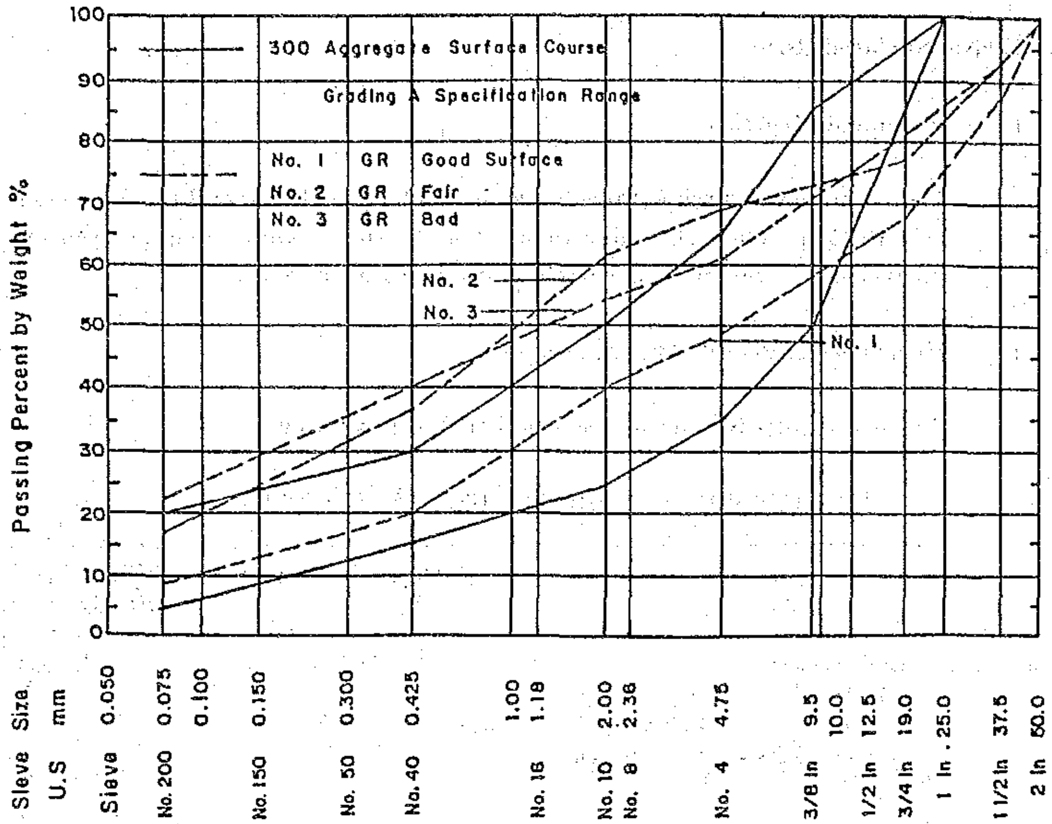


FIGURE 7.3-10 GRAVEL SURFACING GRAIN SIZE DISTRIBUTION CURVE
(passing % by weight)

TABLE 7.3-8 SURVEYED GR ROAD SURFACE CONDITION

Surface Condition Rating		Good	Fair	Bad
Survey No.		No. 1	No. 2	No. 3
Location		Magallanes to Maragondon Rd.		Jct. Alfonso to Magallaness Rd.
ADT		80		106
Distress	Cracks	– %	– %	8.9 %
	Potholes	– %	– %	– %
	Abrasion	– %	– %	– %
	Deformation	– %	– %	33.6 %
	Depression	8.6 %	9.0 %	40.3 %
Roughness σ	Right Lane	5.9 mm	9.7 mm	9.7 mm
	Left Lane	4.4 mm	9.0 mm	14.1 mm
Benkelman Beam	$\bar{X}$	86	112	132
Deflection (0.01mm)	σ	22	26	36
Subgrade Soil Condition		Silty or clayey fine sands CBR = 4 ~ 6 %		Silt and clay CBR = 3~4 %
Time from last regrading operation		About one month		Not known

Rutting , Longitudinal uneveness , Corrugation

- Rutting, Longitudinal unevenness, corrugation:

  Due to the progressive separation of aggregate particles from the sandy gravel layer having weak shear strength and frictional strength, caused by poor gradation and lack of the required binding ability of fines contained.

- Alligator Cracks and Depression:

  Due to subgrade failure. Because the gravel layer is directly placed over the subgrade, this deterioration was observed in the areas where the CBR value is likely to be 3%.

b) Double Bituminous Surface Treatment

Survey results and causes of deterioration by section are presented in Table 7.3-9.

i) Pavement Structure

The Double Bituminous Surface Treatment (DBST) pavement on surveyed at six (6) locations consist of the following structural layers.

Surface Course	DBST with seal coat
Base Course	15 cm thick Blended aggregate of crushed stone and sand
Subbase Course	10 cm thickness Blended aggregate of sand and crushed stone
Subgrade	The CBR value obtained at six (6) locations vary from 4% to 17%

These DBST pavements have service period of about six (6) years since their completion of construction.

ii) Aggregate Properties of Base Course and Subbase Course

Base course aggregates are mostly well graded. Plasticity Index are mostly non-plastic and CBR value varies from 67% to 82%.

iii) DBST Materials

Binder	Cationic emulsified asphalt for DBST and Cut-Back Asphalt for Seal Coat

TABLE 7.3-9 SUMMARY OF SURVEY RESULTS AND CAUSES OF DETERIORATION : DBST

Item	DBST in Good Condition		DBST in Fair Condition		DBST in Bad Condition	
Section No.	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
ADT (Vehicle/day)	268	268	654	654	654	654
Priod in Service	6 years	6 years	6 years	6 years	6 years	6 years
Subgrade CBR (%)	17	11	8	6	4	6
Deterioration						
Cracks (%)	-	-		-	10.3	10.1
Patching (%)	-	-	-	-	4.0	3.9
Abrasion (%)	5.6	12.5	21.9	8.7	16.5	22.6
Depression (%)	-	-	-	-	5.3	8.0
Other Distress (%)	-	-	6.5	20.3	-	-
Roughness (σ) (mm)	2.4	1.5	3.9	2.8	2.8 *	3.6 *
B. B. Deflection (0.01mm)	64	74	85	83	119	162
Description of Condition and Causes of deterioration	The surface texture is dense, smooth and water-proof like a well finished asphalt concrete surface. The aggregates and binder of the DBST layer are properly applied, and by test pit excavation, the layer was found to have sufficient flexibility. Skill for binder and cover aggregate application work is adequate. Benkelman Beam deflection value is very low. It was confirmed that a well constructed DBST pavement has a performance period of more than 6 years under low-volume traffic and good subgrade conditions.		Both good surfaces and deteriorated surfaces exist. The causes of surface deterioration are: (i), partial weak subbase materials, and (ii) insufficient binder and cover aggregate application. The pavement structure is DBST with a 15 cm base course and 10 cm subbase course. The number of years in service is 6 years. B.B. deflection values show that this pavement structure has good structural adequacy. However, due to the above deterioration, an asphalt concrete overlay is required to prevent further progress of surface deterioration. Therefore, it can be said that the performance period up to overlay rehabilitation for this DBST structure under medium-volume traffic and fair subgrade condition is about 6 years.		Some potholes and depressed area were patched and roller compacted several days before this survey. Alligator cracks and depressions due to subgrade failure caused by partially weak subgrade soil were found where the underground water table is high in areas close to rice fields. DBST work skill is insufficient. B.B. deflection value shows that the present pavement structure of DBST with 15 cm base course and 10 cm subbase course has poor structural adequacy. Therefore, reconstruction is required. In this case, the performance period up to reconstruction is 6 years.	

Cover Aggregate Crushed Aggregate
3/4 in. (20 mm) for DBST 1st application
3/8 in. (10 mm) for DBST 2nd application
1/4 in. (6 mm) for Seal Coat

Application Rate:

Layer	Binder	Cover Aggregate
DBST 1st application	1.3 to 1.4 l/m^2	18 kg/m^2
DBST 2nd application	1.6 to 1.8 l/m^2	11 kg/m^2
	1.0 l/m^2	6 kg/m^2

The above data were obtained from the DBST pavement construction report.

Table 7.3-10 shows the application rate of materials for double bituminous surface treatment specified in DPWH Standard Specifications.

iv) Double Bituminous Surface Treatment

Surface treatment, which is applied to all kinds of roads, is a broad term embracing several types of bituminous materials ranging from emulsified asphalt to liquid asphalt and asphalt-aggregate. It is usually applied to a thickness of less than 25 mm.

A single application of bituminous materials to a prepared base or road surface followed immediately by the placing of a single layer of aggregates is known as single bituminous surface treatment.

Two single surface treatment layers placed on top of the other is called double surface treatment. The aggregate maximum size of successive treatment is usually one-half of the first one and a total thickness is about the same as the nominal maximum size aggregate particle of the first layer.

A double surface treatment is a denser wearing and waterproofing layer than a single surface layer, and provides additional strength. The expected service life of a double surface treatment varies considerably, raging generally from 5 to 10 years during which period, service free of major maintenance is ensured. The successful performance of double surface treatment depends heavily on climate and construction control as well as proper selection of materials.

TABLE 7.3-10 APPLICATION RATE OF DBST MATERIALS
(DPWH Standard Specifications)

Sequence of Operations	Bituminous Materials lit/m²	Aggregate kg/m²
First Layer :		
Bituminous Materials	1.58	
Application		
Aggregates Spreading		27.20
Grading B (10-5 mm)		
Second Layer :		
Bituminous Materials	2.04	
Aggregates Spreading		10.88
Grading B (5-2 mm)		
Totals :		
Bituminous Materials	3.62	
Cover Aggregate		38.08
Aggregate Specific Gravity :	2.65	

TABLE 7.3-11 TYPES OF BITUMINOUS MATERIAL FOR SURFACE TREATMENT

Types of Construction	Asphalt Cements		Liquid Asphalts: Rapid Curing (RC)				Medium Curing (MC)					Slow Curing (SC)				Emulsified (Anionic)					Emulsified (Cationic)					
	120/150	200/300	70	250	800	3000	30	70	250	800	3000	70	250	800	3000	RS-1	RS-2	MS-2	SS-1	SS-1h	CRS-1	CRS-2	CMS-2s	CMS-2	CSS-1	CSS-1h
Surface Treatments With Cover Aggregates	X	X	X	X	X	X			X	X	X			X	X	X	X				X	X				
Seal Coats	X	X	X	X	X	X		X	X	X	X					X	X		X[1]	X[1]	X	X			X[1]	X[1]
Slurry Seal																			X	X					X	X
Fog Seal																				X[2]						X[2]
Tack Coat			X													X[2]			X[2]	X[2]	X[2]				X[2]	X[2]
Prime			X	X			X	X	X			X	X													
Dust Laying							X	X				X							X[2]						X[2]	

[1] SS grades can be used when sand is used for cover .
[2] Water diluted .

The important consideration for successful treatment are:

- A uniform application rate of the bituminous binder must be maintained to ensure build-up of a uniform binding layer between the prepared base and spread cover aggregate. Usually, the application rate of the bituminous binder is from 0.6 to 1.8 l/m^2 (0.6 to 1.8 mm film thickness) for each layer application.

- Uniform spreading of the cover aggregates must follow the spraying of binder before the formed film loses its binding viscosity, to ensure a firm bond between the film and cover aggregates immediately.

- Cover aggregates of a uniform size must be used to ensure a uniform blotting of the sprayed binder film by the cover aggregate layer.

- The cover aggregate must be clean to establish a strong bond between the aggregate and bituminous binder.

Bituminous materials that can be ;used for surface treatment are shown in Table 7.3-11. the adequate grade of bituminous materials will be one that meets the following requirements.

- When applied, be flux enough to have fluidity to enable proper spraying and uniform covering of surface.

- After application, retain proper consistency so as to wet the spread aggregates.

- *To cure and develop the required adhesion quickly.*

v) Causes of Deterioration

Mostly frequently observed type of deteriorations are:

- Fine cracks:

  Due to lowering of bearing capacity of pavement structure caused by weak subbase materials.

- Alligator cracks and depression:

  Due to subgrade failure caused by weak subgrade soil where the underground watertable is high close to rice fields.

- Abrasion:

  Progressive wear of seal coat and separation of DBST cover aggregate from DBST layer.

Insufficient amount of binder spraying, spray streaking, (insufficient skill in binder chip application).

c) Bituminous Penetration Macadam Pavement

Survey results and causes of deterioration by section are presented in Table 7.3-12.

i) Pavement Structure

Bituminous Penetration Macadam (BMP) pavements surveyed three (3) locations are of the following structures.

Surface Course	BMP	3 cm to 4 cm thickness
Base Course	Waterbond Macadam	5 cm to 10 cm thickness
Subbase Course	No. 10 location :	14 cm thickness
	Crushed rock fragments and silt	
	No. 11 and 12 locations:	
	No Subbase	

The number of years these pavements have been in service since construction is about 8 years.

ii) Aggregate Properties of Base Course and Subbase Course

Waterbond Macadam base aggregates are crushed rock fragments whose maximum size is about 50mm.

iii) Surface Course Materials

Bituminous Materials Straight Asphalt 80/120
Aggregates

Base layer aggregates	30 – 10 mm
Key aggregates	20 – 10 mm
Cover aggregates	5 – 3 mm

iv) Bituminous Penetration Macadam

Base layer stones, whose single size and maximum size are of 50 mm to 30 mm, are spread over a prepared base and compacted. This is followed by the spraying of bituminous materials for penetration into the base stone layer. Then, size 20 mm to 10 m key stones are spread and rolled, which is then followed by the spraying of bituminous materials for penetration into the key stone layer. After one more this treatment, cover aggregates, 5 mm to 3 mm, are spread and rolled. This is an example of BMP surface construction practice.

TABLE 7.3-12 SUMMARY OF SURVEY RESULTS AND CAUSES OF DETERIORATION : BMP

Item	BMP Pavement in Fair to Bad Condition		BMP Pavement in Bad Condition
Section No.	No. 10	No. 11	No. 12
ADT (Vehicle/day)	668	668	668
Priod in Service	8 years	8 years	8 years
Subgrade CBR (%)	10	7	5
Deterioration			
Cracks (%)	5.9	4.6	10.5
Patching (%)	7.3	4.0	23.4
Abrasion (%)	-	4.5	4.1
Depression (%)	7.6	7.6	14.6
Roughness (σ) (mm)	4.3	5.7	7.1
B.B. Deflection (0.01mm)	138	131	233
Description of Condition and Causes of deterioration	Because of many patched areas and depressions, the riding quality is bumpy. However, most part of the surface shows a dense and waterproof surface texture. The "good" BMP layer has adequate flexibility and the asphalt in the layer that was observed by test pit excavation has not aged. The cause of depression due to partial weak subgrade soil was also observed. The Benkelman Beam deflection value is high, calling for an overlay with asphalt concrete. If properly constructed, it is anticipated that BMP surface course would have an adequate performance period of about 8 years under medium-volume traffic.		The surface in this location is severely deteriorated and riding quality is very bumpy. B.B. deflection is great. Reconstruction is required, for the reason that: (i) The absence of a subbase course has caused structural failure. (ii)BMP surface course abrasion because of aging and oxidization of the asphalt in the layer due to less amount of asphalt application.

The standard application rate for aggregates and bituminous materials used for this BMP method varies from country to country.

Table 7.3-13 shows the standard application rates obtained from the DPWH Standard Specifications.

The following bituminous materials are mostly used.

- Straight Asphalt — Penetration Grade 100-120, 120-150 and 150-200
- Cut-Back Asphalt — MC-800 and MC-3000, RC-800 and RC-3000
- Emulsified Asphalt — Cationic Emulsified Asphalt

Usually high viscosity bituminous materials are used for warmer region and under heavy traffic conditions.

TABLE 7.3-13 APPLICATION RATE OF MATERIALS FOR BMP
(Using Asphalt Cement or Rapid Curing Ashhalt)

	Bituminous Material lit/m	Aggregate kg/m		
		Coarse (50−13mm)	Key (13− 5mm)	Cover (10− 3mm)
First Spreading First Applicatoin	4.0	90		
Second Spreading Second Application	1.8		13	
Third Spreading Third Application	1.4		11	
Fourth Spreading				8
Total	7.2		122	

v) Causes of Deterioration

BMP pavement had been used for pavement construction up to about 8 years ago and since then this pavement has been seldom applied because of the widespread use of hot-mix asphalt concrete paving method.

Causes of deterioration are as follows:

- Surface Cracks:

  Caused by the failure of the BMP surface layer due to lack of stability or shearing resistance where the asphalt in the layer has lost its bonding and adhesive ability.
  Aging and oxidization of asphalt due to insufficient amount of asphalt application.

- Deformation of surface layer:

  Caused by lack of stability or shear resistance due to improper aggregates-asphalt application rate. Lack of interlock of aggregates due to improper application rate for base stone and key stone.

  Lack of interlock of aggregates due to excessive asphalt application rate.

- Alligator cracks and depression:

  Due to subgrade failure caused by weak subgrade.

d) Asphalt Concrete Pavement

Survey results and causes of deterioration by section are presented in Table 7.3-14.

i) Pavement Structure

Asphalt concrete (AC) pavement on surveyed three (3) locations, consist of the following structures.

Surface Course	Dense asphalt concrete 6 cm to 8 cm
Base Course	Crushed stone base 7 cm to 8 cm
Subbase	Crushed rock fragments 7 to 14 cm
Subgrade CBR	CBR Value for three (3) locations varies 5% to 8%

ii) Aggregate properties of Base and Subbase Course

Base course aggregates are mostly well-graded. The plasticity index is non-plastic and CBR value for three (3) locations varies from 31% to 61%.

Subbase course aggregates are rather finely graded. Plasticity index are non-plastic and CBR varies from 11% to 21%.

TABLE 7.3-14 SUMMARY OF SURVEY RESULTS AND CAUSES OF DETERIORATION : AC

Item	AC in Very Good Condition	AC in Fair to Bad Condition	
Section No.	No. 13	No. 14	No. 15
ADT (Vehicle/day)	1,338	2,068	2,064
Priod in Service	3 years	11 years	11 years
Subgrade CBR (%)	8	6	5
Deterioration			
Cracks (%)	-	22.7	25.5
Patching (%)	-	9.5	5.4
Depression (%)	-	15.9	13.8
Roughness (σ) (mm)	0.9	7.7	6.4
B.B. Deflection (0.01mm)	75	113	124
Description of Condition and Causes of deterioration	No deterioration in this section.	Because of the long years of service, the surface has deteriorated considerably and is bumpy. The bearing capacity of the pavement is considered to be fair. The asphalt concrete mixture is brittle and thus lacks adhesive and bonding ability because of the aging and oxidization of binder. Surface cracks are due to fatigue of the asphalt concrete surface layer and due to the base course and/or subbase course failure alligator cracks and depression is due to subgrade failure. Partial replacement and thick asphalt concrete overlay or total reconstruction is necessary for the projected growing heavy traffic volume.	The deterioration type, amount of deterioration and cause of the deterioration are mostly same as AC pavement on location No. 14. For a long lasting asphalt concrete pavement, the consideration for a design and construction of stable and durable asphalt concrete surface course should be given.

iii) Surface Course Materials

The maximum size of asphalt concrete is 19mm. The standard gradation range for dense asphalt concrete mixture is shown in Table 7.3-15.

The asphalt binder used is Asphalt Cement penetration grade 60/70.

TABLE 7.3-15 GRADATION RANGE FOR DENSE GRADED HOT PLANT MIX BITUMINOUS MIXTURE

(DPWH Standard Specifications)

Sieve Designation mm	Percent Passing Sieve by Weight	
	Type D	Type F
19 (3/4 inch)	100	100
12.5 (1/2 inch)	95-100	-
9.5 (3/8 inch)	74-92	-
4.75 (No.4)	48-70	45-65
2.36 (No.8)	33-53	33-53
1.18 (No.16)	22-40	-
0.600 (No.30)	15-30	-
0.300 (No.50)	10-20	10-20
0.075 (No.200)	4-9	3-8

iv) Causes of Deterioration

Mostly observed deteriorations and their causes are as follows:

- Surface cracks:

  Failure or fatigue of surface course asphalt concrete mixture caused by repetition of traffic.

  Low stability mixture at the time of construction.

  Aging of the asphalt for a longer service period of more than several years.

  Uneven bearing of the base course and subbase course.

- Alligator cracks and depression:

  Due to subgrade failure caused by presence of the weak subgrade soil.

  Rutting and deformation due to plastic flow of mixture by repetition of heavy traffic were not observed. Usually richer asphalt content mixture shows these deteriorations.

  Deterioration portions have been patched frequently throughout the year.

CHAPTER 8

EXPERIMENTAL PAVEMENT

8.1 PLANNING AND DESIGN

8.1.1 Selection of Sections for Experimental Pavement Construction

(1) Selection Criteria

The major purpose of experimental pavement construction is to analyze the functional performance of various types of pavement models with time and traffic loading repetition by conducting a follow-up survey for five (5) years and to provide the basic data for appropriate structural design of pavement including proper selection of pavement type according to traffic and subgrade conditions.

In order to achieve the purpose within the limited time, the criteria for selecting road sections for experimental pavement construction were proposed as follows:

a) Selection of Area

- The area should be selected among the Pilot Provinces in the Phase I Study or the Study Provinces in this Study because of availability of road and traffic data.
- The area should be located close to Metro Manila so as to provide convenience in conducting an effective follow-up survey by DPWH.
- All sections should be located in close by, preferably within one province for the same reason given above.
- Out of four (4) types of climate in the Philippines, the coverage of this Study will be limited to one type only, as an initial step of this kind of experimental works.

b) Characteristics of Sections to be Selected

i) Traffic Level

The economical pavement type depends on the traffic volume. Generally, GR and SBST are applicable to low volume roads, DBST and BMP to low to medium volume roads and AC and PCC to medium to high volume roads. To cover various types of pavements, sections should be selected so as to include three (3) different levels of traffic volume, low, medium and high.

ii) Subgrade Condition

Subgrade strength is one of the important factors that affect the structural performance of pavements. Sections should be selected so as to include two (2) different subgrade conditions, good and poor, for each traffic level.

c) Selection of Sections

The criteria for section selection are as follows:

- To satisfy as much as possible the requirements on traffic level and subgrade condition as mentioned in b) above.
- To be either unpaved or in a bad condition in existing pavement.
- To be accessible for construction equipment.
- To be homogeneous over required length, not including undulation, localized condition, etc.
- To be neither steep in gradient nor sharp in horizontal curvature.
- To be free of factors that may cause a drastic change in traffic volume in the near future, such as construction of an interchange in the vicinity.

(2) Selection of Road Sections for Experimental Pavement Construction

a) Selection of Area

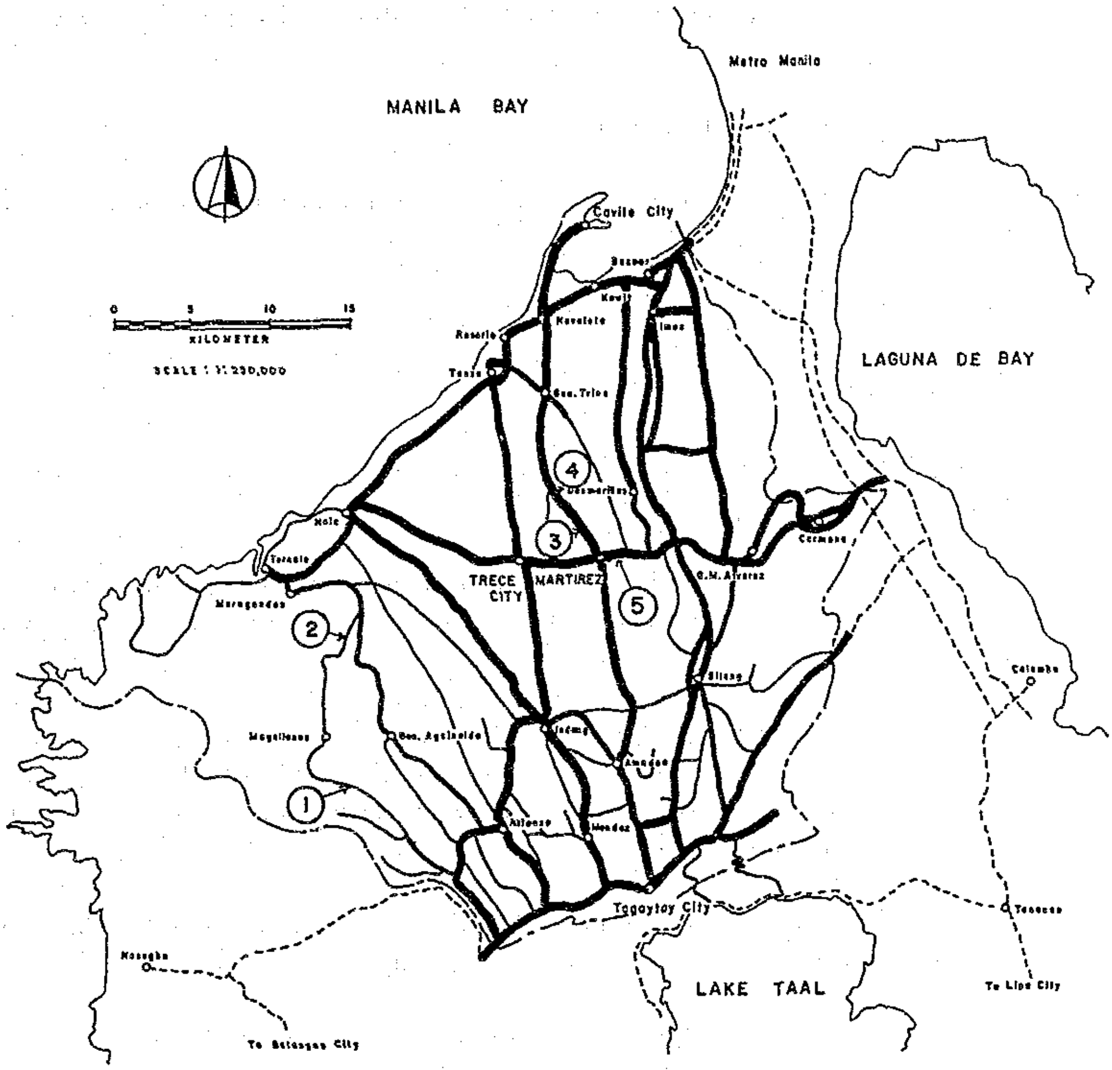
The Province of Cavite, including its vicinity, was selected for the following reasons:

- Cavite is one of the Pilot Provinces in the Phase I Study, where road and traffic data are available.
- Cavite is located near Metro Manila.

b) Selection of Sections

After evaluating many candidate sections through field reconnaissance, five (5) sections were selected as shown in Figure 8.1-1;

Section (1) : Low traffic, good subgrade
Section (2) : Low traffic, weak subgrade
Section (3) : Medium to high traffic, good subgrade
Section (4) : Medium to high traffic, weak subgrade
Section (5) : High traffic, good subgrade



PROVINCE OF CAVITE

LEGEND :

TRAFFIC VOLUME : AADT

> 400

200~400

< 200

PROPOSED EXPERIMENTAL PAVEMENT CONSTRUCTION SECTIONS

SECT. NO.	TRAFFIC VOLUME AADT *	SUBGRADE CONDITION	TYPE OF EXPERIMENTAL PAVEMENT
1	235	GOOD	GR SBST DBST BMP
2	144	POOR	GR SBST DBST BMP
3	942	GOOD	DBST BMP HAC(4cm) HAC(5cm)
4	942	POOR	DBST BMP HAC(4cm) HAC(5cm)
5	2174	GOOD	HAC(5cm) PCC(18cm)

* AS OF JUNE 1988

REMARKS :

GR : GRAVEL SURFACING
SBST : SINGLE BITUMINOUS SURFACE TREATMENT
DBST : DOUBLE BITUMINOUS SURFACE TREATMENT
BMP : BITUMINOUS PENETRATION MACADAM
HAC : HOT MIX ASPHALT CONCRETE
PCC : PORTLAND CEMENT CONCRETE

FIGURE 8.1-1 EXPERIMENTAL PAVEMENT CONSTRUCTION ROAD SECTIONS

The section with high traffic and weak subgrade was not selected, because of the absence of an appropriate section under such category that satisfied the selection criteria.

(3) Characteristics of Selected Road Sections

The characteristics of selected road sections for experimental pavement construction are summarized in Table 8.1-1.

8.1.2 Type of Experimental Pavement Models

(1) Selection Criteria

In selecting the experimental pavement models, the following factors were taken into consideration:

i) Various types of low-class pavement should be tested for their serviceability performance to obtain basic data for determining an appropriate serviceable life for each type of pavement.

ii) In the DPWH/DLG Design Standards, a typical pavement type for the respective levels of traffic is proposed as shown in Table 8.1-2. Model tests should be planned in due consideration of these standards, particularly for pavement type versus traffic volume.

iii) As the follow-up survey period will be five (5) years, the serviceable life should be preferably examined for within that period.

iv) As mentioned in Section 7.1 of this report, SBST and BMP are not commonly used in this country. However, the possibility of using these types of pavement more effectively should be examined through experimental construction and the follow-up survey.

v) For PCC pavements, the most commonly used thickness is 20 cm or above. In this Study, 15cm-thick PCC pavements which is considered to be of the minimum thickness should be tested its performance;

Figure 8.1-2 conceptually illustrates the change in the serviceability of low-class pavements with time.

TABLE 8.1-1 CHARACTERISTICS OF SELECTED ROAD SECTIONS

Experimental Pavement Construction Road Section No.	Road Classifi-cation	Location	Typical Cross-Section (m)	Traffic Volume (AADT)	Present Condition of Pavement	Subgrade Condition	Land Use	Remarks
No. 1	Provincial Road	Jct. Alfonso Magallanes Road	CW-6.0 ROW-12.0	174	TP-Gravel	Good	Coconut and Pineapple Plantation	Gravel Surface: In some portion, subgrade materials are appeared and outcrop bouldersare seen on the surface
No. 2	Provincial Road	Magallanes-Maragondon	CW-6.0 ROW-12.0	123	TP-Gravel SC-Bad	Poor	Ricefield	Gravel Surface: Scattered potholes on surface in some portion No shoulder on both side
No. 3	Provincial Road	Gen. Trias-Jet. Carmona Trece Martirez Road	CW-6.0 Sh-2x1.25 ROW-12.0	784	TP-DBST SC-Bad Deteriorated	Good	Ricefield Residential	DBST Surface: Deteriorated with some cracks and potholes.
No. 4	Provincial Road	Gen. Trias-Jet. Carmona Trece Martirez Road	CW-6.0 Sh-2x1.25 ROW-12.0	784	TP-DBST SC-Bad Deteriorated	Poor	Ricefield	DBST Surface: Deteriorated with some cracks.
No. 5	National Road	Trece Martirez-G.M.Alvarez	CW-6.0 ROW-12.0	2,404	TP-HAC SC-Bad	Good	Sugarcane Plantation on both sides	- with scattered potholes on road surface - alligator cracks on DBST pavement

Legend:

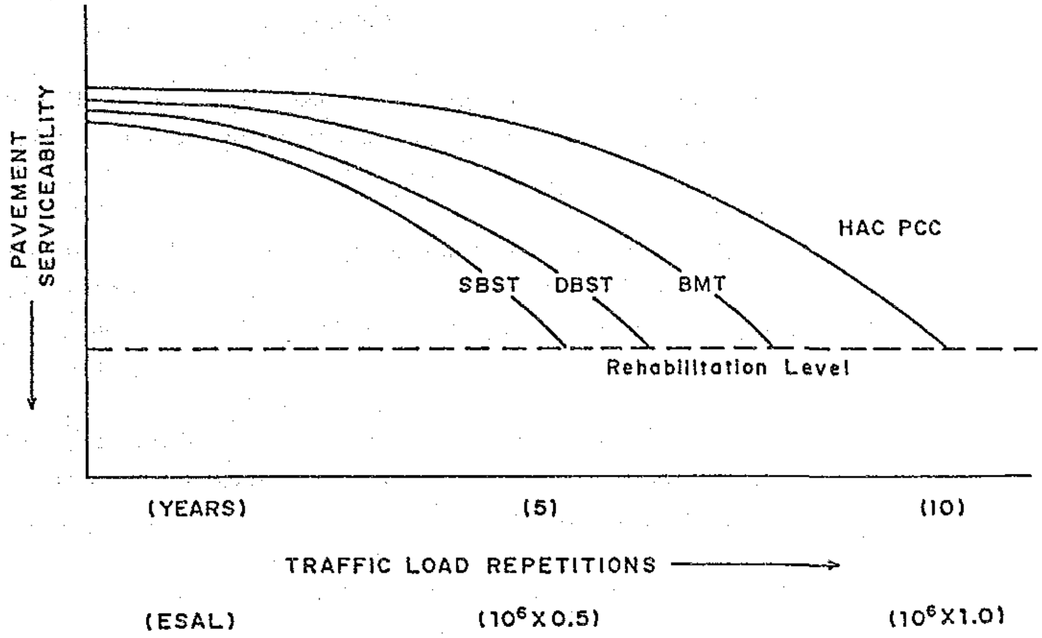
CW - Carriageway with (m)
Sh - Shoulder (m)
Row - Road right of Way (m)

TP - type of Pavement
SC - Surface Condition

TABLE 8.1-2 STANDARD PAVEMENT TYPES PROPOSED BY THE PILOT STUDY OF RURAL ROAD NETWORK DEVELOPMENT PROJECT BASED ON DPWH/DLG DESIGN STANDARDS

Class of Roads	AADT in Opening Year				
	Under 100	100-200	200-400	400-2000	Over 2000
Primary Major Road	GR	DBST/ BMP	DBST/ BMP	HAC	PCC
Secondary Major Road	GR	GR	DBST/ BMP	HAC	HAC

Class of Roads	AADT in Opening Year		
	Under 200	200-400	Over 400
Collector Road	GR	DBST/ BMP	HAC
Feeder Road	GR	DBST/ BMP	HAC



ESAL : Cumulative Equivalent 8.2-ton Single Axle Loads

Serviceability of GR surfacing may be recovered by routine maintenance operation (once a year or so).

FIGURE 8.1-2 CONCEPTUAL ILLUSTRATION OF CHANGE IN SERVICEABILITY OF LOW-CLASS PAVEMENTS WITH TIME

The length of a single model was set to 200 meters for the following reasons:

i) When the model length is shorter than 200 meters;

- As the assessment of performance may be governed by localized damages/ failures, the general performance of the pavement may not be properly assessed.

- Joint areas between models should not be assessed, because these areas may be affected by deterioration of adjacent weak pavement. Therefore, a model length of 200 meters means that a net length of 150 meters will be assessed.

ii) When the model length is longer than 200 meters, it is difficult to find a homogeneous section of a length of more than 1,000 meters in terms of traffic, subgrade and drainage conditions.

(2) Selection of Types of Experimental Pavement Models

The following five (5) sections were selected as the experimental pavement construction sites.

Section (1) : Representative section of low traffic and good subgrade condition.

Section (2) : Representative section of low traffic and poor subgrade condition.

Section (3) : Representative section of medium traffic and good subgrade condition.

Section (4) : Representative section of medium traffic and poor subgrade condition.

Section (5) : Representative section of high traffic and good subgrade condition.

For each section, the following models were recommended for construction. The detailed structural thickness will be determined at Stage 2 after obtaining traffic data and subgrade bearing capacity. Experimental pavement models are summarized in Table 8.1-3.

Section No. 1 AADT = 170, Heavy Vehicle=14/day Subgrade condition = good

4 x 200^m = 800 m.

Models	GR	SBST	DBST	BMP

Design Performance Period (X): X = 2 - 5 years (GR, SBST); X = 4 - 8 years (DBST, BMP)

Expected Output of Follow-up Survey:

- X = 2 - 5 years → Performance Period
- X = 4 - 8 years → Functional Performance within 5 years after construction → Forecast of Performance Period

Section No. 2 AADT = 120, Heavy Vehicle=12/day Subgrade condition = poor

Models : Same as Section No. 1

Section No. 3 AADT = 780, Heavy Vehicle=50/day Subgrade condition = good

4 x 200^m = 800 m.

Models	DBST	BMP	AC-1 (4 cm)	AC-2 (5 cm)

Design Performance Period (X): X = 4 - 8 years (DBST, BMP, AC-1); X = 7 - 10 years (AC-2)

Expected Output of Follow-up Survey:

- X = 4 - 8 years → Performance Period
- X = 7 - 10 years → Functional Performance within 5 years after construction → Forecast of Performance Period

Section No. 4 AADT = 780, Heavy Vehicle=50/day Subgrade condition = poor

Models : Same as Section No. 3

Section No. 5 AADT = 2,400, Heavy Vehicle=390/day Subgrade condition = good

2 x 200^m = 400^m

Models	AC-2 (5 cm)	PCC (18 cm)

Design Performance Period (X): X = 3 years (AC-2); X = 8 years (PCC)

Expected Output of Follow-up Survey:

- X = 3 years → Performance Period
- X = 8 years → Functional Performance within 5 years after construction → Forecast of Performance Period

TABLE 8.1-3 SUMMARY OF EXPERIMENTAL PAVEMENT MODELS

Road Section	Traffic Condition	Subgrade Condition	Pavement Surface Type	No. of Models	Length (m)
No. 1	Low	Good	GR,SBST,DBST,BMP	4	800
No. 2	Low	Poor	GR,SBST,DBST,BMP	4	800
No. 3	Medium	Good	DBST,BMP,HAC (4 cm), HAC (5 cm)	4	800
No. 4	Medium	Poor	DBST,BMP,HAC (4 cm), HAC (5 cm)	4	800
No. 5	High	Good	HAC (5 cm), PCC (15 cm)	2	400
TOTAL :	5 Road Sections			18	3600

8.1.3 Traffic Survey

The two (2) kinds of traffic survey described below were conducted along the sections selected for experimental pavement construction.

(1) Traffic Count Survey

The 12-hour traffic count survey by vehicle type and by direction was conducted at four (4) locations for three (3) days. The locations of survey stations are as follows:

Survey Station 1 : Jct. Alfonso – Magallanes
(Experimental Pavement Section 1)

Survey Station 2 : Magallanes – Maragondon
(Experimental Pavement Section 2)

Survey Station 3 : Mangahan Jct. – Gen. Trias
(Experimental Pavement Section 3 and 4)

Survey Station 4 : Mangahan Jct. – Carmona
(Experimental Pavement Section 5)

The findings of the traffic count survey are summarized in Table 8.1-4.

TABLE 8.1-4 SUMMARY OF TRAFFIC SURVEY RESULTS
(AADT as of November 7 to 9, 1989)

Survey Station	EPC Section	Car/Jeep	Van	Jeepney	Bus	Truck	Total
1	1	26	64	70	0	14	174
2	2	28	14	69	0	12	123
3	3&4	171	242	319	4	48	784
4	5	784	606	622	118	274	2,404

Note : EPC Section = Experimental Pavement Construction Section

(2) Loadometer Survey

Loadometer surveys were conducted for two (2) days at the same survey stations as the traffic count survey.

Loadometer survey was not conducted for Survey Station NO. 2 because of similar track traffic characteristics with Survey Station No. 1.

Number of vehicles weighed is summarized in Table 8.1-5.

TABLE 8.1-5 NUMBER OF VEHICLES WEIGHED

Survey Station	EPC Section	Direction	Number of Vehicles Weighed	
			Trucks	Buses
1	1 & 2	1: To Magallanes	5	-
		2: To Jct. Alfonso	5	-
3	3 & 4	1: To Jct. Mangahan	75	2
		2: To Gen. Trias	86	2
4	5	1: To Jct. Mangahan	151	24
		2: To Carmona	122	25

The vehicle load factor for converting the number of 18-kip (or 8.2-ton) Equivalent Single Axle Load (ESAL) for trucks and buses was computed from the following equation based on the surveyed axle load distribution and Traffic Equivalence Factor for Flexible and Rigid Pavements of AASHTO Road Test.

$$VLF = \frac{1}{N} \sum_{i=1}^{n} (n_i \times e_i)$$

where: VLF = vehicle load factor
n_i = number of axles for axle load group i
e_i = traffic equivalence factor for axle load group i
n = total number of axles
N = total number of vehicles

The computed vehicle load factors are shown in Tables 8.1-6 and 8.1-7 for Asphalt pavements and PCC pavements respectively.

TABLE 8.1-6 VEHICLE LOAD FACTOR FOR ASPHALT PAVEMENTS

Survey Station	EPC Section	Direction	Trucks		Bus	
			Number of Vehicles	Load Factor	Number of Vehicles	Load Factor
1	1 & 2	1	5	0.456	-	-
		2	5	0.551	-	-
			Average	0.503	-	-
3	3 & 4	1	75	0.533	2	0.038
		2	86	1.375	2	0.038
			Average	0.992	Average	0.038
4	5	1	151	2.003	24	0.431
		2	122	0.281	25	0.787
			Average	1.233	Average	0.613

Note: Based on the (AASHTO road Test) axle equivalency factors for flexible pavements, pt = 2.0 and SN = 2.0.

TABLE 8.1-7 VEHICLE LOAD FACTOR FOR PCC PAVEMENTS

Survey Station	EPC Section	Direction	Trucks		Bus	
			Number of Vehicles	Load Factor	Number of Vehicles	Load Factor
4	5	1	151	0.225	24	0.407
		2	122	0.339	25	0.706
			Average	1.362	Average	0.559

Note: Based on the (AASHTO road Test) axle equivalency factors for rigid pavements, pt = 2.0 and D = 7 in.

8.1.4 Engineering Survey

(1) Topographic Survey

Topographic, profile and cross-section surveys were carried out for each experimental pavement construction section and the following drawings were prepared:

Topographic drawings	:	Scale 1 : 1,000
Profile	:	Scale 1 : 1,000 (horizontal)
		1 : 100 (vertical)
Cross-sections at 20-m intervals	:	Scale 1 : 50

(2) Soil Investigation

Soil investigation and laboratory tests were carried out for the experimental pavement construction sections to obtain necessary data for the structural design of experimental pavements.

The survey items examined for each section are shown in Table 8.1-8. Samples from selected sites were obtained and tested by the Bureau of Research and Standard. The test results are summarized in Table 8.1-9.

Road condition survey records, soil boring log records and triangular gradations are attached in Appendices 8-1, 8-2, and 8-3, respectively.

TABLE 8.1-8 SOIL SURVEY AND LABORATORY TEST ITEMS

Survey/Test		Items
Field Survey	Road Condition	100 m internals: Cross section Condition of carriage way Shoulder, drainage
	Auger boring and Sampling	100 m intervals, 1.0 m depth: observation of soil properties water table
Laboratory Tests		. Natural water content . Sieve analysis . Consistency: LL, PL, PI . Soaked CBR

TABLE 8.1-9 (1) SUBGRADE SOIL PROPERTY OF LOW-CLASS PAVEMENT EXPERIMENTAL CONSTRUCTION SECTION

Experiment Section No. Length / Environmental Condition	Boring No.	Sieve Analysis (Passing % by wt.) Sieve Size (mm) 37.5	19.0	12.5	9.5	4.75	2.00	0.425	0.075	Liquid Limit	Plasticity Index	Natural Moisture Content %	* Soaked CBR %	Swell %	Soil Classification	>2.00 mm	200 – 0.075 mm	<0.075 mm
Section No. 1 L = 800 m. Jct. Alfonso to Magallanes road	No. 1	100	94	91	88	82	74	56	36	NP	NP	36.43	12	0	SM	26	38	36
	No. 2			100	99	98	97	89	77	44	11	36.20	5	0.17	ML	3	20	77
	No. 3	100	98	92	90	84	71	46	26	NP	NP	29.17	19	0	SM	29	45	26
The project road at this point run through flat terrain passing accross the level of grassy, coffee, banana, corn, coconut, pineapple plantation and some trees around.	No. 4			100	99	99	97	93	86	64	16	65.93	3	0.065	MH	3	11	86
	No. 5	100	91	87	83	75	58	41	30	NP	NP	48.62	9	0	SM	42	28	30
	No. 6				100	99	99	97	92	73	25	56.50	7	2.42	MH	1	7	92
	No. 7		100	98	98	97	95	92	81	73	31	47.13	6	2.05	MH	5	14	81
	No. 8		100	98	96	97	96	94	92	76	24	60.56	5	0.15	MH	4	4	92
Section No. 2 L = 800 m. Magallanes to Maragondon	No. 1		93	91	90	86	82	73	64	52	20	24.26	4	0.28	MH	18	18	64
	No. 2		100	98	96	92	81	53	24	NP	NP	29.88	15	0	SM	19	57	24
	No. 3		100	99	99	98	94	86	75	58	26	51.55	2	0	MH	6	19	75
The road generally run on the ridge through grassy, young corn, mango, banana and bamboo trees. The vertical alignment is rolling above the surrounding land and the surface is gravel.	No. 4		100	99	98	96	90	78	65	47	17	33.22	10	0.39	ML	10	25	65
	No. 5			100	99	98	96	85	71	42	14	28.62	11	0.39	ML	4	25	71
	No. 6			100	99	95	89	77	67	42	16	22.98	3	5.45	MH	11	22	67
	No. 7		100	97	96	93	87	74	53	56	20	50.14	10	0.24	MH	13	34	53
	No. 8		100	98	97	96	91	78	66	NP	NP	45.54	2	0	ML	9	25	66

UNIFIED SOIL CLASSIFICATION

LEGEND:
- SM Silty sands, silty gravelly sands
- SC Clayey sands, clayey gravelly sands
- ML Silts, Very fine sands, silty or clayey fine sands
- MH Micaceous silts, diatomaceous silts, volcanic ash
- CL Low plasticity clays, Sandy or silty clays
- CH High plasticity clays, sandy clays

NOTE:
- * Natural Water Content
- 67 blows per each 3 layer
- 4 days soaking

TABLE 8.1-9 (2) SUBGRAGE SOIL PROPERTY OF LOW-CLASS PAVEMENT EXPERIMENTAL CONSTRUCTION SECTION

Experiment Section No. Length / Environmental Condition	Boring No.	Sieve Analysis (Passing % by wt.) Sieve Size (mm) 37.5	19.0	12.5	9.5	4.75	2.00	0.425	0.075	Liquid Limit	Plasticity Index	Natural Moisture Content %	*Soaked CBR %	Swell %	Soil Classification	>2.00 mm	200 – 0.075 mm	<0.075 mm
Section No. 3 L = 800 m. Gen. Trias to Amadeo	No. 1	100	95	88	86	80	74	65	53	51	12	45.10	3	0	MH	26	21	53
	No. 2	100	96	93	90	84	71	50	43	NP	NP	24.32	8	0	SM	29	28	43
	No. 3	100	94	91	88	82	72	51	30	NP	NP	29.05	4	0	SM	28	42	30
Through this area of flat terrain the alignment standard are quite good. The profile however is generally low with water standing in the shallow ditch depression. Both sides is residential and vegetated area.	No. 4	100	93	91	87	79	68	54	44	52	21	36.44	4	0	SC	32	24	44
	No. 5		100	98	97	93	84	70	59	44	14	28.57	10	0.54	ML	16	25	59
	No. 6	100	95	93	92	86	71	43	24	NP	NP	26.18	7	0	SM	29	47	24
	No. 7	100	90	82	79	71	60	41	22	NP	NP	17.32	68	0	SM	40	38	22
	No. 8	100	86	80	77	67	57	42	29	NP	NP	31.96	17	0	SM	43	28	29
Section No. 4 L = 800 m. Gen. Trias to Amadeo	No. 1	100	90	87	85	77	64	45	28	NP	NP	19.86	12	0	SM	36	36	28
	No. 2		100	99	98	96	88	67	43	NP	NP	22.34	11	0	SM	12	45	43
	No. 3	100	90	89	88	81	71	57	44	40	15	32.54	8	0.13	SC	29	27	44
The road crosses through rice field on both sides with generally good vertical and horizontal alignment.	No. 4		100	97	97	94	88	77	60	51	21	39.91	5	0.22	MH	12	28	60
	No. 5		100	99	97	93	84	63	36	NP	NP	39.93	3	0	SM	16	48	36
	No. 6	100	80	78	76	73	66	47	26	NP	NP	24.76	14	0	SM	34	40	26
	No. 7		100	99	99	95	89	76	59	42	15	39.49	5	0.13	ML	11	30	59
	No. 8	100	97	96	93	88	78	63	51	41	15	37.98	5	0.13	ML	22	27	51

UNIFIED SOIL CLASSIFICATION

LEGEND:
- SM Silty sands, silty gravelly sands
- SC Clayey sands, clayey gravelly sands
- ML Silts, Very fine sands, silty or clayey fine sands
- MH Micaceous silts, diatomaceous silts, volcanic ash
- CL Low plasticity clays, Sandy or silty clays
- CH High plasticity clays, sandy clays

NOTE:

* Natural Water Content
67 blows per each 3 layer
4 days soaking

TABLE 8.1-9 (3) SUBGRADE SOIL PROPERTY OF LOW-CLASS PAVEMENT EXPERIMENTAL CONSTRUCTION SECTION

Experiment Section No. Length / Environmental Condition	Boring No.	Sieve Analysis (Passing % by wt.) Sieve Size (mm) 37.5	19.0	12.5	9.5	4.75	2.00	0.425	0.075	Liquid Limit	Plasticity Index	Natural Moisture Content %	*Soaked CBR %	Swell %	Soil Classification	>2.00 mm	200 0.075 mm	<0.075 mm
Section No. 5 L = 400 m. Trece Martirez to G. M. Alvarez	No. 1	100	98	96	96	90	81	71	59	54	16	39.49	4	0	MH	19	22	59
	No. 2	100	91	81	78	68	57	42	28	38	13	19.88	19	0	SC	43	29	28
	No. 3	100	92	89	86	76	66	49	33	29	8	19.90	7	0	SC	34	33	33
The road run up accross the ridge through level of grassy pasture land.	No. 4		100	99	98	93	88	79	71	50	17	34.51	8	0.26	MH	12	17	71

UNIFIED SOIL CLASSIFICATION

LEGEND:
- SM Silty sands, silty gravelly sands
- SC Clayey sands, clayey gravelly sands
- ML Silts, Very fine sands, silty or clayey fine sands
- MH Micaceous silts, diatomaceous silts, volcanic ash
- CL Low plasticity clays, Sandy or silty clays
- CH High plasticity clays, sandy clays

NOTE:

\# Natural Water Content

67 blows per each 3 layer

4 days soaking

Current road conditions are as follows:

i) Section No. 1

Surface condition of this section for the most part was found to be irregular and bumpy due to poor graded sand and gravel containing cobbles and boulder.

ii) Section No. 2

This section is in a fair to good conditions, consisting in part a weak subgrade of silty clay soil. The existing gravel surface along the test section is quite well maintained but some portions which is partly comprised of boulder materials tend to be bumpy.

iii) Sections No. 3 and No. 4

These sections are in fair to bad conditions, with deterioration mostly found in areas adjacent to a wide ricefield area. Roadside drainage is poor along the whole length of the ricefield tract requiring ditch reshaping to rectify the problem.

iv) Section No. 5

Although this section has been patched well and maintained at frequent intervals throughout the year, due to repeating loading by heavy trucks passing by, the section deteriorates easily.

(3) Material Survey

a) Material Survey

The pavement material sources for experimental pavement constructions were studied, and laboratory tests on the materials were carried out at the Bureau of Research and Standard Laboratory. The test items are shown in Table 8.1-10.

TABLE 8.1-10 TEST ITEMS FOR PAVEMENT MATERIALS

Test Items	Materials	
Materials Standard Properties	Surface Course	Straight Asphalt Cut-back Asphalt Emulsified Asphalt Portland Cement Gravel, Sand Crushed Stone
	Base and Sub-base Course	Combined Crushed Stone Crushed Stone river-run, sandy, gravel
Mixture Design		Cement Concrete

Test results were examined and applied in structural design and construction of experimental pavements.

b) Findings of Material Survey

i) Base and Subbase Course Aggregates

The test results of combined crushed stone aggregates for the base course and river-run sandy gravel for the subbase course are presented in Appendix 8-4. The results meet DPWH specification requirements.

ii) Surface Course Aggregates

The test results of course aggregates and fine aggregates for the surface course are presented in Appendix 8-4. The results meet DPWH specification requirements.

iii) Portland Cement Concrete Mixture Design

The test results of the mixture design are presented in Appendix 8-4. The results meet DPWH specification requirements.

iv) Straight Asphalt, Cut-back Asphalt and Emulsified Asphalt

The standard properties of these asphaltic materials were studied from the various test reports of the Bureau of Research and Standard Laboratory. Most test results conform to the DPWH specification requirements (AASHTO M20, AASHTO M82 and AASHTO M140). Representative test reports are presented in Appendix 8-4.

v) Cement

The test results obtained for Type 1 cement for PCC pavements are presented Appendix 8-4. The results meet DPWH specification requirements. (AASHTO M85)

8.1.5 Structural Design

(1) Design Methods

a) Design Methods for Bituminous Pavements

The following design methods were reviewed for the structural design of experimental construction for the low-class pavements.

- The Basic Design Equation for Flexible Pavements, AASHTO Guide for Design of Pavement Structures (1986)

- Road Note 29. A Guide to the Structural Design of Pavement for New Roads (TRRL 1970)

- Road Note 31. A Guide to Structural Design of Bituminous Surfaced Roads in Tropical and Sub-tropical Countries (TRRL 1977)

- Manual for Design and Construction of Asphalt Pavements (Japan Road Association 1988)

The design practice of the design methods are described below.

i) AASHTO Guide for Design of Pavement Structures

Design of asphalt concrete and surface treatment pavements carrying significant levels of traffic (i.e., greater than 50,000 8.2-ton ESAL) during the performance period.

Design Equation and Design Chart (Nomograph) are provided.

Design Input:

W = Cumulative number of 8.2 ton ESAL
M = Subgrade soil resilient modulus (psi)
pt = Design terminal serviceability index, or
Δ PSI = Difference between initial design serviceability index and design terminal serviceability index (Δ PSI=po-pt)

Design Output:

* Pavement Structural Number, SN
* Layer thickness of pavement structure obtained from SN equation

$$SN = \sum_i (D_i \times a_i)$$

where, D_i = ith layer thickness (inches),
a_i = ith layer coefficient

The flow of structural design by the AASHTO design method is shown in Figure 8.1-3.

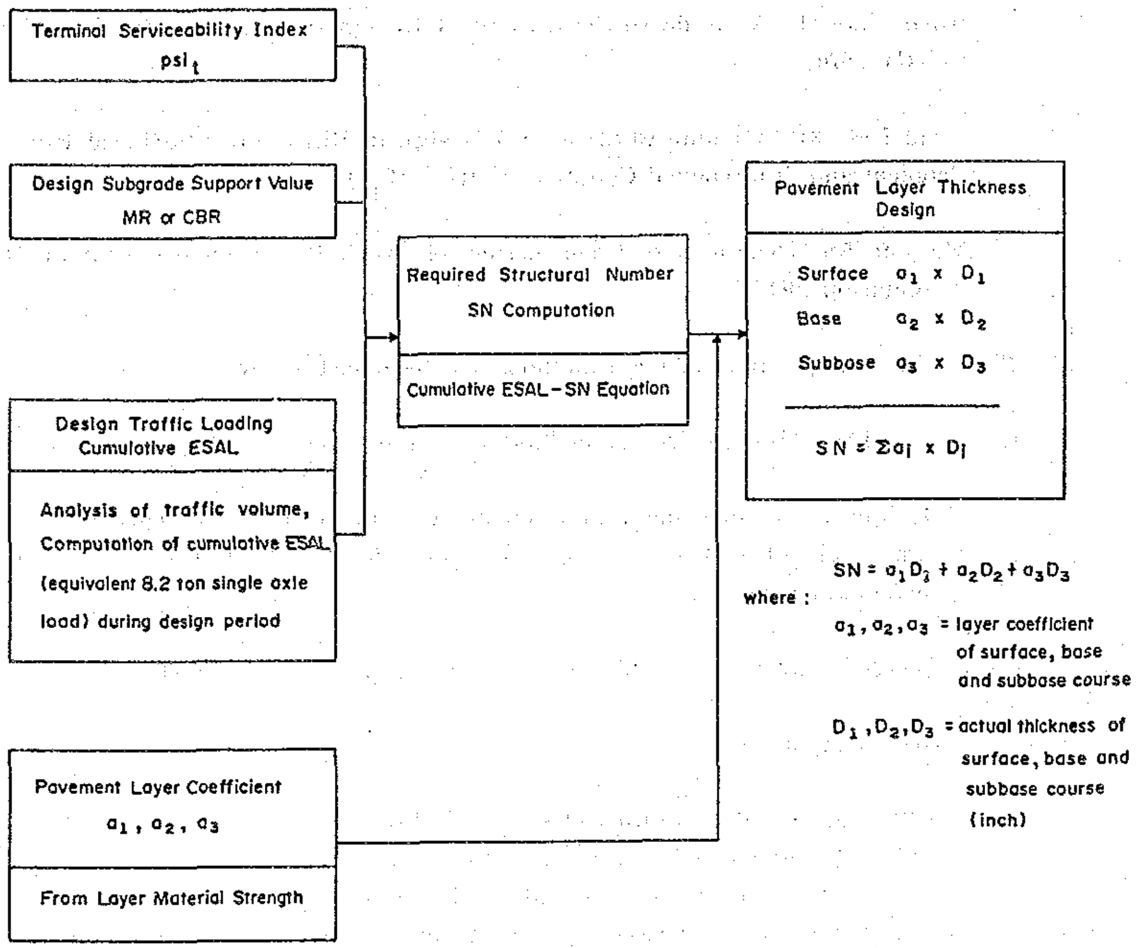


FIGURE 8.1-3 FLOW OF FLEXIBLE PAVEMENT STRUCTURAL DESIGN AASHTO DESIGN GUIDE (1986) METHOD

ii) Road Note 29

Design for rolled asphalt and coated macadam pavements carrying from 10,000 to 80 million 8.2 ton ESAL over the design period.

The following design charts are introduced.

Minimum thickness of surfacing and road base for design ESAL

- Rolled asphalt road base
- Dense macadam road base
- Lean concrete road base soil cement and cement-bound granular road base.
- Wet-mix and dry-bound macadam road base

Thickness of subbase for design ESAL and subgrade CBR value

iii) Road Note 31

Design for bituminous surface treatment and asphalt concrete pavements carrying from 50,000 to 2.5 million 8.2 ton ESAL over the design period.

Design charts are introduced for type of bituminous surfacing, base course thickness for the following design ESAL range, and required subbase thickness for the design ESAL and subgrade CBR value.

- Design ESAL of up to 0.5 million

  Bituminous surface treatment with 15 cm crushed stone base.

- Design ESAL of over 0.5 million

  For stage construction:

  To add either a 5cm asphalt concrete overlay or a 7.5cm crushed stone course with bituminous surface treatment.

  For complete construction:

  To be either a 5 cm asphalt concrete surface with 15 cm crushed stone base or bituminous surface treatment with 20 cm crushed stone base.

iv) Japan Road Association Design of Asphalt Pavements

Design for asphalt concrete pavements carrying light-traffic to heavy-traffic.

Design Equations and Design Charts are introduced.

Design Input : Cumulative number of 5.0 ton equivalent wheel loads over design period N, subgrade CBR value

Design Output : Pavement thickness H (cm) Pavement structural thickness T_A (cm).

T_A = Required thickness if the total depth of the pavement is to be constructed using hot asphalt concrete for surface course.

The layer thickness of surface, base and subbase course are obtained from the following T_A equation.

$$T_A = \sum_i (a_i \times T_i)$$

where, a_i = Conversion coefficient of i th layer

Example of conversion coefficient.

Surface hot mix asphalt concrete
$a_1 = 1.0$

Base Crushed stone CBR = 80 %
$a_2 = 0.35$

Subbase Crusher run CBR = 25 %
$a_2 = 0.25$

T_i = Thickness of pavement components of i th layer

A design catalogue for the pavement thickness (Surface, Base and Subbase), is provided for subgrade CBR (CBR = 2, 3, 4, 6, 8, 12 and 20), five traffic volume classes, and for a 10-year design period.

b) Design Methods for PCC Pavement

The Basic Equation for Rigid Pavements provided in the AASHTO Guide for Design of Pavement Structure (1986), was used for the structural design of PCC pavement model.

c) Design Methods for Gravel Surfaced Pavement

Low-Volume Road Design and Design Chart for Aggregate-Surfaced Roads provided in the AASHTO Guide for Design of Pavement structure (1986), were used for the structural design of gravel surfaced pavement models.

After careful studies of the design methods, the Study Team adopted the methods developed by the AASHTO Guide for Design of Pavement Structure, 1986.

Design equations and design charts are provided in Appendix 8-5.

(2) Structural Design of Experimental Pavement Models

a) Design Condition

The following design conditions were applied for the structural design of experimental pavement models.

i) Traffic Condition

Based on the findings of the traffic volume survey and axle load distribution survey, the following traffic data as shown in Table 8.1-11 were adopted in design.

TABLE 8.1-11 TRAFFIC CONDITION

Section	Truck		Bus		Traffic Growth Rate p.a.
	Number of Vehicles*	Load Factor	Number of Vehicles*	Load Factor	
No. 1, No. 2	7	0.503	-	-	3.0%
No. 3, No. 4	24	0.922	2	0.038	3.0%
No. 5	137	1.233	59	0.613	5.0%
No. 5	137	1.362**	59	0.559**	5.0%

* Number of vehicles: per day direction
** Vehicle Load Factor for PCC pavement
Traffic growth rate was assumed.

ii) Design Performance Period

The expected performance period up to the point the pavement terminal serviceability index (pt = 1.5 and pt = 2.0) level is reached for each pavement model shown in Table 8.1-12 was adopted in design.

TABLE 8.1-12 DESIGN PERFORMANCE PERIOD

Section	Traffic Condition	Pavement Model	Terminal Serviceability Index pt	Design Performance Period
No. 1 through No. 4	Low and Medium	GR	*RD=2.5 in	5 years
		SBST	1.5	2 years
		DBST	1.5	4 - 5 years
		BMP	1.5	7 - 8 years
		AC (4 cm)	2.0	7 - 8 years
		AC (5 cm)	2.0	9 -10 years
No. 5	Heavy	AC (5 cm)	2.0	3 years
		PCC (18 cm)	2.0	8 years

* RD : Allowable Ruting Depth

As the means used for investigating the service performance of medium-type, 5 cm AC pavement structures and 18 cm PCC pavement structures, during the 5-year follow-up survey period, the accelerated procedure for accumulation of heavy traffic was adopted for road section No. 5.

Pavement structures with an expected performance period of 3 years (pt = 2.0 level) were designed for 5 cm AC pavements and that of 8 years (pt = 2.0 level) for 18 cm PCC.

iii) Design CBR Values for Subgrade

Based on the findings of the subgrade soil condition survey conducted for each section and those of subgrade soil laboratory tests, design subgrade values as shown below were adopted.

TABLE 8.1-13 DESIGN CBR VALUE

Section	Pavement Model	Design CBR	Section	Pavement Model	Design CBR
No. 1	No. 1 GR	4 %	No. 2	No. 5 GR	3 %
	No. 2 SBST	4 %		No. 6 SBST	3 %
	No. 3 DBST	4 %		No. 7 DBST	3 %
	No. 4 BMP	4 %		No. 8 BMP	3 %
No. 3	No. 9 DBST	3 %	No. 4	No. 13 DBST	8 %
	No. 10 BMP	3 %		No. 14 BMP	5 %
	No. 11 AC (4cm)	8 %		No. 15 AC (4cm)	3 %
	No. 12 AC (5cm)	8 %		No. 16 AC (5cm)	3 %
No. 5	No. 17 AC (5cm)	5 %			
	No. 18 PCC(18cm)	5 %			

The subgrade CBR values determined for each section are as described in Appendix 8-6

The required SN was computed from the $M_R = 1500 \times CBR$ correlation formula, instead of from the subgrade soil Resilient Modulus M_R (psi).

iv) Material

Cavite province has scarce material sources and only materials of subbase course are found near the construction sites. Although experimental pavements including the use of locally available material for base course and/or gravel surfacing are considered worthwhile in pursuit of cost savings, the use of local materials are, in this project, limited for subbase course in construction of the purpose of the project which is to analyze the functional and structural performance of various types of pavement models constructed in the conventional way with conventional materials in accordance with the current specifications. Thus, all materials are assumed to be procured in Metro Manila and Rizal Province except for subbase course material to be obtained from the quarry near the construction sites.

v) Layer Coefficient

In flexible pavement design, AASHTO Design Guide (1986) suggests the structural layer coefficients (a value). A value for this coefficient is assigned in the pavement structure in order to convert actual layer thickness into structural number (SN).

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where a_i : i th layer of coefficient
D_i : i th layer (inches)
m_i : i th layer drainage coefficient

The representative structural layer coefficients in the AASHTO design guide are listed in Table 8.1-14.

TABLE 8.1-14 REPRESENTATIVE LAYER COEFFICIENTS FOR FLEXIBLE PAVEMENTS (AASHTO DESIGN GUIDE)

Materials	Material Strength	Layer Coefficient, a
Surface:	Elastic Modulus (psi)	a1
Dense Graded	400,000	0.42
Asphalt Concrete	350,000	0.39
	300,000	0.38
Base:	CBR	a2
Granular	100	0.14
Aggregates	80	0.135
	60	0.12
Subbase:	CBR	a3
Granular	30	0.110
Aggregates	25	0.10
	20	0.095

For the structural design of the experimental pavements, the layer coefficients shown in Table 8.1-15 were applied based on the material test results and the representative layer coefficients explained in Table 8.1-14.

TABLE 8.1-15 STRUCTURAL DESIGN OF EXPERIMENTAL PAVEMENTS

Pavement	Construction Material and Method	Conditions	Layer Coefficient
Surface	Hot mix AC	Marshall stability: 1600 lb. or more	0.39
	BMP		0.25
	DBST		0.25
	SBST		0.25
Base	Crushed stone	CBR value: 80 %	0.135
Subbase	Granular aggregates	CBR value: 25 %	0.10

Note: Layer coefficients for SBST/DBST/BMP surface courses, a_1 = 0.20 - 0.30 were assumed and a_1 = 0.25 were adopted.

vi) Drainage Coefficient

Drainage coefficient values for modifying structural coefficient of base and subbase materials for flexible pavements, m_2=0.9 (for base) and m_3=0.9 (for subbase) are applied.
For rigid pavement, drainage coefficient Cd=0.9 is used.

vii) Design Reliability Factors Z and S

In AASHTO's Basic Design Equation Z and S

Z_R : standard normal deviation
S_O : combined standard error of the prediction and performance prediction are included as design reliability considerations.

In this design, Z_R = 0 corresponding to a 50 percent level of reliability was applied.

b) Pavement Structure of Experimental Pavement Models

Table 8.1-16 summarizes the structural design for eighteen (18) experimental pavement models, while design computations conducted for each model are given in Appendix 8-6. The pavement structure and typical roadway section for each model are shown in Figure 8.1-4.

TABLE 8.1-16 (1) SUMMARY OF STRUCTURAL DESIGN OF EXPERIMENTAL PAVEMENT MODELS

EPC Sec. No.	Design Traffic Volume: Bus	Design Traffic Volume: Truck Day-direction	Model No. Pavement Type	Design Subgrade CBR %	Design Period Year	Design ESAL	Design SN	Surface cm		Base cm	Subbase cm	Total cm
No. 1	–	7	No. 1 GR	4.0	5	6.82×10^3	-	GR	15	-	5	20
	Vehicle Load Factor		No. 2 SBST	4.0	2	2.55×10^3	1.046	SBST	0.5	15	8	23.5
	–	0.503	No. 3 DBST	4.0	4	4.71×10^3	1.184	DBST	1.5	15	9	25.5
			No. 4 BMP	4.0	8	1.08×10^3	1.387	BMP	5	15	5	25
No. 2	–	6	No. 5 GR	3.0	5	6.82×10^3	-	GR	15	-	8	23
	Vehicle Load Factor		No. 6 SBST	3.0	2	2.52×10^3	1.192	SBST	0.5	15	12	27.5
	–	0.503	No. 7 DBST	3.0	4	4.99×10^3	1.361	DBST	1.5	15	14	30.5
			No. 8 BMP	3.0	8	1.08×10^3	1.564	BMP	5	15	10	30
No. 3	2	24	No. 9 DBST	3.0	4	3.74×10^4	1.928	DBST	1.5	15	30	46.5
	Vehicle Load Factor		No. 10 BMP	3.0	7	7.00×10^4	2.131	BMP	5	15	26	46
	0.038	0.922	No. 11 AC 4 cm	8.0	8	7.31×10^4	1.472	AC	4	12	8	24
			No. 12 AC 5 cm	8.0	10	9.90×10^4	1.554	AC	5	12	6	23
No. 4	2	24	No. 13 DBST	8.0	5	4.22×10^4	1.326	DBST	1.5	15	13	29.5
	Vehicle Load Factor		No. 14 BMP	5.0	7	6.61×10^4	1.742	BMP	5	15	16	36
	0.038	0.922	No. 15 AC 4 cm	3.0	7	6.89×10^4	2.147	AC	4	15	23	42
			No. 16 AC 5 cm	3.0	9	8.70×10^4	2.229	AC	5	15	21	41

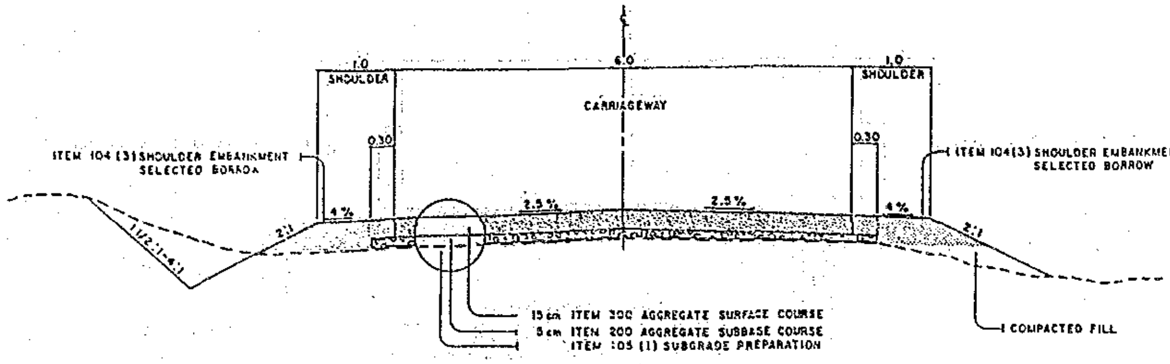
Traffic Growth Rate: 3 percent p.a.
EPC: Experimental Pavement Construction

TABLE 8.1-16 (2) SUMMARY OF STRUCTURAL DESIGN OF EXPERIMENTAL PAVEMENT MODELS

EPC Sec. No.	Design Traffic Volume: Bus	Design Traffic Volume: Truck Day-direction	Model No. Pavement Type	Design Subgrade CBR %	Design Period Year	Design ESAL	Design SN	Surface	Surface cm	Base cm	Subbase cm	Total cm
No. 5	59	137	No. 17 AC 5 cm	5.0	3*	2.33×10^5	2.158	AC	5	15	19	39
	Vehicle Load Factor (for Flexible Pavement) 0.613	1.233										
No. 5	59	137	No. 18 PCC 18 cm	5.0	8*	7.56×10^5	-	PCC	18	-	20	38
	Vehicle Load Factor (for Rigid Pavement) 0.559	1.362										

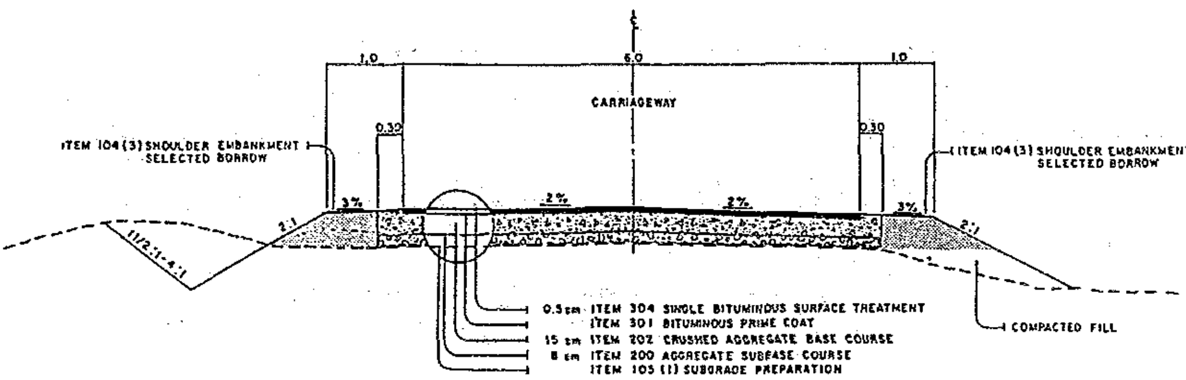
Traffic Growth Rate: 5 percent p.a.

* for the experiment of serviceability performance of medium-traffic type AC and PCC pavement by accelerated accumulating heavy traffic of this road section.



MODEL No. I GRAVEL

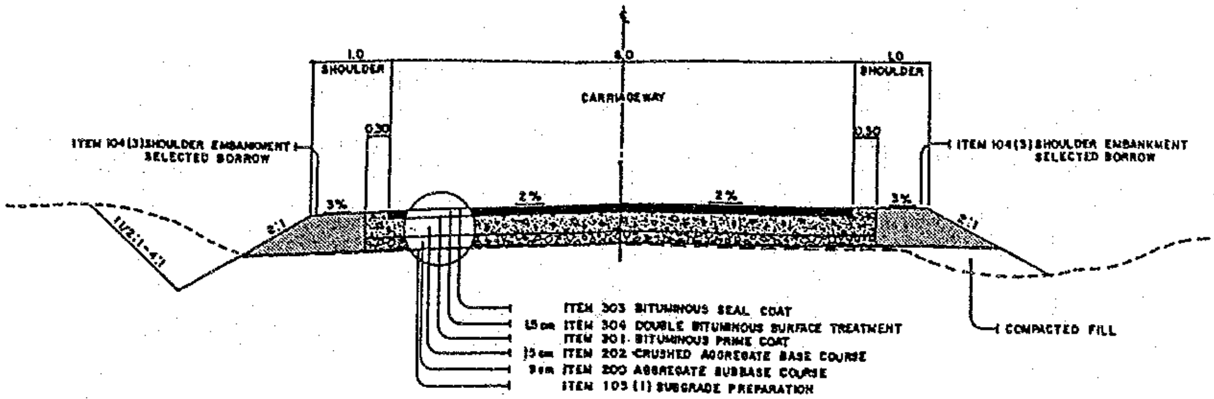
STA. 0 + 600 – STA. 0 + 800



MODEL No. 2 SINGLE BITUMINOUS SURFACE TREATMENT

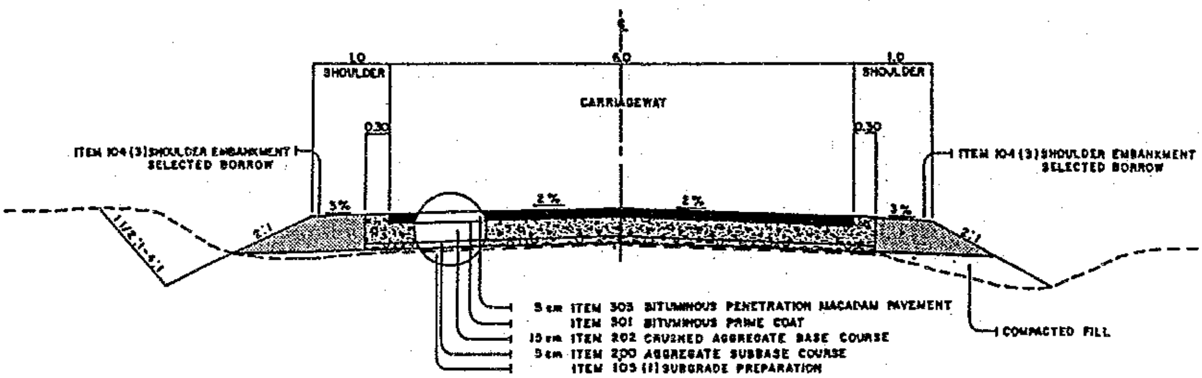
STA. 0 + 400 – STA. 0 + 600

FIGURE 8.1-4 (1) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 1



MODEL No. 3 DOUBLE BITUMINOUS SURFACE TREATMENT

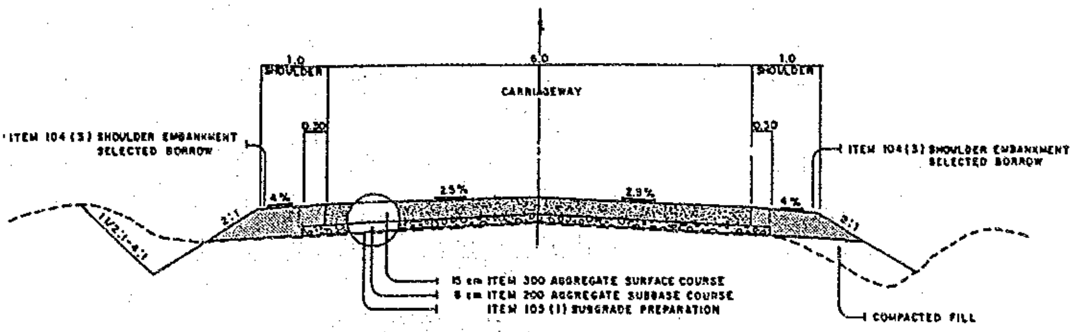
STA. 0 + 200 – STA. 0 + 400



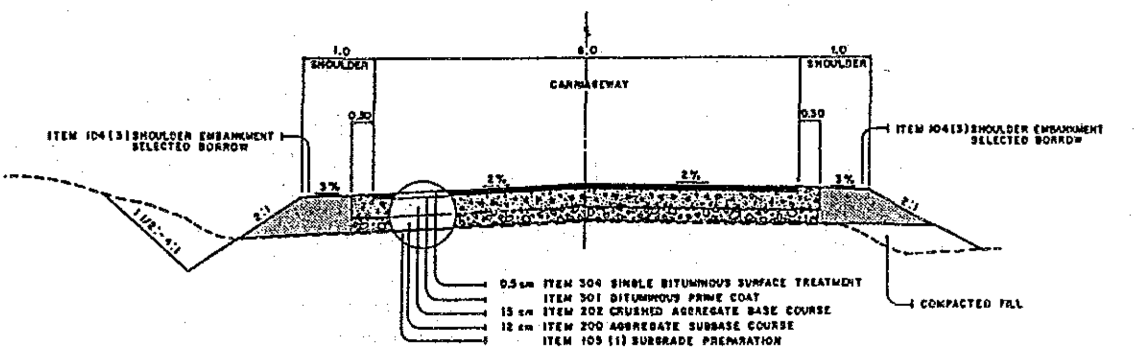
MODEL No. 4 BITUMINOUS PENETRATION MACADAM

STA. 0 + 000 – STA. 0 + 200

FIGURE 8.1-4 (2) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 1

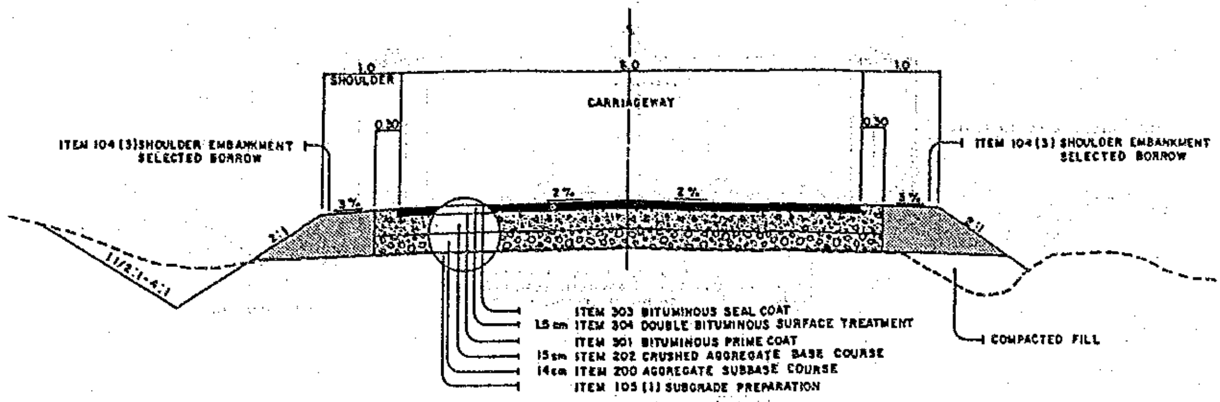


MODEL No. 5 GRAVEL
STA. 0 + 600 - STA. 0 + 800



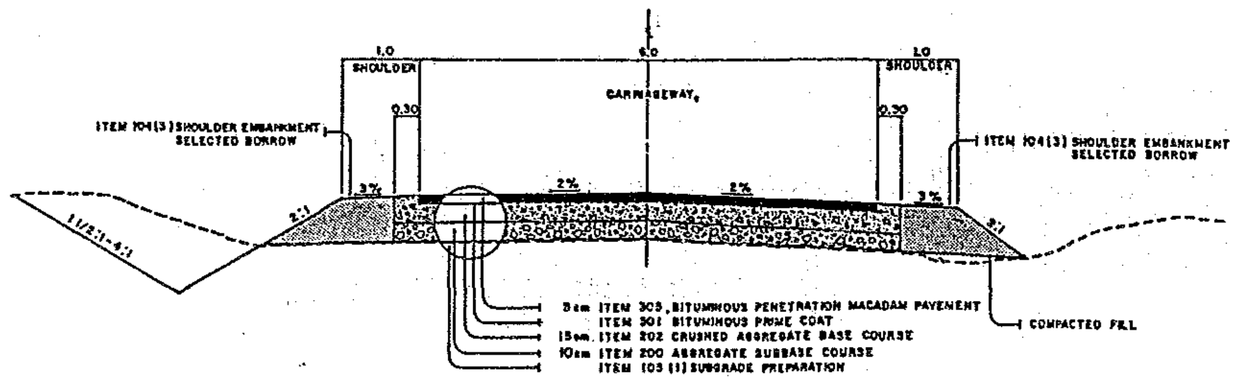
MODEL No. 6 SINGLE BITUMINOUS SURFACE TREATMENT
STA. 0 + 400 - STA. 0 + 600

FIGURE 8.1-4 (3) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 2



MODEL No. 7 DOUBLE BITUMINOUS SURFACE TREATMENT

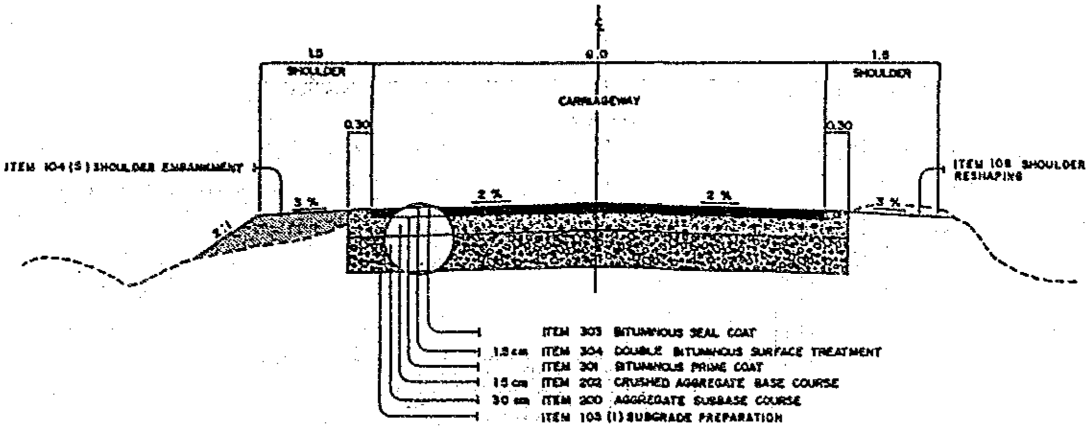
STA. 0 + 200 - STA. 0 + 400



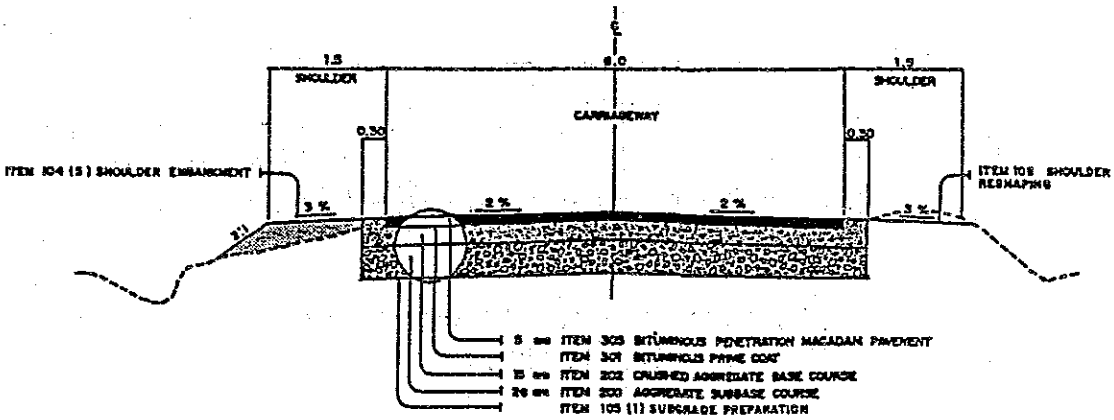
MODEL No. 8 BITUMINOUS PENETRATION MACADAM

STA. 0 + 000 - STA. 0 + 200

FIGURE 8.1-4 (4) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 2

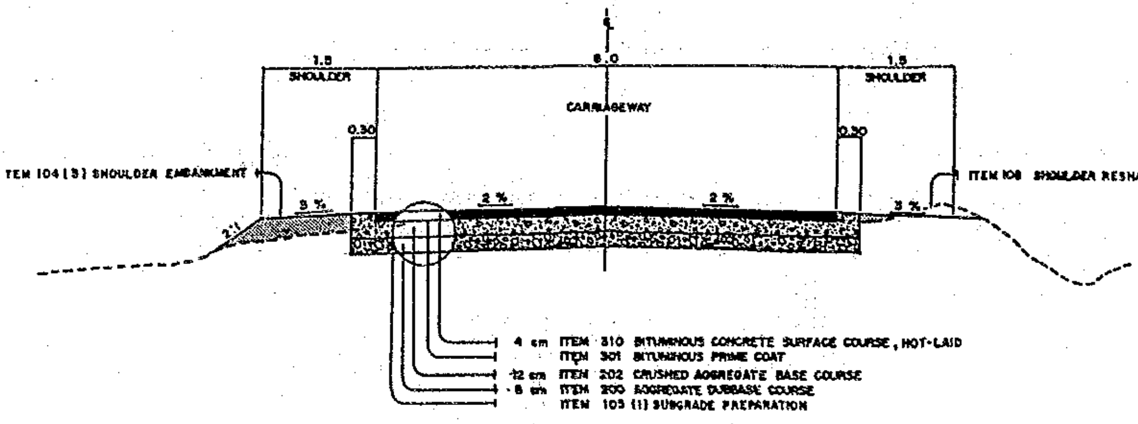


MODEL No. 9 DOUBLE BITUMINOUS SURFACE TREATMENT
STA. 0+000 - STA. 0+200

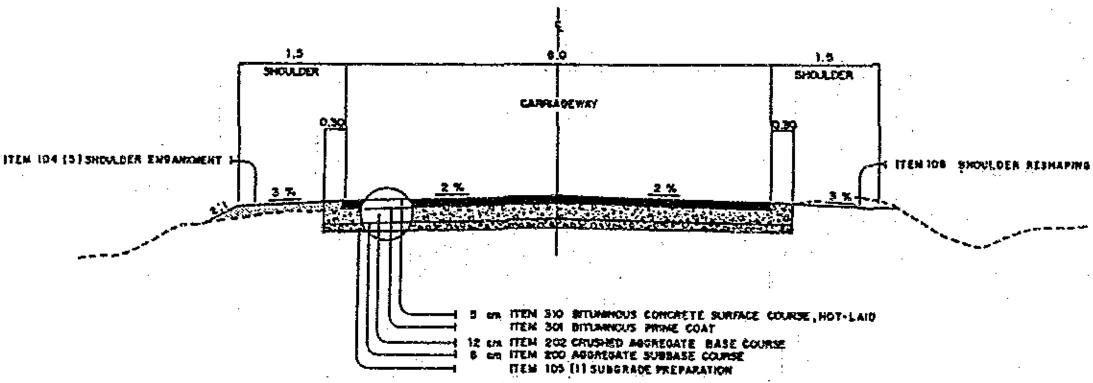


MODEL No. 10 · BITUMINOUS PENETRATION MACADAM
STA. 0+200 - STA. 0+400

FIGURE 8.1-4 (5) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 3

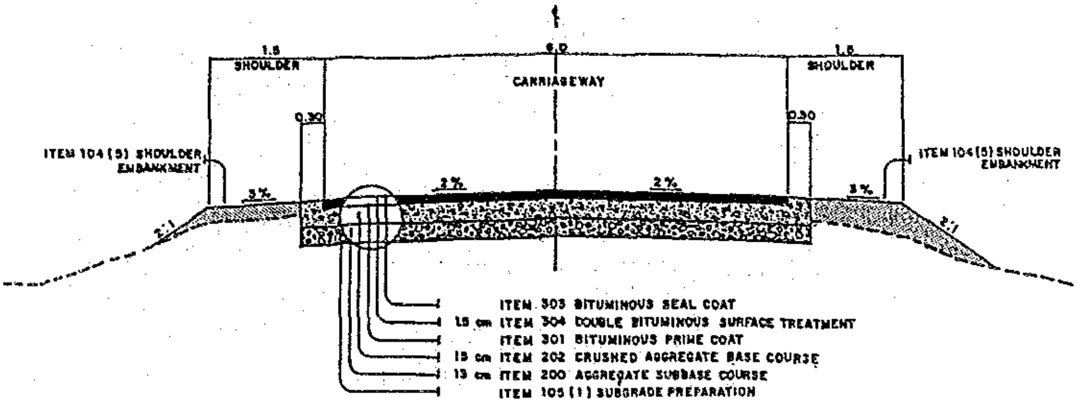


MODEL No. 11 ASPHALT CONCRETE (4 cm)
STA. 0+400 - STA. 0+600



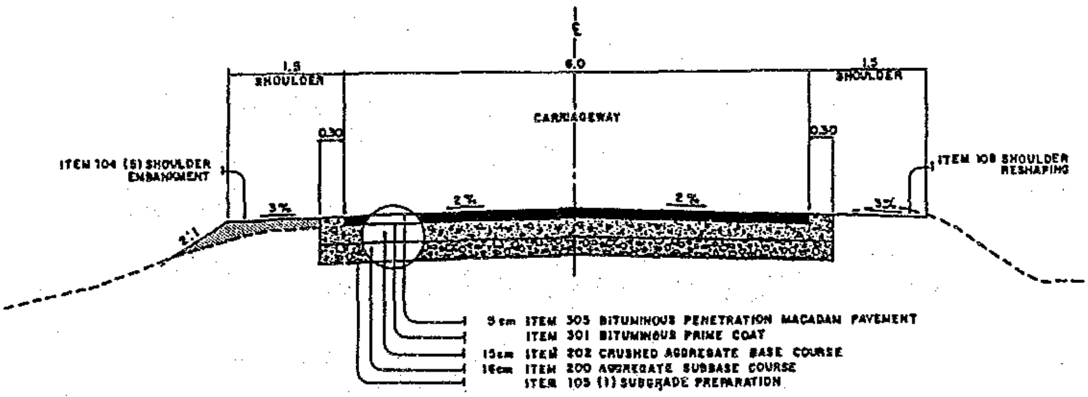
MODEL No. 12 ASPHALT CONCRETE (5 cm)
STA. 0+600 - STA. 0+800

FIGURE 8.1-4 (6) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 3



MODEL No. 13 DOUBLE BITUMINOUS SURFACE TREATMENT

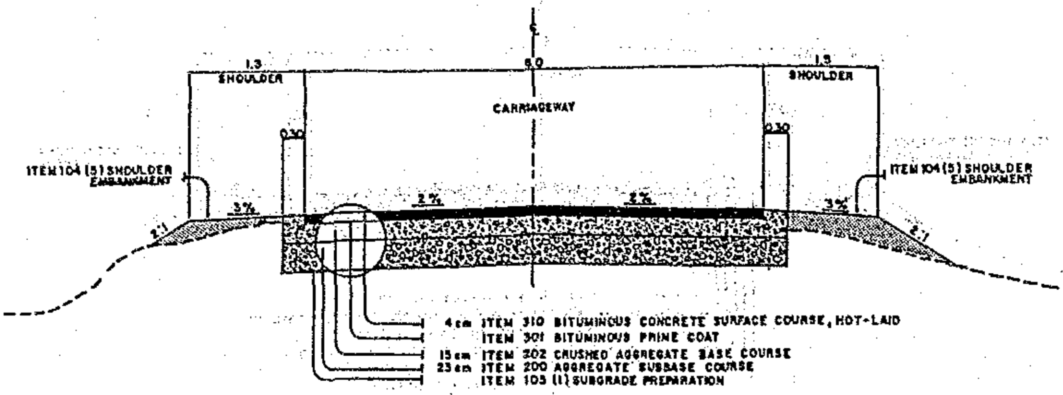
STA. 0+000 – STA. 0+200



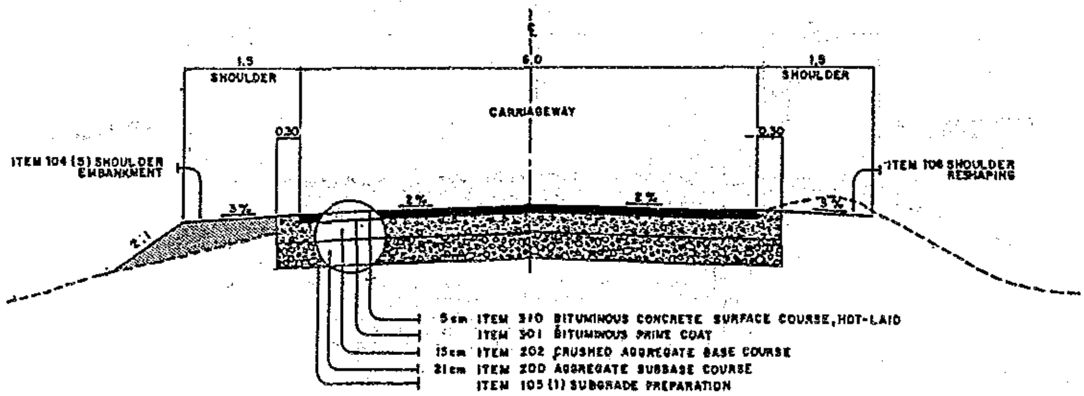
MODEL No. 14 BITUMINOUS PENETRATION MACADAM

STA. 0+200 – STA. 0+400

FIGURE 8.1-4 (7) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 4

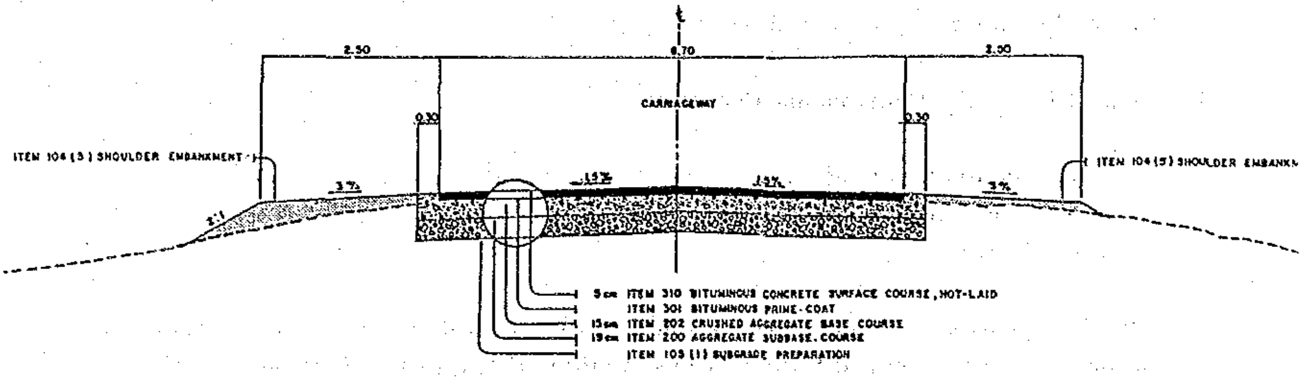


MODEL No. 15 ASPHALT CONCRETE (4 cm)
STA. 0+400 - STA. 0+600



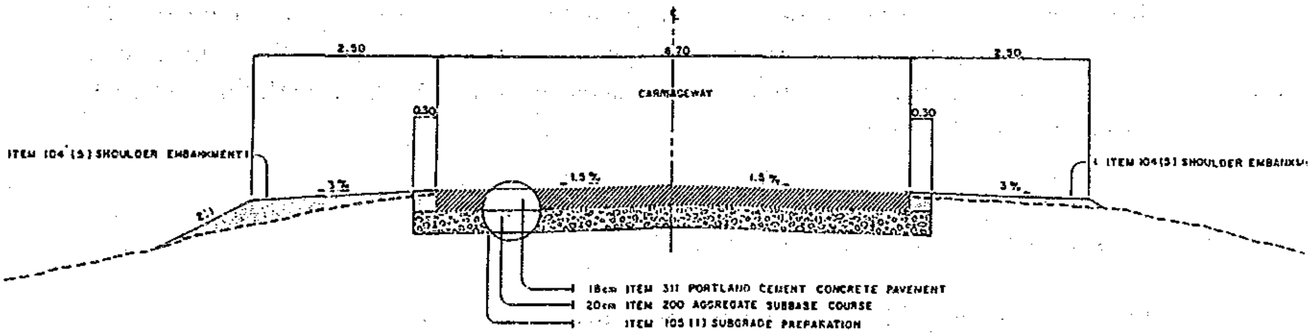
MODEL No. 16 ASPHALT CONCRETE (5 cm)
STA. 0 + 600 - STA. 0+800

FIGURE 8.1-4 (8) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 4



MODEL No. 17 ASPHALT CONCRETE

STA. 0 + 200 - STA. 0 + 400



MODEL No. 18 PORTLAND CEMENT CONCRETE

STA. 0 + 000 - STA. 0 + 200

FIGURE 8.1-4 (9) TYPICAL ROADWAY SECTION
CONSTRUCTION SECTION NO. 5