PERFORMANCE OF LOW COST PAVEMENT IN THE PHILIPPINES

Experimental Pavement

for

Rural Road Network Development

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1.0 EXPERIMENTAL PAVEMENT

1.1 Objectives

In line with the government's development policy envisaged in the Medium-Term Philippine Development Plan, increased emphasis on the highway development plan was given to rehabilitation, improvement and expansion of the feeder and secondary network, particularly in the rural areas. The characteristics of rural roads projects are as follows:

- About 80% of rural roads are low traffic roads, serving less than 500 vehicles per day.

- Pavement types for low traffic roads are generally gravel surfaces and low-class bituminous surface pavements. However, no data for performance period, selection criteria of pavement type, etc., are available.

- Cost of pavement structure generally shares 60-70% of total civil work costs, therefore, selection of an appropriate type of pavement is quite important.

The needs for rural roads development are quite high, thus huge investments are expected. In order to implement rural road projects which are economically and structurally sound, a study of low-class pavement is essential.

Based on the above background, the study of low-class pavement through experimental pavement construction was planned. The objectives of the experimental pavement construction are summarized as follows:

1. To analyze the functional and structural performance of various types of pavement models with time and traffic loading repetitions by conducting a follow-up survey for five (5) years, and

2. To provide basic data for appropriate structural design of pavement including selection of pavement type according to traffic and subgrade conditions.

The experimental pavement construction commenced in April 1990, but was completed only in October 1990, due to adverse weather conditions. The follow-up surveys were then conducted on a regular basis and were expected to be done for a period of five (5) years.

1.2 Location and Type of Pavement

Five (5) sections were selected in the Province of Cavite in consideration of the three (3) levels of traffic (low, medium and high) and two (2) subgrade condition (good and poor).

Location and types of pavement are shown in Figure 1.2-1 and traffic volume and selected pavement types are shown in Table 1.2-1.

Table 1.2-1 TRAFFIC VOLUME/TYPE OF PAVEMENT

LOW TRAFFIC		MEDIUM TRAFFIC		HEAVY TRAFFIC	TOTAL	
GR	2 Models		-	-	GR	2 Models
SBST	2 Models		-	-	SBST	2 Models
DBST	2 Models	DBST	2 Models	-	DBST	4 Models
BMP	2 Models	BMP	2 Models	-	BMP	4 Models
		AC 4cm	2 Models	-	AC 4cm	2 Models
		AC 5cm	2 Models	AC 5cm 1 Model	AC 5cm	3 Models
			-	-	PCCP 18cm	1 Model
Sub-total	8 Models	Sub-total	8 Models	Sub-total 2 Models	Total	18 Models
	1,600m		1,600m	400m		3,600m

Remarks:

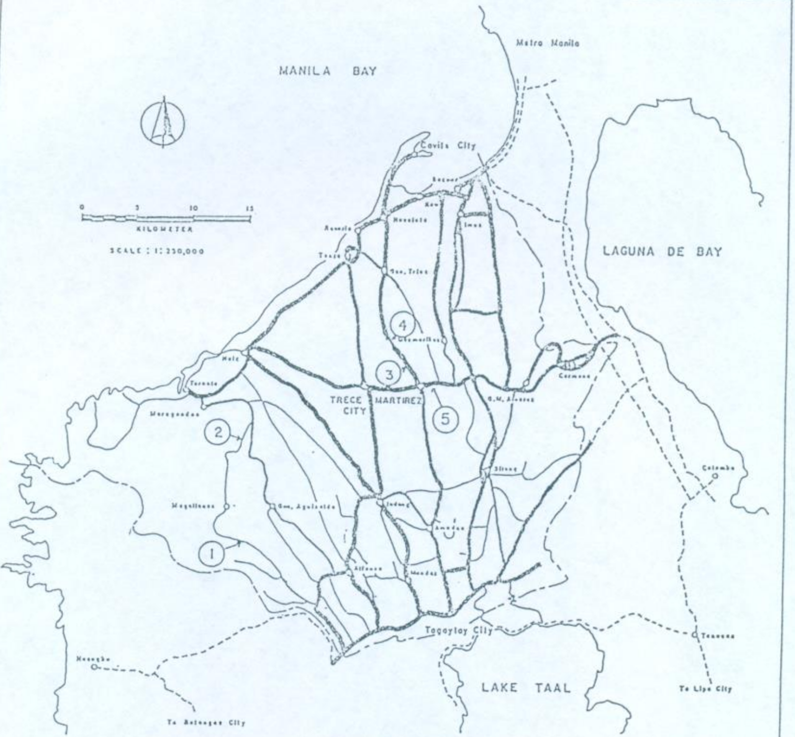
GR : Gravel Surfacing
SBST : Single Bituminous Surface Treatment
DBST : Double Bituminous Surface Treatment
AC : Asphalt Concrete
PCCP : Portland Cement Concrete Pavement

1.3 Structural Design of Each Pavement Models

Based on the data of the traffic surveys and soil investigations on each experimental road section, the structural design of eighteen (18) pavement models was carried out using AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES 1986. The summary of the design with traffic volume, soil supporting value CBR, design performance period, thickness of each layer (Surface course, Base course and Subbase course) and SN (Structure Number) for asphalt pavement models are shown in Table 1.3-1.

1.4 Construction

The construction of the experimental pavement commenced in early April, 1990 and Sections No. 3, 4 and 5 were completed in the beginning of September 1990. However, Section No. 1 was completed in the beginning of November 1990 and Section No. 2 was completed by the end of September 1990.



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	132	GOOD	GR SBST DBST BMP
2	241	POOR	GR SBST DBST BMP
3	1,535	GOOD	DBST BMP HAC(4cm) HAC(5cm)
4	1,535	POOR	DBST BMP HAC(4cm) HAC(5cm)
5	3,334	GOOD	HAC (5cm) PCC (18cm)

* AS OF 1991

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 1.2-1 : LOCATION AND TYPES OF PAVEMENT

TABLE 1.3-1 : PAVEMENT MODELS

TYPE OF PAVEMENT	DESIGN PERFORMANCE PERIOD	TRAFFIC VOLUME				
		LOW		MEDIUM		HIGH
		AADT 132 Truck 11 [SECTION-1]	241 25 [SECTION-2]	AADT 1535 Truck, Bus 261 [SECTION-3]	[SECTION-4]	AADT 3334 Truck,Bus 631 [SECTION-5]
GRAVEL SURFACE	5 years	Model - 1 Surf. C = 15cm Sub. B = 5cm (CBR = 4%)	Model - 5 Surf. C. = 15cm Sub. B = 8cm (CBR = 3%)	–	–	–
SBST	2 years	Model - 2 SN=1.05 0.5 cm Base = 15cm Sub. B = 8cm (CBR = 4%)	Model - 6 SN=1.19 0.5 cm Base = 15cm Sub. B = 12cm (CBR = 3%)	–	–	–
DBST	4 ~ 5 years	Model - 3 SN=1.18 1.5 cm Base = 15cm Sub. B = 9cm (CBR = 4%)	Model - 7 SN=1.36 1.5 cm Base = 15cm Sub. B = 14cm (CBR = 3%)	Model - 9 SN=1.93 1.5 cm Base = 15cm Sub. B = 30cm (CBR = 3%)	Model - 13 SN=1.33 1.5 cm Base = 15cm Sub. B = 13cm (CBR = 8%)	–
BMP	7 ~ 8 years	Model - 4 SN=1.39 5.0 cm Base = 15cm Sub. B = 5cm (CBR = 4%)	Model - 8 SN=1.56 5.0 cm Base = 15cm Sub. B = 10cm (CBR = 3%)	Model - 10 SN=2.13 5.0 cm Base = 15cm Sub B = 26cm (CBR = 3%)	Model - 14 SN=1.74 5.0 cm Base = 15cm Sub. B = 16cm (CBR = 5%)	–
A C	7 ~ 8 years	–	–	Model - 11 SN=1.47 4.0 cm Base = 12cm Sub. B = 8cm (CBR = 8%)	Model - 15 SN=2.14 4.0 cm Base = 15cm Sub. B = 23cm (CBR = 3%)	–
	9 ~ 10 years (3 years for Section - 5)	–	–	Model - 12 SN=1.55 5.0 cm Base = 12cm Sub. B = 6cm (CBR = 8%)	Model - 16 SN=2.23 5.0 cm Base = 15cm Sub. B = 21cm (CBR = 3%)	Model - 17 SN=2.16 5.0 cm Base = 15cm Sub. B = 19cm (CBR = 5%)
P C C	8 years	–	–	–	–	Model - 18 PCCP = 18cm Sub. B = 20cm (CBR = 5%)

Note: CBR is the design CBR of subgrade.
- Follow-up survey on section 5 was ended in 1993 for the reconstruction of Regional Tourism Road which includes the said road section.

2.0 FOLLOW-UP SURVEY

2.1 Objectives of Follow-up Survey

The objectives of the follow-up survey were as follows:

1) To verify performance period of selected types of pavement.
2) To verify an appropriate timing of rehabilitation.
3) To provide basic data for an appropriate structural design.
4) To establish selection criteria of pavement types and level of rehabilitation, based on 1), 2) and 3) above.

Performance period is defined as the period that an initial pavement structure will last before it needs rehabilitation and is equivalent to time elapsed from its initial serviceability to its terminal serviceability. The follow-up surveys was to be conducted for five (5) years, during which it would have been possible to verify the performance period under different conditions to traffic load repetition and subgrade bearing capabilities. Those models which do not reach the terminal serviceability and performance period was to estimate by analyzing the relationship between serviceability and traffic repetitions.

Another important objective was to verify timing of rehabilitation. As low-class pavements are usually designed for a performance period of 3 to 8 years, timely, rehabilitation must therefore be implemented. Rehabilitation level was to be recommended by analyzing data obtained from the follow-up surveys.

The pavement design methods recommended by the AASHTO Guide for Design of Pavement Structures require design variables, performance criteria, etc. The data obtained from the follow-up surveys will provide useful information for the designer.

Based on the follow-up survey results and life cycle cost analysis, an appropriate pavement type and rehabilitation level was to be established for different level of traffic and subgrade conditions.

2.2 Survey Items

The following surveys were conducted:

Traffic Survey
- Traffic Count Survey (4 times a year)
- Loadometer Survey (once a year)

Surface Condition Survey (4~2 times a year)

- Roughness
- Cracking
- Patching and Pothole
- Rutting
- Deflection
- Present Serviceability Rating (PSR)
- Rehabilitation Requirement Rating (RRR)

2.3 Survey Method

(1) Traffic Survey

1) Traffic Count Survey

Traffic count surveys by vehicle type and direction were undertaken for three (3) consecutive days at 12 hours a day quarterly (every January, April, July and October for each year).

2) Loadometer Survey

The loadometer survey was undertaken once a year in October at the same survey stations as the Traffic Count Station except Survey Station No. 2 where the loadometer survey was not required. The loadometer was conducted for 12 hours from 6:00 A.M. to 6:00 P.M. for three (3) consecutive days, weighing the following vehicles:

- Trucks, semi-trailers, Truck-trailers
- Large-buses, Mini-buses

The measured axle loads comprising of single axle loads and tandem axle loads of trucks and buses were converted to 18-kip equivalent single axle load (ESAL) using axle load equivalency factors. Then Vehicle Load Factor (VLF) was computed using the following formula.

$$VLF = \frac{1}{N} \sum_{i=l}^{n} (ni \times ei)$$

where:

- VLF = Vehicle Load Factor
- ni = number of axles for axle load group i
- ei = axle load equivalency factor for axle load group i
- n = total number of axles
- N = total number of vehicles

(2) Surface Condition Survey

1) Roughness Survey

Roughness was measured with the used of a bump integrator. A Bump Integrator is a device, attached to the vehicle,which produces an electrical impulse for a particular amount of movement of an axle relative to the frame of the test vehicle. The pulses are counted and expressed in figures as a total amount of movement.

The measurements were made at a speed of about 30 km per hour. Measured values were converted to the standard roughness values by the following formula:

$$\text{Roughness Value} = \frac{\text{Average of Measured Value} \times 2.54}{\text{Length of the Measured Section in Km.}}$$

where: Roughness Value = cm/km
Average measure value = inches
Length of section = 0.15 km

2) Cracking Survey

Craked areas were measured in square meters of surface area. Cracked areas is converted to "cracking index" which is calculated as follows:

$$\text{Cracking Index} = \frac{\text{Total Cracked Area } (m^2)}{\text{Total Surface Area } (m^2)} \times 100$$

3) Patching Survey

Areas of pavement surface repaired by skin patching or deep patching were measured in square meters of surface area. All existing patched areas were measured on the pavement surface by a measuring tape and area in square meter was computed. Patched areas was converted to "Patching Index" which is calculated as follows:

$$\text{Patching Index} = \frac{\text{Total Patching Area } (m^2)}{\text{Total Surface Area}} \times 100$$

4) Rutting Survey

Rutting was measured for gravel surface and bituminous surface pavement models in the same manner explained hereunder.

Rut depth in mm. was measured in each survey unit (25 meter). A 1.2 meter straight edge was laid across the rut and maximum depth was measured. Measurement was made for both wheel paths of a lane and taken every five (5) meters along the length of the rut. Rutting was expressed by mean depth of rut in both wheel paths.

5) Deflection Survey

Deflection survey by Benkelman Beam was conducted twice a year in April and October, one time each during dry and rainy seasons. Deflection were measured at 25m. interval using a two (2) axles dumptruck having an 8.16 ton rear axle load and inflated tire pressure of 80 psi.

6) Present Serviceability Rating (PSR)

Present serviceability rating (PSR) refers to the rate of riding comfort of the passengers with regards to the quality of the pavement. Such rating were established by asking each member of a rating panel consisting of five (5) road users to rate the serviceability (comfort and rideability) of the pavement using his own judgment while the vehicle is travelling at 60km per hour.

PSR, defined as the mean of the individual rating, were calculated for the middle 150-m section for each pavement model.

The criteria of the rating are as follows:

5 - 4	Very Good
4 - 3	Good
3 - 2	Fair
2 - 1	Poor
1 - 0	Very Poor

7) 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 rehabilitation works are needed, when judged from the engineering point of view.

To assess the rehabilitation needs, a rating panel was organized (involving experienced engineers) to conduct the rating based on ocular surveys the pavement condition, paying attention to pavement distress such as cracking and pothole. Each engineer was required to rate his engineering judgment on the middle of 150-m section of each pavement model while the survey vehicle is running at 20 kph.

Rehabilitation Requirement Rating is the rate of the rehabilitation works needed for the pavements.

Rating Method:

Each member of the rating panel organized by four (4) highway engineer in charge of design, construction and maintenance conduct the rating based on the ocular survey on the pavement condition, paying their attention to pavement distress such as cracking and potholes.

The criteria of the 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

Rehabilitation Requirement Rating

3.0 TENTATIVE ANALYSIS AND EVALUATION OF FOLLOW-UP SURVEY DATA

3.1 Survey Results

The results of the follow-up surveys have been summarized, and are presented in the tables following. Table 3.1-1 shows the traffic volume expressed in ADT (total for all vehicles) from 1991 to 1994 at the 4 test sections. The vehicle load factors obtained separately for buses and trucks by test section for each year is shown in Table 3.1-2.

Table 3.1-1 TRAFFIC VOLUME

Average ADT (All Types of Vehicles)

SECTION NO.	1991	1992	1993	1994
1	131	143	167	242
2	241	240	304	387
3	1540	1694	2383	2344
4	1540	1694	2383	2344

Average ADT (Heavy Vehicles)

SECTION NO.	1991	1992	1993	1994
1	11	5	20	42
2	25	16	13	43
3	261	231	210	239
4	261	231	210	239

Table 3.1-2 VEHICLE LOAD FACTOR FOR COMPUTATION OF ESAL

Section	Direction	Type of Vehicle	Vehicle Load Factor			
			1991	1992	1993	1994
Section Nos. 1 & 2	1	Trucks	0.356	0.752	1.063	1.102
		Buses	-	-	0.403	0.526
	2	Trucks	0.447	0.608	0.728	0.870
		Buses	-	-	0.368	0.504
Section Nos. 3 & 4	1	Trucks	0.868	1.091	1.372	1.400
		Buses	-	-	-	-
	2	Trucks	1.206	1.502	1.464	1.458
		Buses	-	-	-	-

Tables 3.1-3 and 3.1-4 show the results of measured pavement condition based on the surveys undertaken in 1991 and 1994.

Table 3.1-3 MEASURED PAVEMENT CONDITION (1991)

Section	Pavement Model	Cracking Index (%)	Patching Index (%)	Rutting Index (%)	Roughness (cm/km)	PSR	RRR	PSI	RRI
1	SBST	0.61	4.60	10.00	231	3.00	3.00	2.89	2.08
	DBST	0.28	0.59	5.00	310	3.50	3.50	2.79	2.61
	BMP	4.28	12.56	9.00	369	3.00	3.00	2.60	2.03
2	SBST	2.08	0.00	2.00	185	4.00	4.00	3.32	3.30
	DBST	0.00	0.00	1.00	226	4.00	4.00	3.15	3.18
	BMP	1.27	0.07	1.00	218	4.00	4.25	3.98	3.61
3	DBST	1.14	1.02	2.00	233	3.75	4.00	3.01	2.65
	BMP	4.54	1.84	5.00	261	3.50	3.50	3.52	3.08
	AC(4cm)	0.16	0.00	8.00	68	3.75	4.50	4.24	3.99
	AC(5cm)	0.00	0.00	0.00	91	3.75	4.50	4.03	4.08
4	DBST	1.55	0.52	7.00	383	3.25	3.50	2.62	2.52
	BMP	3.87	1.88	4.00	256	3.25	3.50	3.53	3.08
	AC(4cm)	0.00	0.00	0.00	87	3.75	4.00	4.06	3.87
	AC(5cm)	3.42	0.17	24.30	176	2.25	2.50	3.49	2.78

Table 3.1-4 MEASURED PAVEMENT CONDITION (1994)

Section	Pavement Model	Cracking Index (%)	Patching Index (%)	Rutting Index (%)	Roughness (cm/km)	PSR	RRR	PSI	RRI
1	SBST	10.44	0.50	30.00	564	2.10	1.75	2.29	2.31
	DBST	23.96	1.19	0.00	285	2.50	3.00	2.83	2.50
	BMP	87.89	1.42	10.50	502	2.00	2.00	2.86	2.90
2	SBST	38.81	0.00	13.00	186	3.50	3.60	3.31	3.29
	DBST	1.44	0.00	0.00	127	3.90	3.90	3.64	3.51
	BMP	12.45	0.13	0.00	462	3.60	3.50	3.15	3.69
3	DBST	30.69	9.01	19.50	211	2.50	2.25	2.87	1.69
	BMP	84.67	4.48	0:00	296	2.75	2.00	3.19	2.71
	AC(4cm)	3.95	0.77	7.50	73	4.00	3.50	4.21	3:61
	AC(5cm)	3.31	0.10	11.25	48	4.00	4.00	4.45	4.03
4	DBST	58.11	6.68	0.00	330	2.00	2.25	2.54	1.57
	BMP	91.42	13.49	10.00	383	1.75	1.50	2.53	1.96
	AC(4cm)	0.19	0.00	3.80	50	3.75	4.00	4.46	4.14
	AC(5cm)	21.18	21.65	117.02	257	2.50	2.75	2.57	1.49

3.2 ANALYSIS AND EVALUATION

3.2.1 Performance Period

One of the ultimate aims of the experimental pavement study is to be able to verify the performance period of each pavement model. As stated earlier, performance period refers to the period that an initial pavement structure will last before rehabilitation is to be needed. It is equivalent to the time elapsed from its initial serviceability to its terminal serviceability.

The serviceability of a pavement is defined as its ability to serve the type of traffic which uses the facility. It is usually measured in terms of Present Serviceability Index (PSI) and/or Rehabilitation Requirement Index (RRI). PSI is an index which indicates the level of the functional serviceability of the pavement, ranging from 0 (impassable road) to 5 (perfect road). RRI on the otherhand is an index that shows the level of the structural serviceability of the pavement, likewise from 0 (immediate rehabilitation required) to 5 (no structural deficiencies).

PSI and RRI are calculated by the following equations which were developed in the Feasibility Study on the Rural Road Network Development Project for bituminous surface pavement.

DBST : $PSI = 7.76 - 1.96 \log R - 0.11 \sqrt{P}$ $(r = 0.739)$
BMP : $PSI = 9.80 - 2.46 \log R - 0.25 \sqrt{P}$ $(r = 0.917)$
AC : $PSI = 7.32 - 1.68 \log R - 0.14 \sqrt{P}$ $(r = 0.817)$

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 : $RRI = 6.04 - 1.12 \log R - 0.39 \sqrt{P}$ $(r = 0.859)$

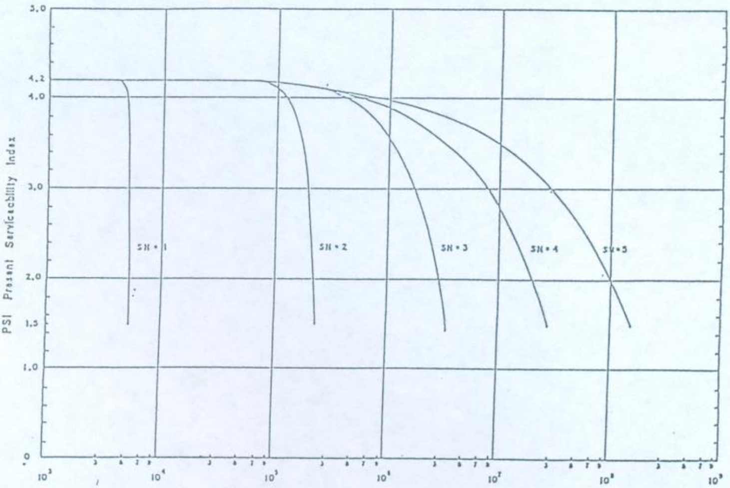
where, PSI = Present Serviceability Index
RRI = Rehabilitation Requirement Index
R = Roughness (cm/km)
P = Patching plus pothole (%)
r = Correlation coefficient

The PSIs and RRIs of the pavement models under study thus have been calculated using the above equations, as presented earlier in Tables 3.1-3 and 3.1-4.

Pavement performance is defined as the trend of serviceability of the pavement. Based on AASHTO Flexible Pavement Design Equation as illustrated in Figure 3.2.1-1, the Present Serviceability Index (PSI) is supposed to decrease as cumulative ESAL increases (repetition of wheel load) for various class bituminous surface pavement structures.

PSI Decrease vs Wheel Load Repetition

Subgrade CBR 6 %



W = Number of 18 Kip Equivalent Single Axle Load

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 x 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	
			3.00/2.54 = 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	
As. Treated Base	15 cm	15 0.30	
Cem. Treated Subbase	21 cm	21 0.20	
			12.70/2.54 = 5.0

FIGURE 3.2.1-1 FLEXIBLE PAVEMENT SERVICEABILITY DECREASE CURVE
BASED ON AASHTO BASIC DESIGN EQUATION

The PSI vs. cumulative ESAL curves in the Figure show that the higher the SN (Structure Number), the longer the performance period will be.

SN (Structural Number) is an index number expressed by the following equation.

$$SN = a_1 \times D_1 + a_2 \times D_2 + a_3 \times D_3$$

where, a_1, a_2, a_3 = Layer Coefficient of Surface, Base and Subbase Course, respectively

D_1, D_2, D_3 = Layer thickness of Surface, Base and Subbase Courses in inches, respectively

In order to verify the performance period of the pavement models, the calculated RRIs covering the entire period of the follow-up surveys have been plotted on the graph, against the cumulative 18-kip ESAL recorded as well as with the corresponding years elapsed. Examples of these are shown in Figure 3.2.1-2

With terminal serviceability of low-class pavement placed at 2.0, as per AASHTO Guide for Design of Pavement Structures, it is apparent that most of the pavement models under study have not yet reached the terminal serviceability level, in which case total rehabilitation work is not yet required. The results moreover, show that RRI decreases as time elapses and ESALs accumulate. Verifications made in fact indicate that the equation developed for RRI very well fits into the RRI vs. time curve.

The terminal serviceability of each pavement model which is indicated by the point where the curve meets the RRI line at 2.0 forms the basis for calculating and/or predicting the overall performance period of each model, assuming that the desired RRI has been established at the onset of the study period. Based on the initial results of the follow-up surveys, the performance period of the different types of pavement studied have been estimated in Table 3.2.1-1 below.

Table 3.2.1-1: ESTIMATED PERFORMANCE PERIOD OF EACH TYPE OF PAVEMENT

Section	Traffic Volume	Pavement Type	Years	Cumulative ESAL
1 & 2	Low Volume	SBST	3 ~ 5	0.7 - 2.0 x 10^4
		DBST	4 ~ 6	1.5 - 3.0 x 10^4
		BMP	5 ~ 8	1.5 - 3.0 x 10^4
3 & 4	Medium Volume	DBST	2 ~ 3	0.3 - 0.4 x 10^6
		BMP	4 ~ 6	0.6 - 1.0 x 10^6
		AC 4 cm	8 ~ 10	2.0 - 3.0 x 10^6
		AC 5 cm	10 ~ 12	> 3.0 x 10^6

Note:

Estimated performance is based on (1) RRI change with time curve, (2) RRI change with cumulative ESAL curve and (3) periodic surface condition survey.

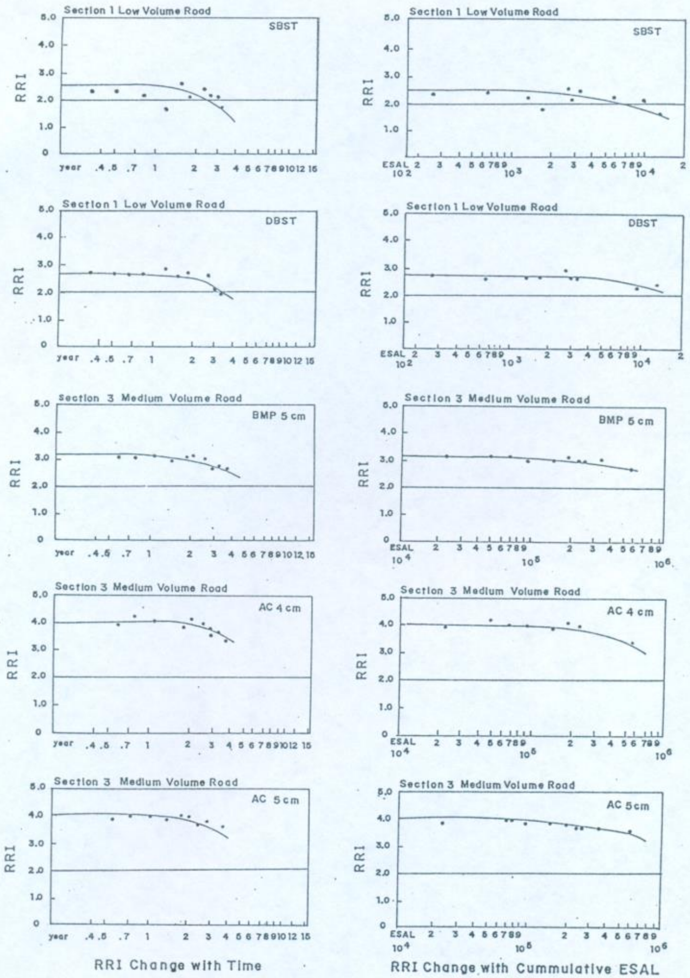


FIGURE 3.2.1-2 : EXAMPLES OF PERFORMANCE OF EACH PAVEMENT MODEL

NOTE :

ESAL : Equivalent 8.2-Ton Single Axle Loads
RRI : Rehabilitation Requirement Index

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

The predicted performance period of the pavement models will be finally estimated as soon as the on-going follow-up surveys are completed by 1995.

3.2.2 Pavement Stage Construction for Low to Medium Traffic Road

When a pavement reaches its terminal serviceability level, rehabilitation becomes necessary.

From the analysis of the follow-up survey results of the Experimental Pavement Models, the predicted performance period of each bituminous surface pavement ranges from 5 to 10 years. On this basis, a number of pavement stage construction design options have been formulated and are presented in Table 3.2.2-1 based on AASHTO Basic Design Equation for Flexible Pavement and the predicted performance period of each pavement type as established during the experimental study.

Table 3.2.2-1 DESIGN EXAMPLES FOR LOW TO MEDIUM TRAFFIC ROAD PAVEMENT STAGE CONSTRUCTION (20 years Performance Period)

Design Traffic: Initial Year Heavy Vehicles 200 per/day-direction
20th Year Heavy Vehicles 505 per/day-direction

VLF : Trucks 1.20, Buses 0.80 — Cumulative ESAL : 1st year 8.03×10^4, 20th year 2.66×10^6

Traffic Growth Rate = 5 percent p.a. Design Subgrade CBR = 10%

Stage	Case I	Case II	Case III
1 st	DBST Pavement 5 years performance	DBST Pavement 5 years performance	AC 5cm Pavement 10 years performance
2 nd	6th year DBST Surface Reconstruction	6th year AC 5cm Overlay	11th year AC 5cm Overlay
3 rd	11th year DBST Surface Reconstruction	14th year AC 4cm Overlay	Total 20 years performance period
4 th	16th year DBST Surface Reconstruction	Total 20 years performance period	
	Total 20 years performance period		

1) Case I using Four (4) Stage Construction: 1st DBST Pavement, 2nd to 4th DBST Reconstruction

When the initial DBST Pavement reaches the rehabilitation level, the existing DBST surface will be removed and the existing base will be scarified and strengthened by adding crushed stone of about 50mm, then bladed and compacted. On this prepared base, the new DBST surfacing will be applied. Subsequently, this will be the procedure that will be followed for its reconstruction period.

2) Case II using Three (3) Stage Construction: 1st DBST Pavement, 2nd AC Overlay and 3rd AC Overlay

This practice is widely experienced in many countries.

3) Case III using Two (2) Stage Construction: 1st AC Pavement and 2nd AC Overlay

This practice is also widely used for bituminous surface pavement stage construction in many countries.

The concept and the design of Case II Pavement Stage Construction (3 stage) is illustrated in Figure 3.2.2-1.

The life cycle costs for the three pavement stage constructed options presented herein have been computed and the summary is shown in Table 3.2.2-2 likewise, in Figure 3.2.2-2.

The total cost of each case are as follows:

DBST Pavement with DBST Surfacing every 5 years	7.48 MP/KM
DBST Pavement with AC5cm and AC4cm overlay	6.90 MP/KM
AC5cm Pavement with AC5cm overlay	6.07 MP/KM

In terms of absolute figure, these appears substantial differences among the three cases. However, when the costs are discounted, the differences become marginal, with the first option costing about 3.61 MP/km and the third, about 3.74 MP/km.

4.0 PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

4.1 Performance Period

With three and half years of follow-up surveys, the following performance period of each type of pavement are presently estimated:

- Double Bituminous Surface Treatment (DBST)	: 3 to 5 years
- Bituminous Macadam Penetration (BMP)	: 5 to 8 years
- Asphalt Concrete Pavement (AC/4cm)	: 8 to 10 years
- Asphalt Concrete Pavement (AC/5cm)	: 10 to 12 years

In relation to the above, however, the following survey deficiencies must be taken into consideration:

1) The experimental pavements were constructed during the rainy season of 1990. Due to this adverse weather condition, the DBST and BMP pavements showed deficiencies in some parts of the model sections in the earlier stage of the follow-up surveys. These are as follows:

   - Ravelling
   - Stripping

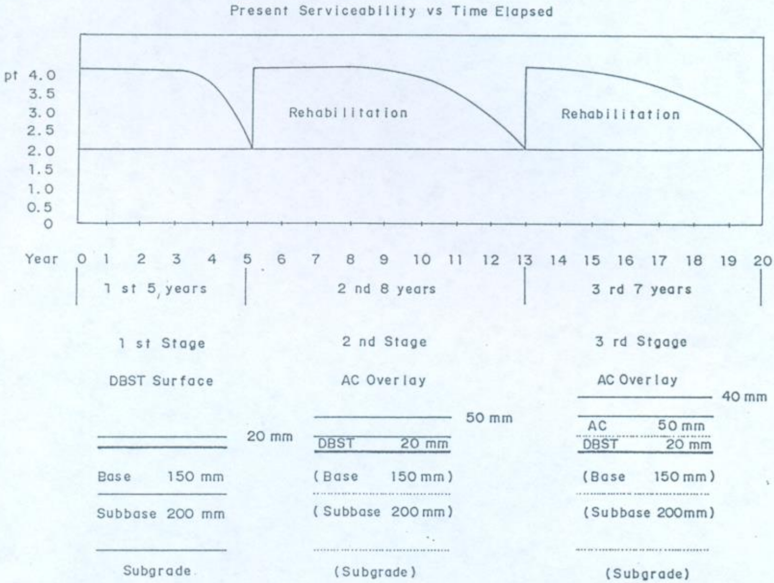


FIGURE 3.2.2-1: AN EXAMPLE OF PAVEMENT STAGE CONSTRUCTION METHOD

Table 3.2.2-2 LIFE CYCLE COST EXAMPLES OF LOW TO MEDIUM TRAFFIC ROAD PAVEMENT STAGE CONSTRUCTION

Analysis Period 20 years
Discount Rate 15 percent p.a.

Case I DBST Pavement/DBST every 5 years

Construction		Cost Peso/km
a) Initial Construction	DBST Pavement	1,982,500.00
b) Rehabilitation at 6th year	DBST Reconst.	1,375,550.00
c) Rehabilitation at 11th year	DBST Reconst.	1,375,500.00
d) Rehabilitation at 16th year	DBST Reconst.	1,375,500.00
e) Total Maintenance Cost		1,323,426.00
Total Cost		7,432,576.00
Discounted Cost (20 years)		3,607,185.49

Case II DBST Pavement/AC 5cm Overlay/AC 4cm overlay

Construction		Cost Peso/km
a) Initial Construction	DBST Pavement	1,982,500.00
b) Rehabilitation at 6th year	AC Overlay 5cm	2,031,300.00
c) Rehabilitation at 14th year	AC Overlay 4cm	1,665,300.00
d) Total Maintenance Cost		1,216,266.00
Total Cost		6,895,366.00
Discounted Cost (20 years)		3,668,250.66

Case III AC 5cm Pavement/AC 5cm Overlay

Construction		Cost Peso/km
a) Initial Construction	AC Pavement 5cm	2,867,000.00
b) Rehabilitation at 11th year	AC Overlay 5cm	2,031,300.00
c) Total Maintenance Cost		1,173,402.00
Total Cost		6,071,702.00
Discounted Cost (20 years)		3,743,690.09

Remarks:

$$\text{Discounted Cost} = \Sigma \frac{\text{Annual Cost}}{1 + r^{\,n-1}}$$

where, n = number of year (1 to 20), r = Discount Rate

Maintenance Cost

DBST	69,654.00 Peso/km		
AC	58,938.00 Peso/km 1st 5 years	61,617.00 Peso/km 2nd 8 years	64,296.00 Peso/km after 8 years

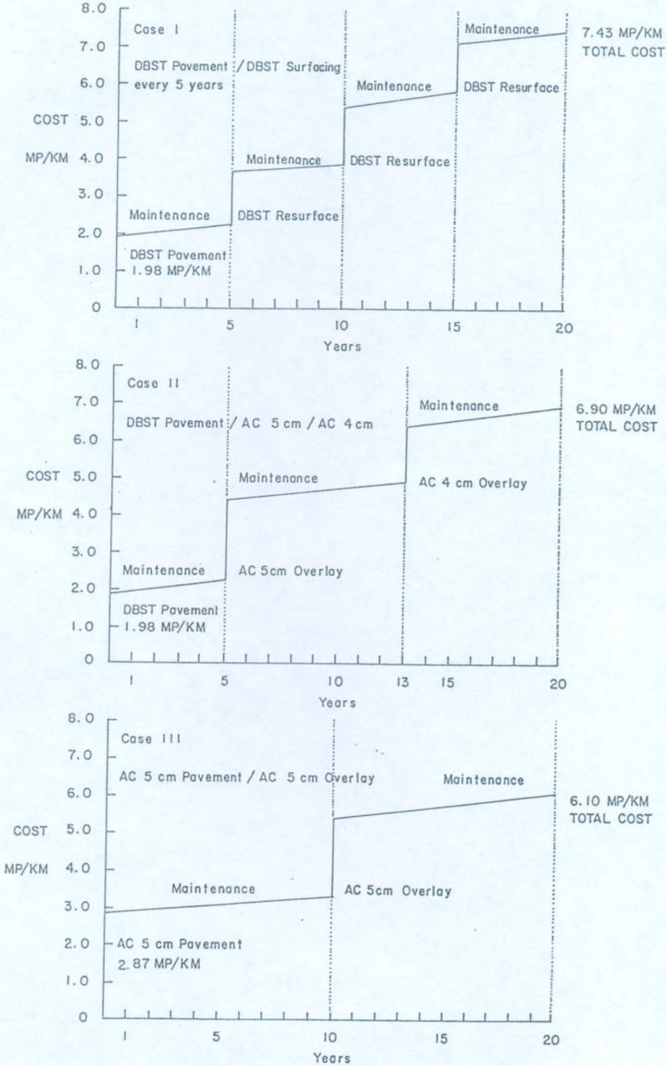


FIGURE 3.2.2-2: LIFE CYCLE COST OF PAVEMENT STAGE CONSTRUCTION

- Fretting or potholes in the surface layer
- Wide range cracks and
- Depression of the pavement

2) The abovementioned deficiencies were due to the following reasons:

   - Rainwater penetrated into the surface layer
   - Rainwater penetrated into the base and roadbed through the damaged non-watertight surface layer.
   - The repetition of wheel load to the pavement and the wheel shearing action to the surface layer under the presence of water.

3) In the case of the pavement models, the actual SN that has been reduced to about 90% of the design SN because of the lower quality of materials, substantial workmanship and inappropriate construction owing to bad weather conditions. This had the adverse effect of reducing the performance period to about 51% of the expected life as shown below.

Pavement	Structural Number	Performance Period	
Design	SN = 2.0	Initial year Heavy vehicles 140/day/ direction	10 years
Actual	SN = 1.8	Same as above	5.1 years

4.2. Pavement Structural Design

The DPWH has already established a standard design for low to medium traffic road specifying thickness of surface, base and subbase courses. It is however, recommended that such standard design be reviewed, and if necessary, be revised in order to incorporate the findings of the experimental study.
For the pavement management design system on the rural road network, it is particularly recommended that the following pavement charts be further developed: Chart for Design Traffic vs. Required Structural Number (SN) and Chart for Design Traffic vs. Required Thickness of Surface, Base and Subbase of Pavement.

4.3 Surface Condition Indexes

The study has verified the effectivity of using the RRI measurement method in calculating the performance period of each pavement model. The use of such method is therefore recommended for pavement management system.

4.4 Pavement Stage Construction

By being able to predict the performance period of each type of pavement based on surface course durability characteristics and applying structural design knowledge, pavement stage construction may be planned with time schedule.
For low to medium traffic roads, 1st stage with Double Bituminous Surface Treatments (DBST) and 2nd/3rd Stage with Asphalt Concrete (AC) overlay may be the main stream of pavement construction. For medium traffic road, 1st stage with AC pavement and 2nd stage with AC overlay is recommended, and in fact is a prevailing practice.

From the point of view of quality and economic consideration, the practice of a thin AC overlay with 30-40 mm. thickness may be further developed.

Mix design and other construction practices pertaining to AC overlay may pursued, preferably with the participation of pavement technology research institutes.

LIST OF APPENDICES