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MAINTENANCE COST ANALYSIS

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PREFACE

A road maintenance is one of the major concerns of the Department of Highways. Each kilometer of a road is terribly expensive in comparison to other facilities belonging to the country. Inadequate road maintenance results in a reduction of the road life from the expected one. On the other hand, an excessive road maintenance creates a high maintenance cost. Both improper techniques reduce the cost benefit of the road. Only a proper way of maintaining roads can lead to an optimum benefit. This stand point is a virtue, and can not be achieved from one man's ideas or experiences of few people. Tremendous amount of properly collected datas in combination with experiences from different sources are the essentials. The Department of Highways realises the need for a research work in this field and strongly supports any kind of research which will be able to induce a method of road maintenance to achieve the goal.

Chaleo Vajrabukka.

Chaleo Vajrabukka

Director General

Department of Highways

MAINTENANCE COST ANALYSIS

INTRODUCTION

Since the amount of highways is increasing nowadays maintenance work is also increased as a consequence. Setting the maintenance budget in such a way that the amount of money can be distributed properly into functional requirements of each road is of great difficulty. Previous datas of maintenance cost is being collected for each road type under different environments and conditions of traffic. One efficient way to project future maintenance cost is to apply results of the previous datas as the base of the projection. This paper presents interpretation and analysis of the maintenance cost datas collected from the Chachoengsoa district. From the results, behavior and characteristics of maintenance cost can be explained by the percentage of each work, its average magnitude, and its fluctuation within the year. Finally from the regression analysis a maintenance cost as a non-linear function of the five different factors, road characteristics and traffic conditions, was obtained to represent characteristic of the maintenance cost of the district

Arrangement of Control Section

To obtain a more accurate data for the purpose of collecting expense at different portion of road in different environment. Roads are divided into control sections of about 30 kilometers each. Setting up the control section was done by experiences. Each control section may not be equal in length. The arrangement was done according to the past expenses and the environment.

Routine Maintenance Work

Routine maintenance work is divided according to characteristic of work as follow :-

1. Traffic lane maintenance work
2. Shoulder maintenance work
3. Drainage " "
4. Right of way " "
5. Traffic sign " "
6. Bridge " "

The traffic lane maintenance work is the most important one and normally consumes highest amount of maintenance. Depreciation rate of the traffic lane is normally depending on type of surface, type of base course, type of subgrade, traffic load, service age, and environment.

Variables Concerning

Variables that affect the maintenance cost can be separated into two types. One is the dependent variable, F, and the other is the independent variables. In this article only those of the asphaltic surface type are presented as follow :-

The independent variables are:-

1. Surface condition, X1
2. Subgrade soil condition, X2
3. Traffic Volume, X3
4. Service time of road, X4
5. Width of surface, X5
6. Width of R.O.W, X6
7. Width of shoulder, X7
8. Traffic sign, X8
9. Quantity of culverts, X9
10. Quantity of bridge, X10

Analytical Method

From the tremendous amount of numerical values of the expense for maintaining the road in the control sections, analytical method was performed according to the following steps

1. To find trend of expense for each variable
2. Using regression analysis to obtain a representative of maintenance cost in term of all variables :-

Application of the mathematical models :-

$$F = a_o + \sum_{i=1}^{n} a_i x_1 \qquad (1)$$

$$\text{or} \quad F = a_o . x_1^{b_1} . x_2^{b_2} \ldots\ldots\ldots\ldots\ldots x_n^{b_n} \qquad (2)$$

$$\text{and or} \quad F = a . e^{b_1 x_1 + b_2 x_2 \ldots\ldots\ldots\ldots\ldots + b_n x_n} \qquad (3)$$

The maintenance cost F can be a linear function of the independent variables Xi (i = 1,2,3.....n) if the equation(1) is applied, while non-linear relationship between F and Xi can be obtained if equation (2) and (3) are in use. In this paper only five independent variables were selected and applied in the analysis. The regression analysis was dons by the use of a computer program name "Multiple Regression", which takes about 128 K bytes capacity.

3. To find a maintenance that yields the ninimum maintenance cost.

This step of research work is just a proposal. To obtain the maintenance method, different methods of maintaining roads must be applied. For example, at the present time most of the highways in the country are maintained under human judgement. Decision to rapair the road is normally made when visible failure occurs. The method of human judgement may be the worst way to maintain the road. Another method can be done by observing efficiency of the road by any means at different time after construction and open to traffic, and setting up a repair limit. The repair limit will eventually stay below failure limit. By this method repairment will be done before

failure is visible and will save life of the road. After methods of maintenance are applied for trial, collection of maintenance cost will be done for years until the road reaches its life. The optimum maintaining method is the one that yields lowest rate of expense,

$$\text{rate of expense} = \frac{(\text{construction cost} + \text{total maintenance cost})}{\text{life}}$$

Results of Maintenance Cost Study for Chachoengsao District

The Chachoengsao district has 1,719.208 kilometers (as shown in figure 1.) in its responsibility. The roads are the combination of 1,086.418 kilometers asphaltic surface road, 454.926 kilomaters soil aggregate surface road and 195.862 kilometers unidentified surface road. One hundred and thirty one control sections were set up. The total amount of money spent in 1971 is 12,093,475 bahts and 10,341,085 bahts in 1972.

Results analysed were found to be as follow:-

1. As shown in figure 1, the average maintenance cost per kilometer of the asphaltic concrete or penetration macadam plus crushed rock base was found to be higher than others. Not much different in maintenance cost was found between the surface type 2 and the surface type 4 (soil aggregate surface). Theoretically all types of road should give about the same depreciation rate since they are all disigned under the same factor of safety.

Differentiation of maintenance cost among different surface types should then be depending on cost of the materials used in the road structure rather than depreciation rate. It seems here that maintenance cost of the soil aggregate surface is approximately as high as the asphaltic surface treatment surface. The high maintenance cost observed in the soil aggregate surface is expected to be mainly due to high rate of depreciation since they are not properly constructed and repaired.

2. Figures 2 and 3 show maintenance cost of each maintenance work by which the total maintenance cost are presented in figure 2 and the maintenance cost per kilometer of each surface type are presented in figure 3. It is obvious that the expenditure for maintaining all type of roads is mainly for repairing the road surface, 65 percent by average. About 25 persent were spent for maintaining shoulder and ROW. Another 10 percent left were used for the maintenance of drainage system, traffic signs and bridges. It is expected that the maintenance cost for traffic sign will be increased in percentage when more roads are in the urban area and sufficient traffic signs are installed along the roads.

3. Figure 4 is the mass diagram indicating frequency of maintenance rate (maintenance cost per kilometer per year) for each type of roads. It can be seen that for all types of roads the maintenance rates are still mainly within 5,000 baht per km. per year, even though the average maintenance cost rate of the road surface type I as presented in 1 will be higher than others. In the diagram there are quite anumber of rates that are much higher than 5,000 baht

per km. per year. Those are expected to be due to the following concerned factors:-

a. the roads are in the area of extremely soft foundation,

b. the road condition stays beyond repair limit,

c. process of repairment had not properly been done

d. too heavy traffic load is illegally allowed on the roads.

4. To observe fluctuation of maintenance cost in a year round, the maintenance cost per km. at each month are presented in figure 5. A continuous line was drawn through points of average values. From the mean line it can be seen that for all types of roads the mean maintenance cost rises up twice a year. The first rising occurs between October - February which is the time covering the ending and the beginning of annual budget, and the second rise occurs between April to August which is about middle of the year. To get more detail about the maintenance cost fluctuation, the maintenance cost per km. in each month of some control sections are shown in figure 6. Some control sections have similar behavior as the average values, but about half of them indicate uniformity all year round.

5. The data of average maintenance cost and factors affecting from 25 control sections for 2 years were gathered. Three different mathematical models were fitted to the data by regression analysis method. As a result, the best filted model is

$$F = 1694.393\ (7.583)^{x1}(0.149)^{x2}$$
$$(0.307)^{x3}(0.999)^{x4}(1.025)^{x5}$$

where F is the average maintenance cost in thousand baht/km/year

x1 is the pavement type,

x2 is the subgrade condition,

x3 is the pavement width,

x4 is the traffic volume in vehicles per day,

and x5 is the percentage of buses and trucks.

The model gives correlation coefficient of 0.924 indicating good fit to the data. Threfore, it is condident that the model reflects the district maintenance characteristics. Investigation on the model reveals that the maintenance cost varies directly with x1 and x5 as it varies inversely with x2 and x4. Thus the highway of good subgrade, wide pavement and high traffic volume yields lower maintenance cost comparing with that of bad, narrow and low traffic. This indicates the district maintenance characteristics that the major portion of the average maintenance cost was allocated for the lower standard highways. The equation is representative of maintenance cost of the Chachoengsao district of the past two years and can be used to predict future maintenance period of time.

CONCLUSION

In this paper analytical results of the maintenance costs were presented only for the district of Chachoengsao during 1971 - 1972. It reveals:-

1. the average maintenance cost of each type of roads,

2. the expenditure for maintaining all types of roads is mainly for the repairment of the road surface,

3. for all types of roads the maintenance cost rates are mainly less than or equal to 5,000 bahts per km. per year,

4. for all types of roads the average maintenance cost rises up twice a year, and

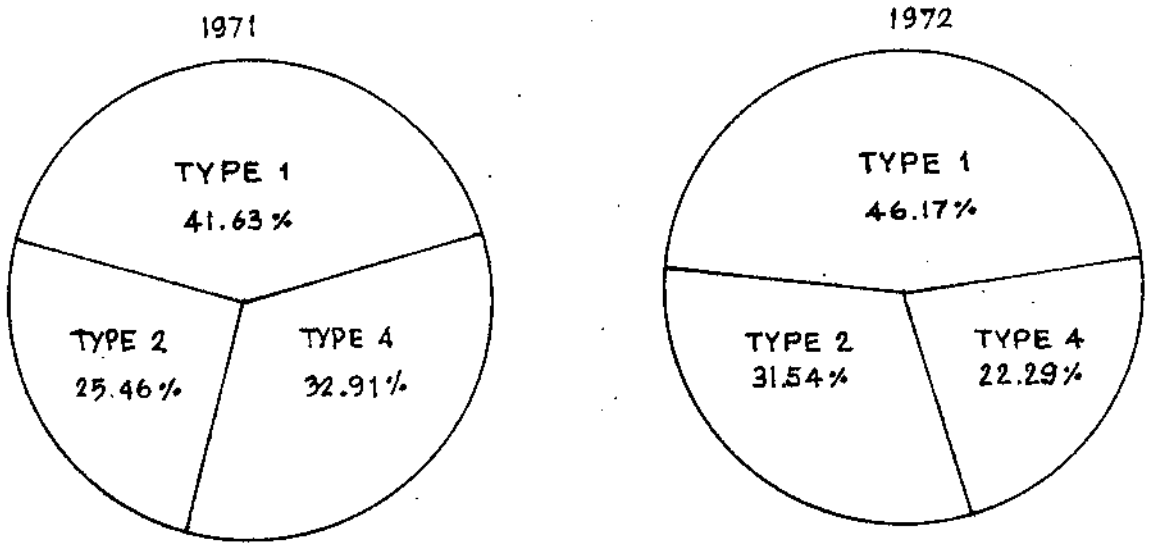
5. regression analysis was performed only for the asphaltic surface road and a good relationship between the maintenance cost, F, and the concerning factors, Xi, is a non-linear function as follow:-

$$F = 1694.393(7.583)^{x1}(0.149)^{x2}$$

$$(0.307)^{x3}(0.999)^{x4}(1.025)^{x5}$$

prediction of future maintenance cost can be done for the asphaltic surface roads in the Chachoengsao district with realistic conditions.

Fig. 1 Comparison of Percentage of Maintenance Cost per Km for Each Type of Roads



Note :- Type 1 - Asphaltic Concrete or Pen. Mac. + Crushed Rock Base
Type 2 - Asphaltic Concrete or Pen. Mac. + Soil Stabilized Base
or Double Surface Treatment + Crushed Rock Base
Type 3 - Surface Treatment + Soil Stabilized Base
Type 4 - Laterite.

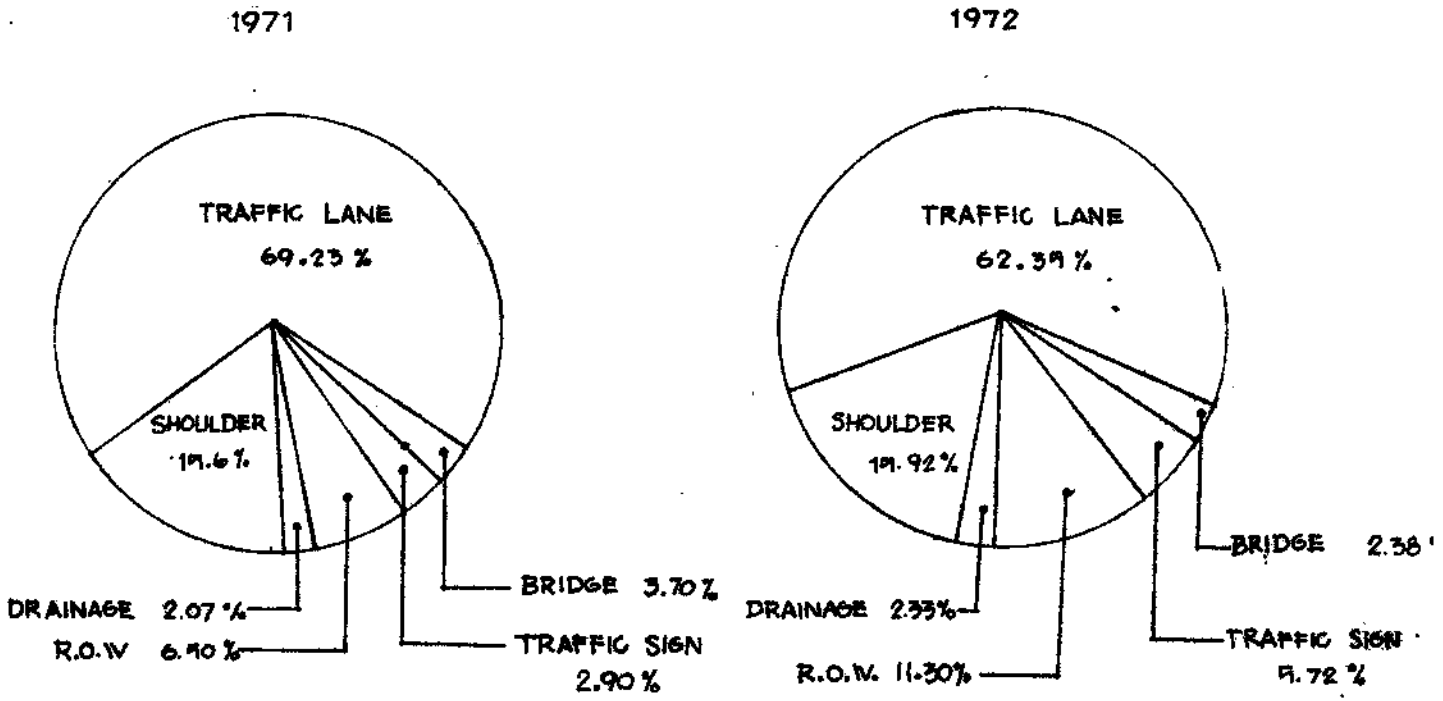
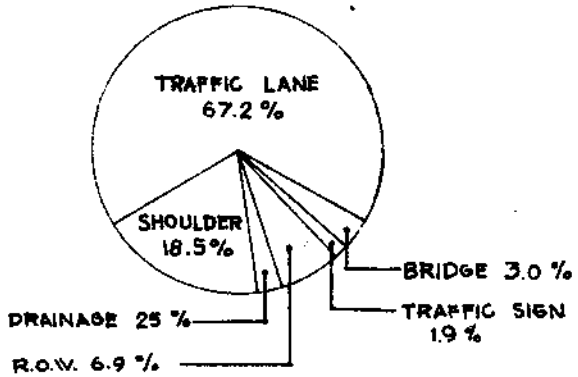


Figure 2. Percentage of Maintenance cost of Each Work.

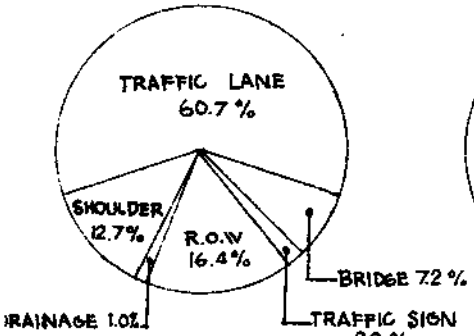
FIGURE 3. PERCENTAGE OF MAINTENANCE COST PER KM. FOR EACH TYPE OF ROADS

1971

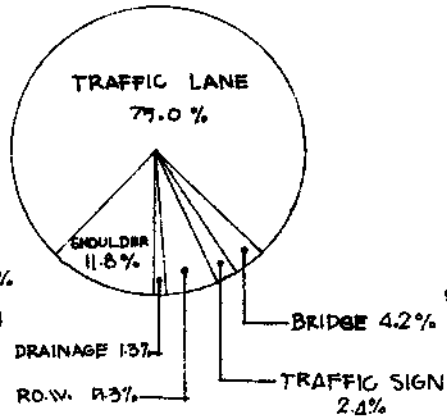
TYPE 1.



TYPE 2.

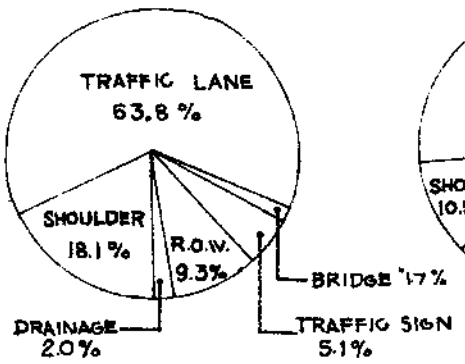


TYPE 4.

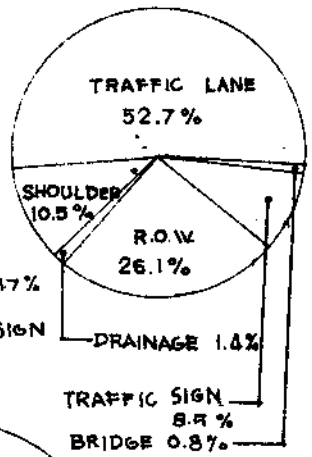


1972

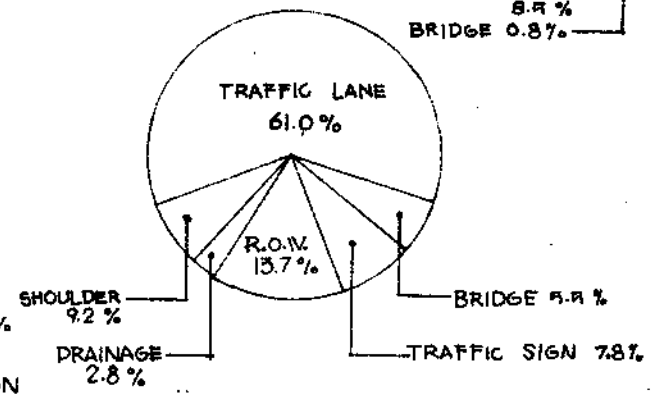
TYPE 1.



TYPE 2.



TYPE 4.



Note. TYPE 1 – Asphaltic Concrete or Pen. Mac. + Crush Rk. base

TYPE 2 – Asphaltic Concrete or Pen. Mac. + Soil Stabilized base or Double Surface Treatment + Crush Rk base.

TYPE 3 – Surface Treatment + Soil Stabilized base

TYPE 4 – Laterite

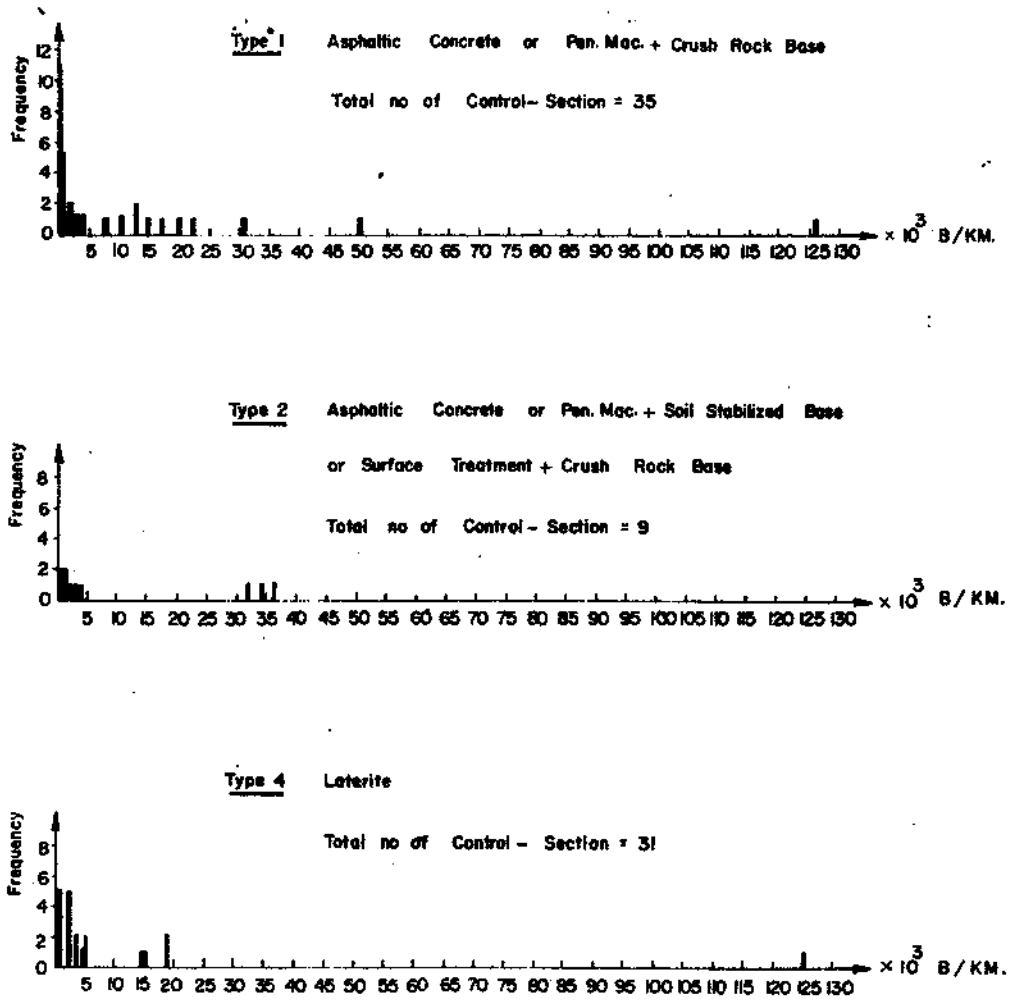


Fig. 4 – 1

Mass diagram (Maintenance cost / KM.) of each type of Road in 1971

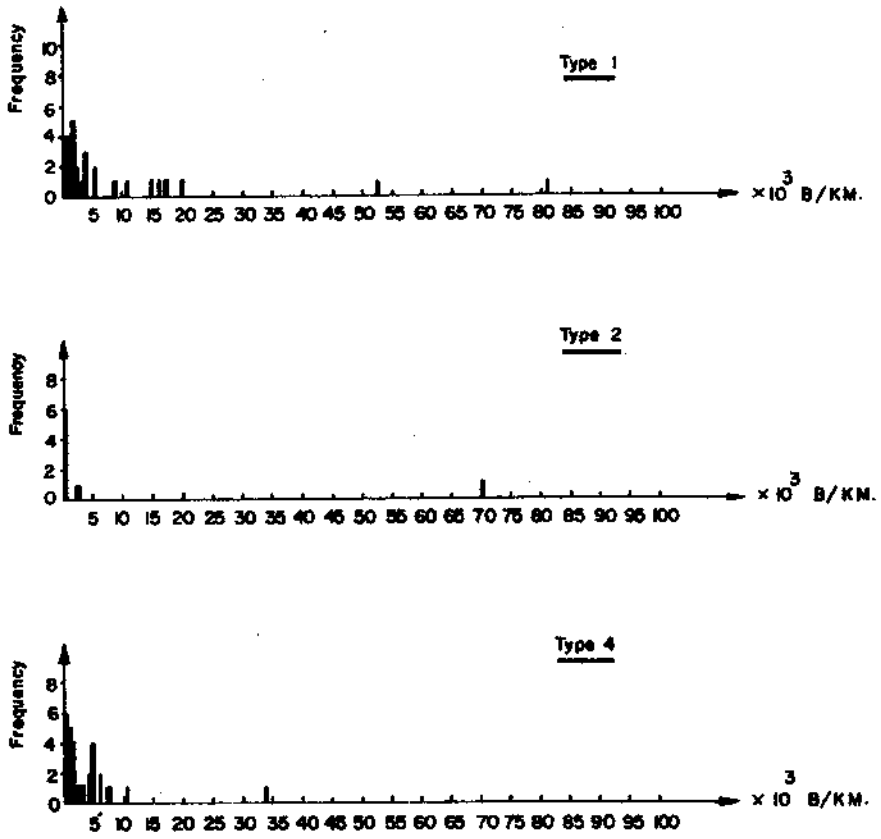


Fig. 4 -2

Mass Diagram (Maintenance cost /KM.) of each type of Road in 1972

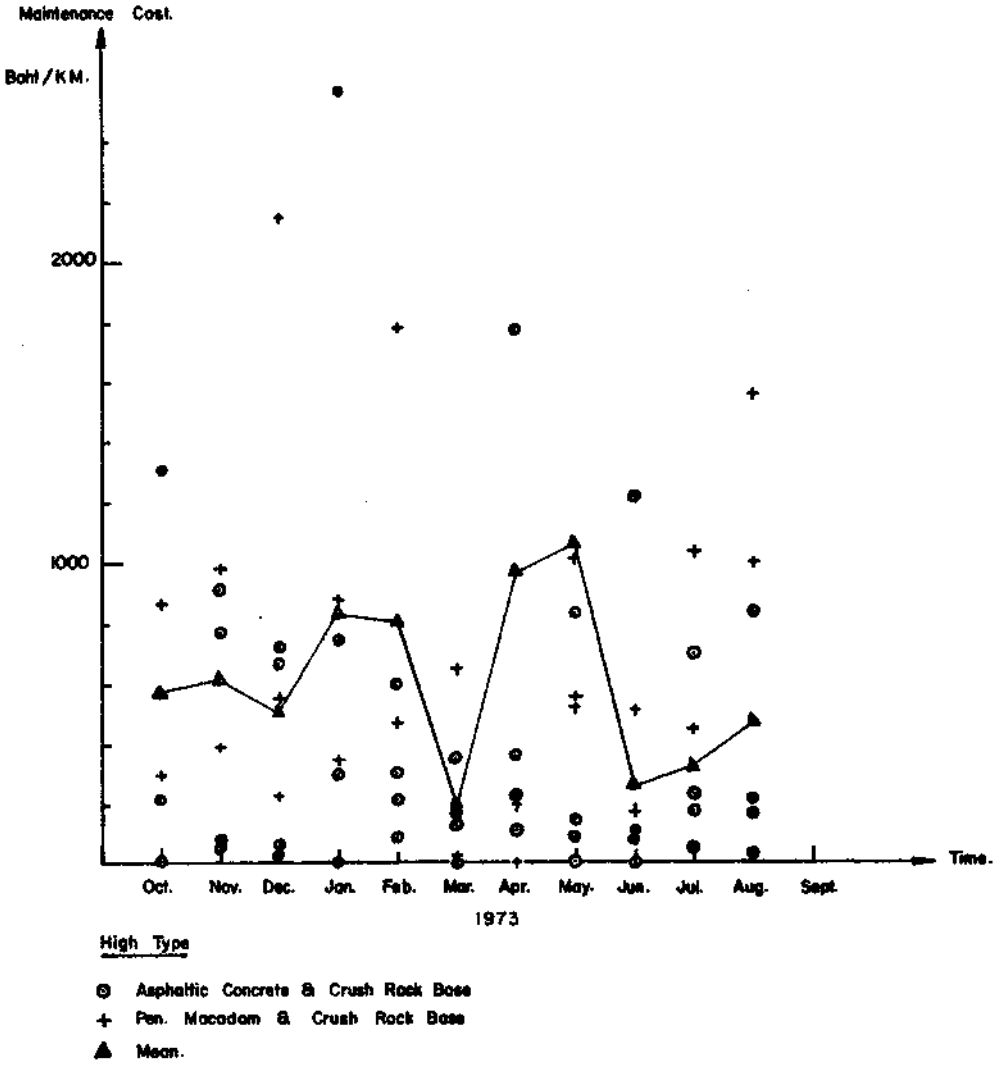
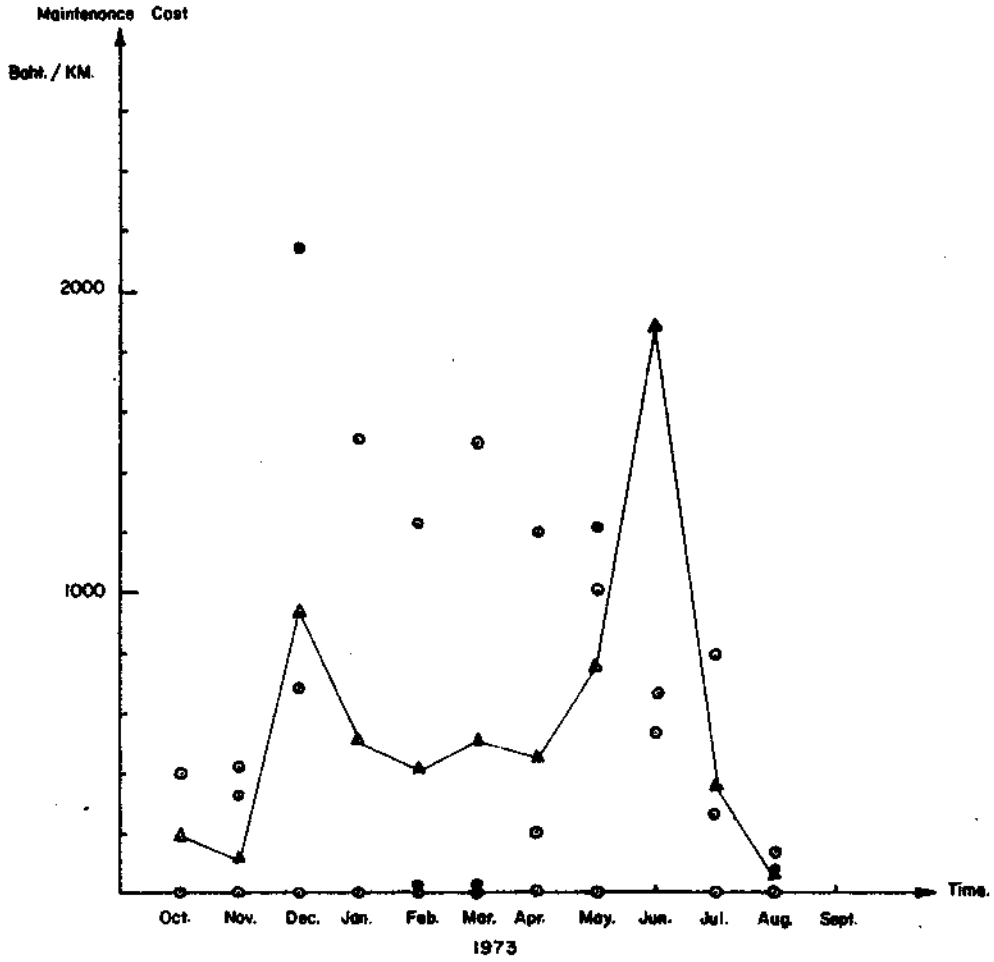


Fig. 5 – 1

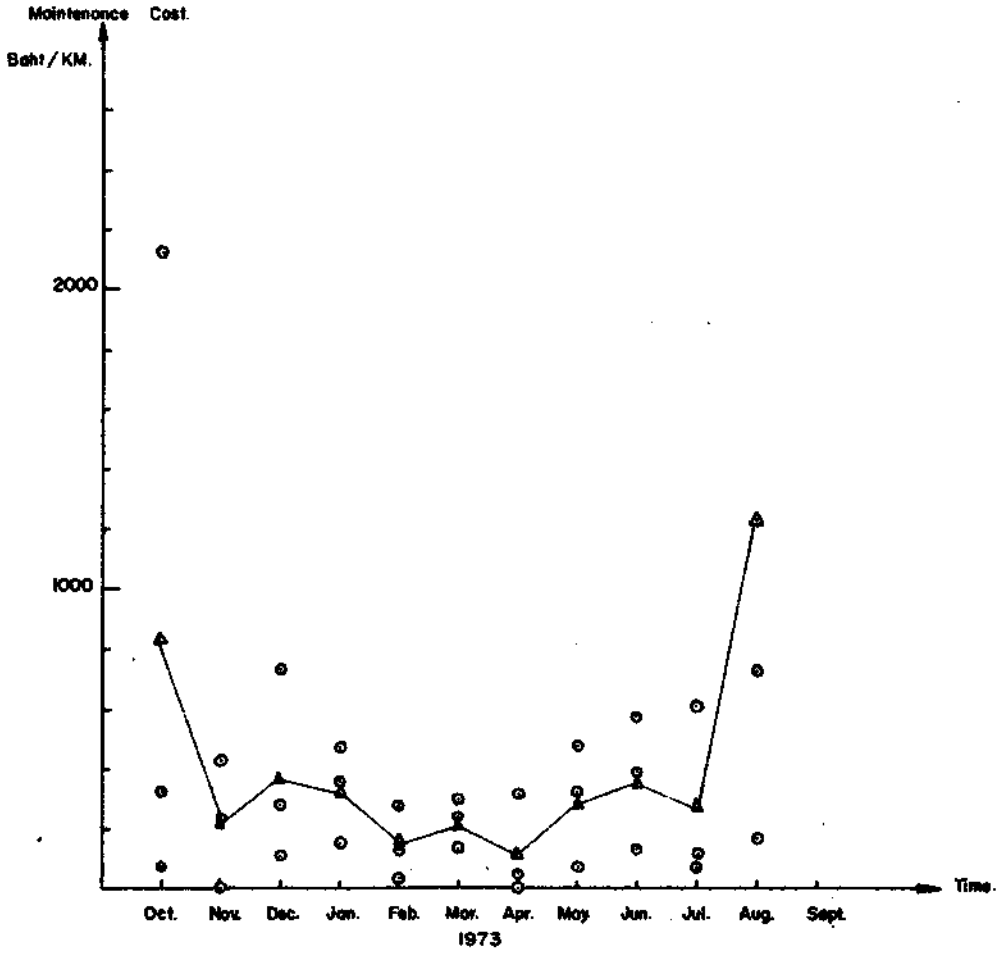
Surface Maintenance Cost / KM. in Kwang Chachoeng Chao



Intermediate Type

Fig. 5-2

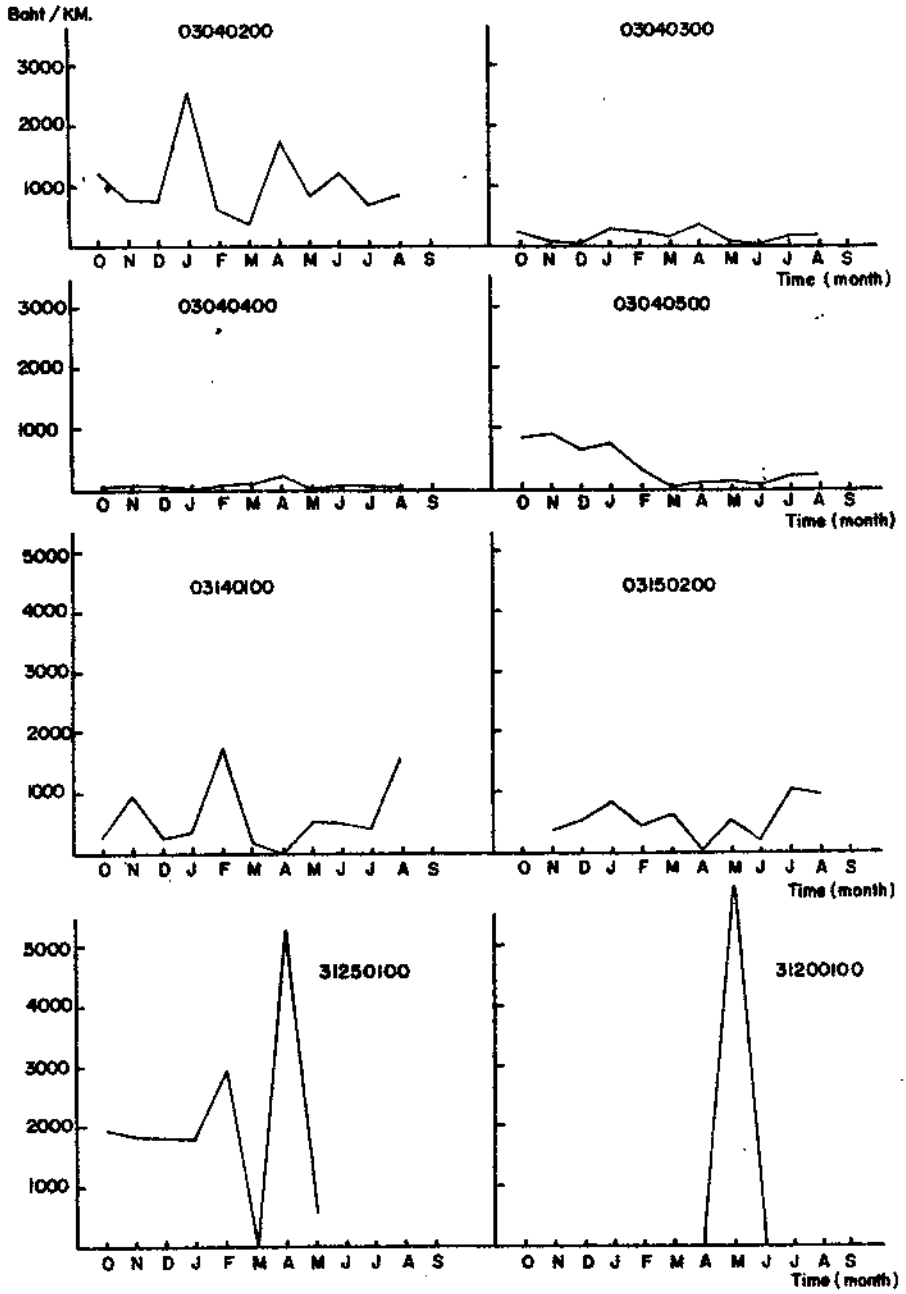
Surface Maintenance Cost / KM. in Kwang Char



Laterite

Fig. 5-3

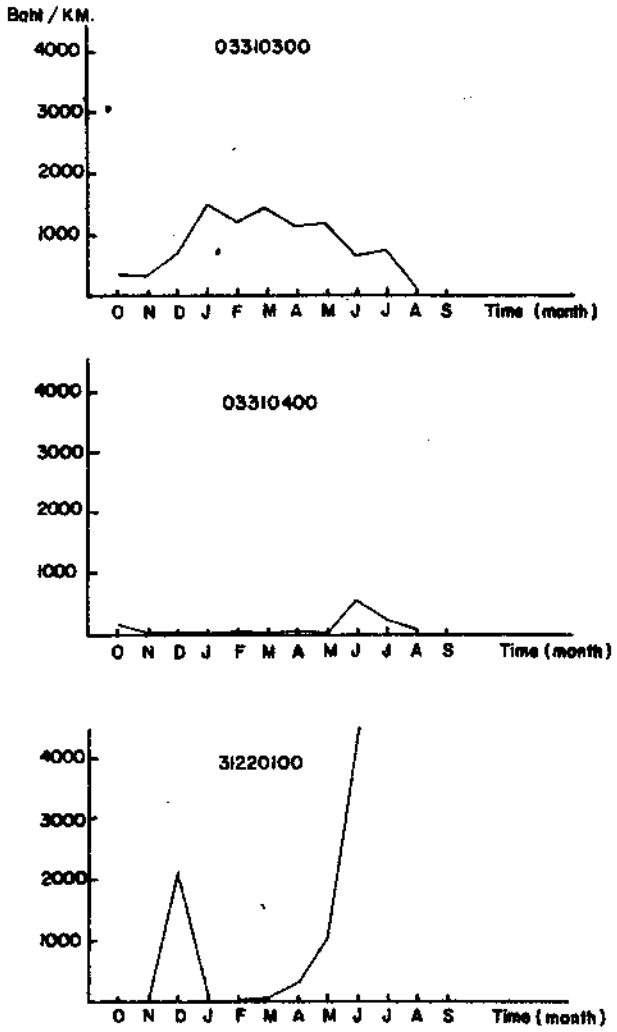
Surface Maintenance Cost/KM. in Kwang Chacheeng Choo



Type I High Type — Asphaltic Concrete or Pen. Mac.+ Crush Rock Base.

Fig. 6 – 1

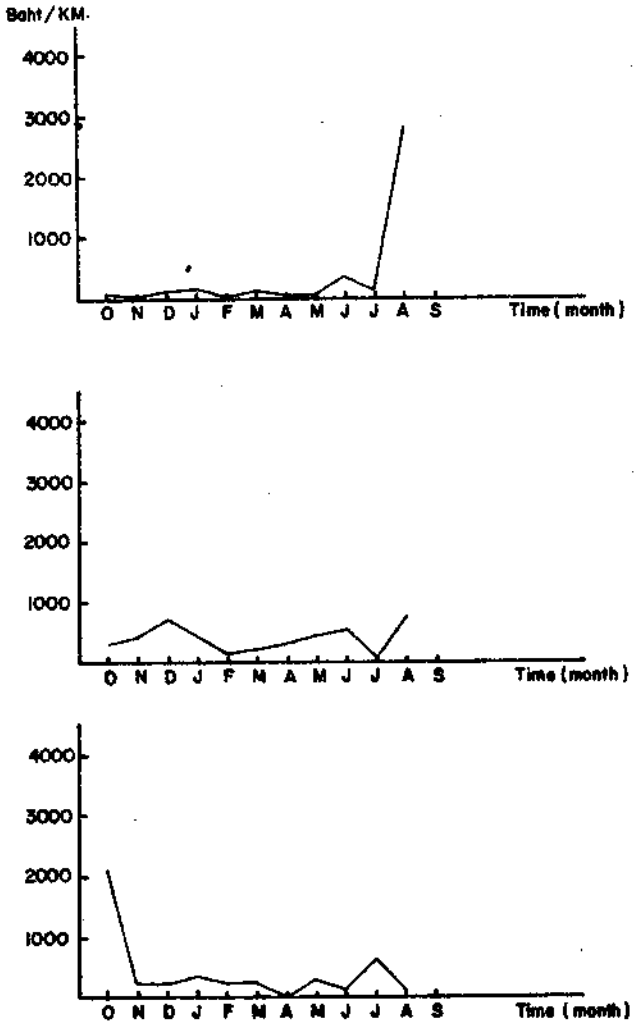
Surface Maintenance Cost of Type I Pavement / KM. / Month in Kwang Chachaeng Chod in 1973



Type 2 Intermediate Type— Asphaltic Concrete or Pen. Mac.+ Stabilized Base or Surface Treatment + Crush Rock Base

Fig. 6-2

Surface Maintenance Cost of Type II Pavement / KM. / Month in Kwang Chachaeng Choa in 1973



Type 4

Laterite

Fig. 6-3

Surface Maintenance Cost of Type ⅸ Pavement / KM. / Month in Kwang Chachaeng Chod in 1973

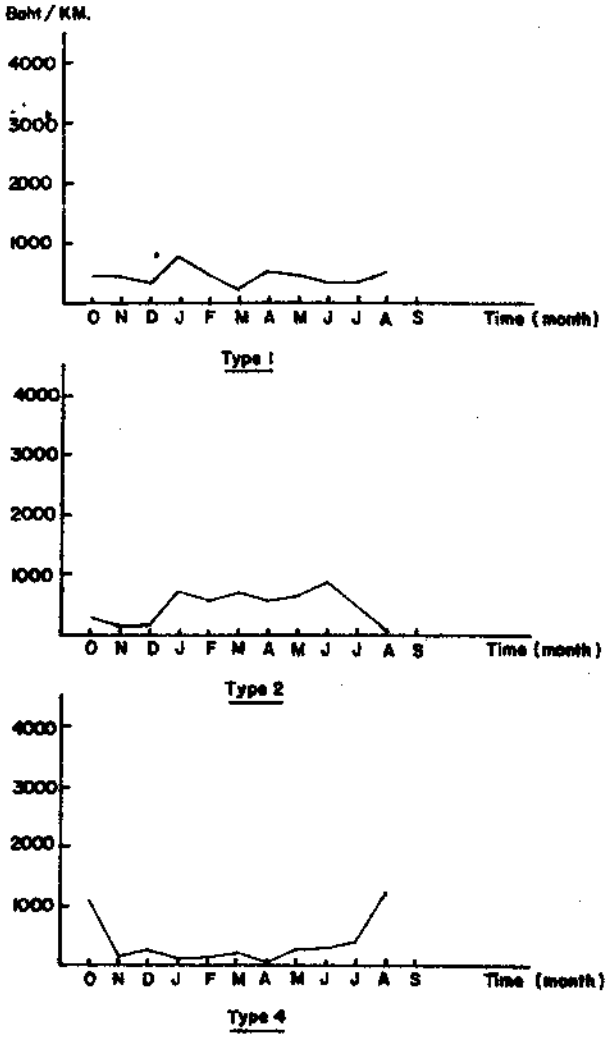


Fig. 6-4

Average Maintenance Cost of Each Pavement type in Kwang Chachaeng Chao in 1973

ERRATA

Page	Line	Change	To
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8	10	condident	confident

Fig.		
5.1 5.2 5.3 6.1 6.2 6.3 6.4	Kwang Chachaeng Choa	Chachaeng Choa district