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PAVEMENT FAILURE EVALUATION AND CORRECTIONS IN THAILAND

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PAVEMENT FAILURE EVALUATION AND CORRECTIONS IN THAILAND

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PREFACE

Any road pavement has its own life which depends on load repetition and pavement strength. It is necessary for the design engineers to accept this fact and provide the way and method to correct the failure and strengthen the pavement to prolong the life of the pavement .

This report is presented in the hope that it will render some benefit to the design and maintenance engineers.

Chaleo Vajrabukka.

(Chaleo Vajrabukka)

Director-General

TABLE OF CONTENTS

PAVEMENT FAILURE EVALUATION AND CORRECTIONS IN THAILAND

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SYNOPSIS

Thailand is located in the tropical zone with an abundant rainfall so the moisture content in soil and pavement is the most influential factor to cause failures of pavements. This report states different types of failures commonly occur in surface, base, sub-base and subgrade. The major problem ordinary arises from an excess moisture in the pavement layers. Thus the pavement drainage is highly recommended. Eventhough the corrections mentioned in this report can be used as a general rule, considerable variation may be found therefore it is important that the more exact analysis be made before the conclusions are drawn.

1. INTRODUCTION

Thailand is located in Southeast Asia, lying entirely between the Equator and the Tropic of Cancer. The country has a warm and generally humid climate almost all year round, with the average temperature of 27°C. Being in the tropic zone, it has an abundant rainfall, caused by the seasonal monsoon, varying from 1300-1600 mm. The distribution of annual rainfall is over all parts of the nation with a higher amount in the southern peninsular, over 2200 mm. per year. As the result, most parts of the country are very fertile and the national economy is dominated by the agricultural products.

The topography of Thailand differs from region to region, the far north and western areas are rugged and mountainous, the northeast consists of the gently undulating topography of the Korat Plateau, the central area contains the flat alluvial plains of the Chao Phya River, the southern region is a peninsular, comprising of coastal plains with rolling and hilly areas of hinterlands.

2. THE PRESENT HIGHWAY NETWORK

The patterns of the road network in Thailand had been arranged in accordance with the geographical features, national resources, economic and social requirements also the strategic planning and political conditions.

The roads under the responsibilities of the Department of Highways are classified into 3 categories:

2.1 Primary roads. These are considered as main arteries of the nation, passing major important cities and ports and usually carry high number of traffic. They form a road network throughout the country, radiating from Bangkok to the northern border at the Burmese frontier, to the northeastern border of Laos, to the east at Khmer frontier and runs towards the southern peninsular at the Malaysian border. The design classification is of high standards, capable to carry relatively high volume of traffic with high speed. Rights of way are always provided for future expansion to at least 4 lane divided highways. The present highway network in Thailand is illustrated by Figure 1.

2.2 Secondary roads. This type provide access to primary roads and also connect important towns and districts. The design classification is of the secondary type.

2.3 Feeder roads. These are roads connecting village to village and chanelling them to the country's secondary and primary roads. Farm to market roads also fall into this category. The standard specifications of these roads vary from unsurfaced farm to market roads to the high standards as dictated by the traffic volumes and loads.

3. PAVEMENT DESIGN STANDARDS

In brief the minimum pavement design standard will be based on the accumulating number of equivalent axle loads predicted during the first 7 years after the construction. Or it may be justified by the economic feasibility study.

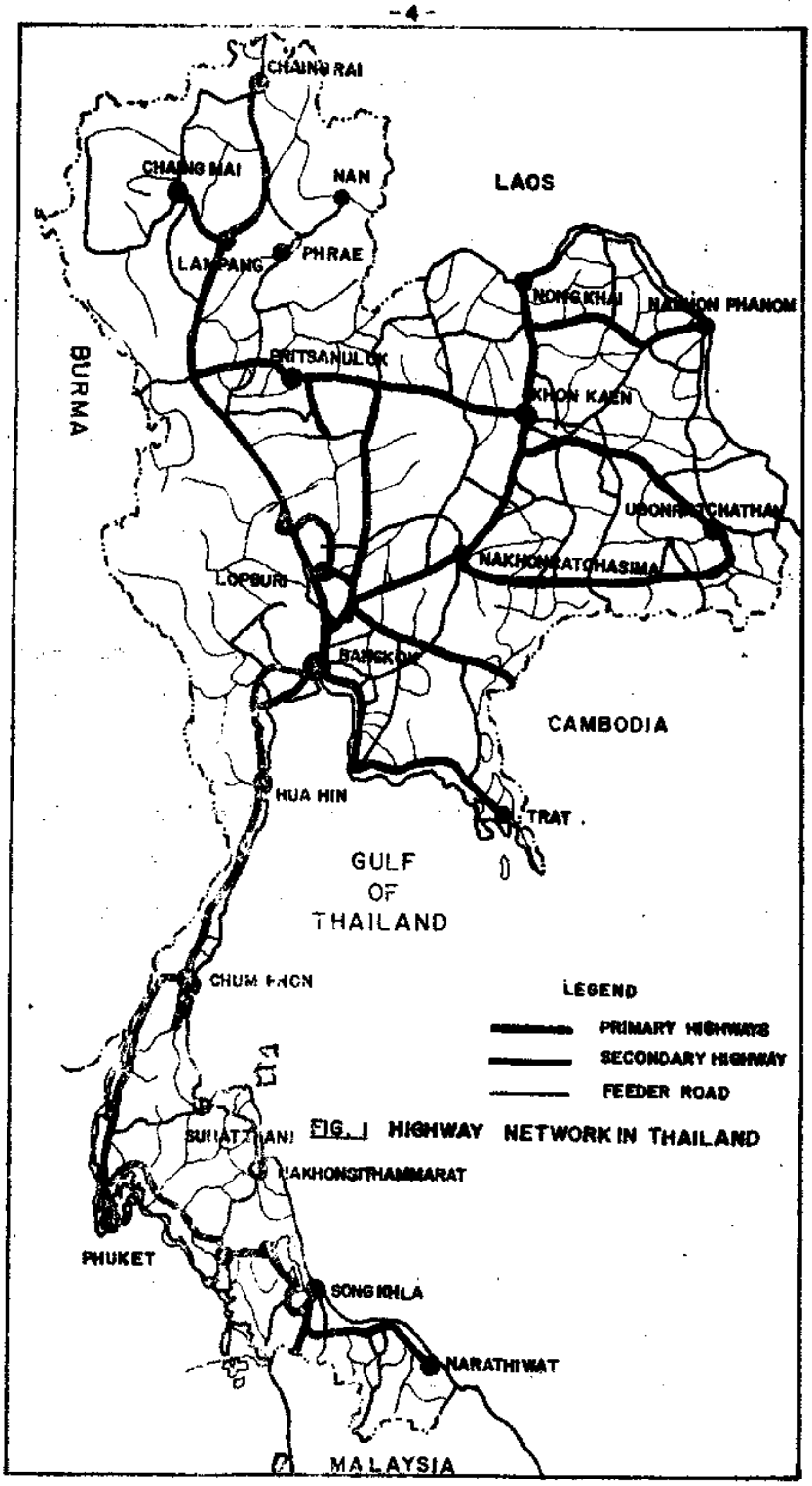

FIG. I HIGHWAY NETWORK IN THAILAND

In Thailand, rigid pavement and flexible pavement being the 2 types of pavements used for roads, with only 1 % of concrete pavement, the rest of surfaces are flexible and unsurfaced. The nation has approximately 21,600 km. of highways and feeder roads, out of these 141.5 km. are concrete pavement, 16,000 bituminous surface and about 5,400 km. of unsurfaced.

In this report the author stresses only on the study of flexible pavement as this type covers the major portion of the country's highways.

The methods of the flexible pavement design employed in Thailand are the California Bearing Ratio Method from the Asphalt Institute Thickness Design Manual Series No. 1 (MS-1) 1969; the California Overlay Deflection Method or the combination of the mentioned CBR Method and the California Overlay Method. In the design the AASHO Road Test and Group Index are generally applied.

For an economical purpose, at the life of pavement between 7-10 years, base course is always used at the minimum thickness that the maximum size of aggregates allows. The thickness of surface is specified by experience due to the numbers of traffic as follows:

Vehicles per day	Type of surface required
0 - 200	unpaved
200 - 1,500	single or double surface treatment
1,500 - 5,000	5 cm. asphaltic concrete
5,000 - 10,000	7.5 cm. asphaltic concrete
over 10,000	10 cm. or over asphaltic concrete

For unsurfaced roads, the full pavement for 7 years life both by the CBR and the Deflection Methods can comparatively be designed and the most economical one will be selected. Surface and base course must be left out. The design thickness of materials will be used and covered with the minimum thickness of sub-base that maximum size of aggregates allows. Temporary surfacing of suitable soil aggregates should be provided in accordance with traffic volumes.

4. PAVEMENT STRUCTURE AND MATERIALS

The flexible pavement structure commonly used in Thailand is shown in Figure 2 and the construction materials widely employed are as follows:

4.1 Surface. The popular type are asphaltic concrete, surface treatment and penetration macadam.

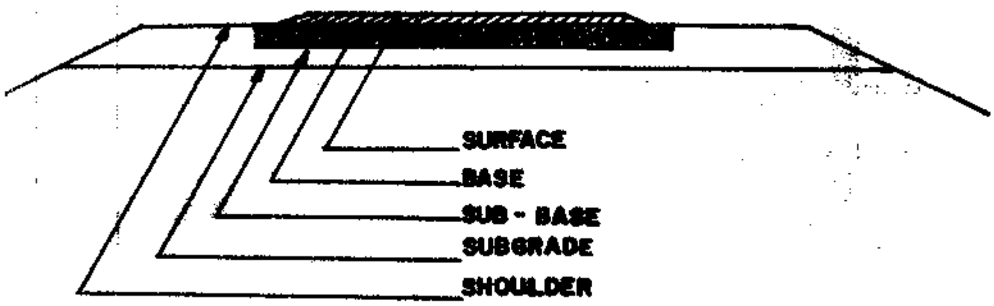

FIG.2 CROSS SECTION OF ROAD PAVEMENT

4.2 Base. Types of base : well graded unbound crushed rocks, water-bound macadam and cement stabilized laterite.

4.3 Sub-base. Types of sub-base : well graded, soil aggregate (usually lateritic soil and sand gravel).

5. PAVEMENT FAILURES AND CORRECTIONS

As mentioned earlier, Thailand is in the tropical zone with heavy rainfall and the terrains vary from flat alluvial plains to mountainous areas. The factor of the failure is mainly moisture content developing in the pavement. In this report, the brief accounts on the failures are given together with the ordinary used methods of correction.

5.1 Pavement failure due to wrongly designed structures, as shown previously in Figure 2. Considering the economic purpose, the pavement structures in Thailand are always in the way that part of the pavement forming a trench in the embankment as clearly shown in Figure 3. At the edge of surface base and road shoulders, it is considered to be the weak point in every pavement design where water can seep in more easily than any other areas of the road surface. If sub-base and road shoulders are impermeable then water will be intercepted in permeable base and seep slowly through sub-base and shoulders. The amount of water will be greater if it can penetrate through the permeable surface or cracks. The Materials and Research Division, Department of Highways has performed the test and found that for well graded

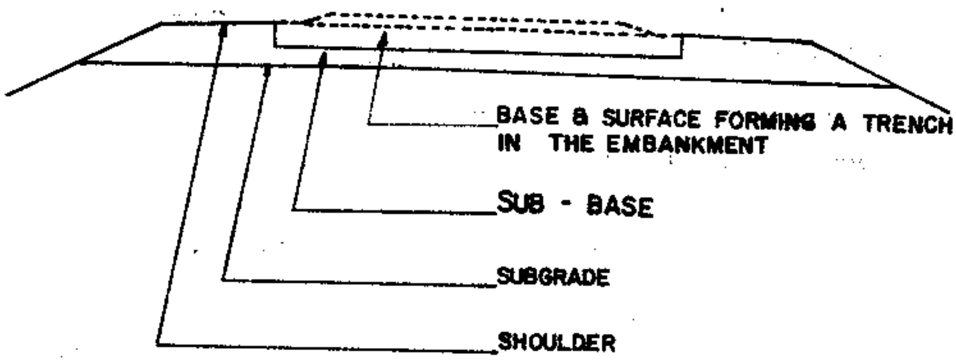

FIG. 3 CROSS SECTION OF ROAD PAVEMENT (WITH WIDER EXTENDED BASE)

soil aggregate crushed rock base at 95 % Modified Proctor density, the coefficient of permeability varies very little and can be averaged at about 16.5 X 10^{-6} cm./second, whereas the coefficient of permeability of shoulder or sub-base lateritic soil of well grade type can be averaged at about 3.67 X 10^{-8} cm/second. It is evident that the permeability of well graded crushed rocks is about 450 times of that of the laterite sub-base. This courses an excess amount of moisture content in the unbound base course before it can seep through sub-base by gravity. This problem can be noticed during the pavement repairs. The moisture content not only softens base course but also creates weakness in sub-base and rutting will progresively occur on the road surface. Then the correction is needed to be done down to some depth. To prevent this problem, the best way is to extend base course all the way to shoulders or to use very dense permeable base, for that asphaltic stabilization is necessary. To provide drain pipes under base course is also a good practice to release excess moisture content. But expenses for these practices are costly. One of the low cost method is to put sand layer under shoulders to drain water out from the bottom level of base course.

This present practice should be corrected immediately to stop the road surface from being cracked which will rapidly become major pavement failure. To the author's knowledge many developing countries in the tropic still employ this practice.

5.2 Pavement failure due to lack of side ditch. As being stressed several time earlier that Thailand has a heavy rainfall especially in the rainy season, then crown or cross slopes should be provided in conjunction with side ditch where embankment is low. These pavements should be designed with its sub-base being at least 30 cm. over high water level. Side ditch should be provided, for most places, to drain the free water out of the road as rapidly as possible. It will also help reducing the ground water table to a certain extent and moreover it will lessen the capillary moisture influence. Several highways without side ditch show sign of deep foundation settlement or corrugated surface after some period of service and that will cause major failure later on. So it is necessary for highway construction in the tropical countries to provide side ditch.

5.3 Pavement failure due to soft foundation. The central plains of Thailand compose of approximately 25 m. in depth of alluvial clay. This type of material causes great problem in the design and construction of embankment and raises construction cost. However owing to high settlement it can be expected that after a period of road service, the settlement creates irregular level on the surface and that requires regular maintenance.

For constructing the road of this type, the Thai Department of Highways has to tolerate the failure to a certain amount due to limited fund. Light weight materials and spread slab footings are employed in sections where high embankment is required.

5.4 Pavement failure due to termination of its life. Before the set up of any programme on road construction, it is initial to study the feasibility of that road and its life needs to be clearly specified to meet the demand of traffic. This should reasonably be a sound plan for an investment for countries under development. The programme to strengthen the road should be implemented before its life terminates otherwise failures will unavoidably occur. This also happens in Thailand as the need of roads is tremendous but the financial situation is not in the state to meet the demand. Eventhough the road have constantly been studied by the rating programme together with the deflection study to check their lives, still, due to the shortage of budget and the demand for new highways, the strengthening programmes have been postponed year by year. The programme should be recognized of its significance and should be included as a part of road construction programme. Also it should be brought into effect or the cost of rehabilitation will be very high.

5.5 Surface failure. As stated before, there are 3 popular types of surface in Thailand, namely, asphaltic concrete, surface treatment and penetration macadam. This report does not cover the failures in details but it includes major items causing the failures and the corrections as follows:

5.5.1 Surface failure due to prime coat. Generally the standard specification in every highway department gives some instructions on variations of an amount of bituminous prime coat to be applied. The incorrect application sometimes causes an excess amount of bitumen for prime coat. The construction engineers are only aware when the amount is not sufficient but they need experience to judge not to use the amount of bitumen over the necessary requirements. It appears in many of the construction projects that the sweeping and brooming of the surface of base is not adequately done and the amount of bituminous materials is over requirements. This causes the pumping up of bituminous materials of the prime coat to the surface course and produces the bleeding and slipperiness of the surface when wet. The other problem happening in the rainy season, during which the evaporation is slow owing to the high humid atmosphere, the volatile matters in the cutback are not allowed to evaporate completely. Then the asphaltic carpet is rapidly laid on and causing insufficient bond between base and surface carpet. The corrugation, slippage or cracks can be observed.

5.5.2 Failure in asphaltic concrete. The author does not include, in this paper, the localized failure occur from other failures such as the weakness of the pavement as it is not the failure which happens due to the surface itself. The asphaltic concrete originally designed to meet the specifications, pertaining to voids, flows, bituminous content and aggregate grading following the Marshall stability requirements, the compaction during construction is 98 % Marshall density. After some period of service the surface always bleeds to certain limit. The Thai Department of Highways has made investigations on the problem and found that after the hot mix has been paved, the kneading compaction from traffic load causes gradual increase of bituminous content on the surface to certain extent. The filler also increases as well as the filler binder ratio. The void ratio decreases approaching to zero in some cases but the Marshall stability is still in the satisfactory state. This causes a problem of slipperiness, the Deparment of Highways is working on detailed study including studies on various types of mixes, the change of bitumen asphalt from AC 85-100 penetration to 60-70 penetration. The conclusion of this behaviour, in the meantime, can only be judged by the pumping of bitumen from the bottom part of the mix through the surface and the excess filler may come from the aggregate breaking. The author would like to invite any comments on this matter.

5.5.3 Failure in surface treatment. By the standard specifications of the Department of Highways surface treatment is employed when the traffic is between 200-1,500 v/d. The major problem of the failure for this type of surface is the slip out of the base when the base composing of high P.I. over 9 has been used. The base must prossess P.I. between nonplastic to 9. The slipping is due to an accumulation of moisture content under the surface.
Another problem can easily happen owing to the construction, the longitudinal streaking and the un-uniformed application of bitumen can occur because of an incorrect setting up of spray bar, truck speed and nozzle pressure. This problem may be remedied by checking the distributor truck before allowing the use of it.
The other problem which easily happens to this type of surface is the throwing off of aggregates by the traffic because of an insufficient amount of bitumen to hold aggregates together. To correct the problem, the Department of Highways now applies the method of design by the Australian Country Road Board together with single size stones. It is important that the stripping test should be performed to check whether wet aggregates will be stripped out from bitumen.

5.5.4 Failure of penetration macadam. Penetration macadam had its popularity in Thailand until 1970. The Department of Highways still uses this type of surface for its direct labour works or some particular types of base, i.e., maintenance work on existing penetration macadam surface.

There are various problems causing failures to this type of surface. Penetration macadam composes of crushed rocks of uniform size where penetration asphalt is sprayed through the voids and the keystones are spread to key the former interlocked stones. The major problem to cause failure comes from its permeability, water can seep through surface to base. It is difficult to find the appropriate amount of bitumen to be applied to penetration macadam surface. With the design based on full impermeability of the surface from the first stage, then the percentage of bitumen for application must be high and that causes bleeding within a short period as crushed stones can move under the traffic especially when the pavement deflection is rather high. The practice of the Department of Highways is to employ certain amount of penetration asphalt in order to obtain complete seal of the surface within 6 months after being open to traffic and that can protect bitumen from flushing. Nevertheless in the first period, it is expected to allow water to seep through the surface. The correct quantity of bitumen can be acquired by the trials on test section of each project.

Another problem of this type of surface is an intrusion of the fines up through penetration macadam stone voids that will cause cracks and finally lead to major failure. Therefore the surface should be put on the firm strata of base with non plastic to P.I.6 with small portion of fines passing no.200 U.S. standard sieve. The practice used in Thailand is penetration macadam will be put on bituminous prime, well graded crushed rocks or water-bound macadam base or cement stabilization base. The finding from previous studies done in Thailand was that penetration macadam can minimize reflected cracks from soil cement base. Then the surface of this kind should always be applied together with cement stabilization base.

5.6 Base.

5.6.1 Well graded crushed rocks. This type of base has been greatly used in Thailand since 1970 as the cost of production is lower than other types of crushed rock base and the construction method is much easier than that of the others. The failure of this type is vital in itself. The problem commonly occurs by the cause of other factors such as the incorrect design of the pavement structure of trench type stated previously and the excess moisture content in the base can easily reduce the strength of the base.

5.6.2 Water-bound macadam. The water-bound macadam base comprises of uniform size of crushed rocks laid on compacted sub-base and rolled to interlock among themselves and the voids usually filled with dust stones. The water, then, helps bringing the fines down to fill the voids. The major problem here is this type of base should be put on the firm strata of sub-base with less fines and lower P.I. in order to stop failure due to intrusion of clay through the base which can easily occur by a collection of water during the process of construction or an accumulation of water later on.

As this type of base is practically permeable then the drainage should be provided to drain water from the base course. Due to high cost of production of stones, this type of surface has ceased to be popular in Thailand.

5.6.3 Cement stabilization base. The practice in Thailand is the design being based on 10.5 kg./sq.cm. unconfined compression strength at the age of 7 days. The stabilization can be either road or plant stabilization. After completion of compaction, the traffic must be allowed on the base course to reduce the size of shrinkage cracks. This kind of base course being applied in the areas where ground water tables are low to prevent the problem of high deflection foundation. The penetration macadam can be used as surface course to prevent reflected cracks or otherwise application of seal coat for 2-3 times should be needed at 1 or 2 years interval. The failure of this type of base can easily occur if the mixing takes longer than the final setting time of cement. The breaking of soil cement slab can be expected if the soil underneath contains high percentage of moisture. The fact that the base of this type cracks is accepted. Therefore the measure to prevent that problem is taken by sealing all reflected cracks to stop the penetration of moisture through them otherwise the cracks will progress and that will certainly cause major failure.

5.6.4 Other stabilization. The Thai Department of Highways has developed soil stabilization by a combination of bituminous emulsion and cement. In order to prevent the shrinkage cracks in the base, the stabilization by emulsion and cement was used as test sections and considered effective. From this type of stabilization, it may be assumed that cement will cause an agglomeration of soil and this will be fully or partly covered with bitumen then the materials will act as ordinary aggregates in the base. However the strength of soil will be developed by cement and cracks cannot be observed on the base. The stabilization of this type is hoped to be used extensively, providing that it is considered economical.

5.7 Sub-base. Sub-base materials are usually available well graded materials with P.I. less than 12. Blended of 2 types of materials such as lateritic soil and sand is always needed. The CBR is also controlled during construction. Experience ascertained from some projects indicated that the use of inferior sub-base materials was the cause of failure to the whole pavement after a certain increment of moisture content in that particular soil. Therefore the control of gradation, liquid limit, CBR and P.I. is strictly regarded.

5.8 Subgrade. Subgrade materials ordinary are accessible materials alongside of the road compacted to required standards Proctor density. There has been no problem for new embankments but for the roads constructed before modern techniques were developed in Thailand, various problems arose due to uncompaction of pavement layers, soft spots are expected to occur in the embankment. Heavy equipment on the embankment as well as the Benkelman Beam deflection test may be employed to observe the elastic behaviour of these soft spots. It is needed that the soft spots be taken out for some certain depth and replaced with new materials of which quality meet the requirements of design.

6. CONCLUSION

This report covers a wide scope of the cause of pavement failures and corrections. However they cannot possibly be explained in details as the paper has to be confined within the length limit. Close investigation on the problems is necessary to judge the cause of failure and to find suitable remedial procedures. The major factor of failure found in Thailand is the moisture content in the pavement.

7. ACKNOWLEDGEMENT

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8. REFERENCE

The Asphalt Institute. Asphalt in pavement maintenance. Manual series no.16 (MS-16) 1967.

The Asphalt Institute. Thickness design-full depth asphalt pavement structures for highways and streets. Manual series no.1 (MS-1) 8th ed. 1969.

Rananand, Nibon. Penetration macadam as a surface to minimize reflected cracks from soil cement base. Materials and Research Division, Department of Highways. Research report no.6. 1973.

Ruenkrairergsa, Teeracharti, Pussayanavin, Pravitra and Kangvanpanich, Sunthorn. Performance of test road using silty sand stabilization as base course materials. Materials and Research Division, Department of Highways. Research report no.20. 1976.

Thailand. Department of Highways. Highways in Thailand. 1975.

Yoder, E.J. and Witezak, M.W. Principles of pavement design. 2nd ed. Wiley. 1975.

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