FORENSIC STUDY ON RURAL ROAD PAVEMENT FAILURES ALONG PARIT SUMARTO

JESTIN BINTI JELANI

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Specially dedicated to my beloved mother and father, family and friends. Thanks for all the patience and love. May The Almighty Allah SWT bless you all always.

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ABSTRACT

Road deformation was occurred so prevalent on rural roads of Batu Pahat vicinity moreover when it's constructed on soft ground. This study presents the results of forensic investigation of a deterioration portion of the Parit Sumarto rural road. This road had been selected as represent of most common types of road deterioration found in Batu Pahat vicinity through field survey conducted for month in August, 2006. The deformation occurred at the right side of the road which located adjacent to the open drain. No deformation seen at the opposed side. The deterioration mechanism hypotheses may due to inadequate layer thicknesses and inappropriate geometry conditions. Extensive field and laboratory testing was conducted to verify the hypotheses. Field investigation was initiated by nondestructive testing (NDT) like ground penetrating radar (GPR) to observe pavement layer thickness and subsurface condition. Mini falling weight deflectometer (MFWD) measure the modulus of the unbound layer and lastly density gauge (DG) for density measurement. Subsequently destructive testing (DT) like dynamic cone penetrometer (DCP) for assessment of unbound layer and thickness determination was conducted. Also, coring and trenching to obtain samples for further laboratory tests. Two locations were trench; one at deteriorated section and one were outside the deteriorated location. MFWD results in this study revealed unsatisfactory as they are significant low. Layer thickness determination via GPR, DCP and trenching was at acceptable differences. The data obtained from NDTs, DTs and laboratory were than used in 2D finite element method (Plaxis) and multilayer elastic analysis (Kenlayer). By using Plaxis in this study, it is found that the root cause of the deformation was inappropriate geometrical design pertaining to road shoulder width. Meanwhile, Kennlayer analysis had shown that apparent differences in road layer thicknesses seem to be a contribution factor in deformation. In this study, evaluation of instrumentations used is also discussed to determine its suitability and effectiveness.

ABSTRAK

Enapan jalan sering terjadi lazimnya pada jalan kampung di sekitar kawasan Batu Pahat, tambahan pula apabila ia dibina di kawasan tanah lembut. Kajian ini mempersembahkan keputusan kajian forensik dari bahagian jalan yang rosak di jalan kampung Parit Sumarto. Jalan ini telah dipilih mewakili kerosakan jalan yang banyak dijumpai di sekitar kawasan Batu Pahat melalui tinjauan tapak selama sebulan pada bulan Ogos, 2006. Enapan berlaku di bahagian kanan jalan yang berhampiran dengan parit. Hipotesis mekanisma kerosakan mungkin disebabkan ketidakcukupan ketebalan lapisan jalan dan ketidaksesuaian keadaan geometri jalan. Ujian tapak dan makmal telah dijalankan untuk menentusahkan hipotesis tadi. Kajian tapak dimulai dengan Ujian Tanpa Musnah (UTM) seperti *GPR* untuk menentukan ketebalan lapisan jalan dan meninjau keadaan bawah tanah. *MFWD* bagi menentukan modulus keanjalan dan yang terakhir adalah *DG* untuk mengukur ketumpatan. Kemudian, Ujian Musnah (UM) seperti *DCP* untuk menilai keadaan lapisan jalan dan juga menentukan ketebalan lapisan jalan. Selain itu, *coring* dan korekan dijalankan untuk mendapatkan sampel bagi ujian di makmal seterusnya. Dua kawasan telah dikorek; satu di kawasan yang mengalami kerosakan dan satu lagi di kawasan yang tiada berlaku kerosakan. Keputusan MFWD tidak memuaskan kerana nilainya sangat rendah. Perbezaan ketebalan lapisan jalan yang ditentukan melalui GPR, DCP dan korekan adalah kecil. Data-data yang diperolehi dari UTM, UM dan ujian makmal kemudiannya digunakan dalam analisis 2D *finite element* (Plaxis) dan *multilayer elastic* (Kenlayer). Dengan menggunakan perisian Plaxis dalam kajian ini, didapati punca sebenar kepada kerosakan adalah ketidaksesuaian rekabentuk geometri jalan iaitu kelebaran bahu jalan. Ini telah menyebabkan enapan berlaku lebih besar di kawasan laluan tayar kenderaan terutamanya yang terletak berhampiran dengan parit. Sementara itu, dari analisis Kenlayer telah menunjukkan perbezaan ketebalan lapisan jalan juga adalah penyumbang kepada enapan.Tesis ini juga ada membincangkan kesesuaian dan keberkesanan alat yang telah digunakan.

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LIST OF SYMBOLS

AC	Asphalt Concrete
ADT	Annual Daily Traffic
CBR	California Bearing Ratio
DCP	Dynamic Cone Penetrometer
DG	Density Gauge
DO	District Office
DT	Destructive Test
E	Modulus Elasticity
ESAL	Equivalent Standard Load
FWD	Fallinf Weight Deflectometer
GPR	Ground Penetrating Radar
KPRJ	Kumpulan Prasarana Rakyat Johor
NDT	Non-Destructive Test
PCC	Pozzolan Cement Concrete
PWD	Public Work Department

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CHAPTER I

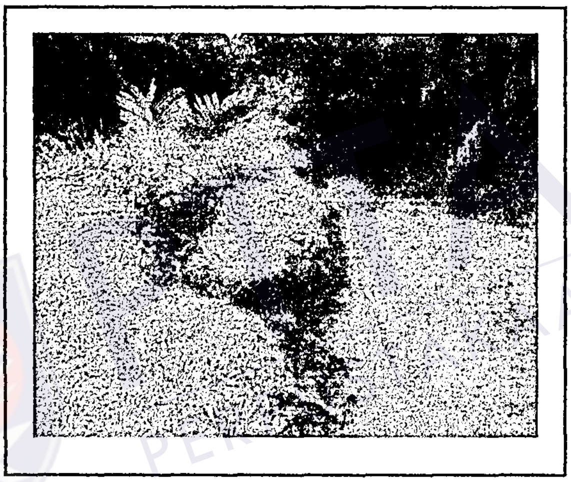
INTRODUCTION

1.1 Preamble

Maintenance as define by AASHTO is "the preservation and keeping of each type of road, roadway, roadside structure, and facility as nearly as possible in its original condition as constructed or as subsequently improved, and the operation of highway facilities and service provide satisfactory and safe transportation" (Oglesby and Hicks, 1982). In the event of structural failure, major rehabilitation works are needed. Some rehabilitation efforts failed and resulted in a very costly maintenance financing. In Malaysia, problems of rural road failures are very pertinent and seem unavoidable moreover when it's constructed on soft ground. Undulating of road surfaces, longitudinal cracks and rutting, large potholes and sudden structural failure were several common failures for rural roads on soft ground condition in Malaysia (Masirin et al., 2005). It is either failed to sustain its design life or performed unsatisfactory during its service to the public thus creating a dangerous environment to road users who are likely to be involved in road accidents.

1.2 Problems statement

A literature review and research by Azman and Idrus (2000) found that most rural roads constructed on soft soil in Malaysia have sustainable life-span shorter than the design-life. They found most of rural road in Batu Pahat vicinity encountered surface failures within 5 years of initial construction period. It is either failed to sustain its design life or performed unsatisfactory during its service to the public thus creating a dangerous environment to road users who are likely to be involved in road accidents. Inclusion in their report, which was 36 out of 60 roads surveyed have experienced significantly damaging failures along its approximately 360 km road pavement; from surface failures to structural failures.



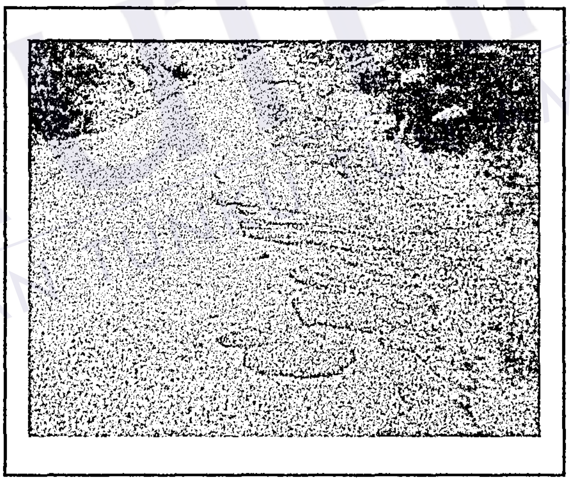


Figure 1.1: Typical pavement failures on rural road in Parit Raja vicinity (Azman and Masirin, 2000).

Local authority is concerned about their road and has applied extensive seal coats, thin overlays and other types of surface treatments to preserve and/or improve the surface condition. Those measures provide a temporary improvement of the surface condition, but they do not provide the remedy to any structural deficiency associated with the pavements. As a result, the overall pavement condition keeps deteriorating because the structural deformation of pavement layers and the subgrade, even though surface treatments have been applied periodically (Zhang et al, 2005). For example, gravel course overlay of a deteriorated asphalt concrete (AC) pavement would not prevent further similar deterioration if the distresses were caused by the existence of underlying soft subgrade soil. Rather, the adoption of a thin Pozzolan Cement Concrete (PCC) overlay that spreads load horizontally would significantly reduce the stresses on the subgrade and thus increase the effective subgrade modulus and performance.

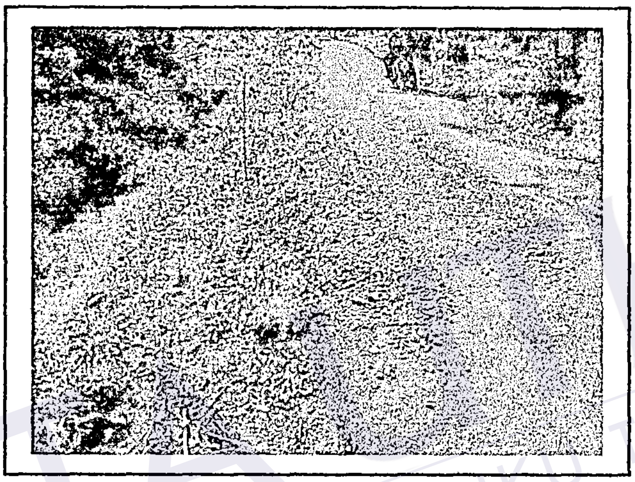


Figure 1.2: Unsuitable selection of remedy treatment.

Therefore, the practice of forensic engineering within the field of infrastructure management has to be applied for proper diagnosis of the root cause of particular pavement deterioration, cost-effective pavement rehabilitation and restoration strategies (Mooney, 2000).

1.3 Scope of works

The work carried out was focused on Parit Sumarto rural road. About 60 meters length of rural road was evaluated. Selection of study area was based on field survey which was conducted for a month. The Parit Sumarto was selected as represent of most common type of rural road deterioration found so prevalent in Parit Raja vicinity. Beside field observation and onsite testing were performed at test site, laboratory tests are also carried out. On site testing includes several measurements like density determination using Density Gauge (DG), thickness determination and assessment for unbound layers by Dynamic Cone Penetrometer (DCP), and subsurface and thickness survey by Ground Penetrating Radar (GPR). These testing are non-destructive testing (NDT). Further, destruction test (DT) is performed, where two locations are selected for trenching based on the previous NDT test. Trenching was performed significantly to obtain underlying material used for further lab testing. The comprehensive results obtained were utilized in Plaxis and Kenlayer software in order to predict the root causes of deteriorations and determine the best selection of treatment that should be applied.

1.4 Objectives

The objectives of this study were follows:

- To identify and determine the causes of pavement deterioration for rural road at Parit Sumarto
- To identify and conduct site observations, sampling, field and laboratory tests in order to analyse the defective road points
- To analyse and determine the appropriate solutions for the defects identified at the forensic test site

1.5 Hypotheses

After analyze all the information gathered during field survey and at available resources (i.e Public Work Department and District Office), then hypotheses were formed as follows. The factors contributing to rural road deteriorations as follows;

(i) Inadequate thickness layer may contribute to less load sustainability and higher deformation probability

(ii) Inappropriate of geometrical configuration in road shoulder will contribute to excessive load distribution to road side structures and conditions.

1.6 Organisation of the thesis

Outline of this thesis is briefly summarized as follows. **Chapter 1**presents problem statement, objective and scope of the project work. **Chapter 2** presents the literature review on the project title which includes background and significance of the forensic study, overview on rural roads construction and management of Parit Raja vicinity, and information towards causes and types of road pavement deteriorations. **Chapter 3** presents detailed on instrumentations, justification of the instrumentations for the project is explained which include precautionary steps during instruments calibration with relevant photographs. **Chapter 4** describes the methodology used for collecting the on site and laboratory test results. **Chapter 5** discusses data observed from the on site and laboratory testing. The discussions include assessment from the results obtained. Subsequently, verify the hypotheses via Plaxis and Kenlayer software. **Chapter 6** presents the summary, conclusions and recommendations of the project.

CHAPTER II

LITERATURE REVIEW

2.1 Forensic engineering definitions

Forensic engineering attempts to find such cures and to uncover the causes of failures so that improved facilities can be engineered. A forensic engineer was originally considered as a professional engineer who dealt with the engineering aspects of legal problems (Carper, 1989).

Campbell-Allen (1987) considered that forensic engineering is:

"[The] application of the art and science of engineering in the jurisprudence system, requiring the services of legally qualified professional engineers."

He acknowledged that the definition was too narrow for the Australian scene, since most engineers do not have legal qualifications

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