A Review on the Incident of Flexible Pavement Defects in Malaysian Road

By

Tan Chin Chien

Dissertation submitted in partial fulfillment
of the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERIFICATION OF APPROVAL

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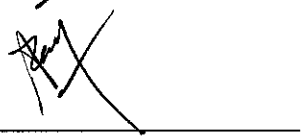
Approved by,



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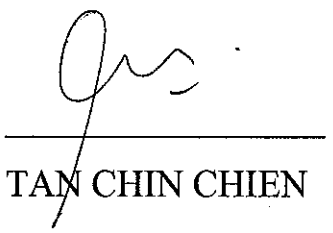
JUNE 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own expect as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



TAN CHIN CHIEN

ABSTRACT

Malaysia has one the of the most fine road network systems in the world, stretching over 60,000km covering each and every state. The major road types in Malaysia are flexible pavement and a small portion of concrete pavement. Every year, federal government has to invest a lot of money to maintain and repair the road. Although a lot of studies on road defects had been carried out oversea and lots of recommendation had been provided on how to minimize the chances of road defects to occur, it might not all be applicable here in Malaysia due to the different in weather condition. Thus, there is a need to carry out a research on identifying the major pavement distresses in Malaysia. This research is conducted to investigate and to identify the major road defects and the causes of failures. Data and information gathering will be the main method to conduct the research. Information will be gathered from authorized department such as Jabatan Kerja Raya (JKR) and also through interviewing the local people. Visual condition survey will be conducted as well to identify the location and type of defects that occur in the area. Photos will be taken during the survey for record purpose. By the end of the research, the research shall be able to suggest an efficient and cost saving repairing methods bass on statistical data and details collected on the local road defects.

ACKNOWLEDGEMENT

I would like to take this opportunity to express my greatest gratitude to all the parties who have given me support and help that guided me through. First of all, I would like to thank my supervisor, Ms Koh Moi Ing. Without her guidance, this project would not have been possible. I would like to thank Mr. Zainal and Mr. Zarkashi, both from JKR department, and those who involved in the interview session for the invaluable information they provided. My course mates, especially Miss Wong Siew Mee, who has been giving me support and advices in order to make this project possible. Lastly I would like to thank every particular whom I have failed to mention their names, thanks.

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CHAPTER 1

1.0 INTRODUCTION

This chapter will provide the brief explanation on why the project is being performed and what is expected from the project. These include background of the project, problem statement, objectives and scope of the study. Background of the project provides information on the selected highway as the targeted area to be investigated and also the expected results from the project. Problem statement indicates problems that had lead to the research to be carried out. And lastly, the objectives and scope of study will be discussing on how this project should be carried out.

1.1 BACKGROUND OF THE PROJECT

Malaysia is proud to have one of the finest road systems in the world stretching over 60,000km covering each and every state. The major road types in Malaysia are flexible pavement and a small portion of concrete pavement.

Road pavements, especially flexible pavement will not last forever once construct. After some time, sign of wear will appear. These signs include cracking, rutting and polishing of the road surface. A point will arrive where the wear and tear is at such an advanced stage that the integrity of the pavement and hence the standard of service provided by it has diminished. Maintenance is required at this point to prolong the highway's useful life. Loss of skidding resistance and loss of texture are forms of deterioration eventually suffered by all highway pavements.

In order to carry out the maintenance in a more cost-effective way, a logical coherent procedure must be adopted in order to select the most effective form that the maintenance should be taken.

Ipoh – Lumut highway has been chosen as the typical asphalt pavement with moderate traffic to study pavement defects. The research will be focusing on identifying

the types of the defects and the causes that lead to the deterioration. Only by identifying the defects and its major causes, cost-effective and time saving maintenance can be suggested. To do so, information will be gathered from all kind of sources.

Due to restriction in materials and equipment, laboratory tests such as SCRIM and High Speed Road Monitor were unable to be performed. However, visual condition surveys will be carried out. The purpose of the survey is to identify the types and locations of defects found along the studied highway.

This research will be able to provide details regarding problems currently faced by Ipoh – Lumut highway by the end of research. Statistical analysis, graphs and tables will be performed to classify the data gathered.

1.2 PROBLEM STATEMENT

In Malaysia, two types of pavements were used to construct most of the roads like rural roads and expressways, namely, flexible pavement and concrete pavement. However, majority of the roads are constructed using flexible pavement. The construction of flexible pavement must strictly follow the specifications issued by Jabatan Kerja Raya (JKR).

Most flexible pavements do not last long, usually 10 years of design life is adopted. However, flexible pavement usually does not withstand the design life and tends to deteriorate faster than rigid pavement. Maintenance is often required and this involves a large amount of money. Therefore, better method of road construction or road maintenance was now the concern of JKR.

The deterioration is mainly the road deformation under traffic loading, and environmental effects. The major types of defects were identified previously as cracking, rutting and polishing of the road surface.

The purpose to conduct this research is to identify the types and causes of defects on flexible pavement. By studying the behavior of the defects, hopefully, more effective and time saving repairing method can be suggested.

1.3 OBJECTIVES AND SCOPE OF STUDY

Basically, there are three main objectives for this project to be carried out:-

- To investigate major pavements distress in Malaysian road.
- To identify the causes and repair methods of pavement distress in Malaysian roads and compare with other country.
- To suggest improvements for road maintenance and repair methods in Malaysia.

CHAPTER 2

2.0 LITERITURE REVIEW AND THEORY

This chapter will be discussing on all the information and previous research findings that contribute to the understanding of project. This chapter is basically the analytical, critical and objective review of written materials on the chosen topic and area. It provides the background information on the research question and to identify what others have said or discovered about the question. It contains all relevant theories, hypotheses, facts and data which are relevant to the objectives and the findings of the project.

2.1 Flexible Pavement

A flexible pavement is a layered structure consisting of the sub-base, road-base and the surfacing overlying the natural ground or sub-grade. The general function of a road pavement is to provide safe and comfortable riding surface for the road users. Its condition with respect to these characteristics is normally assessed by two groups of people which are the users and the road engineers.

2.2 Brief History of Malaysian Road Pavements

Bituminous or flexible pavements were first constructed in Malaysia some time before the Second World War. In those years, the road pavements were constructed using block stone pitching on sand or laterite sub-base covered with a layer of tar or bitumen stabilized aggregate[2]. Since the war, road pavements have been constructed using crushed stone road bases and sand sub-bases with dense bituminous surfacing. This construction method is still being practiced today.

To ensure the smooth operation of the road network, the road pavements have been constantly maintained and upgraded. Inevitably, the road networks along the main trade routes were given more attention than the others. As such the road pavements along these routes are thicker than those along the minor roads. Even though the roads were regularly maintained and upgraded, there were, generally, a lack of record keeping, on the conditions of the roads and the type of maintenance carried out. Most of the

upgrading works carried out were either not designed or designed using methodologies imported from the various western countries. An engineering-based road management system was only introduced in Malaysia in 1974 when a Benkelman Beam survey of 2291km of Federal and State roads was carried out by KAMPSAX International.[2]

2.3 Need for Engineering Evaluation Of The Road Pavements

In order to ensure that the road network is able to satisfy the ever increasing demand placed on it due to increased traffic, there is a need for a systematic approach to the maintenance of the road network. The lack of proper engineering records on past construction and maintenance works now necessitates the need for full engineering evaluation to be carried out before the design of further road improvements or rehabilitation. After a new pavement is constructed, both environmental and traffic stresses will cause it to deteriorate. The rate of deterioration will depends on the severity of the traffic loads and the variability of the road materials. In the evaluation process, the identification and classification of the type of failures is necessary if correct remedial treatments are to be undertaken. [3]

By using definitive and sound engineering decisions, appropriate solutions for pavement maintenance problems can be found [2]. Comprehensive evaluation on distressed pavements can fulfill this requirement. This allows the most appropriate method of rehabilitation to be selected thus minimizing long term total expenditure.

After a new pavement is constructed, both environmental and traffic stresses will cause it to deteriorate. The rate of deterioration will depends on the severity of the traffic loads and the variability of the road materials. In the evaluation process, the identification and classification of the type of failures is necessary if correct remedial treatments are to be undertaken.

Pavement engineers are faced with the difficult task of evaluating pavements that have been subjected to varying traffic loads under variable environmental conditions and material properties. Field measurements are valuable practical tools in the evaluation of

road performance and in the identification of the causes of failure. The task becomes more difficult if the pavement has gone through a series of previous unrecorded maintenance.

2.4 Failure Modes/ Defects in Flexible Pavement

Defects in flexible pavements can be group into five types. These are cracking, distortion, disintegration, slippery surfaces, and surface treatment problems [10]. The figure of each defect can be referred in the appendixes.

Types of Defect	Description
Alligator Cracks	Interconnected cracks resembling an alligator skin
Edge Cracks	Longitudinal cracks approximately 1 foot from the edge of the pavement
Edge Joint Cracks	Occur between the pavement and the shoulder
Lane Joint Cracks	Longitudinal separations along the seam between two paving lanes
Reflection Cracks	Occur in asphalt overlays, reflect the crack pattern in the pavement structure underneath
Shrinkage Cracks	Interconnected cracks, forming a series of large blocks usually with sharp corners or angles
Slippage Cracks	Crescent-shaped cracks
Distortion	Any change in a flexible pavement surface, consist of channeling, corrugation, shoving, upheaval and depression
Channeling	Channelized depressions that develop in the wheel tracks of flexible pavements
Corrugation	A form of plastic movement typified by ripples across the flexible pavement surface
Shoving	Plastic movement of the pavement
Upheaval	Localized upward displacement of the pavement
Depression	Localized areas of limited size that may or may not be accompanied by cracking
Slippage Cracks	Crescent-shaped cracks
Potholes	Bowl-shaped holes of various sizes in the pavement
Raveling	Progressive loss of surface material by weathering or traffic abrasion
Bleeding	Upward movement of bituminous material in a flexible pavement
Polished Aggregates	Those that have been worn smooth under traffic

Table 1:- Type of Defects and Description

2.5 Failure Mechanisms

Extensive research has established the various mechanisms that cause road failures [4]. Some common mechanisms are:-

1. Repeated axle loading
2. Excessive loading
3. Thermal and moisture changes
4. Material densification
5. Consolidation of sub-grade
6. Shear in sub-grade
7. Time dependant deformation (creep)
8. Abrasion by traffic
9. Chemical degradation
10. Degradation of aggregate
11. Hardening of the bitumen

Early detection of these modes of defects during the evaluation process can help in identifying the probable remedy. Suitability and accuracy of evaluation procedures and analysis is dependant on accurate identification of actual modes of failure. Table 2 illustrates some of the failure modes with its mechanisms and manifestation.

Mode	Manifestation	Common Mechanisms
Fracture	Cracking	Excessive loading Repeated loading Moisture changes Age hardening
Distortion	Permanent Deformation	Excessive loading Creep Densification Consolidation Moisture changes
Disintegration	Stripping and Ravelling	Lack of adhension Chemical aggression Abrasion by traffic Degradation of aggregate

Table 2: Failure modes, manifestation and mechanisms

2.6 Previous studies

Two previous studies had been referred to in order to get an idea on how this project should be conducted. The selected case studies are having similar objectives with this ongoing project.

2.6.1 Previous study 1:- Guideline and Procedures for Pavement of Airport Pavement

The main objective of this research is to provide guidelines and procedures for maintaining rigid and flexible airport pavements [8]. The research suggested typical

maintenance and repair techniques for several pavement defects. Table 4 shows the types of pavement surface defects, with respective causes of defects and recommended repairing techniques.

Problem	Suggested Repair Technique
Crack and joint sealer missing	Remove old material sealer if extensive areas affected; sandblast joints and cracks; reseal properly
Random cracking	Seal newly formed cracks; replace subbase to establish support; if pavement being overloaded, probably will require overlay.
Surface Irregularities	Patch local areas; apply leveling course; roto-mill.
Bleeding	Scrape off excess material; blot with sand
Potholes	Remove and replace base (and subbase if required); replace surface and seal.
Map cracking, crazing, alligator cracking	Overlay; apply seal coat.
Slipperness	Apply textured seal coat; grooving; remove rubber.
Oxidation of bituminous binder	Apply seal coat; heater planer; resurface.

Table 3: Maintenance and Repairs of Pavement Surfaces

2.6.2 Previous study 2:- Flexible Pavements Rehabilitation Manuals

The objective of this research is to provide guidance to those who intend to recommend flexible pavement rehabilitation for planning, design and maintenance of the highways. The research stresses on the engineering judgment which must be exercised throughout the investigation and design process [7]. Suggestions are made on improving the design of pavements and also the rehabilitation. These suggestions are taken into consideration and some of it is being implemented in the project carried out.

The research listed out the guidelines for both pavement design and rehabilitation. These guides including designing a pavement governed by structural adequacy, reflective cracking, and ride quality respectively, and pavement rehabilitation design guide including basic overlay using DGAC, rubberized asphalt concrete, stress absorbing membrane interlayers, cold recycled asphalt concrete pavement and etc.

CHAPTER 3

3.0 METHODOLOGY

Methodology refers to relevant and acceptable methods or procedures used to achieve the objectives of the project.

The very first step involved is to understand the topic of the project and understand what is expected upon completion of the project. To do so, the topic of the project entitled 'A review on the incidents of flexible pavement defects in malaysian roads' is discussed with supervisor.

The second steps will be planning the appropriate sequence and flow of the projects. The steps involved throughout the project are further discussed with supervisor. All the steps involved were analyzed and any irrelevant steps were removed. This stage is very critical because by selecting the appropriate sequence and flow, the project will be able to complete in time besides achieving its objectives.

Then, literature review will be carried out. This was done through browsing through internet, journal, referring relevant information from the library and seeking opinion from relevant personnel. Information gathering is important in providing more knowledge on the background of project and also provide firm understanding on topic to be researched. This stage will be carried throughout the whole project from time to time.

On-site information gathering will be carried out after the literature review is done. On-site information gathering involved interviewing the relevant authorities, visual inspection on the road surface condition, data collection and also photo taking of any relevant object.

After on-site inspection is carried out, all the information and data gathered will be tabled and perform in a proper way, such as graph and flow chart. This information will be discussed in details and will be elaborated.

Finally, conclusion and recommendations will be done. Conclusion will be made based on the information and data gathered, and analysis performed. Recommendation will be suggested if there is any.

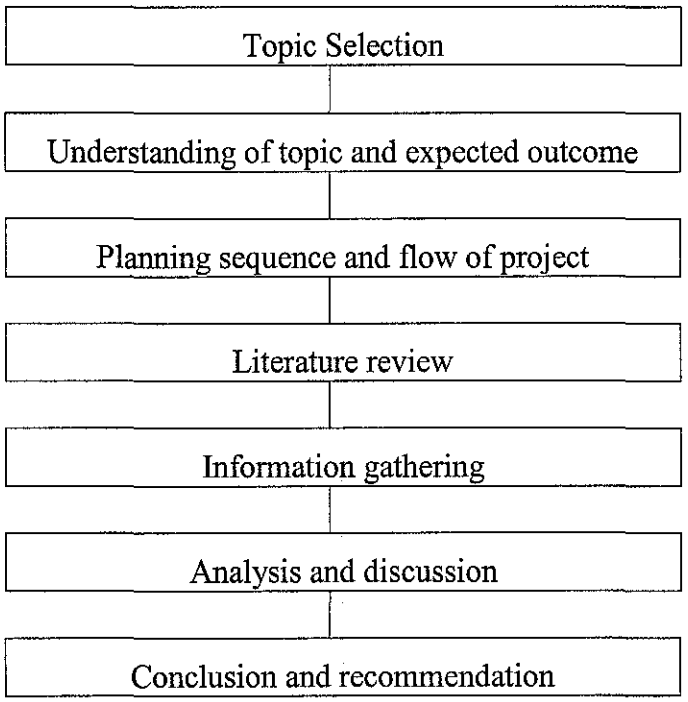

Figure 1: Flow of methodology

3.1 Topic Selection

The topic selected for this research is "A Review on the Incident of Flexible Pavement Defects in Malaysian Road". The objectives of carrying out this project are to investigate the major flexible pavement distress in malaysian road and to identify the causes and repair methods of pavement distress.

3.2 Understanding of Topic and Expected Outcome

The topic is discussed with the supervisor. The discussion includes how the research should be conducted and what are the expected outcomes. The expected outcomes from the research are to further recommend more effective methods for road maintenance and repair in Malaysia if there is any.

3.3 Planning Sequence and Flow of the Project

The project is break down in to multi-task. Each task should be complete in the duration stated in order for the research to be completed on time. To do so, a Gantt-Chart is prepared to indicate clearly the duration of each break down task.

3.4 Literature Review

Literature review is done in order to gain more understanding on flexible pavement. Also, previously conducted case studies were review to understand more the topic and how the topic should be carried out. Literature review is mainly done through reading and surfing on the internet.

3.5 Information Gathering

Information gathering is conducted to retrieve information needed for this project. Information gathering is mainly done by referring related journals, surfing internet, questionnaire session and also to conduct visual inspection on the selected road.

3.5.1 Visual Inspection

The visual inspection will be carried out on Ipoh – Lumut highway. The inspection of the project should describe the general condition of the pavement in terms of visual appearance including the type, severity and extent of distress [3]. This should include items such as rutting, bleeding, raveling, patching, potholes, shoving (sometimes called slippage), corrugations, and the various types of cracking. Photo of the spotted defects will be taken for further analyze.

3.5.2 Questionnaire Session

Questionnaire session is conducted to obtain the opinion of professionals that are from the related field. Theirs views on the causes of defects and the appropriate remedy and prevention will be invaluable to this research.

3.6 Results and Discussion

After the needed information is gathered, an analysis will be conducted. The purpose of analysis is to analyze all the data and to compile them. Discussion will be done right after all the data is analyzed and discussed.

3.7 Conclusion and Recommendation

The final stage of this research will be to conclude all the information and data gathered. Based on the conclusion, recommendation will be made.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

This chapter presents the finding or outcome of project work. All the gathered data from the project work is presented in the form of tables and figures such as graph, diagram or others. The data need to be analyzed, and the results need to be discussed.

4.1 Results

Repairing methods in Malaysia and in USA are listed out. The repairing methods in both countries are compared later in discussion.

4.1.1 REPAIRING METHODS IN MALAYSIA

Generally, the repairing methods used in Malaysia can be divided into 3 categories, which are restoration, resurfacing and reconstruction.

Restoration

As the pavement condition deteriorates further, particularly when distress such as cracking and polishing of the aggregate become apparent, the restoration option is warranted. Restoration will repair the existing distress, decreases the rate of increase of roughness and slow down the subsequent pavement deterioration by arresting the mechanism causing the distress [2]. Techniques involved:

Rejuvenating

Hardened or aged bituminous surfacing can be restored by spraying a layer of bitumen or polymer modified bitumen to improve its existing condition. Rejuvenating agents have been introduced as an alternative as they can restore the original properties of the bitumen. Currently the available products claimed that the rejuvenating agent depends on careful study on the bitumen condition in the existing surface as it will dictate the type and amount of rejuvenating chemicals to be used. The application of the rejuvenating chemicals is simple to carry out. There is no special equipment needed for this work. On a larger size job, it may be economical to use a mechanical sprayer. Since the chemicals used tend to leave a later of residual oils on the road surface, slowing down the traffic

during the initial periods is essentially important. The performance of the rejuvenating chemicals depends upon how deep the chemicals are drawn down into the bituminous layers and is useful when used with other methods such as surface recycling, where the chemicals are used to replenish the lost chemical constituents in the asphalts.

Crack Sealing

Crack sealing is a cheap restoration alternative which would seal the cracks from ingress of water. Before cracks are sealed it is better to remove dirt and loose materials from the cracks. These are done using air compressors. Care must be taken to ensure safety of vehicles before opening to traffic. Any loose material must be swept away. If sand is used as additional filler, allowing slow moving traffic can help the embedment of the small particles into the cracks. Excess filler material must be removed since this could reduce the skid resistance of the surface. Generally, crack sealants will not completely fill the full depth of the cracks. Only the top few millimeters are filled. Because of this the use of crack seals is limited to those cracks which have not propogated completely through the surfacing layer.

Cutting and Patching

Cutting and patching is replacement of deteriorated asphalt surfacing with suitable bituminous mix, placed and compacted to similar level to adjacent un-deteriorated asphalt. Two types of bituminous patching materials which are commonly used, namely hot mix asphalt and cold mix asphalt. Bituminous patching mixtures must have sufficiently good properties, such as

- Stability - to resist shoving and rutting
- Cohesiveness - to stick with host material
- Resistance to water – to prevent water penetration
- Durable – to resist wear
- Workability – to easily handled and constructed
- Storage ability – to be stored without deteriorating for immediate works

The very first step in carrying carry out cutting and patching would be marking the area which is intend to be cut. The area marked is then cut. The cut section is then clean and dry to ensure the section is free of dust. This is important to ensure good bonding when the section is patched. Tack coat will be sprayed onto the cut section and filled with bitumen. Compaction will be carried out right after the section is filled. Lastly, the patched section is clean up and the joints are checked to ensure the proper seal between the existing pavement and the newly patched section.

Thin Asphalt Overlay

Thin asphalt overlays provide a feasible alternative for low cost pavement surface restoration. The common used thin asphalt overlays are *surface dressings, slurry seals, and thin hot mix overlays*. A surface dressing is an application of bitumen followed with an aggregate cover in a single or multiple applications. In double surface dressings the larger sized stones are placed in the first application with the smaller sized stones in the second application to fill in the voids in the first layer. The aggregates used have to be cleaned and free from dust. This will facilitate cohesion between the aggregates and the bitumen. If dusty aggregates are used, then pre-coating them first in more suitable.

Slurry seals are a mixture of aggregates; water and filler (cement) bound with bitumen emulsion, and mixed in-situ prior to laying using specialized equipment. It has potential for both corrective and preventive maintenance of asphalt surfacing. However, it is not a structural layer. Application of slurry seal is known to retard the hardening process of the top portion of asphaltic concrete surfacing. There are 3 types of slurry seals, namely type I, II and III as specified by the International Slurry Seal Association (ISSA) [(2)]. Thin hot mix asphalt is an asphalt mix which is normally less than 40mm thick. Any type of hot asphalt mix or modified mix can be used. The thin asphalt layer is mainly to correct surface deficiencies and will not add much structural strength to the road.

Surface Recycling

Pavement surface recycling is the reworking of the pavement surface to improve its performance and correct surface failures particularly surface cracking. It is a growing field in pavement rehabilitation but must be used with care. Suitability of its application will depend primarily on the structural conditions of the existing pavement. Normally it can be applied only when the pavement is structurally sound and the mode of failure is confined to the top of the surfacing.

Resurfacing

When the cumulative traffic load increases the fatigue life of the surfacing is exceeded, which eventually manifests itself in the form of crocodile cracking, and the pavement has suffered severe and extensive structural damage, restoration works may not be effective. Resurfacing is the most popular method used in Malaysia (1). It involves the placement of fresh material on the existing surface which improves riding quality and provides additional structural strength. It is necessary to design the overlay thickness in order to achieve the desired design life. Resurfacing can be applied to all types of distressed surfacing, but pre-treatment is sometimes necessary before resurfacing is actually carried out. The most commonly used resurfacing materials are *thick asphalt overlays* and *granular overlays*. [2]

Reconstruction

Reconstruction of the pavement layers will be necessary when any of the layers has deteriorated beyond economical repair. Depending on the layers needing repair, reconstruction can be divided into full or partial reconstruction. Full reconstruction is needed when the existing sub-grade has deteriorated and become unstable. Partial reconstruction is carried out when only the road base or the sub-base layers have deteriorated.

4.1.2 REPAIRING METHODS IN USA

Crack Seals

Crack seal products are used to fill individual pavement cracks to prevent entry of water or other non-compressible substances such as sand, dirt, rocks or weeds. Crack sealant is typically used on early stage longitudinal cracks, transverse crack, reflection cracks and block cracks. Fatigue cracks are most often too extensive to warrant filling with crack sealer; they usually require an area treatment such as a patch or reconstruction. [6]

Figure 2: Crack Sealing

Crack sealing is best done in moderate temperatures (spring or fall) and is most effective if performed immediately after cracks develop. Before applying crack sealant, cracks should be routed out and cleaned

Fog Seals

A fog seal (see Figure 3) is a light application of a diluted slow-setting asphalt emulsion the surface of an aged (oxidized) pavement surface. Fog seals are low-cost and are used to restore flexibility to an existing HMA pavement surface. They may be able to temporarily postpone the need for a BST or non-structural overlay.

Figure 3: Fog Seal on the Right Hand Side

Bituminous Surface Treatments (BST)

A bituminous surface treatment, also known as a chip seal, is a thin protective wearing surface that is applied to a pavement or base course. BSTs can provide all of the following:

- A waterproof layer to protect the underlying pavement.
- Increased skid resistance.
- A fill for existing cracks or raveled surfaces.
- An anti-glare surface during wet weather and an increased reflective surface for night driving.

BSTs are used more often in Eastern Washington than Western Washington because of the generally lighter traffic volumes and because the predictable periods of good weather those BSTs require achieving satisfactory results are more prevalent in Eastern Washington. However, BSTs are used in Western Washington (for instance, the City of Seattle has a BST program).

Patches

Patches are a common method of treating an area of localized distress. Patches can be either partial or full-depth, although typically HMA pavement patches are full-

depth. A high quality HMA patch can be considered a permanent repair although many patches are done as emergency repairs in poor conditions (e.g., cold, rainy) and therefore are only considered temporary repairs. Patching material can be just about any HMA or cold mix asphalt material as well as certain types of slurries. Typically some form of HMA is used for permanent patches, while cold mix is often used for temporary emergency repairs. One of the most common patching technique is pothole patching. Pothole patching probably receives the greatest amount of public attention. Pothole patching procedures cover a wide range of methods and intentions from permanent full-depth patches to temporary on-the-fly patches. However, potholes are the result of pavement failure and therefore any patch is considered temporary until the underlying cause is determined and corrected. Two general patching involved are semi-permanent pothole patch and throw-and-roll. [1]

Semi-Permanent Pothole Patch (from FHWA, 1998)

1. Remove all water and debris from the pothole.
2. Square up the pothole sides so they are vertical and have in-tact pavement on all sides.
3. Place the patching material into the clean squared-up hole. The material should mound in the center and taper down to the edges so that it meets flush with the surrounding pavement edges.
4. Compact the patching material starting in the center and working out toward the edges. Compaction can be accomplished using a vibratory plate compactor or a single-drum vibratory roller. Check the compacted patching material for a slight crown. This is done so that subsequent traffic loading will compact it down to the surrounding pavement height.

Throw-and-roll (from FHWA, 1998)

1. Place the patching material into the pothole without any preparation or water/debris removal.
2. Compact the patching material using the patching truck tires (usually 4 to 8 passes).

3. Check the compacted patch for a slight crown. If a depression is present add more patching material and compact.

Although it may seem that the semi-permanent technique would produce a higher quality patch than the throw-and-roll technique, the FHWA's Long Term Pavement Performance (LTPP) Study found that the "throw-and-roll technique proved just as effective as the semi-permanent procedure for those materials for which the two procedures were compared directly" (FHWA, 1998). Since the semi-permanent technique is more labor and material intensive, the throw-and-roll technique will generally prove more cost effective if quality materials are used.

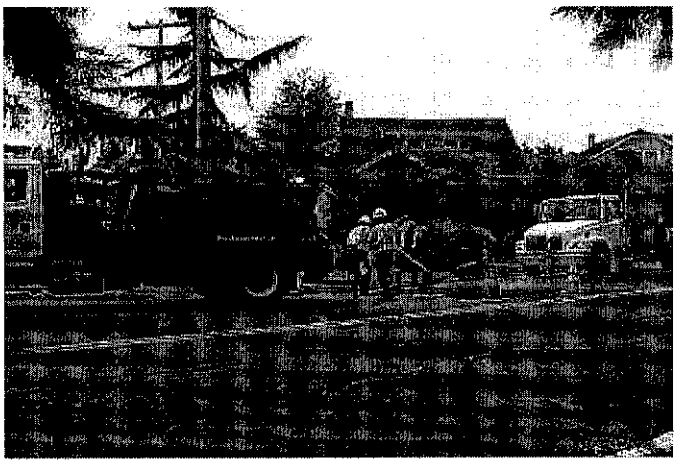

Figure 4: Semi Permanent Potholes Repair

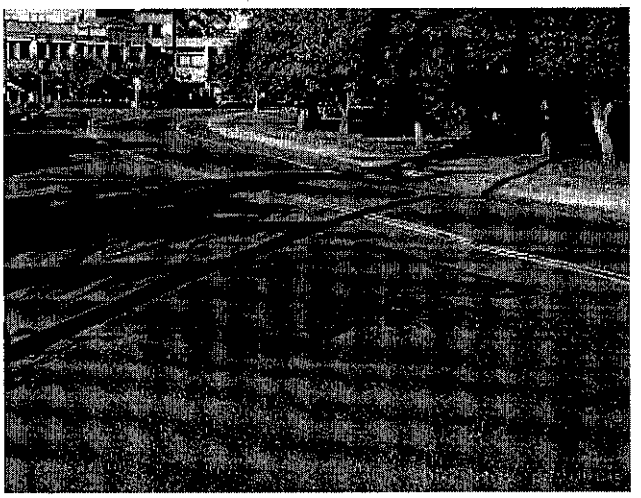

Figure 5: The same pothole repaired- one year later

4.2 Analysis and Discussion

Discussion is carried out to compare the causes of defects and also the repair techniques between Malaysia and USA.

4.2.1 Comparison of Causes of Defects in Malaysia and USA

There are different causes of deterioration in Malaysia and seasonal countries due to different in weather. Malaysia is having excessive amount of rainfall and the weather is hot throughout the year. As for seasonal countries, the temperature and rainfall volume change from season to season. Due to the difference, the causes for some of the road deterioration might be different.

Alligator cracks

The cause of alligator cracks in Malaysia is different from the one in seasonal countries. The cause in Malaysia is mainly due to excessive movement of the surface over unstable sub-grades or base courses [(2)]. Other causes might be due to be improper design and also poor drainage system installed to direct storm water. Basically seasonal countries are having the same reasons for the occurring of alligator cracks. However, due to the different in weather, they are having additional causes such as spring thaw and frost heave. Spring thaw is a process where changes in the weather cause the transforming of a solid into liquid form. Spring thaw usually happens towards the end of winter and the early of a spring. Frost heave occurs only in winter when water penetrates the sub-grade. Frost heave will weakened the sub-grade and thus, lead to the occurrence of alligator cracks.

Potholes

Potholes are small bowl shaped depression, usually less than 0.9 meters in diameter, having sharp edges and vertical sides near the rim. The causes for the occurrence of potholes in Malaysia is usually caused by weakness in the pavement[(2)], resulting from too little binder; too thin a surface, too many fines, or poor drainage, while for those in US are mainly due to water penetrating the pavement structures and also segregation in base course material.

Distortion

Distortion refers to a change in the surface pavement original position. The common causes of distortion are identified as foundation settlement. For Malaysia, the main reason for the foundation settlement is due to excessive rainfall through out the year[2]. Water penetrates the sub-base, turning the soil into clay and mud, and as a result, the foundation settles. The reason for the foundation settlement to occur in seasonal country is due to frost heave. Seasonal countries do not experience rainfall frequently but when entering winter, the water that remains in the foundation will frost and weaken the foundation.

Rutting

A rut is characterized by a surface depression in the wheel path. In many instances, ruts become noticeable only after a rainfall when the wheel paths fill with water. Rutting is usually caused by the permanent deformation in any of a pavement's layers or subgrade[2], usually caused by consolidation or lateral movement of the materials due to traffic loading.

Temperature is also one of the important issues for rutting to occur. Conditions where the pavement reaches a temperature above 45 degrees Celsius, or goes above the softening point of the binder used within the wearing course will causes rutting to accelerate.

Generally, rutting is more serious in Malaysia compared to seasonal countries due to the high temperature through out the whole year. The rate of rutting is much higher in Malaysia if compared to the seasonal countries due to the different in temperature and weather.

Loss of skid resistance

Loss of skid resistance includes bleeding and also polished aggregates. The most common cause of bleeding is too much asphalt in one or more of the pavement layers.

This is usually the result of a rich plant mix or a prime or tack coat that is too heavy. Bleeding normally occurs in hot weather. Therefore, bleeding will be more serious in Malaysia compared to those seasonal countries. Seasonal countries experience bleeding more during summer where temperature is high, but for Malaysia, bleeding is a problem whole year due to high temperature of the country.

The cause for polished aggregates is same in Malaysia and in USA, where it is due to the repeated traffic application on the road.

Disintegration

Disintegration in a bituminous pavement is caused by insufficient compaction of the surface, insufficient asphalt in the mix, loss of adhesion between the asphalt coating and aggregate particles, or overheating of the mix. The most common type of disintegration in bituminous pavements is raveling.

Raveling in Malaysia is mainly caused by the poor construction methods and poor mix design. Usually, compaction is not carried out properly during the construction of the flexible pavement. As for US, the main cause is due to dislodging of aggregate particles and the loss of asphalt binder. The mix design usually is strong enough but due to the thermal and moisture movement in this seasonal country, raveling occurs.

Depression

Depressions are localized low areas of limited size. In many instances, light depressions become noticeable only after a rain, when ponding creates "birdbath" areas. In Malaysia, the causes of depression are caused by the traffic loading heavier than that for which the pavement was designed, poor construction methods and sub-grade settlement. The causes in seasonal country are almost the same. The only different cause in Malaysia and seasonal country is that the sub-grade in Malaysia is weakened by the excessive rainfall that penetrates the sub-grade while the sub-grade is weakened by frost heave process in seasonal country.

4.2.2 Comparison of Repairing Technique in Malaysia and USA

Aged bituminous surface

Aged bituminous surface refers to those bituminous surfaces that had already hardened. Fog sealing is used in most developed country as an option to restore flexibility to the existing road condition[10]. Fog seals agents are low in cost and are able to temporarily extend the need of carrying out Bituminous Surface Treatment (BST) or resurfacing. Besides that, flexibility of aged bituminous surface can be restored using rejuvenating technique. A layer of bitumen or polymer modified bitumen is sprayed on the affected area to improve its existing condition.

The cost of fog sealing agent and rejuvenating agent are the same for comparison purpose (ranges RM 2 to RM 4 per meter square)[2]. The manpower required to carry out both techniques is almost same since both techniques use machine to perform the job. The main difference between two techniques is that fog sealing had proven to be able to prolong the flexibility of the pavement for at least another year under moderate traffic condition. As for rejuvenating, the flexibility of the existing road condition can be restored but the effectiveness is yet to be studied under Malaysia environment. Correct choice of rejuvenating agent depends on careful study on the bitumen condition on the existing surface as it will dictate the type and amount of rejuvenating chemicals to be used.

Fog sealing is more environmental friendly as compare to rejuvenating agents. Fog sealing is just a light application of a diluted slow-setting asphalt emulsion on the surface of an aged (oxidized) pavement surface. As for rejuvenating agents, polymer modified bitumen is used. It is believed this might endanger the workers who are working with the material.

Resurfacing of the existing road condition is usually the last alternative considered, when the condition of the road is at critical stage. The unpopularity of this

technique is due to the high construction cost where a lot of machinery, labor and material are needed.

Cracking

Cracking take in many form, namely alligator cracks, reflective cracks, lane cracks and etc. To effectively overcome minor cracking problem, the solution would be crack sealing[10]. The purpose of the sealing is to prevent ingress of water and avoid the cracks to worsen. Crack sealing is a cheap way to restore the performance of flexible pavement, the cost ranging RM 0.50 to RM 3.50 per square meter[2]. However, this technique does not guarantee the period the services life of pavements can be prolonged.

Thus, surface recycling is introduced. Surface recycling can prolong the service life of a flexible pavement to its design life when it is properly constructed. However, surface recycling can only be applied for failure modes that causes and extent are known. Therefore, assessment and on site investigation should be carried out before the surface recycling can be executed.

In terms of cost, surface recycling is higher than crack sealing, ranges from RM 6.00 to RM 13 per square meter[2]. But in terms of effectiveness, surface recycling would provide better restoration performance as compared to crack sealing. Another advantage of surface recycling have over crack sealing is that crack sealing agents are easily washed off due to the on-going traffic and also rain. As for surface recycling, after the work is done, the asphalt layer can be preserved better due to the ease of controlling traffic passing on it.

Another alternative in overcoming cracking will be patching. The cost will be between RM 8.00 to RM 10.00 per square meter[2]. Patching is only appropriate if the affected area is not large. Often, patching will badly affected the overall appearance of the road and the road surface will be uneven if the patching is not properly done.

Rutting

Rutting refers to surface depression in the wheel path. Rutting can be dangerous especially in countries that are having winter seasons. During snowing, snow will accumulated in the affected area and hardened. This hardened ice will greatly increases the slipperiness of the road. Therefore, salting, gritting or ploughing must be carried out according to the depth of hardened ice. Of course, the repairs mentioned here are temporarily work only.

The common repairing methods practiced world wide in tackling the rutting problem are patching and cold milling[2]. The cost of carrying out the mentioned tasks ranges from RM 8 to RM 10 per square meter[2]. The performance of a patched area depends heavily on the type of mix used and the construction standard. If constructed properly, this alternative would be able to last the life of the untreated sections. But if poorly constructed, this alternative can increase the roughness of the road section.

A more effective method to repair rutting would be resurfacing. According to Marshall Report, a research carried out in UK for road maintenance, area affected by rutting should be treated when more than 30% of wheel rutting is more than 13mm under a 2m straight edge[11]. Resurfacing can strengthens the road pavement, making it capable of carrying increased traffic and also improves ridding quality.

Although resurfacing would be a better choice to overcome rutting, but patching and cold milling is still the preferred alternative provided that the area is not affected at a severe stage that warrants resurfacing. This is due to the ease of performing patching and cold milling works. The traffic flow will not be much affected by the repair work. The opposite lane of the affected lane can still be opened. Unlike patching and cold milling, resurfacing involve big machinery and required a lot of manpower. The flow of traffic will be very much affected if the repair works were to schedule to carry out during daytime when the traffic is busy. Further more, the cost of resurfacing is higher than cold milling and patching, ranges from RM 8 – RM 20 per square meter[2]. The cost

mentioned is excluding of the labor cost. So, the total cost might increase to the range of RM 20 – RM 30 per square meter[2].

The other advantage of using cold milling instead of resurfacing is that the milled material can be salvage and recycled. This would reduced pollution to the environment and also saves in term of materials.

Potholes

Potholes are small bowl shaped depression, usually less than 0.9 meters in diameter, having sharp edges and vertical sides near the rim. The method used to tackle the problem is cutting and patching. The cost of carrying out the task ranging from RM 8 – RM 10 per square meter[2]. For early remedy action, slurry seal can be used to seal the fatigue cracks before the cracks become worst and turn into potholes form. The cost of slurry seal ranges from RM2 to RM8 per square meter depending on the size of the job[2].

Usually, slurry seal is a much preferred alternative in preventing potholes compared to late rectification action, cutting and patching. To effectively carry out slurry seal, road condition assessment must be conducted frequently to check on the severity of road cracking. If the cracks are not severe, then slurry seal is applicable. If the cracks are found to be severe, then cutting and patching is applied.

The odor released from the slurry seal agents might be hazardous to the workers working with it. As for cutting and patching, the impact on environment will be significant as cutting process produces a lot of dusts. These dust not only endangered the health of workers and nearby neighborhood residents, but also interrupt the view of road riders especially motorcyclist.

The manpower and machinery involved in slurry seal is lesser compared to cutting and patching.

Loss of Skid Resistance

Loss of skid resistance takes forms in bleeding and polished aggregates. This defect endanger the safety of road users especially motorcyclist, where the pavement does not provide grip to the braking of vehicle. Thus, remedy action shall be taken as early as possible.

Currently, Malaysia is using cold milling as the main remedy action to overcome this problem. The cost of carrying out this task ranges from RM 8 – RM 10 per square meter. As for US, besides cold milling, diamond grinding repair method is used as well for this kind of defects.

In terms of efficiency, both methods mentioned can prolong the service life of the flexible pavement if the repair work is carried out properly. Diamond grinding is not adapted in Malaysia due to several factors. Firstly is the expensive cost to own the machine and to operate it. Then, skilled worker will be needed to properly operate the machine. This actually increase the labor cost. Secondly, diamond grinding is more efficient to cut pavement that have high hardness index. As for Malaysia, the hardness index of the pavement is not high, thus, such machine is not preferred.

Both milling and diamond grinding techniques will induce dust. The dust comes from the repair work which involves cutting and replacing pavement. The dust could disturb vision of road riders and endanger their safety. Thus, the repair work must be carry out during off peak hour to minimize the disruption to the traffic flow.

Depression

Depression refers to localized low area of limited size. Usually, patching is used to overcome this problem. The cost of patching ranges from RM 8 – RM 10 per square meter[2]. Patching can prolong the service life of the flexible pavement if carried out properly. The traffic flow will not be heavily interrupted during the progression of the repair work.

The main cause for depression is identified as foundation settlement[4]. Thus, a better remedy action would be reconstruction where the pavement (including the sub-base) is excavated and replaced with new material and compacted properly.

Reconstruction definitely has the higher efficiency to overcome depression compared to patching. But due to economical constraint, patching is the much preferred alternative unless the affected area is large enough and the severity is very high. This is due to the high cost in carrying out reconstruction, which ranges from RM 35 – RM 50[2]. Further more, reconstruction demand the road to be closed for repair work. This will heavily interrupt the traffic flow which is very much unwanted.

Type of Defects	Repairing Technique	Applied In Malaysia	Cost In Malaysia (per square meter)
Aged Bituminous Surface			
	Fog Sealing	No	
	Rejuvenating	Yes	RM 2.00 - RM 4.00
	Resurfacing	Yes	RM 8.00 - RM 20.00
Cracking			
	Crack Sealing	Yes	RM 0.50 - RM 3.50
	Surface Recycling	Yes	RM 6.00 - RM 13.00
	Patching	Yes	RM 8.00 - RM 10.00
Rutting			
	Patching	Yes	RM 8.00 - RM 10.00
	Cold Milling	Yes	RM 8.00 - RM 10.00
	Resurfacing	Yes	RM 8.00 - RM 20.00
Potholes			
	Cutting and Patching	Yes	RM 8.00 - RM 10.00
	Slurry Seal	Yes	RM 2.00 - RM 8.00
	Reconstruction	Yes	RM 35.00 - RM 50.00
Depression	Cutting and Patching	Yes	RM 8.00 - RM 10.00

Table 4:- Types of Repair Technique Adopted in Malaysia

Repair Technique	Impact		
	Environment	Health	Traffic
Fog Sealing	Low	Low	Low
Rejuvenating	Low	Medium	Medium
Resurfacing	High	Medium	High
Crack Sealing	Low	Low	Low
Surface Recycling	Medium	Medium	High
Cutting and Patching	Medium	Low	High
Cold Milling	Medium	Low	High
Slurry Seal	Low	Low	Low
Reconstruction	High	High	High

Table 5:- Type of Impact of Each Repair Technique and the Corresponding Level of Severity

4.3 Conclusion

From the discussion carried out above, it is clearly seen that the causes of defects are very much affected by the weather. Different weather will lead to different degree of deterioration and also different type of defect. Generally, flexible pavement tends to deteriorate faster under hot weather and environment which contains excessive rainfalls.

Malaysia is a typical tropical country with high temperature and rainfall throughout the year. Therefore, flexible pavement will tend to deteriorate faster.

As discussed in the previous discussions, the major cause of pavement defects in Malaysia is due to water penetrating the road base. The water mainly comes from the excessive rainfall that Malaysia received, and partly the groundwater. Some area in Malaysia, especially in Kelantan, the water table is high. High water table is not good to the road base as the water will soften and weaken the road base. As the result, the road base will settle and gradually causes cracking and depression. High amount of water on the road is also undesirable to flexible pavement. If the excessive water is not drained properly, then problem will occurs.

High temperature is another condition that is undesirable to flexible pavement. As mentioned, one of the reasons for rutting to occur is due to traffic loading under high temperature. If the temperature is generally high, asphalt will soften and cause the flexible pavement unable to withstand the designed traffic loading.

Another reason for defects to occur is due to the unproper construction methods and quality controls. The methods suggested in JKR manual to construction a roadway has no problem, but construction methods might not be proper. Sometimes, the compaction of each road layer is not sufficient or the rolling patterns carried out do not meet the design and specification.

As a conclusion, most of the causes of pavement defects in Malaysia cannot be avoid but some can be prevent. Under the weather condition like Malaysia, drainage design for the road must be good and capable of discharging the excessive stormwater. Also, area where a road to be built must be assessed to gather sufficient information before design can be made. Last but not least, good supervision during construction work is very important to ensure the construction follows the design and specification.

As for repair techniques, it can be conclude that the repair techniques applied in Malaysia is effective to tackle most of the problems. Currently, Malaysia does not have enough information to carry out its own research on improving the effectiveness of the repair techniques used.

Most of the current available techniques are adopted from other developed countries which have been proven to be effective under their condition. But when the same techniques applied in Malaysia, the effectiveness is not guaranteed. Thus, modifications and calibration have to be made to suit the condition in Malaysia. One good example is that the formula for sealing agent is origin from Australia. Modification is made on the formula, where the polymer content was changed to rubberize chemical. The modification is made based on the available resources Malaysia have and the relatively higher cost polymer chemical if were to be imported from Australia.

The impacts from the repairing work on the environment and traffic condition have to be taken into account as well. The impacts must be reduced as much as possible so that the repair work would not cause undesirable interruption to road users and the environment.

In general, the repairing technique currently used is still within the acceptable level, but further improvements, research and also modification must be made to ensure the effectiveness of each technique is at its maximum level.

CHAPTER 5

5.0 Visual Inspection and Questionnaire Results

This chapter will be showing the results obtained from the visual inspection and also from the questionnaire conducted. Based on the results gathered, discussion will be carried out.

5.1 Results from Visual Inspection

Visual inspection on road condition is carried out along Ipoh – Lumut highway, specifically from UTP towards Lumut area. Generally, Ipoh – Lumut highway is located in rural area and it function either as highway or primary road with all traffic volume. The purpose of the inspection is to evaluate on the general condition of the pavement in terms of type, severity and the extend of the defects. The inspection will also check on how the defects affect the traffic flow of the road.

From the inspection carried out, 55 defects were found. These defects can be categorized into cracking, potholes, rutting, heaving and bleeding type. Figure 6 show the frequency of the defects occurs along the stretch.

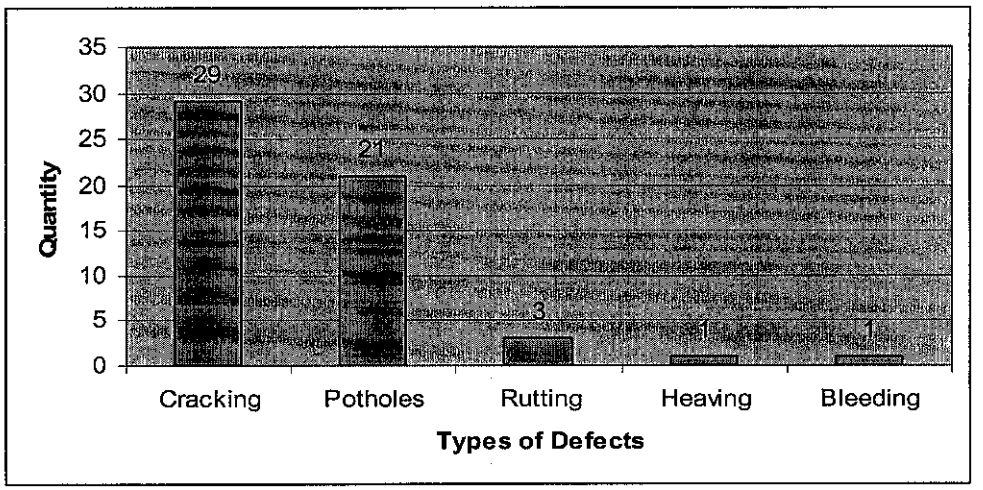

Figure 6: Type and Frequency of occurrence for pavement defects along Ipoh – Lumut Highway

Types of Defects	Occurrence (Defects/km)
Cracking	0.58
Potholes	0.42
Rutting	0.06
Heaving	0.02
Bleeding	0.02

Table 6: Type of Defects and respective Occurrence along Ipoh – Lumut Highway

The occurrences of each defects is shown in Table 6. For cracking, it is determined to have occurrence of 0.58 defects/km. For potholes, the occurrence is 0.42 defects/km. As for rutting, heaving and bleeding, the occurrence is 0.06, 0.02, and 0.02 defects/km respectively.

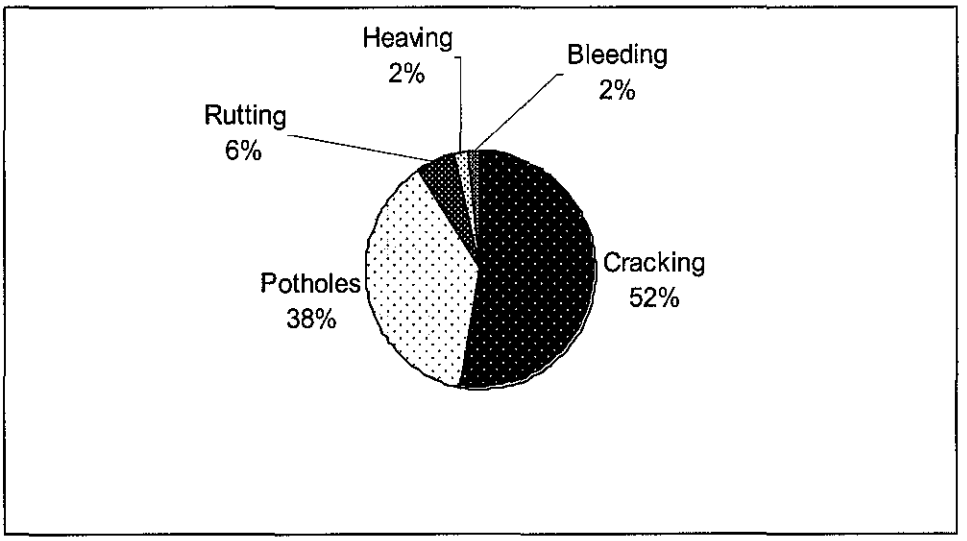

Figure 7: Percent of Defects Corresponding to Defect Type

It shows that cracking is the most frequent defect found on the Ipoh – Lumut highway where which is 29 spot. The second highest in the rank is found to be potholes which is 21 spot. While for rutting, heaving and bleeding, it is 3 spots, 1 spot and 1 spot, respectively. From these data collected, it can be concluded that 52.7% of defect found on Ipoh – Lumut highway is cracking, 38.2% is potholes, 5.5% is rutting and 1.8% is heaving and bleeding respectively. The results are shown in Figure 7.

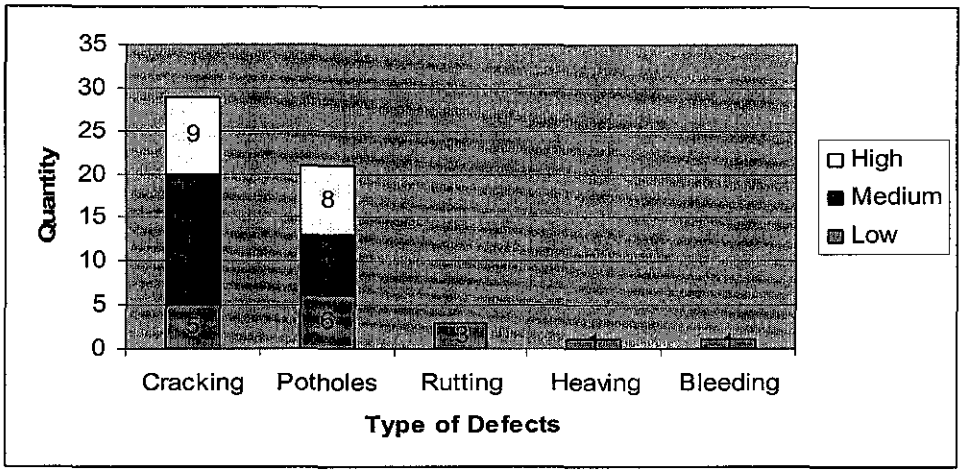

Figure 8: Type, Amount and Severity of Defects Found

The defects found on the Ipoh – Lumut road were classified according to their severity and affected area. There are 3 classes of severities for cracking, potholes and rutting respectively. For cracking, crack width smaller than 3mm is considered low severity, crack width more than 3mm is considered medium severity and cracks with several spalled cracks is considered as high severity[6]. As for potholes and rutting, depth which is less than 1 inch is considered as low severity, 1 inch – 2 inches depth is considered as medium severity and if the depth is more than 2 inches, it is considered as high severity [11]. For heaving and bleeding, the severity is classified as how large is the area affected. Affected area less than $0.5m^2$ is considered low severity, affected area between $0.5m^2$ and $1m^2$ is considered medium and if it is more than $1m^2$, it is considered as high severity.

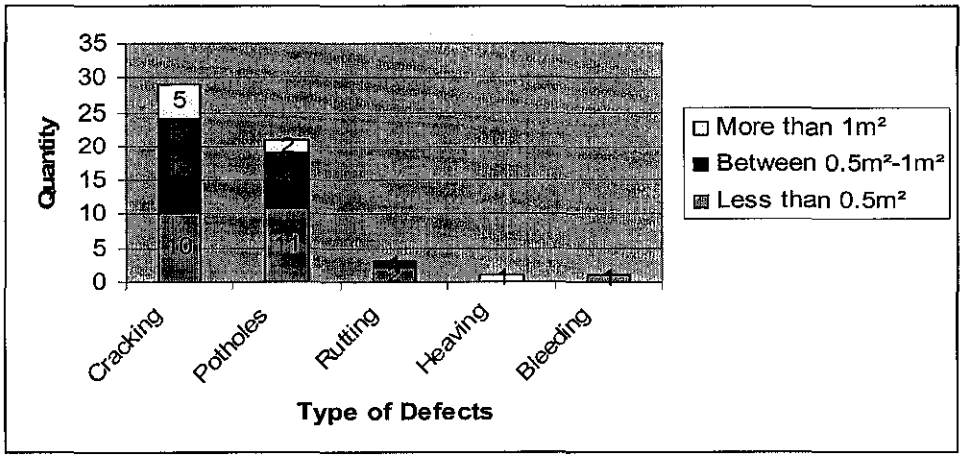

Figure 9: Types, Amount and Affected Area of Defects

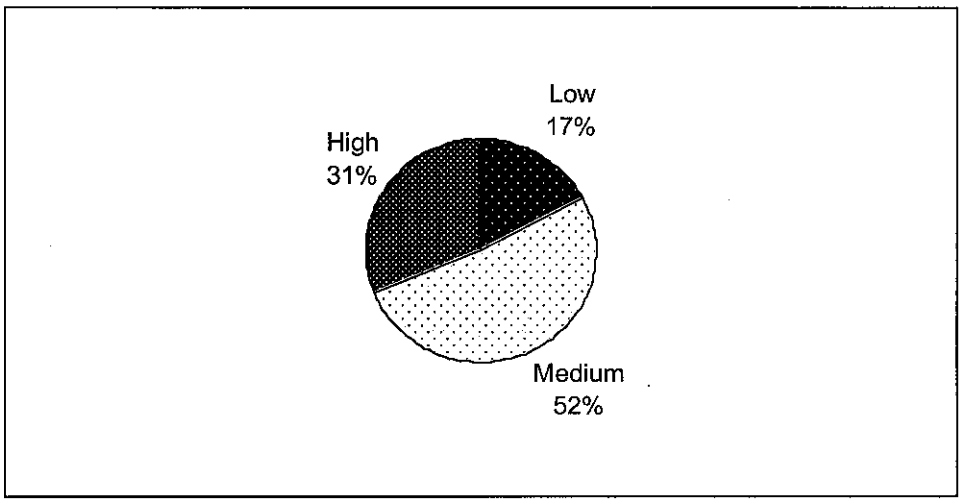

Figure 10: Percentage on Level of Severity for Cracking

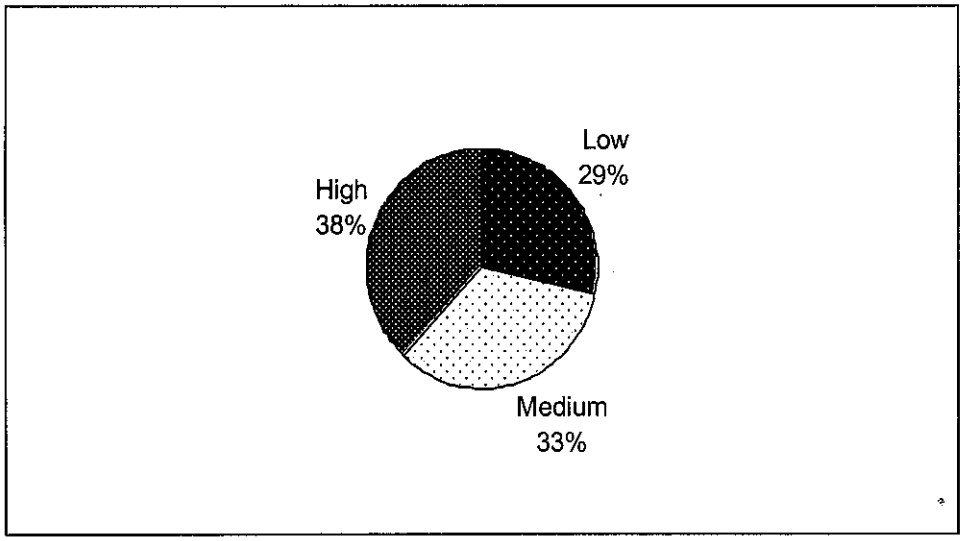

Figure 11: Percentage on Level of Severity for Potholes

Figures 10 and 11 show the percentage on level of severity for cracking and potholes, respectively. From figure 10, it shows that 31% of cracking is a high severity stage, 52% at medium severity stage, and 17% of cracks is at low severity stage. As for potholes, most of it is at high severity stage (38%), 33% is at medium severity stage and 29% is at low severity stage. Rutting, heaving and bleeding are all having low severity.

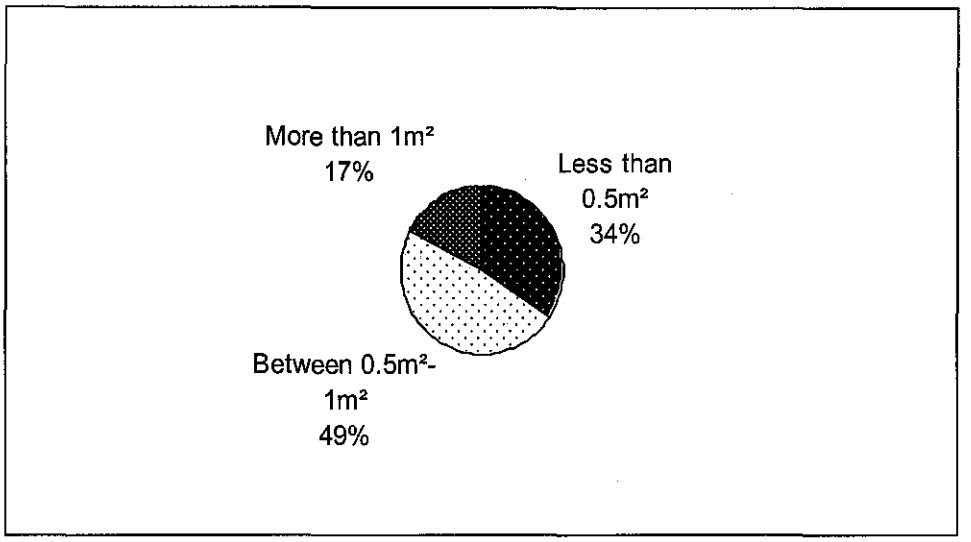

Figure 12: Percentage of Affected Area for Cracking

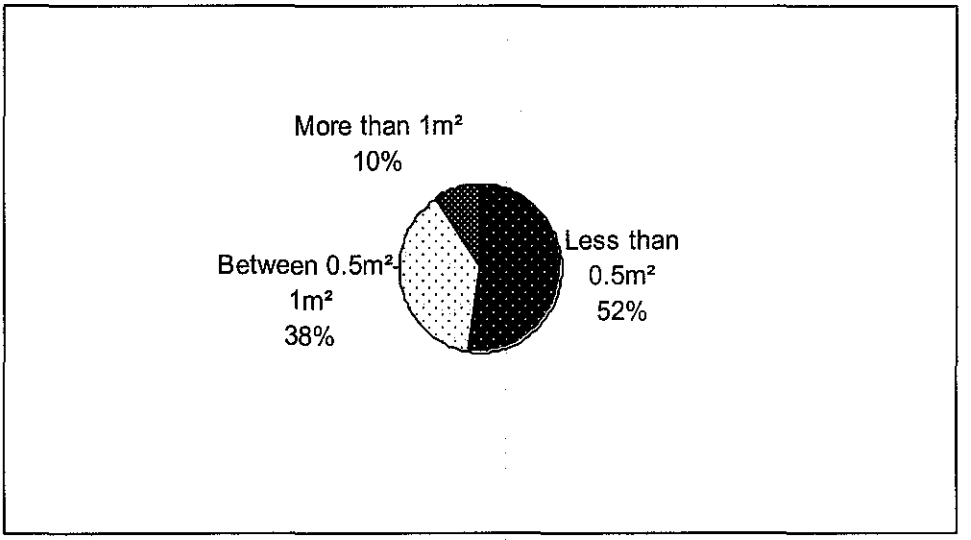

Figure 13: Percentage of Affected Area for Potholes

Figures 12 and 13 reflect the percentage of affected area for cracking and potholes, respectively. As shown in Figure 7, most of the cracking are only affecting small area (34%), 49% of it affecting medium area and 17% of cracking is affecting large area. Figure 13 shows the percentage of affected area for potholes. 52% of the potholes are found occurring in small area, 38% are in medium area and only 10% of it is affecting large area.

5.2 Results from Questionnaire Conducted

Questionnaire survey is conducted to obtain the opinions of professionals from the related field. The questionnaire covers topic such as the most common flexible pavements defects, the causes of defects, precautions steps, remedy measures and etc.

Table 6 shows the result collected from the questionnaire conducted. Potholes is rated the most common flexible pavement defects (75% of the total votes), rutting/depression comes after potholes and cracking comes after rutting/depression. The major cause of potholes could be due to unproper construction methods (75% of the total votes) and unproper material specification (50% of the total votes). The precautions suggested by the professionals to prevent potholes from happening is to have better supervision during construction (50% of total votes) and also to design and construct good drainage system along the road (25% of total votes). Economical constraint (50% of total votes) and methods of construction (50% of total votes) had been the two major issues restricting the construction of a good flexible pavement. The suggested period where a road condition assessment should be carried out is once a year (75% of total votes). The Malaysian's road construction technology level is a bit left behind (75% of total votes) if compared to other developed countries such as USA, Japan and Germany. The repairing methods that other developed countries is using currently is not suitable to be used in Malaysia (100% of total votes), unless some modifications is made. This is due to the material used and also the different in weather as Malaysia is having high rainfall intensity.

Questions	Most Suggested Answer
Most common flexible pavement defect in Malaysia	Potholes
Major causes of mentioned defect	Unproper construction methods
Precaution taken to prevent the mentioned defect	Proper supervision during construction
Suggested remedy action	Patching if not serious, else resurfacing
Frequency of road condition assessment	Once a year
Level of construction technology in Malaysia compared to other developed countries	A bit left behind
Possibilities of applying other developed countries' repairing technique	No unless modification made

Table 7: Results of Questionnaire

Based on the result gathered from questionnaire, several conclusions can be made. Firstly, the most common flexible pavement defects found in Malaysia is potholes due to the unproper construction methods. Proper supervision will be a pre-requisite to prevent the occurrence of potholes. If the potholes are not serious, patching technique can be used to overcome the problem, else, the pavements need to be resurfaced. The ideal road condition assessment should be carried out at least once a year to ensure that early remedy action can be taken.

Secondly, the level of road construction technology is still lacking compared to other developed countries. The lack of technology might be restricted by the economical constraint, where most of advanced equipments are too expensive to be used here. Also, Malaysia does not have their own research centre to further develop the skills, techniques and equipments based on the needs and condition here.

Finally, some techniques and equipments from other developed countries may not be suitable to be applied in Malaysia. This is due to the different climate and also construction and maintenance materials used. Unless modification is made based on the needs and condition in Malaysia, else, similar problems are to be expected in the future.

5.3 Discussions

There are 55 defects which were spotted during the visual inspection from UTP towards Lumut area. 29 of them are cracking, 21 potholes, 3 rutting and 1 each for bleeding and heaving. It was found that the result obtained from the visual inspection on site is different from the outcome of the questionnaire conducted, which stated that the most frequently found defect on flexible pavement is potholes. This is due to the current construction that is on-going on the road. The purpose of the current construction is to upgrade the current road from two lanes to four lanes road. Thus, repairing work has been done at most part of the road. Also, lots of major defects, specifically pothole, had been repaired and patched. There are a lot of areas that found to be newly patched, especially around Ayer Tawar area. These newly patched parts are believed to be previously pothole

area judging from the size and the area of the patching. Figure 14 shows a pothole with high severity.

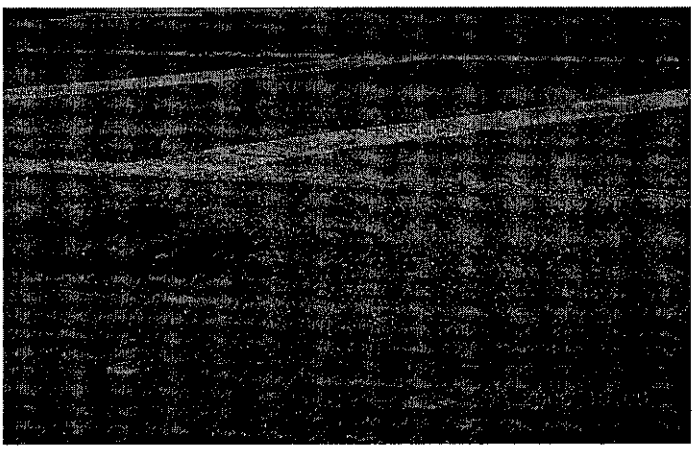

Figure 14: Pothole with High Severity

Ipoh – Lumut road is a busy road. Lots of heavy vehicles, such as concrete mixer lorry, lorry and truck, travel along the road every day. The loads resulted from these heavy vehicles caused the pavements to deteriorate faster than its design life. Cracking is one of the sign that showing this road is deteriorating. Most of the cracks found on this road are already at their critical stage that if no immediate remedy action is taken, pothole will occur. Figure 15 shows cracks with high severity found near UTP area.

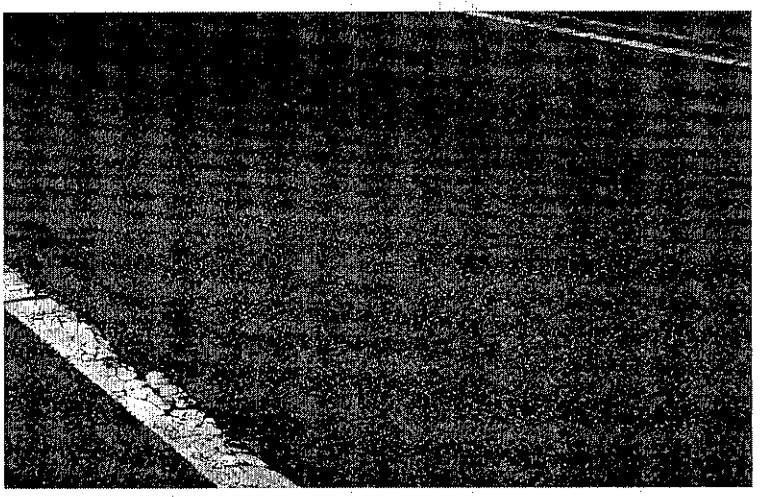

Figure 15: Cracks with High Severity

The impact of the analyzed defects was also evaluated during the inspection. Generally, the defects will not endanger the safety of the car and truck drivers. However, it could endanger the safety of motorcyclist. Among all analyzed defects, pothole is the defect that would bring the most severe impact to motorcyclist. Motorcyclist will ride and fall if they run into the pothole, especially when the hole is deep and motorcyclists are traveling at high speed.

Most rutting problems found to be occurred at the exit of main road into collector road and usually occur at the edge of the pavement. One of the rutting is found at the turning from the main road into Taman Maju housing area and another one is found near the entrance to the main gate of University Technology Mara. Heaving defect was found at area near Taman Maju. The heaving occured at the middle of the road is dangerous to road users as the elevation of the affected area is higher than the adjacent pavement. It also decreased the comfortability of riding. Figure 16 shows heaving found at Taman Maju area and figure 17 shows rutting near entrance to UiTM.

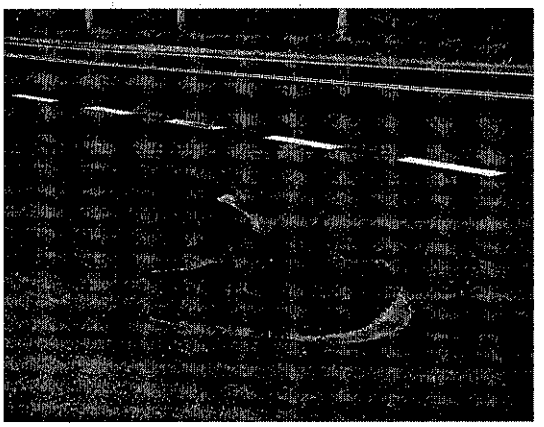

Figure 16: Heaving

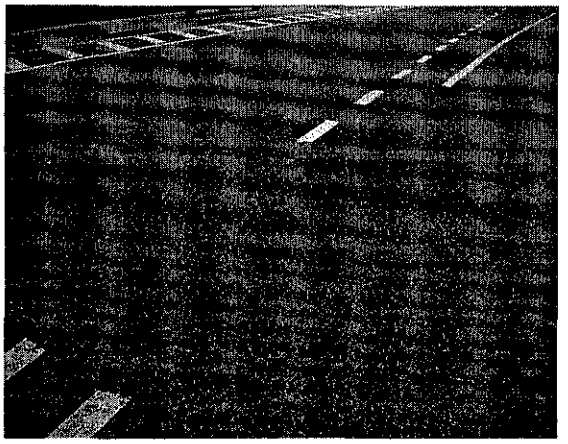

Figure 17: Rutting

Bleeding was found to be occurred at the cross road near Bota Kanan area. The occurrence of bleeding at the area is expected to be due to rich plant mix or a prime or tack coat that is too heavy. Figure 18 shows bleeding at cross road near Bota Kanan area.

Figure 18: Bleeding at Cross Road near Bota Kanan Area

5.4 Conclusion

The results obtained from the visual inspection are compared to the results obtained from questionnaire survey conducted among professionals.

Firstly, the results produced from the visual inspection do not match the opinion of the professionals on the most common defect found on flexible pavement in Malaysia. Instead of potholes, cracking was found to be the most frequent encountered defect along

the studied road, Ipoh – Lumut road. The results obtained are due to two reasons. First, this survey is only conducted along Ipoh – Lumut highway. The results obtained from the survey on this highway may not reflect the overall defects at Malaysian road. Secondly, the pothole could have been repaired during the major repairing work which is currently undergoing.

The methods found to overcome potholes on Ipoh – Lumut road is patching. This matches the previous discussion where patching is the effective methods to overcome potholes. Unfortunately, it was also found that cracks are not seal at the early stage and most of the cracks are allow to extent under the traffic loading. This means that there is still lack of maintenance that should be carried out more frequently. Technology wise, Malaysia is not much left behind but maintenance wise, there are still plenty of rooms for improvement.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

This chapter will be highlighting the most significant findings in relation to the objectives of the project. This section will also include recommendations for future project work.

6.1 Conclusion

As discussed in the previous chapter, the most common flexible pavement defects found in Malaysia are potholes. Cracking and rutting are among the other defects that were frequently found. The causes of the mentioned defects are very much affected by the weather. High intensity of rainfall and also high temperature in Malaysia increases the frequency of occurrence of these defects.

Discussion in chapter 4 had clearly specified that the biggest problem that Malaysia pavement condition, or even in some other tropical countries, faced is rainfall. High intensity of rainfall throughout the year had increases the chances of water penetrating the road base and subsequently weakens the road base. As a result, depression and crack will take place and if no immediate remedy action taken, the depression will worsen and become potholes. Some others factors contributing to flexible pavements deterioration are high temperature, and lack of quality control and supervision. Most of the causes contributing to the flexible pavement deterioration cannot be avoid, but definitely can be prevent by implementing systematic and quality supervision during and after construction, and also by having good drainage design.

Currently, the level of repairing techniques in Malaysia is at a satisfying level, but there is still room to improve. As discussed in chapter 4 and chapter 5, the repairing techniques and technology Malaysia are implementing now, is mostly adopted from other developed countries. Most of these methods are proved to be efficient to perform in their origin countries but when implemented here, the efficiency is not guaranteed. In most

cases, modifications need to be made before the techniques or technology can be used in Malaysia.

As a conclusion, the biggest problem that Malaysia needs to overcome, in order to have a good and strong pavement, is to overcome the drainage problem due to the high intensity of rainfall. There is not much problem with the design and the repair technique but to increase the durability of the flexible pavement, excessive stormwater must be discharged in the first place.

6.2 Recommendations

As mentioned in the conclusion, flexible pavement design and repairing technique is still at a satisfactory level. However, several improvements can be made to increase its efficiency.

Firstly, the design of flexible pavement in Malaysia is very much guided by the guidelines from AASTHO and HCM which have a totally different climate. The design might not consider much about high intensity of rainfall. They are dealing more with frost and thaw problems. For Malaysia purpose, rainfall is the most deadly cause that leads to the pavement deterioration. Thus, it is a need to conduct research on how the rainfall affecting the pavement and how to discharge the stormwater from the road surface without affecting the road base.

Secondly, Malaysia is lack of historical data to be used to come out with its own design specifications and guidelines. Thus, there is a need to form a team of professional that collect all the required data. Adopting design and specifications from other developed countries is not sufficient to guarantee the durability and performance of flexible pavement in Malaysia.

The other major problem that most of the professionals pointed out during the questionnaire survey is the lacking of quality supervision during and after road construction. The specification issued by Jabatan Kerja Raya (JKR) is good enough to

construct a good highway but due to lack of supervision, these specifications are not closely followed. Further more, there is no systematic inspection for maintenance in Malaysia currently. A major inspection should be done once a year to check on the road surface conditions, road base condition and the drainage functionability. Any defects that require immediate action must be repaired before it reaches critical stage. This will save a lot in terms of maintaining costs.

Research should also be carried out on replacing the current road and maintenance materials with cheaper local resources. The example given in chapter 4 is a good one as it managed to cut down the maintenance cost by substituting expensive polymer content with rubberized chemical. More of similar research should be conducted so that cheaper and efficient techniques or material can be produced.

As a conclusion, highway agencies in Malaysia still need to improve on their current design and repairing technique. Design and techniques from other developed countries can only be implemented here if modifications are made to suit the condition here, or else, it will definitely fail to achieve its maximum efficiency.

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APPENDICES

No.	Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
	- Propose Topic														
2	Submission of Project Title Proposal														
3	Preliminary Research/Design work														
	- Introduction														
	-Objective														
	-List of references/literature														
	-Project Planning														
4	Submission of Preliminary Report														
5	Project work														
	-List of References/Literature														
	-Practical														
6	Submission of Progress Report														
7	Project work continue														
	- Practical														
8	Submission of Dissertation Final Draft														
9	Oral Presentation														
10	Submission of Project Dissertation														

No.	Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project work Continue														
	Practical														
2	Submission of Progress Report														
3	Project Work Continue														
	Practical														
4	Submission of Progress Report 2														
5	Project work Continue														
	Practical														
6	Submission of Dissertation Final Draft														
7	Oral Presentation														
8	Submission of Project Dissertation														

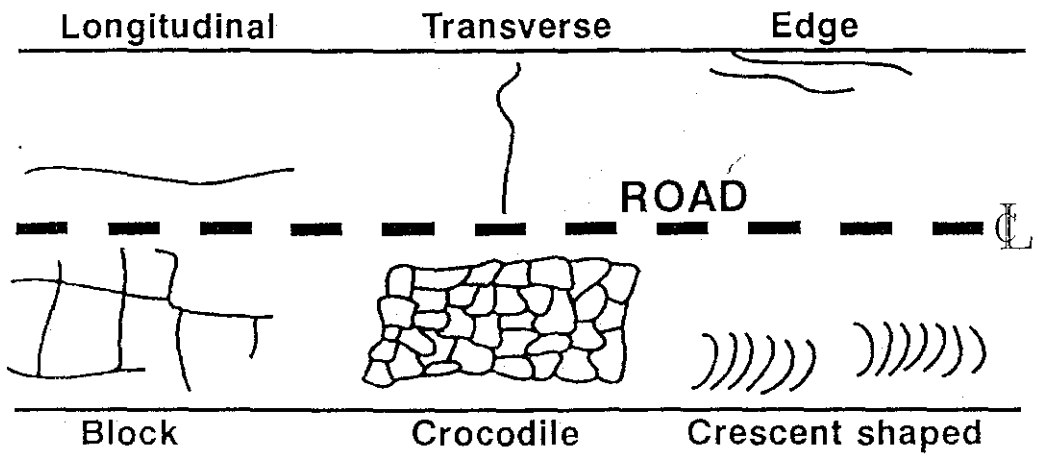

FIGURE 1 : TYPES OF CRACKS

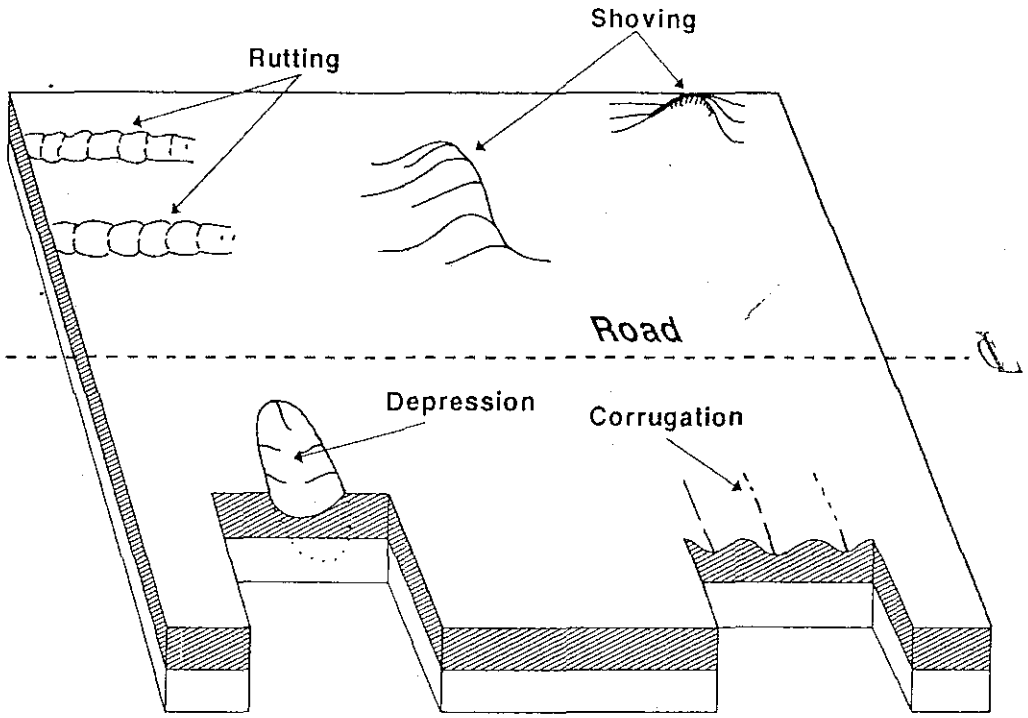

FIGURE 2 : TYPES OF SURFACE DEFORMATION

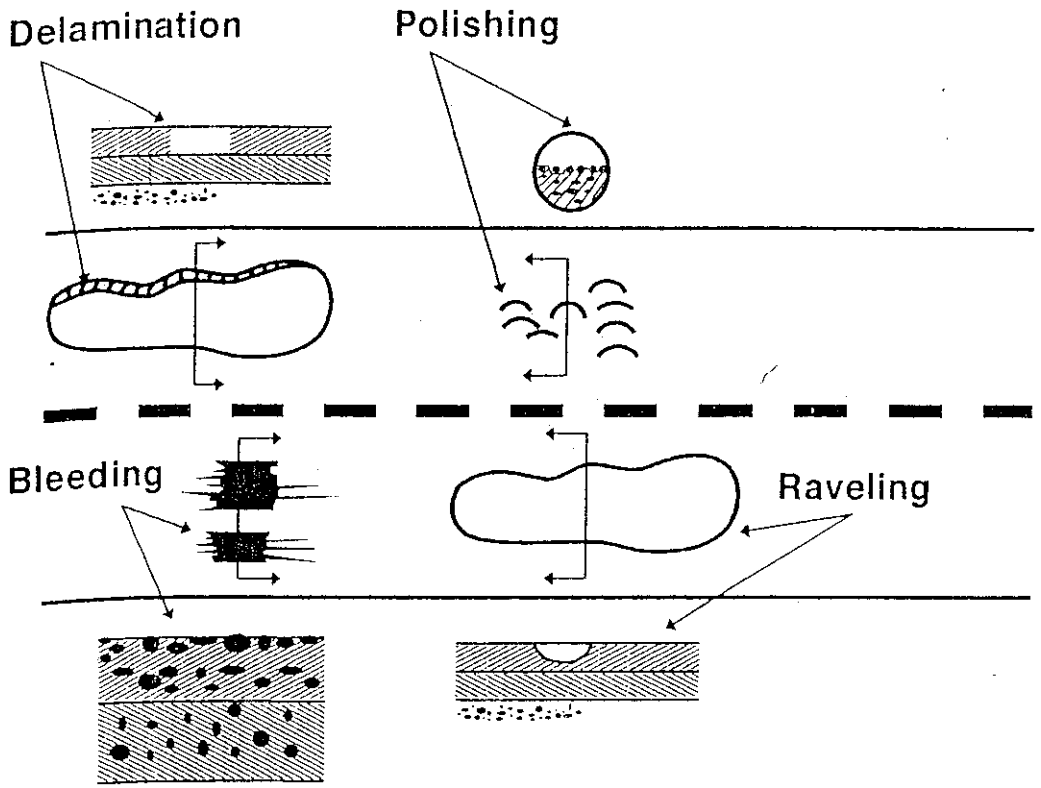

FIGURE 3 : TYPES OF SURFACE DEFECTS

UNIVERSITI TEKNOLOGI PETRONAS

A Study on Flexible Pavement Defects In Local Road

Date of study: 31/3/2006
Name of road: Ipoh - Lumut Highway(from UTP - Lumut)
Type of road: Federal Road
Latest date of major repairing work:
Estimated Traffic Volume(per hour):595

Time: 9am
State: Perak
Number of lanes: 2
Weather: Cloudy

Location (measure from UTP, in km)	Types of Defects	Severity	Affected Area	Impact
0.6	Cracking	→	▼	No significant impact to road riders
0.7	Cracking	→	▲	Uncomfortable riding
2.7	Heaving	▼	▲	Uncomfortable riding
5.1	Rutting	▼	▼	Water ponding
7.2	Cracking	→	▲	Uncomfortable riding
8.4	Potholes	/	▼	Endanger motorcyclist
8.9	Cracking	↓	▶	No significant impact to road riders
10.5	Cracking	↓	▼	No significant impact to road riders
14.4	Bleeding	▼	▼	Loss of skid resistance
16.5	Cracking	↑	▼	No significant impact to road riders
19.9	Cracking	→	▲	Uncomfortable riding
21.2	Cracking	→	▼	No significant impact to road riders
23.2	Potholes	–	▲	Endanger motorcyclist
24	Cracking	→	▼	No significant impact to road riders
25.7	Potholes	–	▶	Endanger motorcyclist
25.7	Potholes	/	▼	Endanger motorcyclist
26.8	Cracking	–	▶	No significant impact to road riders
28.8	Rutting	▼	▶	Water ponding
30	Potholes	√	▼	Endanger motorcyclist
30.3	Cracking	→	▶	No significant impact to road riders
32.2	Potholes	/	▼	Endanger motorcyclist
32.8	Cracking	→	▶	No significant impact to road riders
33	Cracking	→	▶	No significant impact to road riders
33.8	Cracking	→	▼	No significant impact to road riders
38.7	Potholes	–	▶	Endanger motorcyclist

UNIVERSITI TEKNOLOGI PETRONAS

A Study on Flexible Pavement Defects In Local Road

Date of study: 31/3/2006
Name of road: Ipoh - Lumut Highway(from UTP - Lumut)
Type of road: Federal Road
Latest date of major repairing work:
Estimated Traffic Volume(per hour):595

Time: 9am
State: Perak
Number of lanes: 2
Weather: Cloudy

Location (measure from UTP, in km)	Types of Defects	Severity	Affected Area	Impact
39.2	Potholes	/	▼	Endanger motorcyclist
43.6	Cracking	↑	▲	Uncomfortable riding

Legends:-

↓ - crack width smaller than 0.5cm
→ - crack width ranging between 0.5 - 1cm
↑- crack width more than 1cm
/- less than 1 inch depth
– - between 1 - 2 inch depth
√- more than 2 inch depth

▼ - less than 0.5m²
► - between 0.5cm² - 1cm²
▲ - more than 1cm²

UNIVERSITI TEKNOLOGI PETRONAS

A Study on Flexible Pavement Defects In Local Road

Date of study: 31/3/2006
Name of road: Ipoh - Lumut Highway(from Lumut - UTP)
Type of road: Federal Road
Latest date of major repairing work:
Estimated Traffic Volume(per hour):595

Time: 11am
State: Perak
Number of lanes: 2
Weather: Cloudy

Location (measure from UTP, in km)	Types of Defects	Severity	Affected Area	Impact
5.6	Rutting	▼	▼	Water ponding
6.4	Potholes	–	▼	Endanger motorcyclist
6.6	Potholes	√	▲	Endanger motorcyclist
6.6	Cracking	↑	▼	No significant impact to road riders
9.6	Potholes	–	▶	Endanger motorcyclist
13.6	Potholes	/	▼	Endanger motorcyclist
14.8	Cracking	→	▼	No significant impact to road riders
16.8	Potholes	√	▶	Endanger motorcyclist
16.9	Cracking	→	▲	Uncomfortable riding
17.8	Cracking	↑	▶	No significant impact to road riders
18.7	Cracking	↑	▼	No significant impact to road riders
18.7	Potholes	/	▶	Endanger motorcyclist
18.8	Potholes	√	▶	Endanger motorcyclist
19.1	Cracking	→	▶	No significant impact to road riders
21.1	Potholes	→	▶	Endanger motorcyclist
23.7	Cracking	↓	▼	No significant impact to road riders
27.1	Cracking	↑	▶	No significant impact to road riders
27.7	Potholes	√	▶	Endanger motorcyclist
27.7	Potholes	√	▼	Endanger motorcyclist
29.3	Cracking	↓	▶	No significant impact to road riders
29.3	Cracking	→	▶	No significant impact to road riders
32.6	Cracking	↑	▼	No significant impact to road riders
34.1	Cracking	↑	▶	No significant impact to road riders
37.9	Potholes	–	▼	Endanger motorcyclist
37.9	Potholes	√	▶	Endanger motorcyclist

UNIVERSITI TEKNOLOGI PETRONAS

A Study on Flexible Pavement Defects In Local Road

Date of study: 31/3/2006
Name of road: Ipoh - Lumut Highway(from Lumut - UTP)
Type of road: Federal Road
Latest date of major repairing work:
Estimated Traffic Volume(per hour):595

Time: 11am
State: Perak
Number of lanes: 2
Weather: Cloudy

Location (measure from UTP, in km)	Types of Defects	Severity	Affected Area	Impact
40.8	Potholes	√	▼	Endanger motorcyclist
48.7	Cracking	↓	►	No significant impact to road riders
48.9	Cracking	↑	►	No significant impact to road riders

Legends:-

↓ - crack width smaller than 0.5cm
→ - crack width ranging between 0.5 - 1cm
↑- crack width more than 1cm
/- less than 1 inch depth
- - between 1 - 2 inch depth
√- more than 2 inch depth

▼ - less than 15cm²
► - between 15cm² - 30cm²
▲ - more than 30cm²

A Study on Flexible Pavement Defects in Local Roads

Questionnaire

Date: 15. 3. 2006.

Name: CR. AZNI B. MOHD. YUSOFF.

Company: HSSI - RAPI.

Title/Position: RESIDENT ENGINEER

Contact Number: 079-2393169.

Working Experience in Flexible Pavement (years): 25 yrs.

Questions

1. What is the most common flexible pavement defect(s) encountered in Malaysia?

(Please rate in ascending order according to the frequency of occurrence)

Potholes (1)	Bleeding (4)
Rutting (2)	Skidding (5)
Disintegration (7)	Depression (6)
Cracking (3)	
Others:	

2. In your opinion, what is the major cause(s) of the mentioned defects?

(i) Construction methods.

(ii) Material supply.

(iii)

Others:

3. What is the precaution(s) taken to prevent the mentioned defects?

(i) Proper testing of the materials.

(ii) proper supervision during construction.

(iii)

Others:

4. What is the rectification(s) made to rectify the mentioned defects?

(i) Remove & replace with suitable materials

(ii) Check on the probable cause & defects;

(iii) maybe high water table.

Others:

5. In your opinion, what is the major issue(s) affecting the cause(s) of flexible pavement defect(s) in Malaysia and how the mentioned issue(s) affect the cause(s)?

(i) Economical constraint

When the cost is high, normally the Contractor tend to find ways of not using it.

(ii) Technique of construction

The increase in cost of diesel affect the cost of m/c.

(iii) Level of technology

The higher level, the more complicated the process of work, then less no. of competent contractors

(iv) Selection of material

Normally good materials cost more, therefore, Contractors tend to propose cheaper materials.

(v) Design of pavement

Follow specs.

Others:

(Please state clearly how the chosen issue(s) affect the cause(s) of flexible pavement defect(s))

6. In your opinion, how does the different in climate of Malaysia and seasonal conutry affect the cause(s) of flexible pavement?

- Water is the enemy no. 1 for flexible pavement.

7. In your opinion, how frequent should a road condition assessment be carried out?

(i) 1-3 months

(ii) 3-6 months

ii) 6-12 months

v) More than a year

) Others

lease state clearly the period a road condition assessment should be carried out)

In your opinion, what is the most important element(s) in building a good flexible

ıvement?

, Good quality material selection.

) Proper supervision upon construction.

i)

thers:

In your opinion, what is the level of technology for road construction in Malaysia

compared to other developed countries such as Germany, USA and Japan?

(i) very much left behind

(ii) a bit left behind

(iii) level

(iv) advanced

(v) very advanced

In your opinion, will it be efficient to adapt the repairing method(s) from other

anced countries in Malaysia and why?

yes

no

y:-

The technology is too advanced.
The cost of material resources is still
cheaper as compared to recycled materials.

2. In your opinion, is there any need(s) to improve for the existing road onstruction and maintenance technique? (if yes, please list out the ecommendations)

i) yes

ii) no

Recommendations:

- to find a more effective techniques so that can achieve the required strength.
- to expedite the work process so as not to interupt the traffic flow.

A Study on Flexible Pavement Defects in Local Roads

Questionnaire

Date: 25/1/2006

Name: Tan Chee

Company: Swee Premix Sdn Bhd

Title/Position: Project controller

Contact Number: 019 3887706

Working Experience in Flexible Pavement (years): 20 years

Questions

1. What is the most common flexible pavement defect(s) encountered in Malaysia?

(i) cracking

(ii) rutting

(iii)

Others:

2. What is the major flexible pavement defect(s) in Malaysia?

(i) cracking

(ii)

(iii)

Others:

3. In your opinion, what is the major cause(s) of the mentioned defects?

(i) weak base due to ingress of water

(ii)

(iii)

Others:

4. In your opinion, what is the major issue(s) affecting the cause(s) of flexible pavement defect(s) in Malaysia and how the mentioned issue(s) affect the cause(s)?

(i) as Q3

(ii)

(iii)

Others:

5. In your opinion, how does the weather affect the cause(s) of flexible pavement defect(s) in Malaysia?

High rainfall increase the possibility of weakening the base

6. What is the precaution(s) taken to prevent the mentioned defects?

(i) to have good drainage system

(ii)

(iii)

Others:

7. What is the rectification(s) made to rectify the mentioned defects?

(i) cracking – surface sealing (short term), reconstruction (long term)

(ii) rutting – resurfacing(short term), reconstruction (long term)

(iii)

Others:

8. In your opinion, how frequent should a road condition assessment be carried out?

(i) 1-3 months

(ii) 3-6 months

(iii) 6-12 months

(iv) More than a year

(v) Others : every two years

(Please clearly state the period a road condition assessment should be carried out)

9. In your opinion, what is the most important element(s) in building a good flexible pavement?

(i) proper design of flexible pavement

(ii) correct selection of materials

(iii) good practice of construction method

Others:

10. In your opinion, what is the technology level of road building in Malaysia if compared to other advanced countries such as Germany, USA and Japan?

(i) very much left behind

(ii) a bit left behind ←

(iii) level

(iv) advanced

(v) very advanced

11. In your opinion, will it be efficient to adapt the repairing method(s) from other advanced countries in Malaysia?

(i) yes

(ii) no ←

12. In your opinion, is there any need(s) of improvement for the existing road building and maintenance skill? (if yes, please list out the recommendations)

(i) yes ←————

(ii) no

Recommendations:

Systematic monitoring / assessment of the pavement condition

Proper training to the contractor on the proper method of construction

Proper supervision

A Study on Flexible Pavement Defects in Local Roads

Questionnaire

Date: 23/5/2006

Name: Dr. Madzlan Napiah

Company: UTP

Title/Position: Lecturer

Contact Number:

Working Experience in Flexible Pavement (years): 15 yrs.

Questions

1. What is the most common flexible pavement defect(s) encountered in Malaysia?

(Please rate in ascending order according to the frequency of occurrence)

Potholes (1)	Bleeding (6)
Rutting (2)	Skidding (5)
Disintegration (4)	Depression (-)
Cracking (3)	

Others:

2. In your opinion, what is the major cause(s) of the mentioned defects?

(i) Under compaction.

(ii) Quality control.

(iii) Material specification.

Others:

3. What is the precaution(s) taken to prevent the mentioned defects?

(i) Better supervision.

(ii) Standardized method of quality control.

(iii) Independent testing (lab/field).

Others:

4. What is the rectification(s) made to rectify the mentioned defects?

(i) To have a proper SOP.

(ii) Need to revise the manual.

(iii) Appointment of accredited checker.

Others:

5. In your opinion, what is the major issue(s) affecting the cause(s) of flexible pavement defect(s) in Malaysia and how the mentioned issue(s) affect the cause(s)?

(i) Economical constraint

- Not very serious in supervision and quality provision.

(ii) Technique of construction

- Technique - ok but still lack of proper supervision and quality testing.

(iii) Level of technology

- Satisfactory.

(iv) Selection of material

- Good materials. Absent of full range of quality testing.

(v) Design of pavement

- Still using empirical method. Need to move towards analytical.

Others: Coefficient used may be not suitable.

Please state clearly how the chosen issue(s) affect the cause(s) of flexible pavement defect(s))

6. In your opinion, how does the different in climate of Malaysia and seasonal country affect the cause(s) of flexible pavement?

- Wet climate required proper drainage (sub-surface / surface).
- Adverse effect to the foundation.

7. In your opinion, how frequent should a road condition assessment be carried out?

(i) 1-3 months

(ii) 3-6 months

iii) 6-12 months

iv) More than a year

v) Others

Please state clearly the period a road condition assessment should be carried out)

3. In your opinion, what is the most important element(s) in building a good flexible pavement?

i) Workmanship

ii) Standards and regulations.

iii) Funding / Price.

Others:

. In your opinion, what is the level of technology for road construction in Malaysia f compared to other developed countries such as Germany, USA and Japan?

(i) very much left behind → not much research.

(ii) a bit left behind

(iii) level

(iv) advanced

(v) very advanced

1. In your opinion, will it be efficient to adapt the repairing method(s) from other dvanced countries in Malaysia and why?

) yes

i) no

Vhy:-

Whatever method used and proven to be effective is desirable to be implemented here but need to adapt to local condition. Thus, need some modification.

12. In your opinion, is there any need(s) to improve for the existing road construction and maintenance technique? (if yes, please list out the recommendations)

(i) yes

(ii) no

Recommendations:

Should follow a certain procedure such as full assessment and modelling.

A Study on Flexible Pavement Defects in Local Roads

Questionnaire

Date: 7/3/2006

Name: Mokhtaruddin bin Mohd Shukor.

Company: MRCB

Title/Position: Project Engineer.

Contact Number: 05-3711280 / 019-5721851
05-6720162

Working Experience in Flexible Pavement (years): 8 years.

Questions

1. What is the most common flexible pavement defect(s) encountered in Malaysia?

(Please rate in ascending order according to the frequency of occurrence)

Potholes (1)	Bleeding (6)
Rutting (4)	Skidding (7)
Disintegration (5)	Depression (2)
Cracking (3)	
Others:	

2. In your opinion, what is the major cause(s) of the mentioned defects?

(i) Excess traffic loading.
(ii) Material used could be sub-standard. (premix item DBM, ACBC, ACWC).
(iii) Workmanship (insitu works).
Others: Weather.

3. What is the precaution(s) taken to prevent the mentioned defects?

i) To control excess loading run over the road.
ii) Testing material to be carried out accordingly.
ii) Sub-base and road-base to be applied following the
Others: specified thickness as been design.

4. What is the rectification(s) made to rectify the mentioned defects?

(i) Re-surfacing the defect patton.
(ii) If too serious, rehabilitation must be conducted
(iii) at that area.

Others: - Road maitainence ex: patching pot hole.

5. In your opinion, what is the major issue(s) affecting the cause(s) of flexible pavement defect(s) in Malaysia and how the mentioned issue(s) affect the cause(s)?

(i) Economical constraint

(ii) Technique of construction ✓

(iii) Level of technology ✓

(iv) Selection of material ✓

(v) Design of pavement ✓

Others:

(Please state clearly how the chosen issue(s) affect the cause(s) of flexible pavement defect(s))

6. In your opinion, how does the different in climate of Malaysia and seasonal conutry affect the cause(s) of flexible pavement?

Design flexible pavement for road in Malaysia is already been established to suit the ~~climate~~ current climate which should be able to last for 10 years.

7. In your opinion, how frequent should a road condition assessment be carried out?

(i) 1-3 months

(ii) 3-6 months

(iii) 6-12 months ✓

(iv) More than a year

(v) Others

(Please state clearly the period a road condition assessment should be carried out)

8. In your opinion, what is the most important element(s) in building a good flexible pavement?

(i) Crusher run (road-base).

(ii) Bitumen content.

(iii) Thickness of premix layer.

Others: —

9. In your opinion, what is the level of technology for road construction in Malaysia if compared to other developed countries such as Germany, USA and Japan?

(i) very much left behind

✓(ii) a bit left behind

(iii) level

(iv) advanced

(v) very advanced

11. In your opinion, will it be efficient to adapt the repairing method(s) from other advanced countries in Malaysia and why?

(i) yes

(ii) no

Why:- Material and weather are different.

↓

refering to local resources. (sub-base is road-base).

12. In your opinion, is there any need(s) to improve for the existing road construction and maintenance technique? (if yes, please list out the recommendations)

(i) yes

(ii) no

Recommendations: