INVESTIGATION ON THE STRENGTH OF THE RECYCLED ASPHALT PAVEMENT AS A BASE MATERIAL

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ABSTRACT

Every year Hot Mix Asphalt (HMA) roadways are rehabilitated by milling the existing roadway and replacing the milled portion with new HMA. As a result of this practice, a tremendous amount of recycled asphalt pavement (RAP) is created. And it is become a big amount of wastage in highway construction. At the same time, the structural damage to the pavement has become high when a pavement base layer can no longer adequately support the heavy traffic loadings. Hence to overcome these problems a research will be carried out by blending recycled asphalt pavement (RAP) with virgin aggregates by the proportion to improve or upgrade the base layer in the future. Therefore, a laboratory testing investigation is to be conducted on the strength of the blended material. The objectives of the study are to investigate the effectiveness of the recycled asphalt pavement (RAP) by using California Bearing Ration (CBR) test and to determine the suitability RAP material as a base for new and upgrade pavement. The percentage of the RAP was added are 10%, 20%, 30%, 40%, 50% and until 100%. As a result, before adding RAP with the virgin aggregates the CBR value was 81.07%. After adding 50% of the RAP, the CBR value was reduced to 37.09% whereby 100% of RAP content managed to reduce the strength to 7.24%. Finally, the RAP material for a road base becomes unsuitable for new and upgrade pavement due to decreasing in effectiveness of engineering properties of RAP mixtures.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to the current statement, there are many thousands of miles of roads, many of which are near, at or past their design life (1). The need for roadway maintenance and roadway deconstruction has afforded a material who can be readily used for the repairs, recycled asphalt pavement (RAP).

Recycled asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. In addition when properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement.

Asphalt recycling is not a novel concept. Cold recycling dates back to the early 1900's. The first hot in-place recycling was reported in the literature in the 1930's. Modern asphalt recycling technologies that are used today evolved in the 1970s (2,4). Asphalt pavement is generally removed either by milling or full-depth removal. Milling is typically done in rehabilitation projects where the upper level of pavement is removed and then replaced to increase the pavement's service life. RAP that is produced from milling is ready to be recycled with little to no processing, depending on the amount being used in the mixture. An additional screening, crushing and fractioning may be required if the percentages of the mixture exceed 15 to 25 percent. RAP that is milled is frequently segregated in separate stockpiles at processing facilities. This is done because the RAP has come from a specific site where the pavement was consistent when placed, hence making the RAP consistent in quality. This allows for the potential of the RAP to be included in more mix types as it is well classified (3).

In full-depth removal bulldozers or front end loaders break the entire pavement structure into manageable slabs and then load them into trucks, which transport the pavement to a reprocessing site. RAP that was removed in the full-depth fashion may be segregated like millings, but not necessarily. Large quantities of uniformly consistent full-depth RAP may be segregated for crushing and sizing later. This is done because once the RAP is processed it will provide consistent stone gradation, quality, asphalt content and asphalt characteristics.

However, it is more common that small quantities of full-depth RAP arrive at a reprocessing facility. Typically full-depth RAP from various sites is stored in common piles before crushing and blending. The RAP is then crushed down to the largest aggregate size. This allows for the creation of a consistent product from various sources. Experience has demonstrated that with thorough blending and crushing RAP with a consistent stone gradation and asphalt content can be manufactured (3).

Although the majority of old asphalt pavements are recycled at central processing plants, asphalt pavements may be crushed in place and incorporated into granular or stabilized base courses using a self-propelled pulverizing machine. Hot in-place and cold in-place recycling processes have evolved into continuous train operations that include partial depth removal of the pavement surface, mixing the reclaimed material with beneficiation additives (such as a virgin aggregate, binder, and/or softening or rejuvenating agents to improve binder properties), and placing and compacting the resultant mix in a single pass.

This paper presents a laboratory assessment of the feasibility of utilizing recycled asphalt pavement (RAP) in the base course at addition levels from 0% until 100% by adding 10% for each sample. Based on the mechanical properties derived from the laboratory test programmed, a preliminary catalogue of designs has been developed to enable users to carry out a flexible pavement design.

1.2 Problem Statement

The use of recycled materials in pavements has become an increasingly widespread practice in recent years (5). This is especially on recycled asphalt pavement (RAP) that is milled off the existing road surfaces and recycled for reuse in pavement construction. At the same time, the structural damage to the pavement has become high when a pavement base layer can no longer adequately support the heavy traffic loadings for which it was designed. Hence to overcome these problems a research were carried out by replacing recycled asphalt pavement (RAP) with the proportion to improve or upgrade the base layer in the future.

1.3 Objective of The Study

The main objective for this project is to investigate the strength of recycled asphalt pavement (RAP) material used in base of the road pavement layer.

The specific objectives for the project are,

a) To investigate the effectiveness of the recycled asphalt pavement (RAP) by using California Bearing Ratio (CBR) test.
b) To determine the suitability RAP material as a base for new and upgrade pavement.

1.4 Scope of Study

Scope of this study is included following procedures, which are laboratory testing to obtain the strength of the recycled asphalt pavement (RAP) by blending 0% until 100% of RAP with the crusher run. The RAP materials were obtained from the construction site from Jalan Kuantan to Pekan (AZRB Sdn Bhd). However, the crusher runs were obtained from Pancing Quarry Sdn Bhd. They are total 30 samples were prepared and tested. Finally, the strength of the samples was determined by using California Bearing Ratio (CBR) test according to BS 1377-4:1990 and the material's standard was followed by the JKR specification 4.1.4.2.

1.5 Rationale & Significance

This research is important because to solve the problems of recycle asphalt pavement (RAP) and the structural damage that occurs at pavement base layer. Both will be solved by reuse the RAP in the road construction by adding as road base pavement layer. Furthermore, the using RAP again in the road will reduce the demand of aggregates and reduce the waste of recycle asphalt pavement (RAP).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recycling hot mix asphalt (HMA) material results in a reusable mixture of aggregate and asphalt binder known as reclaimed asphalt pavement (RAP). Recycling of asphalt pavements is a valuable approach for technical, economic, and environmental reasons (Kenned yet et al. 1998). Using RAP has been favored over virgin materials in the light of the increasing cost of asphalt, the scarcity of quality aggregates, and the pressuring need to preserve the environment. Many state agencies have also reported significant savings when RAP is used (Page and Murphy 1987).

Considering material and construction costs, it was estimated that using recycled HMA pavement provides a saving ranging from 14 to 34% for a RAP content varying between 20 to 50% (Kandhal and Mallick 1997). This analysis considered the cost of HMA at $11.90 per ton, which can only be considered as an indicator of the true savings when RAP is used now.

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The use of RAP also decreases the amount of waste produced and helps to resolve the disposal problems of highway construction materials, especially in large cities such as Chicago. In 1996, it was estimated that about 33% of all asphalt pavements in the United States was recycled into HMA (Sullivan 1996). In 2001, the Illinois Department of Transportation (IDOT) used 623,000 tons of RAP in highway construction and anticipates increasing its use soon (Griffiths and Krstulovich 2002). After more than 30 years since its first trial in Nevada and Texas, it appears that the use of RAP will not only be a beneficial alternative in the future but will also become a necessity to ensure economic competitiveness of flexible pavement construction.

2.2 Engineering Properties

Some of the engineering properties of RAP that are of particular interest when RAP is used in granular base applications include gradation, bearing strength, compacted density, moisture content, permeability, and durability.

Gradation**:** The gradation for milled RAP is governed by the spacing of the teeth and speed of the pulverizing unit. Wider tooth spacing and the higher speed results in larger particle sizes and coarser gradation. RAP can be readily processed to satisfy gradation requirements for granular base and sub base specifications, such as AASHTO M147.(7)

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Bearing Strength: The bearing capacity of blended RAP is strongly dependent on the proportion of RAP to conventional aggregate. The bearing capacity decreases with increasing RAP content. The California Bearing Ratio (CBR) is reduced below that expected to conventional granular base when the amount of RAP exceeds 20 to 25 percent.(8) CBR values have been shown to decrease almost directly with increasing RAP contents.(6)

Compacted Density: Due to the coating of asphalt cement on RAP aggregate, which inhibits compaction, the compacted density of blended granular material tends to decrease with increasing RAP content.(6)

Moisture Content: The optimum moisture content for RAP blended aggregates are reported to be higher than for conventional granular material, particularly for RAP from pulverizing operations, due to higher fine content and the absorptive capacity of these fines.(8)

Permeability: The permeability of blended granular material containing RAP is similar to conventional granular base course material.(8)

***Durability*:** Since the quality of virgin aggregates used in asphalt concrete usually exceeds the requirements for granular aggregates, there is generally no durability concerns regarding the use of RAP in granular base, especially if the RAP is less than 20 to 25 percent of the base.

2.3 Benefits of Recycling

One of the major advantages of using HMA in road pavements is the ability to recycle the material once the service life of the pavement has been consumed. Harrington (2005) reports that asphalt is the single most recycled material in the world. Recent data indicate that the annual production of RAP in the US alone amounted to approximately 41,000,000 tones and, of that, over 80% was re-used in pavement applications. Recycling asphalt pavements provides a number of environmental, social and economic benefits by reducing:

- Demand for aggregates;
- Demand for bituminous binders;
- Waste.

Reduced demand for aggregates. Aggregate resources are becoming more and more scarce, especially in urban areas where most heavily trafficked pavements are located. Quarries are not viable in urban areas where the land is of premium value and public resistance to any operations that create noise. Dust or heavy vehicle movements are increasing. In addition, increasing fuel costs mean that transporting aggregates from remote quarries attracts high costs. Therefore, the ability to recycle aggregates and, in general, have them located close to the site where they will be re-used provides significant benefits.

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Reduced demand for bituminous binders. The quantity of additional bitumen that is needed to produce RHM is reduced because the RAP already contains some bitumen. This provides benefits in terms of reduced cost and lower energy demands with respect to both the production and distribution of bituminous binders.

Reduced waste. Using RAP in pavement applications means that fewer waste materials are going to landfills. This saves valuable space in landfills, thereby extending their lives and reducing the need for new landfills. This is an important factor considering the cost of establishing environmental compliance for new landfill operations. It also removes the disposal costs of cartage and dumping (InfraGuide 2004).

Reducing waste by recycling is a universal objective for government agencies around the world. The New Zealand Government has a Transport Strategy comprising five main objectives and one of those is to ensure environmental sustainability. This has accordingly been adopted into Transit New Zealand's strategic goals, i.e.

... to improve the contribution of state highways to the environmental and social well being of New Zealand ... (Transit 2004).

2.4 Description of Asphalt Millings

Asphalt millings are generally defined as the fine particles (generally from dust to approximately 25 mm) of bitumen and inorganic material who are produced by the mechanical grinding of asphaltic concrete roading materials (NJDEP 2001).

Millings are generally source from road surface layers that are being removed to allow resurfacing to be carried out. This source of material is obtained from surfaces that are too high to accommodate an overlay, or deemed to be inappropriate, or not able to support the new surface layer, and therefore, they have to be removed. Millings typically contain 5% to 7% bitumen (NJDEP). However, the exact composition and properties of the material will be dependent on a number of variables, such as:

- Age of the source asphalt mix;
- Type of mix;
- Properties of the bitumen used in the mix;
- Properties of the aggregate used in the mix;
- Configuration and performance of the milling plant; and
- Clipping of underlying layers during the milling process.

Ageing of the asphalt results in the recovered RAP binder being significantly more viscous and having lower penetration values than the virgin bitumen (TFHRC 1997). Contractors typically separate their stockpiles of millings from different sources to ensure that the variability of the material is minimized.

2.5 Application

The UK Design Manual for Roads and Bridges (The Highways Agency (UK) 1995) allows bituminous millings to be used in the following applications providing the material complies with the applicable specification requirements:

- Embankment and fill;
- Capping; and
- Cement-bound sub-base.

Asphalt millings are not allowed in the following applications;

- Unbound sub-base;
- Cement bound road base; and
- Pavement quality concrete.

Steel et al. (2004) carried out an investigation into the use of asphalt millings in pavement sub-base layers in the UK. They reported that Type 4 asphalt millings sub-bases performed in a manner that was comparable to conventional Type 1 granular sub-bases, in which the Type 1 material was considered to be the highest quality sub-base aggregate. However, the authors warned that very thick layers of asphalt millings (750 mm plus) could be susceptible to excessive compressibility.

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NJDEP (2001) reported the use of millings in a number of applications, including:

- Sub-base material beneath, and fully contained by, an asphalt or concrete pavement structure;
- Surfacing material if an appropriate binder is applied to keep the millings in place;
- Base course material for minor pavements, such as car parks, as long as the millings have sufficient viable asphalt, and the material is laid and rolled in a hot condition;
- Other beneficial applications subject to the approval of NJDEP.

Some roading authorities, e.g. Illinois Department of Transport (DOT) and Massachusetts DOT, use a significant proportion of millings in the non-structural backfill situations and road shoulder mixes.

Trevino et al. (2003) reported that millings have been used with some success as a tack coat for new asphalt layers. Millings were evenly spread in the grooves left by the milling plant, and the new asphalt layer was placed without applying a tack coat. The heat provided by the new asphalt mat was sufficient for mobilise the binder associated with the millings.

This promoted a high level of cohesion between the two layers. Strength tests carried out on cores taken from trial pavements showed that failures generally occurred in the underlying material rather than at the interface between the old and the new asphalt layers.

The literature shows that asphalt millings have been used to construct secondary road pavements with mixed results. The City of Greeley, Colorado, US, reported that asphalt millings have been used to upgrade existing gravel roads. The millings were placed and compacted in a layer typically with a thickness of at least 150 mm. This treatment has proved to be successful in terms of reducing maintenance costs and dust complaints (City of Greeley, undated)

Koch Pavement Solutions (2002) reported that many of the highways in the state of New Mexico have been successfully rehabilitated using RAP that has been mixed with asphalt emulsion. The treated RAP forms the base course layer that is subsequently surfaced using a new HMA mat.

Russell (undated) described the rehabilitation of approximately 8 kms of gravel roads in the state of Missouri using asphalt millings combined in situ with a bituminous binder. The key aspects of the construction were to achieve effective mixing of the millings and the binder, and for the work to be carried out on hot summer days so that adequate cohesion and compaction could be achieved. The resulting pavement structures were reported to be performing well and very cost-effective.

Westphal (2001) reported that a highway in Ventura, Albuquerque, that was rehabilitated using asphalt millings, failed prematurely by forming potholes and suffering from severe erosion. A second attempt to rehabilitate the pavement by heating the millings also failed because the millings were highly oxidized and the residual binder was not mobilized.

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Roads & Bridges (2004) described pavement rehabilitation work carried out in Denver, Colorado. The City of Denver adopted a strategy of upgrading gravel roads by excavating 200 mm of the existing pavement and replacing it with compacted millings. The millings knitted together to for a uniform surface, effectively rebinding in the sun. The result was a firm surface that has performed well under residential traffic loads.

Huang & Shu (2005) investigated the performance of RAP in Portland cement concrete mixes. The authors tested mixes that had virgin aggregates substituted with either fine or coarse graded RAP materials. The investigation included workability, tensile strength, compressive strength, and toughness testing. The results showed that small quantities of RAP increased the slump of the concrete, thus increasing the workability of the mix.

However, larger quantities of RAP tended to decrease the concrete slump significantly. The strength tests showed that increasing the proportion of RAP in the mix resulted in a decrease in tensile and compressive strength, regardless of the type of RAP. There was, however, a significant increase in the toughness of the mix with increasing RAP content. This could have practical importance for a number of civil engineering applications where structures are required to have a relatively high strength and yet be able to absorb repeated loading without suffering fatigue failure. These properties are required of road base and sub-base layers.

The City of St Joseph, Missouri (undated), reported the successful use of millings in an innovative approach to solving pothole problems. Potholes were traditionally repaired using cold-mix asphalt. However, the material was found to be susceptible to water, and it did not perform well. Other more technical asphalt materials were used, but the production cost was very high.

The current strategy is to use asphalt millings combined with a small amount of solvent derived from orange peel oil as well as a small quantity of cutback bitumen. The orange peel oil appears to rejuvenate the residual binder in the millings, and the additional bitumen provides extra adhesion. The mix is generally produced as required in a wheelbarrow and the cost is reported to be approximately half that of a conventional cold-mix asphalt.

2.6 Results from Previous Studies

State material engineers were contacted to determine the current practice of state DOTs regarding the use of RAP as a base course material. The following states were contacted: Colorado, Florida, Illinois, Minnesota, Montana, New Jersey and Utah. Information from California, New Mexico, Rhode Island, South Dakota and Texas is included in this report. However, the state material engineers were not contacted due to lack of contact information or the states were unresponsive. Information for these states was obtained solely through their respective standard specifications.

Table 2.1: Survey of the practices of state DOTs regarding the use of RAP as a base course material

State	Rap Allowed[1]	Max %[2]	Processed[3]	Testing[4]
Florida	No	---	---	---
Illinois	No	---	---	---
Montana	Yes	50-60%	No	Corrected Nuclear Gauge
New Jersey	Yes	50%[5]	Yes - Gradation	Corrected Nuc. Gauge + Sample
Minnesota	Yes	3%[6]	Yes - Gradation	Dynamic Cone Penetrometer
Colorado	Yes	50%[5]	Yes - Max Agg. Size	Roller Compaction Strip
Utah	Yes	2%[6]	Yes - Gradation	Nuc. Gauge or Breakdown Curve
Texas[7]	Yes	20%	Unknown	Various (including Nuc. Gauge)
California[7]	Yes	50%	Unknown	No special testing procedure listed
New Mexico[7]	Yes	Unknown	Unknown	Corrected Nuc. Gauge
Rhode Island[7]	Yes	Unknown	Yes - Gradation	Unknown
South Dakota[7]	No	---	---	---

1) Describes whether state allows RAP as a base course material.
2) The maximum percentage of RAP (by weight) allowed.
3) Describes whether the listed state requires the RAP blend to be processed prior to placement and what requirements must be met.
4) Describes the type of QA testing required.
5) These are modified values. The current values are 100%, but the materials department is in the process of modifying current values.
6) These values are the maximum AC content allowed in the RAP blend.
7) These states were not contacted and the information listed in the table is from the state's current standard specification.

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