STUDY ON PERFORMANCE OF FLAT AND ELONGATED AGGREGATE IN LOW TRAFFIC ROAD

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ABSTRACT

Aggregate are the largest amount of material that can be found in HMA. Aggregates make up between 80% to 90% of total volume or 94% to 95% of the mass of hot mix asphalt (HMA). With this facts, it is totally agree that aggregate properties are very important in HMA because it will affect the performances of the HMA. The objectives of this research are to evaluate the performances of the pavement using flat and elongated aggregate as the main material and to compare the strength of using flat and elongated aggregate in pavement mixes for low traffic road with the normal mixes. During the first stage, the aggregates were tested in order to know the characteristic. The test that had been done were AIV Test, ACV Test, LA Abrasion Test, Flakiness Index and Elongation Index. The bitumen also had been tested with the Penetration Test and Softening Point Test. After that, the mixtures were designed and prepared. The mixtures were designed as ACW14 and were tested in accordance with the JKR Specification:Arahan Teknik Jalan. 15 samples were prepared using Marshall Mix Design methods in order to determine the optimum asphalt content (OAC). The second stage of the research was to evaluate the performances of the mixture consist of flat and elongated aggregates. 12 samples were prepared with different percentage of flat and elongated aggregate which is 0% as the standard mixture, 20%, 40% and 60% as the experimental mixture. Based on the results, it is observed that flat and elongated aggregate might implies a significant effect on the performance of the mixtures. Thus, it can be concluded that the flat and elongated aggregate can be used in pavement mixtures but the percentage of aggregate must be limited to certain level to make sure the strength characteristics of the mixes can be maintained.

ABSTRAK

Batu baur merupakan bahan yang mempunyai jumlah terbesar di dalam campuran tar panas. Batu baur mewakili antara 80% ke 90% daripada isipadu atau 94% ke 95% daripada berat campuran tar panas. Dengan fakta ini, ianya telah dipersetujui bahawa ciri-ciri batu baur adalah sangat penting di dalam campuran tar panas kerana ia akan memberi kesan kepada prestasi campuran tar panas. Objektif kajian ini dijalankan adalah untuk menilai prestasi jalan yang mengandungi batu baur yang leper dan memanjang sebagai antara bahan utama dan untuk membandingkan kekuatan jalan yang mengandungi batu baur yang leper dan memanjang untuk jalan yang rendah aliran trafik dengan campuran biasa. Pada peringkat pertama, batu baur telah diuji untuk mengetahui ciri-cirinya. Antara ujian yang telah dijalankan ialah ujian AIV, ACV, LA Abrasion, indeks keleperan dan indeks pemanjangan. Bitumen juga turut diuji dengan ujian penetrasi dan ujian titik kelembutan. Selepas itu, campuran jalan di reka dan disediakan. Campuran telah direka sebagai ACW14 dan telah diuji mengikut spesifikasi JKR:Arahan Teknik Jalan. 15 sampel telah disediakan menggunakan kaedah rekabentuk campuran Marshall untuk mendapatkan kandungan tar yang optimum. Peringkat kedua dalan kajian ini adalah untuk menilai prestasi campuran yang mengandungi batu baur yang leper dan memanjang. 12 sampel telah disediakan dengan peratusan batu baur yang leper dan memanjang yang berbeza iaitu 0% sebagai campuran piawai, 20%, 40% dan 60% sebagai campuran kajian. Berdasarkan keputusan, didapati bahawa batu baur yang leper dan memanjang telah memberikan kesan kepada prestasi campuran. Oleh itu, konklusinya batu baur yang leper dan memanjang boleh digunakan di dalam campuran jalan tetapi peratusan batu baur mestilah dihadkan kepada satu tahap untuk memastikan ciri-ciri kekuatan campuran tersebut boleh dikekalkan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS / SYMBOLS

AASHTO	American Association of State Highway and Transport Officials
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BSI	British Standard Institution
cm	centimetre
d	bulk density
g	gram
g/cm^3	gram per centimetre cube
G_{mb}	Bulk specific gravity
G_{se}	effective specific gravity of the mix
G_b	specific gravity of asphalt content
G_{mm}	maximum theoretical specific gravity of the mix
G_{sb}	bulk specific gravity of the aggregate
HMA	hot mix asphalt
kg	kilogram
kN	kilo newton
kPa	kilo pascal
kg/mm	kilogram per milimetre
LA Abrasion	Los Angeles Abrasion
LVDT	Linear Variable Differential Transducers
MATTA	Material Testing Apparatus
MPa	mega pascal
mm/min	milimetre per minute
m	metre
mm	milimetre

ms	milisecond
N	newton
PWD	Public Work Department/JKR
P_b	asphalt content, percent by weight of the mix
rpm	rotation per minute
TMD	maximum theoretical density
VFA	void filled with asphalt
VMA	void in mineral aggregate
VTM	void in total mix
W_D	mass of specimen in air
W_{SSD}	surface dry mass
W_{SUB}	mass of specimen in water
%	percentage
°C	degree Celcius

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Highway plays an important role in the development and sustainability of human civilization from ancient times to the present. Today, throughout the world, highways dominate the transportation system and providing access of natural resources, retail marketing, industrial production, human population and to connect between two towns (Mannering et al, 2009). Highway transportation also gives a big influence on the economic, social and political. In the twenty-first century, the role of highway continues to evolve and investments in highway infrastructure have been made continuously. But, highways require maintenance and rehabilitation at regular interval. Thus, there is a strong emphasis in developing a new ways to more economically construct and extend the life of the new facilities and to effectively combat an aging highway infrastructure (Mannering et al, 2009).

Pavements are among the costliest item associated with highway construction and maintenance. In Malaysia, there are 74 603 km of road length comprises in Semenanjung Malaysia, Sabah and Sarawak. Some of the road in Malaysia are not paved but are composed of either gravel or a stabilized material

consisting of an aggregate material bound together with a cementing agent such as Portland cement, lime fly ash, or asphaltic cement. Malaysia's road system comprises several types of roads which are highway/expressways, federal roads, state roads and municipal roads. The roads are either be design and maintenance by major concessionaries, federal government, state government or municipal council.

Pavement provides two basic functions. The first function of pavement is to guide the driver and delineate the roadway by giving a visual perspective of the horizontal and vertical alignment of the traveled path. The second function of pavement is to support vehicle loads. These function is the reason why pavement design is very important (Mannering et al, 2009).

1.2 Background

In flexible pavement, mineral aggregate constitutes approximately about 95% of hot mix asphalt (HMA) by weight (J.S. Chen et al, 2005). Coarse aggregate is the dominant material in the mineral aggregate. One of the main characteristics in aggregate is the shape and sizes. Shape is important for proper compaction, load resistance and workability. This is supported by the research that had been done by Brown et al. 1989, Kandhal et al. 1992 and Kim et al. 1992 where the research has shown that aggregate characteristics such as particle size, shape and texture influence the performance and service ability of hot mix asphalt pavement. Generally, cubic-angular shaped particles with a rough surface texture are the best.

1.2.1 Flexible Pavement

Flexible pavements are so named because the total pavement structure deflects or flexes under loading. A flexible pavement structure is typically composed of several layers of material which is surface course consist of wearing course and binder course, base course, sub-base and sub-grade (Mannering et al, 2009). Each layer receives the loads from the above layer, spreads them out, then passes on these loads to the next layer below. Thus, the further down in the pavement structure a particular layer is, the less load (in terms of force per area) it must carry. Flexible pavement is laid with hot mix asphalt (HMA) at the surface layer. The flexible pavement surface layers components are :-

- Seal coat : seal coat is a thin asphalt surface treatment used to waterproof the surface or to provide skid resistance where the aggregates in the surface course could be polished by traffic and become slippery. Depending on the purpose, seal coats might or might not be covered with aggregate.

- Surface course : the surface course is the top course of an asphalt pavement and sometimes called wearing course. It is usually constructed of dense graded HMA. It must be tough to resist distortion under traffic and provide a smooth and skid-resistant riding surface. It also must be waterproof to protect the entire pavement and subgrade form the weakening effect of water.

- Binder course : the binder course or sometimes is called the asphalt base course, is the asphalt layer below the surface course. Asphalt

will be too thick if only be laid in one layer. Thus, binder course is used. Binder course generally consist of larger aggregates and less asphalt and does not require as high quality as the surface course. Resulted in a more economical design.

- Tack coat and prime coat : a tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water and used to ensure a bond between the surface being paved and the overlying course. A prime coat is an application of low-viscosity cutback asphalt to an absorbent surface, such as an untreated granular base on which an asphalt layer will be placed. Its purpose is to bind the granular base to the asphalt layer. The difference between a tack coat and a prime coat is that a tack coat does not require the penetration of asphalt into the underlying layer whereas a prime coat penetrates into the underlying layer, plugs the voids and form a watertight surface.

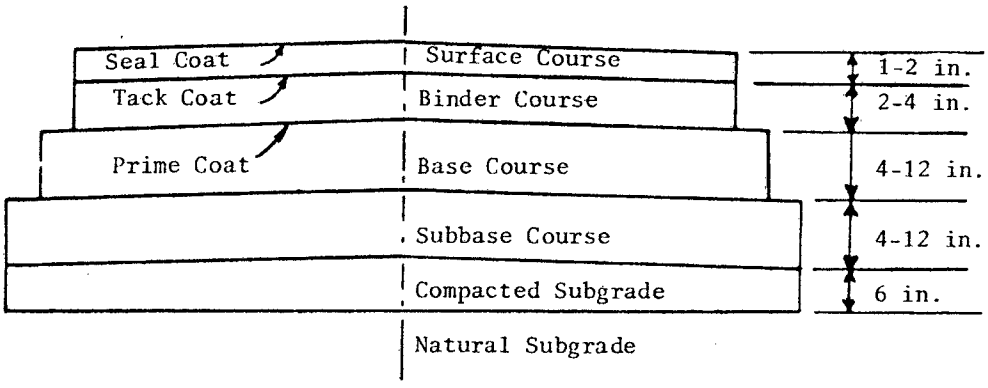

Figure 1.1 : Flexible pavement layer

1.2.2 Aggregate shape and surface particles

Aggregates are the largest component of HMA, making up 80 to 85 percent of the mixture by volume and roughly 95 percent of the mixture by weight. Aggregate characteristics and quality are major factors in the performance of HMA. Aggregate is one of the most important materials in flexible pavement design besides asphalts as these two materials will direct effect to the strength of the highway segment (Mannering et al, 2009).

Mixtures with crushed coarse aggregate with sharp, angular shapes will usually have the greatest shear resistance and, hence, the highest resistance to rutting (J.S. Chen et al, 2005). These materials create HMA mixtures with the highest voids in the mineral aggregate (VMA). Coarse aggregate angularity is defined as the percentage by weight of the aggregate with one or more fractured faces according to American Society for Testing and Materials (ASTM) D5821. Similar to coarse aggregate, crushed angular fine aggregate will usually have the greatest shear resistance. The use of crushed angular fine aggregate typically increases the mixture VMA. Fine aggregate angularity is established by AASHTO T304, Method A, which measures the percentage of air voids present in loosely compacted aggregate that passes the 2.36 mm sieve.

The percentage of flat and elongated particles in coarse aggregate is another important aggregate parameter. Flat and elongated aggregates are known to have adverse effects on the performance and strength properties of bituminous paving mixtures (Oduroh, P.K, 1999). Besides, it will also affect the workability which may lead to low densification, fatigue cracking and decrease in the fatigue resistance of the pavement. Flat and elongated aggregates are aggregates with the thickness less than three-fifths of their dimension and length greater that one and fourth fifth times their mean dimension. Flat and elongated particles of coarse aggregates have a tendency to fracture more easily than other aggregate particles. It

can break during the construction process, changing the mixture gradation and the overall mixture properties. Therefore, aggregate shape is one of the important properties that must be considered in the mix design of asphalt pavements to avoid premature pavement failure. The shape of the aggregates affects the particles interlock which affects the rutting resistance of the HMA pavement (Mannering et al, 2009).

Soft aggregate has a greater tendency to break than hard aggregate (Oduroh, P.K, 1999). Flat, slivered aggregate particles also have a tendency to lie flat in the pavement, creating slippage planes and reducing aggregate interlock. The way in which aggregate particles pack together for any given gradation is influenced by the surface texture of the particles. Rougher texture generates more friction between aggregate particles and the mixture therefore resists compaction. Hence, for a given number of design gyrations, the mixture will not compact as much and the VMA will be higher.

Smooth texture, by contrast, does not generate as much friction between aggregate particles. For a given number of design gyrations, the mixture containing smoother particles will compact more easily and the VMA will be lower. Typically, crushed faces have more texture than uncrushed faces. In the case of gravel aggregate, the uncrushed portion of the particles tends to have a smooth texture. The greater the percentage of each individual particle surface area that is fractured, the more surface texture that will be present. Usually, the more a gravel is crushed, the more surface texture it will have. Particles with two crushed faces tend to have a greater percentage of surface area with rough texture than will particles with only one crushed face (Oduroh, P.K, 1999).

However, crushing will not always increase texture, because some aggregates fracture with very smooth faces. For any given gradation, the density to

which aggregate particles will pack is influenced by the shape of the particles. Angular particles those with sharp, defined edge tend to produce mixtures with a higher VMA than mixtures containing rounded particles. Cubical particles that retain a sharp, angular edge tend to create a higher VMA than particles with rounded edges. But in this case, the flat and elongated aggregate will be used as the material in the mixture for a low traffic road.

1.3 Problem Statement

Pavements tend to distress after only a few years of construction. Pavement's failure such as cracking, stripping, rutting and so on happens due to traffic loading and some other causes like how well the mix is done and the quality of the mixture. Cost of constructing the pavement is usually expensive. It also consists of the cost of crush / round particles aggregate which is high. Meanwhile, the cost of flat and elongated particle is cheaper than angular particle. So, in this research, the angular particle in HMA is changed with the flat and elongated particles. This research is conducted to test whether the flat and elongated aggregate can be used in the pavement mixture or not. The alternative is also designed to reduce the cost of low traffic pavement construction and to extend the life of the new facilities besides to effectively combat an aging highway infrastructure. Moreover, a better road can be designed for a low traffic road so that the road user will have a better road quality in the future. But, if only the characteristics and strength of the mixes meet the specification then the flat and elongated particle can be used in the mix for low traffic road. That is why the strength of normal mix and experimental mix is compared.

1.4 Objectives

The objectives of this research are to :

i. To evaluate the performance of pavement mixes designed using flat and elongated material.

ii. To compare the strength of flat and elongated pavement mixes and standard pavement mixes in accordance to specification for low traffic road.

1.5 Scope of Study

The limitation for the this pavement design is :

a. The design is only for low traffic road : For this case study, a specification of low traffic road will be used as a guidelines in making comparisons on pavement strength.

b. Using flat and elongated aggregate as one of the material : Flat and elongated aggregates will be used to replace a small portion of coarse aggregate having round and angular shaped. The percentage of flat and elongated aggregate in each mixes are grouped into three different group which is 0%, 20%, 40% and 60%. Flat and elongated aggregate will not replace the whole amount of coarse aggregate but only a small part of it while the rest of coarse aggregate will maintain using normal aggregate.

c. This design is only apply to HMA only : HMA is usually used for pavement design for road in Malaysia.

1.6 Significant of Study

This research aims to create a new approach in pavement design by using different type shape of aggregate. It is done in order to find a way to reduce the cost of constructing a new pavement for certain area as it is known that constructing a new pavement is a bit pricey. This research will allow for an explicit study on the new approach in pavement design which may be useful to the Public Works Department (PWD) of the Ministry of Works Malaysia and the road engineer in order to mitigate the problems that rise due to the construction of new pavement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An economical and adequate design is one of the important element in pavement design. An underdesigned pavement will fail prematurely and costing more money for repairs (Asphalt Institute, 1989). It is therefore important to recognize that the proper selection of aggregate is pertinent to the achievement of the desired performance of bituminous paving mixtures (Oduroh, P.K, 1999). The design of a pavement structure is very important because it directly affects on the construction and maintenance of the pavement. A good design would give a great benefit to the economy if the life of the road could be extended.