EVALUATION OF MARSHALL PROPERTIES OF ASPHALT MIXTURES WITH AGGREGATE GRADATIONS DESIGNED USING THE BAILEY METHOD

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ABSTRACT

This study investigates the properties of asphalt concrete mixtures with aggregate gradations designed using Bailey method and compared with the JKR specification. Bailey method is a systematic approach in blending aggregates with difference gradation (fine aggregate and coarse aggregate) that provides aggregate interlocking as the backbone of the structure and a balanced continuous gradation to complete the mixtures. The Bailey gradation parameter separates the aggregate structure into three gradation namely coarse, medium and fine. This separation were quantified by the decrease in the volume of coarse aggregate in the structure when changing from coarse to fine gradation. The aggregates structures designed using Bailey method were applied in Marshall mix design method to obtain the Marshall properties based on Malaysian Standard and the gradation parameters were compared with the requirement from JKR specification. Two hot mix mixtures considered in this study were Asphalt Concrete Wearing (ACW 14) and Asphalt Concrete Wearing (ACW 10). The mixtures have nominal maximum aggregate sizes (NMAS) of 12.5 mm and 9.5 mm respectively and each sample was compacted using 75 blows per face. The compaction characteristics of the mixtures were analyzed using data from the Marshall Compactor. The value for both VTM and VMA from graph shows when the size of aggregate is smaller (fine aggregate), the percentage of voids in mineral aggregate is low, on the other hand the percentages of VMA and VTM is higher for coarse aggregate.

ABSTRAK

Kajian ini dijalankan untuk mengkaji campuran konkrit berbitumen dengan pengadunan batu baur menggunakan kaedah Bailey dan membandingkan dengan spesifikasi JKR. Kaedah Bailey adalah secara sistematik campuran batu baur yang gradasi (batu baur halus dan batu baur kasar) yang menyediakan saling kunci batu baur sebagai tulang belakang kepada struktur dan gradasi berterusan yang seimbang bagi melengkapkan campuran. Parameter gradasi bagi kaedah Bailey mengasingkan struktur batu baur kepada tiga iaitu kasar, sederhana, dan halus. Pengasingan ini dibezakan melalui penurunan isipadu bagi batu baur kasar di dalam struktur apabila ia bergerak dari gradasi kasar kepada gradasi halus. Rekabentuk struktur batu baur menggunakan kaedah Bailey di gunakan dalam kaedah Marshall untuk mendapatkan ciri-ciri Marshall berdasarkan piawaian Malaysia dan parameter gradasi di bandingkan dengan spesifikasi JKR. Dua campuran panas telah digunakan dalam kajian ini iaitu konkrit berbitumen (ACW 14) dan konkrit berbitumen (ACW 10). Campuran ini mempunyai saiz nominal maksimum batu baur 12.5 mm dan 9.5 mm dan setiap sampel dipadatkan dengan 75 hentaman. Ciri-ciri pemadatan bagi campuran dianalisa menggunakan data dari pemadat Marshall. Nilai bagi kedua-dua VTM dan VMA daripada graf menunjukkan apabila saiz batu baur kecil (batu baur halus), peratus udara dalam mineral batu baur tersebut adalah rendah, manakala peratus bagi VMA dan VTM adalah tinggi untuk batu baur kasar.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Background

Hot mix asphalt (HMA) is the most common material used for paving applications around the world. It primarily consists of asphalt cement binder and mineral aggregates. It is defined as a combination of heated and dried mineral aggregates that are uniformly mixed and coated with a hot asphalt binder. When bound by asphalt binder, mineral aggregate acts as a stone framework that provides strength and toughness to the system. The behavior of HMA depends on the properties of the individual components and how they react with each other in the system. HMA is a composite material consisting of aggregate particles with different sizes, an asphalt binder that is much softer than the aggregate, and air voids (Alshamsi, 2006)

The mixture design process consists of two main parts, the volumetric design portion and empirical mechanical testing to verify the design. In addition, the design method may include other requirements that the mixture must meet in order to satisfy the overall specification standard. Such requirements may include certain aggregate qualities like minimum percent of crushed aggregate, maximum amount of rounded sand materials and specific aggregate gradation requirements (Asphalt Institute, 2001).

Controlling the volumetric in HMA is not a new concept and in fact has been around for over a century. In 1903, Bitulithic Macadam, an early HMA design based on volumetric, was patented by Frederick J. Warren, founder of Warren Brothers Company in Boston, Massachusetts. Back then, Mr. Warren designed an experiment to determine the optimum size and gradation of aggregate particles needed to fill a container of known volume (Roberts *et al.*, 1996).

1.2 Problem Statement

Generally, in the conventional method the mixtures is accepted or rejected based on those criteria at an early stage in the design process without any validation of their expected performance. An example of such criteria is the percentage of voids in the mineral aggregate (VMA). VMA is the total void space between the aggregate particles in compacted asphalt concrete, including air voids and asphalt not absorbed by the aggregates. It were report by several researchers and highway agencies that there exist difficulties in meeting the minimum voids in VMA requirements (Kandhal, Foo and Mallick, 1998).

Studies have also shown that the current defined VMA criteria were seen to be insufficient to correctly differentiate well performing mixtures from poor ones. In other words, the design process in the Marshall mix system does not properly address the expected performance of the designed mixtures in terms of major pavement distresses like permanent deformation and rutting through laboratory performance testing. So, the new method is looking for improvement on those specifications and requirements especially designing the aggregate gradations to improve mixture stability. In the current Marshall mix system, guidance is lacking in the selection of the design aggregate gradations and understanding the interaction of the aggregate structure with mixture design and performance (Asphalt Institute, 2001). Furthermore, the trial and error nature of the actual conventional process of formulating the gradation curve, and the use of weight instead of volume when blending aggregates, offer alternatives to evaluate more rational approaches to design an aggregate structure based on principles of aggregate packing concepts (Vavrik *et al.,* 2002)

A key to a successful mixture design is the balance between the volumetric composition and the properties of the raw materials used (binder and aggregates). The interaction between these components coupled with the different types and magnitude of loadings the pavement were subjected to results in highly complex mixture responses that require more complete understanding of asphalt mixture behavior. The key step to achieve that is to understand how the mechanical performances of asphalt mixtures were affected by different mixture components and properties (Kandhal, Foo and Mallick, 1998).

From the above discussion, there is clearly a need to address the issues of concern in the current Marshall mix design system by introducing more rational which is the new method for aggregate structure known as Bailey method. It is a systematic step to the current system for better design and evaluation of asphalt mixtures.

The Bailey method of gradation evaluation focus on the aggregate properties that affect the way aggregates fit together (or pack) in a confined space or volume. To analyze the packing factors, the method defines four key principles that break down the overall combined aggregate blend into four distinct fractions. Each fraction is then analyzed for its contribution to the overall mix volumetric (Vavrik *et al.*, 2001).

By comparing the size of particles that fit into the voids between the largest aggregate pieces to the size of the largest aggregate pieces found in a fraction, ratios can be developed that is an indication of how well all the particles in the fraction fit together. Once a mix designer has been taught the principles of the Bailey method and how to apply them, and then begin to predict how changes in the factors that affect packing will change volumetric and compactability of a particular mixture (Vavrik *et al.*, 2001).

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1.3 Objective of the Study

The objective of this study is to evaluate Marshall properties of asphalt concrete mixtures with aggregate gradations designed using Bailey method.

1.4 Scope of the Study

In order to archive the objective, the two types of mix designs of asphalt concrete (ACW) were prepared in accordance to the JKR Specification. They were ACW 10 and ACW 14. The aggregate structure (coarse, medium, and fine) was design using the Bailey method of aggregate gradation evaluation. The coarse aggregate structure has the highest volume of coarse particles. This volume decreases as the structure becomes finer. Asphalt cement 80-100 PEN was used in the designed mixture.

This study focus in designing the aggregate gradations and performing Marshall mixture design to determine the design asphalt content that provides four percent air void that is currently being used by the Marshall system as an acceptable design parameter for dense graded mixtures (Lavin, 2003). The evaluation tests were conducted in order to determine the best performing aggregate skeleton for each aggregate type and size combination (Thompson, 2006). This evaluation includes determining compaction properties of the mixtures.

1.5 Significance of the Study

From the results of this study, it can provide a better understanding in the relationship between aggregate gradation and mixture voids. The Bailey method procedure help to ensure aggregate interlock and good aggregate packing, giving resistance to permanent deformation, while maintaining volumetric properties that provided resistance to environmental stress (Thompson, 2006). Use of the Bailey method will ensure coarse aggregate interlock and control of aggregate packing, allowing the designer to specify desired mixture properties. This will eliminate the normal trial and error process used in determining the design aggregate gradations and will help in the transition to contractor mix design. The evaluation tools in the Bailey method can also be used for quality control during the construction process. The proper changes to the production process can be made to meet the quality requirements in the field as a result of the understanding of the effects of aggregate gradations on the properties of the asphalt mixture (Aurilio, William and Lum, 2005). It were expected that, the results of this research will provide a better understanding of the relationship between aggregate gradations and the volumetric properties, ease of construction, and performance.

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