EFFECT OF RUBBER BITUMEN INTERACTION ON THE PROPERTIES OF DRY MIXED RUBBERIZED ASPHALT MIXTURE

ABDULWARITH IBRAHIM BIBI FAROUK

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Dedicated To my sisters

ACKNOLEDMENT

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ABSTRACT

ABSTARCT: The use of recycled scrap tires in asphalt mixtures is not a recent development with reclaimed tire crumb being used in the asphalt industry for over 40 years. Reclaimed tire crumb can be incorporated into asphalt mixtures using two different methods, referred to as the wet and dry processes. This study investigates the effect of rubber-bitumen interaction on the properties of rubberized asphalt mixture using dry process. The rubber-bitumen interaction is a significant issue in dry process even though this interaction is neglected in most of the previous studies. The 'rubber swelling' activity occurs within the compacted asphalt mixture as a result of the bitumen absorption by the rubber particles that could result in inconsistent density of the compacted asphalt mixture, thus, affecting its performance. First, the effect of using different rubber gradation, bitumen content, and curing time on the interaction between rubber and bitumen or in other words the degree of bitumen absorption was investigated using 'Basket Drainage Method'. The investigation focused on the influence of these variables in achieving the target density as for rubberized asphalt mixture, it is important to achieve low target air void content after compaction for its stability. The relationships between the aforementioned variables and the target density of the mixture design were determined. An aggregate gradation of Asphalt Concrete with nominal maximum aggregate size 14 (AC14) was used for preparing the gyratory compacted samples modified with 2% crumb rubber with different rubber sizes. Finally these samples were tested for evaluating its performance in terms of dynamic creep and resilient modulus and compared with the conventional mixture. The results indicate a decrease in the resilient modulus and an increase in the dynamic creep for the rubberized asphalt mixtures. Fine rubber particles and the interaction time provided were observed to positively affect the mixture properties. Samples with fine rubber particles were found easily to compact compared to the one with coarse rubber.

ABSTRAK

Penggunaan tayar sekerap yang dikitar semula dalam campuran asfalt bukan merupakan satu perkembangan baru dengan tayar yang ditebus guna (*reclaimed tire crumb*) ini sudah digunakan dalam industri asfalt selama lebih 40 tahun . Tayar yang ditebus guna ini boleh dimasukkan ke dalam campuran asfalt dengan menggunakan dua kaedah yang berbeza , iaitu yang disebut sebagai proses basah dan kering. Kajian ini adalah untuk menyiasat kesan interaksi getah dengan bitumen pada sifat-sifat campuran asfalt getah menggunakan proses kering. Interaksi getah dengan bitumen adalah isu penting dalam proses kering walaupun interaksi ini diabaikan dalam kebanyakan kajian sebelum ini. Aktiviti 'pembengkakan getah' berlaku dalam campuran asfalt yang dipadatkan akibat daripada penyerapan bitumen oleh zarah getah yang boleh menyebabkan kepadatan tidak selaras dalam campuran asfalt, dengan itu mengurangkan prestasinya. Pertama sekali , kesan daripada penggunaan penggredan getah yang berlainan, kandungan bitumen, dan masa mengubati bagi interaksi antara getah dan bitumen atau dalam erti kata lain tahap penyerapan bitumen telah dikaji dengan menggunakan ' Kaedah Bakul Saliran ' . Kajian ini memberi tertumpu kepada pengaruh pembolehubah dalam mencapai ketumpatan sasaran kepada campuran asfalt getah , ia penting untuk mencapai sasaran kandungan lompang udara yang rendah selepas pemadatan untuk kestabilan. Hubungan antara pemboleh ubah yang dinyatakan di atas dan ketumpatan sasaran reka bentuk campuran ditentukan. Satu penggredan agregat asfalt konkrit dengan nominal saiz agregat maksimum 14 (AC14) telah digunakan untuk menyediakan sampel padatan menggunakan mesin padatan '*gyratory*' yang diubahsuai dengan 2 % getah yang ditebus guna dengan saiz getah yang berbeza. Akhirnya sampel ini telah diuji untuk menilai prestasi dari segi rayapan dinamik dan modulus berdaya tahan berbanding campuran konvensional. Keputusan menunjukkan penurunan dalam modulus berdaya tahan dan peningkatan dalam rayapan dinamik untuk campuran getah asfalt. Zarah getah halus dan masa interaksi yang disediakan diperhatikan untuk memberi kesan positif kepada sifat-sifat campuran. Sampel dengan zarah getah halus didapati mudah untuk dipadatkan berbanding dengan getah kasar.

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CHAPTER 1

INTRODUCTION

1.2 Introduction

Tire rubber has been used in asphalt mixtures since the late 60's. With a lot of research being done in this field, there are many terminologies associated with tire rubber modified asphalt concrete mixes. Some of the commonly used terminologies are Crumb Rubber Modifier (CRM), asphalt-rubber, rubber modified asphalt mixes (coarse CRM & fine CRM mixes), rubberized asphalt etc. These terms refer to uses of rubber in asphalt mixes that are different in their mix composition, method of production or preparation and in their physical and structural properties. As a result, the considerations in using the above mentioned materials will be different. This necessitates the need to clearly define the terminologies associated with the rubber modified binders and mixes. The use of crumb rubber in asphalt pavement has gained more attention in many parts of the world as this material gives better mechanical and functional performance as well as being an efficient way of dealing with this waste product (Epps, 1994). Crumb rubber modified asphalt (CRM) is a general type of modified asphalt that contains scrap tire rubber. Rubberized asphalt mixture products can be produced with several techniques, including a wet process and a dry process. In the wet process CRM binder is produced by adding fine crumb rubber (0.075 mm to 1.2 mm) with bitumen at elevated temperatures prior to mixing with the aggregate. The binder modification for this technique is contributed by the physical and compositional changes due to the interaction process where the rubber particles swell in the bitumen by absorbing a percentage of the lighter fraction of bitumen to form a viscous gel. Whereas for the dry process, granulated crumb rubber (0.4 to 10 mm) is used to substitute a small portion of aggregates, typically between 1 and 3% by mass of the total aggregate in the mixture. The rubber particles are blended with the aggregates prior to the addition of the bitumen. This study investigates the effect of rubber bitumen interaction on the rubberized asphalt mixture produced with dry process method..

1.2 Problem Statement

The dry process is a less popular method in rubberized asphalt production compared to the wet process due to the difficulties in getting consistent performance due to the inconsistent density after compaction. This problem could be as a result of the rubber-bitumen interaction and the swelling of the rubber particles during mixing and transportation (Amirkhanian et al., 2000, Fager, 2001, Hunt, 2002). During mixing and transportation of rubberized asphalt mixture, the rubber particles tend to absorb the bitumen that will result in the swelling of the rubber. The problem occurs when the swelling process take place after the compaction which increases the volume of the rubber and affect the density of the mixture. However, if the swelling process takes place before compaction, it is expected that the rubber will not further swell after compaction, which therefore the target density can be easily achieved. Previous studies show that, the rubber-bitumen interaction will change the properties of the bitumen as well as the shape and rigidity of the rubber particles which result in poor asphalt mixture performance (Singleton et al., 2000; Aireyet al., 2002). For dry mix process, the problem of rubber swelling could result in the reduction in density of the mixture which in turn leads to premature failures in terms of cracking and raveling and high air void content for dense graded mixes. The results from extensive laboratory studies have indicated that the rate of absorption is directly related to the bitumen penetration grade, viscosity as well as the chemical composition of the bitumen (crude source). However it was found that, the total amount of absorption is controlled by the nature or the properties of the crumb rubber (Airey et al., 2003). This study investigates the effect of rubber-bitumen interaction on the properties of dry mixed rubberized asphalt mixture in achieving the target density.

1.3 Aim and Objectives

The aim of this study is to investigate the effect of rubber-bitumen interaction on the asphalt mixture compaction and its mechanical properties. This is to develop an understanding of the level in which recycled crumb rubber modifier expands after compaction, the causes and possible measures to be used to achieve the target density by using dry process. The objectives of this study are as follows:

i. To investigate the effect of different mixture design variables on the degree of rubber -bitumen interaction.

ii. To investigate the effect of rubber-bitumen interaction on the target density of the compacted sample or mixture density.

iii. To investigate the effect of rubber-bitumen interaction on the mechanical properties of the compacted rubberized mixture in terms of resilient modulus and creep (permanent deformation).

1.4 Scope of Study

This study covers the investigation on the rubber-bitumen interaction. The crumb rubber was used to modify a dense graded mixture of AC14 and 80/100 penetration grade bitumen was used as the binder. Three different sizes of rubber particles were studied; 1.18, 3.35 and 5.0mm. Gyratory compactor was used to fabricate the laboratory compacted samples which were then subjected to the investigation of the compacted target density and the performance tests (resilient modulus and dynamic creep).

1.5 Methodology

The study was divided into three main phases. First, is the investigation on the rubber-bitumen interaction to determine the degree of bitumen absorption by the rubber particles. Second, the investigation focuses on the compaction to achieve the target density and its relationship to the compaction effort. Finally, the mechanical properties of the compacted mixture were investigated in terms of resilient modulus and dynamic creep (permanent deformation). Details of the phases are summarized as follows:

Phase One: The absorption of bitumen into crumb rubber was determined using Basket drainage method. The swelling tests consisted of placing 5 g of the crumb rubber particles into wire mesh baskets and then placing the baskets into 400 ml beakers. The baskets were constructed with 0.28 mm square aperture steel mesh with diametric dimension of 50 mm and a height of 100 mm. Bitumen was heated for 2 hours at 160^{o}C in a fan-assisted oven and fixed quantities of the binder poured into each of the beakers. The proportion of rubber to bitumen was altered by changing the mass of bitumen with three quantities of 20, 30 and 40 g of bitumen being added to the 5 g of rubber to give rubber–bitumen ratios of 1:4, 1:6 and 1:8. The test was conducted for three different size of crumb rubber and the amount of swelling (bitumen absorption) and the rate of swelling of the crumb rubber was calculated by measuring the mass of the rubber before and after rubber –bitumen interaction at 1, 4, 24 and 48 h.

Phase Two: In this study a dense graded mixture, AC14 was used in three different size of crumb rubber modifier and 80/100 penetration grade bitumen. The first step was done using fine rubber size 1.18 to replace an aggregate sample and then blended with bitumen and subjected to zero curing period condition and also different bitumen content. The second step is to repeat the first step but using a coarse rubber 3.35 mm size and the third step is rubber size of 5.0 mm. Target density and actual density was measured in each case.

Phase Three: In this section the mechanical properties of compacted mixture in terms of resilient modulus test and creep test was measured for the designed mixture.

1.6 Significance of Study

Considering the amount of the scrap tire produced every year all over the world, United Kingdom produces more than 30 million scrap tires every year while United States of America more than 270 million waste tires are generated annually in which more than 800million are stockpiled. This will raise a few potential environmental and health problems to the including fire hazard and a part of the solid waste management problem. From the recent observation, it was found that dry process has a potential to consume larger quantities of crumb rubber compared to the wet process. In addition, the production of rubberized asphalt mixtures by the means of dry process is a lot of easier or quicker than the wet process and therefore the dry process is potentially available to a much larger market. However, previous studies on the dry process method are limited particularly on the rubber-bitumen interaction. Usually, the main assumption with the dry process is that crumb rubber is solely part of the aggregate and the reaction between bitumen and crumb rubber is always negligible. However recent investigation found that crumb rubber swells and reacts with bitumen at elevated temperatures and has an effect on the performance of bitumen and asphalt mixture (Singleton, 2000)

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