COMPARISON BETWEEN SUPERPAVE GYRATORY AND MARSHALL LABORATORY COMPACTION METHODS

NAEEM AZIZ MEMON

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To my beloved mother, father, wife and kids

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ABSTRACT

The last decade has witnessed a dramatic increase in vehicular traffic on roads in developing countries like Malaysia. This has raised additional traffic, augmented axle loads and increased tire pressure on pavements designed for earlier era. In this regard, besides considering increasing the pavement thickness due to the traffic loads , steps must also be taken to extend the pavement life by using different compaction methods such as gyratory laboratory compaction method to have durable mix and better simulate field conditions. However, the main shortcoming of gyratory compaction method is that the gyratory compactor is very costly as seven times more than that of the available Marshall hammer.To overcome that shortcoming, studies have been done to compare both laboratory compaction methods but more are needed to verify different findings according to different conditions and climate. In this research four asphalt concrete mixes asphalt wearing course(ACW)10, ACW14, ACW20 and ACB28 were designed using Marshall mix design to evaluate HMA properties such as density and air voids. Based on the Marshall results, specimens were fabricated to obtain the required number of gyrations that could produce same results in terms of density. Using the equivalent number of gyrations samples were designed using superpave to obtain the optimum bitumen content (OBC). The results indicate that at 75 blows Marshall, the equivalent number of gyrations for ACW10, ACW14, ACW20 and ACB28 are 105, 67, 58 and 107 respectively. The results also suggest that there is no significant difference in OBC except for ACW10, which is 0.6%. This shows that numbers of gyrations obtained are reasonable in comparing with 75 blows Marshall.

ABSTRAK

Dekad yang terakhir telah menyaksikan peningkatan yang mendadak dalam lalulintas di jalan-jalan di negara-negara membangun seperti Malaysia. Ini telah menambahkan pembebanan lalulintas, peningkatan beban gandar, dan pertambahan tekanan tayar ke atas jalan yang direkabentuk untuk zaman terdahulu. Selain daripada pertimbangan untuk meningkatkan ketebalan jalan akibat daripada beban lalulintas, langkah-langkah juga haruslah diambil untuk memanjangkan jangka hayat jalan dengan menggunakan kaedah pemadatan yang berbeza seperti *kaedah pemadatan putaran makmal* untuk menghasilkan campuran yang lebih tahan lasak dan menyerupai keadaan tapak. Walau bagaimanapun, masalah utama kaedah pemadatan *putaran* ialah pemadat *putaran* ini lebih mahal harganya, tujuh kali ganda daripada tukul Marshall yang sedia ada. Untuk mengatasi masalah ini, kajian telah dijalankan untuk membandingkan kedua-dua kaedah pemadatan makmal tersebut tetapi lebih banyak kajian diperlukan untuk mengesahkan keputusan yang berlainan mengikut keadaan dan iklim yang berbeza. Dalam kajian ini, empat campuran konkrit berasfal, lapisan haus konkrit berasfal (ACW)10, ACW14, ACW20, dan ACW28, telah direkabentuk menggunakan rekabentuk campuran Marshall untuk menilai sifat-sifat seperti ketumpatan dan lompang udara. Berdasarkan keputusan Marshall, spesimen-spesimen dihasilkan untuk mendapatkan bilangan *putaran(gyration)* yang diperlukan untuk memperoleh keputusan ketumpatan yang sama. Dengan menggunakan bilangan *putaran*(gyration) yang sama, sampel telah direkabentuk menggunakan Superpave untuk mendapatkan kandungan bitumen yang optimum (OBC). Keputusan menunjukkan bahawa pada 75 hentakan Marshall, bilangan *putaran(gyration)* yang bersamaan untuk ACW10, ACW14, ACW20, dan ACB28 adalah 105, 67, 58, dan 107 masing-masing. Keputusan juga mencadangkan bahawa tiada perbezaan yang nyata dari segi OBC kecuali ACW10, iaitu 0.6%. Ini menunjukkan bahawa bilangan *putaran*(gyration) yang diperoleh adalah munasabah jika dibandingkan dengan 75 hentakan Marshall.

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CHAPTER 1

INTRODUCTION

1.1 Introduction:

Compaction of Asphalt concrete mixtures in flexible pavements plays a major role in the performance of these pavements. Mix properties, such as density and air voids are highly dependent on the degree and the method of compaction. These properties in turn affect pavement performance indicators, such as rutting and fatigue cracking.

The difference between laboratory compaction methods is not only the result of the evaluation procedure but is also the consequence of the compaction technique used. The goal of a mix design procedure is to combine aggregates and a binder in a proportion that is able to satisfy a desired level of performance. Realistic procedures for evaluating the strength of bituminous mixtures is therefore quite important. There are several factors that affect the strength of bituminous mixtures; one of them is the method of forming a realistic test specimen in the laboratory that represents the structure of the paving mixture when it is placed in the field. Duplicating the composition of a field mixture in the laboratory presents some problems, but they are minor compared to producing in the laboratory a specimen of the mixture that truly represents the mixture as it exists in the field (Blankenship et al.. 1994).

The quality of an asphalt pavement depends largely on the quality of the construction techniques used. An asphalt mix might be well designed and well produced, but if it is placed in the road in an improper way, the pavement performance will be poor. Therefore next to mix design, degree of compaction must be considered the main quality parameters of a laid asphalt mixture. A well designed and well produced mixture performs better, has better durability, and has better mechanical properties when it is well compacted.

1.2 Laboratory compaction

The objective behind laboratory compation is to simulate the ultimate compaction achieved in and asphalt pavement. Historically three laboratory compaction methods have been used in asphalt laboratory mix design and those are:

1.2.1 Compaction by Impact

Figure 1.1: Marshall Impact Hammer

This is oldest technique in laboratory compaction. In the beginning of the 20th century, Hubbard and Field used a Proctor hammer to compact asphalt mixtures. This hammer was borrowed from the Geotechnical field. In the 1930s. Bruce Marshall adopted the Hubbard-Field method and began developing the method, which bears his name. The only difference was that he used a compactor face equal to the mould diameter. The number of blows applied to each face of the specimen was set to be 35, 50 or 75 depending upon the anticipated traffic volume. The higher the volume of traffic, the greater the number of blows. This is the most common mix design method used today. The Marshall Mix design or a variation thereof has been adopted by 75 percent of the highway agencies in the U.S. However. Consuegra et al. (1989) concluded that the Marshall hammer least simulates the actual field conditions that will be encountered by pavement during its service life.

1.2.2 Kneading Compaction

Figure 1.2: Kneading Compactor

In the 1930s and 1940s F.N. Hveem developed a mix design method referred to as kneading compaction. This method was different from the Marshall Mix design method. The compacting force in this compactor is applied through a roughly triangular-shaped foot, which partially covers the specimen face. To effect compaction, tamps are uniformly applied on the specimen face. The traffic volume is represented by the pressure of tamps. More tamps and higher lamp pressure simulates mixtures subjected to high traffic volume. This type of compaction is used primarily in pans of the Western United Stales, but used infrequently elsewhere.

1.2.3 Gyratory Compaction

Figure 1.3: Gyratory Compactor

Gyratory compaction was developed in the 1930s in Texas (Blankenship et al.. 1994). This compaction produces a kneading action on the specimen by gyrating the specimen through a horizontal angle. The range of the angle varies from 1.00 to 6.00 degrees. During the process of compaction a vertical load is applied while gyrating the mould in a back-and- forth motion.

Development and use of compaction via gyratory action has continued by the U.S Army Corps of Engineers and by the Central Laboratory for Bridges and Roads (LCPC) in France (Blankenship. 1994). Such development has focused on the application of the principle of gyratory movement and oil the establishment of a new method of asphalt mix design to simulate service under extreme traffic conditions. The use of this compactor became commonplace in the early 1960s; however, the costly gyratory testing machine has achieved little acceptance as a routine mix design tool and is used mainly as a research tool. The LCPC had evaluated parameters affecting gyratory compaction and had finalized a gyratory protocol, where three major variables had been studied: angle of gyration, speed of rotation, and vertical pressure. Today, the gyratory compaction method is commonly used in the mix design process in France. A major difference between the French design process and North American design is that in the French design the compactor simulates density at the end of construction instead of during service.

In 1993, The SHRP introduced a trademarked "Superpave" laboratory mix design procedure based on a gyratory compaction device (Cominsky et al.1994). This laboratory design procedure was deemed to be appropriate for original and/or recycled hot mixtures and with and/or without modified binders. The Superpave mix design method recommended three hierarchical levels of design, namely Level 1, 2 and 3 based on anticipated traffic volume. Each design level also took into account the influence of the site climatic conditions. However, in 1995 the SHRP decided to employ the Level 1 design for all volumes of traffic (low, medium and high). The sophisticated and complex analytical techniques and costly test equipment for levels 2 and 3 design did not lend themselves to usage in a Hot Mix Asphalt production facility. The HMA industry concurred with this decision and was of the opinion that most pavements forming part of the National Highway System (NHS) would perform well if designed using the concepts of the Superpave Level I mix design (Decker. 1995).

1.3 Problem statement

In developing countries like Malaysia the dramatic growth in vehicular traffic have augmented axle loads and increased tire pressure on the pavements resulting in rutting and cracking. Compaction of asphaltic concrete mixtures in flexible pavements plays a major role in the performance of these pavements. Mix properties, such as density and air voids are highly dependent on the degree and the method of compaction. These properties in turn affect pavement performance indicators, such as rutting and fatigue cracking.

1.4 Objectives

Objectives selected for this study were:

- to compare HMA properties (density and air voids) of laboratory compacted samples and ;

- to examine co-relation between Marshall and gyratory laboratory compaction methods**.**

1.5 Scope of Study

The key points aimed to maintain the scope during the study were compaction of asphalt concrete mixes by Marshall and gyratory compaction methods to evaluate HMA properties of the mix and to find some co-relations in HMA properties between two laboratory compaction methods. Further more, to compare the effect of different number of blows and different number of gyrations as compactive efforts for ACW10, ACW14, ACW20 and ACB28 mix designs, as performance of mixes in terms of density and air voids were observed according to the serial tests.

The compaction methods used to evaluate HMA properties were Marshall and superpave laboratory compaction methods. Standard mix design procedures were differentiated on their method of compaction, which is assumed to simulate field compaction. With the Marshall design methods, specimens are prepared by impact compaction, while in the superpave design method, specimens are fabricated by gyrations. This type of compaction was developed to produce realistic specimens which compared favorably to in-service mixtures after traffic compaction. The gyratory compaction technique was introduced to simulate the increasing loads and tire pressures of vehicles operating on the pavement. Prior to this compaction technique, it was not possible to achieve a realistic field density in laboratory specimens. Recently, the Strategic Highway Research Program (SHRP) adopted, with some modification, the gyratory compaction procedure in asphalt mix design.

1.6 Purpose of study

The goal of this study was to compare and evaluate laboratory compaction methods that are widely used and/or resemble as closely as possible. The objective of this study was to select a compaction technique that is able to achieve material and engineering properties (such as air voids and density), which are similar to those of material placed in the field using standard compaction practices. The selected compaction techniques for this study were Marshall Automatic Impact Compaction and Gyratory Compaction. Required aggregates were collected from the Malaysian Rock Products (MRP) quarry, other material required and Laboratory tests facilities were provided by Transportation Laboratory University Technology Malaysia to prepare samples for comparison and evaluation. Procedure as described by the National Asphalt Paving Association (NAPA) to determine the optimum bitumen content (OBC) was selected. The asphalt content percentage, which corresponds to the 4% air void at VTM, is determined. The 4% is the specification of media void content.

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