THE RELATIONSHIP OF BITUMEN CONTENT, AGGREGATE SURFACE AREA, AND EXTRACTION TIME USING ASPHALT IGNITION FURNACE

TRAN TRANG NHAT

UNIVERSITI TEKNOLOGI MALAYSIA

ABSTRACT

Aggregates make up between 80% and 90% of total volume or 94% to 95% of the mass of hot mix asphalt (HMA). For this reason, aggregate properties are very important. It directly affects the workability of the HMA. One of the properties of aggregate is coated surface area. The main objective of this study was to search the relationship of the surface area of aggregate, bitumen content, and extraction time in order to find the coated surface area of aggregate to be correlative with the optimum bitumen content. Three types of aggregate grading including dense grading, open grading, and gap grading that designed as ACW14, PA, and SMA14 were tested in accordance with the JKR Specification. A total of 45 specimens were prepared using Marshall Mix design method with three types of grading: ACW14 (dense graded), SMA14 (gap graded), and PA (open graded) in order to determine the optimum bitumen content (OBC). The second phase was to determine the coated surface area of aggregate by using the surface area factor. 45 samples were prepared and subjected to extraction of the bitumen content using NCAT ignition furnace to determine the time to remove bitumen from the aggregate in different types of mixes. Based on the results, it was observed that the bitumen content was significantly affected by the aggregate surface area while the aggregate surface area was influenced by the fine aggregate. Moreover, all of the observed parameters fitted highly to the linear relationship. Thus, it can be concluded that the bitumen content, aggregate surface area and the characteristics of bitumen have an influence on the extraction time.

ABSTRAK

Batu baur mewakili antara 80% dan 90% daripada isipadu atau 94% hingga 95% daripada berat campuran tar panas. Oleh itu, sifat batu baur adalah sangat penting. Ia secara langsung akan memberi kesan kepada cara kerja campuran tar panas. Satu daripada cirri batu baur ialah sebagai lapisan kepada luas permukaan. Objektif utama kajian ini adalah untuk mencari hubungan luas permukaan batu baur, kandungan tar, dan masa perahan dalam arahan untuk mendapatkan lapisan kepada luas permukaan batu baur yang lebih tepat dengan kandungan tar yang optimum. Tiga jenis tahap batu baur termasuklah tahap padat, tahap terbuka, dan tahap ruang yang telah di reka bentuk sebagai ACW14, PA, dan SMA14 yang telah diuji berdasarkan kepada spesifikasi JKR. Sejumlah 45 spesimen telah disediakan menggunakan kaedah rekabentuk campuran Marshall dengan menggunakan tiga jenis tahap: ACW14 (tahap padat), SMA14 (tahap ruang), dan PA (tahap terbuka) dalam arahan untuk mendapatkan kandungan tar yang optimum. Fasa kedua adalah untuk mendapatkan lapisan luas permukaan batu baur dengan menggunakan faktor luas permukaan. 45 sampel telah disediakan dan bergantung kepada perahan kandungan tar dengan menggunakan NCAT nyalaan relau bagas untuk mendapatkan masa bagi mengasingkan tar daripada batu baur dengan menggunakan jenis campuran yang berbeza. Berdasarkan keputusan, dapat dinyatakan bahawa kandungan tar adalah nyata member kesan kepada luas permukaan batu baur apabila luas permukaan dipengaruhi oleh batu baur yang halus. Dari analisa, diperhatikan semua parameter adalah berkadar terus. Oleh itu, boleh di simpulkan bahawa kandungan tar, luas permukaan batu baur dan sifat-sifat tar mempengaruhi masa perahan.

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CHAPTER I

INTRODUCTION

1.1 Background

Asphalt has been used as a construction material from the earliest days of civilization. Though it has long been used as a waterproofing material in shipbuilding and hydraulics, its use in roadway construction is much more recent. A recent survey revealed a total of over 2.3 million miles of hard-surfaced asphalt or concrete roads in the United States, of which approximately 96% have asphalt surfaces (Roberts, 2002). In Malaysia, most of the road networks are asphalt surfaces that have expanded rapidly in line with pace of economic growth. There are about 80,000 km of asphalt surfaces in Malaysia. Asphalt mixture consists of asphalt, coarse and fine aggregate and a number of additives occasionally used to improve its engineering properties. The purpose of mixture design is to select optimum asphalt content for a desired aggregate structure to meet prescribed criteria. Hence, aggregate is an important constituent of asphalt concrete. The shape, angularity, and surface texture of aggregates affect the surface area of the coated aggregate that significantly influences mixture properties.

1.2 Problem Statement

New asphalt pavement roads tend to distress after only few years because of traffic loading even though they have been designed to last longer. These asphalt pavements can exhibit various distresses that will cause the pavement's failure such

as rutting, cracking, stripping, bleeding, and so on. Among of these distresses, permanent deformation (rutting) is one of the major distresses in hot mix asphalt (HMA) pavement. Repeated application of traffic loads causes structural damage to asphalt pavements in a form of rutting which occurs along the wheel track. Moreover, the surface area of coated aggregate has an important effect on the characteristic of HMA. If asphalt mixes that have high surface area and low optimum asphalt content are undesirable, these mixes will have a thin asphalt film on aggregate and will probably not have enough durability. As a result, HMA can encounter some distress by insufficient binding aggregate such as raveling, stripping and cracking. On the other hand, if the asphalt content is too high, bleeding and rutting will occur. Hence, the asphalt content must be carefully controlled during construction. This optimum content can be obtained by determing the relationship of time to extract bitumen content, the coated surface area of aggregate, and the bitumen content of different grading mixes, concentrating of several research efforts on the purpose of overcoming these pavement problems.

1.3 Aim and Objective

This aim of study was to search the relationship between the surface area of aggregate and bitumen content in order to find the coated surface area of aggregate to be correlative with the optimum bitumen content.

The objectives of this study were to establish;

(i) The relationship of bitumen content, aggregate surface area, and extraction time for different types of mixes, and

(ii) To determine the relationship between optimum bitumen content (OBC) and the aggregate surface area.

1.4 Scope of Study

Aggregate, bitumen, and filler were evaluated to satisfy the JKR specifications JKR/SPJ/rev2005. Then, Coating and Stripping of Bitumen-Aggregate Mixtures were tested based on (ASTM D1664-80). The flakiness and elongation index of aggregate were also carried out. Each sample of HMA mixes was prepared according to JKR specifications JKR/SPJ/rev2005 using Marshall Design and Ignition Furnace Procedures. Three types of mixes were ACW 14 (dense graded), PA (open graded), and SMA14 (gap graded). In designing the mixtures, total of 45 specimens (Marshall) and 45 specimens (Ignition Furnace) were prepared to determine the optimum bitumen content and time to remove the bitumen from aggregate. The tests were performed at Highway & Transportation Laboratory, UTM and UTHM.

1.5 Significance of Study

From the results of the study, the time to extract bitumen content, the optimum bitumen, and the coated surface area of different mixes with varied types of grading can be obtained. Then, the relationships between time to extract the bitumen and the coated surface area of aggregate for different types of mixes can be gained. Next, the relationship between time to extract the bitumen content from the coated surface area of aggregate and the bitumen content for different types of mixes was found in order to determine the coated surface area of aggregate to be correlative with the optimum bitumen content of the samples that meet the best performances by comparing with the values suggested according to the JKR specifications. As a result, the best hot mix asphalt, which can be gained, not only overcomes the problems such as rutting, bleeding, and stripping but also achieves the high economic and effective hot mix in pavement design.

REFERENCES

1. American Society for Testing and Materials (1992a). Method for Sieve *Analysis for Fine and Coarse Aggregate.* Philadelphia, ASTM C 136.

2. American Society for Testing and Materials (1992). Test Method for *Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing.* Philadelphia, ASTM C 117.

3. American Society for Testing and Materials (1992b). *Test Method for Specific Gravity and Absorption of Coarse Aggregate.* Philadelphia, ASTM C 127.

4. American Society for Testing and Materials (1992c). *Test Method for Specific Gravity and Absorption of Fine Aggregate.* Philadelphia, ASTM C 128.

5. American Society for Testing and Materials (1992d). *Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.* Philadelphia, ASTM D 2726.

6. American Society for Testing and Materials (1992e). *Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.* Philadelphia, ASTM D 2041.

7. American Society for Testing and Materials. (1992). *Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*. Philadelphia, ASTM D 1559.

8. American Society for Testing and Materials, ASTM (1994). *Annual Books of ASTM, Standards American Society for Testing and Materials*. Philadelphia.

9. American Society for Testing and Materials (2001a) *Concrete and Aggregates*, West Conshohocken, Pennsylvania: American Society for Testing and Materials.

10. American Society for Testing and Materials (2001b) *Road and Paving Materials; Vehicle – Pavement System*, West Conshohocken, Pennsylvania: American Society for Testing and Materials. West Conshohocken, Pennsylvania: American Society for Testing and Materials.

11. American Association of State Highway and Transportation Officials, AASHTO (1986*). Standard Specifications for Transportation Materials and Methods of Sampling and Testing*. Washington, DC, Ed. 20.

12. Asphalt Institute (1988). *Principles of Construction of Hot-Mix Asphalt Pavement.* United States of America: Asphalt Institute.

13. Asphalt Institute (1983). *Principles of Construction Of Hot-Mix Asphalt Pavements.* MS-22. Kentucky: Asphalt Institute.

14. Asphalt Institute (1989). *The Asphalt Handbook.* MS-4. Kentucky: Asphalt Institute.

15. Atkins, H. N. (2003). *Highway Materials, Soils and Concretes.* Fourth Edition. Upper Saddle River, New Jersey: Prentice Hall.

16. Aggregate Evaluation Project, (2008). Faculty of Civil Engineering - Universiti Teknologi Malaysia.

17. Brown, E.R., and Brandau, L.S. (2000). *Hot Mix Asphalt Paving Handbook 2000,* US Army Corps of Engineers.

18. British Standard Institution, BS: 812. (1975). *Method for Sampling and Testing of Mineral aggregate, Sand, and Filler*. London, UK.

19. Brown, E.R., and Acott, M. *Asphalt Content Determination by NCAT Test Method.* National Asphalt Pavement Association (NAPA), NAPA Research and Education Foundation.

20. Compaction America (2000). *Hot Mix Asphalt Fundamental,* Compaction America, Inc.

21. Coree, B. J. (1998). *HMA Volumetrics Revisited – A New Paradigm,* Center for Transportation Research and Education.

22. Chadbourn, et. al (2000). *The Effect of Voids in Mineral Aggregate (VMA) on Hot-Mix Asphalt Pavements*, Final report prepared for Minnesota Department of Transportation.

23. Fwa, T.F. (2006*). The Hand Book of Highway Engineering*. Taylor & Francis. New York.

24. Garber, N. J. and Hoel, L. A. (2002). *Traffic and Highway Engineering.* Third Edition. United States of America: Brooks/Cole.

25. *Guide to the Selection of Bituminous Surfacing for Pavements* (1985). National Association of Australia State Road Authorities.

26. Hunter, R. N. ed (2000). *Aphalts in Road Construction.* London: Thomas Telford Services Ltd.

27. Hwee, L.B and Guwe (2005), V. *Performance-Related Evaluation of Porous Asphalt Mix Design.* Hanson Building Materials Malaysia & Singapore.

28. HMA Pavement Mix Type Selection Guide (2001). National Asphalt Pavement Association (NAPA), NAPA Research and Education Foundation

29. Hot Mix Asphalt (HMA) Technician Training Manual, FHWA Multi-Regional Asphalt Training & Certification Group (1999). *Method for Determination of the Asphalt Binder Content of Hot Mix Asphalt (HMA) By the Ignition Method.* AASHTO TP 53.

30. Hunter, R. N. ed (1994). *Bituminous Mixtures In Road Construction.* London: Thomas Telford Services Ltd.

31. Jabatan Kerja Raya (JKR) (2005). Standard Specifications for Road Works. Kuala Lumpur, Malaysia, JKR/SPJ/rev2005.

32. Kandhal, P. S., Foo, K. Y., and Mallick, R. B. (1998). A Critical Review of VMA Requirements in Superpave. *NCAT Report No. 98-1*, National Center for Asphalt Technology, Auburn, Alabama.

33. Kandhal, P.S. and Mallick, R.B (1998), "Open-graded friction course: State of the Practice", Transportation Research Circular Number E-C005, Transportation Research Board, National Research Council, Washington, D.C.

34. Khalid, H. and Perezz Jimenez, F.K. (1996), "Performance Assessment of Spanish and British Porous Asphalts", Proceedings for Performance and Durability of Bituminous Materials, 1996.

35. Lavin, P. (2003). *Asphalt Pavements: A Practical Guide to Design, Production, and Maintenance for Engineers and Architects.* London: Spon Pess.

36. Lab Manual, (2004). *Determination of the Asphalt Binder Content of Hot Mix Asphalt (HMA) By the Ignition Method.* AASHTO Designation T308, Test method A (MN/DOT Modified).

37. Molenaar, A.A.A (2007). *Permanent Deformation of Asphalt Mixtures.* Road and Railway Engineering, Faculty of Civil Engineering and Geosciences Delft University of Technology.

38. Mathew, B.S., Bhuduru, S., and Isaac, K.P. (2006). *Influence of Flaky and Elongated Aggregates on the Properties of Bituminous Concrete Mix*. Department of Civil Engineering, College of Engineering, Thiruvananthapuram.

39. Mulder, E.A., (1993) "Porous Asphalt", Proceedings of Flexible Pavement Seminar, Penang.

40. Roberts, F. L., Kandhal, P. S., Brown, E. R., Lee, D. Y., Kennedy, T. W. (1996). *Hot Mix Asphalt Material, Mixture Design, and Construction*. 2nd Edition. Maryland: NAPA Research and Education Foundation.

41. Roberts, F. L., Mohammad, L. N. and Wang, L. B. (2002). "History of hot mix asphalt mixture design in the United States", *Journal of Materials in Civil Engineering*, ASCE, pp. 279-293.

42. *Stone Mastic Asphalt Surfacing, Asphalt Guide, (2002).* The Australian Asphalt Pavement Association.

43. Wallace, H.A., and Martin, J.R.(1967). Asphalt Pavement Engineering, Mc Graw Hill, United States of America.