Available online at www.sciencedirect.com
ScienceDirect
Construction and Building Materials 22 (2008) 1143–1147
Construction and Building MATERIALS
www.elsevier.com/locate/conbuildmat

Compactibility of hot bituminous mixtures made with crumb rubber-modified binders

Osman Nuri Çelik [a,*], Cengiz Duran Atiş [b]

[a] Engineering and Architecture Faculty, Civil Engineering Department, Selçuk University, 42031, Selcuklu/Konya, Turkey
[b] Faculty of Engineering and Architecture, Department of Civil and Mining Engineering, Çukurova University, 01330, Balcali/Adana, Turkey

Received 21 March 2006; received in revised form 16 February 2007; accepted 22 February 2007
Available online 16 April 2007

Abstract

Badly compacted mixtures will develop undesirable properties of low stiffness, bad fatigue resistance, bad durability, etc. that is not expected from a good pavement. This paper is to evaluate the compactibility of hot asphalt mixtures (HAM) made with crump rubber modified bitumen, which was manufactured by incorporating the waste shredded-tire rubber particles in base bitumen in different sizes and concentration. Type of binder and binder viscosity during compaction has a great effect on the compactibility of HAM. Compaction Coefficient (CC), which is variation in porosity line throughout compaction, could be related with the energy needed to compact the mixture. Less energy is needed for the mixture having low CC. Modification of bitumen with rubber makes the mixture less compactable when compared with the mixtures made without rubber.

Keywords: Compactibility; Workability; Rubber-modified binders; Hot asphalt mixtures

1. Introduction

It is rather difficult to quantify the workability of asphalt mixture and it is influenced by many factors, including aggregate type (shape, size and texture), aggregate gradation, binder grade, binder content, mixing and compaction temperature. Workability of asphalt mixtures can be related with the compactibility of mixtures. Compactable mixtures were assumed more workable. Leeds workability method [1] is based on experimental relations between compaction energy and mixtures porosity. Porosity of asphalt mixtures [2] is also one of the main approaches in determining the optimum binder content and it affects the durability of the mixtures.

The workability of asphalt mixture is defined as the property, which allows producing, handling, placing, compacting a mixture with minimum application of energy. It is an important practical requirement that asphalt mixtures are tolerant to a wide variation of laying conditions and that in relatively adverse conditions. They will still spread easily and compact sufficiently well to give a durable surfacing. Too harsh a mix may cause it to tear under the screed of the spreading machine and render compaction more difficult. Badly compacted mixtures will develop undesirable properties of low stiffness, bad fatigue resistance, bad durability, etc. that is not expected from a good surfacing.

Workability of fresh concrete, on the other hand, is defined as the fluidity, mobility and compactibility of the cement, water and aggregate mixture [3,4].

The only workability-meter for asphalt mixture developed by Marvillet and Bougault [5] consist of a chamber connected to a rigid frame, into which the test introduced, and a speed controller, which drives a blade in the mix. They measured the torque required for mixing and proposed the reciprocal of the resistance moment produced in the mix against the rotation of the blade as the mixture workability.

* Corresponding author. Tel.: +332 2232017; fax: +332 2410635.
E-mail addresses: oncelik@selcuk.edu.tr (O.N. Çelik), cengiz@cukurova.edu.tr (C.D. Atiş).

0950-0618/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2007.02.005

A recent work conducted on workability of hot mix asphalt [6] shown that workability measurement is an important subject. This research also suggests a device to measure the workability.

The purpose of this investigation is to show the compactibility determination of rubberized mixtures using by Gyratory Testing Machine (GTM). The values derived during the compaction process i.e. compaction coefficient (CC) and workability index (WI) can be used to determine the mixture behaviour before and during compaction.

2. Materials

In this investigation binder used was 50 and 100 penetration grade base bitumen in the control mixtures. Properties of the base bitumen used in this experiment are given in Table 1.

Different sizes of shredded-tire rubber particles were incorporated in the base bitumen to assess the compactibility and to improve the properties of the mixtures. The rubber concentrations were selected between 2% and 20% in bitumen by weight. Tables 2 and 3 show the gradations and specific gravities of the rubber particles, respectively.

An adjustable speed vertical shaft mixer was used to mix the rubber and bitumen. The mixing speed used was 200 rpm. Mixing temperature and mixing time have an important effect on the properties of rubber-bitumen blends [7]. A preliminary work carried out in the laboratory showed that the mixing temperature should be approximately 160 °C [8] and mixing time used was half an hour. The temperature used in this work resembles to the work done with EVA polymer modified bitumen [9]. Rheological properties of the rubber bitumen blends used in this investigation can be found in the related references [8,10,11].

Table 1
Standard test results conducted on base bitumen

Binder type	Penetration at 25 °C (0.1 mm)	Softening point (°C)	Penetration index
100 pen. base	99	42	−0.4
50 pen. base	48	53	−1.8

Table 2
Rubbers' gradation

Sieve size (mm)	Passing (%)			
	3's mesh	12's mesh	12/16's mesh	40's mesh
3.35	100.00	100.00	100.00	100.00
2.36	96.22	100.00	100.00	100.00
1.18	14.62	78.74	99.87	100.00
0.6	0.74	2.52	48.86	99.83
0.075	0.00	0.00	0.00	0.00

Table 3
Rubbers' specific gravity

Rubber type	Rubber specific gravity (g/cm^3) (By Helium pycnometer)
3's mesh (3)	1.153
12/16's mesh (26)	1.156
12's mesh (12)	1.168
40's mesh (40)	1.198

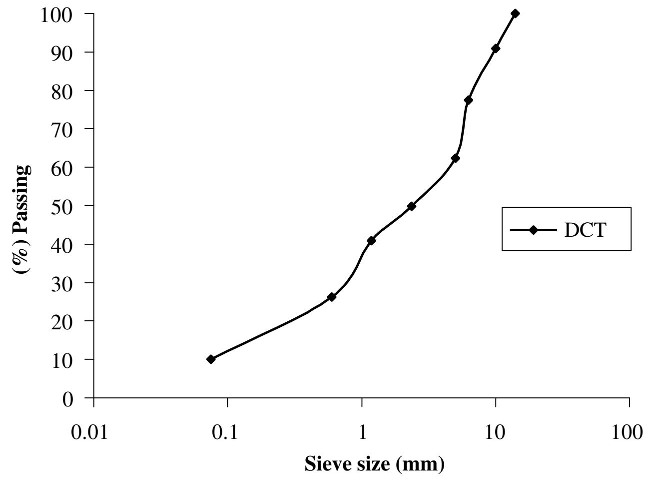

Fig. 1. Aggregate gradation investigated.

The aggregate gradation selected was the optimal aggregate gradation obtained by experimental dry compaction test (DCT) [8]. The gradation curve is given in Fig. 1. The aggregate used in the investigation are typical crushed limestone which was supplied by Tilcon Ltd. from Skipton Quarry in West Yorkshire, UK. The apparent relative densities of the aggregates are obtained as described in British Standards [12] and the specific gravity values are obtained from the helium pycnometer.

3. Testing procedure and mixing conditions

The aggregate, filler and binder are heated at 150 °C (±5), and mixed in a heat-controlled mixer. Mixing is completed in 1 min, the compaction temperature used was 130 °C (±5).

The standard 63.5 mm × 101.6 mm ø specimens were compacted using GTM to determine the compactibility of the mixtures. The GTM is equipped with a dial gauge to continually monitor the changes in specimen height as it is being compacted. The GTM parameters were:

Angle of gyration	1°
Axial load	0.7 MPa
Number of revolution under load	30

These conditions were found to be equivalent to the energy used in the standard compaction using the Marshall hammer (50 blows) [1].