Construction and Building Materials 121 (2016) 265–277

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Density profile of hot mix asphalt layer during compaction with various types of rollers and lift thickness

Mohd Rosli Hainin [a,*], Ebenezer Akin Oluwasola [b], E. Ray Brown [c]

[a] Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
[b] Department of Civil Engineering, Federal Polytechnic, Ede, Osun State, Nigeria
[c] National Centre for Asphalt Technology, Auburn University, Auburn, AL 36849, United States

HIGHLIGHTS

- We investigate density profile of hot mix asphalt layer during compaction.
- The higher the mix temperature the better density could be attained.
- The optimum t/NMAS for best compactibility is between 3.0 and 5.0.

ARTICLE INFO

Article history:
Received 1 December 2015
Received in revised form 12 May 2016
Accepted 22 May 2016
Available online 5 June 2016

Keywords:
Lift-thickness
Roller
Cooling rate
Compactibility
Hot-mix asphalt

ABSTRACT

The effects of different compactors and lift thickness on hot mix asphalt (HMA) have been persistently discussed among asphalt experts. In many cases, pavements paved with the high-in-place air voids permit water to penetrate the permeable pavement causing an increased tendency for pavement deformation. The thin lifts have had problems achieving high density, which leads to high-in-place air voids. The present paper is aimed at evaluating the effects of different compactors, an 11-ton steel drum compactor and a 15-ton pneumatic tyre roller, on the HMA mat with different ratios of thickness to nominal maximum aggregate size (t/NMAS). In order to achieve this aim, seven field sections with a total 36 locations with distinct HMA mixes, thicknesses and rolling patterns were built. Each of the sections was approximately 40 m long and 3.5 m wide. The section was constructed with t/NMAS ratio varying from 2.0 at the beginning to 5.0 at the end of the section. The air temperature during construction varied from 26 °C to 35 °C. More so, for comparison purposes, the simulated HMA mat temperatures using MultiCool 3.0 software and their respective measured temperature were also taken. The results indicate that the optimum number of passes to achieve maximum density is four passes. This could be achieved by merely using the steel roller with vibratory mode. However, the introduction of rubber tyre roller during the intermediate rolling initially reduced the density by one to two percent but started to increase after several passes.

1. Introduction

Compaction can be described as application of the external forces to reduce the volume of air in an HMA mixture. The removal of air increases the unit weight or density of the mix, which enables the mix to occupy a smaller space [28,4]. Proper compaction of HMA mixtures is one of the important parameters required in building stable and durable pavement. Inadequate compaction generally results in high-in-place air voids which allow the passage of air and water into the permeable pavement; endangering the strength of the pavement [16,19,27,22,7].

The effect of material behaviors on compaction level is highly significant. Also, the level of compaction is influenced by the shape, granular distribution, and surface texture of the aggregates, all of which affect both the ease of compaction and the distribution of voids [10,8]. In addition to this, the grade of the asphalt and the binder content, which affect binder viscosity at hot temperatures, are also sensitive to the compaction level [14,30]. Another important factor that influences compaction level is the construction practices, in terms of the compaction temperature, compaction power, type of compactor and compaction time [12,20,5,3].

The compactors are used to provide the compaction energy required to sufficiently reduce the volume of freshly laid HMA to produce the specified density [15,25,23]. The compaction train generally consists of two or more rollers, both of which aim to

* Corresponding author.
E-mail address: mrosli@utm.my (M.R. Hainin).

http://dx.doi.org/10.1016/j.conbuildmat.2016.05.129
0950-0618/

achieve the specified density requirements, and to provide a smooth surface (Hainin et al., 2013 [15,24]. These two objectives are accomplished through the use of breakdown and intermediate (or transitional) rollers to achieve the desired density, and via a finish roller to remove roller marks.

Meanwhile, some factors that affect the compactibility of mixtures in the field and the ultimate density that is obtained include: HMA temperature at lay down, layer thickness/nominal maximum aggregate size, temperature and firmness of the layer on which HMA is being placed, air temperature, wind velocity and humidity, and solar radiation levels [10,18,1,13,2]. Most of these factors directly affect the cooling rate of the HMA mat and the length of time the material stays hot enough to be compacted [26,11,17].

Another major factor affecting compaction is lift thickness. Although, there have been many studies on the effect of thickness on compactibility of HMA mixtures [13,9,29,6,21,13], no documented research has been performed to systematically determine the appropriate minimum thickness of a given HMA lift. The Superpave Construction Guidelines [31] propose a minimum thickness of nominal maximum aggregate size (t/NMAS) ratio of at least 3.0 but no background as to how this value was selected is given. Some other organizations have proposed a minimum t/NMAS of 4.0. Recent research studies have provided a guide to select a minimum thickness for a specific mix type. The recommended minimum t/NMAS ranges from 2.6 to 3.4. However, these recommendations and guidelines for minimum thickness were obtained from private organizations, state agencies, and from individual experts. No specific research study was performed to develop these guidelines. Thus, there is a need to evaluate the minimum thickness of HMA mixes through field experiments.

Thus, this paper aims to investigate the compaction behavior and characteristics of HMA at various t/NMAS values through field experiment. The effect of different types of rollers on the HMA mat was is also evaluated. The simulated temperature and the measured temperature are also assessed. The former is obtained through a computer program, MultiCool 3.0, which measures the degree of cooling in an asphalt mix while compaction is taking place. This step will assist in the evaluation of the characteristics of hot HMA subjected to different compactors.

2. Experimental program

The methodology chart for the field study is display in Fig. 1. The NCAT Test track at Auburn, USA given the chance to construct sections (off the track) with different thickness from one segment of individual section to another is reconstructed. Seven mixes made up of different NMASs, mix types, and gradations were selected. Fig. 2 shows the gradations used in the section and Table 1 presents the volumetric properties for the section. The 19.00 mm NMAS CG used PG 76-22 binder while the other19.00 mm NMAS CG and the remaining five mixes used PG 64-22 binder. The study was performed in the course of the preliminary mixing stage. Each section was constructed to different t/NMAS ratios varying from nearly 2.0–5.0. Each section was approximately 40 m long and 3.5 m wide. In order to do the investigation, ambient temperature, existing surface temperature, cloudiness and wind speed were taken as surrounding parameters. Humidity was not considered because from previous study it has been found that humidity has very less influence on density. For the temperature measurements, three locations were selected because the degree of cooling of the asphalt mix differed from each segment of the section as a result of change in thickness. The three locations were selected such that one was close to the beginning of the section, one was close to the middle and the other was close to the end. This was affected to ascertain that the asphalt mix was compacted in a period of the available compaction time. Two thermoelectric devices for measuring temperature instantly were positioned at each location in the mat after the paving process as illustrated in Fig. 3. An infrared temperature gun was used to obtain the surface temperature. Thereafter, the three temperature readings were obtained and the average was recorded as the temperature of the mat at that location. At every one to five minutes and after every roller pass, temperature readings were obtained. The weather conditions as well as base and air temperatures were also monitored and recorded.

Regardless of the t/NMAS ratio, consistent and reasonable compactive force was applied throughout the section. One segment of the mat incorporated only an 11-ton steel drum compactor and the other segment utilized a 15-ton pneumatic tyre roller as a transition roller in order to predict the actual rolling patterns used in real field constructions. The steel drum roller worked in both static and vibratory modes. A high frequency and amplitude of the vibratory roller was used for 19.0 NMAS mixes and a low frequency and amplitude for 12.5 mm and 9.5 mm NMAS mixes. A Pavement Quality Indicator (PQI), which is a non-destructive density gauge, was used in monitoring the density after individual passage of the rollers through the points where temperature readings were obtained. This was carried out to ensure that the compacted mat

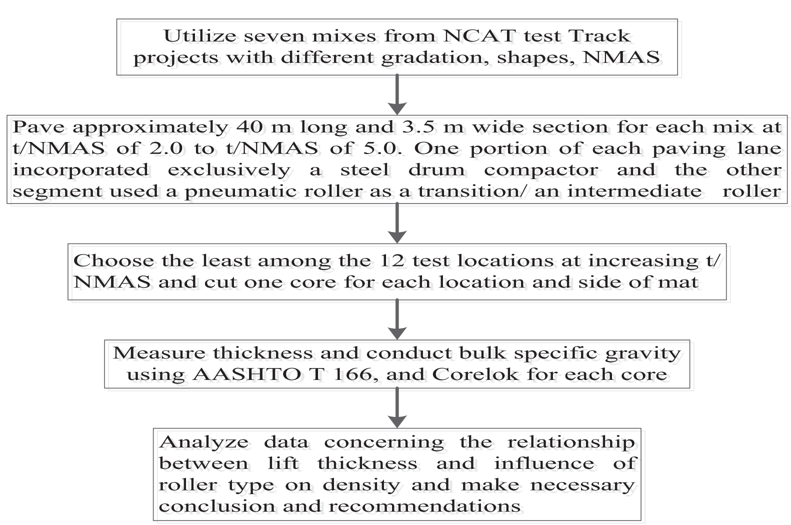

Fig. 1. Experimental plan for the study.