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Quality verification of polymer-modified asphalt binder used in hot-mix asphalt pavement construction

Yuhong Wang [a,*], Dan Chong [b], Yong Wen [a]

[a] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[b] Department of Management Science and Engineering, Shanghai University, Shanghai 200444, China

HIGHLIGHTS

- IDT strength surpasses ITSM in testing asphalt quality difference in cored samples.
- Rolling-thin film oven does not well simulate the short-term aging of PMA.
- Phase angle surpasses complex shear modulus in testing quality difference of PMA.
- The ratio of FTIR peak area surpasses the ratio of peak value in testing PMA quality.
- FTIR with phase angle of extracted PMA offers a promising quality control method.

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ABSTRACT

In many regions and countries, highway agencies are interested in verifying the quality of asphalt binders placed on roads for quality assurance purpose. Particularly, as PG-graded, polymer modified asphalt (PMA) is increasingly used, the agencies are interested in examining if the specified PMA is fully used in the field or if the PMA has not been severely degraded after storage, handling, and plant production. This research investigated and compared various test methods for such purpose. Besides laboratory-prepared asphalt binder samples, actual pavements built with neat asphalt (pen 60/70), 30% of neat asphalt with 70% of PG76-16 PMA, 15% of neat asphalt with 85% of PMA, and 100% of PMA were used for study. The mixture production and construction processes were carefully planned and monitored to ensure that they are consistent with real construction operations. Test methods evaluated in this study include indirect tensile (IDT) strength and indirect tensile stiffness modulus (ITSM) of field cores, rheological parameters (G^*, δ, temperatures at which $G^*/\sin\delta = 2.2$ kPa) from dynamic shear rheological tests of binders, Gel Permeation Chromatography (GPC) and Fourier Transform Infrared Spectroscopy (FTIR). The study found that samples made of different proportions of PMA can be effectively differentiated by IDT strength, phase angle (δ), and FTIR spectrum. Even the FTIR spectra of extracted asphalt binders without being subject to strict binder extraction and evaporation procedure reveal useful information for quality assurance purpose. The study also further proved that RTFO-treated PMA samples cannot be used to establish quality criteria for field-extracted PMA binders because RTFO does not well simulate field aging of PMA.

1. Introduction

Quality of built pavement depends on "all those planned and systematic actions [1]" to ensure quality. Quality assurance, therefore, should cover all the stages in the life-cycle of pavement and involve all the quality-related activities by agencies, contractors, and consultants [1]. One of the fundamental factors that decide the quality of asphalt pavement is the quality of asphalt binder. In recent decades, polymer modification has been increasingly used around the world to improve asphalt pavement's high temperature performance [2–4] without degrading its low temperature performance. Polymer modified asphalt (PMA), however, is more expensive than neat asphalt binder: It may increase binder cost from 30% to 100% [5,6]. In addition, PMA may become unstable when being stored at high temperature for a prolonged period of time [7–10] and may be subjected to degradation in mixture production, transportation, and construction [11].

* Corresponding author.
E-mail addresses: ceyhwang@polyu.edu.hk (Y. Wang), chongdan@shu.edu.cn (D. Chong), yong.wen@connect.polyu.hk (Y. Wen).

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To ensure asphalt binder quality, standard procedures such as those specified in the AASHTO standard M320 have been routinely used by agencies to check the Superpave™ performance grading (PG) of asphalt binder. In addition, various Superpave™ plus specifications have been made to specifically test PMA in addition to the test procedures in AASHTO standard M320 [12]. However, for most agencies, asphalt binder tests are limited to binder samples provided by suppliers (or retrieved by agencies themselves) before mixture production [13]. It is assumed that the specified binder type will not be changed or blended with low-quality binder during mixture production, nor be severely degraded by improper production conditions. From the perspective of quality assurance, this assumption may not be always safe [14], particularly considering the possibly large price difference between PMA and neat asphalt binder. In addition, quality loss due to improper binder storage and mixture production cannot be adequately assessed. This creates a concern in the quality assurance procedure of asphalt pavement.

One of the approaches to improving binder quality assurance program is to expand asphalt binder sampling locations [13]. It is recommended in Texas that sampling locations such as the storage tank of contractor site, transfer line from storage tank to hot-mix asphalt (HMA) plant, spray bar of asphalt emulsion distributor truck may be considered [13]. This practice, however, would require full knowledge of HMA production and construction schedules. Any change in production and construction will disrupt the sampling plan and create a logistic difficulty for agencies. Another approach, as adopted by a number of European countries, is to extract and recover PMA from cored field samples and conduct verification tests on the extracted binder [14]. Germany and several other countries legally require that the extracted PMA to be tested for softening point and elastic recovery after being recovered from rotary evaporation extraction [14]. These two test methods, however, demand a relatively large quantity of recovered asphalt binder. The binder extraction and recovery process using a rotary evaporator is both time consuming and expensive. Questions have also been raised on the accuracy of using these two methods to verify binder type [14]. Therefore, more efficient and reliable methods to verify the type and quality of asphalt binder actually placed in the field are highly interested by many highway agencies worldwide.

The overall goal of this study is to evaluate test methods that can be potentially used to forensically verify the type and quality of PMA used in asphalt mixture production. Particularly interested are methods to differentiate PG-graded PMA with neat non-modified asphalt binder, binder artificially created by blending a portion of PMA with neat asphalt, or binder that is subjected to severe polymer degradation due to material storage and handling issues. The reliability, costs, and amount of efforts of the potential test methods are also part of the consideration. The detailed objectives include:

- To compare change in the asphalt mixture properties of a same mixture design using PG-graded PMA blended with different proportions of neat asphalt binder;
- To compare change in the dynamic shear properties of PG-graded PMA blended with different proportions of neat asphalt binder;
- To compare change in the chemical indicator characteristics of PG-graded PMA blended with different proportions of neat asphalt binder;
- To assess different test methods and recommend a feasible procedure to evaluate the quality of PMA in as-constructed asphalt mixtures.

This research is expected to have practical values for highway agencies who are interested in verifying the specified quality and/or the sufficiency of polymer content in PMA used in asphalt pavement construction.

2. Research methods

Styrene-Butadiene-Styrene (SBS) modified PG76-16 (PG 76 hereafter) PMA and pen 60/70 neat asphalt binder are used in this tudy. Both binders are commonly used in Hong Kong (HK), where this study was conducted. The PG grade of the pen 60/70 binder is PG 64-10 according to the Superpave™ grading system. The overall research methods and procedures are shown in Fig. 1 and discussed in details as follows.

2.1. Sample preparation

2.1.1. Asphalt binder samples prepared in the laboratory

Both asphalt binder and mixture tests were conducted and compared in this research. Besides 100% PG 76 and pen 60/70 binder, special binders were created in laboratory by blending these two binders at 165 °C into the following proportions: 70% PG 76

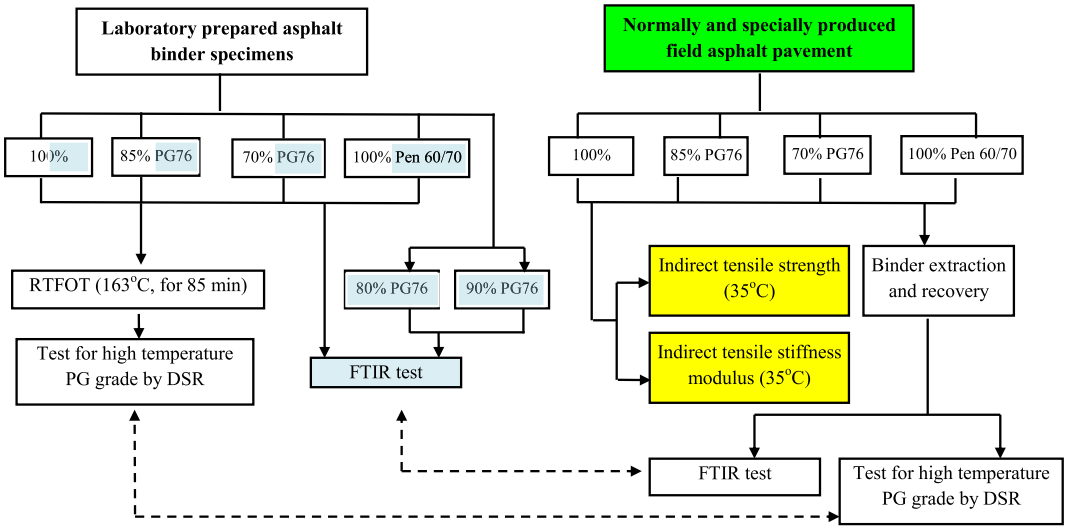

Fig. 1. The analytic method of this study.