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Laboratory investigation of the performances of cement and fly ash modified asphalt concrete mixtures

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Abstract

The influence of filler materials on volumetric and mechanical performances of asphalt concrete was investigated in this study. The AC60/70 asphalt binder incorporating with cement and fly ash as filler materials was mixed with limestone following the Marshall mix design method. The filler contents of cement and/or fly ash were varied. The non-filler asphalt concrete mixtures of the AC60/70 and the polymer modified asphalt were prepared for the purpose of comparison. The investigation programme includes the indirect tensile test, the resilient modulus test and the dynamic creep test. The tests are conducted under the humid temperate environments. All tests were then carried out under standard temperature (25 °C) and high temperature (55 °C) by using a controlled temperature chamber via the universal testing machine. The wet-conditioned samples were prepared to investigate the moisture susceptibility. Results show that cement and/or fly ash were beneficial in terms of improved strength, stiffness and stripping resistance of asphalt mixture. In addition, the combined use of cement and fly ash can enhance rutting resistance at wet and high temperature conditions. The results indicate that the strength, stiffness and moisture susceptibility performances of the asphalt concrete mixtures improved by filler are comparable to the performance of the polymer modified asphalt mixture.

Keywords: Asphalt concrete; Filler; Resilient modulus; Dynamic creep test; Moisture susceptibility

1. Introduction

Materials broadly employed to construct the surface layer of flexible pavement is an asphalt concrete, which is the composite material mixed from aggregates and asphalt binder. While the aggregates conduce resistance to support traffic loads, the asphalt binder contributes viscous-elastic behaviour to help with the adhesion of aggregate particles. The practicable size range of aggregate is from 50 mm to 0.075 mm. From this range the fine aggregates are defined to be smaller than 4.75 mm and the coarse aggregates are bigger than 4.75 mm. Even though particle size of the filler is less than 0.075 mm, it is well-known that the filler plays an important role in providing better packing conditions between the coarse and fine aggregates. It also leads to the greater stability within asphalt concrete and the reduction of optimum asphalt content.

Filler is categorised as a fine material which can be used to modify the properties of asphalt binder and asphalt concrete mixture. To this point, Portland cement, hydrated lime, fly ash, limestone dust, and clay particles are counted as fillers. The filler is not considered as a part of the aggregates. It is a modifier to improve the temperature susceptibility and durability of the asphalt binder as well as the asphalt concrete mixture [1]. The moisture susceptibility

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can be reduced by using the mineral fillers, for instance, hydrated lime [2,3]. In addition to utilisation of mineral fillers, the strength and stiffness of asphalt concrete can be increased [4]. The purpose of studying the characteristics of mineral filler is to enhance the performance of asphalt concrete in particular to increase the stability and durability against rutting and shoving. Lesueur et al. [3] presented that the durability of asphalt concrete mixtures can be increased by 2–10 years when the 1–1.5% of hydrated lime is used in the mixture. It is also found that Portland cement utilised as the filler can improve the anti-stripping properties of asphaltic concrete [5,6]. Additionally, the significant improvement on the moisture resistance characteristics can be observed when fly ash is employed to replace the cement and hydrated lime in producing asphalt concrete mixtures [7,8].

The key factors separating the fillers are particle shape and size, void content, surface area, mineral, chemical properties, and other physical properties [9]. By this reason different kinds of fillers replaced in the asphalt mixture lead to various asphalt mixture performances. This research aims to study the influence of filler types and fractions on the asphalt concrete mixture's properties. The materials selected to be the filler for this study are cement and fly ash. The contents of cement, fly ash and their combination were varied in the mixtures. The performance characteristics of the asphalt concrete mixture containing different types and fractions of filler were evaluated by various laboratory tests. The tests are conducted under the humid temperate environments of Thailand. To reach the standard test requirement, a minimum of three specimens was evaluated in each test.

2. Materials and testing programme

2.1. Materials

Most pavements in Thailand are constructed using asphalt mixes, consisting of AC60/70 penetration grade asphalt cement and aggregates. Mineral fillers such as limestone dust and cement are used to enhance the stability and durability of the asphalt concrete mixture. There is still no specification of filler material approved by the Thailand's Department of Highways (DOH). In the study, a local asphalt mix design based on the standard of the DOH commonly used in a flexible paving project was employed. In order to compare the performance of filler mixtures, the typical hot mix asphalt (HMA) without fillers and the polymer modified asphalt (PMA) mixtures were also prepared. Therefore, the locally-produced AC60/70 asphalt binder and the polymer modified asphalt were chosen in this study. The limestone aggregate used in the lab mixes was also obtained from an approved paving project. The aggregate particles were sieved according to the required size ranges in preparation to blend the considered asphalt mix with the approved gradation as shown in Fig. 1. Basic properties of aggregate were tested and summarised in Table 1. The two main variables in the specimens are the type and content of the filler. The filler used in this research are Portland cement type I and fly ash class C. The Portland cement type I is a common construction material locally made and consumed in the country. The fly ash is a by-product of lignite-fired power generation from the Mae Moh Power Plant in Lampang province. The chemical component and physical properties of cement and fly ash are summarised in Tables 2 and 3, respectively. The results of scanning electron micrograph of cement and fly ash are presented in Fig. 2.

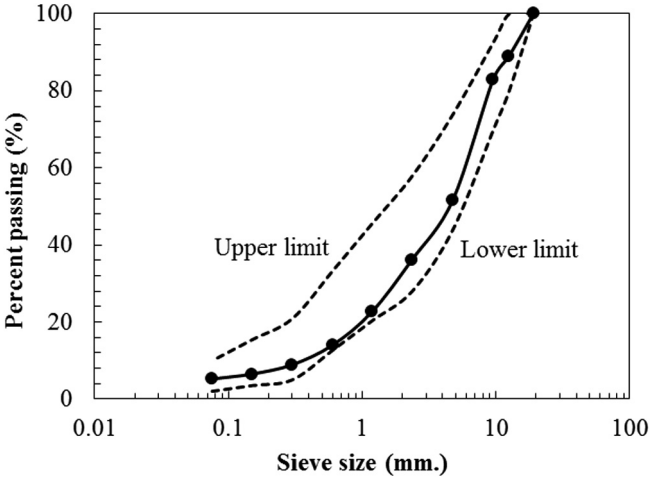

Fig. 1. Grain size distribution of aggregate.

Table 1
Properties of aggregate.

Aggregate type	Limestone
Bulk specific gravity	2.70
Flakiness index (%)	33
Asphalt absorption (%)	0.25
LA abrasion value (%)	
Aggregate 3/4″	22.70
Soundness (%)	
Weight loss aggregate 3/4″	1.0
Fine aggregate	3.2
Sand equivalent	64

Table 2
Chemical composition of materials from X-ray fluorescence (XRF) test (after Ref. [10]).

Chemical composition (%)	Portland cement	Fly ash
SiO_2	20.90	30.90
Al_2O_3	4.76	17.60
Fe_2O_3	3.41	14.80
CaO	65.41	23.24
MgO	1.25	2.12
SO_3	2.71	3.87
Na_2O	0.24	1.50
K_2O	0.35	2.73
LOI	0.96	1.20