Construction and Building Materials 179 (2018) 566–575

Contents lists available at ScienceDirect

Construction and Building Materials

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

Impact analysis of Carboxyl Latex on the performance of semi-flexible pavement using warm-mix technology

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HIGHLIGHTS

- The appropriate proportion of Carboxyl Latex added is determined.
- The open-graded asphalt mixture matrix with varied air void contents is prepared based on the warm-mix technology.
- The influence of Carboxyl Latex added on the performances of semi-flexible pavement material is evaluated.

ARTICLE INFO

Article history:
Received 6 September 2017
Received in revised form 18 May 2018
Accepted 22 May 2018
Available online 2 June 2018

Keywords:
Semi-flexible pavement
Cement mortar
Carboxyl Latex
Warm mixed open-graded asphalt mixture matrix
Pavement performance

ABSTRACT

In order to improve the performance of semi-flexible pavement material, Carboxyl Latex is tried to be added into cement mortar as additives, in this study. Then, the degree of cement mortar performance improvement is evaluated, and the appropriate proportion of Carboxyl Latex added is determined. The improved cement mortar performance evaluation indicators used include fluidity, compressive strength, flexural strength, and drying shrinkage. Then the influence of the Carboxyl Latex on semi-flexible pavement material performance (high-temperature rutting, low temperature crack, water damage and fatigue) with warm mixed open-graded asphalt mixture matrix of varied air void contents is tested. Study results show that the addition of Carboxyl Latex reduces the rutting depth of pavement material by 30% or more, increases the dynamic stability by more than 40% and the strain energy density to 1.6 times, and the freeze–thaw splitting tensile strength is also increase by over 93%. Furthermore, the value of K increases by more than 6%, and the n value decreases by 12% or more, in where, the two parameters, K and n, represent the fatigue resistance of semi-flexible pavement material that can be obtained from the regression equation of loading numbers vs. stress levels of fatigue test. The larger K value or the smaller n, the better the fatigue resistance. Overall, after adding the Carboxyl Latex into cement mortar, the high-temperature rutting resistance, low-temperature crack resistance, water damage resistance, and fatigue resistance of semi-flexible pavement materials have been significantly enhanced.

1. Introduction

Semi-flexible pavement is a pavement combining both of flexibility and rigidity, which asphalt pavement and cement concrete pavement have respectively. The characteristics of the semi-flexible pavement are brought by filling the air voids of more than 20% of the open-graded asphalt pavement by special cement mortar. That cement mortar can enhance stiffness or rutting resistance, load bearing ability, oil resistance, and heat resistance of the asphalt pavement [1–4].

As a part of semi-flexible pavement material, cement mortar is able to interlock with the asphalt mixture matrix to form strength and then enhance the performance of the pavement. Furthermore, the type and dosage of additive will also affect the performance of cement mortar and semi-flexible pavement material, and influence the performance of pavement in varying degrees [5–7].

Some achievements of cement mortar additives used in semi-flexible pavement material have been obtained. Pei et al. [8] studied the design and performance validation of high-performance cement mortar, and explored different impacts on the cement mortar fluidity and strength caused by a water-reducer (TH-928 polycarboxylic acid type), an UEA expansion agent, and a ZY-99 saponin air-entraining agent. Hu et al. [9]

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https://doi.org/10.1016/j.conbuildmat.2018.05.173
0950-0618/

studied the influences of the polycarboxyl acid water reducer and expansion agent on the performance of the cement mortar. Cai [10] investigated effect of mineral admixture on loss of water and dry shrinkage performance of mortar. The effects of the penetrating and water reducing agents and SBR latex on cement mortar of semi-flexible pavements and the blending ratio were studied by Fang et al. [11]. Huang et al. [12] prepared the emulsified asphalt cement mortar by mixing emulsified asphalt into cement mortar, and then studied the crack resistance of semi-flexible pavements based on the asphalt mortar.

Carboxyl Latex has many good characteristics as the cement mortar additive, such as the adhesion strength and impermeability. In this study, Carboxyl Latex is selected as the cement mortar additive to improve the property of shrinkage of cement mortar so that the shrinkage stress level within the semi-flexible pavement material can be reduced and the shrinkage cracking can be prevented. In this study, a series of effects from Carboxyl Latex on the performance of the semi-flexible pavement material will also be evaluated.

As another part of the semi-flexible pavement material, the open-graded asphalt pavement matrix plays the role of the skeleton. This study attempts to use foam asphalt warm-mix method and to evaluate the performance of the semi-flexible pavement with warm mixed open-graded asphalt mixture matrix. This work is meaningful for reducing carbon emissions, air pollution and fuel consumption.

2. Objective and scope of this study

(1) The performance of improved cement mortar with Carboxyl Latex and conventional cement mortar are tested and compared, to explore the feasibility of modified mortar with Carboxyl Latex and to determine the appropriate proportion of Carboxyl Latex added. In where, the performances tested and compared include fluidity, compressive strength, flexural strength, and shrinkage of cement mortar.

(2) Through the multistage aggregate skeleton space filling method, the open-graded asphalt mixture of varied air void contents are designed and produced by foamed asphalt warm-mix technology. The open-graded asphalt mixture will be the matrix of semi-flexible pavement material that will be tested and evaluated.

(3) A series of pavement performances of the semi-flexible pavement material are tested. In this study, the pavement performances that will be evaluated include high-temperature rutting, low-temperature cracking, water damage, and fatigue.

3. Materials

The performance indices of raw materials used for preparing the semi-flexible pavement material are shown in the following tables, including the cement, standard sand, mineral filler, Carboxyl Latex, aggregate, and asphalt (See Tables 1–7).

4. Testing program

4.1. Modified cement mortar

Referring to "Explain for General Code of Asphalt Pavement Engineering" [13], the general performance requirements of cement mortar used for semi-flexible pavement material are shown in Table 8.

In this study, the performance indices, fluidity, compressive strength, flexural strength, and dry shrinkage of cement mortar, were selected for laboratory experiment evaluation. According to prior research [14–15], three design parameters value of the

Table 1
P.O 42.5 Cement performance indices.

Material type	Density (g/cm^3)	Fineness	Stability	Setting time (min)		Compressive strength (MPa)		Flexural strength (MPa)	
				Initial	Final	7 days	28 days	7 days	28 days
P.O42.5	3.25	1.2	Stable	186	347	35.5	48.1	5.4	7.2

Table 2
Gradation of standard sand.

Sieve size (mm)	1.18	0.6	0.3	0.15	0.075	Content of clay (%)
Percentage passing (%)	100	98.5	92.7	51.5	2.2	0.5

Table 3
Technical indices of mineral filler.

Testing indices	Expressway or first grade highway	Other grade highway	Test results	Comment
Apparent relative density (g/cm^3)	≥2.50	≥2.45	2.761	Qualified
Water content (%)	≤1	≤1	0.27	Qualified
Appearance	No agglomerate granule	No agglomerate granule	No agglomerate granule	Qualified
Hydrophilic index (%)	<1	<1	0.33	Qualified
Plastic index	≤4	≤4	2.4	Qualified

Table 4
Gradation of mineral filler.

Sieve size (mm)		0.6	0.3	0.15	0.075	Comment
Percentage passing (%)	Test result	100	97.50	92.30	80.34	Qualified
	Expressway or first grade highway	100	–	90–100	75–100	
	Other grade highway	100	–	90–100	70–100	