ARTICLE IN PRESS

Available online at www.sciencedirect.com

ScienceDirect

International Journal of Pavement Research and Technology xxx (2017) xxx–xxx

www.elsevier.com/locate/IJPRT

Study on direct coal liquefaction residue influence on mechanical properties of flexible pavement

Jie Ji [a,b,*], Di Wang [a,b], Zhi Suo [a,b], Ying Xu [a,b], Shi-fa Xu [b,c]

[a] *School of Civil Engineering and Transportation, Beijing University of Civil Engineering and Architecture, Beijing 100044, China*
[b] *Beijing Advanced Innovation Center for Future Urban Design, Beijing 100044, China*
[c] *Beijing Collaborative Innovation Center for Metropolitan Transportation, Beijing 100044, China*

Received 1 March 2017; received in revised form 29 August 2017; accepted 2 September 2017

Abstract

To study the influence of DCLR (direct coal liquefaction residue) on mechanical properties of flexible pavement, the DCLR/compound DCLR modified asphalt mixture was prepared. The 15 °C and 20 °C compression resilience moduli of DCLR/compound DCLR modified asphalt mixtures were measured using the uniaxial compression test. The influences of DCLR/compound DCLR modified asphalt mixture on deflection, upper layer thickness, and bending flexural tensile stress of layer bottom were analyzed using Bisar3.0 and HPDS software. The test results show the DCLR/compound DCLR modified asphalt has higher compression resilience modulus. Due to higher resilience moduli of DCLR/compound DCLR modified asphalt mixture, they can be used as bottom layer in pavement. Under the identical loadings, the upper layer thickness can be reduced by adding DCLR and compound DCLR. If the upper layer thickness is same, the bending flexural tensile stress of layer bottom and deflection will decrease significantly.

Keywords: Road engineering; DCLR; DCLR modified asphalt mixture; Compound DCLR modified asphalt mixture; Compression resilience modulus; Mechanical analysis

1. Introduction

Direct coal liquefaction (DCL) is a process for converting coal to liquid fuels. It involves dissolving coal in an organic (hydrogen donor) solvent in the presence of hydrogen gas in a reactor under moderate temperatures (400–450 °C) and high pressures (200–300 MPa). The liquefaction product can be broadly separated into gases (more than 15%), mixed oils (more than 55%) and residue (more than 30%) [1,2]. But the main residue DCLR (direct coal liquefaction residue) that is account about 30% of the total raw coal will be subsequently produced during the DCL process. DCLR is typically dark in appearance and highly viscous. DCLR are more chemically complex and their processing and use are much less well developed [3,4]. Then, how to use DCLR is a big issue now.

In China, methods have been developed for high-value use of DCLR, including directly use as asphalt or asphalt modifiers, preparation of advanced carbon materials and production of marketable fuels through hydrogenation. DCLR is abundant of polycyclic aromatics of asphaltenes and resource of fragrant carbon and might be used effectively as a value-added carbon resource from the viewpoints of the resource conservation and economy [5,6]. At present, DCLR is mainly used as fuel. But this procedure can bring serve air pollution and resource waste. As some

* Corresponding author at: School of Civil Engineering and Transportation, Beijing University of Civil Engineering and Architecture, Beijing 100044, China.
E-mail address: jijie@bucea.edu.cn (J. Ji).
Peer review under responsibility of Chinese Society of Pavement Engineering.

https://doi.org/10.1016/j.ijprt.2017.09.006
1996-6814/

Please cite this article in press as: J. Ji et al., Study on direct coal liquefaction residue influence on mechanical properties of flexible pavement, Int. J. Pavement Res. Technol. (2017), https://doi.org/10.1016/j.ijprt.2017.09.006

literature mentioned Irdi et al. [7], DCLR contains heavy oil and asphaltene, it is a very precious potential resource that can be developed into asphalt modifier.

Since the last century, scholars began to study the properties of DCLR. The basic structure and pyrolysis characteristics of DCLR are discovered [8,9]. Nie et al. [10] studied the extraction asphaltenes from DCLR with ILs (ionic liquids) and found the structure and size of anion and cation of ILs probably were the main factors that influence the extraction yield and the physicochemical characteristics of extracted asphaltenes. Yang et al. [11] found the DCLR modification ability is similar to that of Trinidad Lake Asphalt (TLA), a superior commercial modifier and DCLR modified asphalt binder met the specification of ASTM D5710. Zhang [12] studied that DCLR was used as the precursor for preparing hierarchical micro-/macro-mesoporous carbon by KOH activation with addition of Al_2O_3, and the resultant carbon AlRC was used as the catalyst for catalytic methane decomposition. Lu [13] used alkyl sulfate based ILs as solid liquid separation solvents to extract asphaltene type materials from DCLR. Li et al. [14] studied on co-pyrolysis of lignite and DCLR were conducted with a fixed-bed reactor under atmospheric pressure in high purity nitrogen. Wang [15] used iron-containing magnetic ILs to dissolve DCLR to obtain asphaltene fractions under the conditions of given time, temperature, and mass ratio of ILs to DCLR. Lv [16] proposed to blend DCLR with low-rank coals to prepare DCLR–coal–water slurries as feedstock for gasification. He [17] prepared DCLR modified asphalt binder by blending method in Lab, determined the optimum content of epoxy soybean oil and DCLR. Zhang [18] found when DCLR content was about 5%, DCLR modified asphalt binder could satisfy the standard of Pen.50 asphalt binder set by *Technical specification for construction of highway asphalt pavement* (*JTGF40-2004*) [19] in China. Ji [20] studied the performance of DCLR modified asphalt binder, and found the addition of DCLR could improve the high-temperature performance but the low-temperature performance would be reduced. Zhao and Ji [21] tested the performance of DCLR modified asphalt mixture and pointed the addition of DCLR could obviously improve the resistance to rutting.

However, in U.S.A. and other countries, DCLR has been frequently designated as a feed stoke for gasification or combustion, which is low of market value and causes difficulties to the feed system due to the presence of asphaltenes. DCLR used as asphalt modifier has not been studied.

As mentioned above, although China's coal liquefaction technology had been correspondingly developing, the application of DCLR has become more and more essential from aspects of resource utilization and environment protection. DCLR can prepare many high value-added materials and contribute to mitigate energy shortages. As a result, the objective of this study is studying the properties of asphalt binder and mechanical properties of pavement affected by DCLR.

2. Objectives

The scope of this research includes the following:

- Prepare four types of asphalt binders, such as SK-90 asphalt binder, SBS modified asphalt binder, DCLR modified asphalt binder and compound DCLR modified asphalt binder.
- Prepare four types of asphalt mixtures, including asphalt mixture made with SK-90 asphalt binder, SBS modified asphalt binder, DCLR modified asphalt binder and compound DCLR modified asphalt binder respectively.
- Measure the compressive resilience modulus of four types of asphalt mixtures using the uniaxial compression test.
- Analyze the thickness and mechanical properties of flexible pavement affected by DCLR using Bisar3.0 and HPDS software.

The flow chart of this study is shown in Fig. 1.

3. Materials and test methods

3.1. Modifier

In this study, DCLR, SBS, and rubber powder were used as modifier respectively. DCLR was from Inner Mongolia Branch Company of China Shen Hua Coal to Liquid and Chemical Co., Ltd. Physical properties of DCLR are seen in Table 1. The typical composition of DCLR is shown in Fig. 2.

SBS was obtained from Sinopec Beijing Yanshan Company Co., Ltd. Physical properties of SBS are seen in Table 2.

The rubber powder was obtained from Antai Rubber Company Co., Ltd. Physical properties of rubber powder are shown in Table 3.

3.2. Asphalt binders

SK-90 asphalt binder was obtained from South Korea and used as base asphalt binder in this study, named as SK. The 10% DCLR (by weight of SK-90 asphalt binder) and 3.4% SBS (by weight of SK-90 asphalt binder) were added to prepare modified asphalt binder respectively, denoted as DCLR and SBS. Moreover, the compound DCLR (2% SBS + 15% rubber powder by weight of DCLR modified asphalt binder) modified asphalt binder was also prepared, denoted as compound DCLR. The additive content of modifier was determined by properties of asphalt binders. The most appropriate additive content of DCLR is 10%. The 10% DCLR modified asphalt has the best

Please cite this article in press as: J. Ji et al., Study on direct coal liquefaction residue influence on mechanical properties of flexible pavement, Int. J. Pavement Res. Technol. (2017), https://doi.org/10.1016/j.ijprt.2017.09.006