Construction and Building Materials 178 (2018) 10–18

Contents lists available at ScienceDirect

Construction and Building Materials

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

Evaluation of pure and mixed modes (I/III) fracture toughness of Portland cement concrete mixtures containing reclaimed asphalt pavement

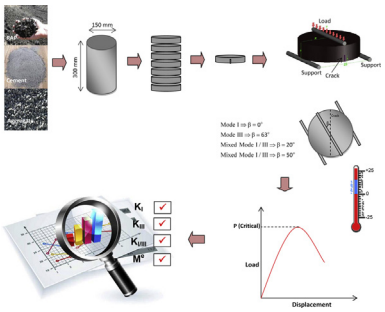
Ahmad Mansourian [a,*], Shabnam Hashemi [b], Mohammad Reza Mohammad Aliha [c]

[a] Department of Bitumen and Asphalt Road, Housing and Urban Development Research Center (BHRC), Tehran, Iran
[b] Department of Highway Engineering, College of Engineering, South Tehran Branch, Islamic Azad University, Iran
[c] Welding and Joining Research Center, School of Industrial Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran, Iran

HIGHLIGHTS

- Fracture toughness of specimen with RAP is lower than that of the without RAP.
- Fracture toughness of the mixture containing RAP increases when temp. decreases.
- The lowest values of effective fracture toughness are related to the pure mode III.
- For all temp. the lowest change in the fracture toughness occurs at pure mode III.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 11 November 2017
Received in revised form 8 May 2018
Accepted 12 May 2018

Keywords:
Reclaimed asphalt
Fracture toughness
Concrete
Disc shape bend specimen
Mixed mode I/III

ABSTRACT

The usage of waste materials in industrial application is one of the main issues around the world. The reclaimed asphalt pavement is one of the waste materials that due to environmental and economical benefits is usually used in road construction. This research study investigates the fracture toughness of concrete mixtures containing different percentages of reclaimed asphalt pavement (i.e. 0, 15, 30 and 45%). For this, a large number of cracked disc shape specimens containing different percentages of reclaimed asphalt pavement were loaded in pure (I and III) and mixed (I/III) modes at temperatures of −25 °C, 0 °C and +25 °C. The results of this research indicate that the reclaimed asphalt pavement decreases the fracture toughness of the concrete mixture in pure and mixed modes (I/III). Meanwhile, the results show that by decreasing the temperature, the fracture toughness of the concrete mixtures containing reclaimed asphalt pavement increases.

1. Introduction

Milling and post-processing of old asphalt concrete pavement is referred as reclaimed asphalt pavement (RAP). Each year, millions of tons of asphalt concrete are produced from damaged asphalt pavements in the world. Investigations show that using RAP has technical, economical and environmental advantages [1]. Cost saving due to reduction in the amount of aggregates and asphalt binders in new mixtures and reduction in transporting virgin materials to plant are the main economic benefits of using RAP. In addition, reduction in fuel usage related to extraction and transportation of virgin materials, reduction in demands of non-renewable resources, and reduction in landfill space for disposal of damaged pavement may be considered as the environmental benefits of using RAP.

* Corresponding author.
E-mail address: a.mansourian@bhrc.ac.ir (A. Mansourian).

https://doi.org/10.1016/j.conbuildmat.2018.05.130
0950-0618/

Using RAP as aggregate in cement concrete mixtures is one of the reasonable application of this material that has been investigated in recent years. Berry et al. [2] prepared concrete mixtures containing 50 and 100 percent RAP. They conducted mechanical (creep and shrinkage, compressive and tensile strength and elastic modulus) and durability tests and concluded that the mixtures had appropriate performance. However, they indicated that the concrete mixtures containing RAP had lower performance in comparison with the control mixture (100% virgin aggregates).

Brand et al. [3,4] carried out mechanical and durability tests on a ternary blend concrete (cement, slag, and fly ash) containing 0%, 20%, 35%, and 50% fractionated RAP and concluded that RAP decreased the mechanical and durability properties of concrete mixtures. They showed that the mixtures up to 50% RAP met the Illinois department of transportation requirements. The mechanical tests were compressive, split tensile, flexural strength and fracture test with single-edge notched beam (SENB) specimens in tension mode. In another research study Brand et al. [5] constructed full-depth and two-lift concrete slabs containing different percentages of fractionated RAP (FRAP) and recycled concrete aggregate (RCA). They stated that FRAP and RCA reduced the flexural, split tensile and compressive strengths of the concrete, however the fracture resistance of the SENB specimens containing recycled aggregate were similar to the control concrete.

Erdem and Blankson [6] investigated the mechanical and environmental performance of concrete containing 100% recycled aggregates of RAP and indicated that these concrete mixtures exhibited a reduction in modulus of elasticity and compressive strength and increase in flexural strength of concrete. Based on the test results they recommended that the RAP aggregate should not be used in structural elements, however, it could be used in non-structural applications.

Hassan et al. [7] evaluated the Portland cement concrete containing different percentages of RAP and concluded that using of RAP reduced the compressive and tensile strength of concrete, but improved its strain capacity. They recommended using RAP concrete mixtures in subbase and base of roads. Hossiney et al. [8,9] measured the compressive strength, indirect tensile strength, elastic modulus and flexural strength of the concrete mixtures containing 10, 20 and 40% RAP and stated that all of the mentioned parameters decreased when the percentage of RAP increased. Su et al. [10] evaluated the indirect tensile strengths and compressive strength of the concrete mixtures containing 35, 64 and 100% RAP and indicated that RAP could reduce the split tensile strength and compressive and strength of the concrete mixtures. Moreover, they concluded that the lower the content of RAP in concrete mixtures, the higher the compressive and split tensile strengths. Huang et al. [11] investigated the mechanical properties of Portland cement concrete containing coarse and fine RAP and concluded that RAP reduced the split tensile and compressive strengths and improved the energy absorbing toughness of the Portland cement concrete. In another research study, Huang et al. [12] replaced fine and coarse RAP with an equal amount of virgin fine and/or coarse aggregate for investigating the mechanical properties of concrete mixtures containing RAP. Meanwhile, two additives including silica fume and high-range water-reducing agent, were added to the concrete mixtures for minimizing the strength reduction due to incorporation of RAP. They concluded that increasing RAP could cause significant reduction in the compressive strength, split tensile strength, elastic modulus. Moreover, they stated that the addition of high-range water-reducing agent had improved the mechanical properties of concrete mixtures containing RAP. Mathias et al. [13] conducted compressive and tensile strengths and E-modulus on concrete mixture containing 11.9, 24.6, 51.2 and 90% RAP (by weight of the total aggregates) and concluded that all these parameters decreased when RAP percentage increased.

Fakhri and Amoosoltani [14] studied the effect of RAP and crumb rubber on fracture properties of roller compacted concrete mixture in pure modes I and II using semi-circular bending and four-point bending tests. They stated that mixtures containing

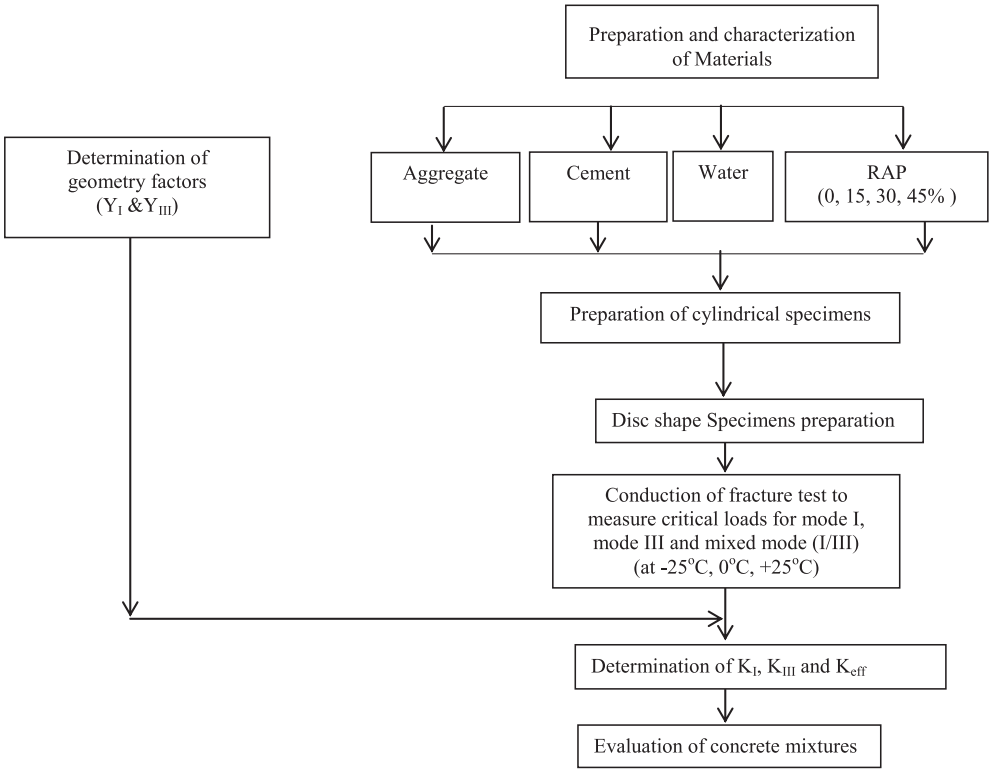


Fig. 1. Research framework of the current study.