Construction and Building Materials 166 (2018) 808–816

Contents lists available at ScienceDirect

Construction and Building Materials

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

Laboratory investigation of RAP aggregates for dry lean concrete mixes

Surender Singh *, G.D.R.N. Ransinchung, Kumari Monu, Praveen Kumar

Department of Civil Engineering, Indian Institute of Technology Roorkee, 247667 India

HIGHLIGHTS

- Mechanical properties of RAP of different age is studied.
- Coarse RAP has more potential to be used in DLC mixes than fine RAP.
- OLD RAP can be used up to 75% in DLC mixes.
- NEW RAP can be again utilized in Bituminous mixtures.

ARTICLE INFO

Article history:
Received 8 October 2017
Received in revised form 2 January 2018
Accepted 23 January 2018

Keywords:
RAP
Concrete
Bituminous
Strength
Oxidation
DLC

ABSTRACT

In the present study, the suitability of coarse (C) and fine (F) RAP aggregates extracted from two flexible pavements (OLD (O) & NEW (N)) having different service (20 yrs. & 2½ yrs.) and stockpiling life (8 months & 0 months) for productions of Dry Lean Concrete (DLC) and bituminous mixtures is assessed. For the same, a total of 15 DLC mixes were cast, consisting of 9 mixes containing different proportions (25–100%) of CO and CN aggregates and 6 mixes containing FO (25–100%) and FN aggregates (25% and 50%). The effect of both fractions of RAP on optimum moisture content (OMC), maximum dry density (MDD), compressive strength, water absorption and permeable voids were studied. Volumetric properties of compacted bituminous mixes containing aggregates milled from new pavement were also investigated. It was found that aggregates obtained from old pavement have the potential to replace 75% coarse and 50% fine natural aggregates whereas 25% CN and zero FN aggregates may be utilized for DLC mixes. Contrary, aggregates obtained from new pavement were found to be suitable for construction of base and wearing course of flexible pavements whereas aggregates from older pavement could not be even molded while preparing test sample due to loss of binding properties of asphalt mixtures by virtue of oxidation process.

1. Introduction

Reclaimed asphalt pavement (RAP) is a waste generated during milling and rehabilitation of old flexible pavements [1]. Usually, in high altitude regions after every monsoon season, the flexible pavements are resurfaced and this contributes a large amount of RAP waste. Millions of tons of RAP aggregates are extracted every year [2] and are found either in open farms or in disposal sites. RAP aggregates consist of a layer of asphalt around them which gets stiffen due to oxidation of volatile compounds during service life and stockpiling [3]. Reuse of RAP with aged asphalt film was found to increase the stiffness [4] and rutting resistance [5] but compromised with the crack resistance of the bituminous mixtures [6]. In terms of pavement performance, replacement of conventional aggregates up to 30% by RAP aggregates was found to be suitable [7]. As far as inclusions of RAP in wearing course of flexible pavement is concerned, only 10–15% is recommended whereas for lower layers half of the material can be partly replaced by RAP aggregates. Marshall Stability of bituminous mixtures was observed to be significantly improved on inclusions with RAP aggregates and this was attributed to the presence of stiffened asphalt coating [8]. Volumetric properties such as voids in mineral aggregates (VMA) were observed to be increased with increase in RAP content [9].

Utilization of RAP with aged asphalt film could favor a layered system with virgin binder that may enhance the pavement performance [10]. However, this has proven a hindrance in the formation of bonding between cementitious matrix and aggregate surface [11–19]. Delwar et al. 1997 [18] observed that presence of asphalt coating around the RAP could reduce the compressive strength of

* Corresponding author.
E-mail addresses: surendr.singh38@gmail.com, sunny.dce2015@iitr.ac.in (S. Singh), gdranfce@iitr.ac.in (G.D.R.N. Ransinchung), monughad.dce2016@iitr.ac.in (K. Monu), pkaerfce@iitr.ac.in (P. Kumar).

https://doi.org/10.1016/j.conbuildmat.2018.01.131
0950-0618/

Nomenclature

ACV	aggregate crushing value
AIV	aggregate impact value
BC	bituminous concrete
C	coarse RAP
CN	coarse RAP from new pavement
CNA	coarse natural aggregates
CN25	Mix containing 25% CN
CN50	Mix containing 50% CN
CN75	Mix containing 75% CN
CN100	Mix containing 100% CN
CO	coarse RAP from old pavement
CO25	Mix containing 25% CO
CO50	Mix containing 50% CO
CO75	Mix containing 75% CO
CO100	Mix containing 100% CO
C-RAP	coarse aggregates from both source
DBM	dense bituminous macadam
DLC	dry lean concrete
F	fine RAP
FN	fine RAP from new pavement
FNA	fine natural aggregates
FN25	Mix containing 25% FN
FN50	Mix containing 50% FN
FN75	Mix containing 75% FN
FN100	Mix containing 100% FN
FO	fine RAP from old pavement
FO25	Mix containing 25% FO
FO50	Mix containing 50% FO
FO75	Mix containing 75% FO
FO100	Mix containing 100% FO
F-RAP	fine aggregates from both source
IS	Indian standards
LAV	Los Angeles abrasion value
MDD	maximum dry density
MORTH	Ministry of Roads Transport and Highways
NA	natural aggregates
NEW (N)	RAP extracted from relatively new pavement
OLD (O)	RAP extracted from relatively old pavement
OMC	optimum moisture content
PCC	Portland cement concrete
RAP	reclaimed asphalt pavement
RCC	roller compacted concrete
VFA	voids filled with asphalt
VMA	voids in mineral aggregates
WBM	water bound macadam

Portland cement concrete (PCC) mixes significantly. However, it was found the asphalt coating could increase the toughness of PCC mixes. Owing to the lower compressive strength of RAP inclusive PCC mixes, it was suggested to incorporate the RAP aggregates for other concrete applications such as for gutters, barriers, sidewalks, and driveways etc. Contrary, Brand and Roesler 2015 [11] recommended incorporations of coarse RAP up to 50% for highway applications. Similarly, Singh et al. 2017 [17] recommended 100% replacement of coarse natural aggregates by beneficiated coarse RAP aggregates for the productions of cement concrete mixes. Huang et al. 2005 [14] observed that incorporations of finer fraction of RAP would have a more negative effect on the hardened properties of concrete as compared to the coarser fraction of RAP. This was attributed to the presence of soft asphalt film around the aggregates which induces stress concentration and thus causes microcracking within the cement mortar matrix. Similarly, Singh et al. 2017 [21] found that incorporations of fine RAP could reduce the compressive strength of cement concrete mixes significantly as compared to coarse RAP aggregates. Huang et al. 2006 [20] found that RAP consists of significant amount of agglomerated particles which tends to break under impact loading and thus refinement of same is necessary for increasing its suitability for PCC mixes. Refinement of coarse RAP aggregates by providing mechanical roughening has been reported to enhance the strength of concrete mixes significantly [22]. Brand and Roesler 2017 [23,24] found that the oxidation of asphalt around RAP plays a pivotal role in affecting the properties of concrete mixes. With the increase in the stiffening of asphalt coating, the mechanical properties such as compressive strength and split tensile strength etc. were found to be enhanced. Singh et al. 2017 [15] found that most of the physical properties of RAP were lower than that of conventional aggregates. However, the presence of asphalt was found to be beneficial in terms of lower impact, crushing and Los Angeles abrasion value. Singh et al. 2018 [19] found that the fine RAP extracted employing uncontrolled milling technique was relatively well graded whereas the fine RAP obtained using controlled milling technique were coarser and gap graded in nature. Utilization of fine RAP was found to decrease the compressive strength of concrete mixes significantly, however, incorporations of the same up to 50% was found to achieve the minimum recommended flexural strength for constructions of major highways.

Many studies have been carried out to investigate the potential use of RAP aggregates for subbase and base applications of flexible pavements whereas its compatibility in subbase of concrete pavement has never been investigated in detail. Several authors [12] have suggested utilizing coarse RAP aggregates for part replacement of natural aggregates in subbase application but their studies are based upon the investigations on Portland cement concrete (PCC) mixes wherein Abraham's law is valid. In case of DLC and roller compacted concrete (RCC) mixes, maximum compactness plays a vital role in achieving the desired properties. For achieving the dense microstructure, the DLC and RCC mixes are cast at optimum moisture content. Settari et al. investigated the potential of RAP for roller compacted concrete pavements (RCC) [25]. Mixes were cast at optimum moisture content (OMC) wherein it was found that combination of 50% coarse and 50% fine RAP (RCC 50/50) mix achieved maximum dry density (MDD) value after control mix. It was found that RCC mixes were highly sensitive to the porosity induced owing to incorporations of RAP aggregates. RCC 50/50 mix resulted in higher mechanical properties than other replacements and was attributed to the better compactness of the mix. It was concluded that identifications of optimum replacement level of natural aggregates by RAP aggregates is very important as it could reduce the overall porosity of the mixes and thus improves the mechanical properties of resultant mix considerably. However, owing to a drastic reduction in mechanical properties it was suggested to utilize RAP aggregates for other applications such as; subbase for low traffic pavements, rural roads and large areas of pedestrians. Moddares et al. prepared RCC mixes with different proportions of coarse and fine RAP aggregates [26]. Contrary to Settari et al. [25] findings, it was found that OMC of mixes reduces as the incorporations of RAP aggregates increases. This was attributed to the lower water absorptions of RAP aggregates compared to natural aggregates. It was observed that substitution of natural aggre-