ARTICLE IN PRESS

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International Journal of Pavement Research and Technology xxx (2018) xxx–xxx

www.elsevier.com/locate/IJPRT

Behavioural study of pavement quality concrete containing construction, industrial and agricultural wastes

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Received 7 June 2016; received in revised form 8 May 2017; accepted 31 March 2018

Abstract

This study proposes the use of industrial and agricultural wastes as mineral admixtures for enhancing the mechanical and durability aspects of concrete containing recycled concrete aggregates derived from concrete waste. The study was carried out by testing specimens prepared from concrete mixes with and without recycled concrete aggregates and three different mineral admixtures viz: fly ash (an industrial waste), rice husk ash and bagasse ash (agricultural wastes) for their compressive strength, flexural strength, split tensile strength, workability, chloride ion concentrations, carbonation, sorptivity and abrasion resistance in order to assess the variations and improvements. It was observed that concrete mix upon incorporating mineral admixtures showed significant improvement in both mechanical and durability properties when compared to concrete mix with recycled concrete aggregates alone.

Fly ash admixed mixes showed a gain of 15% and 24% for compressive and flexural strength parameters, while the gain for rice husk ash mix and bagasse ash mixes was observed to be 12% and 25%, 13% and 20% respectively when compared to recycled aggregate concrete mix without mineral admixtures. Improvements in durability aspects were observed by incorporating mineral admixtures supported by lower parameters for water absorption, sorptivity coefficients and chloride ion concentrations and increased hydration products as concluded from scanning electron microscopic investigations.

Keywords: Recycled concrete aggregate; Durability; Mineral admixture; Pavement quality concrete

1. Introduction

Incorporating recycled materials in newer construction purposes is a very old concept, from the times of Roman Empire when people often used stones obtained from previous roads in building new ones. Recycled materials have been into study for their incorporations in new construction works for quite some time. Recycling concrete has great economic and environmental benefits. Recycling of concrete waste will decrease the amount of space taken up in landfills as well as eliminate pollution produced by moving the concrete waste by trucks. Moreover using recycled aggregates reduces need to transport new materials

Abbreviations: PQC, pavement quality concrete; RCA, recycled concrete aggregate; NAC, natural aggregate concrete; RAC, recycled aggregate concrete; CA, coarse aggregate; FA, fine aggregate; IS, Indian standards; IRC, Indian Road Congress; ITZ, interfacial transition zone; SEM, scanning electron microscope; CSH, calcium silicate hydrate; CH, calcium hydroxide

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Peer review under responsibility of Chinese Society of Pavement Engineering.

https://doi.org/10.1016/j.ijprt.2018.03.007
1996-6814/

Please cite this article in press as: A. Jindal, G.D. Ransinchung R.N., Behavioural study of pavement quality concrete containing construction, industrial and agricultural wastes, Int. J. Pavement Res. Technol. (2018), https://doi.org/10.1016/j.ijprt.2018.03.007

which in turn helps to reduce water and air pollution and greenhouse gas emissions.

Recycled concrete aggregates (RCA) in general derived from processing of demolished concrete waste, consist of aggregate particles coated upon by adhered mortar. This mortar is weak and porous which makes inferior the quality of aggregates produced. When used in fresh concrete, this leads to durability issues along with associated inferiority in its mechanical properties.

Researchers from various countries have investigated the effects of using recycled materials in construction works. Inclusion of recycled aggregates is said to depreciate the quality of concrete produced by lowering its compressive, flexural strengths and increasing the water absorption and shrinkage values. Mishra et al. [30] discussed that by incorporation of recycled materials in normal concrete, a reduction in compressive strength of the order of 15–20% in recycled aggregate concrete was observed assessing to referral concrete at 100% replacement. Etxeberria et al. [7] studied the use of recycled concrete aggregate as a replacement of primary aggregates in proportions of 0%, 25%, 50% and 100%. They found that 28 day compressive strength of recycled aggregate concrete was lower than that of natural aggregate concrete by 20–25%, while the tensile strength of recycled aggregate concrete was also reported to be lower than that of conventional concrete. They suggested that RCA could be used for low and medium strength concrete (30–45 MPa) as medium strength concrete incorporating 25% RCA also showed quite similar compressive strength to that of conventional concrete thereby keeping water-cement ratio and cement content uniform. de Oliveira and Vazquez [21] discussed that the compressive and flexural strength of concrete was reduced considerably on using recycled concrete aggregates in air-dried or saturated surface dry state. They also reported reduced durability for concrete prepared with dry and saturated recycled aggregates when investigated for freezing thawing resistance, carbonation etc. However, they discussed than concrete prepared with semi saturated aggregates displayed better mechanical and durability properties.

This depreciation in concrete properties may be attributed to weak adhered mortar, fine cracks and fissures associated with recycled concrete aggregates leading to higher water absorption of concrete. Kanai et al. [20] reported similar properties for recycled aggregate concrete as those for conventional concrete on replacing 25% natural coarse aggregates and 50% natural fine aggregates by recycled concrete aggregates. However loss in compressive strength was reported to the order of 30–40% and 15–40% for flexural strength on incorporating recycled concrete aggregates.

Concrete incorporating recycled concrete aggregates are believed to observe durability issues such as increase in carbonation depth, shrinkage, water absorption and chloride ion concentration values. Crentsil et al. [32] studied the effects of carbonation on concrete containing recycled concrete aggregates. They reported that the carbonation values of recycled aggregate concrete were higher than those for conventional concrete by 1.3–2.5 times. This was explained as a result of old adhered mortar in recycled concrete aggregates which increases the depth of carbonation and permeability of concrete. Results discussed by Xiao et al. [38], Yong and Teo [40], Rao et al. [23], Akbari et al. [39] and Martínez-Lage [25] also implicate towards the reduction in strength and durability properties of concrete with increase in content of recycled concrete aggregates.

Review from above studies concludes that incorporating recycled concrete aggregates does lower the concrete properties both in mechanical and durability aspects. This is largely associated with the adhered surface mortar surrounding the aggregate particle. Few beneficiation methods proposed by various researchers help in removal of this mortar thereby improving the quality of aggregates. Some of the studies pertaining to use of beneficiated RCA in fresh concrete carried out by Ong et al. [27] using RCA beneficiated by microwave beneficiation proposed by Akbarnezhad et al. [2], Ismail and Ramli [19], Purushothaman et al. [29] and Murali et al. [26] using RCA treated by acid beneficiation method proposed by Tam et al. [35] and Shima et al. [33] using RCA treated by thermal beneficiation method discusses the improvements in properties of recycled concrete aggregates in comparison to their untreated counterparts.

Mineral admixtures are believed to improve the mechanical and durability aspects of concrete attributed to their pozzolanic properties. Ransinchung et al. [8] used wollastonite and micro silica as mineral admixtures in pavement quality concrete and studied them for effects on water absorption and chloride ion penetrations. They concluded that using 15% wollastonite and 7.5% micro silica refines the microstructure and reduces pore spaces thereby improving the water tightness of concrete. Berndt [4] discussed best mechanical and durability properties for recycled aggregate concrete with blast furnace slag as 50% replacement of cement with marginal increase in permeability and chloride diffusion coefficients. Kou and Poon [28] discussed the improvement in durability properties of concrete with the use of fly ash which otherwise was reported to be inferior with the inclusions of recycled concrete aggregates. Similar trends depicting improvements in concrete properties were discussed by Tangchirapat et al. [37] using high fineness fly ash, Somna et al. [34] using ground bagasse ash, Wagih et al. [36] using silica fumes, Çakır [5] using silica fume and ground granulated blast furnace slag and Maier and Durham [24] using ground granulated blast furnace slag.

In the present study an investigation is carried out on the effects of using industrial and agricultural wastes along with construction waste in pavement quality concrete. In order to incorporate construction waste, recycled concrete aggregates manufactured from concrete waste were used in the study. Inclusion of industrial waste (fly ash), and agricultural wastes (rice husk ash and bagasse ash) was carried