engineering proceedings

MDPI

Abstract

Reclaimed asphalt and alkali-activated slag systems: the effect of metakaolin†

Juliana O. Costa [1,2,*], Flavio A. dos Santos [2], Augusto C. S. Bezerra [2], Paulo H. R. Borges [2], Johan Blom [1], Wim Van den bergh [1,*]

[1] EMIB Research Group, Faculty of Applied Engineering, University of Antwerp 2020 Antwerp, Belgium; johan.blom@uantwerpen.be (JB); wim.vandenbergh@uantwerpen.be (WVdb)
[2] Department of Civil Engineering, Federal Center for Technological Education of Minas Gerais (CEFET-MG), Belo Horizonte 30510-000, Brazil; paulo.borges@cefetmg.br (P.H.R.B.); flaviosantos@cefetmg.br (F.A.d.S.); augustobezerra@cefetmg.br (A.C.S.B.)
* Correspondence: Juliana.oliveiracosta@uantwerpen.be (JOC)
† Presented at the 1st International Online Conference on Infrastructures, 7–9 June 2022.

Keywords: recycled aggregates, geopolymers, concrete, alkali-activation, pavements

1. Introduction

The demolition of old flexible pavements layers generates large quantities of reclaimed asphalt pavement (RAP). This material can be milled and reused for new pavement sections as aggregates. Alkali-activated materials (AAM) are alternative cementitious binders with high strength and chemical resistance [1]. The main problem associated with RAP in cementitious materials is the strength loss due to the porous interface [2–5]. The use of metakaolin (MK) can improve slag based AAM's properties [6,7]. The objective of this study is to investigate if the properties of RAP-AAM produced with low alkali concentration (4% Na_2O and Ms = 0 and 1) can be improved with 5% MK replacement. This investigation compared isothermal calorimetry, compressive and flexural strength results for RAP-AAM produced with and without MK replacement.

2. Materials

The RAP-AAM was produced mixing a powdered precursor with an alkali solution. The precursors used were ground granulated blast furnace slag (GGBFS) supplied by Ecocem and MK (Caltra). The alkali solution was prepared using sodium hydroxide sodium silicate solution form VWR. Fine RAP aggregate was obtained by removing the fine fraction (< 4mm) of a locally milled flexible pavement supplied by Willemen Infra Recycling. Table 1 shows the compositions studied.

Mortar mixing details and experimental procedures can be found elsewhere [5].

Table 1. Compositions (Ms = silica modulus, w = water, p = precursor, a = fine RAP aggregate)

	Precursor		Alkali-solution			a/p
	GGBFS	MK	Na_2O	Ms	w/p	
R4-0	100.0g	0g	4%	0	0.5	1.5
5MK4-0	95.0g	4.5g	4%	0	0.5	1.5
R4-1	100.0g	0g	4%	1	0.5	1.5
5MK4-1	95.0g	4.5g	4%	1	0.5	1.5

3. Results and discussion

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Eng. Proc.* **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Published: date

Figure 1 presents the calorimetry results for the different RAP-AAM samples studied. The sharp peak at the start of the experiment was only partially captured. The second and main peak is related to the precipitation of the reaction products [8,9]. Samples with sodium silicate (R4-1 and 5MK4-1) have a delayed second peak due to the workability retention and the reduced availability of OH- [10,11]. Replacing 5% of GGBFS with MK decreased the intensity and delayed the second peak. It also reduced the cumulative heat of the samples. The retarding effect of MK in the formation of reaction products was also observed in another research [12].

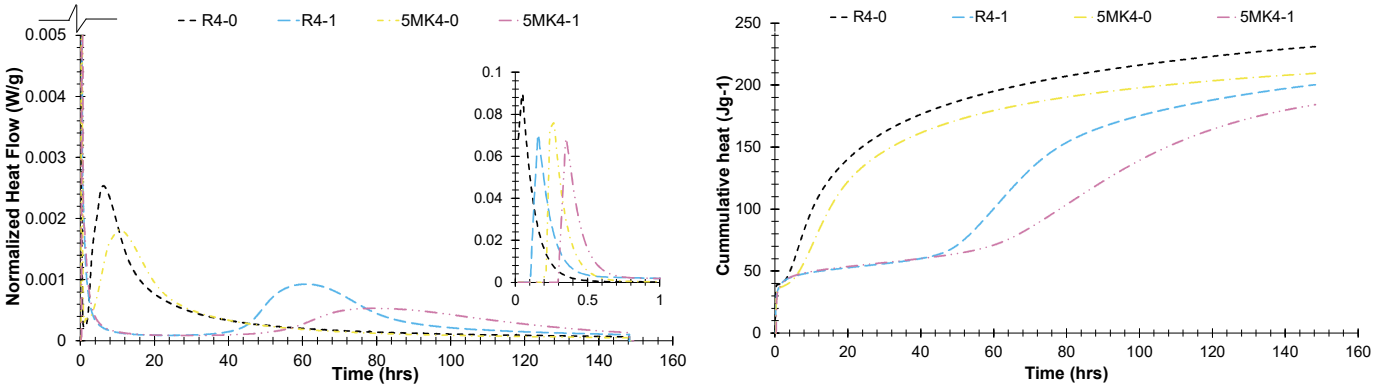

Figure 1. Calorimetry results of RAP-AAM

The compressive and flexural strength of the samples is presented in Figure 2. The use of MK reduced the early strength of the samples (both compressive and flexural). At later ages, however, the use of MK caused some slight improvements in strength. This result differs from other studies [7,13] that reported a reduction in compressive strength and gains in flexural strength for sodium hydroxide alkali-activated pastes and mortars.

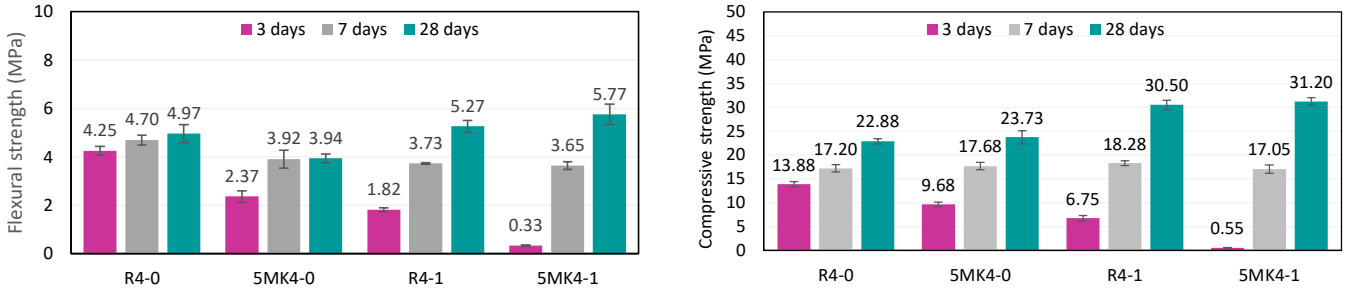

Figure 2. Compressive and flexural strength results for RAP-AAM.

4. Conclusion

The use of MK delayed the formation of main reaction products, which significantly impacted the early strength of the studied mixes. The filler effect of MK may have helped anchor RAP particles to the matrix and caused slight improvements in compressive strength observed at 28 days. This study did not see significant improvement in flexural strength as observed elsewhere [7], most likely due to the low alkali concentration used. Further studies of the benefit of MK for RAP-AAM at higher concentration of alkalis is needed.

Author Contributions: Conceptualization and writing—original draft preparation, J.O.C.; writing—review and editing, P.H.R.B.; supervision, J.B; W.V.d.b and A.C.S.B.; funding acquisition, W.V.d.b and F.A.d.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was financed in part by Coordenação de Aperfeiçoamento de Pessoal deNível Superior Brazil (CAPES) [Finance code 001]; and DOCPRO1 Project 42476 UAntwerp, Universiteit Antwerpen, Faculty of Applied Engineering (research group EMIB)- [Finance code 001.BOF].

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Shi, C.; Ana, F.-J.; Palomo, A. New cements for the 21st century: The pursuit of an alternative to Portland cement. *Cem. Concr. Res.* **2011**, *41*, 750–763, doi:10.1016/j.cemconres.2011.03.016.
2. Singh, S.; Ransinchung, G.D.; Debbarma, S.; Kumar, P. Utilization of reclaimed asphalt pavement aggregates containing waste from Sugarcane Mill for production of concrete mixes. *J. Clean. Prod.* **2018**, *174*, 42–52, doi:10.1016/j.jclepro.2017.10.179.
3. El Euch Ben Said, S.; El Euch Khay, S.; Loulizi, A. Experimental Investigation of PCC Incorporating RAP. *Int. J. Concr. Struct. Mater.* **2018**, *12*, doi:10.1186/s40069-018-0227-x.
4. Brand, A.S.; Roesler, J.R. Bonding in cementitious materials with asphalt-coated particles: Part I – The interfacial transition zone. *Constr. Build. Mater.* **2017**, *130*, 171–181, doi:10.1016/j.conbuildmat.2016.10.019.
5. Costa, J.O.; Borges, P.H.R.; dos Santos, F.A.; Bezerra, A.C.S.; Blom, J.; Van den bergh, W. The Effect of Reclaimed Asphalt Pavement (RAP) Aggregates on the Reaction, Mechanical Properties and Microstructure of Alkali-Activated Slag. *CivilEng* **2021**, *2*, 794–810, doi:10.3390/civileng2030043.
6. Bernal, S.A.; Rodríguez, E.D.; Mejia De Gutiérrez, R.; Provis, J.L.; Delvasto, S. Activation of metakaolin/slag blends using alkaline solutions based on chemically modified silica fume and rice husk ash. *Waste and Biomass Valorization* **2012**, *3*, 99–108, doi:10.1007/s12649-011-9093-3.
7. Li, Z.; Liang, X.; Chen, Y.; Ye, G. Effect of metakaolin on the autogenous shrinkage of alkali-activated slag-fly ash paste. *Constr. Build. Mater.* **2020**, *278*, (under review), doi:10.1016/j.conbuildmat.2021.122397.
8. Fernandez-Jimenez, A.; Puertas, F.; Arteaga, A. Determination of kinetic equations of alkaline activation of blast furnace slag by means of calorimetric data. *J. Therm. Anal. Calorim.* 1998, *52*, 945–955.
9. Huanhai, Z.; Xuequan, W.; Zhongzi, X.; Mingshu, T. Kinetic study on hydration of alkali-activated slag. *Cem. Concr. Res.* **1993**, *23*, 1253–1258, doi:10.1016/0008-8846(93)90062-E.
10. Liu, S.; Li, Q.; Han, W. Effect of various alkalis on hydration properties of alkali-activated slag cements. *J. Therm. Anal. Calorim.* **2018**, *131*, 3093–3104, doi:10.1007/s10973-017-6789-z.
11. Kashani, A.; Provis, J.L.; Qiao, G.G.; Van Deventer, J.S.J. The interrelationship between surface chemistry and rheology in alkali activated slag paste. *Constr. Build. Mater.* **2014**, *65*, 583–591, doi:10.1016/j.conbuildmat.2014.04.127.
12. Li, Z.; Nedeljković, M.; Chen, B.; Ye, G. Mitigating the autogenous shrinkage of alkali-activated slag by metakaolin. *Cem. Concr. Res.* **2019**, *122*, 30–41, doi:10.1016/j.cemconres.2019.04.016.
13. Fu, B.; Cheng, Z.; Han, J.; Li, N. Understanding the role of metakaolin towards mitigating the shrinkage behavior of alkali-activated slag. *Materials (Basel).* **2021**, *14*, 1–19, doi:10.3390/ma14226962.