EFFECTS OF GLASS POWDER AS AGGREGATE AND BINDER ON ASR

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1. INTRODUCTION

The decrease of natural resources, due to the intense exploration, is making the construction industry search for alternative materials to apply in construction sites. This necessity, together with the availability of wastes and by-products of other industries, made arise many alternatives to the natural material. Recycled glass is nondegradable and normally is used to make new glasses bins. However, if contaminated and mixed with different colors, it can modify the new glass characteristics so not all glass can be reused. There are many studies about its application in concrete and mortar, however, its characteristics still not have consensus between the researchers and more studies are necessary to clarify its behavior and contribute to its use in construction. One of the most studied topics about recycled glass in concrete and mortar is the alkali-silica reaction (ASR). ASR is a deleterious problem caused by the bulking of silica gel formed by the silica compounds dissolution in an alkaline environment. Many materials are often incorporated in concrete to prevent or mitigate ASR to occur, giving more durability to the structure. Usually, blast furnace slag, fly ash, metakaolin, silica fume and also glass powder can be used to decrease the effects of the reaction, Lu at al. (2017). Glass cutlet fine aggregate is highly reactive and, if used for concrete or mortar, it demands ASR suppressants materials. As the glass powder has an opposite effect in concrete and mortars, the researchers had explained the cause by the pozzolanic activity of the fine particles of glass powder that can mitigate or suppress ASR. Most studies analyze the effects of glass individually as aggregate or binder in the mix, so this study aims to analyze the use of them simultaneously and verify what is the effect of glass powder in ASR in a highly reactive glass aggregate mortar as binder and aggregate. It also aims to provide information about the most suitable application of the glass powder between the mix designs presented.

2. EXPERIMENTAL OUTLINES

2.1 Materials and Mix Proportions

For mix designs, this study used glass sand as the fine aggregate with finesse modulus of 3.06. The glass powder (GP) used had a particle size of 75µm and ordinary Portland cement was used as a reference binder. The water-cement ratio used was 0.47 and the unitary proportion of 1:2.25 as required for ASTM AMBM C1567. The mixes were divided into two parts. First with glass powder as a binder in a replacement proportion of 10%, 20% and 30% in mass of cement corresponding to 45g, 90g, and 135g, respectively. Second, the same amount in the mass of powder was used as fine aggregate, corresponding to 3.3% (45g), 6.6% (90g) and 135% (135g). The mixes designs are shown in table 1.

Table 1 Mix Design

Mix	*Water (g)*	*Cement (g)*	*Glass Powder (g)*	*Glass Sand (g)*
REF	206.8	440	0	990
BIN 10%	206.8	395	45	990
BIN 20%	206.8	350	90	990
BIN 30%	206.8	305	135	990
AGG 3.3%	206.8	440	45	945
AGG 6.6%	206.8	440	90	900
AGG 10%	206.8	440	135	855

2.2 Testing Methods

The samples were mixed in accordance with required of ASTM C305 and cast manually being compacted with the tamper. After the cast, the samples were placed in a controlled chamber with constant temperature 20ºC and relative humidity (RH) of 60%. The potential alkali-silica reactivity was verified using the ASTM accelerated mortar-bar method C1567. The length measurements were taken following the ASTM C490.

3. RESULTS AND DISCUSSION

3.1 Alkali-Silica Reaction

The results for expansion show that glass powder used as a replacement for binder or aggregate reduce ASR for all mix designs at 16 days when compared with the reference mix (0% GP), as can be seen in figures 1 and 2. For the use as a binder, the replacements of BIN 20% and BIN 30% did not show expansion that indicates deleterious behavior at 16 days of the test. However, the replacement of BIN 10% of cement with GP as a binder presented potential deleterious behavior. For GP used as fine aggregate, also all mixes indicate a decrease in ASR when compared with the reference

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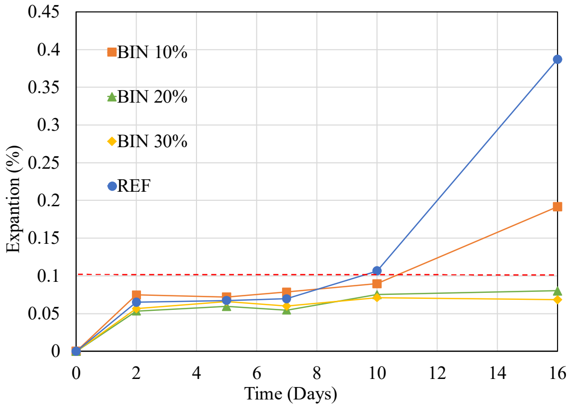

Fig. 1 ASR GP Binder

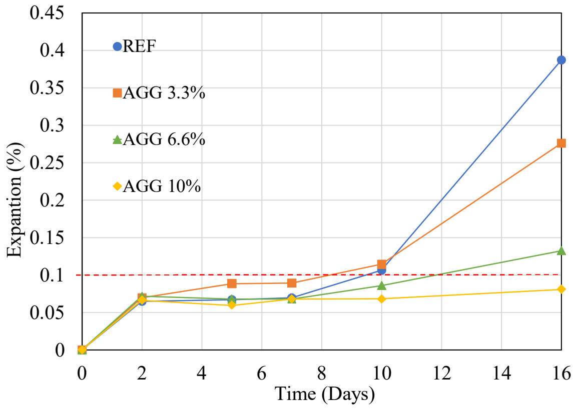

Fig. 2 ASR GP Aggregate

mix at 16 days (figure 2).However, the results for AGG 3.3% and AGG 6.6% presented indication of potential deleterious the expansion, overcoming the 0.10% of the variation in 16 days. When comparing the same amount, in mass, of GP as binder and aggregate, the results for glass binder showed a more effective reduction of the expansion. The difference in the mixes consists that, for GP as a binder, less cement is used so the amount of alkalis decreases proportionally. For glass as aggregate, the amount of cement still the same but the reactive aggregate decrease in mass reducing the amount of reactive aggregate. The ASR happens between glass grains and alkali in pore solution, Zheng (2016), so as fewer alkalis are available in the mix of GP as a binder, less material for reaction and consequently a smaller expansion tends to happen.

3.2 Mass Change

The expansion of ASR is generated by the formation of ASR products in a sufficient amount and its swelling behavior by absorbing water. Also, liking is prevented by the high alkalinity of the solution. The gains for the mortar are mainly controlled by the amount of ASR products formed, Shi et al. (2018). For this study, figures 3 and 4 show an increase in mass.

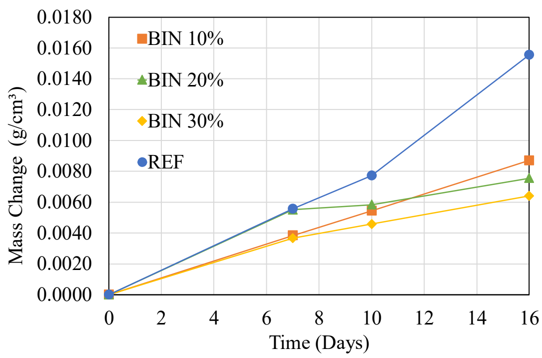

Fig. 3 Mass Change GP Binder

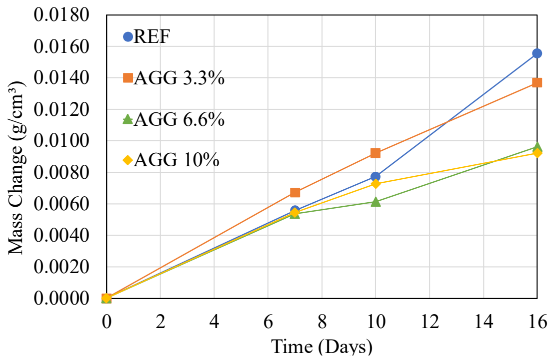

Fig. 4 Mass Change GP Aggregate

4. CONCLUSIONS

The effects of the use of GP in order to prevent ASR in mortar can be beneficial. For all the results, the GP showed a reduction of potential deleterious expansion when compared with the reference mix (0% GP). The replacements of binder using BIN 20%, BIN 30% and aggregate using AGG 10% showed no deleterious expansion using a method the ASTM AMBM C1567. Furthermore, when used as a binder, the GP showed a smaller expansion when compared with the aggregate substitution for most mixed. This behavior indicates a better suitable application of the glass powder as a cement replacement in order to decrease ASR deleterious expansion.

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REFERENCES

Lu JX, Zhan BJ, Duan ZH, Poon CS. Using glass powder to improve the durability of architectural mortar prepared with glass aggregates. Materials & Design. 2017 Dec 5; 135:102-11.
Zheng K. Pozzolanic reaction of glass powder and its role in controlling alkali-silica reaction. Cement and Concrete Composites. 2016 Mar 1; 67:30-8.
Shi Z, Shi C, Zhang J, Wan S, Zhang Z, Ou Z. Alkali-silica reaction in waterglass-activated slag mortars incorporating fly ash and metakaolin. Cement and Concrete Research. 2018 Jun 30; 108:10-9.