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Microscopic characterization of alkali-silica reaction (ASR) affected recycled concrete mixtures induced by reactive coarse and fine aggregates

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1. INTRODUCTION AND BACKGROUND

The use of recycled concrete aggregates (RCA) is gaining interest in the industry due to the pressure to adopt more sustainable practices yet, concerns regarding the potential for ASR in concrete made with RCA remain. In the current literature, the original extent of the ASR damage is often unknown and therefore, inconsistencies regarding the potential for further ASR in concrete made with affected RCA are observed in the literature [1-4]. RCA is a multi-phase material consisting of the original virgin aggregate (OVA) and RM (i.e., residual sand and cement paste) and ASR may originate from the reactive OVA or residual sand and its extension into the cement paste depends on the extent of reaction/damage. Consequently, the level and extension of previous damage due to ASR originating from the OVA or residual sand may influence the potential for secondary damage and its nature. This work, therefore, evaluated the secondary damage generation and propagation in concrete made with RCA presenting two levels of initial damage (i.e., 0.05% and 0.30% of expansion, representing a returned and demolished concrete, respectively) induced by either reactive coarse OVA or residual sand. A microscopic tool (i.e., Damage Rating Index - DRI) was used for the analysis while distress features (i.e., cracks) were measured in counts per 100 cm^2, length, width and types of propagation to characterize the distinct damage patterns induced by various types of RCA affected by ASR. The full extent of this research can be found in [5].

2. MATERIALS AND METHODS

Highly reactive coarse aggregate (i.e., Springhill - Greywacke) and sand (i.e., Texas – Polymictic sand) were used to make CC and provide two distinct origins of ASR. CC cylinders were fabricated following the procedures as per ASTM C1293 [6] and jaw-crushed upon reaching 0.05% and 0.30% of expansion thus, creating 4 types of RCA. The recycled mixtures were then proportioned using the equivalent volume [7] while using ASTM C1293 as the companion mixture and white cement (CSA Type GU) was used to better distinguish distress features in the residual vs new cement paste. The CC and recycled concrete mixtures were cast, cured for 24h, prepared for length change measurements then monitored over time. Expansion levels of 0.05%, 0.12% and 0.20% were selected for the microscopic analysis of the recycled mixtures. Details of the sample preparation and analytical procedures are described in [5].

3. RESULTS AND DISCUSSION

The expansion as a function of time presented in Figure 1 shows the differences between CC and recycled mixtures (overall standard deviation of 0.01-0.07%). First, the CC made with reactive sand and coarse aggregate (i.e., Texas CC and Springhill CC, respectively) achieved greater expansion levels in less time when compared to all recycled mixtures manufactured with the reactive sand CC presenting the fastest kinetics. On the other hand, the slightly and severely damaged RCA made with reactive coarse aggregate (i.e., 0.05%-SPR-RCA and 0.30%-SPR-RCA, respectively) followed a more parallel trend to one another. The parallel trend was only apparent after 87 days for the slightly and severely damaged RCA made with reactive sand (i.e., 0.05%-TX-RCA and 0.30%-TX-RCA, respectively) and the severely damaged RCA made with reactive sand exhibited a delay in expansion for 43 days. The delay in expansion is likely attributed to the barrier effect of the residual cement paste which was also observed in the crack propagation where cracks in the severely damaged RCA made with reactive sand were generated from the deeper portion of the RM within the RCA (further details in [5]). Moreover, both slightly damage RCA mixtures presented lower overall expansion levels compared to the severely damaged RCA mixtures and CC.

The distress features however significantly differed per expansion level (Figure 2) where the lowest DRI numbers were obtained for the RCA made with reactive coarse aggregate compared to the RCA made with reactive sand; meanwhile both slightly damaged RCA mixtures presented lower DRI numbers compared to the severely damaged RCA mixtures. Cracks in the cement paste (i.e., without or with gel - CCP and CCPG) were significantly more abundant in the RCA made with reactive sand while open cracks in the aggregate (i.e., without or with gel – OCA and OCAG) governed the damage in RCA made with reactive coarse aggregate. Even though the same expansion levels were achieved, it was evident that the distress mechanisms in terms of crack counts, characteristics (i.e., length and width) and propagation varies as a function of the previous ASR damage (i.e., slightly and severely damaged) and its origin (i.e., reactive sand and coarse aggregate) [5].

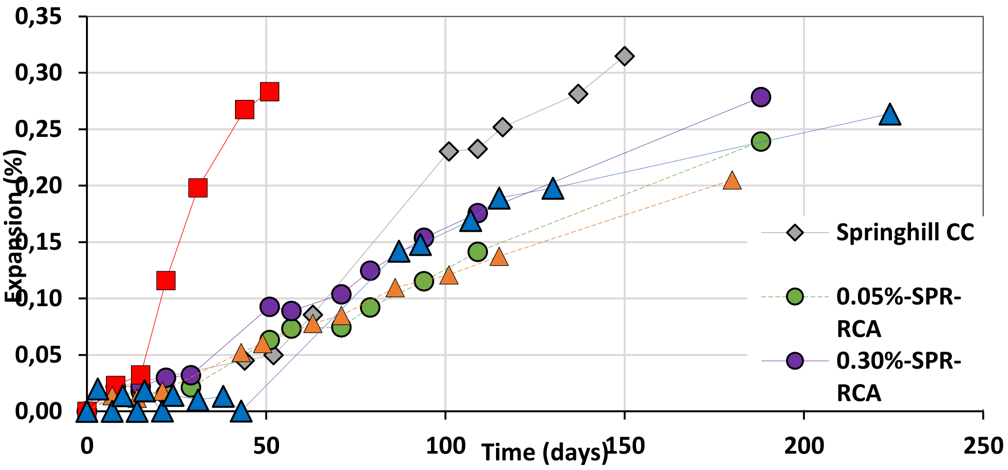

Figure 1: ASR kinetics for CC and recycled mixtures.

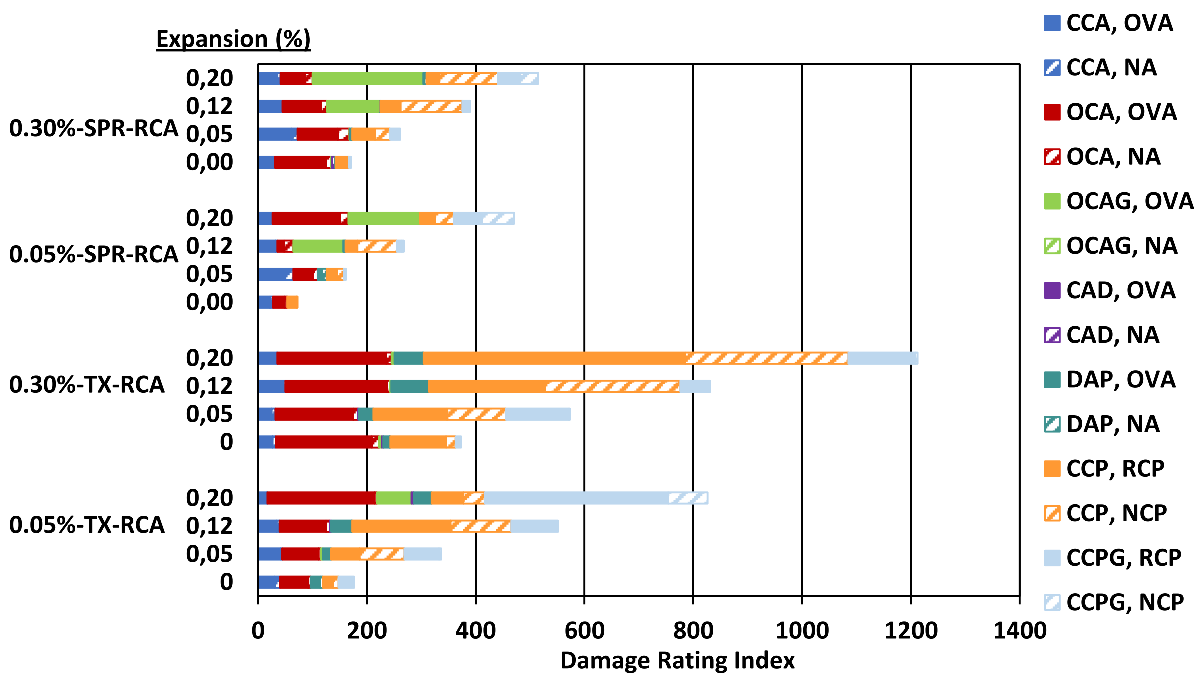

Figure 2: DRI for distinct recycled mixtures per expansion level.

4. CONCLUSION

The purpose of this study was to characterize different types of ASR-affected RCA while varying the origin of ASR and the original level of damage. The overall levels of expansions achieved by the recycled mixtures were lower than CC while the severely damaged RCA mixtures presented higher overall expansion levels compared to the slightly damaged RCA mixtures. The distress mechanism of recycled mixtures through the crack propagation differs according to the origin of ASR (i.e., reactive sand or coarse aggregate) and previous level of damage (i.e., slighty and severely damaged, 0.05% and 0.30% expansion levels, respectively). Therefore, ASR-affected RCA should be characterized before its use in concrete and not be considered as a single material.

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