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Evaluation of alkali reaction potential of different aggregates based on petrographic studies and chemical tests

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Abstract

The alkali-silica reaction (ASR) within the concrete can shorten its lifespan due to the expansive pressure build-up and cracking, caused by the deleterious action of ASR by-products. Therefore, concrete aggregates should be tested for their alkali-silica reactivity before their use. The ASR is a gradual reaction that can happen between the alkaline pore solution of the concrete and various types of aggregates. Understanding the behaviour of the aggregate, as the main reactive component, is essential in the understanding of the ASR mechanism, reducing the ASR potential or even preventing it. Thus, detecting susceptible aggregates and selecting the ones with low levels of reactive materials is essential in building a durable structure. The aim of this research is to assess the susceptibility of four commonly used aggregates in construction projects: Granite (representing the outer igneous rock), Rhyodacite (representing the inner igneous rock), as well as Limestone and Dolomite (sediments aggregates). The study is performed under accelerated conditions and in accordance with the ASTM test method C1260. The experimental test is validated using microanalysis technique such as Scanning Electron Microscopy (SEM), Energy-dispersive X-ray Spectroscopy (EDS) and X-ray diffraction (XRD).

***Key words**: Alkali-silica reaction, Aggregate, Concrete, Accelerated Test, Petrography.*

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Extended Abstract:

1. Introduction

One of the most destructive factors in concrete is alkali reaction, which divided into two different reactions: Alkali silica reaction and Alkali carbonate reaction. The reaction between alkaline cement and minerals in some aggregates can lead to the formation of expansive gel-type by-products which in the long-term can affect the durability of concrete structures (Hou, Struble and Kirkpatrick, 2004) . This reaction occurs when aggregates containing active forms of SiO2 react with alkalis from cement (Na and K) and form amorphous alkali-silica gels. Once the gel absorbs water, its volume will increase, which creates a build-up of internal stress and pressure, and subsequently cracking of concrete(Poole and Sims, 2015, Chatterji et al., 1989). Thus, predicting and detecting deleterious aggregates could reduce the chance of cracking and extend the service life of a concrete structure. Several factors can cause ASR, such as the high alkali content in the cement paste, the presence of reactive forms of silica in aggregates, and the presence of an adequate amount of moisture(Langer, 1988, Swamy, 2002) . Reactive aggregates are commonly identified through the presence of very fine-grained quartz, and different forms of silica (opal, chalcedony) while the slow reactive aggregates are typically crystalline quartz-bearing type rocks (mylonite, granite, gneiss, quartzite, greywacke, phyllite, and argillite)(Lindgård et al., 2010). These aggregates thus need to be comprehensively analyzed before their application in concrete.

The petrographic method based on RILEM AAR-1 is often the first step in evaluating the potential alkali-reactivity of aggregates (Sims and Nixon, 2003). This method is generally used to identify rock types and minerals that might react with hydroxyl ions from the concrete pore solution. Analytical techniques such as scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) and X-ray diffraction (XRD) are widely used in detailed identification of by-products of the destructive ASR process and they are considered as a complementary physicochemical method to the petrographic approach (Alonso and Martınez, 2003). The petrographic method is followed by accelerated laboratory tests based on RILEM AAR-2 and AAR-3. In these accelerated evaluation approaches, mortar or concrete bars are exposed to the severe condition of alkalinity and temperature to initiate expansion within days, weeks or years, depending on the method. Thus, the most popular and effective method of detecting ASR potential of aggregates are ASTM C1260, the accelerated mortar bar test, and ASTM C1293, the accelerated concrete prism test (Lindgård et al., 2010).

2. Materials and methods

In this study, two silica reach volcanic igneous rocks, Rhyodacite and Granite, as well as two sedimentary carbonate rocks, Limestone and Dolomite, were compared. The Granite sample was collected from Nehbandan County in South Khorasan Province of Iran. The Rhyodacite sample was collected from Yazd Province in Iran. The dolomite sample was collected from Damavand City in Tehran Province of Iran. The limestone sample was collected from Bathurst, New South Wales in Australia. Granite represents the outer igneous rock while the Rhyodacite represents the inner igneous rock. Similarly, limestone and dolomite represent the Sedimentary aggregates. The sulphate resisting cement was obtained from Boral Cement Australia and complies with AS3972 as type SR.

The concrete was prepared by mixing aggregate (0.125 – 5 mm fraction), sulphate resisting cement (comply with AS3972 as a type SR cement) and water in the ratio of 2.25:1:0.47 (aggregate: cement: water). For each type of aggregates, four mortar bars were prepared using this mixture (based on ASTM C 1260). The experimental methods are separated into three sections: (a) Accelerated Mortar Bar Test, (b) Scanning Electron Microwave and Elemental Analysis and (c) XRD analysis.

3. Tests results

The changes in the expansion of the mortar bars with increasing immersion duration for all the samples. According to the Australian Standard, aggregate is classified as reactive if the expansion exceeds 0.1% in 14 days. The guideline specified by ASTM C1260 is shown as a solid grey block, where the expansion below the horizontal line (0.1%) is considered as non-reactive and above the line as reactive aggregates. Based on this test, Limestone and Rhyodacite aggregates exceeded the limit of 0.1% after 14 days of testing while Granite and Dolomite showed a lower value. Therefore, Limestone and Rhyodacite can be classified as reactive aggregate while the Granite and Dolomite can be classified as non-reactive.

The diffraction profile was indexed using an XRD. The XRD results showed that the peak intensity generally increased with time which is mainly due to the reaction between aggregates and cement, and an increase in the mineral’s crystallization. There were a few peaks which decreased in intensity with time. This can be attributed to the mineral’s growth or shrinkage in the concrete. The appearance of new peaks was observed which is due to the reaction between the existing minerals producing new reaction products with time

4. Conclusion

The reactivity of four different aggregates in cement mortar was studied using accelerated mortar bar test, SEM/EDS and XRD techniques. The test included periodic measurement of the length change of mortar bars and their microanalysis while immersed in 1M NaOH solution at 80° C. The accelerated mortar bar test showed that among four aggregates, Limestone and Rhyodacite were reactive while the Dolomite and Granite were non-reactive. The reactivity of the Limestone and Rhyodacite aggregate was further verified by the presence of micro-cracks and ASR gels during SEM/EDS analysis. Based on these tests, it can be concluded that mortars containing smaller size aggregates and a higher amount of quartz-rich aggregates are more susceptible to ASR. The amount of Silica in the Limestone aggregate was more than Dolomite aggregate which resulted in ASR. Similarly, Rhyodacite contains a higher amount of fine-grained quartz minerals than Granite aggregates which made Rhyodacite susceptible to ASR.

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