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INVESTIGATION OF POTENTIAL FOR ALKALI-SILICA REACTION IN GRANITIC AGGREGATES

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Abstract

Crushed granite aggregates due to good physical and mechanical properties are widely accepted for production of durable concrete. This kind of aggregates are considered as not alkali-silica reactive (ASR). However, all of them contain silica. In some of them SiO_2 occurs in a strained form or the crystals are small enough to be treated as microcrystalline, so they can be prone to ASR.

Various granite aggregates taken from largest exploited Polish quarries were tested. Petrographic analysis on thin sections and accelerated mortar-bar test were carried out to assess potential of the alkali-silica reactivity.

The petrographic analysis revealed differences in mineral composition of the tested granites. The strained quartz and microcrystalline quartz were the main potentially deleterious mineral in analyzed granite aggregates. Also the myrmekites were particularly visible in the granitic rocks. The results of the mortar-bar tests confirmed such predictions. The mortar beams showed expansion more than 0.1% after 28 days of exposition in 1M NaOH and 80°C. The bars made with RILEM cement showed fast and large elongation. In all cases the increase in mortar beam elongation was linear. The SEM-EDS analysis confirmed the presence of the ASR gel both, in the aggregate and in the matrix.

1. INTRODUCTION

Granitic rocks are known as good source of the aggregate for concrete due to their physical and mechanical properties. Nowadays, when the construction of concrete pavements in Poland started to develop significantly, granite aggregate is also used for the construction of roads with the highest traffic loads - motorways and expressways. A wide scale of concrete roads construction makes necessary to focus on the critical elements, which include proper materials selection. So the requirement for aggregate due to no susceptibility to alkali-silica reaction (ASR) is taken into consideration.

Granite aggregate is known in some countries to be non-potentially reactive to alkalis, but there are reported cases of alkali-silica reaction related to this kind of aggregates, [1]. RILEM recommendations from year 2016 describe granites as potentially alkali-reactive. Their potential is attributed to strained quartz from deformation, or poorly (micro-, crypto-) crystalline quartz, [2]. Earlier research carried out by [3] showed that besides the content of the microcrystalline and subgranulated quartz, the susceptibility to alkalis of granite aggregate might be increased by the presence of deformation in feldspars and in cleavage planes of muscovite and biotite crystals. Also myrmekite might enhance the potential for ASR, [1]. In the research of [5] myrmekitic quartz was included in the microcrystalline quartz group and considered as a potentially reactive form of silica.

The paper presents the results of the petrographic evaluation and results of the accelerated mortar bar test (AMBT) of four granite aggregates from Polish quarries. The microscopic analysis was conducted to prove the presence of the products of alkali-silica reaction.

2. MATERIALS AND METHODS

Petrographic analysis was conducted on 4 granitic aggregates (G1, ..., G4) from deposits from the south-west part of Poland. All analyzed aggregates were selected from larger population based on the appropriate physical and mechanical properties. Aggregates were impregnated with fluorescent epoxy and then cut, polished and lapped up to 20±2 μm. Thin sections were analyzed in a Olympus BX51 microscope using transmitted illumination in plane-polarized light (PPL), cross-polarized light (XPL), and XPL with λ plate (GXPL), as applicable. The petrographic analysis was focused on characterisation of potentially reactive forms of silica.

The AMBT tests were made according to RILEM AAR-2.1 standard method, [4]. According this protocol, the test method provides a means of screening aggregates for their potential alkali-reactivity. It may be especially useful for aggregates that react slowly or produce expansion late in the reaction such as granite. Criteria for the interpretation of the results of AAR-2 have not yet been finally agreed, [1]. However, it seems that results in the test (after the standard 16-days) of less than 0.10 % are likely to indicate non-expansive materials. In the research the test was extended up to 28 days to in order to evaluate if this type of aggregates show expansion with higher test durations.

Reference ordinary Portland cement CEM I 42.5R as reported in RILEM Recommendation was used. Na_2O equivalent was equal 1.12% and Blaine's specific surface 546 m^2/kg. The MgO soundness evaluated through Le Chatelier test was 0 mm. The granite aggregates were processed by crushing and sieving to the appropriate gradation.

3. RESULTS AND DISCUSSION

The petrographic analysis conducted on thin section allowed to classify the tested granites as: biotite granite (G1, G4), bimicaceous granite (G2) and a hornblende – biotite granite (G3). All analyzed granites mainly consisted of plagioclase, albite and K-feldspar, quartz and biotite. Granite G2 was characterised by mica's orientation, and contained also muscovite. Granite G3 contained also hornblede. The petrographic analysis revealed the presence of the potentially reactive forms of silica in each of the tested granites. Strain quartz, the microcrystalline form of quartz but also the myrmekites have been found, Fig. 1.

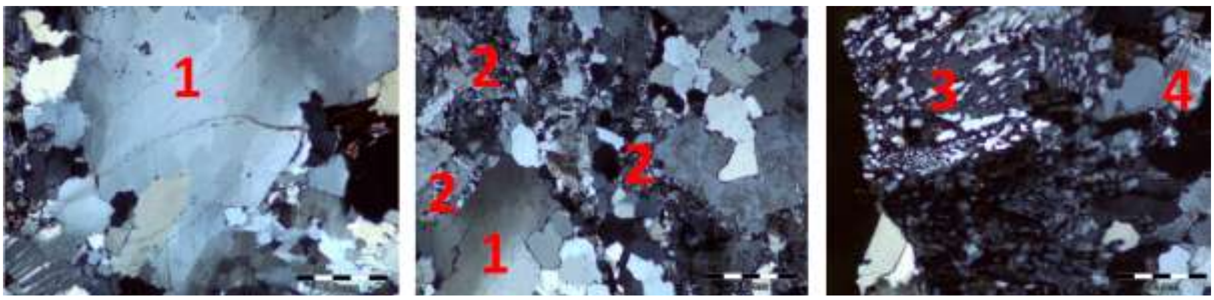

Figure 1. Examples of the potentially reactive forms of silica in analyzed granites:1- strain quartz, 2-microcrystaline quartz, 3- myrmekites, 4-K-feldspar, XPL, scale bar=500 μm

In the analyzed aggregates the presence of the myrmekites was particularly visible in the granitic rocks (G2).

Figure 3 presents the results obtained in AMBT for four granitic aggregates. As can be observed, no tendency for expansion stabilization was visible. All the tested granites showed continuous expansion of beams without any clearly marking the plateau or even decreasing of the degree of slope of the curve. The adopted trend lines showed an almost perfect straight line with R^2=0.99.

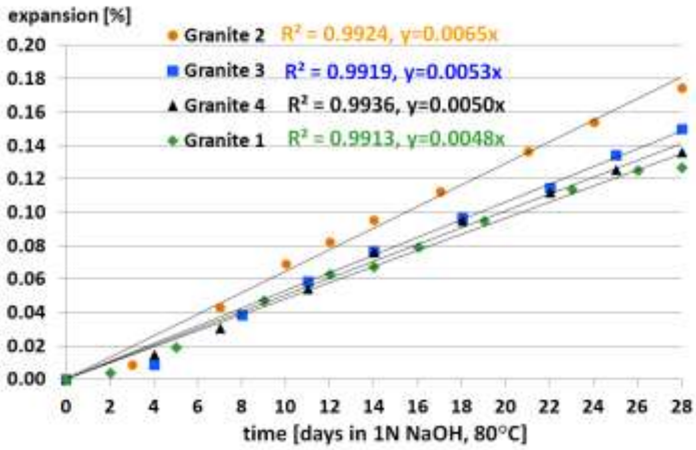

Figure. 2. Results of the mortar bars expansion stored in 1M NaOH and 80°C

The microstructure analysis was conducted after AMBT test. The SEM-EDS analysis revealed the presence of the ASR gel in all beams. The gel was present in quartz, and further moved to the matrix and air voids, Fig. 3.

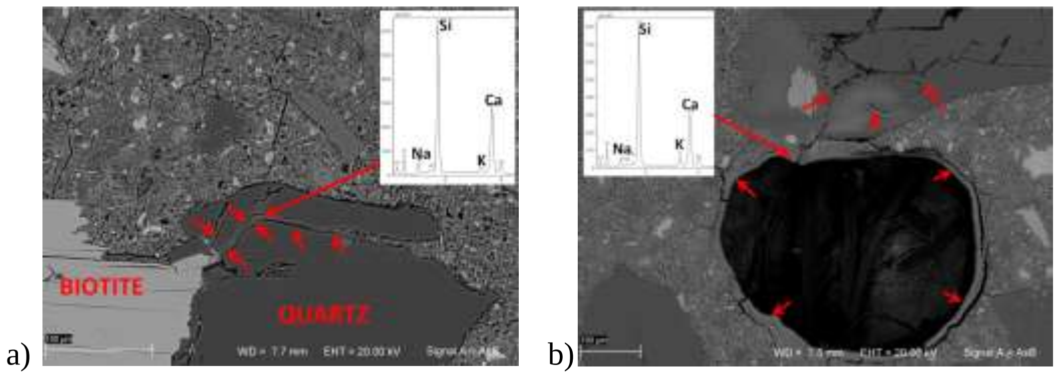

Figure 3. ASR-gel formed: a) in contact with biotite and quartz, b) in quartz, lining the air-void; SEM-EDS, scale bare=100μm

The results presented above have proven that ASR-gel formation has taken place in granitic rocks. The presence of strain quartz and microcrystalline form of quartz was visible on thin sections. The myrmekites were visible too, which could influence on the ASR potential. The final result of the myrmekitization process is the transformation of the primary minerals into concentration of clay minerals with the release of sodium and potassium ions. Alkali release from aggregates could enable ASR to occur even with low alkali cements. Also, the content of biotite and feldspar could influence on alkali-silica reaction acceleration. Biotite is able to rise the local micro pH, which should have an effect on silica dissolution in concrete, and feldspars have contributed to gel formation, as evidenced by their close association to gels as well as apparent dissolution phenomena, [6].

The results from the AMBT are in compliance with the results presented in [5]. According to the [5], in the AMBT the accepted limits are not enough to detect the reactivity of granites. In order to evaluate if this kind of aggregates show expansion, tests made on 10 different granites were extended until the expansion curve reaches the plateau. But after 6 months of testing the plateau wasn't achieved and any tendency for expansion stabilization was noticed.

4. CONCLUSIONS

The performed microscopic examinations revealed the presence of the forms of silica with potential for ASR such as strained or microcrystalline quartz. A myrmekites found in granite aggregates have also been identified. The result form AMBT after 14 days showed a poor correlation with the petrographic results, but the SEM-EDS analysis proved the ASR occurrence by the presence of the gel. The AMBT is assumed to be a quick test, but extending the test time to 28 days would allow a more precise determination of the reactivity of the granite aggregate.

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