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PETROGRAPHIC EVALUATION OF REACTIVE MINERALS IN SELECTED CRUSHED AGGREGATES IN POLAND

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ABSTRACT

The long term performance of concrete pavements can be reduced due to improper selection of aggregates, thus prevention of damage due to alkali-silica reaction (ASR) requires a detailed examination of minerals in aggregates. The amount of reactive silica in the aggregate is an important factor governing the severity of ASR, which depends critically on the nature of the reactive aggregate.

In the present study the potential for ASR in selected rocks in Poland was evaluated using petrographic methods. The tests were performed on crushed aggregates from different regions, covering a variety of rock origin and their geological structure. The optical microscopy in transparent light on thin sections was used as a principal tool to assess the mineral composition of aggregates. The content of reactive siliceous minerals was assessed. The petrographic examination concerned different forms of silica. Quartz grains were classified according to their mean diameter so as to identify the reactive range.

The application of the petrographic method allowed for classification of aggregate for ASR potential using RILEM recommendation. The results of the study allow to make a quick and responsible decision to direct the aggregates to further detailed tests, reject or accept them as concrete components for concrete pavements.

KEY WORDS

ALKALI-SILICA REACTION / POLYMINERAL GRAINS / PETROGRAPHIC ANALYSIS

1. INTRODUCTION

Over the past twenty-thirty years, the construction of concrete roads in Poland started to develop significantly, especially the roads with the highest traffic loads - motorways and expressways. Admittedly the first concrete motorway was made using whitetopping technology (covering of an existing asphalt road with a concrete layer), but nowadays, the two-lift concrete pavements with exposed aggregate layer are realized. At present, there are 120 km of concrete expressways under construction, and 800 km is planned to be built until 2023. Due to the anticipated high demand for aggregate, its relatively low price at the site of excavation/processing and usually a high price of transport, it is economically reasonable to use local natural raw materials. Such a large scale of concrete roads construction makes necessary to focus on the critical elements, which include proper materials selection.

Besides the fundamental requirements for physical properties like grain size, frost resistance or abrasion aggregates have to meet the requirement of no susceptibility to alkali-silica reaction (ASR).The first step to prevent ASR occurrence is an evaluation of the aggregates due to reactive components and if possible further avoidance of these aggregates or modification of mix design. Petrographic assessment is the first stage of aggregate selection. The characterization of the aggregates is based on the determination of the reactive forms of silica in order to classify the aggregate as innocuous or as potentially reactive (RILEM AAR-1).

The paper presents the results of the petrographic evaluation of the selected 19 crushed aggregates in Poland. All analyzed aggregates came from the same geological area and they belong to the Fennoscandian rock material. According to (Czubla et al. 2006) usually a simplified petrography of larger aggregate fraction is employed, whereas more advanced techniques, based on interpreting certain rock types of Fennoscandian provenience, are still rarely used in Poland. So the aggregates were selected due to the expected location of a new concrete road constructions and they were analysed on thin section. The result of the macroscopic petrography which was used to identify rock types and to determine the modal contents of rock types in coarse aggregates was presented in (Naziemiec & Pabiś-Mazgaj, 2017).

2. MATERIALS AND TESTING METHODS

Petrographic analysis was conducted on 19 crushed aggregates produced from glacial deposits from the north part of Poland. Eleven different aggregates were crushed from the glacial gravels (G1, G2, ..., G11) and 8 aggregates were cut from the single boulders (B1, B2, ..., B8). All analyzed aggregates were selected from larger population based on the appropriate physical and mechanical properties including grain size, shape, abrasion and frost resistance. Aggregates with insufficient degree of crushing (below C95/1), low strength or no frost resistance were not used for the further tests.
Aggregates were impregnated with fluorescent epoxy and then cut, polished and lapped up to 20±2 µm. The detailed manufacturing thin section procedure was previously described in (Jóźwiak-Niedźwiedzka et. al, 2015). 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, as applicable. The microscope was connected with an Olympus DP25 digital colour camera and automatic moving table Prior ES11BX/B.
The petrographic analysis was focused on characterisation of potentially reactive forms of silica. The presence of amorphous form of silica - opal, Si-rich volcanic glass, cristobalite, tridymite and chalcedony is supposed to be the principal reason for the reactivity.

3. RESULTS AND DISSCUSSION

All tested 11 aggregates originating from the crushed glacial gravels (G1, ..., G11) were characterised by great mineral diversity, Fig. 1. The various rock types were identified: limestone, granite, diorite, sandstone, mudstone, spongiolite, quartzite and siliceous rock (chalcedony-rich rocks). Small quartz crystals founded in the gravel aggregate were originated from re-crystallization of larger crystals. These small crystals were ca. 40-80 µm, which classified them as microcrystalline. According to (Alaejos & Lanza, 2012) quartz crystal size10–60 µm corresponds to reactive quartz and size 60–130 µm – to doubtful quartz.
Grains originating from quartzite and silica rocks were also found. Crushed gravel included strained quartz, which have ASR reactivity potential especially for granite, gneiss, argilite, greywacke, phyllite, mudstone and certain natural sands and gravels, (Farny & Kerkhoff, 2007).

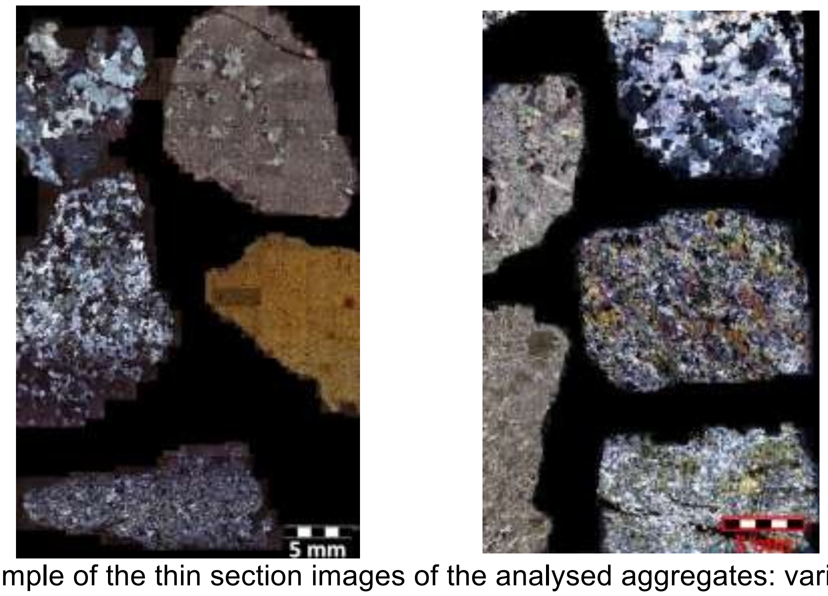

Figure 1 - Example of the thin section images of the analysed aggregates: various grains of crushed gravel from glacial deposits, XPL, scale bar = 5 mm

Aggregates from the single boulders (B1, B2, ..., B8) were classified as granite, granodiorite, granitoid, quartz-sandstone and cryptocrystalline metamorphic volcanic rock with acidic chemistry, Fig. 2. The main constituent minerals were silica (chalcedony) and chlorites.

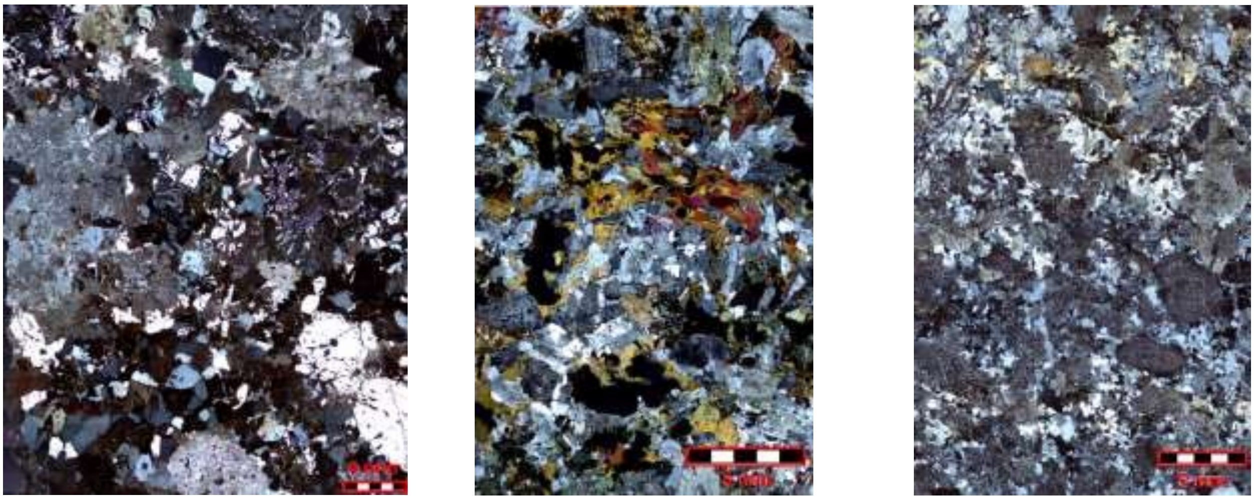

Figure 2 - Example of the thin section images of the analysed aggregates: homogenous aggregate from the single boulders, XPL, scale bar = 5 mm

In the analyzed aggregates the presence of the myrmekites was particularly visible in the granitic rocks from the single boulders, Fig. 3. The process of the myrmekitization is the most common process observable in the aggregates from northern Poland (Naziemiec & Pabiś-Mazgaj, 2017). The formation of “verrucous” overgrowths of plagioclase and vermicular quartz at the contact between potassium feldspars and plagioclases occurs often in granitic rocks, like granites, gneisses and others. 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 (Constantiner & Diamond, 2003). Additionally, it is known that if the quartz in myrmekite is fine-grained, it could be prone to develop deleterious ASR (RILEM 2016).

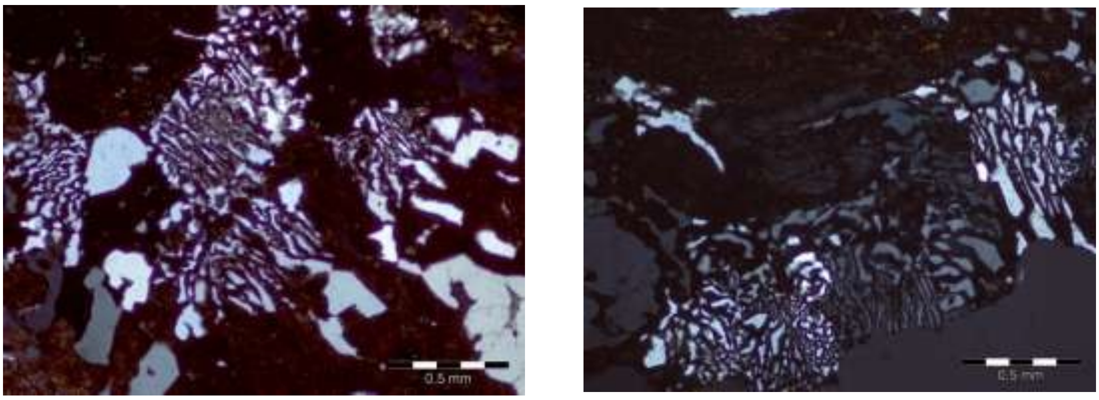

Figure 3 - Image of the aggregates from the single boulders (examples of the myrmekites), XPL; scale bar = 0.5 mm

All analysed particles of crushed gravel from glacial deposits and fragments of larger single boulders included strained quartz and small crystals of quartz of up to ca. 80 µm in size, classifying as microcrystalline material. Moreover, not only the aggregates originating from the crushed glacial gravels but also the single boulders from glacial deposits were found to be composed of a large variety of rock material including granite, granodiorite, quartz-sanstone and cryptoctystalline amorphous rock built primarily of silica (chalcedony). The myrmekites in the granitic rocks from the single boulders were also found. When crushed aggregates both, from glacial deposits or from single boulders are used in concrete technology the risk of alkali-silica reaction should be taken into account, with particular regard to concretes for infrastructure facilities.

4. CONCLUSIONS

Identification of deleterious constituents in the mineral composition of aggregates was limited to determining the content of reactive silica minerals. The performed microscopic examinations revealed the presence of the forms of silica with potential for aggregate-silica reaction such as chalcedony-rich rock. Also strained quartz and myrmekites were found in the analysed thin sections . According to the RILEM classification of reactivity potential seventeen of them are Class II and two is Class III aggregates: cryptocrystalline metamorphic volcanic rock with acidic chemistry and an aggregate built entirely of cryptocrystalline silica with chlorite.
In one aggregate the fragments of silica, chalcedony-type rocks included chert – a silica rock forming in limestone rocks and spongiolite – a sedimentary silica rock built mainly of opal and chalcedony has been found, and fourteen of the analysed aggregates included quartz crystals smaller than 60 µm and thus classifying as microcrystalline material.
In accordance with the requirements of RILEM and on the basis of results of the performed petrographic analyses further laboratory tests are required for all the nineteen aggregates due to a threat of reaction with sodium and potassium hydroxide.
It should be taken into consideration the localisation of the particular deposit. The alkali reactivity issue should be considered and analyzed not globally, but locally.

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