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The role of lithium compounds in mitigating alkali-gravel aggregate reaction

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HIGHLIGHTS

- Factors that affect the reactivity of polymineral glacial gravel aggregates were determined.
- The benefits of lithium nitrate to mitigate alkali-aggregate reaction were evaluated.
- The microstructure of the reaction products in mortars modified with lithium nitrate was studied.

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ABSTRACT

Alkali reaction with reactive aggregates is an example of concrete internal corrosion. Cracks and damage to elements of a concrete structure are the result of the formation of an expansive alkali-silica gel. One of the ways to minimise the effects of this damaging reaction is to use lithium compounds as an admixture to concrete mixes. Lithium ions are believed to reduce the reaction between the alkalis and aggregate or minimise damaging expansivity by modifying chemical composition of the reaction products.

This paper presents the results from the tests carried out on mortars from reactive polymineral gravel with lithium nitrate according to the modified ASTM C1260 standard and ASTM C227. The findings show that lithium ions decrease mortar expansion until it reaches the levels markedly lower than those set out in the standards. A considerable reduction in the number of microcracks may indicate either lower swelling capacity of the gels or reduced reactivity of the aggregate, leading to the reduction in the quantity of damaging expansive products.

1. Introduction

One of the causes of concrete deterioration is the reaction between siliceous aggregates and alkalis in the cement. Reactive aggregates contain reactive forms of silica which enter into reaction with sodium and potassium hydroxides quickly – opal, tridymite, cristobalite, acid volcanic glass – and those which react slowly – chalcedony, cryptocrystalline quartz and strained quartz [1]. Alkali reactivity of aggregates depends on their geological origin, mineralogical composition and texture. Identification of the factors that affect the gravel reactivity is difficult, and due to its polymineral character, qualitative and quantitative analyses of reactive constituents have to be performed to be able to choose proper methods for reducing reactivity potential. Gravel aggregate are commonly used in concrete, thus the minimisation of the alkali-aggregate reaction effects is critical [2].

The idea that lithium compounds can be used to mitigate negative effects of the aggregate reaction with sodium and potassium hydroxides first appeared in the 1950 s. Having conducted a comprehensive investigation on the inhibition potential of over 100 different compounds, McCoy and Caldwell reported lithium compounds to be most effective [3]. Worldwide interest in the lithium-bearing compounds has found lithium nitrate, used as a replacement for mineral admixtures, to have the highest effectiveness in preventing negative effects of alkali-aggregate reaction [4–7]. It has been demonstrated that this neutral and well soluble salt does not raise the pH value of the solution in the concrete pores, thus eliminating the risk of the pessimum effect [8]. Inappropriate doses of lithium ions in the form of lithium carbonate and lithium hydroxide lead to increased expansion and are deleterious to concrete, as observed by Diamond and Ong [9], Kawamura and Fuwa [10] during their studies of mortars containing LiOH and Li_2CO_3. The lithium compound introduced ions introduced into the

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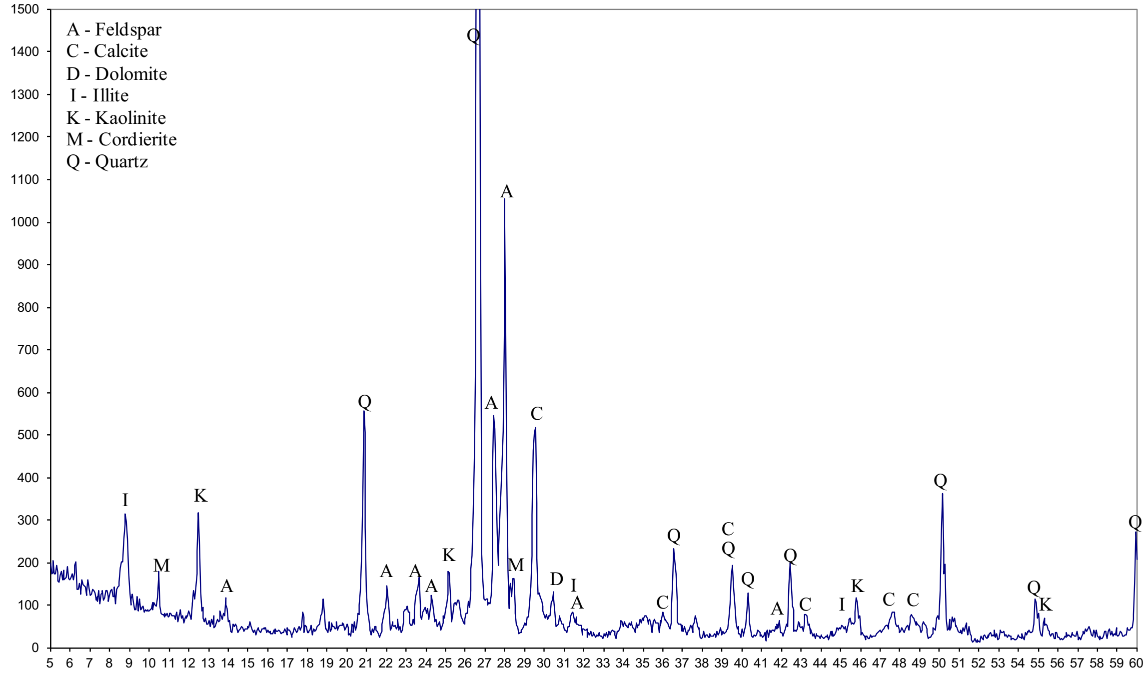

Fig. 1. XRD diffraction pattern of gravel aggregate.

concrete mix is thus of great importance. According to Feng et al., the effectiveness of lithium ions may vary for aggregates with different reactivity levels [11].

Several mechanisms of the reaction in the presence of lithium ions have been proposed. Some of them are based on increased stability of silica due to reduced pH of pore solutions or a change in their chemical composition [12]. It is presumed that amorphous or crystalline products containing silicon and lithium may form on the surface of reactive silica grains [13], acting as a protective barrier against Na^+ and K^+ ions. Other reaction mechanisms, not related to the Li^+ induced increase in silica stability, focus on the modification of the resulting gel products with lithium ions, rendering the modified gels less capable of swelling than traditional gels [13,14]. Crystalline lithium silicate may also form on the surface of the reactive silica. The literature reports the effect of Li^+ ions on the increased solubility of silica, which remains in the solution and prevents the gel from swelling [15].

2. Materials and methods

2.1. Aggregates

Polymineral glacial gravel aggregates, 0/16 mm, from the northern regions of Poland were used. Fig. 1 shows the results of the X-ray analysis. The aggregates tested contain large amounts of quartz, calcite and plagioclase series with albite and anorthite, and lower amounts of clay minerals (illite, kaolinite) and dolomite.

Mass loss results from the aggregate fraction measurements conducted according to PN-92/B-06714-46 [16] and the results for silica leachability according to ASTM C289 [17] classify the gravel aggregate as potentially reactive (PN-92/B-06714-46) and reactive (ASTM C289) (Fig. 2a, b).

Those aggregate grain types, identified in macroscopic observations, which showed the greatest mass loss in the potential reactivity evaluation were subjected to a petrographic analysis. The following reactive components were found using an optical microscope: organodetritic sparite – micrite limestone, metamorphic quartz pyroxene shale with opal cement, quartz – glauconite sandstone with clay-carbonate binder including some chalcedony, and quartz grains in feldspar – biotite granite. Three main constituents, chalcedony, opal and strained quartz, are probably responsible for the reactivity of the aggregate. Table 1 shows the analysis of the quantitative composition of minerals in the aggregate.

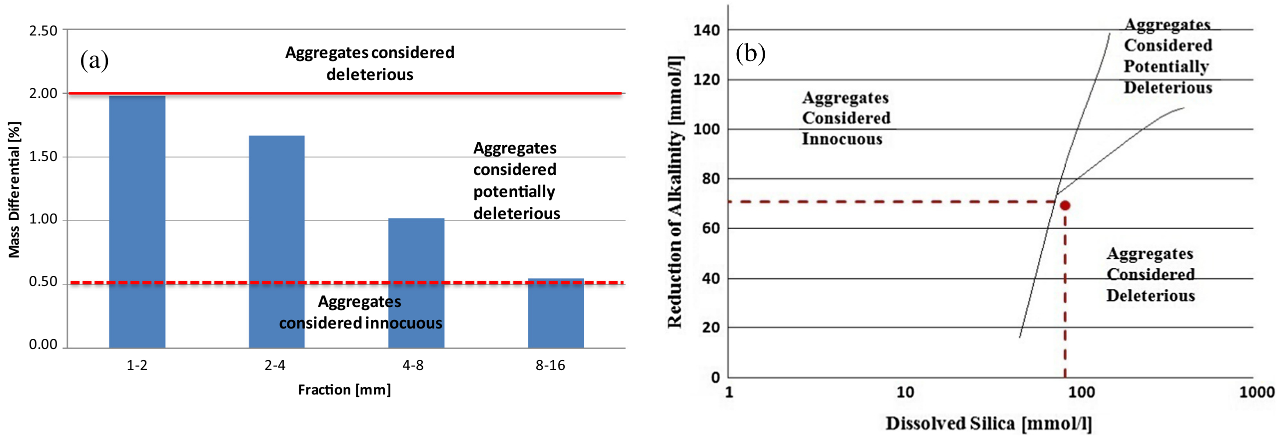

Fig. 2. Reactivity Of Gravel Aggregate According To Specifications (a) PN-92/B-06714-46 (b) ASTM C289-94.