Alkali-Aggregate Reactivity Investigations in Poland— A Review

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Abstract

The paper presents the results of investigations covering twenty six deposits of limestones varying in age and twelve deposits of dolostones and dolomitic limestones, as well as twenty deposits of sandstones and chalcedonite. The research included also ten deposits of gravel aggregates from postglacial formations. Few of them have proved to be alkali reactive.

Introduction

Modernization of cement kilns has led to higher alkali levels in Polish cements. Glacial gravels, one of the main sources of aggregates in Poland, contain reactive rocks. Some dolostones, limestones, sandstones, basalts and siliceous rocks also appear to be reactive and can cause concretes containing high alkali cement to deteriorate at a fast rate. Up till 1960, Polish cements contained, on an average, 0.40% of alkalies. A change from wet to dry process kilns resulted in the average alkali content in cements rising to 0.9%, and when electrofilters were added and alkali recycled together with the dust, alkali levels increased to as much as 1.55% . In 1968 research was commenced on possible problems associated with the use of crushed rock as aggregate in concrete. In the seventies, in Poland as elsewhere, a rapid increase in the number of cases of damage to concrete due to alkali-aggregate reactivity was observed.

Methods of Investigation

Standard petrographical and analytical methods were used to characterize the rocks and gravels. In addition to changes in weight, apparent density, water absorption before and after soaking the samples in Na OH solution was determined, Fig.1. The ASTM C-586 test was also done along with length change measurements of prisms, in 1 N Na OH and in an autoclave for 21 days at 110°C and 1.75 atm Vredenburgh method . An increase in length by more than 0.15% indicates excessive expansivity. Test conditions were severe so that porous silica rocks, silicified limestones and cherts often underwent a process of deformation, if not even decay. Expansion of powdered rock was measured in a dilatometer (Gillott 1969). Some results are shown in Fig. 2. Expansion of ASTM C-227 mortar bars is shown in Fig.3. Fig.4 illustrates the effect alkali content of cement has on the expansion of mortar bars stored according to ASTM C-342. Scarcely any correlation was observed between expansion according to ASTM C-227 and according to ASTM C-342. The ASTM C-227 ought to be employed, when dedolomitization reaction is probable and silica content in the aggregate is not high. With more silica present in the aggregate, bars ought to be tested according to ASTM C-342; then, some silica leaches into the water, but sufficient remains in the concrete to give rise to expansion. Deformation, warping and cracking of bars is also possible. Aggregates were also tested as concrete prisms /10x10x50cm/. None of the samples showed excessive expansion, even though the mortar bars tended to expand. It seems that the thickness of these bars was not suited to this type of test.

Discussion of Test Results in Rocks

Limestones, (Penkala B., 1969 and 1974-76); Twenty two deposits of Devonian, Jurassic and Triassic compact very fine grained limestones (apparent density from 2.21 to 2.71 g/cm^3) have been tested. They contained from 0 to 5.35% of dolomite, 0.76 to 1.14% of the silica, and 0.68 to 4.74% of the HCl-insoluble matter. They were all non-reactive, or only slightly more reactive than the Morawica limestone. The limestone from two deposits of the Jurassic Age had more dolomite, viz. 10.65 and 13.29%, silica 13.35% and 19.45% respectively, and 16.0 and 21.75% HCl-insoluble matter. Their linear changes according to ASTM C-586 ranged from -0.12 to +0.075%; and from +0.06 to +0.076% when tested by the Vredenburgh method. The reactive carbonate rocks usually contain a few per cent of clayey minerals and small sized isolated dolomite crystals in a microcrystalline mass of calcite. There were also four deposits of extrafine-grained, porous, white Cretaceous limestones. Their apparent density was 1.32-1.59 g/cm^3; they looked silicified and contained 2.31-46.26% of the silica, chiefly as opal, and 0.92 to 3.28% of the dolomite. Length changes according to ASTM C-586 ranged from 0.40 to 0.45%. Tested according to Vredenburgh method the specimens underwent a process of deterioration. They were very reactive.

Dolostones; Twelve deposits of the Devonian, Triassic and Jurassic dolostones and dolomitic limestones were subject to testing. These were fine-grained compact rocks; their apparent density was 2.32-2.84 g/cm^3. Three of them contained 64.70 to 77.75% dolomite, the remaining ones 80.54 to 89.55%. Three of them proved to be alkali reactive, viz. Korzecko IV, Brzeziny, and Zachełmie. Their linear changes according to ASTM C-586 ranged from 0.175 to

2.025% and 0.126-1.82% according to the Vredenburgh method.

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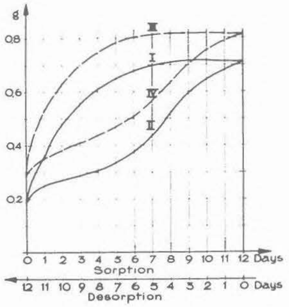

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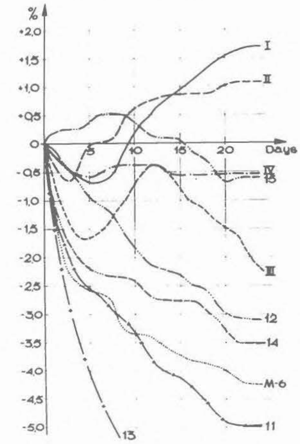

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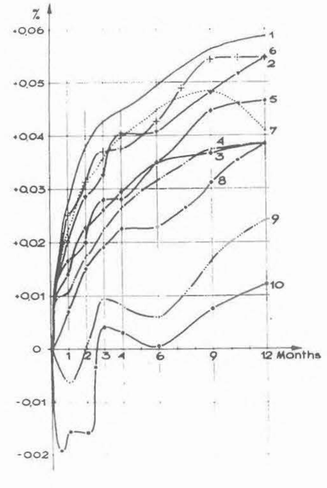

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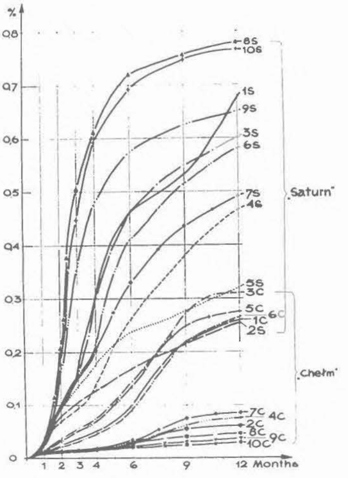

Figs.: 1 - The sorption and desorption curves of the Morawica limestone; I,II - natural state, III and IV after exposure to NaOH. Fig.2 - Changes in the volume of rocks after exposure to NaOH in a powdered state: limestones M-6,11,13,14,15 and dolostones I,II,III,IV,12. Fig.3 - The graph of linear changes for mortar bars, ASTM C-227, with Portland 350 Saturn cement (alkali 1.15% as Na_2O)and ten fine-grained glacial aggregates. Fig.4 - Graph of linear expansion of mortar bars, ASTM C-342, with Portland 350 Saturn and Chełm cements (alkali 0.64% as Na_2O) using the same ten aggregates as in Fig.3.

Sandstones, (Penkala B., 1976-76); The testing included five deposits of the Carpathian Flysch Cretaceous sandstones containing 0.64 to 12.13% of dolomite and 17.1 to 111.5 mmol/l of active silica. Two of these sandstones showed (ASTM C-585) an expansion of 0.025 to 0.125%. Examined by the Vredenburgh method, the specimens expanded excessively (0.138 to 0.579%). Three deposits were recognized as being weakly reactive. Six deposits, from the Devonian, Cambrian and Ordovician, have also been tested but demonstrated only slight alkali reactivity. Two deposits of the Triassic ferruginous sandstones also proved weakly reactive. Six deposits of Jurassic sandstones were also weakly reactive.

Siliceous rock-chalcedonite; of the Jurassic Period. The silica is present in it in the form of very fine grains, or as a fibrous-looking quartz and amorphous silica in the opaline condition. There are two main varieties of chalcedonite in the bed. One of them, cohesive, being non alkali reactive, Fig.5, and the other - an alkali-reactive porous variety, Fig.6.

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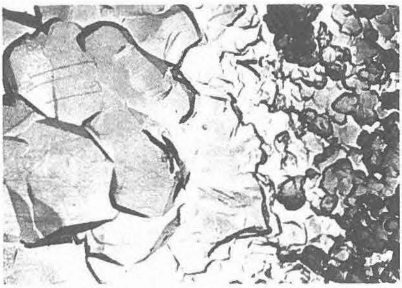

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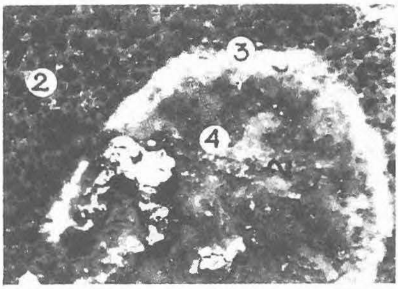

Fig.5: Non-reactive chalcedonite. Fig.6: Porous reactive grain -1 of chalcedonite in the mortar - 2, reactive zone - 3, infiltrations of silicate - 4.

Gravel aggregates, (Penkala B., et al., 1974-76); Natural aggregates in the Polish Depression postglacial formations represent petrographically material of Scandinavian origin, including also rocks of the surrounding area. Dominant in it are the Palaeozoic and Jurassic hard limestones and magmatic crystalline rocks, e.g. granites, porphyries, diabases and amphibolites. There are also Cambrian and Devonian sandstones. The dolostones and Cretaceous limestones represent a less important constituent. The potentially reactive rocks include: certain sandstones, limestones. dolostones and flints, quartzites, diabases and Cretaceous limestones, and marles. Sandstones cemented by silica and opaline silica in limestones are non-resistant to alkali. The content of silica in rocks tested (ASTM-C289) falls between 11 and 38 mmol/l. The reduction in alkalinity Rc of 158.0 to 447.3 mmol/l shows no correlation with the content of silica in the rocks. To check the behaviour of concretes, three Portland 350 Nowiny II (1.29 as Na_2O), Saturn (1.15 as Na_2O), Chelm (0.64 as Na_2O) cements were used with ten gravel aggregates in mortars and concretes. For results of the 12-month length-change test (ASTM C227) on Saturn cement mortar bars refer to Fig. 3

An ASTM C-342 test was also carried out, see Fig.4. Mortar bars in dry air laboratory conditions showed after one year a shrinkage of 0.074 to 0.128%, with no perceptible changes on bar surfaces. Bars with high-alkali cements stored according to ASTM C-227 had appreciable surface changes after 2 months, e.g. numerous white and dark spots, outflows, extrusions of colloidal alkali silicates plus occasional irregular scratches and losses on the edges, and deformation. Bars containing Chełm cement, stored according to ASTM C-227, demonstrated less unfavourable changes. No changes were found in mortar bars made with Chełm, Nowiny or Saturn cements and tested according to ASTM C-342 for eight deposits. Bars with two deposits only underwent deformation. Spots, leaks of the dark colloidal silica as well as tiny scratches, fissures filled with gel and cracked swollen aggregate grains could be seen on the surfaces of reinforced large-panel precast units subjected to thermal treatment (Penkala B., 1979). All those symptoms point to an alkali -silica reaction process taking place in the concretes.

Conclusions; Systematic alkali-reactivity tests of mineral aggregates to be used as concrete aggregates must be conducted to assess their degree of reactivity. When potentially reactive rocks are likely to occur in aggregates, concrete made with them should contain low alkali cement.

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