REVIEW OF UP TO DATE INVESTIGATIONS OF ALKALI REACTION IN CONCRETE WITH AGGREGATES FROM BASIC SOURCES IN SOME REGIONS OF YUGOSLAVIA

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Although the alkali-aggregate reaction phenomena have been known for more than thirty five years, first investigations in this direction have been carried out in Yugoslavia as late as 1960 year. To the necessity of testing materials for possible alkali-aggregate reaction first pointed out Institute for Testing Materials in Beograd, during preliminary testings of concrete and concrete components, which had to be used for building a large gravitational dam on the river Drina**.

By these preliminary investigations has been established that cements which were available for this object had an alkali content of more than 0.6 % and, by the mineralogical analysis of perspective aggregates from sources closest to the object, has been found that the percentage of chert in different fractions of aggregates is from 2 % to 11.5 % (Table 1).

Table 1

Fraction, mm	Chert content, percents		
	Excavation site 1	Excavation site 2	Excavation site 3
2-8	9.3	2.4	5.2
8-16	11.5	10.4	5.2
16-63	6.8	2.6	2.0
63-150	0	0	0

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** Drina is the major tributary of the river Sava, with the lenght of more than 300 km and with the river basin area of about 20,000 km^2.

Data presented had shown that further investigations,to prove wether an alkali-aggregate reaction is taking place, should proceed.

Investigations which were carried out are as follows:

1. Testing of alkali reactivity of chert by a fast chemical method, according to ASTM C 289-58 T.

2. Investigation of cherts structure by X - ray difraction method.

3. Testing of chert activity, according to the Yugoslav standard B.C 1.018 (Standard for testing activity of pozzolan).

4. Investigation of chert activity, by the accelerated method of cement resistance to sulphate corrosion testing (Method I.I. Karpinski *).

First two testing methods are common procedures to identify harmfull ingredients in an aggregate which could possibly produce tne alkali-aggregate reaction. Investigations by 3 and 4 were not used for identification of alkali-aggregate reaction before, but it have been chosen as additional proofs fo the possible chert reactivity.

Investigations by the method 3 were carried out by making mortar probes with grinded chert (separated from the aggregate) and comparing its compressive and flexural strenghts with strenghts of corresponding probes made with grinded quartz sand and grinded pozzolan opaline breccia. All these materials were grinded and sieved to the fineness better than 90 μ .

Results of this test are given in the Table 2.

* Karpinski I. I. Augmentation de la resistance à la corrosion du micro-beton par la substitution limitèe calcaire dans le granulat quartzeux. - Revue des materiaux No. 568 (1963).

Table 2

Series of probes	Compressive strenght kp/cm^2	Flexural strenght kp/cm^2
R	0	0
K	0	0
OB	172	41.5

R - Mixture of grinded chert with hydrated lime and standard sand.
K - Mixture of grinded quartz sand with hydrated lime and standard sand.
OB - Mixture of grinded pozzolan opaline breccia with hydrated lime and standard sand.

Investigations by the method 4 were carried out by comparative measurements of weight loss of mortar prismes (4x4x16 cm). Test probes were subjected to cyclic submersions into the saturated solution of Na_2SO_4 and drying periods on 30°C and 50 % relative humidity. Four series of probes were prepared. All probes were made of mortar 1:3 (cement:standard sand) and with W/C = 0,50.

- Series KT
  Portland cement with 25 % of cement substituted by grinded quartz sand.
- Series KU
  Portland cement with 25 % of cement substituted by grinded chert (separated from an aggregate).
- Series KW
  Pozzolanic cement (the same Portland cement as for other series with 30 % opaline breccia). 25 % of cement substituted by grinded quartz sand.
- Series KX
  Pozzolanic cement with 25 % of cement substituted by the grinded chert.

All probes were cured for 28 days in water before the actual testing. Mechanical characteristics tested were after 28 days as follows in the Table 3.

Results of accelerated corrosion tests are given in diagrames 1 and 2.

Table 3

Series of probes	Compressive strenght kp/cm^2	Flexural strenght kp/cm^2
KT	238	39.3
KU	237	38.3
KW	204	35.6
KX	210	41.3

On the basis of all methods presented has been concluded:

- The aggregate is not reactive according to the first method (ASTM C 289-58 T). This, by results obtained by other autors, is not allways corresponding to the real behaviour of the aggregate in concrete and it can be inconsistent with results of the other testing methods.

- Investigations by the X - ray difraction are showing the crystal structure of chert, which correspond to the α - quartz.

- The finely grinded chert is not showing any activity, based on activity tests, and its behaviour is the same as that of the pure quartz sand grinded to the same fineness in composition with the hydrated lime, while control experiments with the pozzolan opaline breccia are showing an activity corresponding to the 170 kp/cm^2 compressive strenght of probes.

- The same conclusion can be obtained on the basis of testings by the method 4. From tests results could be established that the series KU, in which 25 % of the cement was substituted with the finely grinded chert, had not shown any retarding effect to the deterioration of probes in the agressive solution compared to the series KT, with 25% of grinded quartz sand. This conclusion is valid also for series KW and KX.

Since all conclusions are consistent, it was established that the aggregate from the river Drina basin is not reactive.

Few years after these initial investigations started broader testings of aggregates from Drina basin, both upstream and downstream from the dam mentioned. These testings, although not performed in a small scale, are still not completely systematic. However, results gave sutable data about reactivities or nonreactivities of aggregates obtained from various locations along the river. Besides the other points, it has been demonstrated that aggregates from various deposits close to the mouth of Drina and downstream from the dam mentioned are potentialy reactive, so that an aggregate from this region should be tested before its use as a concrete component.

In the future, during the next few years, investigations about reactivity of gravel and silicate aggregates along the river Drina will be completed and systematized to obtain complete survey of aggregates behaviour from the Drina basin.

Some incomplete and local investigations of aggregates reactivities were performed in various parts of Yugoslavia, in much smaller scale. Systematic investigations started two years ago, with aggregates from the river Velika Morava* and along the whole river basin of Velika Morava. These investigations are proceeding and will be completed in few more years.

Investigations were proposed and programmed by Institute for Testing materials, which is carrying out the whole programm. Investigations are including testings of very numerous samples of aggregates from many separations along the Morava basin. Aggregates, which are of the silicate origin, are subjected to complex testings, including mineralogical investigations, investigations by the chemical ASTM method, investigations on mortar probes and, in the further phase, testings on larger concrete specimens. Together with laboratory testings will be investigated behaviour of concrete objects, which in the past were builded with aggregates from the same origin and which are subjected to conditions favorable for the development of alkali-silicate aggregate reaction in concrete.

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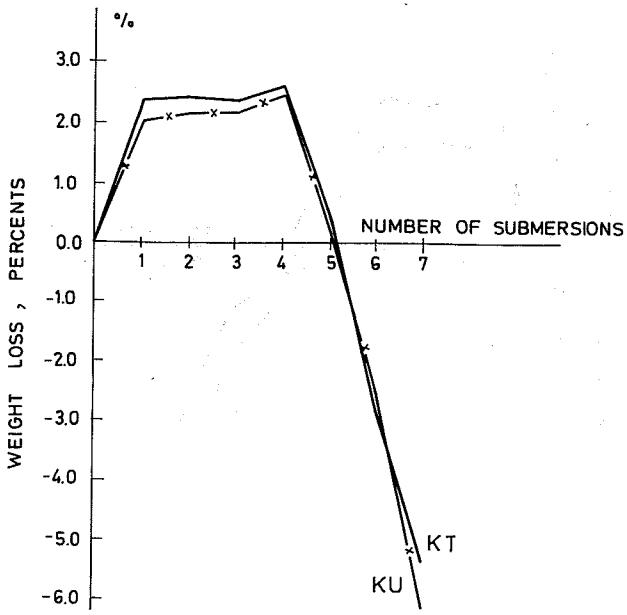
* Velika Morava is a Danube tributary, with the lenght of 215 km and with a river basin of 36,000 km^2.

It has to be stated that up to date, in Yugoslavia were not observed any damages, due to alkali-silicate aggregate reaction, in concrete objects.

First results of complex investigations of aggregates from Velika Morava basin are indicating that it is a potentially reactive material. If it will be confirmed during the further investigations and so if aggregates are reactive wihout doubt, it will be necessary to prevent alkali-aggregate reaction in concrete objects builded with such aggregates. It will be a very difficult task, since Velika Morava basin is one of the basic sources of aggregate in this part of Yugoslavia and up to now its use in concrete objects building was quite successfull.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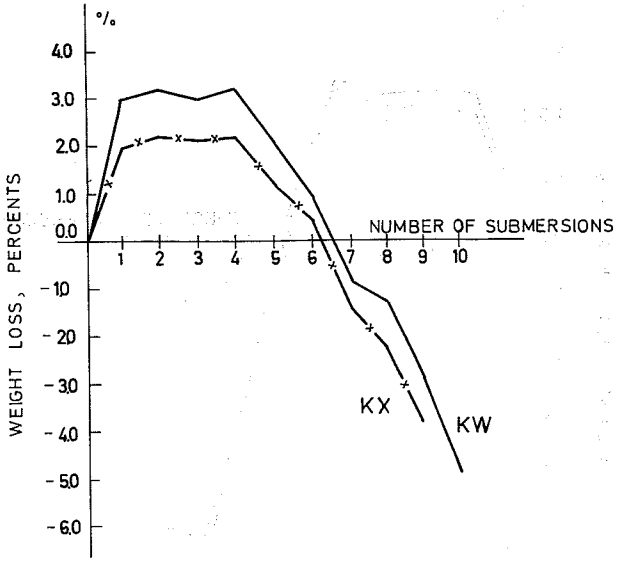
WEIGHT LOSS , PERCENTS
NUMBER OF SUBMERSIONS
1
2
3
4
5
6
7
KT
KU

DIAGRAM 1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WEIGHT LOSS, PERCENTS
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2
3
4
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6
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8
9
10
KX
KW

DIAGRAM 2