Study of Potential Alkali-Silicate Reactivity of Aggregate from Fluvial Deposits in Serbia (Yugoslavia)

Slobodan Cmiljanić and Mihailo Ršumović
The Highway Institute
Belgrade, Yugoslavia

ABSTRACT

Fluvial deposits in rivers, which drain terrains in Serbia, contain sandy gravel with grains of amorphous silica. Several variants of chert are separated with different contents of amorphous silica. Amorphous grains of minerals and rock are in most cases recrystallized and appear in more stabilized forms. Petrographic investigations and chemical tests, according to ASTM C 289, show that harmful alkali - silicate reaction, may occur with some of river aggregates. The results of investigation, according to ASTM C 227, have shown that linear expansion on mortar prisms is proportional to the content of alkalies only. Traces of the products of alkali-silicate reaction were observed.

1. INTRODUCTION

Alkali-silicate reactivity of aggregate in Yugoslavia has been investigated for the last 25 years. In the first work, published in our contry, *(Maksimović et al.,1962.)*, estimated that aggregate from one source contained 15% of chert and may be harmful, but the results of the chemical test according to ASTM C 289, showed them to be innocuous.

It must be underlined, that in Yugoslavia up until the present, no cases of deterioration of concrete due to alkali aggregate reactivity have been reported, but this does not mean that they have not occurred. In March 1984, The Highway Institute organized the first national conference on this topic, at which the results of investigations in Yugoslavia were presented. Numerous investigations presented at the The Highway Research Institute conference in 1984 showed that many aggregates contain potentially reactive components.

Fluvial deposits from rivers, which drain terrains of green volcanic rock, terrains of intensively hydrothermal altered rocks, and also more altered silicate rocks, contain sandy gravel with grains of rock and amorphous silica. The above mentioned rocks occur mostly in eastern parts of Yugoslavia, in Serbia.

In this paper the results of a two-year systematic investigations of aggregates from river sources in Serbia are reported and the deposits and their possible influence on alkali-silica reactivity in concrete is discussed.

2. MATERIALS AND PROCEDURES

Sandy gravel was picked up from river sources, which are exploited, from largest rivers *(Danube, Velika Morava, Drina, Western Morava and Southern Morava)*. These rivers drain, almost all the surface of Serbia (about 50 000 km^2), FIG. 1.

Natural gravel deposits were investigated by separating the different size fractions and studying them. Particular emphasis was placed on studying the quartz and chert grains. Analysis was carried but by means of petrographic studies, x-ray diffraction and testing according to ASTM C 289 and ASTM C 227. Microscopic analysis and x-ray diffraction were carried out on the same samples which were finely ground.

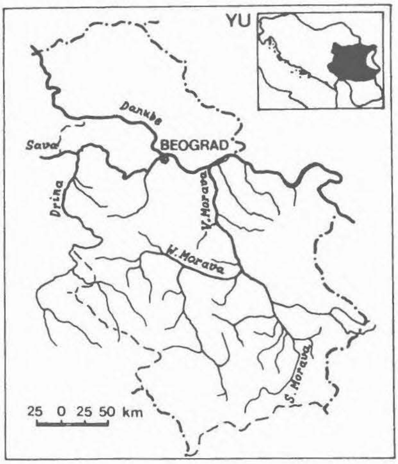


FIG. 1 Map of investigated river deposits in Serbia.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Mineralogical-petrographic investigations, on aggregates from river sources in Serbia, have shown that they have a heterogeneous composition. The content of particular grains of minerals and rock varies. Grains of silica and silicate rocks are predominant, namely quartz, sandstone, chert, gneiss, andesite and dacite, and less often grains of serpentine peridotite *(W.Morava)*, limestone *(Drina, Danube, S.Morava)* and granular diorite *(Danube)*. The content of mineral grains with amorphous silica varies with the particular fractions of aggregate, samples from *W.Morava* (2-25%), *S.Morava* (1-21%), *Velika Morava* (2-10%), *Drina* (3-33%) and from *Danube* river terraces (3.5-12%). Investigations have shown that potential alkali reactive silica grains, in most cases, appear in form of chert, then chalcedony and less often opal.

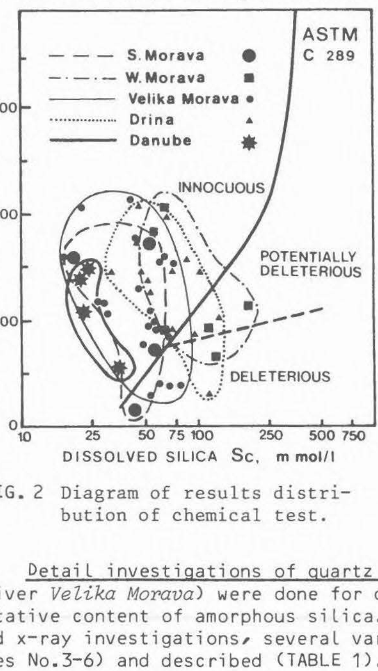


FIG. 2 Diagram of results distribution of chemical test.

Chemical tests, for potential alkali-silicate reactivity of aggregate, from the above river sources, according to ASTM C 289, have shown that some gravel samples from rivers *W.Morava, S.Morava, Velika Morava and Drina* may be considered as harmful for concrete. A great many samples were investigated. In Figure 2, are shown the test results for particular rivers. The volume of soluble silica (Sc) is proportional to percent of opal in the aggregate.

Detail investigations of quartz and chert grains, from aggregate "Moravac" (river *Velika Morava*) were done for determination of the qualitative and quantitative content of amorphous silica. On the basis of petrographic, chemical and x-ray investigations, several variants of chert are separated (FIG.3, samples No.3-6) and described (TABLE 1). We have presumed that the surface appearance of grains reflect their internal structure and texture and also partly their genesis.

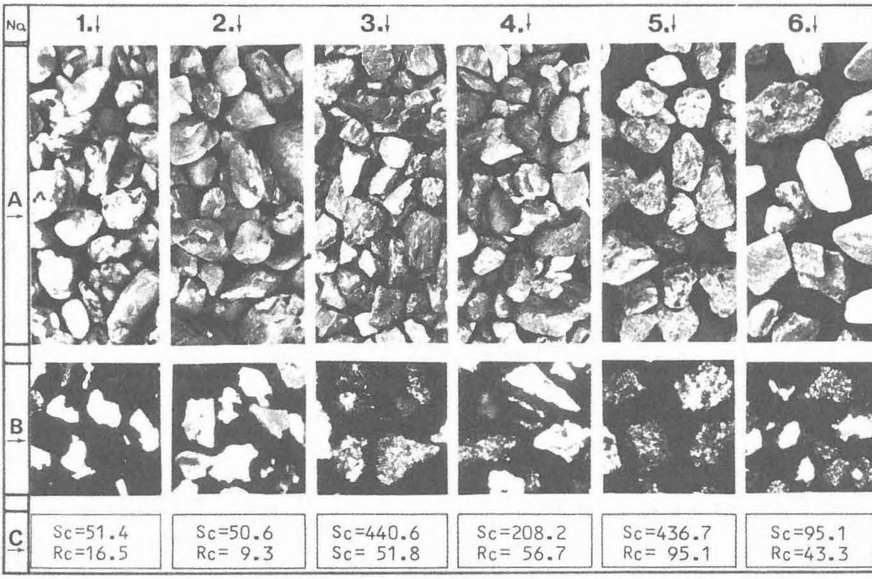


FIG. 3 A) Typical grains of quartz and chert in gravel from river *V.Morava;*
B) Thin sections of grains viewed with a petrographic microscope.
C) Results of chemical test ASTM C 289 (Sc and Rc in m mol/l).

TABLE 1

No.	MACROSCOPIC DESCRIPTION	MICROSCOPIC ANALYSIS	
1.	Quartz-white; grain surface fine rough; milk white coloured; ball -like form of grains, less often longish and slate-like.	Quartz grains .... Quartzite grains .... Cryptocrystalline quartz grains .. Chalcedony grains	85% 8% 4% 3%
2.	Quartz-transparent-clear; grain surface fine rough; yellowish -white and grey coloured; round grains, ball-like.	Quartz grains .... Quartzite grains .... Chalcedony grains .... Cryptocrystalline quartz grains ..	80% 8% 8% 4%
3.	Chert, grain surface greasy and glassy;dark yellow, dark red and grey coloured; angular, a few round grains, hook-like.	Chalcedony-opal grains .... Cryptocrystalline quartz grains .. Crystalline quartz grains	78% 17% 5%
4.	Chert, grain surface matt; dark yellow, dark grey and dark red coloured; round grains, ball-like, less often cube-like.	Chalcedony-opal grains .... Microcrystalline quartz grains ... Cryptocrystall.quartz with clay .. Quartzite grains	46% 37% 9% 8%
5.	Chert, grain surface porous; dark yellow, dark red coloured; a little round grains, slate -like.	Chalcedony-opal grains .... Microcrystalline quartz grains ... Cryptocrystalline quartz grains .. Quartzite grains	43% 37% 15% 5%
6.	Chert, grain surface sandy rough grained;dark yellow, dark grey and dark red coloured; slate-like, half-rounded grains.	Microcrystalline quartz grains ... Quartzite grains .... Chalcedony grains	60% 35% 5%

In quartz samples (No.1 and 2) opal was not discovered, but chalcedony and cryptocrystalline quartz is present. These are partly soluble in alkali. Chert sample (No.3) with a glassy and greasy surface contains mostly chalcedony-opal.

A chert sample with a glassy-greasy surface, dark yellow coloured, with conchoidal fracture, was separated and marked as "opal", with a content of amorphous silica of 50%, and with values for Sc = 825 m mol/l and Rc = 85 m mol/l. This is potentiality the most reactive sample used in investigations in concrete test samples.

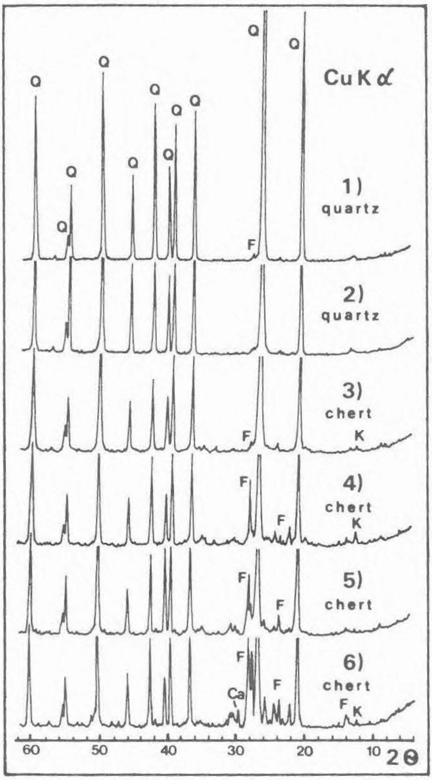


FIG. 4 X-ray diffractograms of quartz and chert variants.

X-ray diffractograms of quartz and chert variant samples (FIG.4) show that is quartz is the commonest mineral. Chert samples contain feldspar (F) in different quantities, clay minerals and hematite.

On the basis of relative proportions of crystalline phases, we can conclude that chert No.3 contains the most amorphous silica, (20%). Chert samples No.4 and No.5 contain about 12% amorphous material, and sample No.6 contains amorphous material in small quantities. Quartz samples No.1 and No.2 contain insignificant quantities of amorphous silica.

The common characteristics of the analysed chert grains are recrystallisation of opaline silica to chalcedony, microcrystalline and crystalline quartz. Opal, formed by organic or inorganic process, in time, transforms in chalcedony and finally in quartz.

Our investigations have shown that chert, from greater rivers in Serbia, in most cases, is recrystallized in more stable modifications.

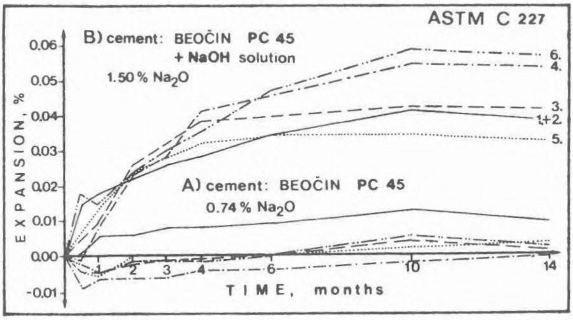
Linear expansion, observed in mortar according to ASTM C 227. Mortar prisms were made of aggregate of standard composition from the river *Velika Morava*, which contained chert grains, and according to results may be considered as harmful for concrete. The expansion was 0.032% after 6 months.

Investigations with selected grains of quartz and chert have not shown the expected differences.

We have used different types of cement with lesser or greater quantities of alkalies (FIG.5 and FIG.6). The results of investigations on mortar prisms are not in agreement with estimations based on petrographic investigations and chemical tests.

Expansions of samples are proportional only to the content of alkalies, and was in all cases less then maximum permitted value (<0.1%). Neither warping nor cracking of the mortar prisms was observed, but a white excretion of alkali-silicate reaction products was found on the surfaces of prisms containing higher alkali levels. With these aggregates, although the alkali silicate rection occurs, significant expansion of mortar bars does not occur.

Expansive destructive effects, of alkali-silicate reaction, are observed with concrete test samples, made of mixture of most reactive silica grains - "opal" and slightly reactive aggregate and a cement with its alkali content increased to 3.4% Na_2O equivalent by the addition of alkali.



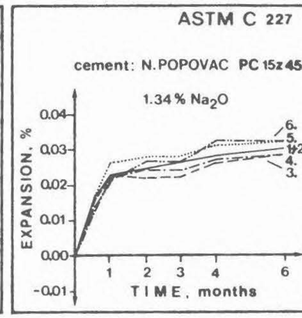


FIG. 5 Linear expansion of mortar prisms quartz and chert with:
a) low content of alkalies and
b) high content of alkalies in cement.

FIG. 6 Linear expansion of mortar prisms of quartz and chert with cement which contains 15% slag.

In the analysis of expansion trends of particular combinations of aggregates Figures 5 and 6 it can be seen that expansion is greatest with cement containing the highest alkali content (1.5% Na_2O equivalent); with this cement expansion continues for 10 months, after which it levels off. With cement PC15z containing 15% slag the main expansion levels off after about 30 days but some continues for four months. The reduction in expansion observed in Figure 6 is probably due to the presence of the finely ground slag.

4. CONCLUSIONS

The presented study has shown that aggregates from river sources in Serbia contain chert grains, which are partially composed of amorphous silica. Most of the chert from rivers in Serbia, is recrystallized in more stable modifications - chalcedony, microcrystalline and crystalline quartz.

Due to the possible occurrence of alkali silicate reaction in these sand - gravel deposits, perminant monitoring of their composition, by petrographic or chemical methods is necessary. Because of the high content of silica and silicate rocks in the gravels, the concentration of active alkalis per unit surface of the most reactive grains is reduced. For this reason, a high concentration of alkalis in the concrete is necessary to obtain a significant level of expansion. Experiments must be continued with concrete test samples to develop methods for accurately predicting the durability of concrete in actual structures. Monitoring the condition of concrete structures in the field will also be continued.

REFERENCES

1. *Maksimović Lj,Ratković N.,Dučić V.,1962.*, Ispitivanje potencijalne reaktivnosti agregata iz nalazišta Gaočići sa alkalijama iz cementa, Saopštenja Instituta za ispitivanje materijala Beograd, Godina X, Broj 16, pp. 24-34.

2. *The Highway Institute,1984.*, Savetovanje - alkalna reaktivnost agregata u betonu, Zbornik radova, Beograd, p.p. 1-192.