Investigation on The Diffusion of Na-Ion in Concrete

H.-G. Smolczyk

Summary

With respect to alkali silica reaction one of the possible parameters might be the movability of alkali-ions in the concrete. A first attempt was therefore made to measure the diffusion of Na^+ out of a 3 mol NaCl solution into 9 different concretes. (3 types of cement, 3 w/c ratios) The layers 2/4 cm and > 4 cm of the concrete bars 10 x 10 x 50 cm were chemically analysed after 6 months, 1 year, and 2 years. The resistance against Na^+-diffusion distinctly depended on the w/c ratio and very distinctly on the type of cement.

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1. Introduction

The reactions of alkali with reactive aggregates and the possible detrimental effects on the concrete are complicated processes. These reactions and their results cannot be predicted with only the knowledge of the reactivity of the aggregate and the alkali content of the concrete. Several other parameters, such as particle size distribution of the aggregates, humidity conditions, quantity and type of cement, and additives have a decisive influence on the reaction and its result.

We are predominantly interested in the favourable effect of certain natural and artificial puzzolanlike materials either as additives or as cement components. Their efficiency might have either one or both of the two following reasons:

a) A specific bonding capacity for alkali.
b) A favourable change in the quantity or size distribution of pores.

Both phenomenons would cause a decrease of the movability of alkali-ions within the concrete, and at the same time they would cause an increase of the resistance against alkali diffusion into the concrete.

The penetration of chemicals is also important with respect to several other problems, such as steel corrosion, chemical attack, and frost-deicer action. The resistance against diffusion is therefore being investigated in Rheinhausen on a wide scale. Part of this research programme is the diffusion of Na-ions (Na_2SO_4, NaCl, NaOH) and the results of the diffusion of NaCl into concrete bars over a period of two years are already available.

2. Experimental Part and Results

Concrete bars 10 x 10 x 50 cm with w/c 0.50, 0.60 and 0.70 were stored in 3 molar NaCl solution. 3 cements were investigated: A normal portland cement and two portland blastfurnace slag cements with 40 % and with 70 % granulated slag. The increase of Na in the paste of the concrete was measured in different layers after 6 months, 1 year, and 2 years.

In Fig. 1 and 2 the increase of Na is plotted against the time of immersion. Fig. 1 shows the results of the layers 4/5 cm of the 9 concretes. The experimental deviation might be in the order of 0,1 or 0,2 % Na. The differences between the 6 conretes with slag cements are therefore not very significant. On the other hand the 3 concretes without slag show a distinct influence of the w/c ratio.

Even more significant are the relations in the layers 2/4 cm shown in Fig. 2. In this diagram the predominant effect of the blastfurnace slag becomes evident. This effect is obviously stronger by far than the influence of the w/c ratio. For this reason the conclusion was drawn that the very marked influence of the slag cannot be explained with the lower porosity of the slag cements alone. There must be a chemical reaction of the blastfurnace slag involved which cuts down the movability of the Na-ions to a very low level.

At first sight one is taken by surprise that after 2 years the Na^+-diffusion of the layers 2/4 cm and 4/5 cm of the portland cement concrete with w/c O,7 showed nearly exactly the same value. A rough calculation, however, leads to the result that in this case the Na-content would be sufficient to fill all the pores $\geq$ 15O Å with a 3 mol Na^+-solution. This content (2,35 + O,17 % of the cement = 2,52 %) might be nearly the highest possible Na-content with respect to the 3 mol NaCl solution.

3. Conclusions

These results indicate that the vitreous blastfurnace slag has a strong bonding effect on Na-ions. That means that in a given concrete with a given amount of alkali the slag does not only limit the movability of the Na but also reduces the Na-concentration of the pore solution.

These two phenomenons are probably the main reasons for the protective influence of the slag and also of certain puzzolanic materials against alkali silica reaction. We will draw final conclusions when the results of our other experiments with NaOH, KCl, and KOH and with other puzzolanic additives are at hand.

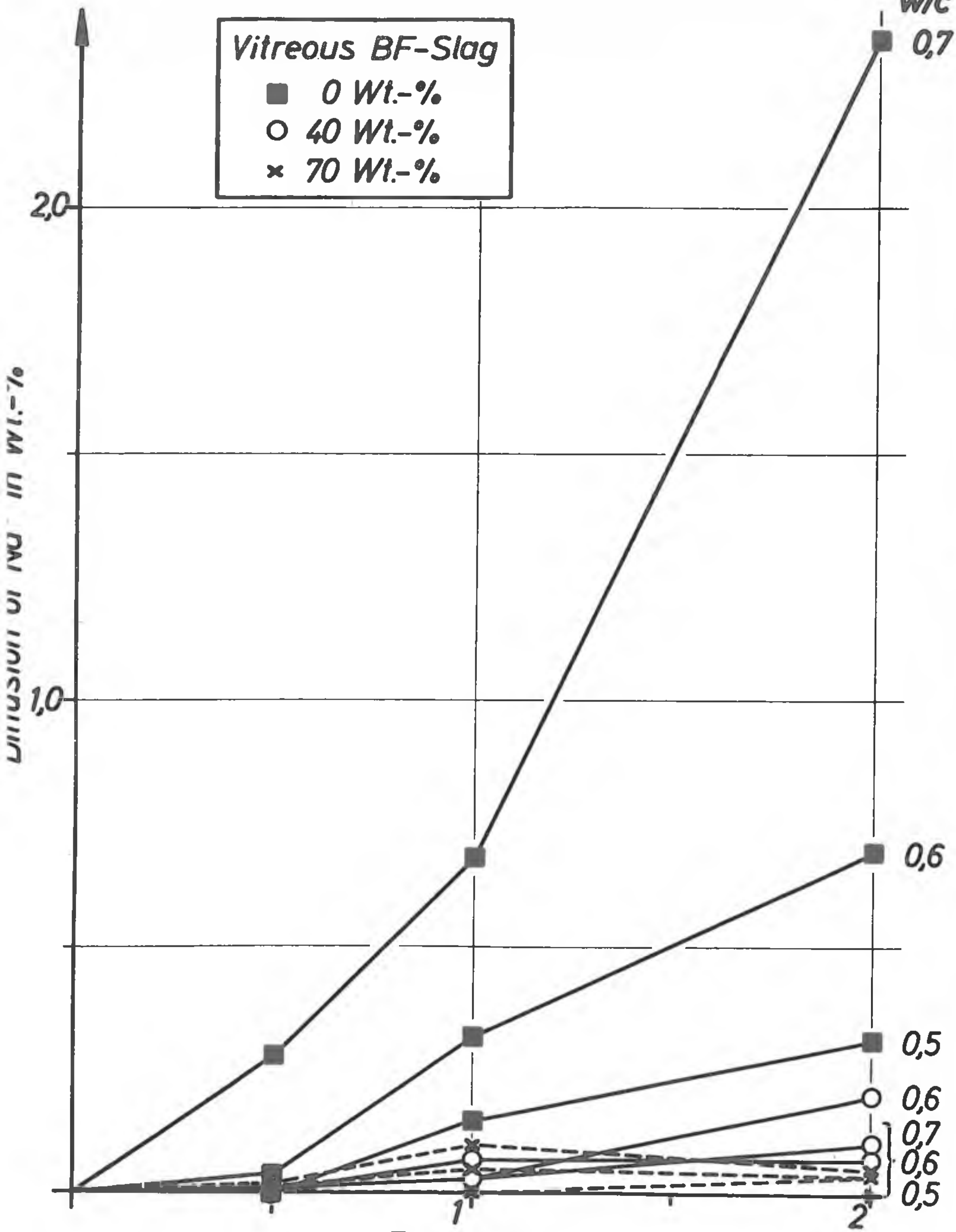

Fig. 1

la+-Diffusion in Concrete Bars with Different Cements.

olution: 3 mol NaCl, Depth of Layer: 4/5 cm

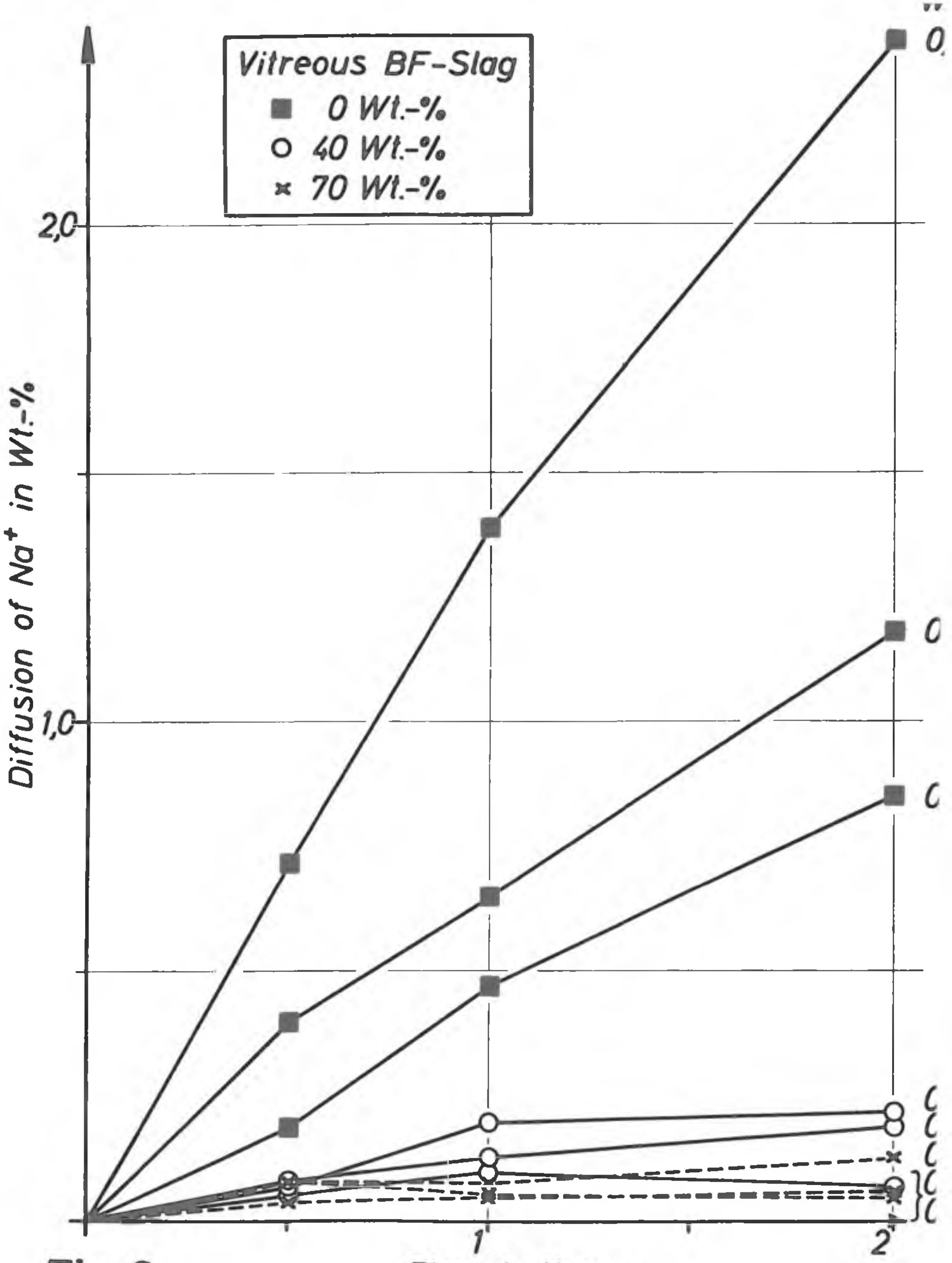

Fig. 2

Na+-Diffusion in Concrete Bars with Different Cemen

Solution: 3 mol NaCl, Depth of Layer: 2/4 cm