

SUMMARY

Alkaline activation of granulated blast furnace slag by highly concentrated solution of sodium or potassium ions has been a subject of numerous investigations for many last decades. Slag alkaline binders appear to be one of the most interesting and prospective building materials because of their high performance, such as very high durability, strength, water tightness, as well as low cost of energy on manufacturing. In many years lasting investigations the author of presented work found that the decisive role in producing alkali activated slag materials extremely high durability should be attributed to the phase composition and specific porosity of hydrating pastes as well as the microstructure of paste – aggregate interface.

Irrespective of the type of activator used, the so – called C-S-H phase, very compact, of low C/S ratio, rich in sodium, aluminium and magnesium is formed as a predominant hydration product. The portion of C-S-H augments significantly with higher concentration of activator. C/S ratio and concentration of Na, Al or Mg in C-S-H do not change substantially with time.

As a consequence of prolonged hydration time or temperature treatment, the number and length of silicate chains in the structure of C-S-H increase; it means the ordering towards tobermorite.

Aluminium ions occur either in tetrahedral coordination, thus replacing the silicate tetrahedra in C-S-H structure, or in octahedral coordination. Then they produce separate hydrated phases, such as hydrogarnets or carboaluminates.

The number of aluminate octahedra in the structure of hydrating material decreases with time, proving the transformation to aluminium – oxygen tetrahedra built up in C-S-H structure. It has been shown that about 6 - 7% Al was incorporated to C-S-H. In the alkali activated slag pastes produced from slag rich in Al (even 19% Al_2O_3) the calcium aluminate hydrates were not detected.

The formation of Mg – rich phases depends upon the alkaline activator content. At the presence of activator giving more than 4% Na_2O in the paste, the hydrotalcite $\text{Mg}_6\text{Al}_2\text{CO}_3(\text{OH})_{16} \cdot 4\text{H}_2\text{O}$ was found. There was no clear difference in the hydrotalcite content between the pastes produced from slags with varying MgO content, that is 4,3 and 8,2% respectively. It is very probable that a part of magnesium ions enters the C-S-H structure to form a solid solution. However, it is difficult to prove this because hydrotalcite is dispersed in C-S-H as nanometric inclusions.

In the classic alkali activated slag pastes the zeolite type products are not observed. Their formation is possible only in case of slags with low C/S and simultaneously high A/S ratio. They are produced after a long curing or as a result of hydrothermal treatment.

Alkali activated slag pastes exhibit very compact microstructure, as concerns both very low total porosity and small mean pore size. The fraction of capillary pores decreases evidently with simultaneous growth of the number of very small gel pores (< 2 nm). It depends upon the type of activator and parameters of curing.

In alkali activated slag mortars and concretes a very homogenous and compact interface layer between the paste and aggregate is observed. It differs significantly with its thickness and microstructure from the one formed in typical cement materials. There is no portlandite crystals and because of high alkali concentration there is a possibility of surfacial reaction between the paste and aggregate.

The following factors, such as absence of portlandite, high amount of amorphous C-S-H with low C/S ratio in the presence of hydrogarnets rich in Si^{4+} ions and hydrogelenite, play a decisive role in producing high corrosion resistance of alkali activated slag materials. The further reason consists in the absence of calcium aluminate hydrate phases.

It is quite possible that the hydrated magnesium carboaluminate (hydrotalcite), formed at higher concentrations of alkaline activator, occurring as submicron particles dispersed in low alkaline C-S-H gives additional tightening of paste microstructure, thus improving corrosion resistance.

Alkali activated slag materials are resistant to the attack of chlorides – the effective diffusion coefficients are of the order of magnitude lower than for portland cement hydration products.

The effective diffusion coefficients in alkali activated slag pastes depend upon the accompanying cations, following the range:

$$D_{\text{efCl(Mg)}} > D_{\text{efCl(Ca)}} > D_{\text{efCl(Na)}}$$

In alkali activated slag mortars and concretes the progress of carbonation is a little better visible. However, a relatively high concentration of alkalis in pore liquid ($\text{pH} = 12,0 \div 13,7$) prevents the steel reinforcement against de-passivation. It has been proved during the examination of 27 years old reinforced alkali activated slag concrete construction – the reinforcement was well protected.

The results of alkali activated slag materials corrosion resistance investigations are in very well accordance with the data dealing with durability of mortars and concretes based on classic portland cement admixed with granulated blast furnace slag. The relation between increasing durability in sulphate or chloride environment and lowering of C/S, C/A, A/S ratios was also proved.

The properties of alkali activated slag materials give the possibility to implement them for many ecological purposes. Therefore they can be potentially used for immobilization of heavy metals or radioactive elements containing wastes, for example

galvanic slurries, municipal wastes incineration ashes. Anti-filtration screens, cut-off walls and other underground constructions are the other fields of alkali activated slag materials application. It has been positively verified in practice for a couple of years.