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Concrete based on fly ash geopolymers

Concrete components

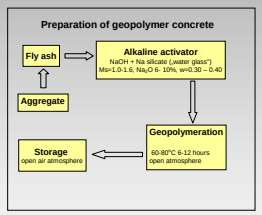
Brown coal fly ash F Type (Czech Republic)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	P_2O_5
53.79	32.97	5.51	1.84	0.92	0.46	1.76	0.37	2.1	0.15

fly ash X-ray analysis : glass + mullite, quartz rest

ground blast furnace slag, limestone

sand, gravel 0/4, 8/16 mm fraction

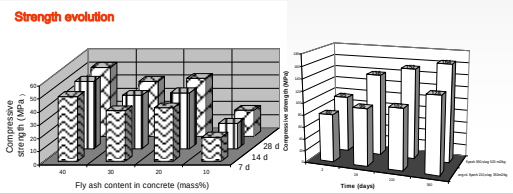


Rheological properties of the fresh fly-composition are dependent on the fly ash content in the mixture. In comparison with the fresh cement concretes, the mixtures containing higher percentages of fly ash exhibit a different rheological behavior.

Correctly composed mix, uniform distribution of the aggregate .

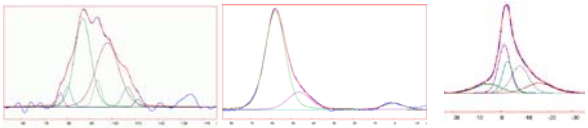
Incorrect mix, aggregate segregation and the mortar displaced towards the surface

Strength evolution



- **The strength** values of pastes, mortars and concretes of the geopolymers on the basis of fly ashes show an increasing trend after 2-360 days from the moment of their preparation; the respective values range from 15 to 70 MPa after 28 days in dependence on the conditions of their preparation and on the composition. The highest strength values were obtained for the geopolymers on the basis of fly ash and blast furnace slag; in this case, the compressive strength measured after 28 days ranged from 100 to 160 MPa.
- **The ratio of the compressive strength to the tensile strength** under bending varies in the range of 10.0 : 5.5 (the ratio for cement-based concrete ranges from 10.0 : 1.0 to 10.0 : 1.5) which means that a higher tensile strength of the geopolymer concrete gives the possibility to reduce the quantity of the reinforcement in the structural elements.

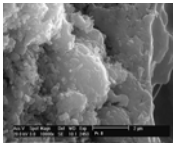
Microstructure



^{29}Si NMR MAS
main shift -89,5 - ppm Q^4 (3Al),
shift -97,6 ppm – Q^4 (2-3Al),
weak shift -107,6 ppm - SiQ^4(0Al)

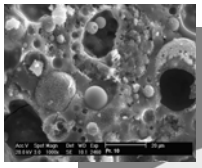
^{27}Al NMR MAS
main shift -55 ppm AlQ^4(4Si),
very weak shift 3 ppm mullite
phase from fly ash rest

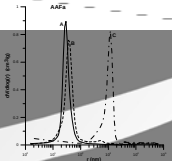
^{23}Na NMR MAS
Na as $\{Na(H_2O)_n\}^+$



Geopolymer (SEM)

Porosity

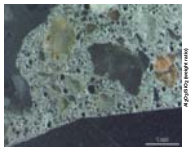




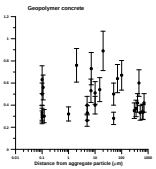
The geopolymer on the basis of fly ashes is a porous material.

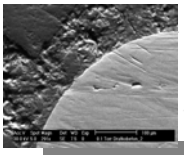
The porosity of the geopolymers is very similar in the region of nano-pores regardless of the conditions of their preparation. The geopolymers' strength is affected substantially by macro-pores (100 nm and more) formed in result of the air entrained into the geopolymers; these may also be fly ash particles that underwent only partial reaction. The presence of Ca-containing additives (slag, gypsum) reduces considerably the porosity - coexistence of the geopolymer phase with the C-S-H phase.

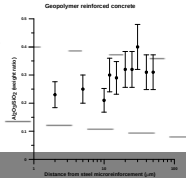
Interface geopolymer – aggregate



Geopolymer concrete
(polished section, optical microscope)







Character of the boundary between the steel micro-reinforcement and the geopolymer (polished section, SEM)

The character of the geopolymer – aggregate (reinforcement) boundary is quite different.

No transition phase with a different composition as this is typical for concretes on the basis of Portland cement was found between the geopolymers and the aggregate (reinforcement).

Freeze - thaw resistance tests

After 150 freezing cycles, the strength values dropped to about 70 % of the strength measured in the same period of time.

Geopolymers materials on the basis of the fly ash possess an excellent frost resistance.

Corrosion

1.5 year
in NaCl solution

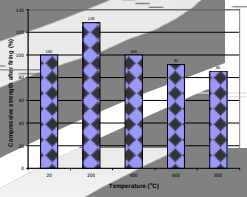
1.5 year
in $MgSO_4$ solution

- Geopolymer mortars and concretes kept in the cloride and sulfate solution for long periods of time resist to corrosion without showing any signs of sample damage. The exposure of the geopolymers materials to the NaCl solution resulted in the consistent increase in the compressive strength during the whole period of measurement (720 days)
- The penetration of chloride and sulfate ions into the body of the geopolymers materials (point analyses, the measurement was carried out in the direction perpendicular to the surface in contact with the NaCl solution) shows a decreasing trend and the chloride concentration in the body is low.
- The exposure of geopolymers materials to the solutions of sulfates and chlorides did not result in the formation of new crystalline phases.

The resistance of geopolymer concretes to the action of salt solutions is better than that of the cement-based concrete

High temeperatures properties

Character of the geopolymers concrete after firing



A geopolymer material exposed to the action of high temperatures loses a substantial part of its strength that drops to 40 % of its original value. The strength already starts dropping at a temperature of 250ºC and it remains practically the same at higher firing temperatures.

The values of the residual strength after the firing were rather higher than those characterizing the materials on the basis of Portland cement.

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