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REGULATION OF FINE GRAINED CONCRETE EFFLORESCENCE PROCESS

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Abstract. The presented research focuses on the investigation of the efflorescence process and its structure and morphology. It aims at the development rational methods to prevent the efflorescence risk, taking into account the specifics of fine grained concrete paving blocks.

Introduction

As distinguished from wall sand cement products, paving blocks are used in more severe temperature and humidity conditions, under continuous effect of exhaust gases. One of the reasons to decrease life of fine grained concrete products and structures is their corrosion causing saline markings on paving blocks, called *efflorescence* in technical literature. Besides the decrease of maintenance parameters, efflorescence worsens the design of paving blocks.

The analysis of existing protection methods showed that most secondary methods, in particular various cleaning and water repelling agents are unacceptable for products used as paving blocks and road blocks. In connection with the specifics of paving blocks maintenance, decrease of efflorescence on the surface of cement concrete road construction materials may be reached by optimization of the composition and structure at the stage of selecting the components for concrete mix which contributes to material's density increase and decrease of soluble ingredients content.

Analysis of useful life impact on microstructure of cement stone

To study the impact of useful life on the intensity of migration and quantity of soluble ingredients in fine grained concrete set, wearing-away model was created [1]. The studies were done on paving block samples, factory-made and used for five years.

Quantitative specification of the chemical composition of effluents depending on the quality of paving blocks allowed to find the growth of removed substances (alkali and earth metals oxides) in the products with 5 years' life (Table 1): CaO − by 37 %, Na_2O and K_2O − by 15 and 33 % respectively. Filtrated waters are destroying the components of cement stone's crystal structure causing softening of concrete structure and therefore, open porosity. That makes soluble materials export more intensively not only from surface layers like in freshly made blocks but also from the whole sample volume.

Thus, it was found that the study of chemical elements behavior of sand cement paving blocks under continuous water cycle effect is evidencing that due to damaged concrete microstructure during service life, the possibility for efflorescence development does not tend to drop but increases.

The analysis of service life's impact on the structure of fine grained concrete's cement stone allowed offering the following view of structural transformation of the fine grained concrete, the adjustment of the composition of which ensured to mark the ways to decrease efflorescence on paving blocks.

Table 1
The influence of the service life at the possibility of chemical elements migration in the pavement blocks

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2	P_2O_5	FeO	LOI
before service life												
Blocks before test*, [%]	62.28	6.72	1.67	14.81	0.48	1.82	1.11	0.60	0.28	0.077	0.47	6.0
Blocks after test, [%]	62.05	6.37	1.63	14.45	0.40	1.40	0.93	0.49	0.26	0.065	0.35	5.72
Δ, [%]	0.23	0.3	0.04	0.36	0.08	0.42	0.18	0.11	0.02	0.012	0.12	0.28
Filtrate, [g/cm^3]	0.05	3.45	0.05	3.2	0.2	22.0	16.0	0.02	n/d	< 0.01	0.09	0.05
after service life												
Blocks before test*, [%[	64.24	6.52	1.70	14.23	0.49	1.63	0.84	0.55	0.30	0.066	0.30	6.05
Blocks after test, [%]	64.05	5.81	1.33	13.98	0.37	1.25	0.79	0.51	0.20	0.058	0.22	5.59
Δ, [%[	0.19	0.71	0.37	0.25	0.12	0.38	0.05	0.04	0.1	0.008	0.08	0.46
Filtrate, [g/cm^3]	0.08	2.82	0.09	5.1	0.2	26.0	24.0	0.01	n/d	< 0.01	0.05	0.05

* tests were carried out in the Soxhlet devise

Cement stone in factory-made paving blocks has rather porous open-grain structure made by globular mass and newly formed crystals of binding material's hydrogenation products. In the pore volume, elongated columnar crystals of hydrated calcium silicates are observed, locally distributed and making microframe of the material.

As distinguished from the structure of the concrete supplied to end-users, the products of the same quality after five years' service life have another type of microstructure. Based on the shape of crystals covering with continuous mass the quartz grains, phase composition of the studied system, absence of those shapes in freshly made samples and conditions of service life their composition may be stated as epigenic calcite.

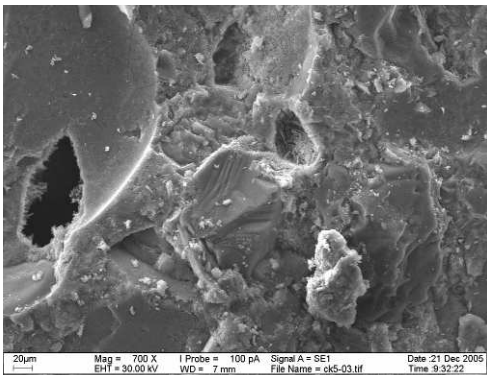
That evidences intensive diffusion of dissolved matters out of the material over the contact zone of cement stone with filling material where soluble components of that system are deposited and crystallized [2].

The analysis of general view of structure is evidencing great porosity established during service life (Fig. 1) which is not typical for the initial sample. Pore volume has both nearly isometric shape and karstic view. That is explained by uniformity of alkali washing by volume when capillary pores and blow hollows are filled with water.

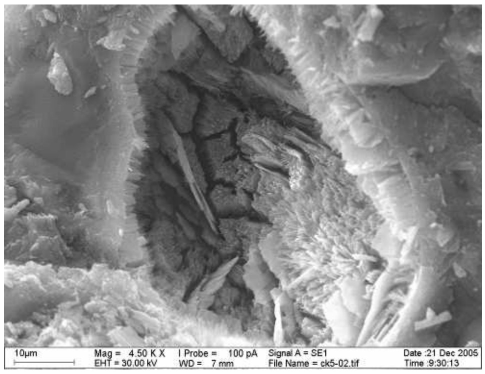
The morphology of new formations observed on pore walls and the way they are filled with crystals is not typical for traditional cement stone. Similar nodules of well-formed crystals may be developed subject to long filling of pore volume by strong solution and favorable conditions for synthesis.

Accounting for the fact that sodium carbonate and sodium sulfate efflorescence are soluble with water and are self-liquidating during service life of paving blocks, the core task is to stop the development of non-soluble calcium carbonate efflorescence. Among the efflorescence of factory-made blocks, the following were found: calcite $CaCO_3$, portlandite $Ca(OH)_2$, water-free calcium sulfoaluminate $3(CA)\cdot CaSO_4$. Efflorescence on paving blocks are sporadic intergrown crystals – nodules. A few portlandite generations are clearly observed, 10-15 um, covered with more fine new formations not exceeding 0.2 um. That may evidence autowave nature of formation process.

Considering the specifics of matter migration and the nature of microstructure change during service, the following steps are offered to prevent efflorescence: use of composite binding materials, improving the density of concrete mix by adjusting its size distribution and rational choice of filling material.



a)



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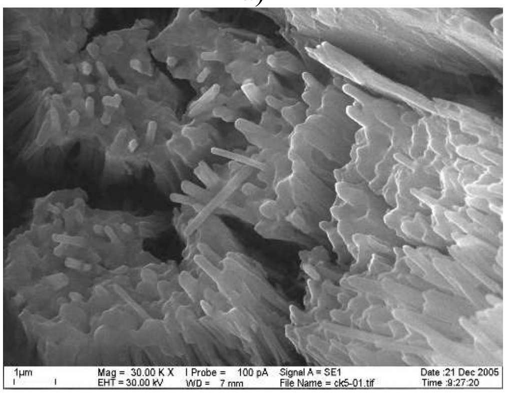

c)

Fig. 1. Microstructure of cement stone and new formations in pore volume of paving blocks after 5 years of service:

a – general view of fine grained concrete structure;
b – pore shape and way of filling;
c – morphology of new formations of pore walls

Experimental confirmations

The study of quartz natural and technogenic sands and the experience in obtaining low water demand binding substances (LWD) using various genetic types of filling materials [3] evidences that quartz materials with low crystallinity are the most effective. Therefore, quartzite sandstones of greenschist facies from Lebedinsly deposit (KMA, the RF) in form of screened siftings were chosen as LWD, as they are due to typomorphic specifics have high defect structure of various orders and therefore have more intensive grindability and high reactive power.

As a quartz component, both in development of dense packing structures and in making composite binding substances, sedimentary rocks were used besides siftings (Table 2, 3). To make LWD-50 mix, cement CEM I 42.5 H made by ZAO «Belgoordskiy cement» was used with superplasticizers Melment F10, Melflux 1641 F, in optimal concentration.

Table 2
Physical and mechanical properties of natural and technogenic sand

Type of raw material	Gradation factor	Density, [kg/m^3]			Water requirement, [%]
		middle	true	bulk	
Viazemsky sand	2.7	1560	2610	1500	6
Crushed- quartzite-sandstone screenings	3.7	1520	2710	1415	5.5

Table 3
Chemical composition of raw quartz

Type of raw material	Oxide content, [% mass]										
	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	Na_2O	K_2O	SO_3	TiO_2	CaO	LOI
Viazemsky sand	93.2	2.1	0.75	–	0.3	0.24	0.35	0.06	0.12	1.5	1.1
Crushed-quartzite-sandstone screenings	94.32	2.61	0.42	0.81	0.66	0.22	0.65	0.01	0.16	0.46	0.65

LWD-50 mixes were developed using weakly ordered quartz of greenschist facies were developed. Use of composite binding materials ensures the solution of several tasks: decrease of cement consumption; binding $Ca(OH)_2$ with amorphized phase of siliceous component; increase of cement stone's density by filling micropores with secondary products of pozzolanic reaction and due to the binding plasticizers added.

High effectiveness of the use of highly dense mixes in fine grained vibration molded concretes using high quality quartz filling material, full dressing/coating and minimal grains spreading with cement dough is reasoned by contract structure of materials and therefore compressive strength and density increase due to filling material and making concrete's structural frame with its grains. The same factors ensure decrease of leaching corrosion [4].

It is seen that the maximal effect is reached when the ratio cement / quartzite sand siftings is increased using high density mix from 1/3 to 1/3.5 [5]. That ensures decrease of filling material's grain spread thickness with cement dough to 30 um and therefore allows not only to increase strength and density of the material and use less binding substance (540 kg instead of 600).

Conclusions

Thus, the principles of low efflorescence fine grained concrete design were offered due to optimization of composition and structure at the stage of concrete mix components selection which contributes to decrease of soluble components content. The feasibility of using composite binding monomineral quartz rocks as a siliceous component of greenschist facies was demonstrated it was found that to increase concrete density by making dense packing, filling material with gradient ≥0.9 is the most rational.

Acknowledgments

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