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Original Article

Concrete mixtures with high-workability for ballastless slab tracks

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ABSTRACT

The concrete track-supporting layer and the monolithic concrete slab of ballastless track systems are made in-situ. For this reason the concrete mixtures of high workability should be used. Influence of the sand kind, the quartz microfiller fineness and quantity as well as quantity of superplasticizer on workability of fresh concrete and durability of hardened concrete is shown. The compositions of the high-workability concrete mixtures with lower consumption of superplasticizer are developed. The results of the research can be recommended for high performance concrete of ballastless slab track.

1. Introduction

At present the ballastless track systems concepts are being developed all over the world. The advantages of such structures are described by (Esveld, 2010) and can be summarized as follows: reduction of structure height; lower maintenance requirements and hence higher availability; increased service life; high lateral track resistance which leads to the future speed increases in combination with the tilting technology and the absence of problems with churning of ballast particles at high-speed.

A concrete slab replaces the ballast in the ballastless slab track. This track structure has been widely used in high-speed railways in Japan, Germany, France and China as shown by the authors (Harada, 1976; Gao et al. 2013; Liu et al. 2011). Currently the most known slab track systems are: Rheda, Züblin and other variants (Germany); Stedef, Sonneville Low Vibration (France); Walo (Switzerland); Edilon block track (Netherlands); Shinkansen slab track (Japan, South Korea); IPA slab track (Italy); ÖBB-Porr (Austria); Embedded Rail Structure (Netherlands); China Railway Track System (CRTS).

The slab track needs the low-maintenance. However, the subgrade layers must be homogenous and capable of bearing the loads imposed. The slabs can be made as the precast or in-situ concrete. The high level of investment is required and it prevents widespread use of slab track on open lines in Russia. The use of more efficient construction methods, concrete compositions can reduce construction costs further.

Configurations of ballastless track slabs vary throughout the world due to the different developments and can be individually adapted to the specific requirements and the individual constraints of each project. The basic system structure consists of modified bi-blocks which are obtained from halves of prestressed reinforced concrete sleepers. These bi-blocks are reliably embedded in a monolithic concrete slab. Concrete slabs are placed on concrete track-supporting layer. To assure the required durability the minimum strength of the concrete layer must be 30 MPa for samples-cubes and 37 MPa for samples-cylinders. (Rheda 2000, 2017). The prestressed reinforced concrete structure must be adapted for decreasing the freezing destruction. The CRTS III RUS ballastless slab track is being developed by the Chinese companies for the operation on the pilot section of the Russian railway. The CRTS III RUS is being made for the VNIIZhT experimental ring in Shcherbinka station for testing in 2017–2018 years (VNIIZhT, 2017).

The monolithic concrete slab is present in the structures of ballastless track of different developers. As a rule the concrete track-supporting layer and the monolithic concrete slab are made in-situ. For this reason the concrete mixtures of high workability should be used. There are several factors affecting the workability of concrete mixtures: the properties of Portland cement, properties

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of aggregates, presence of superplasticizer etc. Inappropriate choice of one of concrete components can lead to the increased consumption of superplasticizer or water, which increases the construction cost and reduces the concrete strength.

The combined effect of the properties of Portland cement and superplasticizer are shown by the authors (Smirnova, 2016; Zhang et al., 2015; Li et al., 2014; Lange et al., 2014). The influence of some mineral fillers on enhancing the workability of fresh concrete is shown in papers (Alonso et al., 2013; Burgos-Montes, 2012; Hallal et al., 2010; Ezziane et al., 2014). The increase of plasticizing effect of the superplasticizers with some mineral fillers are stated in the papers (Petrova and Smirnova, 2010, 2014; Petrova et al., 2011; Smirnova and Petrova, 2013; Elyamany, 2014; Makarevich and Smirnova, 2015). Increase of the dynamic strength characteristics is shown in paper (Kharitonov et al., 2015). However, the use of mineral fillers in concrete of railway structures requires justification and comprehensive research.

Among the many mineral additives for using in concrete of ballastless track one can offer the quartz filler. Unlike many mineral additives quartz filler allows to improve simultaneously: density of cement matrix by optimizing the granular mixture; cement matrix properties by pozzolanic properties; cement matrix properties by reducing water-to-binder ratio in plasticized cement paste. However, these issues of the positive influence of quartz filler on concrete properties were considered in the scientific literature separately. The optimum quartz filler quantity and fineness were stated for each individual property.

In the papers (Juhart et al., 2014, 2015; Mittermayr et al., 2015) it was found that not only packing density but also the water demand and the superplasticizer amount are crucial for the development of eco-mixes. The optimal packing of components that consists of aggregates, cement, microfillers with particles of different sizes, is not only important: workability properties of concrete play an essential role (Tikkanen et al., 2011).

Cement pastes and mortars have been analysed with the replacement to Portland cement by 15, 20, 25% of the ground dune sand with fineness of 5800 cm^2/g in the paper (Arroudj et al., 2017). Workability of these mortars containing 2% of superplasticizer was almost the same as the workability of the reference mortar without ground sand. In the long term (60 days) the mortars with 25% ground quartz sand developed the same strength as reference mortar.

The study (Kumar, 2016) revealed that quartz sand (as fine aggregate) can be used for developing Ultra High Strength Self Compacting Fiber Reinforced Concrete by reducing the water content and obtaining the required flow properties.

In the paper (Bumanis and Bajare, 2017) it was found that the application time factor of ground sand in cement mortar has the critical impact on mortars compressive strength: the greatest strength of the cement mortar was detected when the ground sand was applied in the mixture right after milling. It was concluded that the instant application of the ground sand (fineness $d_{10} = 8{,}5\ \mu m$, $d_{50} = 41\ \mu m$, $d_{90} = 81\ \mu m$) could increase the compressive strength of cement mortar up to 20% if the ground quartz sand is used immediately as partial sand replacement up to 10 wt% in cement mortar. Two days old ground sands applied in cement mortar reduced the increase of compressive strength but was still higher (5 to 11%) compared to the reference mixture while the 28 days old ground sand deteriorates the compressive strength up to 4%.

There are no results on the effect of the quartz filler age (from the moment of grinding) on the plasticizing effect of superplasticizers in literature. In this case one of the objectives was the study of this fact.

Some microfillers can increase the plasticizing effect of superplasticizers. The compositions of high-workability concrete mixes with lower consumption of superplasticizer should be developed for concrete slab of ballastless systems.

Thus, in the above-reviewed papers the directions of the influence of the quartz filler (with fineness similar to Portland cement fineness) on the individual properties of fresh or hardened concrete were studied. The optimal grinding fineness and quantity of the quartz filler to improve certain properties of concrete were specified in the above papers. The aim of this research is a comprehensive approach to the selection of quartz microfiller quantity and fineness for slab concrete of ballastless track. With this approach, the influence of microfillers on properties of fresh and hardened concrete is taken into account with the maximum economy of Portland cement and superplasticizer since the transport facilities require large volumes of concrete.

Properties of fresh and hardened concrete made of local materials were investigated in the paper including properties that determine the durability of concrete. One of the objectives of this paper is to identify the possible ways to reduce the consumption of expensive components of the concrete mixtures.

The differences between the prices of mineral fillers are remarkable. The quartz powders can be more expensive than the Portland cement (Tikkanen et al., 2011). The high cost of the quartz powders is mainly explained by the small production volumes of these mineral additives. Quartz is the major form of pure silica in nature and it is a very hard material with hardness of seven on the Mohr's scale and density of 2.65 g/cm^3 (Aravindhan, 2016). The improvement of grinding technologies should lead to reducing the cost of the quartz microfillers. Modern grinding equipment is used in this research such as a centrifugal-elliptical mill and a centrifugal dynamic classifier. The classifier is designed for separating the filler particles in the air flow by size, density and shape with the aim to precipitate very fine fractions of the total volume of microfiller. Using the classifier reduces the energy consumption of grinding.

2. Materials and methods

The microfiller of ground natural quartz sand with content of SiO_2 more than 94% (Luga field, St. Petersburg) was used in the research. The AC100 centrifugal-elliptical mill (mill class "Activator C") of the Finnish Oy CYCLOTEC Ltd company was used to obtain fine particles.

The working capacity of the ball mill is directly proportional to the specific weight of grinding balls. The idea of replacing the grinding balls of larger specific weight by using centrifugal forces is used in a centrifugal-elliptical mill. This mill consists of two or more parallel cylinders rotating on a circle around a common axis. The combination of the centrifugal force generated by the rotating of cylinders around the main axis and the centrifugal force generated by the rotating of cylinders around their own axis, allows to increase the grinding load and to obtain finer powder. The use of an efficient classifier for separating filler particles in the air flow makes it possible to adjust the particle size distribution of mineral powders. The centrifugal-dynamic classifier of the "Lamel-777″ company was used in this research (Air centrifugal dynamic classifiers, 2017).

Crushed granite of nominal maximum size of 20 mm was used as coarse aggregate. The size distribution of two kinds of the fine aggregates (marked as sand 1 and sand 2) and their chemical compositions are presented in Tables 1 and 2.

Microfillers were obtained by milling sand 1 and sand 2 and marked as S1, S2a, S2b. The microfillers S2a and S2b differed by fineness. The particle size distributions of microfillers were estimated by using the "Analysette 22" analyzer and are shown in Table 3.

Table 1
The size distribution and fineness modulus of sands.

Sieve size, mm	Full remainders on the sieve,%	
	Sand 1	Sand 2
2.5	8.5	5
1.25	20.5	21
0.63	68.5	50.5
0.315	88.5	82.2
0.16	97.7	95.2
< 0,16	100	99.2
Fineness modulus of sand	2.84	2.54

The Ordinary Portland cement was chosen. The chemical composition of Portland cement is presented in Table 4. The plasticizing effect of the chosen polycarboxylate-based superplasticizer (marked as SP) in pastes and mortars was investigated as the slump flow by applying the Hägermann cone.

The composition of the B40 strength class concrete that is currently used for the producing prestressed concrete sleepers was selected as the reference (Table 5).

The influence of superplasticiser and ground sand on the properties of fresh concrete (slump) and hardened concrete (the compressive strength at the age of 24 h, 28 and 360 days, the tensile strength when splitting, frost resistance, water absorption) were studied.

Electrokinetic properties of the mineral fillers were estimated by using the Zetasizer Nano ZS instrument (Malvern Instruments Ltd., UK). This device makes it possible to determine the quantitative distribution of the active centres of different signs on the particle surfaces depending on pH of the liquid phase. The pH value of the solution was adjusted with 0.1 N NaOH by using the 3C Digital pH-meter.

3. Results and discussion

3.1. Fresh concrete properties

The influence of the sand kind (as a fine aggregate) and the quantity of the polycarboxylate based superplasticizer (wt% of Portland cement) on the small cone slump flow was studied (Fig. 1). The mortar composition shown in Table 5 (cement: sand = 1:1.43) was selected for comparison.

Comparing the results in Fig. 1 one can conclude that the sand kind effects the slump flow in the mixtures with the superplasticizer. Quartz sand (sand 2) greatly improves the plasticizing effect of the superplasticizer. Thus, choosing the right sand kind as a fine aggregate allows to increase the workability of the fresh concrete. Based on the foregoing, it is possible to suggest that the mineral microfiller obtained by grinding this quartz sand will also increase the plasticizing effect of the superplasticizer.

The influence of the superplasticizer quantity (wt% of binder) as well as the quantity (wt% of Portland cement) and fineness of the microfiller on the fresh concrete slump was studied by using the big cone (Figs. 2 and 2). A binder is defined as the Portland cement and microfiller mixture. The quartz sand was used as fine aggregate in all mixtures.

Thus, one can see from Fig. 2 that the quartz microfiller in the amount of 10 wt% of Portland cement may significantly increase the value of the slump, the plasticizing effect of SP increasing with the greater microfiller fineness. This is especially noticeable under the reduced SP amount. The reason for this may be the effect of SP on the hydration of Portland cement and, respectively, on pH value of the pore solution. Adsorption of SP (and therefore its plasticizing effect) depends on pH of the pore solution and zeta potential of particles as shown in the paper (Lowke and Gehlen, 2015). The microfiller obtained by grinding of sand 1 does not influence on the plasticizing effect of SP or may slightly reduce the slump.

The effect of storage time (180 days) of quartz microfiller on plasticizing effect of SP is shown in Fig. 4. A slight decrease of the slump is observed for the coarser quartz microfiller in comparison with the results shown in Fig. 3. The effect of storage time of the finer quartz microfiller was not observed.

One can conclude that the use of the microfiller which increases the plasticizing effect of SP can lead to admixture savings. The choice of such microfillers for transport structures requires the further study.

The comparison of the results of Figs. 2 and 3 shows that the plasticizing effect of SP depends on the ground sand fineness and quantity. Another situation arises with the non-plasticized cement paste and fresh concrete containing the ground sand. The water demand of the cement paste rises with the increase of the ground sand fineness and quantity in the compositions of the Portland cement-microfiller. This confirms the influence of the mineral microfiller electrokinetic properties on the effect of SP.

The setting times of cement paste are also important technological properties of the fresh concrete along with its workability. The initial setting time of the cement paste was reduced up to 30 min with the introduction of the quartz microfiller (S2b) in the amount of 5–15%. The end of setting time of the cement paste with the introduction of the quartz filler in the amount of 5% was reduced up to 45 min and in the amount of 10–15% – up to 60 min. This corresponds to the results of numerous studies on the influence of the quartz microfiller on the early hydration of Portland cement. The most important parameter in acceleration of clinker component hydration is the interparticle distance (Berodier and Scrivener 2014). Previously, the enhance of the hydration rate was attributed to the microfiller surface providing the nucleation sites for the C-S-H. Contrary to prior investigations the authors of the paper (Kumar et al., 2017) suggest that differences in the heterogeneous nucleation of the C-S-H on filler particle surfaces caused due to differences in their interfacial properties have little if any effect on C_3S hydration kinetics.

Some authors show that the cement hydration accelerates with the increase of the microfiller quantity. The microfiller quantities up to 30% were investigated in this research and the positive influence of such quantities on plasticizing effect of SP, on setting time of cement paste was observed. However, the decrease of compressive strength at the age of 28 and 360 days was observed with the quartz microfiller in the range of 15–30% which required choosing the microfiller quantity in the range of 1–15% for further research.

3.2. Zeta potential of the microfiller particles

The results (Lowke and Gehlen, 2015; Ferrari et al., 2010) showed that polycarboxylate-based superplasticizers are strongly adsorbed by positively charged materials. The measurements of z-potentials of the quartz microfiller particles make it possible to define their ability to adsorb anionic plasticizing admixtures.

Table 2
The chemical composition of sands.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	L.O.I
Sand 1	65.74	8.67	3.97	7.10	5.47	3.00	5.20	0.85
Sand 2	97.85	0.03	0.09	1.1	0.93	-	-	-

Table 3
The particle size distributions of microfillers.

	The quantity of particles with size less then,%			
	1 μm	5 μm	10 μm	50 μm
S1	3.9	26.5	39.1	90.1
S2a	4.7	21.9	40.5	87.2
S2b	13,0	62,2	79.5	100

Table 4
The chemical composition of Portland cement.

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	Na_2O	Na_2O_{eqv}	$CaO_{св}$	L.O.I.
63.90	21.00	4.88	4.12	0.92	2.77	0.58	0.17	0.55	0.25	1.00

Table 5
The concrete composition.

W/C	Quantity per 1 m^3, kg			Concrete composition	Admixture,%	Concrete density, kg/m^3
	Cement	Sand	Coarse aggregate			
0.35	450	645	1160	1:1.43:2.58	0.5	2403

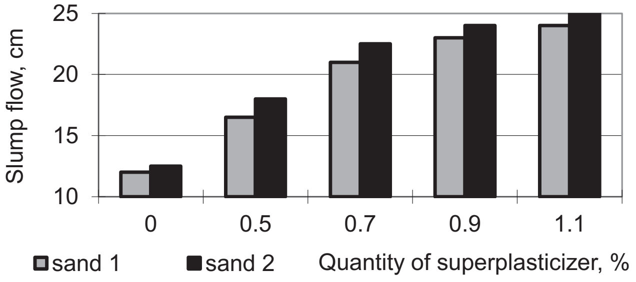

Fig. 1. The slump flow depending on the quantity of superplasticizer and sand kind.

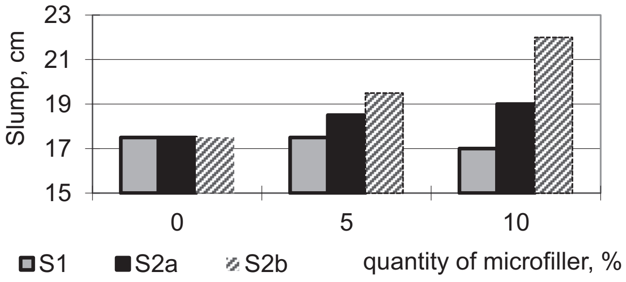

Fig. 2. The plasticizing effect of the superplasticizer (0.5 wt% of binder) depending on the microfiller quantity and fineness.

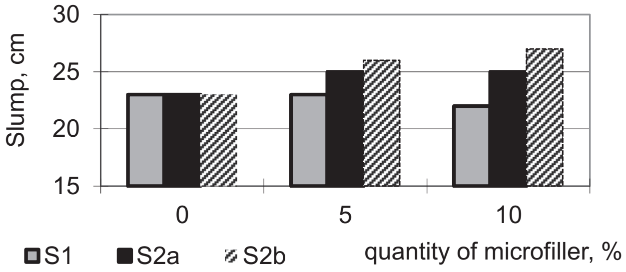

Fig. 3. The plasticizing effect of the superplasticizer (0.7 wt% of binder) depending on the microfiller quantity and fineness.

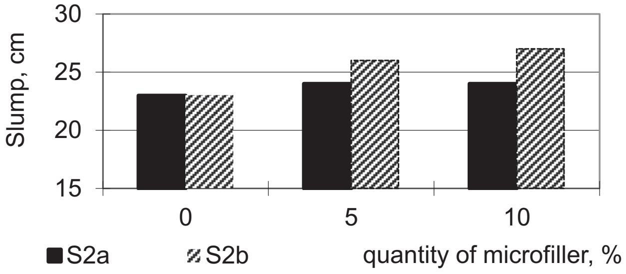

Fig. 4. The plasticizing effect of superplasticizer (0.7 wt% of binder) depending on microfiller age.

It is established that the negatively and positively charged active centres exist on the microfiller particle surfaces (Fig. 5). The greatest number of negatively charged active centres is located on the quartz microfiller surfaces and the number of negative centres grows with the microfiller fineness increasing.

The measurements of z-potential of ultra-fine mineral fillers give some new information on the ability of these particles to influence on the plasticizing effect of the superplasticizers in the compositions of Portland cement- mineral filler. The investigations

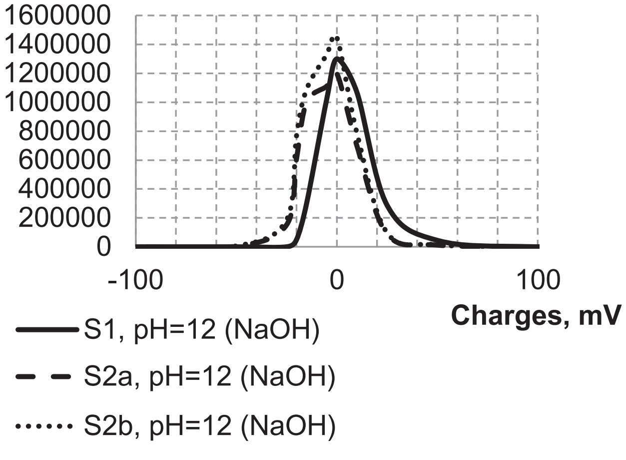

Fig. 5. Quantitative distribution of charges on the microfiller particle surfaces.

showed that particles of the quartz microfiller have negative z-potential with pH = 12 (Fig. 5). Because of the smaller particles of the quartz microfiller (S2b), the z-potential becomes more negative.

The ion concentration of the pore solution significantly effects the zeta potential. In the case of the quartz flour, the high pH of the artificial pore solution caused an increase of negative surface sites (SiO^-) (Lowke and Gehlen, 2015). It is shown that SP is not adsorbed on the quartz microfiller in artificial pore solution, the quartz microfiller fineness being similar to the Portland cement fineness (Lowke and Gehlen, 2015). The quartz microfiller of finer grinding is used in this research and therefore one can assume that its electrokinetic properties should have a greater effect on the plasticization of fresh concrete.

Based on the above mentioned results in Section 3.1 one can conclude that the whole quantity of SP is spent on dispersing Portland cement particles by adsorption on these particles. For this reason the quantity of SP was taken in percent from the Portland cement weight but not from the binder weight to determine the effect of the microfiller on the slump (Fig. 6). The decrease of workability with the S1 microfiller and the improvement of workability with the S2b microfiller are observed compared with the data of Fig. 3. This proves that the quartz microfiller with the fineness of S2b filler can make a significant independent contribution to improving the fresh concrete workability.

Thus, the introduction of finer quartz microfiller can considerably increase the plasticizing effect of SP, which provides the improvement of the workability and gives the opportunity to obtain the self-compacting concrete.

Saving of SP means that the quantity of SP is taken from the Portland cement quantity. But it is necessary to take into consideration that Portland cement quantity in the proposed concrete composition can be reduced up to 10% (due to the Portland cement replacement by the quartz microfiller), at the same time the good workability of mixtures is provided.

Selection of multicomponent concrete composition is a problem with several unknowns (Alqadi et al., 2013), thus it is necessary to consider the influence of all components on the concrete properties that determine its durability.

3.3. Strength characteristics

Concrete durability examining of the under-rail structures is carried out by testing samples of concrete on compressive strength, tensile strength when splitting, frost-resistance, density of the concrete cores drilled from a structure as well the water absorption, testing of concrete sleepers for the fracture toughness under static load.

Frost resistance of concrete is one of the main characteristics of its durability. The concrete used for under-rail constructions that are used in conditions of alternate freezing and thawing must have the required frost resistance that must be not lower than the F200. There is no experience of ballastless track operation in which the concrete contains quartz microfiller with a fineness of as in this study. In this case the evaluation of durability of concrete is essential.

Concrete compressive strength depending on the quantity of the microfiller and duration of hardening is presented in Fig. 7. The composition of concrete was taken from the data of Table 5.

The analysis of the results presented in Fig. 7 shows that the quartz microfiller quantity to increase the compressive strength of concrete at the age of 28 and 360 days should be equal to 5–10%. The increase of the concrete strength with the introduction of quartz microfillers may occur due to changes in the microstructure of hardened cement paste. The introduction of the quartz microfiller changes the conditions of crystallization and, consequently, the morphology of hydration products.

The tensile strength when splitting is the parameter that further characterizes the fracture toughness of concrete structures. In this case the samples-cubes with 10 cm edges that contain the superplasticizer (0.7%) and quartz microfiller (5 and 10%) were tested by tensile splitting at the age of 7 and 28 days. The average values of this parameter were 3.91and 3.89 MPa at the age of 7 days respectively and 3.98 and 3.95 MPa at the age of 28 days respectively which are greater than the requirements for concrete sleepers (3.7 MPa). The tensile strength when splitting increases with concrete age that correlates with results in the paper (Ahmed et al., 2016) obtained for the flexural tensile strength.

3.4. Durability of concrete

Concrete sleepers are laid on ballast prism from the rubble of the normalized granulometric composition with the maximum intergranular voidness of space. Thus the fluid drainage from precipitation is provided. This allows to consider that concrete freezes in the air conditions. The concrete roadbed is under the monolithic concrete slab in the case of balastless track. The mode of freezing of the concrete in the aquatic environment should consider the insufficient drainage capacity of concrete roadbed. Destructive processes in concrete are faster in the case of freezing of concrete in the aquatic environment.

Currently, the frost resistance requirement of railway structure concrete is F200. The frost resistance is designed for structures operation in conditions which ensure water drainage and concrete freezing in dry environments. In this case it is necessary to investigate the ability of the quartz microfiller to provide the required

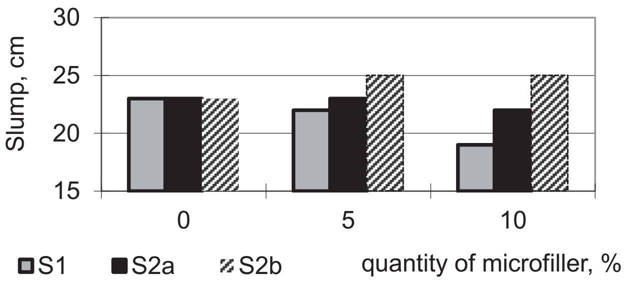

Fig. 6. The plasticizing effect of superplasticizer (0.7 wt% of Portland cement) depending on the microfiller quantity and fineness.

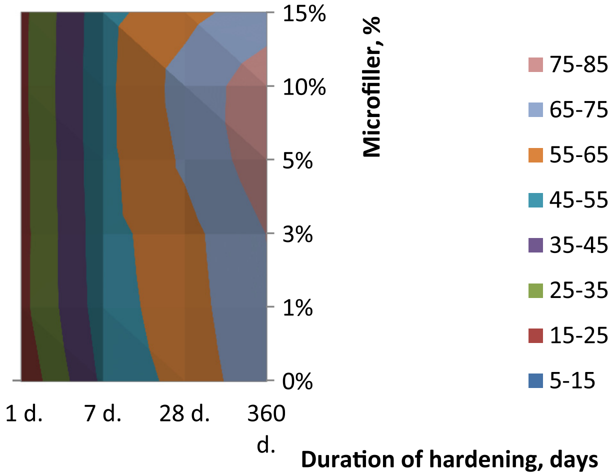

Fig. 7. Isoparametrical diagrams of concrete compressive strength (MPa).

Table 6
Frost resistance of concrete.

Type of additives	Quantity,% from Portland cement mass	W/C	Compressive strength at age of 28 days, MPa	Coefficient of the acceleration of destruction, K_f^{28}	Compressive strength at age of 360 days, MPa	Coefficient of the acceleration of destruction, K_f^{360}
Without additives	0	0.35	58.6	1.345	72.1	1.301
Superplasticizer	0.7	0.35	59.1	1.232	71.3	1.126
Superplasticizer + quartz microfiller	0.7% + 5%	0.35	66.7	1.235	80.9	1.107
Superplasticizer + quartz microfiller	0.7% + 10%	0.35	68.7	1.239	79.3	1.103

frost resistance of concrete when the drainage properties of the concrete roadbed are reduced. The frost resistance tests were made by the methods of freezing in water and air at the temperature of −50 °C. The acceleration of the destructive processes in the concrete volume was estimated by coefficient K_f, representing the ratio of the cycle numbers of frost-resistance in air to the cycle numbers of frost-resistance in the water (Table 6).

The comparison of destruction acceleration coefficients at different ages is shown in Fig. 8. From the analysis of the data in Fig. 8 one can see that the reduction of the destruction acceleration coefficients values is observed in the concrete with the quartz microfiller. The largest reduction of coefficient values is observed for concrete at the age of 360 days. Thus, the quartz microfiller can be an effective supplement that contributes to increasing the frost resistance of concrete when the latter freezes in the water environment.

Water absorption is an important structural characteristic of concrete because it is related to the concrete porosity. The water absorption of the cores that are drilled from concrete shall not exceed 12% in volume according to the requirements for concrete railway structures.

The cores were drilled from the experimental plate to assess the effect of fresh concrete workability and concrete composition on water absorption. The results of concrete density and water absorption of cores are presented in table 7.

Density and water absorption of concrete are increased by using the high-workability mixtures and quartz microfiller. This can be explained by increasing the compaction degree of the concrete mix with the superplasticizer and by filling the part of the capillary pores by the hydration products. These factors increase the homogeneity of concrete and reduce its porosity. The decrease of water absorption in volume was up to 26%. The water absorption on volume was less than 12% which corresponds to requirements to the concrete for under-rail constructions.

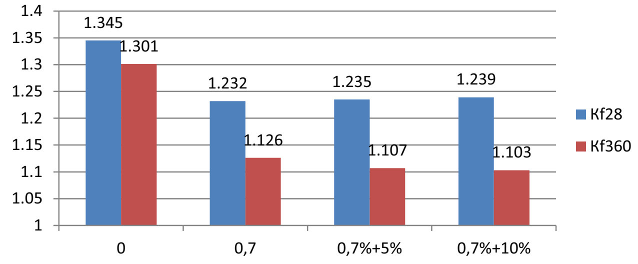

Fig. 8. Comparison of destruction acceleration coefficients at different ages.

4. Conclusion

The comprehensive approach to the selection of quartz microfiller quantity and fineness for slab concrete of ballastless track was studied. With this approach, the influence of microfillers on properties of fresh and hardened concrete is taken into account with the maximum economy of Portland cement and superplasticizer since the transport facilities require large volumes of concrete.

Quartz sand (as fine aggregate) greatly improves the plasticizing effect of the superplasticizer. The improvement of grinding technologies should lead to reducing the cost of the quartz microfillers. Modern grinding equipment was used in this research such as a centrifugal-elliptical mill and a centrifugal dynamic classifier. The classifier is designed for separating the filler particles in the air flow by size, density and shape with the aim to precipitate very fine fractions of the total volume of microfiller. Using the classifier reduces the energy consumption of grinding.

The quartz microfiller in the amount of 10 wt% of Portland cement may significantly increase the value of the slump, the plasticizing effect of SP increasing with the greater microfiller fineness. The effect of storage time (180 days) of the finer quartz microfiller on plasticizing effect of SP was not observed.

It is established that the negatively and positively charged active centres exist on the microfiller particle surfaces. The greatest number of negatively charged active centres is located on the quartz microfiller surfaces and the number of negative centres grows with the microfiller fineness increasing. It correlates with the plasticizing effect of SP.

Saving of SP means that the quantity of SP is taken from the Portland cement quantity. But it is necessary to take into consideration that Portland cement quantity in the proposed concrete composition can be reduced up to 10% (due to the Portland cement replacement by the quartz microfiller), at the same time the good workability of mixtures is provided. The quartz microfiller quantity to increase the compressive strength of concrete at the age of 28 and 360 days should be equal to 5–10%. Reduction of the destruction acceleration coefficients values was observed in the concrete with the quartz microfiller. It can be an effective supplement that contributes to increasing the frost resistance of concrete when the latter freezes in the water environment. Density and water absorption of concrete were increased by using the high-workability

Table 7
Density and water absorption of cores.

Type of additives	Quantity,% from Portland cement mass	W/C	Density, kg/m^3	Water absorption by mass,%	Water absorption by volume,%
Without additives	0	0.35	2346	6.79	14.98
Superplasticizer	0,7	0.35	2352	6.02	12.88
Superplasticizer + quartz filler	0,7% + 5%	0.35	2356	5.79	11.02
Superplasticizer + quartz filler	0,7% + 10%	0.35	2357	5.83	11.13

mixtures and quartz microfiller. This can be explained by increasing the compaction degree of the concrete mix with the superplasticizer and by filling the part of the capillary pores by the hydration products. These factors increase the homogeneity of concrete and reduce its porosity. The decrease of water absorption in volume was up to 26%.

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