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Experimental laboratory validation of reproducing road viaducts concreting processes

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Abstract

In the latest period, hundreds of concrete viaducts were built in Poland within a short time range. Their characteristic feature was the use of high class concrete containing the CEM I 52.5 cement. The concreting works often took place during winter time. Despite successful laboratory tests, the concrete prepared on the concreting site often did not achieve the assumed freeze-thaw resistance.

The lack of freeze-thaw resistance in concrete had an unusual course. A higher than normative decrease of strength with simultaneous high tightness was observed. There was no surface spalling, typical for the low freeze resistance concrete, no edge curvature, etc. In addition, on the sample surface, a characteristic mesh of white leakage of unknown chemical compounds around big aggregate grains was identified. Those compounds were thoroughly investigated with the use the SEM analysis.

It was found that the direct reason of lowering the concrete strength after 150 cycles of freezing and defrosting was the occurrence of numerous micro-cracks formed during the hydration of high amount of clinker cement in concrete block. Moreover, these phenomena were enhanced by the occurrence of white, needle-shaped, hard-soluble salts localised in the boundary between aggregate and cement paste. Based on the EDS analysis, these salts were identified as nickel and calcium phosphates, ettringite ana thaumasite formations and others, which delayed cement hydration [1,2,7,8,9].

The variety of occurring white salts forced the commencement of model laboratory tests on a specially built station for reproducing the processes taking place during concreting and developing recommendations for the construction workmanship.

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Keywords: concrete viaducts, frost resistance of concrete, SEM and EDS analyses, laboratory experiments.

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1. Introduction

In the period before the 2012 UEFA European Football Championship, and later, several dozens of concrete viaducts were built in Poland within a short time. Application of concrete class C40/50 with CEM I 52,5 cement and building in periods of lowered temperatures was characteristic for those objects. Despite successful laboratory tests, concrete made in the building site conditions often did not achieve the assumed F150 freeze resistance. According to the Polish standard PN-B-06250, designation F150 indicates the concrete freeze-thaw resistance after 150 cycles of freezing and defrosting within the range of temperature from -18 to +18°C. This designation means also that predicting time of construction exploitation varied between 101 and 150 years. In technical literature, there was a similar case from a few years ago, concerning the lack of freeze resistance with occurrence of salt leakage on the border areas between aggregate [3]. Nonetheless, the reason for these phenomena has not been yet recognized.

The aim of the research was to define the reasons of the lack of frost resistance of C40/50 concrete, which was used within 2011-2014 to build load-bearing structures of flyovers on routes: A1, A4 and S5. Flyovers' construction solutions were analysed, climate and technological conditions during concrete works were reproduced, parameters of the used concrete mix were evaluated, the concrete used in the structure was analysed. Concrete compression strength was defined on the basis of samples taken during the process of concreting, and then – when criteria for frost resistance were not met – on the basis of core drills taken from various layers of the flyovers' structural elements. In order to explain the lack of frost resistance in both cubic and core samples, an analysis of concrete microstructure was conducted with the use of method of scanning microscopy with EDS probe. The inconclusive results of the EDS tests caused the commencement of model studies.

2. Results of completed road viaducts tests

The concreting works of load-bearing structures (girders and pavement slabs) were executed in the winter seasons of 2011 to 2014. Concrete mixture and concrete with parameters as in Table 1 were used most commonly.

Table 1. Formula and basic technical data of bridge concrete C40/50, F150.

Laboratory formula			Mixture and concrete physical and mechanical parameters
Cement 52.5 N-HSR/Na	-	400 kg	$f\ cm_7$ = 47.5 MPa
Water	-	157 l	fcm_{28} = 73.4 MPa
Sand	-	670 kg/m^3	air content 5.20 %,
Grit 2/8	-	438 kg/m^3	texture measured using the concrete slump test:
			12 cm, after 1 hour - 16 cm
Grit 8/16	-	679 kg/m^3	volume 2349 kg/m^3
Plastifier	-	0.50 % per month	absorbability 4.1 %
Super-plastifier	-	0.80% per month	water tightness degree W8, water penetration 1.8 cm
Air entraining additive	-	0.08% per month	frost-resistance degree F150 at strength loss of ΔR = 5.2 % and mass of ΔG = 0.8 %

The execution of test batches and results of fresh concrete mixture as well as testing of cured concrete samples confirmed the proper selection and proportions of the components and the positive values of all concrete parameters specified in the design specification.

During the execution of the road viaducts, several deviations from the laboratory conditions, however, were noted, which resulted in the lowering of the concrete mixture and concrete parameters, which in consequence resulted in the loss of frost resistance of the structural concretes [4].

The basic deviations include:

- change in texture: instead of a slump of 12/16 cm, a slump of 18 cm or even ≥ 25 cm was noted,
- the degree of aeration of the concrete mixture at the building site fluctuated from 3.5 % to 3.9 % and was